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A SYSTEMATIC LITERATURE REVIEW ON BLOCKCHAIN ARCHITECTURES USING SMART CONTRACTS

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ABSTRACT

Blockchain has received a lot of attention for multiple use cases and applications since the first works emerged about 15 years ago, with its use targeting cryptocurrencies. During this period, a wide variety of platforms (e.g. Ethereum, Hyperledger, and others web3 Blockchain platforms), tools, programming languages and other resources such as smart contracts were proposed. With the aim of better understanding the use of smart contracts in Blockchain-based systems, this article presents a systematic review of the literature on Blockchain application architectures that make use of smart contracts, applied in different areas. It is expected to bring together approaches for the design and implementation of smart contracts on the Blockchain.

Keywords:Smart Contracts, Blockchain, Smart Contracts Architecture, Blockchain Architecture, Software Architecture.

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INTRODUCTION

The need to understand the architectures of Blockchain applications that use smart contracts as well as the motivation for developing this systematic literature review (SLR) are discussed in this section.

Blockchain technology emerged in 2008 with the primary goal of creating a cryptocurrency known as Bitcoin, that operates through a peer-to-peer network and provides security for digital currencies transactions without relying on the trust of any participant on the transaction (Nakamoto, 2008). Over the years and with the success of Bitcoin, researchers realized that Blockchain technology had a potential beyond cryptocurrencies, with Ethereum network platform idea, which enables smart contract developing, the usage of Blockchain technology expanded to diverse fields (Volpe *et. al*., 2022).

Smart contracts, as they will be referred to in this paper, are computer programs that runs on a Blockchain network environment, such as Ethereum. The main reasons for its utilization are the immutability of their programing code and the security provided to its data, this way the utilization of smart contracts can be a solution to data security, requiring only an appropriate Blockchain network environment and the adaptation of architecture that meets the demand (Alboaie *et. al*., 2019).

The smart contracts can be utilized in a wide variety of domains, such as Internet of Things (IoT), supply chains, healthcare, security, among other fields (Volpe *et al*., 2022). These characteristics made Blockchain smart contracts receive several attentions on the present technological context, with this in mind it is essential to search for how the Blockchain smart contracts architecture applications actually works, in which fields are it being applied to, looking forward to comprehend the technology and contribute for its evolution through identifying potential gad and related work proposals.

As the smart contracts has been showing to be effective to solve transaction problems in a Blockchain network environment, its's important to develop a systematic literature review (SLR) analyzing the existing papers that introduces Blockchain smart contracts architecture applications with an objective to better understand how it works and its possible applications.

Smart contracts have contributed to Blockchain evolution, they are crafted in a secure manner, since it ensures integrity, authenticity and non-repudiation (Alboaie *et al*., 2019). Other than that, the present storage method, which is centralized on servers becomes decentralized, reducing fees and enhancing security.

The objective for this paper is to search through the literature for possibilities using architecture based on smart contracts with a goal to identify their main characteristics and make comparations among them. As main objectives for this research there are:

- Find in the literature smart contract based Blockchain architectures;
- Identify which architecture are used in each field;
- Identify gaps, which field of use has no architecture yet proposed;
- Compare the found architectures to find out their main differences.

To achieve the previous mentioned objectives, the following research questions have been created:

- Question 1: What are the Blockchain smart contracts-based architectures?
- Question 2: Are the architectures analyzed flexible enough to allow its smart contracts to evolve over time??

This work is divided in 7 separated sections:

- Sections 1 – Introduction: contextualizes and shows the motivation to write this paper, besides introducing the objectives and research questions;
- Sections 2: Describes the base knowledge for reading this paper;
- Sections 3: Introduces the research methodology, techniques and tools utilized on developing this systematic literature review;
- Sections 4: Introduces the obtained numbers from the results of the elaboration stage of the project;
- Sections 5: Builds up a discussion on the obtained papers and relate them to this research theme;
- Sections 6: Exposes the main characteristics obtained as results and elaborate the final concerns.
- Sections 7: Indicates possible further related research topics and employments.

Theoretical Foundation

Conceitos básicos sobre arquitetura de software, Blockchain e contratos inteligentes são discutidos nesta seção para melhor compreensão deste artigo.

Software Architecture

According to (Tamburri *et. al*., 2023) software architecture consists on detailing the software itself, from the decisions that brought the system idea until its components, relations and properties.

Architecture is the definition of its software components and how they interact to express the software's requirements. A well-defined architecture allows for a better understanding of the system and facilitates decision making. Furthermore, architectures are essential to facilitate evolution and changes in the software and also the organization of the project, distribution of development activities across the team and facilitate the understanding of what will be developed. Typically, a software architecture includes modeling, decision engines, storage planning, and documentation engines (Guaman *et. al*., 2021).

Blockchain e *Smart Contracts*

Blockchain is a peer-to-peer network of distributed computers that aims to record transactions so that all nodes in the network can be verified. Blockchain is built from a chain of blocks with transaction data. Blocks are decentralized and distributed, each block is connected to its previous block through a hash code, this guarantees its inviolability (Volpe *et. al*., 2022). Hash algorithm is used for cryptographic protection. It is a mathematical algorithm whose main objective is to encode data to form a unique character string. Blockchain is a peer-to-peer network architecture where each node acts as a client and server, interacting collaboratively without a specified administrator. (Nascimento, 2023).

The fact that a Blockchain network is decentralized means that it is not possible to exercise total control over the system, thus preventing restrictions from being imposed. Furthermore, other characteristics that make Blockchain reliable, in addition to non-repudiation, is resistance to information tampering. (Alboaie *et. al*., 2019).

Blockchain is a type of distributed and decentralized database on a peer-to-peer network, containing a chain of blocks ordered chronologically, shared and immutable, used to record transactions, increase trust in a distributed base among nodes that are part of the consensus group. Consensus protocols perform the validation of transactions and the state of the system, synchronization, and protocol rules within the network. These consensus groups are resources where validators (known as mining nodes) within a Blockchain network agree with the current state of the network, are linked through a Secure hash algorithm (Khan *et. al*., 2021). The chain of blocks formed is chained to the preceding block by this reference called hash.

The Genesis block initiates the chain of blocks that generate subsequent blocks, these store data from the current transaction and a copy of the previous key code (hash) (Berghel, 2017). The blocks are chained by cryptography, if the information contained is changed, both it and the entire sequence of blocks will be modified, a cascade effect (Gomes *et. al*., 2022), (Khan *et. al*., 2021), (Shahnaz *et. al*., 2019). Transactions are linked to encrypted keys, each client uses two keys, a private one that allows signing the transaction, and a public one, which allows the system to prove authorship (i.e., validate) (Da Silva Rodrigues & Rocha, 2021)we assess the processing efficiency of transactions originated by smart devices and the storeddata integrity. The processing-efficiency evaluation is carried out through queue-theory-based analytical modeling, in which the average time for transaction confirmation is estimated. By its turn, the data-integrity is measured through simulations, where the probability of fraudsters altering already-stored data is estimated. Moreover, the experiments consider a set of scenarios related to different application domains. Final results show that the Blockchain technology may meet IoT efficiency requirements, besides providing adequate data integrity. Lastly, general conclusions and avenues for further research close this article.”,”author”:[{“dropping-particle”:””,”family”:”Silva Rodrigues”,”given”:”Carlo Kleber”,”non-dropping-particle”:”Da”,”parse-names”:false,”suffix”:””},{“dropping-particle”:””,”family”:”Rocha”,”given”:”Vladimir”,”non-dropping-particle”:””,”parse-names”:false,”suffix”:””}],”container-title”:”IEEE Latin America Transactions”,”id”:”ITEM-1”,”issue”:”7”,”issued”:{“date-parts”:[[“2021”,”7”]]},”page”:”1199-1206”,”title”:”Towards Blockchain for Suitable Efficiency and Data Integrity of IoT Ecosystem Transactions”,”type”:”article-journal”,”volume”:”19”},”uris”:[“http://www.mendeley.com/documents/?uuid=d52a8df6-f826-41e4-8a43-fbdf48ca119d”]}],”mendeley”:{“formattedCitation”:”(Da Silva Rodrigues & Rocha, 2021. Based on a network of acceptability verification, a unique encrypted key is generated for each transaction carried out, making transactions secure and immutable (Moura *et. al*., 2020)”ISSN”:”1415-6555”,”abstract”:”RESUMO Objetivo a revisão sistemática desenvolvida neste artigo teve como objetivo apresentar as potenciais aplicações e consequências do uso da Blockchain para a administração pública. Método a partir da busca de artigos nas bases Scopus, Web of Science, SSRN e Science Direct, e seguindo o método PRISMA, foram selecionados 16 artigos que continham as temáticas: Blockchain, participação governamental direta ou como principal regulamentador, política pública. Resultados as principais aplicações encontradas foram referentes a: processamento de dados e segurança de dados públicos, novas propostas de regulamentação estatal e de organização institucional. Quanto aos impactos, destacam-se a melhoria na gestão dos dados, diminuição da burocracia e necessidade de afinar a relação entre Estado, sociedade e mercado. Conclusão a Blockchain apresenta-se como uma tecnologia capaz de renovar os processos de gestão, mas criando novos desafios à administração pública. Classificação JEL: O14, H83, L86.ABSTRACT Objective the systematic review of this article aimed to present the applications and consequences of using Blockchain for public administration. Method from researching articles in the Scopus, Web of Science, SSRN and Science Direct databases, and following the PRISMA method, 16 articles were selected that contain the following themes: Blockchain, direct government participation or as the main regulator, public policy. Results the main applications used were related to: data processing and public data security, required new applications and institutional organization. As for the impacts, we highlight the improvement in data management, reduction of bureaucracy and the need for a relationship between the State, society, and market. Conclusion blockchain is a technology capable of renewing management processes, creating new challenges for public administration. JEL Code: O14, H83, L86.”,”author”:[{“dropping-particle”: ”de”,”family”:”Moura”,”given”:”Luzia Menegotto Frick”,”non-dropping-particle”:””,”parse-names ”:false,”suffix”:””},{“dropping-particle”:””,”family”:”Brauner”,”given”:”Daniela Francisco”,”non-dropping-particle”:””,”parse-names”:false,”suffix”:””},{“dropping-particle”:””,”family”:”Janissek-Muniz”,”given”:”Raquel”,”non-dropping-particle”:””,”parse-names”:false,”suffix”:””}],”contain er-title”:”Revista de Administração Contemporânea”,”id”:”ITEM-1”,”issue”:”3”,”issued”:{“date-parts”:[[“2020”]]},”page”:”259-274”,”title”:”Blockchain e a Perspectiva Tecnológica para a Administração Pública: Uma Revisão Sistemática”,”type”:”article”,”volume”:”24”},”uris”:[“http://www.mendeley.com/documents/?uuid=2d0f5cce-37aa-4f0b-ba08-028e3b8bb77e”]}],”mendele y”:{“formattedCitation”:”(Moura *et. al*., 2020. The users themselves submit these transactions to a network of processors connected by a peer-to-peer network, they operate in the collection of transactions building and validating blocks and connecting them to a linked list (J. Zhang *et. al*., 2020). Thus, a modification of any data in the information chain invalidates all subsequent blocks. The mechanism creates a protected system for continuous data registration. The destruction of a node in the Blockchain does not affects its integrity. As for its security and credibility, once verified data and transactions are permanently stored in all nodes of the Blockchain network, making it impossible to change them. (Li *et. al*., 2021).

Some of the essential characteristics of Blockchain technology and their definitions are presented below (Alahmadi *et. al*., 2021):

I. Block Time or (timelock): It is the fraction of time for the conception of a new block on a Blockchain platform, that is, it is the time used for miners to reach consensus to admit a new block to the network (Gomes *et. al*., 2022). Miners (name of system participants) mutually compete to add the block to the system. This “competition” occurs through the resolution of complex mathematical calculations. A new block is accepted by the network each time a miner presents a new victorious proof of work (resolution), which occurs around approximately 10 minutes;

II. Blocks: They consist of header structures and the list of transactions. The transaction list points to the transactions executed and included in the block. The header has the hash code of the previous block and some information about the transactions carried out, it is the identifier field based on a unique value. It also adds other data, such as timestamp (records the date and time of the transaction) and nonce (a cryptographic token, created arbitrarily, used to contain replay attacks) (Agyekum *et. al*., 2022);

III. Trust and security: Blockchain is decentralized and does not depend on intermediaries and focuses on providing anonymity, security, privacy, and transparency. Trust is produced with the use of consensus protocols in which all nodes of the network validate the transaction (Erdem *et. al*., 2019)which does not require a third-party organization in the middle for achieving the intra-blocks trust. The information about every transaction ever completed in a blockchain is shared and always available to all nodes. This attribute makes the system more transparent than centralized transactions. The goal of blockchain technology is to provide anonymity, security, privacy, and transparency to all its users. This chapter aims to provide the state-of-the-art information on the use of blockchain technology for securing IoT environments. The advantages and limitations of BC technology for IoT architectures are analyzed. Conceptual blockchain-based IoT architectures for seven different cases are also presented. These being: supply chain management and manufacturing , smart cities, smart homes, healthcare IoT systems, identity management and access control systems, electricity market systems, and insurance systems. The most relevant future challenges for the application of blockchain to IoT environments are also discussed.”,”author”:[{“dropping-particle”:””,”family”:”Erdem”,”given”:”Ahmet”,”non-dropping-particle”:””,”parse-names”:false,”suffix”:””},{“dropping-particle”:””,”family”:”Yildirim”,”given”:”Sevgi Özkan”,”non-dropping-particle”:””,”parse-names”:false,”suffix”:””},{“dropping-particle”:””,”family”:”Angin”,”given”:”Pelin”,”non-dropping-particle”:””,”parse-names”:false,”suffix”:””},{“dropping-particle”:””,”family”:”Erdem”,”given”:”A”,”non-dropping-particle”:””,”parse-names”:false,”suffix”:””},{“dropping-particle”:””,”family”:”Yildirim”,”given”:”· S Ö”,”non-dropping-particle”:””,”parse-names”:false,”suffix”:””},{“dropping-particle”:””,”family”:”Angin”,”given”:”P”,”non-dropping-particle”:””,”parse-names”:false,”suffix”:””}],”container-title”:”Security, Privacy and Trust in the IoT Environment”,”id”:”ITEM-1”,”issued”:{“date-parts”:[[“2019”]]},”page”:”97-122”,”title”:”Blockchain for Ensuring Security, Privacy, and Trust in IoT Environments: The State of the Art”,”type”:”article”},”uris”:[“http://www.mendeley.com/documents/?uuid=de25148a-b1a2-4624-a740-c8907e3850fc”]}],”mendeley”:{“formattedCitation”:”(Erdem *et. al*., 2019;

IV. Decentralized: Blockchain facilitates the recording of a transaction securely, traceably, and validly, decentralizing procedures, in which all transactions are cryptographically cataloged in a peer-to-peer distributed network;

V. Smart Contracts: They are lines of code stored in the Blockchain that are automatically executed. They are used to establish some kind of agreement so that all participants can be sure of the result without the involvement of an intermediary, that is, the network has to have a consensus for the execution of the contract (Shah *et. al*., 2021). Smart contracts are enabled to provide a high degree of reliability, are stored in a distributed database, and cannot be changed (Mohanta *et. al*., 2018).

Smart Contracts are contracts entered into in a digital coding model provided with self-enforceability. (Kemmoe *et. al*., 2020) considers the following objectives of a smart contract: observability (monitoring the performance of the contract), verifiability (execution of the document must be proven), privacy (only those responsible can have access to the execution of the processes) and applicability. Smart contracts are pieces of algorithms that executes when a determined activation action is triggered (Volpe *et. al*., 2022). Those algorithms are executed in all the nodes in the network or just some pre-defined number of nodes. The objective of a smart contract is to act as a trustful contract, avoiding bad faith or any human mistake made by any participant and without the need to any third party to intermediate the transaction (Nascimento, 2023). The smart contracts on general have a basic structure which can be adapted by a developer during the implementation meeting the user necessities, a smart contract can be developed in 5 stages : the first one being selecting a Blockchain supported programing language to build you smart contract code with it, which is going to be compiled into byte code. On 2° stage the byte code will be attached to a Blockchain. On stage 3 The users will be allowed to interact with the smart contract through the Blockchain, each interaction corresponds to a implemented function on the smart contract code, Stage number 4 consists on a validation and execution of the transaction made, and the 5° stage the transaction is added to a block and attached to a block on the Blockchain, modifying the initial state of the smart contract (Kemmoe *et. al*., 2020).

Smart contracts are generally implemented on Blockchain technology and include contractual terms between two or more entities. A smart contract is a code that can determine norms and solutions to specific problems. They determine the duties, rights and actions of any of the parties involved, allowing reliability in relationships between the network. In self-executing smart contracts, unlike a traditional contract written in legal language, it is replaced by lines of automatically executable code to carry out automated execution of contractual conditions between untrusted parties (Muneeb *et. al*., 2022). Smart contracts were initially created with the aim of executing financial transactions, however, they are currently used for the most varied domains. The following are the characteristics for creating and executing a smart contract in the financial domain, however, these characteristics and rules are extended to other contexts:

I. The object of the contract: The terms of the contract are associated with the object. This happens because the smart contract implements the governance rules for some type of business object, so that they are automatically applied when the smart contract is executed;

II. Digital signatures: All participants start an agreement by signing the contract with their private keys. It is a secret key created during the process of asymmetric encryption. It serves to decrypt the messages received and transform them into readable information;

III. Contract terms: The terms of a smart contract constitute the form of a chain of operations. These terms must be signed by all participants;

IV. Decentralized platform: The smart contract is implemented in the Blockchain and distributed among its nodes.

A smart contract is executed on the Blockchain, which implies that the terms are stored in a distributed database and cannot be modified (Kemmoe *et. al*., 2020). The contracts contain all the information about the terms of the contract between parties. The contracts are modified in programming code. This provides the exchange of information that automatically triggers the actions provided for in the contract (Pinna *et. al*., 2019). Transactions are also processed by the Blockchain, which automates payments and counterparts (Kemmoe *et. al*., 2020). The next step after generating the contract is to release the contract. These signed contracts are shared with the nodes on the peer-to-peer network. The node temporarily stores the hosted contract in memory waiting for a consensus to be reached (Atici, 2022).

The Blockchain network and smart contract have an objective of executing a secure transaction, making it essential for the architecture to be planned to meet the user requirements, the main characteristic that is indispensable to any smart contracts architecture is its security, although every smart contract architecture must be planned to meet the requirements of the domain where Blockchain and the smart contracts are inserted into, despite that, some authors propose generic architectures which can adapt to domain requirements.

METHODOLOGY

Due to importance Blockchain has achieved in several study fields and with the growing usage of smart contracts, this literature review aims to identify the existing studies of which are the possible architectures that can be used in smart contracts applications, for development of this paper, the methodological tasks followed the recommendations established by (Kitchenham and Charters, 2007), with a goal to get to know the state of the art for this theme.

Having the research questions the keywords were created and with them the search string defined with the objective to find articles related with the theme. The key words were utilized all in English, due to most of the research topic being written in that language. To connect the keywords and make it easier looking through the repositories it's used Booleans logical connectives.

(software architecture OR architecture) AND (smart contract OR blockchain)

Added to this previous search string with a goal to find more relevant articles that contributes with this literature review, it was forward sum the following search string:

(upgradable) AND (smart contracts)

The repositories consulted for this literature review are the following web computer science related libraries: AIS (https://aisel.aisnet.org/?AISeLibrary), IEEE Xplore (http://ieeexplore.ieee.org/Xplore/home.jsp), ACM Digital Library (https://dl.acm.org), Science Direct (https://www.sciencedirect.com), Springer Link (https://link.springer.com/) e Semantcs Scholar (https://www.semanticscholar.org).

To filter only the related found articles were applied the include and exclude criteria, defining the utilizable articles that meet this literature review objectives, applied to the articles found in this research through the search string are the following include criteria:

- (CI1) The article theme must fulfill the research question;
- (CI2) The article must be related to an application architecture that used smart contracts;
- (CI3) Secondary and primary studies are acceptable;
- (CI4) If there are duplicated studies the most recent one is going to be considered.

The exclude criteria are applied the same manner:

- (CE1) Articles not related to the research question;
- (CE2) Articles not available for download.

Besides to the previous exclude and include criteria it's applied a quality analysis. For this quality analysis it's used 5 questions to classify the article quality regarding this literature review, selecting only the articles which meet at least 80% of the following questions:

- (QQ1) Does the article have a detailed architecture?
- (QQ2) The utilized technologies are accessible?
- (QQ3) Does the specified architecture utilize Blockchain with smart contracts?
- (QQ4) Does the article results are clearly detailed?
- (QQ5) Does it specify in which field this architecture is being used in?

For keeping a quality standard to the articles reviewed in this paper, the articles were selected aiming to separate the ones which meet this research focus theme. As a quality criterion it was checked if the articles had a Blockchain smart contract architecture proposal, also it was important to have a clear description of such architecture and its field of usage, the utilized technologies to be recent and the obtained results to be clearly detailed. Fulfilling these questions, it is understood that the article is of a better advantage for this literature review.

QUANTITATIVE RESULTS

On the first article search using the first search string as a filter, having 1587 articles as results. It was applied a secondary filter which consists of checking the articles titles alignment with the search string or this literature review, it was noticed that not all articles were related to the theme, at the end of this phase it was found 168 articles, distributed along the digital libraries as shown in the Figure 1.

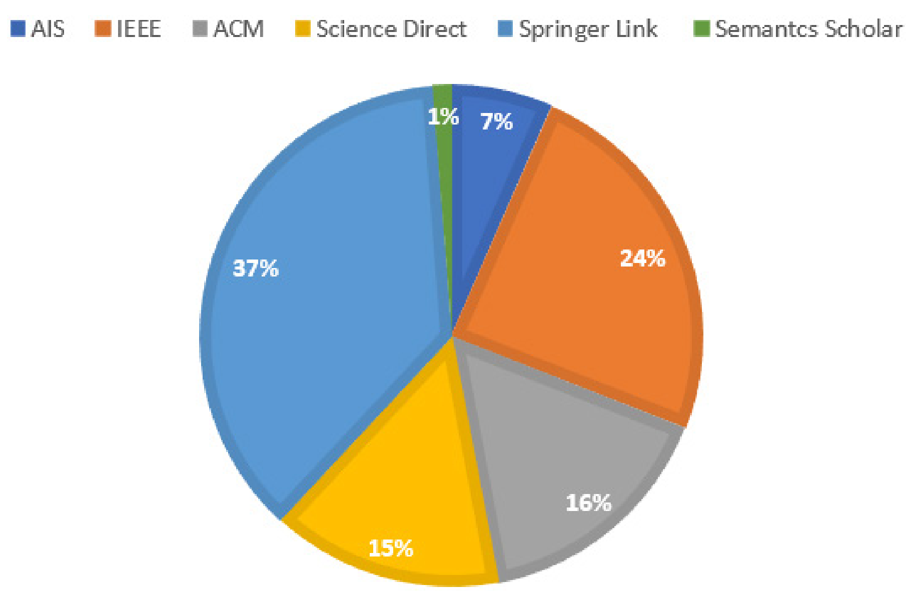

Figure 1. Selected articles per digital library
Source: Elaborated by the authors

The articles selected on the second phase were imported to Parsifal (https://parsif.al), an online tool made for helping with systematic reviews development in all its steps, then it was identified duplicated articles, read the abstract of each article and applied the include and exclude criteria, as a result it had last 18 articles. This abrupt reduction in articles numbers is due to very few articles established a Blockchain smart contract architecture. Next it was applied the snowballing technique, which consists of from the filtered articles references identify relevant other articles, through this technique it was selected 5 more articles which were approve from the previous title and abstract filters to the next phase.

The last filter was the complete read-through of the 24 previously selected articles applying the quality criteria. As a result of this last filter prosses 18 articles were selected, 3 from AIS, 3 from IEEE Xplore, 2 from Science Direct, 4 from Springer Link, 1 from Semantcs Scholar and 5 from snowballing, as shown in Figure 2 bellow.

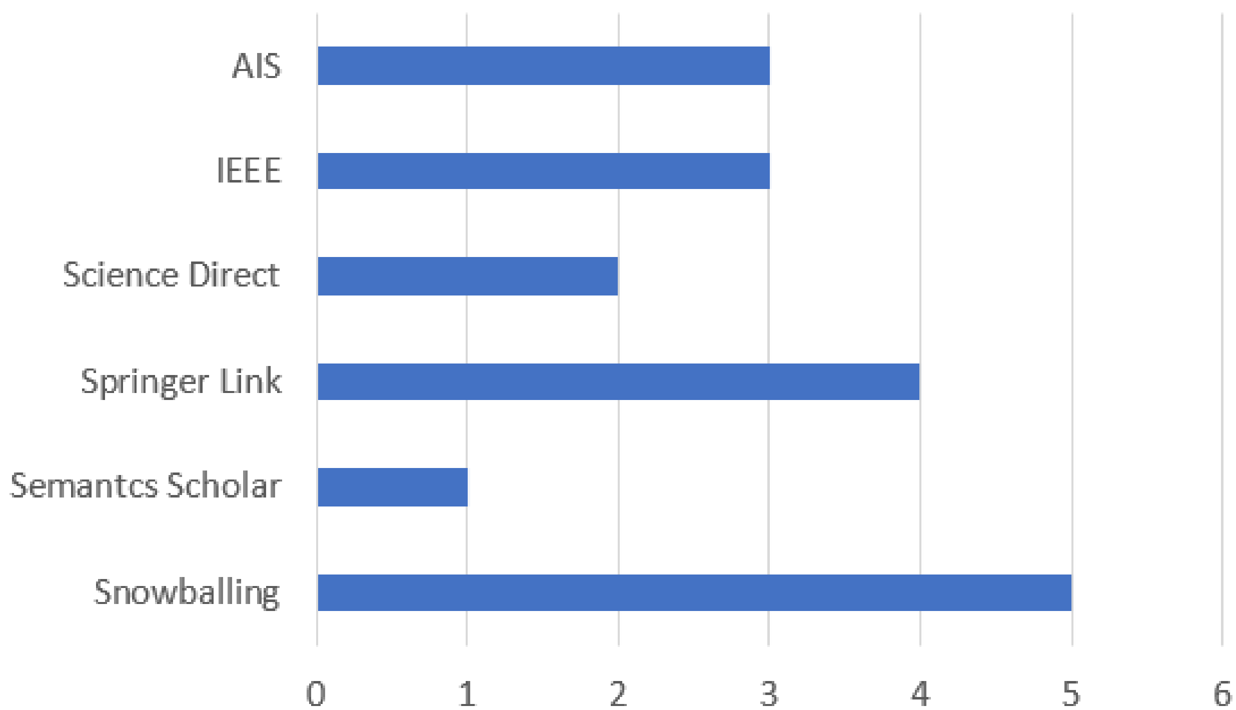

Figure 2. Selected articles
Source: Elaborated by the authors

As for the result of the second search string, 31 articles were found, of those only 6 articles lasted from the first filter, with the abstract analysis none of the articles meet the theme for this Literature review. On Figure 3 all the process for this SLR is explained.

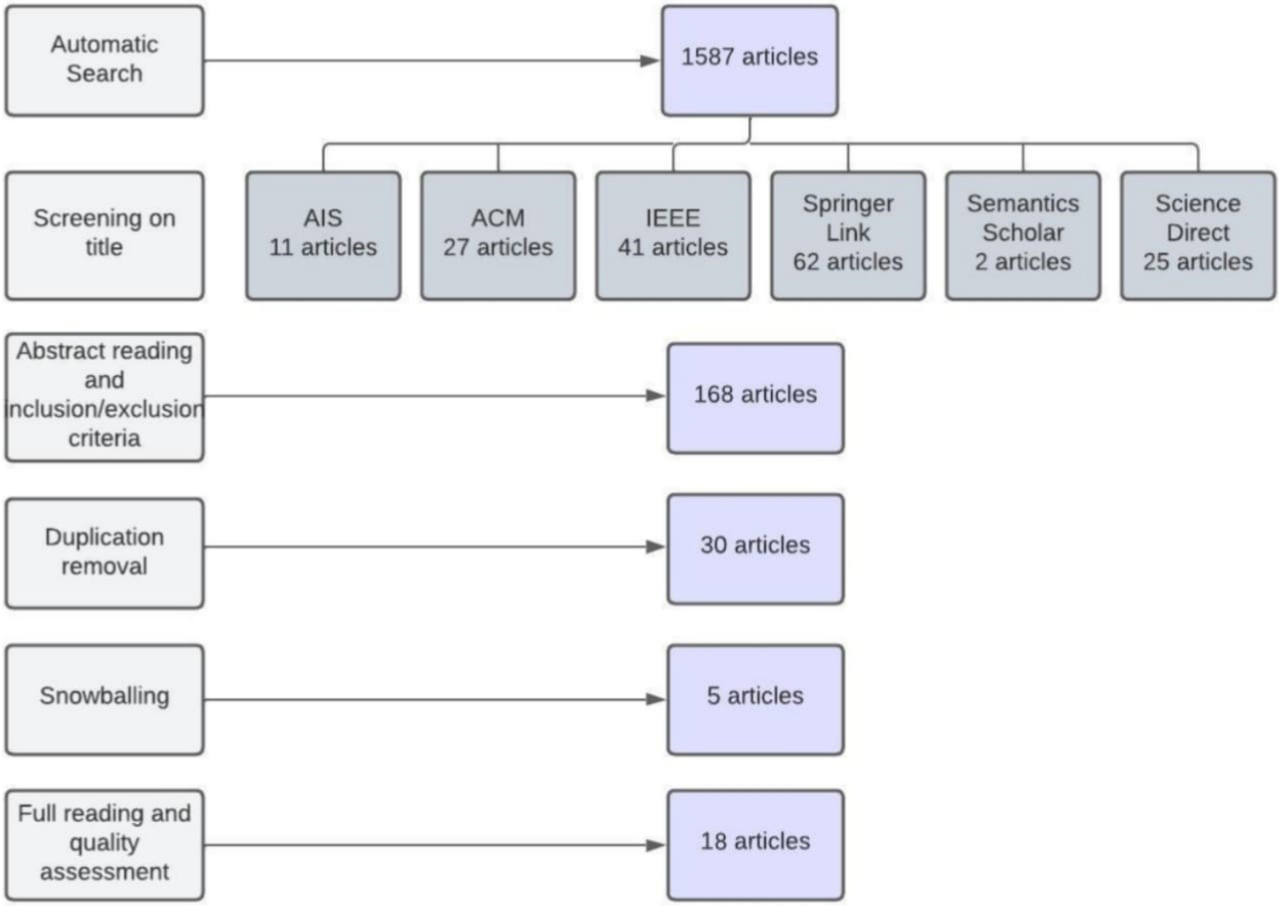

Figure 3. Search strategy and results
Source: Elaborated by the authors

DISCUSSION

After the read through and analysis of the articles it was noticed that smart contract architecture is applied to applications on cloud computing, commercial contracts and industrial production. Besides that, it was noticed that the main characteristic of its utilization was the demand for security.

Within this research development there were some analyzed articles which proposed smart contract solutions to several usages. (Alboaie *et. al*., 2019) proposals a generic architecture which can adapt to a desired situation, the architecture named "PrivateSky" has four layers, one for the application layer, where the applications are been executed on the platform, a layer of a RESTfull API which connects the application to the Blockchain layer, a Near Chain Storage which makes it so every application has its own data layer and a Blockchain that is going to be the core to the platform, where the application layer requirements are going to be accommodated, this architecture has a non-monolithic structure making it easier to maintain and modify their smart contracts whenever necessary, it also uses a hierarchy Blockchain system composed of various smaller Blockchains.

An advantage of smart contracts when utilized as data storage is its spending reduce with storage, the architecture proposed by (X. Liu *et. al*., 2019) utilizes smart contracts for interaction between the Internet of Things (IoT) and external fonts, the smart contracts holds information of specifications and the data provide by monitoring made with IoT equipment or calculated data. This contract is sent by the user, the second stage is to receive this contract, reply to it and execute the requested action. Comparing the Ethereum network smart contracts with the Oracle smart contracts utilization for interacting with IoT, the Ethereum network proved to be more cost effective, reliable and elastic.

The utilization of Blockchain on IoT field can get over with the necessity of decentralized storage. With this objective (Siddiqui *et. al*., 2023) proposal a three layered architecture for interacting with IoT network, the first layer is the perception layer which has an objective of collecting information of the environment through the sensors and transmit it to the control layer which is responsible for processing the information, and the application layer is where smart applications which monitors the whole system are available.

In (Chondrogiannis *et. al*., 2022) the smart contracts are utilized as health insurance contracts for it guarantees the integrity and its non-repudiation of the information within the contract. The architecture allows the insurance system user, called "HIO", to choose the desired insurance, make his payment, and when the user meets the terms established, automatically he receives what its specified on his contract. The system utilizes five smart contracts for it to work, the first smart contract is called "insured data base" and is used only at the beginning when localizing the reference model in which the data is displayed. The second smart contract called "insured data" which contains an exclusive id (hash) of data and a list of users addresses. The third smart contract is named "health insurance organization" and it registers basic information such as name and physical address. The fourth smart contract named "health contract terms" holds the terms, plans of the contract and other information such as coverage, compensation and exclusions. After the information is selected and signed it is stored in another smart contract, other signalize information which includes the user address, contract terms and deadlines, there are also two variables that signalizes if the contract terms are met or not, within the insurance value.

Smart contracts can also be utilized to establish cybernetic insurance contracts. In (Farao *et. al*., 2023) an architecture divided in operations called "INCHAIN" is proposed, the first one it's the emission of a verifiable credential, which consists of registering an verifying the client. The second operation it's the verification of the credential and emission of the cybernetic insurance, in case the credential is successful verified, the insurance contract is digitally created through a smart contract, the third operation is the incident report compensation, the report is made through a smart contract and if all the terms in the contract are met, the compensation is enabled. This article doesn't detail any technical on software structure, it doesn't focus on software development, proposing the architecture only in a theorical manner.

In (Omar *et. al*., 2021) an architecture for medicine negotiation among hospitals, senior centers, suppliers and negotiation groups which intermediate those three, the negotiation happens only when there is a consensus within the parts. The medicine negotiation system structure is built up out of 5 smart contracts, the first is a register smart contract, within it all the participants can register, the manufacturers and distributors a fee is charged when finishing registering. The second smart contract is a purchase negotiation contract, its objective is to negotiate prices. The third smart contract is a purchase order contract, it is responsible for detailing which products are acquired by the purchasing part, so the supplier can have the information on what are the shipping products. The fourth smart contract is a liquidation discount contract, through this contract the distributors require discounts from manufacturers. The fifth smart contract is a discount and fidelity contract, it is worth for suppliers to give discount tickets for future purchases.

Similarly, in (Bandhu *et. al*., 2023) the smart contracts are utilized in a pharmaceutical supply chain, been responsible for selling and purchasing contracts among the manufacturers, distributors, drug stores, and final consumers. A system was proposed to intermediate among the interested parts and the smart contracts are utilized to automize the whole process. The system works like a conventional vending system. Besides every action taken releases an event in the smart contract, so each process will be registered on the Blockchain network, for this case the Ethereum Blockchain is utilized.

In (Seven *et. al*., 2020) the objective for the proposed architecture is to create an auction in which power consortium companies can participate, the platform structure counts with four smart contract modules: the initialization or construction module, it defines all auction specifications. The bidding module configures all bidding rules to prevent frauds and cheating along the process. The withdraw module, at the end of the auction enables those participants who have made bids to withdraw their money back. The control module monitors all the activities and with any fraud suspect the whole pipeline is automatically canceled. In such manner the system produces secure transactions through a peer-to-peer negotiation which is a recently adopted method.

In Liu *et. al* study (C. Liu *et. al*., 2021) is proposed the usage of smart contracts for energy trading. Different to the previous proposals which use smart contracts only as purchase contracts, on this architecture it is also utilized as a control method which can be accessed digitally. The control system called " P2PEBT" has as one of its characteristics being adaptable, as it based on tool utilized in the market, reducing the contract negotiation time it is an efficient system, and it doesn't require third party intervention, it is flexible as it fits the negotiation module, and it is economic since Blockchain transactions doesn't require any third party intervention, The system process is divided in four parts, the first one is the transaction initiation, the transaction manager cryptographs all contract information and a hash in created which serves as access method. On the second part the details for the time quantities for the service are united in a single smart contract. On the third part the consensus commitment occurs, in which the hash is verified, if it is valid the, the process goes to the fourth part which is the block generation, it consists of publishing the transaction data to the Blockchain network, therefore only authorized people get to execute it.

Some of the benefits of smart contracts were described by (Pop *et. al*., 2018) on the utilization of smart contracts technologies for managing energy distribution automation, financial liquidation and validation of events in practically real time. The benefits are expected to come from an architecture in which is registered information of producing or consuming energy, that information is obtained using IoT devices and is automatically registered.

In (Kim *et. al*., 2020) article it is developed a system for real state management, the system utilizes a distributed storage model, with a structure based in XML. The smart contracts are used to stablish a rent contract on a peer-to-peer structure, through the application “dApp”, the owner create a list of his properties on the application, and the person interested on renting can sign the contract through the application which makes the contract legal and only registers it on the Blockchain after the payment.

Smart contracts can also be applied to industrial product manufacturing. In (Volpe *et. al*., 2022) it's developed an architecture for a decentralized and distributed platform, with focus on lens manufacturing, which designers provide the calculated design, and the manufactories produce the lens. For this process Docker technologies for executing the logical core part of the system and for storing, sending or receiving information smart contracts are being used monitoring the lens fabrication process. Docker is a client server platform where several applications can run isolated in containers that can run within the same host (Volpe *et. al*., 2022: 3).

The architecture proposed by (Haridas *et. al*., 2022) has the objective to enable a determined group of designers to send projects to a 3D printing company through smart contracts, this application takes place in the additive manufacturing industry. The system possesses two workflows, the first one being called "3D printing agreement" the 3D printing company can approve or reject a product before it being printed out. On the second workflow called "designer-friendly agreement", the designers have control over the printing process. Both smart contracts have shown themselves to be efficient and to meet the 3D printing company and the designer's requirements.

Cloud computing usage has been growing significantly in recent years and with the rising information production the search for secure manners to store data and exchange information. With smart contracts it is possible to implement solutions that meet the security statements for the cloud computing environment, with this goal an architecture was built with a focus on its storage data cryptography, first, for a user to access the system it was implemented a authentication that aims to guarantee the access of only authorized people, for each information that is storage by the user a smart contract is created to make the register and keep the history (Pourvahab *et. al*., 2019). Besides Blockchain architecture can be applied to docker, cloud storage and deep learning (Volpe *et. al*., 2022).

In (Yu *et. al*., 2022) the proposal is to use smart contracts on financial investment field, those are proposal that for its better functioning it utilizes an oracle which makes the communication between the information provided from web with the smart contracts. One of the architectures of smart contracts is utilized so the investors can argument and contribute data in consensus with a desired investment, execution and negotiation. In other architecture the smart contract role is more direct, focused on the information as transaction reliability.

On the (Kobusinska *et. al*., 2022) article a system facilitates smart contract developing, it utilizes graphic block, each block contains a smart contract function developed in Solidity programing language, the user use blocks to create a diagram that is translated to Solidity language. This project was created to help developers with shallow experience with Solidity language to write smart contracts, making the technology more accessible.

Marco Fiore describes an architecture where a smart city takes advantages of smart contract architecture's immutability, transparency, traceability, and trust-less characteristics as described on their approach, the paper mentioned as possible usages: Supply chain management, since blockchain has a noticeable traceability; Sustainability the paper explains how can the Blockchain reduce its actors carbon footprints by tracking and managing renewable energy; Authentication an identification where blockchain would work as an identity verificatory decentralized secure system; Public records, where blockchain would store property titles or licenses; Transportation, having Blockchain managing and tracking public transportation for better flow and information gathering. The architecture for the system also works based in layers, where different applications and actors communicate with smart contracts using JSON-formatted information with a non-specified front-end application, where smart contracts will check, store, and supply data from the same decentralized Blockchain environment (Marco Fiore, 2023).

As brought by (Hossien Aghahosseini, 2024) a very promisor approach is using Blockchain technology to improve the usage of EHRs (Eletronic Health Records), in this paper review five architecture proposals on the same field and compare their strengths and weaknesses, and brings some challenges that EHRs presents when facing a highly distributed architecture such as Blockchain, such as not having a standard format for EHRs, and having large sized high definition video and image files, the paper brought the following characteristics comparisons:

I. All platforms intend to provide a complete software platform;

II. Three out of five architecture used Blockchain smart contracts, while the others held their code and processing out-of-chain;

III. Two out of five architectures choose to have a third party for users' authentication;

IV. Four out of five architectures held larger files live high-definition images and videos out-of-chain holding whether a pointer or a hash key due to performance of retrieving storage data, the one that held all data in chain explained that security is worth the lower performance;

V. The most diverse characteristic is the Blockchain platform chosen, two opted Ethereum platform, other two gone for private Blockchain and one proposed an architecture that can communicate through different Blockchain networks by translating the different formats.

Within all analyzed articles a common characteristic is shared in why a smart contract architecture is proposed, the proportioned security. Blockchain can offer better security, transparency, traceability and immutability (Nascimento, 2023), those characteristics are indispensable to for the data to be trustful and those characteristics can be present in decentralized data storing. Other characteristics of smart contracts in several analyzed architectures is the capacity of automation from trigger events.

CONCLUSION

The application of smart contracts has been growing in diverse fields of application because it gives several advantages. The main motivation on choosing smart contract is the requirement for better security on access, transparency, integrity and non-repudiation of information which are mandatory characteristics for creating agreements in any field it is applied to.

On the described architectures the objective of the smart contract it to guarantee the integrity and non-repudiation of transactions, other than facilitate a faster negotiation and its decentralized storing. On the most part of the architectures the smart contracts are developed in the Remix IDE utilizing Solidity programing language and the Ethereum Blockchain network, due being a secure platform the supports these tools. Only the responsible for the transaction have access to its transaction data proportionating reliability (Nascimento, 2023).

It is also noticeable that most part of the articles analyzed proposals uses the smart contracts as a link between the application to the Blockchain, making a non-radical transition where the whole traditional application structure would be replaced by a smart contract Blockchain architecture, instead it makes for a harmonious transition between the traditional architecture (using centralized tools such as Docker and others) and smart contracts architecture.

From analyzing the articles, it is observable that the applications have a layered architecture, that is, it is divided in smaller sections, making maintenance and development for the application easier, the application layer are divided in at least in interface with user layer, where there is direct interaction with user, execution layer, where data obtained from user is processed, and storing layer. Other than that, it was noticed that smart contracts are used to compose layers, initialize the application, receive information, and execute actions.

The analyzed architectures have several applications, the main ones are related to purchasing affairs for medicines, energy, intellectual property and services, for rent and application on industrial automation. The application extends to the data keeping field, e.g. industrial process automation and other fields where security is much needed due to high commercial value. From the analyzed architectures it is evident that smart contracts already have many applications and as it is a recent technology there are much more possibilities to be explored, as for the application fields, as to its architecture.

It is also noticeable as one challenge of applying Blockchain to an extremely diverse and specific knowledge fields as they not necessarily have a former standard way of keeping their data, as for a Blockchain distributed architecture may need when transferring information, the way this problem is approached in some of the analyzed papers is by translating information on an in-chain by using smart contracts or out-of-chain using a unattached application.

When managing larger data volumes like high-definition images and videos, Blockchain can lack of performance as all data is properly cryptographed for better security, some of the architectures facing this facing this performance issue held their larger files separately on a cloud computing environment by saving pointer or keys on the Blockchain side reducing the data retrieving spend time, while others architectures for better security considered the longer time took to retrieve all their files from the Blockchain worth it, as this way they'll guarantee an all the way Blockchain data storing with its benefits and characteristics.

FUTURE EMPLOYMETS

As it has already been referred to in the article based on the application domain where smart contracts are developed to, there are proposals for more generic architecture development, especially those related to "Upgradable Smart Contracts".

Deeping the understanding in why Ethereum is the most mentioned applied platform on these articles may be a way of understanding the actual possibilities and limitations of hosting a Blockchain smart contracts decentralized applications distributed through a network assured by Ethereum Foundation, as long as what are the other hosting options and why they're not mentioned as much.

This Systematic Literature Review it's employed to deeper analytic studies that have been made, considering the growing adoption of Blockchain technology in diverse fields, and the search for better practices applied to design of innovative and robust Smart contract architectures.

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