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Application of Blockchain and Smart Contract to Ensure Temper-Proof Data Availability for Energy Supply Chain

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Abstract: Energy supply industries play a vital role in a country. Inefficiencies in the energy supply chain regarding tricky contests and the lack of management instantly change energy tariff calculation. This work proposes the Ethereum blockchain platform with existing traditional infrastructure to track and investigate energy supply chain activities using a unique identity with smart contracts. It maintains the records of the organization's protected and available actions to stakeholders according to the recognized collection of procedures and practices without requiring any centralized administration. The purpose of the study is to focus entirely on analyzing and developing a simplified, low-cost, and secure decentralized application (DApp) in the untrusted environment. It should be fit to quickly connect the present energy supply industry at various geological locations to track and trace the energy market's linked data.

Keywords: Blockchain, smart contract, energy supply chain, decentralization, design science.

區塊鍊和智能合約的應用確保能源供應鏈的防篡改數據可用性

摘要：能源供應行業在一個國家中起著至關重要的作用。 由於棘手的比賽而導致的能源供應鏈效率低下以及缺乏管理，這立即改變了能源費率計算。 這項工作提出了一個以太坊區塊鏈平台和現有的傳統基礎設施，以使用具有智能合約的唯一身份來跟踪和調查能源供應鏈活動。 它根據公認的程序和慣例集合維護組織對利益相關者的受保護和可用操作的記錄，而無需任何集中管理。 該研究的目的是完全專注於在不受信任的環境中分析和開發簡化，低成本，安全的分散式應用程序（DApp）。 它應該適合於在各個地理位置快速連接當前的能源供應行業，以跟踪和追踪能源市場的鏈接數據。

關鍵字：區塊鏈，智能合約，能源供應鏈，去中心化，設計科學。

Introduction

Energy value chains of the electricity supply industry are broad and expanded over the country and offshore. These energy value chains link four critical areas of an economy. The energy supply area involves fuel, generation, grid, and retails. The fuel and generation sources include coal, natural gas, oil, nuclear or waste, heat, and renewable energy, including wind, hydro, solar photovoltaic, solar thermal, and geothermal. The power grid is an integrated electricity grid covering electricity generation, storage, power supply, and control systems, delivering electricity from producers who sell wholesale or retail to customers. Non-renewable energy such as coal, oil, and nuclear or waste emit vast amounts of greenhouse gas carbon dioxide into the air when burnt. The greenhouse gas is trapping heat, bringing global warming into our atmosphere. For over a century, these industries have been mainly relied on centralized fossil fuel plants to generate electricity to deliver it to consumers.

Currently, 1.06 billion people still need electricity access around the world in rural areas [1]. Energy is a social benefit that is key to poverty alleviation and economic development. Electricity and transport fuel prices are controlled or managed by governments at a deficient level, and electricity tariff is fixed through a less transparent process. The majority of the world's distribution system of electricity or ' grid network ' was developed when energy was reasonably low cost, and minor changes have been made to primitive grid

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network to balance the rising demand and supply of energy. In the past few years, the concept of smart grid and decentralization was introduced as a new version of the traditional power grid, which provides two-way energy and information exchange for achieving an efficient way of delivering, managing, and renewable green energy technologies.

However, the electricity industry is dominated by utility companies controlling most of the activities within its operating domain, which has been monopolized by the vertically integrated utilities. It monopolizes the entire electricity business from generating and distributing electrical energy from the power plant to the consumers. Because of the vertically integrated monopoly, customers have no choice but to buy power and choose their specific utility company. Vertically integrated utilities have regulated the entire energy market.

Furthermore, the growth of modern energy supply industries and a global increase in energy costs also increase net metering errors, energy theft, errors in invoicing, altering documentation, and tempering BB (best before) dates of energy resources. Energy to power turbines and retailers tamper with removing or adjusting metering rates with lower ones, such that they maintain an inconsistent price for the targeted consumer or produce higher income. Non-technical loss frauds occur in the Smart Grid and the old power grid [2]. People have a history of using physical stealing energy methods in the conventional power grid [3]. Current statistics reveal that India lost about 25% of its generated power, and Brazil lost about 16%, while both China and the United States lost 6% and 5%, respectively. More than 50% of energy theft income is lost in several developed countries. In terms of sales, the United States, India, and Malaysia announced an annual loss of around $6 billion, $16.2 billion, and RM500 million, respectively [4]. In varying degrees, many other nations are struggling. Northeast group LLC has estimated that $89.3 billion is lost globally because of annual energy theft [5]. This phenomenon shows a fatal threat to government tax calculation and energy supply chain management [6].

Moreover, as COVID-19 pandemics began in December 2019, several countries faced calculating tariffs and delivering electricity invoices [6]. Consumers and stakeholders are now more concerned about their electricity usage history. Future investment and policy regulators seek greater carbon efficiency, accountability, and traceability from the customer's source through the supply chain. The electricity market is becoming increasingly concerned with tracking the sources and supply chains to satisfy customers' and stakeholders' demands. The core purpose of this work is to merge the traditional practice of managing energy supply chains with the blockchain to trace consumer usage from fuel and generation to retail with a unique identity. It shall maintain market activities following business and government policies that are flawless and accessible to stakeholders and agreed contracts for data sharing between companies without central monitoring authority.

Research shows that ensuring the data and identity management's trustworthiness are the crucial fundamentals of the energy supply chain process [7]–[9]. Data manipulation and control of identities are a big problem with any framework for the supply chain. The proposed work aims to solve the issues mentioned earlier by developing an application where stakeholders could focus on the trust of data and transaction logic.

In this paper, firstly, the discussed the background of blockchain technology (Section 1); then, present the current research on the use of blockchain technology in the energy supply chains (Section 2). Based on it, this paper exposes the methodology authors applied for this research (Section 3); then, Section 4 presents the details of our system design and architecture. Section 5 shows the experiment and the results of the research. Finally, the conclusion and future work are described (Section 6).

1 Background

Blockchain, initially initiated by Satoshi Nakamoto, is explicitly intended to facilitate peer-to-peer electronic payment transactions without humans and a trusted third party's intervention. It has been discussed explosively over the past ten years and has shown enormous potential in many areas [10]. In principle, blockchain is a distributed, decentralized, chain-connected ledger-sharing database where each node on the network is faulty and can access point-to-point communications. In the blockchain network, the blocks are linked by cryptography hash. It includes the timestamp, nonce, a hash tree named “Merkle,” and smart contract scripts, illustrated in Figure 1. When

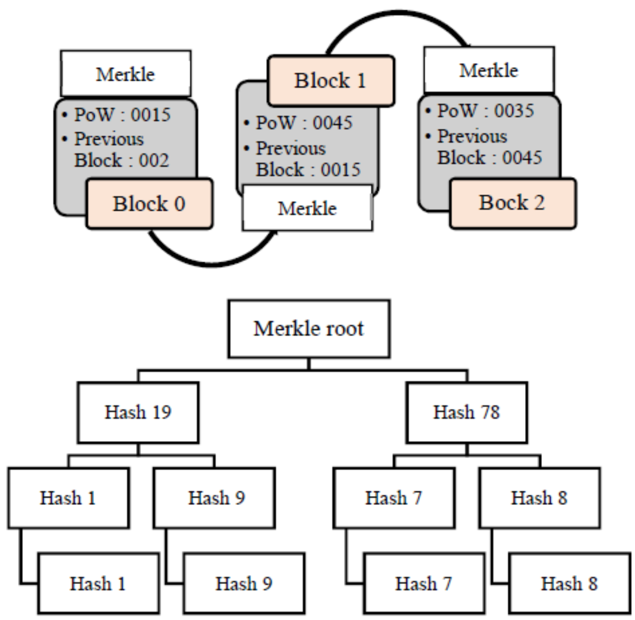

Fig. 1 Blocks arrangement of the blockchain using hash signature

blockchain technology is applied to a distributed energy supply chain. The energy supply chain system can become more efficient, responsive, tamper-proof, and diverse in the energy supply chain.

There are various types of blockchains depending on the type of data being handled, the data storage functionality, and the actions the user can operate. Therefore, blockchains are authorized (permitted) and unauthorized (non-permitted or permissionless) and private and public [11]. The public blockchain is permissionless, while both consortium blockchain and private blockchain are permitted blockchains.

In the public blockchain, anyone can join the chain, participate in the consensus process, read and broadcast transactions, and manage the shared ledger. Most cryptocurrency and some open-source blockchain project platforms are permissionless. In contrast, in the permitted blockchain systems reading activities are also limited to the authorized entities. The blockchain can be programmed to capture virtually everything that can be represented in code. Businesses are already adopting this blockchain platform, and others are working toward it. The supply chain is the most critical element in the energy supply industry. Besides, the supply chain analysis has participated a significant contribution for business process improvement, which are done using the big data analysis [12], [13], [14] (generated supply chain data). Many separate participants engage in a standard supply chain environment and will trace the transaction at any level.

The energy supply chain regularly moves over various levels at various destinations delivered by multiple companies, from fuel and generators to the customers. The energy supply chain process from fuel generators to final customers is seen in Figure 2. There are many blockchain technology projects which use blockchains to protect and open business transactions among organizations. Some of the blockchain-based development platforms are given in Table 1.

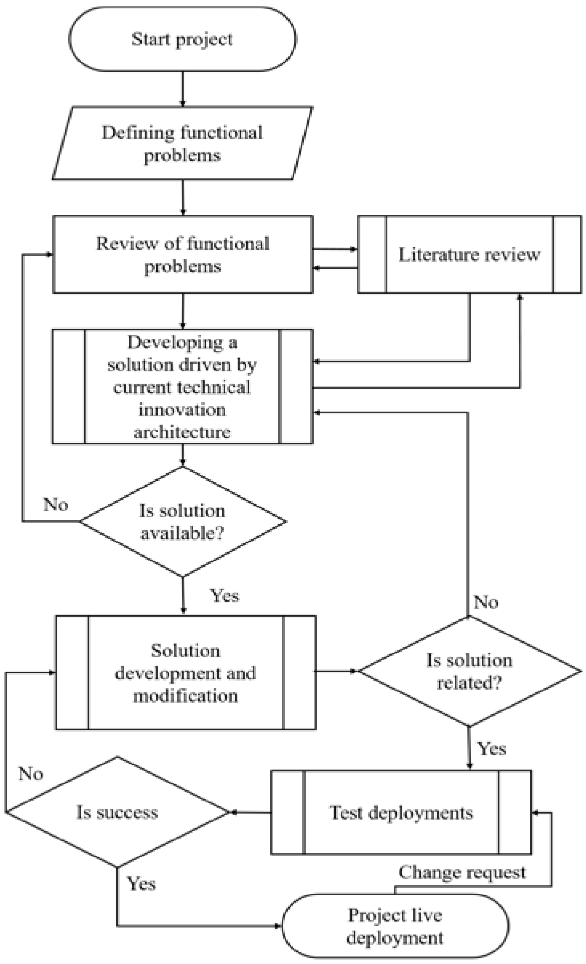

Fig. 2 Research methodology

Table 1 Blockchain-based development platforms DET – Distributed Energy Trading, PoW – Proof-of-Work

Projects	**Fields of activity**	**Platform**	**Consensus algorithm**	**Location**
Power Ledger (P2P Pilot Run) [15]	DET	Ethereum	PoW	Malaysia
Power Ledger (EchoChain) [16]	DET	Ethereum	PoW	Australia
LO3 Energy [17]	DET	Tendermint Proprietary	n/a	US
Energy Bazaar [18]	DET	Ethereum	PoW	India
Eneres [18]	DET	n/a	n/a	Japan
Bittwatt [18]	DET	Ethereum	n/a	Romania

Most developed countries started switching from cash to cashless and digitize, safe micro-payments, regular digital communications, and online transactions [19]. Digital networking currently involves distributed networks. Blockchain technologies are used to deal with anonymity, integrity, and non-repudiation problems. Moreover, the consensus processes are the decision-making process by which any new legitimate or validated block is applied to the blockchain to increase confidence. The proof of work [19] and proof of stake [8] is the most popular consensus mechanism. Blockchain is used for various purposes, such as bitcoin, cloud services, land registry, polling, compliance, and the internet of things (IoT). Consider the use-case of land certify application [20], [30]. The app must recognize and authorize the user before selling or buying the land [21]. The submitted records must also be checked, protected, and validated. Through offering an interface to upload user identity records, land data, enabler monitoring transactions, and checking documents, blockchain can resolve those requirements. Blockchain also guarantees land fraud protection and document tampering. In the related work, existing approaches used for the energy supply chain and blockchain are discussed.

2 Related Work

The following research analysis is performed to clarify current decision-making approaches. Those papers are reviewed to explain the importance and decentralized use of blockchain technologies. The blockchain platform is used in science, health, electricity, and finance areas. It can be used to share almost anything that is digitally represented. Energy blockchain, China founded the world's first energy blockchain laboratory in 2016. The blockchain implementation scenarios involving the control of demand, pose analysis, and stock trading was proposed [15]. All the collected data is processed on the central server; hence the information is not available if the system goes down. In 2016, LO3 energy was credited with facilitating the first peer-to-peer energy sales of solar power on a microgrid using blockchain in Brooklyn, in New York [22]. The centralized authorities manage data and are also concerned about its reliability and trustworthiness. The use of blockchain technologies will solve these problems.

In 2018, the Chilean National Energy Commission (CNE) announced that it had initiated a blockchain initiative focused on electricity. To record, store, and track energy data, the government department uses the Ethereum blockchain. In 2019, a joint eight-month pilot project of peer-to-peer energy sharing technology was initiated by the Malaysian Sustainable Energy Development Authority (SEDA) and an Australian technology firm. The deal will see the company test the blockchain-enabled P2P network in Malaysia [23].

Similarly, Giovanni proposes a blockchain-based supplier and retailer game-theoretic model for supply chain management. The model helps to remove all risks over the supply chain and save the transaction costs [24]. Since blockchain technology is still in advancement, the immaturity of technology is the only problem.

Se-Chang Oh et al. [25] present the blockchain-based energy trading system and asset exchange scenarios. Lai-Wan Wong et al. briefly described the Blockchain use of supply chain methods and processes among Malaysian small-medium enterprises (SMEs). [26]. M.C. Annemarie et al. describe blockchain's service on the actor configuration in the Dutch electricity system [27]. Samuel Fosso et al. presented the benefits, challenges, and future research opportunities of blockchain in the operations and supply chain [28]. It also accommodates how these features can be applied to address the world's different market challenges today.

3 Methodology

This section addresses the basic approach of the methodology to establish a decentralized application. This research is based on a design science research method and the concept of the mindful practice of information technology (IT). IT's intended use focuses on using the most efficient and cost-effective technology features to help solve problems. The design science research methodology focuses on analyzing realistic real-world problems by researchers' collaboration, and practitioners describe approaches utilizing existing concepts of design and technological transformations. The critical analysis and development to be applied in the deploy environment as a solution to this problem is then strengthened and further enhanced. Figure 2 demonstrates the entire process of our methodology focused on design science research.

The distribution of supply products needs to register and associated data in the energy supply chain to trace the electricity usage from fuel and generation to retail. Conventional data database technologies are used in the traditional supply chain environments. It shows the lack of continuous flow of information throughout the energy supply chain in these environments. Figure 3 shows the conventional centralized data flow in traditional energy supply chain environments. In the traditional supply chain, each energy provider transfers the materials and their associated data separately. The availability of the data from fuel and generation to the end consumer is scared in these situations. The existing energy supply chain structure has the following drawbacks due to this centralized architecture: the centralized system control of the data if the server breaks down. The information is not supported by the supply chain anymore. Data can be exploited by those owning the centralized server due to the centrally located storage.

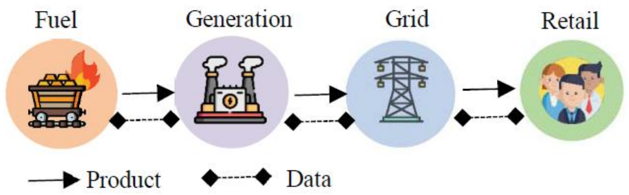

Fig. 3 The conventional associated data flow in the energy supply chain

Cybersecurity attacker or administrator can change the information without any consensus mechanism. The blockchain proves a potential candidate in new emerging techniques. In blockchain-based energy supply chains, a single ledger is distributed among all the system entities. Figure 4 illustrates how the data in blockchain-based energy supply chains relevant to our proposed concept. This research better matches the theoretical approach of design science. Real-world challenges are solved by research using the already developed technologies to construct a new design.

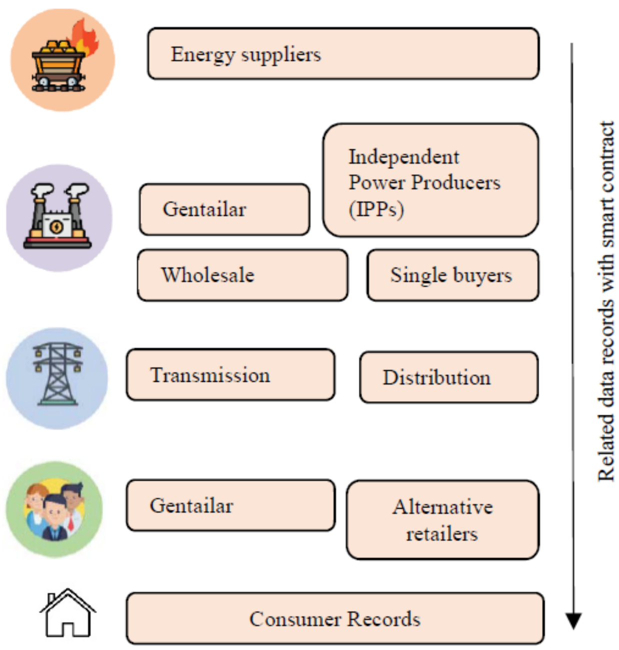

Fig. 4 Related data records with smart contracts

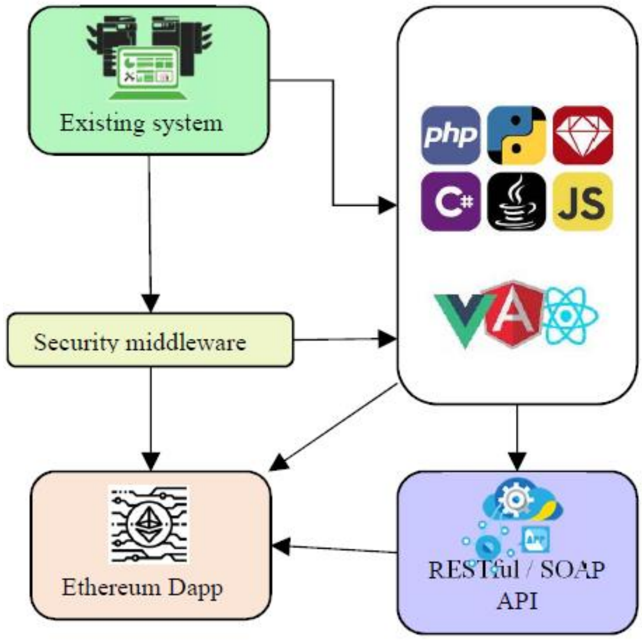

Fig. 5 Ethereum based application development

Figure 6 describes the architecture diagram for the decentralized supply chain Dapp application proposed using the DSR approach. The framework on the client-side, i.e., the front end, is constructed by Reacts and Javascript and deploys on the distributed network. The Ethereum blockchain network guarantees distributed server architecture in the backend, with a copy of the ledger and smart contract maintained in each blockchain network. With 220 test accounts and a private key, the Ganache application is used for the proposed work. The business logic of Dapp is written with solidity in a smart contract. Once deployed, a smart contract cannot be modified; hence, test instances are reported using the object-oriented language to test smart contracts before deploying. A truffle system is used to ensure a transparent arrangement of the application and ensure that the proposed work is adequately organized. The facility can manage, transfer, validate, and execute the smart contract. The next section describes the blockchain platform with its main components important to this work.

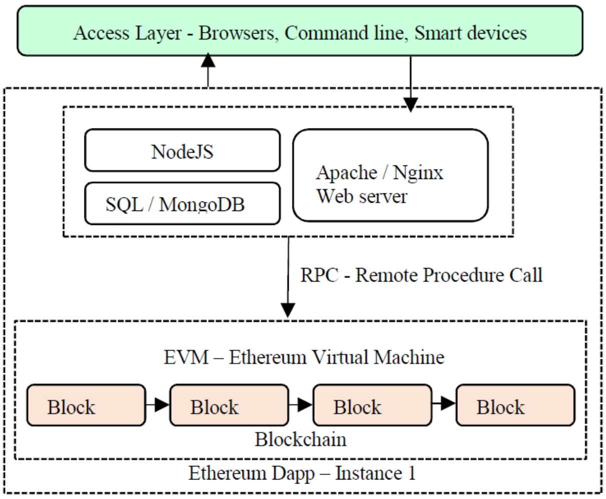

Fig. 6 An overview of the system architecture

4 System Design

In the following subsections, the blockchain emphasizes various appliances, services, and technologies to build DApp. Figure 5 depicts the peer-to-peer blockchain application overview, where the node operates on a server-side as a peer.

The massive success of blockchain in the finance domain indicates that it also has significant potential to reconstruct the energy market. This work proposes to integrate blockchain with current infrastructure at energy companies without interrupting conventional business practices. We choose Ethereum as a blockchain platform. Ethereum provides free access to digital money and data-friendly facilities. A smart contract includes a contract account, a 160-bit address, runtime bytecode, and some associated transactions.

4.1 Authorization-Based Networks

Users also download the software in a distributed blockchain network and start to transact without exposing their identities. It is not an acceptable way of approaching a business network. In a business network, anonymity is not sufficient, and the members always have a unique identity and assigned roles. The Ethereum platform supports authorization-based systems, and it enables the continuity of interactions with individual identities and roles.

4.2 Identity Management

Ethereum applications provide a unique way to assist identity management. Each Ethereum user account has its address and a single key pair. These keys enable the user to control any related blockchain services. One of the account's resources can be a unique identity singled out using the account's address.

4.3 Application Development

The integration with the current framework is stable with the Ethereum blockchain platform. Increasing organizations in the chain can expand an intercommunion method following their needs. The client application can be developed utilizing RESTful API or simple object access protocol) SOAP as middleware could also be designed using a software development kit provided by Ethereum, as depicted in Figure 5. The application program interface (API) and SOAP represent methods (including classes, functions, and procedures) that a single node program could apply to communicate with another. The representation of API internet protocol and standard includes libraries and pre-defined functions. The existing system communicates both Ethereum DApp and front-end applications: PHP, Angular, ReactJs, and C#. Accessing the Ethereum node, the current system uses the security middleware, which provides protocols and validations for authorization.

4.4 System Architecture

The architecture of this approach is illustrated in Figure 6. This system is currently developing as a virtual machine. Applications that use smart contracts are referred to as "decentralized" or "short DApp applications." DApps are client applications to manage or store blockchain data (instead of the database) utilizing smart contracts (instead of servers). Clients communicate with Dapps through external accounts. The blockchain layer is analogous to the base layer, which collects data. In Ethereum, clients compete to secure the next block (proof-of-work) and support consensus mechanism, and its Dapp service provides crash fault tolerance. Figure 6 displays the database server and its block of chains in the Ethereum virtual machine. This architecture base on NodeJs, SQL or MongoDB, and web services for front end communication. The NodeJS provides the RESTfull application program interface and different methods to broadcast, retrieve, and read information from the organizations' existing system. This system practices a chain code to collect information on the blockchain. It moves the necessary data by using this chain code from the current standard database through the blockchain. In a traditional client-server model application, the service provider manages centralized servers. In this architecture, nodes are linking to one another, creating a decentralized platform.

In the access layer, web front ends (browsers), command lines and smart devices are extensively used for blockchain access using web services, which include data of SQL Server or MongoDB. RPC communicates between the Ethereum Dapps and servers of web services. Ethereum virtual machine is the core of the decentralized application, including blocks, smart contracts, and private and public keys. Both the code and transactions are stored in EVM block, including suppliers' information, buyer's request information, and merchandise bidding results.

MongoDB database is used to store and retrieve energy-related information from traditional databases. Nodejs uses to provide RESTful APIs.

The front-end browsers, smart devices, and command-line interfaces are used to capture the details of the energy-related data entered by the users, such as the stack holders, forecast and bid prices, product and customer information, history of supply chain records, and energy usages. NodeJS server receives for the blockchain event when the smart contract triggers.

4.5 Hardware

This proposed blockchain application is an economically efficient approach for SMEs that do not need to spend on technology to develop an entirely new architecture. The Ethereum blockchain is an open-source solution that receives frequent system changes. We are using the Linux based operating system. All the nodes deployed on the 7th generation intel corei3 processor consist of 8GB of RAM and 1TB of storage media. The blockchain is used only as a mechanism to create a record of transactions that cannot be modified. A blockchain-based data exchange network can be extended since any organization can, at any point, join or leave the blockchain consortium. The newly established organizations do not require modifying the system to fulfill the joint organization's requirements. It could be implemented without any additional development costs.

5 Experiment and Results

As previously mentioned, the Ganache is used to create a test blockchain framework. We simulated our proposed architecture and decentralized application (DApp) in Figure 6. The test accounts and private keys are used to test submissions. In Figures 9 and 10, the Ganache gives us the interface to display the transaction status, build-up status, and transaction logs. For digital signing, the private key allocated to each account is used. Based on the test account address, the node or user is authenticated. Figure 13 depicts the graphical user interface of DApp to add records and payment related details. A charge is determined on a performance instruction basis for any transaction. Each transaction will be checked and confirmed by the miner before its execution and locked in the blockchain until a consensus is achieved. Hence, this procedure guarantees that the transactions are accurate and complete. The response will accept, deny, or retain the request, as seen in Figure 9 while examining the request list. When a transaction is made, modifications can be changed as a new block, and data are saved as blockchain transactions. It will lead to settling future disputes and solve the issue of non-repudiation.

Many current networks in the energy supply chain depend on a centralized server or an external server [16], [29]. The clients of the energy supply chain need to trust the server provider. The registry details could have changed if the owner has tempered the data. Trustworthiness and data confidentiality is secured in the proposed DApp by the primary property of blockchain technologies.

Table 2 Dapp-related tools and libraries used in this framework

Tools and libraries	Description
Truffle and Ganache	Truffle is a one-stop DApps solution: compiling and deploying smart contracts, adding them into a web app, creating front-end for DApps, and testing.
Solidity	Solidity is a high-level, object-oriented language for smart contracts.
Web3	Web3.js is a library collection allowing HTTP, IPC, or WebSocket to access a local or remote Ethereum node.
MetaMask	Browser extension that works as a Web3 wallet that uses to create and manage identities. The extension includes the Ethereum Web3 API into the JavaScript code of an application, allowing Applications to read from the blockchain.
Chai	Chai is a Test Driven Development (TDD) and Behavioral Driven Development (TDD) assertion library for testing NodeJs applications.
ReactJS	React is a JavaScript open-source framework to build user interfaces or UI components.
NodeJs	Node.js is a cross-platform that runs code outside a web browser.

In Table 2, Tools and libraries were used to simulate the results of the research. Table 3 shows the tested outcomes of executing the smart contract in a P2P network composed of 220 virtual nodes. In this period, a total of 10812 smart contracts were endorsed. 10786 were successfully executed, and 26 were ineffective, with a success rate of almost 99.75%. The execution failure is because the IPP's collateral is insufficient, or the Gas for managing the smart contract is consumed. At the same time, for each smart contract, the average validation time is about 12 seconds.

Table 3 Executed smart contracts

Date on	Smart Contract	Success	Failure
2020-09-12 01:14:54	2506	2500	6
2020-09-13 08:10:05	1426	1423	3
2020-09-14 11:04:44	3240	3235	5
2020-09-15 09:15:54	787	780	7
2020-09-16 12:14:34	2364	2360	4
2020-09-17 05:10:51	489	488	1

Total	10812	10786	26

The DApp is written in JavaScript by the ReactJs framework; the DApp is executed at the Ubuntu 20.04.1 LTS running platform. The virtual programming instances be component of the Node.js Javascript run time with v12.18.2 and NPM v6.14.5 used for the node package manager. The Ethereum Geth v1.9.22 for Linux standalone node was installed to perform the transaction through the command-line interface. Solidity v0.4.21 was used for writing the smart contract, which is converted into JSON format. Ganache v2.4.0, Web3Js v1.3.0 were utilized for data block keeping and communicate the backend system. Test RPC v6.0.3 used for customizable data retrieval from the Ganache application. As an Attribute-based encryption toolkit, we used the hash function of its functionality in build with the Ganache Truffle application. In enhancement to the encryption identification number, performing with APIs and estimations is used to achieve security strength.

The distributed apps (DApp) use the trust networking protocol on the Peer to Peer (P2P) network. The distributed hash table (DHT) and package communication structures is a thoroughly authenticated message process that provides low level but user-friendly applications (APIs not requiring the hardware attributes that are underlying to be stored). The contract provisions are written in a DApp and are broadcast to the P2P network. To engage in organizing a process (such as signing a smart contract), the DApp sends a signal to other DApps.

In the smart contract approach, the author used four smart contracts, such as *MesiClient.sol*, *MesiLogin.sol*, *MesiSettlementCode.sol*, and *MesiTransaction.sol*, where *MesiClinet.sol* is used for storing the client or energy participant agreement details. *MesiLogin.sol* is used for the client's access credential username, password, email, and access details. Those smart contracts were deployed in the Ganache, depicted in Figure 8, where all smart contacts have a unique string address for communication. The address always begins with 0x…. strings.

The *MesiSettlementCode.sol* has all the scheduled transaction details where *MesiTransaction.sol* provides the transaction details of clients to the *MesiClient.sol* smart contract for validating the transactions. Figure 7 shows that MesiTransaction.sol has a Transaction struct and *setTransaction* function to initialize the record and store records. The string *clientAddress* is used for intercommunication among the nodes. Similarly, the string *history*, *usage*, and *usageHistory* attributes are used to store the transaction recodes that the hash function encrypts records.

```
MesiTransactions.sol
contracts > MesiTransactions.sol
pragma solidity >=0.4.21 <0.6.0;

contract MesiTransactions {
    uint256 public transactionCount = 0;
    mapping(uint256 => Transaction) public transactions;

    struct Transaction {
        uint256 id;
        string history;
        string clientAddress;
        bool status;
        string offerStatus;
        uint256 amount;
        uint256 usage;
        string usageHistory;
    }

    function setTransaction(
        string memory _history,
        string memory _clientAddress,
        bool _status,
        string memory _offerStatus
    ) public {
        transactionCount++;
        transactions[transactionCount] = Transaction(
            transactionCount,
            _history,
            _clientAddress,
            _status,
            _offerStatus,
            0,
            0,
            "{}"
        );
    }
```

Fig. 7 Smart contract for transaction written in solidity

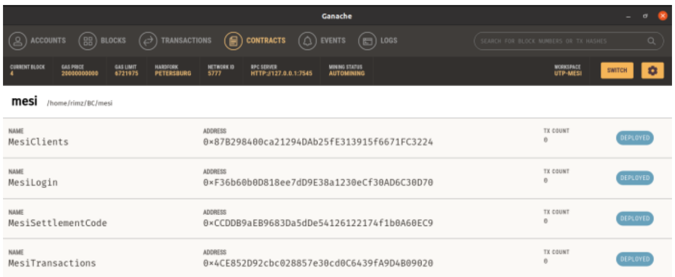

Fig. 8 Deployed smart contract in the Ganache

After deploying the smart contracts, the smart contract details are stored in blocks, as depicted in Figure 9, where block 0 is the initial block called the genesis block. Figure 10 shows a block of a transaction.

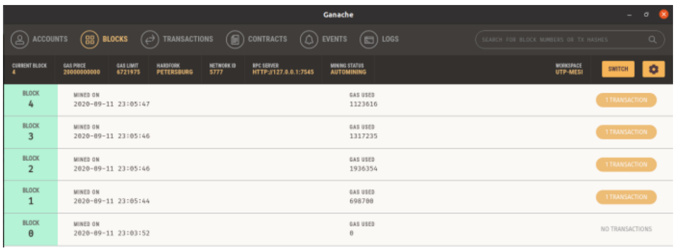

Fig. 9 Initially deployed smart contracts and their blocks

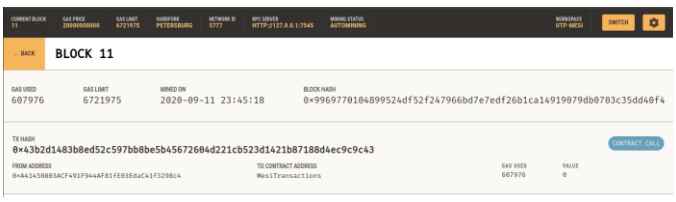

Fig. 10 An example details of a single block and its hash ID

In the blockchain-based supply chain, the transaction records are important and cannot be modified. It provides tamper-proof functionality to data, and the data are securely stored, as depicted in Figure 11. Here, the author has used the SHA256 as the underlying cryptographic hash method. SHA (Secure Hash Algorithm) cryptographic hash features developed by the United States National Security Agency (NSA). In an understandable phrase, the Hash function is like an alphanumeric string (e.g. 0xa16e5aea9d33749c58780ccabdf0087bba537f70c4ee 1de056bf8e9816a02f17), where you insert digital details of some sort and the result (output). The output is 32 bytes with the SHA-256.

Fig. 11 Encrypted record of a transaction

Figure 12 shows the signature signing confirmation and its encrypted records. To sign the smart contract, the client needs the private key of its address. All this secure process helps the energy supply chain to track and trace the transaction securely.

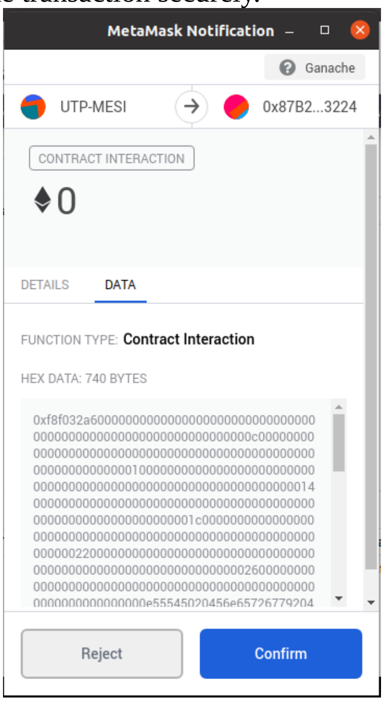

Fig. 12 Signing the smart contract using MetaMask

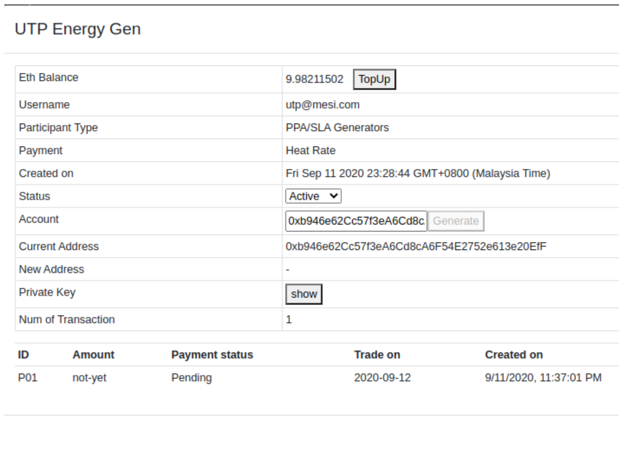

Fig. 13 GUI of distributed user's account in the DApp

6 Conclusion and Future Work

In this paper, the authors propose blockchain technology for the energy supply chain. It serves to implement tamper-proof information about the energy supply chain. Such information is also helpful in tracking supply chains for electricity regulators. It also improves fair contests among companies to provide energy consistently. It accommodates decentralized, reliable, and tamper-proof data saved on the blockchain in conjunction with the current database services without changing the existing business operations. It will help government organizations to track and trace the tariff transparently. Design science research methodology is approached for providing the solutions to the identified organizational problems. It could help with architecting new solutions from existing researchers' works. Many research and commercial companies are currently trailing blockchain innovation in the energy sector.

Many authorities are also concern about adopting blockchain technology in government organizations. It requires developing a system where the separate blockchains container assigns the data to each other. Every business process cannot be entirely centralized or segregated without contributing to cybersecurity, data safety, and efficiency. Government and individual organizations are also concerned about their data security. It requires building a tool to prepare the database services to the blockchain for data review and forecasts. In the future, more energy-related applications developments are expected to be researched on the blockchain.

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