BLOCKCHAIN SOLUTIONS FOR PEER-TO-PEER ELECTRICITY TRANSACTIONS

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Abstract. *The centralized systems dominated the operation of electricity markets and other sectors all over the world. In those systems, only the electricity producers and suppliers could send their notifications to the market operator without direct interactions among the market participants. However, this trend is changing rapidly as a consequence of the new opportunities for the new actors such as prosumers and also because of the development of community's microgrids. Also, the sensors, the smart appliances energized on batteries and the communication technologies are enhancing a better control that encourages the transactions at the consumers/prosumers level or peer-to-peer (P2P) electricity transactions that require a specific platform based on the Blockchain technology. In this paper, we identify the advantages and limitations of the Blockchain solutions for the electricity trade that allow the interaction of multiple users and communities including the centralized market platform fostering the market competition in the era of digitalization and consumers awareness. We also propose a Blockchain platform architecture for P2P electricity transactions.*

Keywords: Blockchain, P2P transactions, electricity market, distributed computing.

JEL classification: L86, L94

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1. Introduction

Blockchain solutions for P2P electricity transactions are the emerging platforms that focus on eliminating the intermediaries that usually keep the electricity prices at higher levels. Some other advantages they bring are the increasing competition and the trading transparency, having benefits from the diversity of distributed generation (PV, micro-wind turbines, diesel generators) that is more and more available in the residential buildings encouraged by policy decision makers and consumers' awareness.

Nowadays, the electricity suppliers struggle to obtain lower electricity prices when they acquire the electricity on different markets. When setting the electricity prices for consumers, their main concern is to provide a competitive price that could be much higher than the acquisition price that is characteristic for every intermediary. Thus, the electricity price could become much lower since many costs, that are encountered by supplier and other grid operators, would be avoided.

Blockchain solutions bring together consumers and generators to set prices and to trade. Several entities such as prosumers, microgrids, storage owners, electric vehicles stations, etc.,

that are interconnected with the power grid (as in Figure 1), have recently appeared leading to more trading opportunities. However, the traditional trading systems are centralized at the market operator level where such parties do not have access or are not allowed to directly interact.

Figure 1. Entities connected to the power grid

The P2P transactions usually involve many participants at the microgrids level and among them, thus several architectures could be envisioned. They can spread from small local communities, that consist of electricity consumers, prosumers, storage and distributed generation owners, to microgrids (as in Figure 2) or to an entire power grid.

Figure 2. P2P electricity transactions

The Blockchain technology is mainly based on data ledger replication, unchangeable transactions stored in blocks that cannot be deleted because one block stores the hash key of the previous block, smart contracts for blockchain trading generated by the platform, etc.

2. Blockchain and smart contracts

Originally devised as a technology behind the distribution and sale of bitcoin digital currency, Blockchain has found, over the time, various other potential uses. Basically, a Blockchain is a system for maintaining distributed ledgers in a way that enables organizations who don't fully trust each other to agree on the updates to the ledger using peer-to-peer protocols rather than a central 3rd party or an online reconciliation process, which are prone to failure.

According to [1], in terms of access permissions, there are three types of Blockchain: public, private and consortium. In a public (also known as "permissionless") Blockchain anyone in the world can read, send transactions and expect to see them included if they are valid. This involves computer resource intensive mining processes to add blocks cryptographically. In the same time, due to the large number of involved parties, consensual models are based on computationally extensive algorithms requiring the processing power of many nodes to ensure security. At the other end of the spectrum, in private Blockchain, the writing permissions are kept centralized to one organization, while the reading permissions may be public or restricted

to an arbitrary extent. The consortium Blockchain represent a hybrid solution where the consensus process is controlled by a pre-selected set of nodes.

There are three core properties of the Blockchain technology, which have helped it gain extensive acclaim: decentralization, transparency and immutability. A Blockchain consists of a distributed database of records, or public ledger of all transactions or digital events that have been executed and shared among participating parties [2]. All participants see consistent data and updates that are replicated across participants. Decentralization is a result of the networked copies. Transparency is due to the fact that the Blockchain is an open file and any authorized party can access it and audit transactions [3]. Each transaction in the public ledger is verified by the consensus of a majority of the participants in the system. The cryptography methods ensure that each block is digitally signed in such a way that changing or altering an entry invalidates every other entry preceding it by going right the way back to the first block [4]. Once the information is entered, it can never be erased. This way the Blockchain contains a certain and verifiable record of every single transaction ever made. This is what guarantees the Blockchain immutability.

The smart contracts are defined in [5] as “executable code that runs on top of the Blockchain to facilitate, execute and enforce an agreement between untrusted parties without the involvement of a trusted third party.” In [6] it is shown how smart contracts facilitate the appearance of general-purpose computations on the Blockchain system. Through a smart contract, domestic electricity transactions could be made without the intervention of price regulation parties, only the buyers and the power generators being the actors (the Blockchain nodes).

Others exemplify in [7] how smart contracts can be deterministic or non-deterministic, if they have/or not an external source they depend on, like weather conditions, traffic alerts and so on. The implementation of a smart contract has to facilitate its terminable property, meaning it has to make sure the process that assures the business logic of a smart contract doesn't go on an endless loop. In order to avoid that, the following measures can be taken: the smart contract has to be finalized in a limited period of time, or with a limited consume of resources and a third party supervisor can check from time to time if there are some additional requests that can't be met by the current contract.

Smart contracts have to have a special security policy because they can bring viruses to the whole Blockchain, so they need to be kept isolated, not to infect the whole system. They can be created by external members that are not yet verified by the Blockchain system.

3. Blockchain solutions

Blockchain technology means a complex of distributing computing, business networks, big data (see [8]), data mining (see [9]), microservices, log-based systems that have emerged to ease and improve the interactions among parties that otherwise wouldn't have interfered, such as the electricity consumers and the generators.

3.1 Permissioned Blockchain for P2P electricity transactions

In comparison with public platforms (such as: Bitcoin or Ethereum) where anyone can join the platform, in the permissioned Blockchain for P2P electricity transactions, only invited members or participants possess a copy of the ledger [10]. It involves affordable resources in correlation with the number of transactions, the network traffic and the replication. For the public platforms, the technology is not mature yet and could be further improved. For permissioned or authorized Blockchain, the membership service that could also administrate the Blockchain network is needed. The fee for such service could be assessed based on the number of transactions.

3.2 Components of permissioned Blockchain platform

The architecture consists in multiple distributed nodes that could belong to organizations or even private persons like the electricity consumers that are making the Blockchain a business transaction network. One node is connected to the others having individual data ledger where transaction data is stored. The smart contracts contain the business logic. Another important aspect when trading via Blockchain is that a consensus protocol of all involved nodes is required. The membership service usually administrates the Blockchain network and provide an application to allow members to trade.

3.3 Characteristics and benefits

The benefits of the Blockchain technology can be related to the characteristics from which they arise. Some of Blockchain's outstanding characteristics along with their underlying benefits are described as follows [10]: **Distributed ledger**: the existence of distributed ledger copies eliminates manual efforts and delays due to reconciliation needs, considering data consistency as a key attribute of the distributed ledger. **Decentralized, peer-to-peer network**: removes the central authority and the reliance on a single point of failure, which reduces transaction costs and leads to near real-time transaction execution. **Immutable transaction history**: the impossibility to make changes to existing transactions without exposure leads to increased confidence and reduces fraud opportunities. **Transparent**: visibility of transactions for all participants increases auditability and trust and reduces the cost of fraud and audits. **Smart contracts**: because business logic is shared and validated by participants, business process automation is implemented in a trusted way.

3.4 Blockchain implementation

Maybe the best way to illustrate the fast growing interest in the Blockchain technology is stating the following fact: if at the beginning of 2018 only two of the leading cloud providers offered Blockchain as a Service (BaaS) services (namely Microsoft and IBM), by the end of 2018 Amazon's AWS, SAP, Oracle, and Google Cloud announced the launching of their Blockchain cloud services [11]. Besides these, several popular open source Blockchain implementations are available, such as Ethereum, Corda and Hyperledger Fabric. While Ethereum is a public platform, the other two require permissioned access. For smart contract specification, the choice of programming languages depends on the platform: Serpent and Solidity (Ethereum), Kotlin and Java (Corda), Java, JavaScript and GO (Hyperledger Fabric).

3.5 Blockchain specific domains

Blockchain applies for all domains, which have users that can interact through a network, eliminating the intermediary parties and participating as anonymous, secure players, by only putting at stake their own computational resources. Blockchain can be implemented for banking (the bank institution is replaced by the Blockchain system), record/movie/ticket selling (the author directly sells to the buyer), renewable energy (household consumers produce their own energy and sell the excess), elections (avoid fraud), Internet of Things (remote management through smart contracts), crowd founding (facilitating the collection of funds), car/couch sharing (eliminating Uber or Airbnb), file sharing (torrents) and so on. Apparently security is a problem that is solved by the Blockchain technology, but it remains the main obstacle. People don't trust things that are not visible, tangible. Also, there can be some errors that can appear in the system due to wanted or unwanted human interaction like emotional decisions, human manipulation, corruption, data leaks or privacy intrusions.

3.6 Limitations

Five limitations that Blockchain solutions might have are identified in [12]. They are environmental costs, lack of regulations, possible extinction of some businesses, slow processing, and complexity. Environmental costs come from the computational power the algorithms need in order to be executed in the system. Each node has to offer its resources and the more complex the system is, the larger the resources cost will become, the harder to be

understood by the potential users and the slower it will run. The Blockchain technology eliminates the intermediary in many businesses and thus some industries like banking, ticketing, book selling, record selling and so on can lose their activity. On top of all these problems, the lack of regulations remains the most powerful one, because it brings security risks and uncertainty.

4. Scalable Blockchain solution for P2P electricity transactions

The way electricity is produced and stored has recently changed. While in the past, the flow was unidirectional from the traditional large power plants to end-consumers, nowadays, facade or roof-top photovoltaic panels and batteries of modern appliances (such as vacuum cleaner, electric chainsaw, hammer drill, etc.) of households allow them to generate, store and trade the surplus to the neighbors. This way they get a much realistic price and a better return, while the consumers are getting a better deal since the intermediaries are avoided.

In the current market platforms, the consumers or prosumers are not able to interact with each other or with the producers, their consumption data being visible only for the supplier. Thus, the consumers' trading opportunities are limited despite the storage and the generating possibilities. However, the benefit would be maximized (from the costs and the peak point of view) if the consumption is optimized and the peer-to-peer electricity trading is possible.

At the microgrid level, the total electricity generation and demand could be settled based on the price offered through smart contracts (as in Figure 3) that keep the record of transactions (prices and quantities). The platform is scalable, allowing multiple nodes and connections between the microgrids. In this case, the access is permissioned, and the membership service manages the blockchain and provides a platform to allow the peer-to-peer trade.

Figure 3. P2P electricity transactions architecture

The transactions data could be stored in json files in blocks that form a chain by keeping the hash representation of the previous block or in distributed database views. No deletion or updating is permitted, all transactions form a data ledger that is replicated to all nodes so the transparency will be maximized.

5. Conclusions

Therefore, the Blockchain can bring greater transparency and accountability across complex business networks and, in the same time, enabling real-time tracking of assets. One of its major characteristics is that there is no central data repository and privileged network participants are able to read and validate the ledger with no single point of failure.

A performing Blockchain electricity system would contain the households as the nodes, the transactions as data ledger, the energy demand and request, the ad-hoc prices and the settlement

as smart contracts, a consensus protocol, authorized access, a platform administrator that could supervise the transaction as an “invisible player” and the user interfaces.

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