Decentralized Energy Management: Blockchain and Federated Learning Approach to Smart Grids

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***Abstract*—This paper introduces an innovative framework for decentralized smart grid management utilizing Ethereum blockchain and IPFS. The proposal seeks to transform smart grid operations, encompassing monitoring, trading, and governance, through the utilization of Ethereum smart contracts to ensure transparency and reliability. Integration with IPFS tackles decentralized data storage hurdles, augmenting auditability. Vital elements encompass Ethereum tokenization, automated smart contract execution, and streamlined IPFS integration, fostering a user-centric, peer-to-peer transactional infrastructure. This study enriches the conversation surrounding blockchain utilities within the Ethereum ecosystem, envisioning a decentralized and efficient future for smart grid management. the proposed system was able to reduce the cost of data hashing while benefiting both the buyer and the seller.**

***Index Terms*—Blockchain, Federated Learning, Smart Grid**

I. Introduction

Smart grids represent the next generation of electrical grids, characterized by their use of digital communication technology to detect and react to local changes in usage. However, the effective management of these grids poses significant challenges, including the need for secure, transparent, and efficient systems to handle data, transactions, and governance [1].

This paper presents a novel framework for decentralized smart grid management leveraging Ethereum blockchain and the InterPlanetary File System (IPFS). The proposed system aims to revolutionize the way smart grids operate by utilizing Ethereum smart contracts to ensure transparency, security, and automation in various processes, from data monitoring and energy trading to grid governance. By integrating IPFS, the framework addresses critical issues related to decentralized data storage, thereby enhancing traceability and reliability [2].

In addition to blockchain-based solutions, our previous research has explored federated learning as a means to enhance smart grid management. This approach significantly improves data privacy and model accuracy by leveraging diverse datasets from multiple users without requiring direct data sharing. This federated learning model is particularly suitable for small devices, reducing the burden of cost and power while maintaining privacy, high prediction accuracy, and low computational complexity [3].

By combining the strengths of blockchain technology with federated learning, this research aims to create a robust, decentralized, and secure framework for smart grid management. This integrated approach enhances the overall transparency, reliability, and efficiency of smart grid operations.

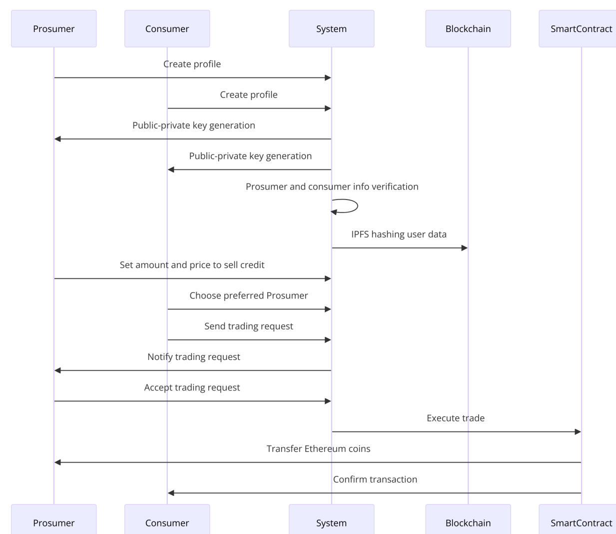

Fig. 1. Proposed blockchain system for energy trading management in smart grid.

II. Proposed Model

The proposed system model integrates blockchain technology and federated learning to create a decentralized, secure, and efficient framework for smart grid management. In this blockchain-enabled smart grid energy trading system, prosumers and consumers first create profiles and generate secure public-private key pairs for authentication. Their information is then verified to maintain integrity. Using InterPlanetary File System (IPFS), user data is securely hashed onto the blockchain for decentralized storage.

Prosumers set energy amounts and prices, while consumers select preferred suppliers. Once a consumer chooses a prosumer, they send a trading request, which the prosumer can accept. Smart contracts execute the trade automatically, ensuring transparency and trust without intermediaries.

Finally, payment is made using Ethereum coins, facilitating fast and secure transactions. This streamlined process empowers participants to engage in efficient and transparent energy trading while minimizing transaction costs and enhancing overall system efficiency. Figure 2 shows the proposed pricing system that prevents the users from turning the system into a financial market which can lead the big providers to short and inflate the market as they want. we suggest that if a seller sets an offer he cant increase his price for an hour while he can reduce it within this time limit.

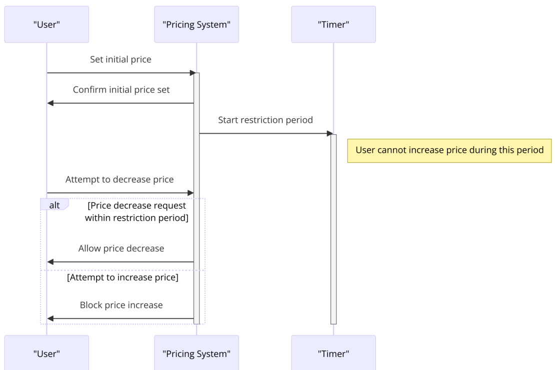

Fig. 2. Pricing method used in the proposal to prevent shorting and manipulating offers.

Federated learning enhances data privacy and reduces the computational burden on individual nodes. Edge devices use local energy consumption data to train models, updating weights without sharing raw data. Aggregators combine these weights to improve the global model, which is then redistributed to all nodes. This process ensures that the global model benefits from diverse data while preserving user privacy [4].

An incentive mechanism encourages participation in the federated learning process. Users are rewarded with tokens based on their data contributions and model training efforts. Smart contracts manage the distribution of rewards, ensuring fair compensation and promoting active user engagement.

The workflow involves the energy service provider uploading the federated learning task to the cloud, which forwards the global model to edge nodes for local training. Updated model weights are aggregated and sent back to the cloud for global updates. The updated global model is redistributed to edge nodes, and users are rewarded for their participation. By integrating blockchain, IPFS, and federated learning, the proposed system model addresses key challenges in smart grid management, enhancing data privacy, security, efficiency, and scalability.

III. Simulation Results

Table I shows parameters' settings that have been used for simulation via the proposed model. The scheme is meticulously crafted to ensure that both consumers and prosumers can reap financial benefits. Correspondingly, Figure 3 demonstrates that consumers can enjoy cost savings by paying less for the same quantity of credit. where in our proposal we consider a flexible market where sellers can be suggested a price but they still can change it. The system holds the price for an hour so if the market price changes the consumer can still benefit from the previous set price.

TABLE I
Simulation parameters settings

Parameters	Settings
Transactions	600
Users	15
Rate	50 to 250 tps
Varied factor	block size transaction rate

Fig. 3. Consumer profit using the proposal.

IV. Conclusion and Future Works

In conclusion, our proposed model seamlessly integrates Ethereum blockchain and IPFS to revolutionize energy trading management in smart grids. By enhancing transparency, security, and efficiency, the model offers a user-centric, decentralized approach to peer-to-peer transactions.The proposed model was able to increase the profit for both prosumer and consumer.

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