A Study on Utilization of Hybrid Blockchain for Energy Sharing in Micro-Grid

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Abstract—With recent developments in the blockchain technology, the energy industry is devoting an overwhelming interest towards it. Moreover, the future society will move towards a zero-energy internet to share energy and minimize the energy usage that contributes in producing greenhouse gas consumption. As a result, energy sharing system is undergoing a paradigm shift from centralized energy supply systems to ICT-based distributed energy supply systems. In this regards, a major challenge for the energy market case study is the presence of the energy double spending problem in Micro-Grid (MG), which threatens the security of the trading infrastructure. In this paper, we propose a mechanism that the problem of double energy spending is solved by applying off-chain Hybrid Blockchain (HB) technology to provide a secure environment where energy can be safely shared between prosumer and consumer at a closer distance, without intermediary intervention.

Keywords— micro-gird; hybrid blockchain; energy sharing; plasma, renewable energy.

I. Introduction

In recent years, there have been active movements in Micro-Grid (MG) to apply blockchain for personal energy sharing. Here, the blockchain is a technology that enables reliable electronic transactions by using peer-to-peer distributed timestamp servers to generate calculated evidence of the time sequence of transactions [6]. The power data trading system, created by the fusion of electrical grid and communication technology, has stability and efficiency compared to the existing electrical grid. It improves scalability that can provide flexibility to link the consumer to electricity networks, even with the emergence of new and renewable energy, electric vehicles, and prosumer. A centralized power distribution system provides higher reliability by providing a constant supply of generated power. Even if the high voltage transmission system meets the growing demand for electricity, it largely suffers from reduced efficiency and resource utilization [1].

Every product (e.g., automobiles, appliances) that we use takes energy to work [2]. The global primary energy demand has been raised by 50% since 1990. By 2035, the energy demand will probably be much higher than that of now. Brooklyn Micro-grid Project and PowerLedger, for instance, are helping to trade energy by using Decentralized Ledger Technology(DLT) [2]. However, Problems of determining transaction rates and using energy usage information remain an open question.

Besides, the MG system stands for local power supply systems centered on distributed power that are independent of the conventional wide power systems [3]. Many prosumers in the power station take charge of the power generation of the grid based on the two-way transmission and distribution. It suggests using distributed energy sources such as renewable energy like solar power, wind power, and fuel cell as their own power generation sources. As the power sources are dispersed, there is a possibility to supply electricity stably and efficiently transfer renewable energy [4].

The combination of the MG and blockchain technology have been evolved as a power grid that allows consumers to trade power with prosumer [5]. A micro-grid system with extended prosumers sharing energy consumption, production, and sales, along with a smart grid system provides power usage information to suppliers using smart meters. To this end, the advantages of micro-grid with blockchain are data integrity, reliability, and distributed decentralization that enables security, and transparency of data. Thus, in this paper, we propose a micro-grid energy sharing framework that enables high security and transparent power trading using smart contract based on the Hybrid Blockchain (HB).

In the case of sharing energy, metering infrastructure is installed along the electrical grid in order to use the capabilities of a distributed computing platform. Through the installation of this metering infrastructure in the power grid, and the utilization of the distributed computing platform, the participants within the blockchain network are able to agree and reach consensus about the state of the system in a decentralized manner. Therefore, participants within the blockchain network look up independently to each other, on whether a particular producer has indeed injected electrical energy into the grid without selling it twice. This problem is particularly classified as a double energy spending problem in blockchain network.

Traditional energy transactions rely on financial institutions. However, if we rely on financial institutions, we have a unique weakness in our trust-based model. Therefore, a platform is needed for direct transactions between the parties of the transaction without the existence of a trusted third party.

In this paper, we study an energy sharing framework using HB using Plasma's Off-chain to solve one of the above

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scenarios of avoiding double energy spending. Key contributions of our study are:

1) We use Hybrid block-chain in our model to solve the double energy problem.

2) Our model is not only energy efficient but also improves scalability and flexibility to link the consumer to electricity networks

3) The use of smart meter gives the benefit of sharing energy efficiently.

The rest of this paper is organized as follows: In Section II, we provide detailed related works for understanding the proposed system. Then, we describe the proposed system with its architecture in Section III. Section IV analyzes the performance of our proposed system. Finally, we conclude and discuss our future work in Section V.

II. Related Work

A. Hybrid Blockchain(HB)

The HB combines characteristics of public and private blockchains in order to provide users with a choice that transactions remain public, and should be accessible only to a smaller group of participants. The hybrid chains combine private and public network states to reach a higher level of safety. This combining provides the transaction process better privacy while ensures verification via immutable public-blockchain history simultaneously. Again, the HB also ensures security, decentralization, transparency, and immutability. Moreover, the hybrid verification functions similar to Satoshi Nakamoto's decentralized public verification [7].

In an HB, the private blockchain can determine which transactions are public, and submit these transactions to the public blockchain for open access. Moreover, the public blockchain can store transactions to secure data provenance. Based on the application design and business logic, the blockchain architect can use the public blockchain, private blockchain, or a hybrid model by leveraging the benefits of both public and private blockchain [8]. To conclude, This paper states that HB offers a new approach to data storage and transaction processing. Fig. 1 shows the overall architecture of HB.

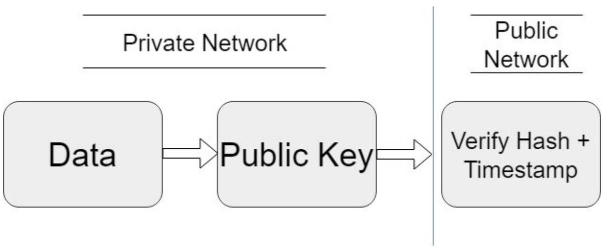

Fig. 1. Hybrid blockchain Network Architecture.

B. Brooklyn micro-grid project

In the setup of the micro-grid project in Brooklyn, New York City, energy consumers can note the maximum price that they are going to pay for electricity consumption during a specific period. Then, the LO3 system automatically determines how much energy that each user would be able to receive from specific energy source based on supply, demand, and bid prices of energy in the MG. Protocols ensure minimum payment for solar-producers with the general market price for electricity, and a peer-to-peer energy market can pay producers significant sums of money for their electricity [9].

The solar panel-owned households (prosumers) produce electricity and the other purchase electricity that is left unused by solar panel holders. Among consumers, a private blockchain network manages and records electricity transactions between neighbors. On the residential streets, households engaged in electricity trading among their neighbors are equipped with smart meters. Therefore, they can confirm the electricity production and consumption. The blockchain network associated with these smart meters records transaction status so that any participant can see the status. Here, the Ethereum platform is used as a blockchain network [5] and Fig. 2 depicts a concept of neighborhood power trading.

C. Ethereum Plasma and Plasma Cash

The hybrid block technique conducts off-chain transactions, but at the same time, relies on the public blockchain to verify these transactions. Besides, plasma "off-chain" (also known as side-chain) technology combines state channels to resolve various issues like double energy consumption, scalability in IoT and every market.

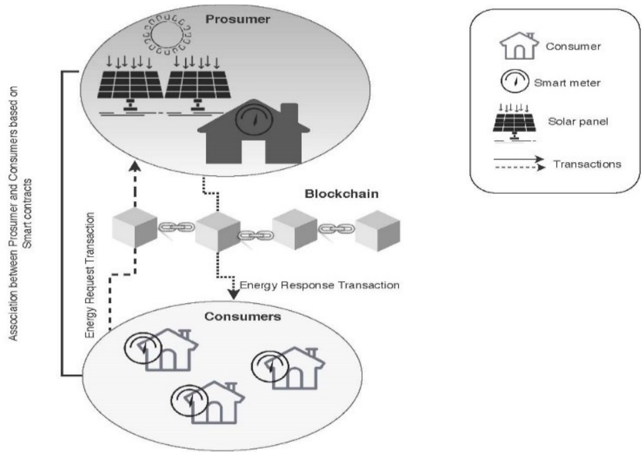

Figure 2. Concept of neighborhood power trading.

It takes operations from the main public chain, transacting and solving them in an off-chain manner. This can be visualized as a side-chain hierarchical tree that systematically provides data to the public chain. Plasma Cash, which is better suited to blockchains supporting smart-contract usage, operates similarly to off-chain transactions [10].

The five components of the plasma are illustrated in Fig.3. Plasma Cash functions on the public blockchain and compares transactions on the side chain. If everything is verified and works well with the Merkle root, then the transaction can be broadcasted on the public chain. The only drawback with Plasma and Plasma Cash is the cost.

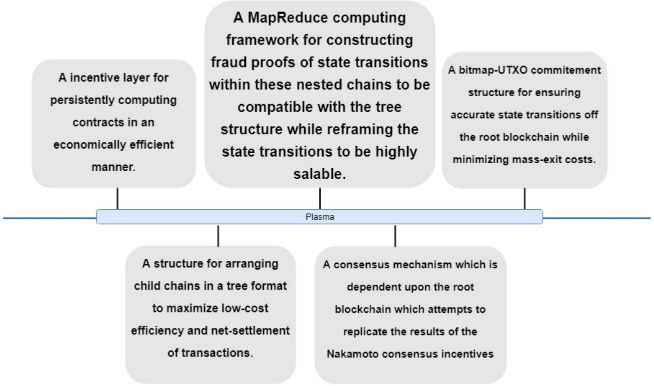

Fig. 3. Plasma's five components.

III. SENARIOS AND SYSTEM ARCHITECTURE

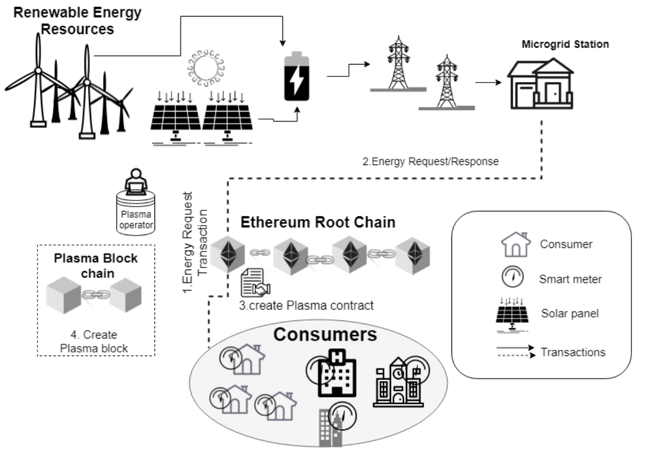

Fig. 4. System Model.

Fig. 4 illustrates the system model of energy trading between MG and consumers using a Plasma. As the figure shows, the system consists of a micro-grid, a plasma operator, and consumers. It is assumed that the consumer requests energy from the micro-grid and Plasma protocol is used to solve security performance, transparency, and the double energy spending problem. We propose a solution using plasma and plasma cash within the hybrid blockchain and discusses how efficiently it solves the problem.

A. Energy sharing framework for micro-grid using plasma in HB

By using Plasma in HB, we propose an off-chain-based solution to address the issue of blockchain scalability to trade the new renewable energy and prosumer's energy in a micro-grid. Our model creates and connects the Child-Chain (Plasma Chain) under Root-Chain (Ethereum main-net). It relieves the burden of idleness by processing the transit in Child Chain and sends the transaction result value only to the upper chain, which reduces speed and costs.

The Plasma estimates only the hash value of the block header in the upper tree depth. The block header of Child Chain is not moved to the Parent Chain, whenever a block is created. Also, to increase efficiency, we collect them once a cycle and go up to the Parent Chain [10].

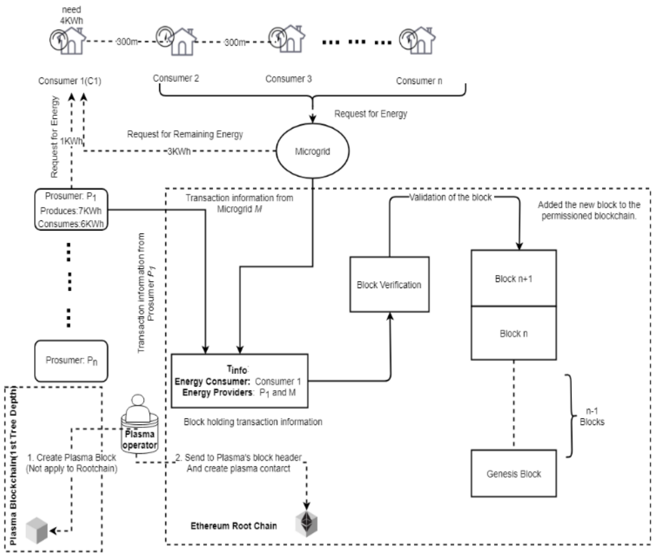

Fig. 5. Work-Flow Diagram of energy trading using hybrid Plasma.

Fig. 5 shows the energy sharing framework, plasma contact based on HB for MG. Here, in this work-flow diagram, smart meters serve as an automated agent to trade electrical energy instead of intermediaries. Consumers with a smart meter infrastructure, denoted by N, can request and trade the necessary power(KWh) to a prosumer with renewable or solar energy remaining through MG with local power supply system with independent distributed power.

As shown in Fig. 5, the energy trading work-flow mechanism is stated in Algorithm 1.

Algorithm 1 : *Plasma Trading*

1: *"C1" requests 4KWh from"P1" according to smart contact.*
2: *MG checks whether transactions can be performed based on electrical routing and power line support.*
3: *Once routing is effective, MG enables "P1" to transmit to "C1" in relation to the line capacity to support the transaction.*
4: *MG requests residual power from MG to meet the terms of the transaction.*
5: *The network provides remaining power of 1KWh to C1 through the MG.*
6: *Finally, MG sends 3KWh to "C1".*
7: *Create Plasma block.(Not apply to RootChain).*
8: *Send to Plasma's hash value and create plasma contract.*
9: *Finally Make Plasma block(apply to RootChain).*

B. Example of an energy double spending avoidance

Currently, the blockchain technique has some limitations. One of the biggest challenges is an issue of double energy spending. As stated earlier, the market case study is the initial step in the adoption of the blockchain, and it faces issues regarding the security of the trading infrastructure due to the existence of the double energy spending problem. The metering case study faces challenges regarding the securitization of the smart metering devices, scalability of the blockchain in order to ensure proper operation of a blockchain energy market [5]. Again, HB implementation is an excellent choice for eliminating attacks and deceitful behavior. Hybrid chains combine personal and public network states to improve safety. In this way, private organizations can use public block chains to track records without intervention while checking transactions.

There are two solutions to the double energy problem such as Ethereum Plasma MVP (Minimal Viable Plasma) and Plasma Cash Solutions. The Ethereum Plasma Protocol is one of the best solutions to ensure a high level of security. It works with blockchains like Bitcoin, Ethereum, and other private block chains such as Hyperledger fabric. The working technique that conducts off-chain transactions, but at the same time relies on the public blockchain to verify these transactions. On the other hand, Plasma “off-chain” (sidechain) technology combines state channels to resolve various problems like smart meter attack, hacking. It takes status from the main public chain, complete transaction, and solve them in an off-chain manner which can be visualized as a side-chain hierarchical tree that systematically provides data to the public chain [11].

In our proposed Plasma MVP scheme, Plasma MVP is the first Plasma implementation since [11]. The biggest key to distinguishing between an inter-chain scalability solution and a plasma using a common sidechain is the connection relationship between the main-net and sidechain.

In a typical inter-chain solution, energy exchange occurs between the main-net and the sidechain in a relatively same relationship, and each chain should provide sufficient safety to itself. In plasma, on the other hand, plasma chains are dependent on the main-net through the plasma cluster on the main-net, and the safety of the plasma chain is dependent on the main-net. When a new plasma block is created, it shares the plasma block with the nodes participating in the plasma chain, but the main-net stores only the root value of the block in the plasma cluster.

Therefore, there are some advantages of storing only one kind of compressed information in the plasma chain on the main-net. They are, 1) more transactions can be processed in parallel compared to the presence of the main-net alone, 2) the effect of reducing the cost of using the main-net, and 3) the malicious behavior that a single operator may incur with the power to create the block will be post-validated on the main-net.

IV. Performance analysis

In this section, we present the result of our analysis for the proposed method of energy sharing without double spending problem and the HB technique. If malicious prosumers could hack their own meter to mimic that production e.g., delivering of electrical energy has taken place, and sell this non-product electrical energy to other consumers within the electrical power system via the blockchain which is classified as the energy double spending problem [7].

In general, the smart metering devices form a critical link where the blockchain trading infrastructure is built with the electrical power system. To guarantee the proper energy exchange operation, these devices should be adequately secured concerning the information technology aspect and the hardware security to prevent malicious alterations to these devices. However, the proposed HB are well-suited to semi-private businesses that prefer to keep their data close, yet verify all types of transactions more securely. Hence, the hybrid solution of performing operations off-chain and broadcasting them on the public chain for verification appears to be a great way out.

V. Conculsion

In this paper, we analyzed the HB platform and micro-grid system to handle the double spending problem. By applying an HB platform to conventional micro-grid systems, it is possible to use Plasma contracts and construct transparent and efficient systems. Besides, the Ethereum Plasma platform can be applied to electric vehicle charging systems as well as electric power fields. From the performance analysis, our model saves energy wastages and tends to zero-energy internet. The proposed model also provides scalability provides security, decentralization, transparency, and immutability.

Future researches need to design an actual use cases that can operate with the micro-grid system.

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