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Results of Blockchain-Oriented Software Engineering 2024 Workshop: speculations on Blockchain for Energy Communities management.

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***Abstract*—In this paper we resume the main results of the seventh International Workshop on Blockchain Oriented Software Engineering and speculate on the perspective of a new trend where Blockchain seeks application to the management of renewable energy communities. The workshop intended to gather researchers from industry and academia to discuss the problems faced by software engineers within the new emerging blockchain technologies, where new software paradigms are involved. This is motivated by the overgrowing interest on this new technology in academy, industry, software communities, finance and media, with an exponential increase of both the companies exploiting the blockchain technology, and published papers about it. The focus of IWBOSE is on the application of software engineering principles and best practices, including re- engineering and analysis, to blockchain-oriented software development and Smart Contracts coding and integration, which need a tailored and specific approach.**

Among the most recent applications, we take a specific look at the management of energy communities and examine some interesting applications of this technology in the energy sector emerged from the most discussed topics on technical forums. We focus on the most discussed related topics, identified amongst a dataset of articles extracted from CoinDesk, which are presented in a paper accepted at the workshop. We aimed to identify from those selected papers important topics related to energy markets, energy communities, energy traceability, and energy certification.

***Index Terms*—Blockchain, Energy Communities, Smart Contracts, Smart Grids, Topic Analysis.**

I. Introduction

Blockchain technology adoption has been wide-spreading in the last years finding application well beyond cryptocurrency management [1–3]. A blockchain is a decentralized and distributed ledger shared among computational nodes within a peer-to-peer network, with no central authority, holding both information and the set of rules on how this information is processed and updated on the ledger [4, 5]. The addition of new records to the Blockchain is made through transactions by the nodes of a network by means of various consensus mechanisms for updating the ledger state. The most used is the "proof of work", a cryptographic challenge where "miners" compete and the winner gains newly minted cryptocurrency [6]. Each block includes the hash digest of the previous block (typically the SHA-256 function) so that it is tied to the previous one, rendering impossible to modify a block without altering all subsequent blocks, hence the name of Blockchain (chain of blocks). Key elements of the technology are:

•Redundancy. The blockchain is replicated and stored in each node.

•All transactions are verified before their validation.

•Block creation is ruled by a consensus algorithm and information recorded in blocks cannot be modified.

•The ability to send transactions is validated using Public-Private key cryptography.

•A scripting/programming language is available to add computational power to the transactions providing computational functionalities through "Smart Contracts".

Even if the technology was created to keep track of exchanges of digital currencies, it has now evolved to perform general purpose computations with the advantages of maintaining unalterable the records of all transactions. Many initiatives are trying to exploit these features. For example the EU Commission launched the European Blockchain Service Infrastructure (EBSI), a common blockchain infrastructure shared among EU member states for providing services to EU citizens and enterprises [7]. In a recent Ministry Low Decrete Italy recognized the DLT technology, and in particular the Italian Blockchain Service Infrastructure, as a mean for promoting and certifying made in Italy products [8]. Despite the increasing interest in the technology, the application of software engineering principles and practices, as well as the adoptoin of specific DSL or MDD is still at the very beginning [9–15]. This caused in the recent past some infamous cases to exploit vulnerabilities: the Ethereum DAO case, where a total of 3.6M Ether (around $70 million at the time) was drained by a hacker in the first few hours of running of the DAO "smart contract" on Ethereum Blockchain; the Parity Wallet library kill, which caused the freezing of about 500K Ethers (about 150M USD), in November 2017 [16]; the Bithumb's (a Korean exchange) hack on June 2019 of about $30 million in tokens stolen; the Upbit hack in November 2019, which costed nearly $50 million at the time. All these cases witness the lack of adoption of good software engineering security practices for blockchain systems even in more recent times [17–24]. Since the technology is becoming more popular also

out of the cryptocurrency contest, such vulnerabilities and security issues can directly impact over common citizens and enterprises [25–27].

Nevertheless the technology appears as a very useful mean in practical applications and in particular in the energy sector [28], [29]. In fact many researches and industrial projects sow the light for energy management purposes, such as energy trading, energy management, promotion of energy sustainability, verification of energy production from renewable sources and so on.

We briefly recall the main topics and results presented at the workshop in the accepted papers and then focus the attention on the results of one of the accepted papers on the analysis on the most interesting applications of this technology in the energy sector from the topics most discussed on technical forums. Specifically, data analyze the most discussed related topics through a topic analysis on a dataset of articles extracted from CoinDesk. From these texts the work identifies important topics related to energy markets, energy communities, energy traceability, and energy certification. A Bidirectional Encoder Representations from Transformers (BERT) model for deep topic analysis was adopted in order to carry out the analysis. The selected dataset clearly displays a narrow focus on blockchain applications for the renewable energy sector.

II. IWBOSE 2024 RESUME

This year IWBOSE features 9 accepted papers, 3 short and 6 full. Among the topic of interest there is a dominance on the analysis of smart contracts followed by the analysis of oracles, a hot topic for the interaction of blockchain smart contracts with the external world.

One paper is about the use of Verifiable Credential on blockchain and their use in the metaverse, one about the consensus algorithm, one regards the application of blockchain to food supply chains and finally we have a paper focusing the attention for blockchain applications in the energy sector, which is our focus in the next section.

In the first paper dealing with oracles authors examine the oracles life cycle through a complete analysis of potential attack types by means of a generalized model where creation, submission, consent, election and data creation deprecation phases are examined. Their model is checked against seven High-profile DeFi exploits. Authors further analyze bond systems designed as a preventative measure against at least a subset of Oracle exploits. Their results suggest that while the bond systems increase the cost of attacks, thus strengthening Oracle data, they also require integrity against adversary manipulations and careful calibration to avoid hindering participation by honest actors.

The second paper about oracles starts from considering the lack of secure implementation guidelines, which expose oracles to potential vulnerabilities and develops a framework designed to improve the security of blockchain oracles. Authors proceed through an implementation of pull-inbound blockchain oracles, demonstrate framework applicability and effectiveness and provide practical insights to developers for implementing secure oracles.

Three papers focus on smart contracts written in solidity. The first one considers the complex architecture and components of dApps in order to identify and retrieve key components during the dApp compilation process when dealing with multiple external dependencies. Authors present a novel tool, DAI (Dependency Analyser and Installer), that automates the identification of compatible external dependency versions for specific smart contracts, which significantly simplifies the compilation process for dApps that incorporate external modules. They proceed with an evaluation of the toll on 57 real-world dApps, successfully determining the right dependency match for 50 cases.

The second one also presents a tool, SoloSphere, designed to optimize gas consumption and enhance the efficiency of smart contracts written in Solidity and designed for the complete checking out, deploying, verification, and gas optimization of Ethereum smart contracts. The tool is composed by three elements, SolO, SMARTS, and SolOLab which provide parsing and deparsing functionalities for Solidity code and a committed environment for gas analysis. The results are achieved integrating OpenAI's GPT via SMARTS-GPT with a supportive role of AI in enhancing smart contract development.

In the third one, authors adopt the use of Digital Twins for creating virtual replicas of assets, processes, or even systems and enabling their evolution in a context, the blockchain, where immutability restricts the ability to make smart contracts updates and upgrades. Authors devise digital twins to dynamically interact with smart contracts within a twin environment where use and testing can be safely implemented and transactions monitored, in order to suggest possible refinements to the developers by discovering smart contract inconsistencies or deviations from the expected behavior.

One paper features the simulation of an Agri-Food DApp system to assess the performance and the bottlenecks of this kind of systems. Authors, unlike other simulators already existing, simulate all components of an agri-food traceability system based on DLT, rather than just the low-level aspects. The simulator is focused on the agri-food supply chain domain but might be adapted also to other DApp systems. The key concepts of the simulator are: *Component*, an hardware or software component able to receive messages and respond to them, after a given time; *Base transaction*, atomic message sent to a component; *Compound transaction*, sequences of basic transactions, with the aim of getting something valuable from the system; *Actor*, person or external system sending compound transactions to the simulated system; *Event*, an action which starts in a given instant of time and changes the state of the system.

One paper presents an analysis of the new consensus mechanism adopted on Ethereum, the PoS. Their research examines unconfirmed transactions and the costs associated with mining under the new PoS consensus. Authors gather data over a three-week period, from December 1st to December 21st 2023, and show that despite the transition to the new that

PoS system, both the costs and the number of unconfirmed transactions remain significantly higher than the expectations that were set regarding the adoption of PoS.

Verifiable Credential and their use in the metaverse is the subject of another accepted paper where authors investigate an approach to remote team work that makes use of the combination of blockchain, metaverse and Verifiable Credentials (VC), focusing attention on the attribution of access credentials to virtual work spaces. Blockchain-based metaverse systems, such as Decentralad, identify a user by his blockchain address, which can store NFTs or other types of virtual property. Verifiable Credentials allow for role attribution in virtual team formation, with the team organizer acting as the issuer and the virtual room acting as the verifier. In their approach authors involve the use of smart contracts for registering and confirming verifiable credentials, directly from the Decentraland virtual room. Authors show that Decentraland virtual room can prevent or allow a user to access a work area based on their VC. Under the proposed approach, the costs of creating the VCs are charged to the issuer, but all verification processes are free.

In the next section we take a deep look into the results presented by the last accepted paper on the use of blockchain in the energy sector [30–32].

III. Trends on Blockchain applications in the Energy Sector

Next we specifically explore the more recent results obtained by an analysis of discussion topics on CoinDesk, carried out by applying topic analysis by means of a Bidirectional Encoder Representations from Transformers (BERT) model for deep topic analysis.

A. The focus.

Blockchain has been identified as a revolutionary technology also in the energy sector since it enables users to preform transactions and notarizations altogether in a much faster and trustable way than in the past. In particular it has been recognized that smart contracts can be used to record energy production and consumption and for the exchange of energy tokens [13]. Recent years saw the rise of interest in renewable energy and an important part of the transformation process regards the possibility of certify the production and the use of renewable energy. This pushes the energy market toward a distributed market, in which renewable energy can be traded directly between prosumers and consumers without the need for a centralized third party [4].

Further applications of the blockchain technology in this sector are not only decentralized energy markets but also the development and management of microgrids, Renewable Energy Communities, data management and energy flow forecasting for electric vehicle management and green mobility, as well as the tracking of sustainable production and consumption of renewable energy. This last topic is of special interest since research in the field are just starting to emerge [33].

A great help in understanding trends and possible future applications came from topic model analysis [34] which, starting from documents, news and discussions present on dedicated websites can suggest a categorization of these trends. Some recent works already analyzed trends of sustainable blockchain technology applications using topic modeling methods often based on LDA, and the results obtained focused on economic and sustainable development topics [28], on relying on patent analysis of DLTs [35] or on broad blockchain technology trends [36]. At IWBOSE 2024 one major point of interest is about a whole analysis of the most popular topics on the use of blockchain in the energy sector as recovered from topic modeling.

B. Methodology

The choice of the primary data source has fallen on CoinDesk which is a news site where blockchain topics are constantly discussed with a monthly average of over eight million visitors and a growth in the last month of 16.73% and it also offers the possibility of data mining.

To retrieve the articles of interest the authors used the following keywords in the appropriate search form: - energy market - energy microgrid - energy communities - energy management - electric vehicle - renewable energy tracking.

The resulting articles were automatically extracted from the CoinDesk web page using Selenium WebDrive and BeautifulSoup.

C. Topic extraction and modelling

Topics are extracted using the BERT (Bidirectional Encoder Representations from Trans- formers), a pre-trained transformer-based neural network model designed to understand the context of a given text by bidirectionally processing it [7]. The specific usage of BERTopic allows to use contextual embeddings from BERT in order to identify and cluster topics within a collection of text documents.

A pre-training approach for BERT requires the training of the model on a large corpus of unannotated text to forecast missing words. After pre-training, the model can be customized for various natural language comprehension tasks on a smaller dataset.

Target of the topic modeling of the text of the selected articles. Since the direct application of the model returns too few topics hard to be interpreted authors provided also a set of keywords related to blockchain and energy generated from the same dataset as well, processing articles' titles. This has been done using KeyBERT, a model specifically designed for keyword extraction which returns a list of keywords when feed with papers' titles. Such a list became a keyword vocabulary provided in input to CountVectorizer, a module of sklearn, which helps BERTopic in topic search. The result has been a set of nine topics each with top 10 terms, each of them associated with a probability.

D. Results

The results consist in finding 9 topics altogether with the ten most important terms and a description:

- Undefined (208) [bitcoin, crypto, like, said, blockchain, new, digital, ethereum, money, decentralized] : general cryptocurrency and blockchain topics that could not be categorized into a specific subject.

- Bitcoin Investment and Trading (81) [crypto, market, bitcoin, price, investors, trading, btc, markets, coindesk, prices] : dynamics of the cryptocurrency market, with a particular emphasis on Bitcoin trading, prices, and investor behavior.

- Energy Consumption in Mining (60) [energy, mining, miners, ethereum, power, carbon, blockchain, bitcoin, said, eth]: energy consumption and mining activities in the cryptocurrency space, especially with a focus on Ethereum and carbon-related aspects.

- Cryptocurrency Market Trends (34) [like, crypto, price, market, ether, coindesk, bitcoin, going, markets, coin] : trends and analysis in the cryptocurrency market, with an emphasis on price movements, market trends, and specific cryptocurrencies.

- DeFi (Decentralized Finance) (29) [defi, crypto, said, new, tokens, token, finance, like, ethereum, assets] : decentralized finance (DeFi), covering aspects such as new developments, tokens, and financial assets within the crypto space.

- Digital Money and Financial Technology (25)[bitcoin, money, digital, financial, currency, like, assets, work, new, technology] : digital currencies, financial technology, and the evolving landscape of digital assets.

- Web3, Crypto Industry and Regulatory Environment (15) [web3, crypto, says, sec, ethereum, industry, new, like, blockchain, community] : Web3 technologies, the crypto industry, and the regulatory environment, including mentions of the SEC (Securities and Exchange Com- mission).

- Business and Industrial Applications (13) [blockchain, technology, china, blockchains, companies, said, need, financial, business, digital] : broader applications of blockchain technology in various industries, including business applications, with a mention of China and the need for such technology.

- Ethereum, DAO and Security (12) [ethereum, dao, blockchain, security, hack, like, crypto, bitcoin, says, blockchains] : aspects related to Ethereum, DAO (Decentralized Autonomous Organization), and blockchain security, with mentions of hacks and the broader blockchain landscape

The analysis reveals that four topics deal with cryptocurrency market related aspects (Bitcoin Investment and Trading, Cryptocurrency Market Trends, DeFi and Digital Money, and Financial Technology) where the use of cryptocurrencies in decentralized energy market is a key solution for the energy trading between prosumers and consumers.

Another key point is about industrial applications and energy consumption. In this respect the blockchain technology appears of strong interest within the community to certify energy consumption, in particular from renewable and sustainable sources not only in homes but also in industries and in mining farms.

IV. Conclusion

From this short resume of articles presented at IWBOSE 2024 it is clear that the interest in blockchain technology is still growing and in particular the technology appears almost mature for practical applications. It is thus of straightforward importance that the adoption of techniques and methodologies of software engineering be applied to the development of this very specific software where hardly software updates may be applied and where decentralization plays a key role. We have seen a strong focus on smart contracts analysis specific architectures or tools which are suggested in order to apply software engineering best practices to this field. We hope that the IWBOSE workshop contributed to achieve improvements in this direction.

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