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Smart Contract: Blockchain-based Energy Exchange Framework with reduced Transaction Cost

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Abstract: Smart grid is an innovation in a communication network, interconnected power framework, advanced control technology, and smart metering has been applied to work on the usage of renewable energy resources and alleviate the energy emergency somehow. Blockchain is basically a decentralized accounting ledger with the potential to enable, manage, track and verify thousands of energy transactions per second. The blockchain energy market is proposed to be utilized by networks that share a nanogrid. The application permits nanogrid participants that have an abundance of electrical energy, to offer that energy to different clients of the nanogrid. The application gives a decentralized marketplace for executing electrical energy. Since this blockchain energy market is implemented by Ethereum smart contract, it suffers from the high operating costs that result from the contract's high gas consumption. Ethereum smart contracts are implemented by reworking on acceptoffer function to verifies its validity and withdraw function which uses a single function call for multiple energy transfer contracts to decrease the operation cost.

Keywords: Blockchain, Smart Grid, Ethereum, Smart Contract, Nanogrid, Off-Chain Offer

1. INTRODUCTION

An electricity distribution approach [1] is required to develop a smart infrastructure for IOT based system. In the conventional electrical grid, the interconnected network connects the generating station to the end-user via a transmission and distribution system. Before there were generating power stations used to fed power into the grid so as to supply to the consumers. So there is always a team of engineers, who will forecast and monitor the load demand depending upon the time slots. So that the grid is always stable. Sometimes due to human error, there might lead to some problems in balancing the load which leads to a brownout, blackout, and load shedding. Currently, the smart grid is used in some countries for electricity generation, delivery and consumption. Here the energy is properly metered, monitored, and managed. Current energy frameworks are confronting a progressive change for both supply and demand sides. Because of power's non-storable nature, supply and utilization of power being taken care of into an electrical grid should continually be adjusted. Using the smart grid, a lot of data is exchanged between the consumer and electrical end which will be a bidirectional communication. Using this smart grid, the energy is exchanged between the consumer and electric end. In the public network, there will be multiple producers and consumers who will interact with the grid and find the price, where demand and supply are done [2]. During energy exchange, a power delivery contract is used to keep the supply and demand in balance. This contract can be done in either a financial or physical way. The financial contract is done for speculation, whereas in physical contract power and cash is delivered based on the expiry of the contract. The ongoing trend is to share the energy generated by renewable methods [3]. This modern energy system is growing to become decentralized, active, and multi-agent, and advanced communication, and data exchange between different power networks become more challenging.

Blockchain innovation with decentralization as its fundamental element is viewed as a progressive innovation for building distributed energy systems. This blockchain data structure or ledger securely stores the digital transaction done between the power nodes in a decentralized way [4]. Blockchain uses a smart contract in a peer-to-peer network to execute this transaction, which allows multiple users to make changes in the ledger. Each node in the network holds the copy of the record and validation is done using consensus. When a new transaction is done it is linked to the previous transaction by cryptography which in turn provides network resilience and security. If any changes were done in the content of any preceding block, which leads to invalidating the chain of hash.

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2. RELATED WORK

Raphaelle Akhras et.al [5] proposed an Ethereum based smart contract using Proof-of-concept to secure the smart grid system, this smart grid is made up of smart meters, automation, and emerging technology that communicate with each other. This smart grid suffers from some cyber-attacks. To secure this system he proposed a smart contract to secure the communication between smart meters. Matthias Lohr et al [6] proposed a blockchain-based transaction protocol, where two parties exchange their transaction. During this transaction, transaction fees must be paid for executing such transactions between two parties. To reduce transaction fees he proposed a maximum cost matrix method and container protocol, novel cost fairness which built on maximum cost matrices which formulate the fees in various combinations of malicious behaviour.

Chunmiao Li et al [7] proposed a trace-based dynamic gas estimation of loops in the smart contract. to estimate the gas costs for the transaction he proposed machine learning models i.e., random forest, KNN, and SVR, here KNN and random forest have better gas estimation rates. Berrak Perk et al [8] proposed a blockchain-based Peer-to-Peer energy trading system using a smart contract. As a Proof-of-Concept, he developed a protocol called Joulin system using Ethereum which achieve flexibility, resiliency, usability, and reliable system with low transaction cost. This system is also ensures security that they are not vulnerable to manipulate the transaction.

MA Abdelwahed et al [9] proposed a blockchain-based energy trading system using a smart contract. He provides a simulation-based energy sharing concept to obtain optimum performance and efficiency of the system service. Syada Tasmia et al [10] proposed a blockchain-based digital voting system using a smart contract. He proposed a sidechain system to reduce the computational cost. It minimizes the limitations of manual voting and decentralized system which provide more security.

3. BLOCKCHAIN ENERGY MARKET

In a Blockchain Energy market, the excess energy can be sell and buy between the client and the electric end. During this transaction, both seller and buyer will receive offers to trade their energy in the network. They will also manage the agreement to sell and buy energy [11]. During this transaction, the payment is facilitated by cryptocurrency. The generation and consumption are done in nanogrid [15].

In the process of purchasing the energy, the seller first creates an offer to sell energy. Here a smart contract is created as an offer. Now, the buyer accepts the offer and makes prepayment to the smart contract. Once the prepayment is done, a purchase agreement is made. This agreement contains the seller's ID, the Seller's smart meter, start time, end time, amount of electricity, and price. Seller and buyer smart meter, schedule the connection to the electricity network [12]. An electrical network transfers the energy to the buyer and reports the successfulness of energy transfer to both seller and buyer as an acknowledgment. Now the transaction process is done in the smart contract. The smart contract will withdraw the payment from the seller based on the agreement. If the payee is the buyer, the withdrawal process is done in the buyer's wallet. If some conflict occurs then the payment process is frozen. The following figure explains the process of purchasing energy.

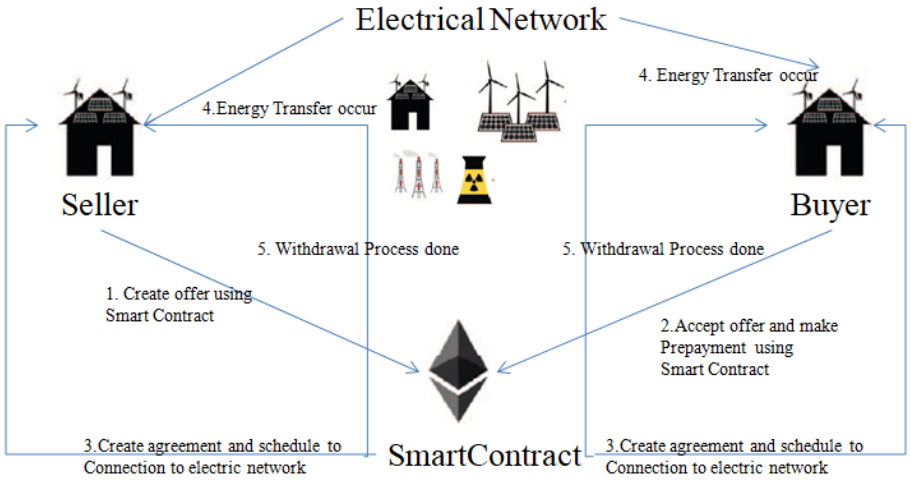

Fig 1. Blockchain Energy Trading Process

Though the system is more secure, there is certain inefficiency in the energy trading system. In Ethereum based smart contracts [13], transaction fees are needed to create a transaction, prevent attacks, and create incentives for validating nodes. The seller needs to spend gas on three transactions: makeoffer, sellerreport, and withdraw. The buyer needs to spend gas on two transactions: acceptoffer and buyerreport. To reduce this transaction cost on both sides, we need to lower the gas value.

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4. Smart Contract

Our main objective to reduce the transaction cost of this trading system [14]. To lower the transaction cost two modifications has been done.

1. By reworking on acceptoffer function.
2. By reworking on withdraw function.

There are five state changing function from both seller and buyer sides for energy marketing.

a. Makeoffer

This function creates a willingness message to sell the excess energy. The parameters used here are OfferID, the Price value of the energy they charging, start time and end time of the transaction, smart meters ethereum address. Using this information, the seller will create an offer.

The proposed system is instead of calling makeoffer function; the sellers create their offers, sign them cryptographically and send them to the buyers. This function holds the following parameters: The Ethereum Signed message, OfferID, price, amount of electricity, start and end time and address of seller's smart meter.

b. Acceptoffer

Once the offer is created, a buyer will use this accept offer function to accept the offer. The parameter used here is OfferID and address of a smart meter of function caller owns. This function does the validity check for the offers. This will verify the signature.

c. Withdraw

These withdrawal functions use the OfferID as a parameter and withdraw the deposit of the offer. This function is successful only when the offer is in readyforwithdrawal state.

The proposed withdraw function contains two implementations. The first implementation uses the interface to will keep track of each user's energy trade and use a parameterless function call to withdraw funds from all traders. The second implementation does not use an interface, it uses the withdraw function and takes a list of traders from the parameter.

Withdraw function is modified in the first implementation with no parameters, here withdrawal is done for all traders who permit to do so. The second implementation takes an array of trade ID's as an argument and does the withdrawal process from all of the listed traders.

d. Sellerreport

This is an acknowledgment report of a successful transaction. This function holds two-parameter, OfferID, and Boolean value. If this report is not submitted within 30 minutes then the smart contract assumes the energy transfer as a failure.

e. Buyerreport

This is an acknowledgment report of a successful transaction. This function holds two-parameter, OfferID, and Boolean value. If this report is not submitted within 30 minutes then the smart contract assumes the energy transfer as a failure.

CONCLUSION

A Blockchain-based energy trading system is proposed with decreased gas consumption. In Ethereum, the transaction cost is gas price increased by the sum of gas consumed by the transaction. To reduce the transaction cost both gas price and gas consumption should be lowered. Due to certain inefficiency in the energy trading system, some modification is done in the offer function and withdraws function. By moving the offer function off-chain and modify the acceptoffer to verify the validity of the transaction. Also by using single function call funds multiple energy transfer contracts can be withdrawn.

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