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Enabling Blockchain Based Energy Transfer Using Ethereum Blockchain

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Abstract

Blockchain technology has made a significant impact on many industries. Integrated with Smart Grids, it can permit secure and reliable exchange of energy. Blockchains can be used to solve many of the problems that the current energy grid architecture faces. We have tried to explore the role of Blockchain in solving problems that the conventional system faces. Similar approaches taken by other projects have shown a reduction in the cost to the end-user. We have also expanded on the stakeholders, their roles in the system, and their properties in a potential implementation while briefly expounding on the salient features of a Blockchain network. To realize this implementation, we use the Ethereum Blockchain platform. Using the Ethereum Blockchain, we aim to ensure the transparent transfer of energy and pertinent funds which adhere to the business logic that is implemented. In this paper, we discuss the implementation and benefits of using Blockchain in a Smart Grid environment, without delving deeper into the technical aspects of a Blockchain network.

Keywords: *Blockchain, Peer-to-Peer, Smart Grid, Ethereum, Smart Contracts*

1. Introduction

Blockchain technology is gaining traction in many industries today. Healthcare, Banking and Real Estate are some of the sectors in which Blockchains have found their usage. Blockchain has enormous potential in the Energy industry as well and has been garnering attention. However, there have not been any large-scale developments in the sector. Pilot projects have risen in many parts of the world and are currently being tested. There have been significant technological strides made in the energy sector that allows us to implement Blockchain in the gird. Using Blockchain in the energy sector can provide the end-user with the benefit of greater transparency and reduced financial burden. With the increasing reliance on renewable energy and the currently ill-equipped infrastructure to handle this change, Blockchain technology will play a pivotal role in ensuring a smooth and efficient transfer of dependency. It has the ability to make a significant impact on the way we manage our electricity grids, distribute energy and make financial transactions.

The existing energy production systems lack the means to assess information about the provenance of energy, interim storage, distribution and consumption. However, using Blockchain and the integration of sensors, these problems can be solved with ease. The potential for the data

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gathered is understated. This data could be made available to authorized users to whom this would be of higher value than the organization which has collected it. Data written to the Blockchain is immutable, thus eliminating the possibility of the written data to being tampered with once pushed on to the Blockchain network.

2. Related Work

The concept of Blockchain was first proposed in 2008 and later implemented in 2009 as the Bitcoin Blockchain [1]. Bitcoin, often called the first cryptocurrency has enjoyed huge success as a financial trading mechanism and platform. The paper described the implementation of the Bitcoin Blockchain, which has become the fundamental foundation for various iterations of Blockchain technologies.

In [2], the authors conducted a comprehensive survey on Blockchain technology. In particular, the paper gave the Blockchain taxonomy, briefly touched upon the various Blockchain consensus algorithms, reviewed its applications and discussed the technical challenges in realizing a real-world implementation.

In [3], the authors discuss challenges the Smart Grid faces and the significant changes it can bring to the energy sector with the capability to transform the economy and society. They review the opportunities that Blockchain can provide to the Smart Grid architecture. They discuss the applications of a decentralized system and propose a custom design suited to the needs of energy sector.

Recognizing the role that Electric Vehicles can play in stabilizing the Energy Grid, the authors in [4] have explored the rise of renewable energy production and storage methods in an increasingly decentralized. They explored how Prosumers, consumers who can produce their own energy, are essential to a system aiming to distribute electricity based on IoT, ICT and smart metering.

In [5], the authors have discussed about Local Energy markets, where the consumers and prosumers in the system can locally trade the produced renewable energy. Their approach concentrated on implementing such a system on a private Blockchain. They presented a preliminary economic evaluation of the market by simulating 100 residential households in a Local Energy market.

3. Enabling Technologies

3.1. Blockchain

A Blockchain system can be simplified as a database of transactions. Multiple transactions are stored in a block, and blocks are linked to each other using cryptographic algorithms. Transactions are the actions carried out at a given point of time and a fixed number of them are stored together in a block. Each block contains a cryptographic hash that connects it to the previous block creating a string. The cryptographic hash is calculated using the transactions in the previous block, it's address and other parameters. This means that a change in any of the parameter or transaction leads to a different hash being computed. This ensures the security of the chain. All the participants of the system can verify or reject the transactions using consensus algorithms. The approved data is

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then stored into the ledger and then hashed for securing the data and provides immutability. Using the Blockchain in the energy sector can ameliorate many problems that the sector faces. Its property of immutability, robustness and decentralization provides many opportunities for growth and realization in the sector.

3.2. Smart Contracts

Smart contracts are unique to the Ethereum Blockchain. They are algorithmic, self-enforcing, and self-executing computer programs. Smart contracts are scripts stored on the Blockchain and have a unique address specified to them. They are triggered by addressing a transaction to it. Once triggered, the smart contract executes independently and automatically in a prescribed manner on every node in the network according to the action and data included in the triggering transaction. It provides the user the ability to embed business logic in the Blockchain.

3.3. Smart Grids

The grid is a network of transmission lines, substations, transformers, and other energy infrastructure that delivers electricity from the power plant to the consumer. A Smart Grid introduces a two-way dialogue where data can be exchanged between the utility and its customers. It is a developing network of communications, controls, computers, automation, new technologies, and tools working together to make the grid more efficient, secure, and reliable. The Smart Grid represents an unprecedented opportunity to lead the energy industry to an era of efficiency, availability, and sustainability that will contribute positively to the economic and environmental health of its adopters. The transformation of traditional electricity grids to Smart Grids would provide all stakeholders with improved efficiency and reduced operational costs.

3.4. Sensor Integration

The term ‘Internet of Things’ (IoT) – denotes the electronic or the electrical devices of various different sizes and capabilities connected to each other via various mediums. This connection is established by using different wired and wireless sensors to communicate with each other. There are many types of IoT devices incorporating a wide range of applications, network domains and protocols. The growing prevalence of IoT technology is enabled by physical objects connected to the internet using various wireless technologies such as RFID, ZigBee, sensor networks, and location-based technologies. Introducing Blockchain technology in any IoT ecosystem will enhance the reliability of the IoT system by completely eliminating the chances of a Single Point Failure which the traditional IoT systems face issues with. Furthermore, in Blockchain, data is encrypted using various cryptographic algorithms along with different hashing techniques. This also adds an added layer of security to the IoT end nodes.

Blockchain and IoT are novel technologies with a promising future in the industry. While Blockchain has widened beyond its initial application for Bitcoin technology, IoT has also proved to be capable of doing far more than simply being a wireless sensor network. The adoption of Blockchain in IoT has is very appealing in terms of solving complex problems through distribution. Integrating IoT technology with Blockchain will enable the Smart Grid to automate its functions and provide a seamless experience to the end user. This integration with IoT permits Smart Meters to be incorporated in the system. Smart Meters provide two-way communication between

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providers and consumers to automate billing, detect failures and dispatch repair crews much quicker to desired locations. Smart Grids rely on Smart Meters for the integration of energy and Information and Communication Technologies (ICT). Smart Meters and associated technologies enable real-time, bidirectional communication between suppliers and consumers – thus dynamically controlling the interaction of energy flows. Smart substations perform monitoring and controlling of critical and non-critical data which include power factor performance and security.

3.5. Electric Vehicle to Grid Networks

A Smart Grid that powers electric vehicles and can utilize the same entities to greater the resilience of the Blockchain network. The power fluctuations and the overall operating cost of the grid can be mitigated with the use of some adaptive and dynamic algorithms and mathematical models which utilize Electric Vehicle (EV) battery as a medium for damping these fluctuations. The emergence of EVs in the market brings forward the concept of a bi-directional transfer/flow of energy. To adapt to the large volumes of EV charging/discharging demands, the Blockchain allows peer-to-peer transaction platforms that utilizes decentralized storage to record all transaction data.

Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) energy transfer assists in load balancing of the grid and EVs act as fast-ramping power back up devices for load flattening, peak shaving, and frequency regulation. The bi-directional flow helps in better managing and utilizing the subsidiary energy generated by transferring it to the EVs. This is envisaged to reduce the generation cost and increase the robustness of the Smart Grid. This could reflect a significant impact on the usability and the system's ability to adapt to such irregularities that may occur in the network. Decentralized consensus techniques and Blockchains can be used both to coordinate the scheduling of distributed energy resources in a Microgrid, and to guarantee a fair payment without requiring a centralized aggregator.

4. Decentralization of Energy

The current Energy infrastructure faces the problem of centralization. The loss of a crucial power source can lead to enormous economic and human loss. Instead of a single source of energy, decentralizing the energy production infrastructure would enable us to solve the problems that the conventional methodology is plagued with. Energy reliance can be shifted from a single source, to a Peer-to-Peer (P2P) network. Every node in the network would have the capacity to produce its own energy in addition to the consumption of it. This would lead to the rise of microgrids and reduce the dependence on external sources of energy. Blockchain technology can be used as an automated accounting technology. The Ethereum Blockchain, through Smart Contracts, provides the facility to add logic to financial transactions. This can be used to develop sophisticated solutions for the energy sector, along with a cryptocurrency, designed for its need. It could also facilitate the rise of an energy sharing market, where surplus energy is sold to neighboring nodes in the microgrids. This will not only promote the usage of renewable sources of energy for economic benefits, but also lead to increased interdependence amongst the community. During times of travail, the microgrid can be used to divert the energy it produces to essential areas. Thus, even in the loss of a major source of energy, military installations, hospital and other indispensable infrastructure are able to be kept running.

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5. Sustainable Local Energy

The term ‘Sustainable Energy’ can be understood as the state of energy generation and consumption where the human use of energy is commensurate to the needs of the present while not compromising the ability of future generations to meet their own needs. To create a more sustainable future, we need to utilize local and renewable resources and make efficient use of energy. Local Energy Markets (LEM) on which consumers and prosumers can trade energy within their community, offer (near) real-time pricing, and facilitate a local balance of supply and demand. Thus, LEM provides a marketplace with access to local energy to a specific community. However, the implementation of LEM requires novel and innovative ICT. Blockchain technology as an emerging ICT offers new opportunities for decentralized market designs. It can provide the transparent and user-friendly applications needed for energy end-users to participate in the process of energy consumption. The market mechanism allows for trading energy between the agents who can virtually trade energy within their community. Local energy trading often aims at empowering the community through possible energy cost reduction. This boosts the local economy, as profits are kept within the community, which may encourage additional investments in local Renewable Energy Sources (RES) generation. This, in turn, will automatically alleviate the problems faced due to the increasing demand for energy.

Local energy systems by employing production where it’s needed. The electricity may be generated from several small-scale producers, such as solar cells on the building roofs or a small wind turbine that a group of neighbors have jointly invested in. These situations are depended on local conditions. It must be noted that all energy produced is given high importance and efforts are taken to ensure it does not go to waste. A smart control system ensures that the production is aligned with the consumers’ requirements and usage. Whenever there’s a production peak – for example, when there are optimal weather conditions– the electricity generated by these renewable sources is stored in batteries and can be utilized when pertinent.

In LEMs, customers generating energy on their own will be able to consume self-generated energy by making optimal use of local Distributed Energy Resources (DER) including Energy Storage (ES) and RES. They thus become prosumers, consumers who also produce the entity consumed, who actively manage their energy affairs. This provides them with a higher level of energy independence and control, when compared to the traditional electricity “price-taker consumers”. They will also be able to trade their energy generation surplus within the boundaries of their local community which facilitates local energy trade and enables the strengthening of the customer’s position, i.e. from a passive to an active role in the energy market/system. With greater involvement, customers also become more energy efficiency-aware LEMs can also enhance the security of supply if, for instance, these would be structured as Micro Grids (MGs) i.e. these could operate isolated from the distribution grid if outages occur. The avoidance of outage costs, particularly in rural areas where electricity delivery service is less reliable than in urban areas, is thus an additional benefit that customers can leverage in LEMs. LEMs will connect communities and drive their participant customers into achieving common goals, such as reducing costs of energy, emitting less greenhouse gas emissions or becoming more energy self-sufficient. The evolution from a traditional energy model to a new paradigm rooted in decentralized and customer-centric energy production and distribution is a massive undertaking with many positive societal repercussions. LEMs not only embrace this paradigm as take it steps further by providing greater market transparency and the promise of more fair distribution of power and more balanced

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allocation of systemic costs and benefits, which are arguably foundations to the advancement of any society. LEMs facilitate the growth of clean energy generation, in particular from RES, which leads to lower local and global emission levels. Thus, the local electricity market is one such market that fits in the existing market structure while making use of the benefits of local power generation, storage, and demand response. It integrates the distributed generation, microgrid, and smart grid into a cohesive electricity market on the distribution side.

6. Proposed Smart Grid Architecture

Entities involved right from the production of energy to the consumption will be a part of the architecture. Each party in question will have its own BlockChain node, with its own unique properties. Along with that, they will have a unique address using which they can be identified. This would not only equip the end-user to analyze where their energy has come from but access the party in question and the information about it that he is authorized to. The key stakeholders include Producers, Providers, and Consumers.

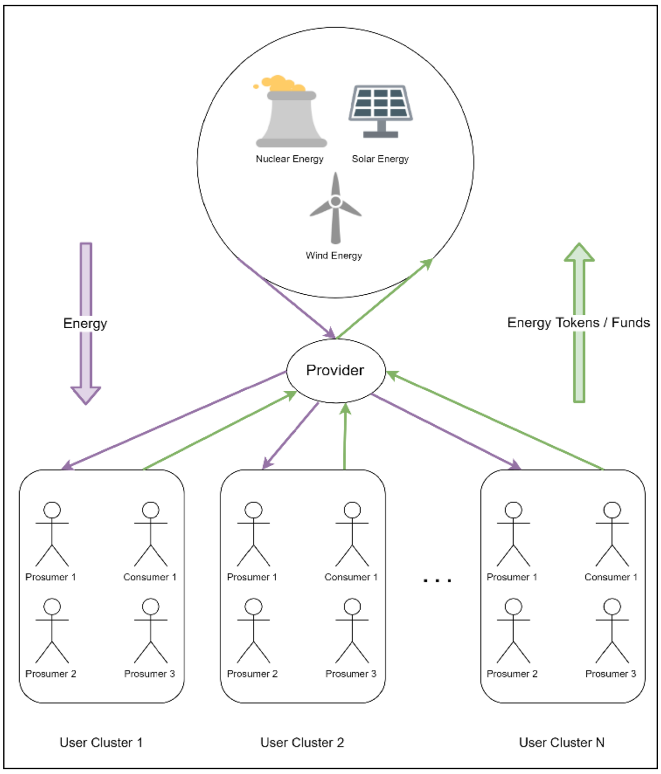

Figure 1. Overview of Proposed System

6.1. Producer

The Producer is the source of the majority of energy in the system. The energy produced can be classified as renewable or non-renewable, and the identification of which enables appropriate Cost Per Unit (CPU) of energy to be levied. Every Producer in the system has a unique Ethereum account address that can be used by other entities in the system to access the publicly available information about it. The Ethereum account also acts as a medium to

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allow the Producer to keep a tab on the remaining units of energy and funds. Incorporating the Producer in the Blockchain enables the end-users to gain access to information about the provenance of the energy that they are consuming. Along with this, it will empower users to comprehend the composition of renewable and non-renewable energy in the energy that they consume.

6.2. Provider

The Consumer in the proposed system, receives energy through an intermediary entity, called Provider. Each Provider in the system maintains a list of all the Consumers that are associated with itself. It is the task of the Providers to ensure that the Consumers receive the energy produced by the Producer. Every Provider in the system has a unique Ethereum account address associated with them, which can be used by other entities in the system to access the publicly available information. It also gives the Provider a platform to keep a tab on the remaining units of energy and funds. The Provider receives energy from the Producer, transforms it into a form that the Consumer can handle. The Provider then distributes the energy to the Consumers that are associated with it according to their needs.

6.3. Consumer

The Consumer in the proposed system also has the ability to produce its own energy. With the rise of solar, and other methods of renewable power generation, the Consumer can be also defined as a Prosumer. The Consumer of energy is also labelled as dispensable or indispensable to indicate their level of importance in a time of calamity. Every Consumer has a unique Ethereum account address associated with it that can be used to access publicly available information about the other entities in the system.

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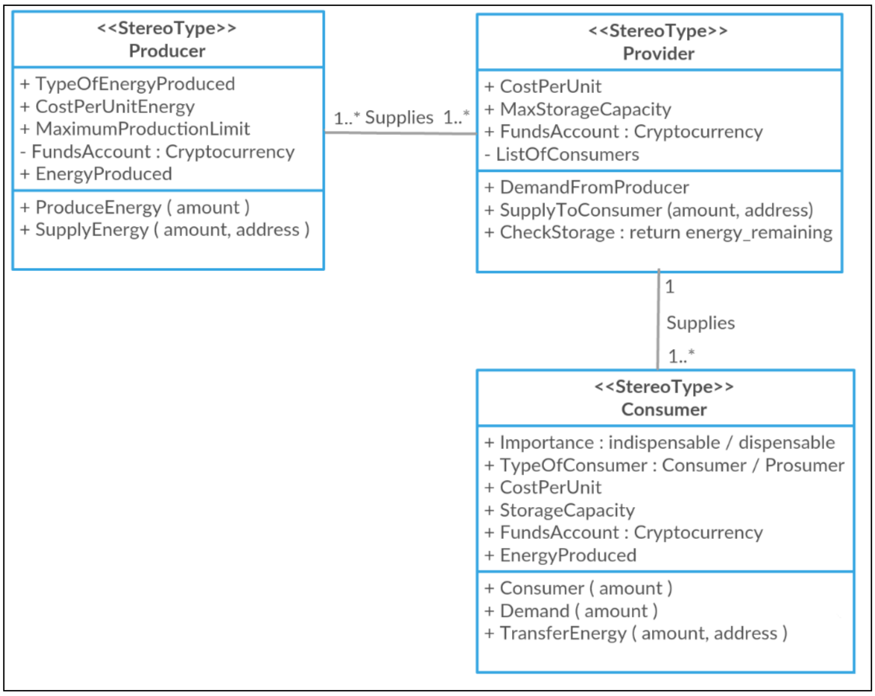

Figure 2. Class Diagram of System

7. Ethereum-based Energy Trading

The Ethereum Blockchain lets us design and implement tokens for financial transactions. The Ethereum-based token can consist of various interfaces and implementations to enable financial interactions amongst entities. The Smart Grid architecture can implement a paradigm where crypto-currencies can be used for commensurate transfer of funds on receiving adequate energy. These funds can be tokens generated that are digital assets built on top of the Blockchain. These tokens can represent a physical object like gold or to a native currency to pay a transaction fee. Tokens may also be used to represent financial instruments. These tokens can be heavily regulated, that is to say, that their supply can be constant or can be governed by a sophisticated monetary policy. Using blockchain in our Smart Grid architecture will permit us to use these elegant tools for financial transactions. Each entity in the system, occupies an account on the Ethereum Blockchain with a specific address, and an array of its own unique characteristics. These account addresses have a certain amount of Ether in their wallet. Though Ether is used as the fuel to run Smart Contracts, it can be bought and sold as a cryptocurrency. We have envisioned a cryptocurrency developed for our implementation as follows.

Our system works on the condition that in the beginning of a financial cycle, the Consumer C_i will demand for a quota of energy E_{Req}^{i} for the period of the financial cycle. The Provider is aware of the requirements of all the *n* Consumers associated with itself. The Provider then submits a request for energy required to the Producer E_{Req}^{Total}.

$$E_{Req}^{Total} = \sum_{i=0}^{i=n} E_{Req}^{i}$$

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The Producer then responds with the total amount of energy that it can produce. It returns a value E_{Avl} which signifies the total amount of energy that can be made available to the Provider to distribute.

$$E_{avl} = Total\ energy\ Producer\ can\ provide$$

We thus define our Cryptocurrency for the system, cryptoBJLi. It is the facilitator in the system that allows for entities to buy and sell energy. The cost of 1 cryptoBJLi is kept equal to the price of a constant number of Ethers *k*.

$$1\ cryptoBJLi = k\ Ethers$$

The purchasing power of 1 cryptoBJLi is then defined as follows:

$$1\ cryptoBJLi^{purchasing\ power} = \frac{E_{Avl}}{E_{Req}^{Total}}\ Units\ of\ Energy$$

This creates a system where the cost of a single cryptoBJLi is constant, yet the Units of Energy that it can buy varies according to the demand and supply for Energy in the grid. It also incentivizes the consumers to contribute to the grid as it would bring down the overall cost. Any transaction to buy energy, is first converted to cryptoBJLi and then commensurate amount of energy is transferred to the requestor.

8. Conclusion

In this paper, we presented an approach for incorporating Blockchain technology to Smart Grids. We discussed the various stakeholders that would be a part of the system with their functionality and attributes. The paper also briefly delves into the enabling technologies that would make such an implementation possible. We presented a mechanism to dynamically adjust the cost of a unit of energy depending on the availability and requirement of energy in the system in the Ethereum Blockchain ecosystem. The authors look optimistic about a potential adoption of a variation of the system proposed. With the advent of energy storage solutions and local renewable energy production means, adoption of Blockchain technology in the leads to a reliable, feasible and decentralized system with huge advantages compared to the traditional system.

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References

[1] Nakamoto. S (2008) Bitcoin: A Peer-to-Peer Electronic Cash System, https://bitcoin.org/bitcoin.pdf.

[2] Z. Zheng, S. Xie, H.-N. Dai, X. Chen, and H. Wang, "Blockchain challenges and opportunities: A survey," International Journal of Web and Grid Services, vol. 14, no. 4, pp. 352–375, 2018.

[3] I. Kotsiuba, I. Skarga-Bandurova, A. Velykzhanin, T. Biloborodova, O. Biloborodov, Y. Yanovich, and V. Zhygulin, "Using blockchain for smart electrical grids".

[4] G. C. Lazaroiu and M. Roscia, "Blockchain and smart metering towards sustainable prosumers," in 2018 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM), pp. 550–555, IEEE, 2018.

[5] E. Mengelkamp, B. Notheisen, C. Beer, D. Dauer, and C. Weinhardt, "A blockchain-based smart grid: towards sustainable local energy markets," Computer Science-Research and Development, vol. 33, no. 1-2, pp. 207– 214, 2018.

[6] K. Mannaro, A. Pinna, and M. Marchesi, "Crypto-trading: Blockchain oriented energy market," in 2017 AEIT International Annual Conference, pp. 1–5, IEEE, 2017.

[7] M. Andoni, V. Robu, D. Flynn, S. Abram, D. Geach, D. Jenkins, P. McCallum, and A. Peacock, "Blockchain technology in the energy sector: A systematic review of challenges and opportunities," Renewableand Sustainable Energy Reviews, vo. 100, pp. 143–174, 2019.

[8] P. Danzi, M. Angjelichinoski, Cˇ. Stefanovic´, and P. Popovski, "Distributed proportional-fairness control in microgrids via blockchain smart contracts," in 2017 IEEE International Conference on Smart Grid Communications (SmartGridComm), pp. 45–51, IEEE, 2017.

[9] C. Pop, T. Cioara, M. Antal, I. Anghel, I. Salomie, and M. Bertoncini, "Blockchain based decentralized management of demand response programs in smart energy grids," Sensors, vol. 18, no. 1, p. 162, 2018.

[10] Z. Guan, G. Si, X. Zhang, L. Wu, N. Guizani, X. Du, and Y. Ma, "Privacy-preserving and efficient aggregation based on blockchain for power grid communications in smart communities," IEEE Communications Magazine, vol. 56, no. 7, pp. 82–88, 2018.

[11] A. M. Antonopoulos and G. Wood, Mastering ethereum: building smart contracts and dapps. O'Reilly Media, 2018.

ISSN: 2233-7857 IJFGCN