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ETHEREUM BLOCKCHAIN MODEL TO ENHANCE DATA INTEGRITY & COST REDUCTION IN OIL & GAS

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ABSTRACT

Data in the oil and gas supply chain faces numerous challenges due to big data, contracts, inaccuracy, data accessibility, and the loss of some of this data, leading to significant problems. Critical data is at a greater risk of cyberattacks because the oil and gas industry is a very important sector that involves multiple-party transactions, ultimately resulting in data inconsistency and insecurity. This research aims to overcome these issues by providing an Ethereum blockchain model to enhance data integrity, cost reduction using blockchain technology in the oil and gas industry. The first step involves installing IoT sensors on oil and gas valve ports to monitor the quantities sent and received, utilizing the Ethereum blockchain platform to secure this data. Three smart contracts have been created and specific conditions have been added to these contracts, where data for oil and gas is aggregated and only the total value for each transaction is stored on the blockchain network. This leads to a reduction in transaction costs on the blockchain network since only the important transactions are recorded. This also leads to the protection of data in the supply chain from malicious attacks and data loss, real-time data recording, and the absence of a trusted third party as the system performs these tasks while also reducing traditional system costs. The proposed model offers promising results in enhancing data consistency and security, cost reduction using blockchain technology in the oil and gas industry.

Keywords: *Blockchain Technology, Oil and Gas Industry, Ethereum Smart Contract, Data Integrity*

1. INTRODUCTION

The oil and gas industry is a critical sector that relies on collaboration and partnerships between various stakeholders. Therefore, the industry faces a unique set of challenges that impact data integrity, including the fact that oil and gas data originates from diverse data sources and formats, making it difficult to integrate into a cohesive system. An oil and gas industry can experience a disruption event as a result of a cyberattack at any time during one of the three main phases of oil and gas operations: upstream, midstream, or downstream [1]. A cyber-attack on an oil and gas industry may result in plant or production shutdowns, utility outages, equipment damage or loss of quality, undiscovered leaks [2] so ensuring the security and privacy of data from multiple sources is a significant challenge.

Additionally, ensuring data accuracy, completeness, and consistency across multiple sources is a complex task. Moreover, scalability is a concern when it comes to handling increasing volumes of data and growing numbers of data sources. Finally, consolidating data from multiple sources can be expensive. The blockchain technology has been gaining increasing attention in recent years due to its potential to transform various industries. This decentralized, distributed ledger system has been found to offer several advantages, including enhanced security, transparency, and immutability. Data integrity is crucial in blockchain technology, ensuring accurate, consistent, and reliable data. This maintains trust and confidence in the network, enables data security and smart contract execution, facilitates data sharing and collaboration, and protects privacy and confidentiality. Data integrity is vital for preserving data over time. While blockchain technology provides benefits related to data integrity and protection, it still faces some potential data integrity challenges. Some common issues that can compromise the integrity of blockchain data are human errors in data input,

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insufficient data validation, network outages causing inconsistencies, and bugs in smart contracts can cause data to be recorded incorrectly or inconsistently. Blockchain systems are vulnerable to various types of attacks, including 51% attacks where a single entity controls the majority of the network mining power, eclipse attacks that isolate nodes from the rest of the network, and physical attacks on network infrastructure and hardware. There are numerous attack vectors that can compromise the integrity and security of a blockchain network[3].

In this paper, we propose an Ethereum blockchain model to demonstrate the efficacy and reliability of utilizing Blockchain technology in the oil and gas industry, Supply chain management between different parties, highlighting its key advantages that have substantially mitigated security concerns, ensured data integrity and cost reduction. To minimize the impact of problems resulting from data integrity issues in the blockchain, we place sensors on oil and gas outlets to directly read data from them without human intervention. These sensors must be secured from eclipse attacks and physical attacks on infrastructure. We created smart contracts and tested them thoroughly in a logical manner before running them on the network to maintain consistency and integrity of data. To reduce the risk of 51% attacks, we created our smart contracts on the Ethereum global network because it has infrastructure with many mining devices on the network, as the more mining devices on a blockchain network, the more secure the network is.

Our model emphasizes the importance of leveraging Blockchain technology's unique features, such as decentralization, transparency, and immutability, to enhance the security and reliability of data-driven processes. Additionally, Smart contracts and transactions are the major advantages of utilizing blockchain technology in the oil and gas industry [4]. Moreover, Blockchain structure adds basic features such as speed, scalability, consistency and verifiability [5]. Blockchain technology can ensure the integrity of files stored in a database by leveraging its inherent security features, such as well-formed transactions, authentication, and auditing. These features prevent unauthorized access, tampering, and alteration of data, thereby reducing the likelihood of threats to data integrity[6].

By implementing blockchain technology, organizations can enhance the security and reliability of their databases, ensuring that sensitive information is protected and tamper-proof. The contributions of this paper are as follows A proposed model running on the Ethereum blockchain network has been developed to ensure the integrity of vital data in the oil and gas supply chain. The necessary algorithms were designed and developed, and three smart contracts were built, including a contract to register the user's account on the network, another contract to follow the oil process, and a third contract to follow the gas process. Smart contracts were tested using the Remix IDE development environment and showed good results that can be used in practice. Specific conditions have been imposed in smart contracts, whereby not all data is recorded on the blockchain network. Instead, only aggregated values for oil and gas are collected and stored. This is because blockchain is not suitable for storing large amounts of real-time data and its primary focus is on data validation rather than actual storage. This approach has led to a reduction in transaction costs on the blockchain network since only the total value is added to the transaction. The cost of transactions in the system was analyzed when executed on the Ethereum blockchain network. A graph was created showing the cost reduction when we used Blockchain in our proposed model. cost reduction and comparison between the traditional system and the blockchain-based system in the oil and gas supply chain were analyzed and discussed. They were compared based on the following elements: blockchain fees, communication & coordination, administration & HR, mediation costs, and audit & verification.

The structure of this paper is as follows: Section (2) will cover Related Work, while Section (3) will introduce the proposed Ethereum blockchain model. In this section, we will discuss the Data Set Specification, Architecture using blockchain technology in oil and gas, propose model for Smart Contract Authentication, Methodology, and Implementation, where we delve into the Algorithm and Smart Contract Architecture. Section (4) will present the Experimental Results, encompassing testing and validation, Cost Analysis, Data integrity, and the Advantages of using blockchain in our proposed model. Finally, Section (5) will Conclusion the paper.

2. RELATED WORKS

The application of blockchain technology in the oil and gas industry is still in its infancy, and there are some attempts to study the application of blockchain technology, the current section identifies

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the most important research-related works as follows:

L Hang et al. [7] “the paper presents a promising approach for integrating blockchain technology with IoT devices to enhance data integrity and security, that addresses scalability, identity, and data security challenges using a permissioned blockchain network. Demonstrates the potential of blockchain and IoT coevolution to revolutionize various industries. Future research directions include testing the interoperability of the proposed system with different IoT frameworks, as well as testing other consensus algorithms and data storage technologies to improve the transaction processing rate and make data query more efficient.”

H Wang et al. [8] “the paper proposes a novel blockchain-based data integrity verification scheme for large-scale IoT data, which combines smart contracts with bilinear mapping and offers improved efficiency, security, and scalability. The proposed scheme has significant practical applications in various IoT scenarios, ensuring data integrity and avoiding the need for trusted third-party auditors. The future work will focus on extending the scheme for more complex data types, such as graph data, and solving data recovery problems in large-scale IoT data.”

M Altulyan et al. [9]" The paper proposes a blockchain-based framework for a data integrity-enhanced recommender system in IoT environments. The proposed solution has practical application in healthcare, where data integrity is paramount."

AA Varfolomeev et al. [10] “The paper presents a data access control model based on blockchain technology, which ensures data management security through its distributed nature, reducing the impact of human error and protecting against intentional attacks.The authors also highlight the benefits of using blockchain technology, such as true digital freedom, decentralization, and suitability for market aspirations.”

B Haque et al. [11] "The paper discusses the challenges of the traditional oil supply chain, such as lack of transparency, security, and traceability, and proposes a framework based on Blockchain and Smart Contract technology to address these issues. The proposed framework includes the use of IoT sensors to track products in real-time, and smart contracts to automate the tracking process and ensure immutability of data. The paper also discusses the challenges of implementing such a system, such as large amounts of data and computational expenses, and suggests possible solutions, such as off-chain transactions and decentralized databases. The authors also provide a detailed description of the smart contract structure and its functions, and suggest possible applications of the framework for different purposes. The paper concludes by highlighting the future research directions, such as mitigating data management and maintenance issues, and developing more advanced working prototypes and agile systems."

IA Omar et al. [12] "The paper discusses the importance of inventory sharing in supply chain management and proposes a blockchain-based solution using smart contracts to improve transparency, trust, and security. The proposed approach uses a private Ethereum network to connect suppliers and retailers, and a decentralized storage system to ensure data integrity and confidentiality. The smart contract is developed using Remix IDE . The solution is analyzed for security vulnerabilities and transaction costs, and is found to be economical, commercially viable, and effective in reducing inefficiencies. The article also discusses potential future work, including developing decentralized applications for automating other supply chain processes and addressing open challenges such as scalability, governance, and energy consumption."

Urvashi Kishnani et al. [25] "The objective of this scientific paper is to conduct a comprehensive literature review on the use of blockchain technology in the oil and gas supply chain from the perspective of user security and privacy. The research aims to analyze the academic research published in this field and classify it according to its applications in various stages of the supply chain, in addition to identifying the anticipated challenges in implementing and enhancing blockchain technology in terms of security and privacy. The research also aims to explore the potential opportunities and benefits of using blockchain technology in the oil and gas industry. The research indicates that blockchain technology offers a promising solution for the oil and gas industry, which relies on collaboration among participating companies in the supply chain. However, it faces anticipated challenges in terms of implementation, stability, and improvement, especially regarding security and privacy. The researchers intend to explore further dimensions of security and privacy for blockchain technology within the context of industry consortia. Additionally, they plan to conduct a user study and experimental prototype to evaluate the real-world effectiveness of blockchain technology in the oil and gas industry."

Javed Aslam et al. [26] "The objective of this scientific paper is to explore the adoption of

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blockchain technology in the context of oil and gas (O&G) supply chain management (SCM). The study aims to describe the relevance of blockchain technology for O&G SCM and proposes a framework that suggests the implications of blockchain for agile and lean supply chains in the industry. The paper examines the impact of agile and lean SCs on firm performance and identifies the key requirements of agile SCs. It also highlights how blockchain technology can enhance agile SCs by providing features such as data-driven management, information sharing, data privacy, cyber-security, transparency, smart contracts, visibility, traceability, and reliability. The paper emphasizes the importance of blockchain technology for supply chain management in the context of agile and lean SCs, with a focus on the O&G industry. It highlights the positive impact of both SC types on firm performance, with agile SC being particularly significant in the O&G sector. The study contributes to the understanding of the need for blockchain technology in supply chain management and suggests that blockchain is well-suited for agile SCs due to its advanced features. The paper has managerial implications by providing guidance on the implementation of blockchain according to supply chain types. From a practical standpoint, it suggests that supply chain managers evaluate their supply chain types and consider the implementation of blockchain technology. However, the study has limitations, such as relying on literature rather than empirical evidence and focusing only on the O&G sector. Future work could explore the concept of "blockchain as services" and investigate the barriers and challenges to blockchain adoption and implication in SCM."

3. PROPOSED MODEL

The proposed Ethereum blockchain model offers a private blockchain-based solution to facilitate the transmission of oil and gas between producers and recipients, whether factories or different companies in the network. The proposed solution adopts blockchain technology to enhance transparency and data integrity and cost reduction , encourage trust and enhance information security among stakeholders in the oil and gas supply chain. Furthermore, the proposed model develops smart contracts and uses decentralized storage technology in the Ethereum network, as shown in Figure 1. This would allow recipients to keep track of the quantities ordered in the network.

3.1 Data Set Specification

This section contains real data about oil and gas operations from IoT sensors of a company operating in the petroleum production field. It includes some other technical data as well. In Table 1 of the OIL & CONDENSATE section, we find that it contains data such as TEMP, which measures the temperature of the oil. GRAV refers to the relative density of the crude oil and is measured in API units. The minimum density is 10 degrees, indicating heavy and dense oil, while it can reach 70 degrees for light and impurity-free oil. BS&W refers to the solid sediments and water present in the oil, which are undesirable elements in the oil and are measured as a percentage. RATE represents the rate of transported oil without compensating for density and temperature and is measured in STB/D, which indicates the number of barrels transported without compensating for density and temperature.

The GAS section, Rate represents the rate of transported gas and is measured in MSCF/D, which stands for a Thousand Standard Cubic Feet per Day. GRAVITY indicates the percentage of air in the gas composition and is measured as a percentage. It is an undesirable element as it reduces the quality of the gas. CO2 refers to carbon dioxide, which is present in the gas during extraction and is one of the components that affects the gas composition. H2S refers to hydrogen sulfide, which is also present in the gas composition and is a toxic gas for humans. It also affects the gas composition

Table 1: Oil and gas data from IOT sensors

WELL TEST DATA REPORT

Company Name: xxx **Area Name: xxx** **Port Name: xxx**

DATE	OIL & CONDENSATE				WATER		GAS				GOR	GROSS	BS&W FROM CHOKE MANIFOLD
	TEMP.	GRAV	BS&W	RATE	RATE	SALINITY	RATE	GRAVITY	CO2	H2S			
dd/MM/yyyy hh:mm	*Deg. F*	*DEG API*	*%*	*STB/D*	*BBL/D*	*Chioride*	*MSCF/D*	*% of AIR*	*%*	*PPM*	*STB/SCF*	*STB/D*	
18/09/2022 10:00	132	42	78%	Initial	Initial	40779	Initial	89	2	2	Initial	Initial	
18/09/2022 10:30	134	41	77%	175	588	40779	35	89	2	2	199	763	82%
18/09/2022 11:00	134	41	75%	193	579	40779	39	89	2	2	202	772	84%
18/09/2022 11:30	135	41	78%	169	598	40779	37	89	2	2	219	767	86%

18/09/2022 12:00	135	41	76%	184	583	40779	40	89	2	2	217	767	85%
18/09/2022 12:30	135	41	78%	173	612	40779	34	89	2	2	197	785	87%
18/09/2022 13:00	138	41	65%	273	507	40779	40	89	2	2	147	780	84%
18/09/2022 13:30	138	41	62%	288	469	40779	45	89	2	2	156	757	82%
18/09/2022 14:00	138	41	58%	318	439	40779	36	89	2	2	113	757	85%
18/09/2022 14:30	138	41	56%	315	402	40779	40	89	2	2	127	717	83%
18/09/2022 15:00	138	41	55%	329	402	40779	47	89	2	2	143	731	85%
18/09/2022 15:30	132	41	54%	350	411	40779	45	89	2	2	129	761	83%
18/09/2022 16:00	132	41	56%	329	418	40779	52	89	2	2	158	747	86%
18/09/2022 16:30	130	41	55%	342	419	40779	49	89	2	2	143	761	83%
18/09/2022 17:00	130	41	54%	352	414	40779	40	89	2	2	144	766	84%
18/09/2022 17:30	130	41	55%	341	416	40779	47	89	2	2	138	757	83%
18/09/2022 18:00	130	41	53%	362	409	40779	42	89	2	2	116	771	83%
18/09/2022 18:30	128	41	52%	368	399	40779	51	89	2	2	139	767	80%
18/09/2022 19:00	128	41	54%	351	411	40779	44	89	2	2	126	762	86%
18/09/2022 19:30	128	41	53%	352	397	40779	46	89	2	2	131	749	88%
18/09/2022 20:00	126	41	54%	349	410	40779	49	89	2	2	141	758	84%
18/09/2022 20:30	126	41	55%	348	425	40779	52	89	2	2	150	772	82%
18/09/2022 21:00	126	41	52%	368	399	40779	49	89	2	2	134	768	84%
18/09/2022 21:30	124	41	55%	344	420	40779	46	89	2	2	134	764	85%
18/09/2022 22:00	124	41	54%	358	420	40779	52	89	2	2	146	778	87%
18/09/2022 22:30	124	41	53%	363	410	40779	49	89	2	2	136	773	83%
18/09/2022 23:00	122	41	56%	338	431	40779	46	89	2	2	137	769	84%
18/09/2022 23:30	122	41	52%	365	395	40779	49	89	2	2	135	760	86%
19/09/2022 00:00	122	41	54%	356	418	40779	52	89	2	2	147	774	82%
19/09/2022 00:30	122	41	53%	362	408	40779	46	89	2	2	128	769	84%
19/09/2022 01:00	120	41	52%	365	396	40779	49	89	2	2	135	761	87%
19/09/2022 01:30	120	41	54%	356	418	40779	48	89	2	2	134	775	84%
19/09/2022 02:00	118	41	56%	333	424	40779	46	89	2	2	139	757	87%
19/09/2022 02:30	118	41	54%	355	416	40779	51	89	2	2	144	771	84%
19/09/2022 03:00	118	41	52%	368	398	40779	48	89	2	2	131	766	87%
19/09/2022 03:30	118	41	56%	339	432	40779	53	89	2	2	155	771	82%
19/09/2022 04:00	118	41	51%	378	393	40779	43	89	2	2	114	771	88%
19/09/2022 04:30	118	41	53%	360	406	40779	48	89	2	2	133	766	83%
19/09/2022 05:00	118	41	54%	361	424	40779	46	89	2	2	128	785	85%
AVG			**58%**	**324**	**440**						**146**	**764**	**84%**

3.2 Architecture of the Proposed Framework Using Blockchain Technology in Oil and Gas

The proposed model in the oil and gas industry using decentralized technology (Ethereum blockchain) includes three phases as in Figure 1 . The first phase is the data collection phase and consists of:

- One of these components is Internet of Things (IoT) sensors, which collect data related to oil and gas from production fields, such as temperature, humidity, density, gravity, flow rate, and more.
- Additionally, the model includes another component known as an IoT server, which facilitates communication and interaction between IoT sensors and blockchain technology using communication protocols like HTTP. This server stores and processes real-time big data coming from the sensors.
- An Application Programming Interface (API) is another component in the framework, which sends and receives data between the server and connected devices, providing the required data in the network.

The second phase is our proposed model and consists of:

- Furthermore, the framework utilizes the Ethereum blockchain network to execute smart contracts and store data. Smart contracts work to execute and regulate transactions between stakeholders in the oil and gas industry, enabling secure and reliable sending and receiving of oil and gas without the involvement of a third party for verification and confirmation. Smart contracts also determine the type of data passed to the blockchain network.

The third phase is dealing with the model and consists of:

- The framework also includes a Decentralized Application (DApp) that operates on the blockchain network and leverages smart contracts to perform its functions, such as submitting transactions to the blockchain network.
- Finally, the framework includes oil and gas recipients, who are active stakeholders in the

system, as they receive oil and gas from the decentralized network (blockchain).

In the proposed system, IoT sensors are installed on oil and gas pipelines at production sites and also at delivery points. The system records all momentary data from the sensors on the IoT server, and then an API is created to transfer the data to the blockchain network. The validity of the data is verified using smart contracts before adding it to the blockchain. Specific conditions are set in the system where not all data is stored to the blockchain, but the total quantity is stored after the completion of the required oil or gas transfer operation, storing all real-time data on the IOT server. As Blockchain is not preferred for storing huge, real-time data for several reasons, including that Blockchain aims to verify the validity of data more than physical storage, as well as the high cost of storing data due to network requirements, so it is preferable to use regular databases for big data and Blockchain to verify data. The distributed application is used to facilitate system usage, where stakeholders can register device data and view transaction information from the ledger in the blockchain network.

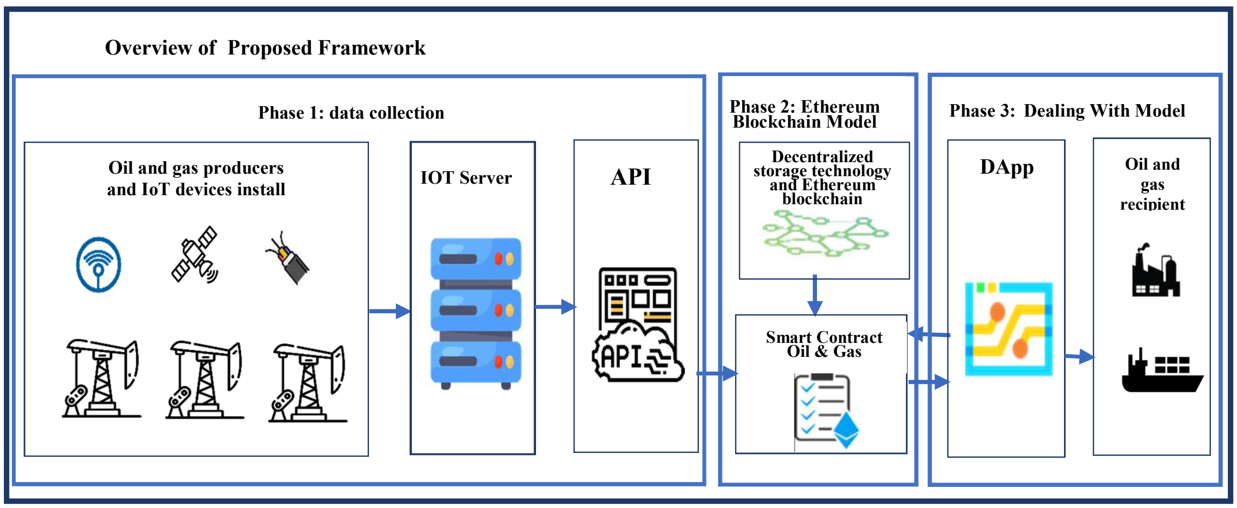

Figure 1: System Overview of a blockchain-based system for oil & gas distribution using Ethereum smart contract

3.3 Model for Smart Contract Authentication

In our proposed model, as in Figure 2. The user starts by creating a user account on the blockchain system. The user registers account information and sensors, and specifies whether the account is related to oil or gas. Afterward, production companies record the quantities of oil or gas produced using sensors connected to production line outlets. These quantities are added to the balance of the producing company's account on the blockchain network.

Then, production companies determine the contracted quantity of oil or gas, set the unit price, and specify the receiving account. Verification is performed to check the availability of sufficient balance for the desired quantity to be sent through the system. Subsequently, the actual quantity is sent and calculated using the sensors, and the real-time data sent from the sensors is verified. If the actual quantity does not match the contracted quantity, it is temporarily added and accumulated until it reaches the contracted quantity. At that point, it is permanently added to the blockchain network. This is done to avoid adding momentary data, but only add the aggregated quantities, as the blockchain is not preferred for storing large real-time data.

After this process, the sent quantity of oil or gas is added to the receiver's account and subtracted from the sender's account .

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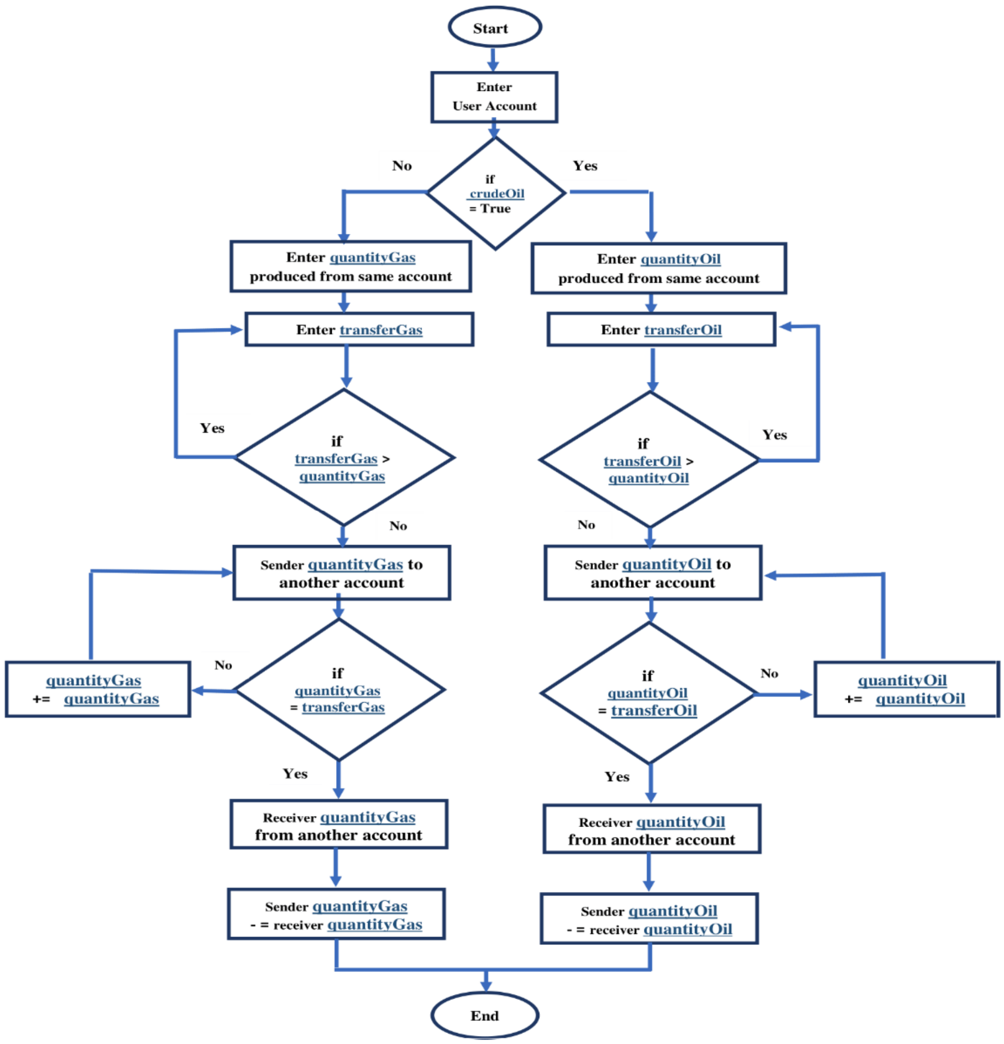

Figure 2: Ethereum blockchain model for Smart Contract Authentication

3.4 Methodology

Initially, oil and gas data were collected from IOT sensing devices as shown in Table 1. The model uses IoT sensors to collect oil and gas production data. The model involves IoT sensors, an IoT server, an API, the Ethereum blockchain and smart contracts, a DApp, and recipient access as illustrated in Figure 1. After extraction and processing, oil and gas are tracked via sensors. Smart contracts validate functions and data transfers, enabling auditing of the network.In Figure 2 users create accounts and register sensors. Production companies record quantities via connected sensors, which get added to their blockchain account balance. Companies set contracted quantities, unit pricing, and recipient accounts. Validation occurs to ensure sufficient sender account balance. Sensors track real-time quantities, but only aggregated amounts get added to avoid blockchain bloat. Once the contracted quantity transfers, it deducts from the sender's account and adds to the recipient's account.

In summary, the model uses IoT devices and smart contracts on a blockchain to securely record and transfer oil and gas production data and quantities between parties.

3.5 Implementation

This section illustrates the details of the implementation of the proposed Ethereum blockchain model and the structure and programming of smart contracts and their algorithms, we programmed smart contracts in

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Ethereum Solidity language and tested the project on the Remix IDE.

3.5.1 The proposed model algorithm

The proposed model consists of three-phase . The objective of the first phase is for every user on the network, whether they are a production company or a distributor, to register user account data, including the company name, field name, and port name. Additionally, the type of commodity, whether it is oil or gas, is recorded. Furthermore, the port is examined, as outlined in Table 2.

Table 2: User Account Algorithm

Phase 1: User Account Algorithm
Input: Address Sender, Company Name, Area Name, Port Name, Crude Oil
User account information registration
Choosing a crude oil or gas
if Crude Oil Equal True ***then***
Recording data in oil smart contract
else
Recording data in Gas smart contract
end if

The second phase aims to record oil operations from various IoT sensors for oil and verify that the current user account is associated with oil or gas. If the account is registered as an oil account in the previous phase, a new quantity is generated for this account and added to its balance, which is recorded on the Ethereum blockchain network. However, if the account is a gas account, no new quantity is generated. Afterward, the sending company's account sells the quantity of oil from its balance to other recipient companies, following the agreement on quantity and price, and these transactions are recorded on the blockchain network, provided that the sending company has sufficient balance.Then, the actual transfer of the contracted quantity of oil takes place, and each time it is verified whether the actual quantity of oil sent from the sensors matches the contracted quantity. If they do not match, the new quantity of oil is added to the previous quantity, and verification is performed each time. Once the total actual quantity of oil matches the contracted quantity, it is recorded on the Ethereum blockchain. The purpose of this verification is to avoid recording all momentary data of the oil transfer process, but only record the important aggregated data on the blockchain network to ensure data integrity, as outlined in Table 3.

Table 3: Oil Algorithm

Phase 2: Oil Algorithm
Input: addressSender, quantityOil, temperature, gravity, bsw, rate
if crudeOil Equal true ***then***
Create a new quantityOil and other properties by IOT Senior
end if
Input: addressReceiver, transferOil, priceOil
if transferOil Greater Than quantityOil ***then***
Error message quantityOil not available
else
insert a new transferOil and priceOil
end if
Input: addressReceiver, quantityOil, temperature, gravity, bsw, rate
loop
if quantityOil Equal transferOil ***then***
Add quantityOil to the receiver account
Subtract quantityOil from the sender account
else
quantityOil + quantityOil
end if
end loop

The third stage aims to record gas operations from various IoT gas sensors and verify that the current user account is associated with oil or gas. If the account is registered as a gas account in the first stage, a new quantity is generated for this account and added to its balance, which is recorded on the Ethereum blockchain network. However, if the account is an oil account, no new quantity is generated. Afterward, the sending company's account sells the quantity of gas from its balance to other recipient companies, following the agreement on quantity and price, and these transactions are recorded on the blockchain network, provided that the sending company has sufficient balance. Then, the actual transfer of the contracted quantity of gas takes place, and each time it is verified whether the actual quantity of gas sent from the sensors matches the contracted quantity. If they do not match, the new quantity of gas is added to the previous quantity, and verification is performed each time. Once the total actual quantity of gas matches the contracted quantity, it is recorded on the Ethereum blockchain. The purpose of this verification is to avoid recording all momentary data of the gas transfer process, but only record the important aggregated data on the

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blockchain network to ensure data integrity, as outlined in Table 4.

Table 4: Gas Algorithm

	Phase 2: Gas Algorithm
1	**Input**: addressSender, quantityGas, gravity, co2, h2s , rate, calorificValue
2	***if*** crudeOil Equal false ***then***
3	Create a new quantityGas and other properties by IOT Senior
4	***end if***
5	**Input**: addressReceiver, transferGas, priceGas
6	***if*** transferGas Greater Than quantityGas ***then***
7	Error message quantityGas not available
8	***else***
9	insert a new transferGas and priceGas
10	***end if***
11	**Input**: addressReceiver,quantityGas, gravity, co2, h2s , rate, calorificValue
12	***loop***
13	***if*** quantityGas Equal transferGas ***then***
14	Add quantityGas to the receiver account
15	Subtract quantityGas from the sender account
16	***else***
17	quantityGas + quantityGas
18	***end if***
19	***end loop***

3.5.2 Smart contract architecture

The smart contracts is built in the Solidity language and using the Ethereum platform we created up to three smart contracts. The first smart contract, is responsible for registering user accounts on the network. It facilitates the creation of new users on the Ethereum blockchain. The contract stores important information such as the company name, field name, port name, and the type of resource being dealt with (oil or gas). This information is captured and stored within the smart contract.By utilizing the Solidity language and writing the smart contract in accordance with the specified requirements, the first smart contract enables the creation and management of user accounts on the Ethereum blockchain network. It ensures that the necessary information related to each account, is accurately recorded and stored within the blockchain for transparency and integrity purposes. We used functions and attributes as in table 5.

Table 5: smart contracts Architecture for user account registration

UserAccount	
Functions	setUserAccount() getUserAccount()

Attributes	Address: public minter
	struct : UserAccount{
	string : compName
	string : areaName
	string : portName
	bool : crudeOil
	}

Events	event : user

Secondly, this smart contract is specifically designed for oil, and it generates a new quantity of oil using the IOT sensor through the "mintOil" function. The contract then enters into an agreement with another company, the oil recipient, to specify the quantity and agreed-upon price of the oil using the "setTransferOil" function. Subsequently, the actual quantity of oil is sent to the designated recipient account with whom the agreement was made. During this process, data such as temperature, humidity, BSW (Basic Sediment and Water), total price, quantity, and rate are recorded using the "sendOil" function as in table 6.

Table 6: smart contracts Architecture for Oil

Oil Architecture	
Functions	setTransferOil() getTransferOil() mintOil() sendOil()

Attributes	struct : sendOilReceiver {
	uint : transferOil
	uint : priceOil
	}
	struct : DataOil{
	uint : quantityOil
	uint : totalPriceOil
	uint : oilTemp_F
	uint : oilGravity_API
	uint : oilBSW_Percent
	uint : oil_rate_STBd
	}

Events	event : SentOil event : MintOil

Thirdly, this smart contract is specifically designed for gas, and it generates a new quantity of gas using the IOT sensor through the "mintGas" function. The contract then enters into an agreement

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with another company, the gas recipient, to specify the quantity and agreed-upon price of the gas using the "setTransferGas" function. Subsequently, the actual quantity of gas is sent to the designated recipient account with whom the agreement was made. During this process, data such as quantity Gas, total Price, Gravity, CO2, H2S, rate, and calorific Value are recorded using the "sendGas" function, as shown in Table 7.

Table 7: smart contracts Architecture for Gas

Gas Architecture	
Functions	setTransferGas() getTransferGas() mintGas() sendGas()

Attributes	struct : sendGasReceiver {
	uint : transferGas
	uint : priceGas
	}
	
	Struct : DataGas{
	uint : quantityGas
	uint : totalPriceGas
	uint : gasGravity_AIR1
	uint : gasCO2_Percent
	uint : gasH2S_PPM
	uint : gas_rate_MMSCFd
	uint : calorificValue
	}

Events	event : SentGas event : MintGas

4. EXPERIMENTAL RESULTS

4.1 Testing and Validation

In this section, the smart contract codes were programmed using the Solidity language and code testing was performed using Remix IDE. Remix IDE can also be used to deploy smart contracts on the Ethereum blockchain network.

The setUserAccount() function, which adds a new account to the system, was tested along with the account details and the selection of the account in the case of inputting crude oil or gas, as shown in Figure 3.

Figure 3: Create New User Account

The mintOil() function was also tested to generate a new quantity of oil for the same user account, typically obtained from oil production companies and sent from various IOT sensors for oil, as shown in Figure 4.

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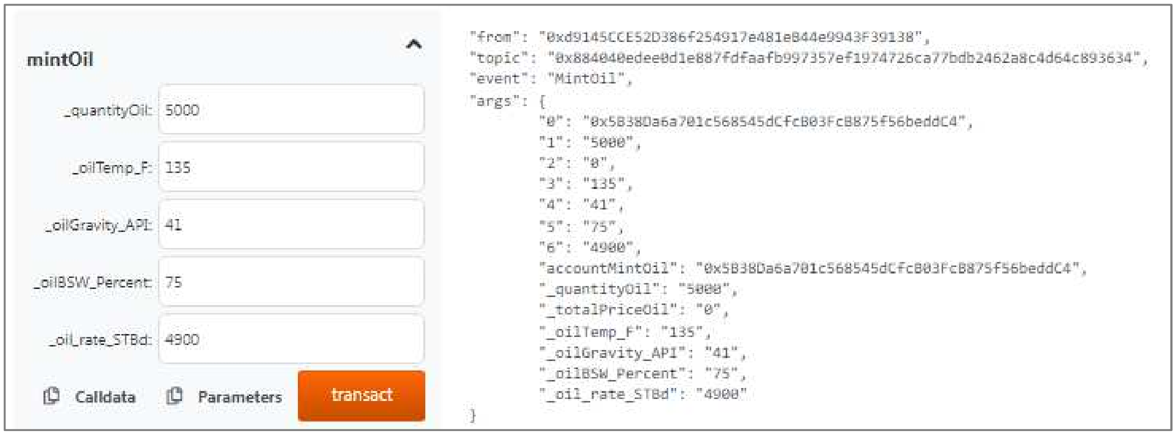

Figure 4: Create a New Quantity of Oil via IOT Sensors

The setTransferOil() function was also tested, where the quantity and agreed-upon price are entered for another user account, as shown in Figure 5.

Figure 5: Create the Quantity and Price to Send to Another User's Account

If the setTransferOil() function is used and the entered quantity exceeds the available balance in the mintOil() function, an error message is displayed indicating that the quantity is not available, as shown in Figure 6.

Figure 6: Error The Requested Quantity is Not Available

The sendOil() function was also tested to send a quantity of oil to another account, which is sent through various IOT sensors. Each time, it verifies that the actual quantity matches the contracted quantity, as shown in the setTransferOil() function in Figure 5. If they do not match, the excess quantity is temporarily accumulated, as illustrated in Figure 7. If they match, the quantity is permanently added to the Ethereum blockchain network, as shown in Figure 8.

Figure 7: Entering a Lower Actual Quantity than the Contracted Quantity Will be Temporarily Saved

Figure 8: The Total Quantity is Permanently Entered After Accumulating the Previous Quantities, and it Matches the Contracted Quantity.

We now query the sender's account and find that their balance of oil quantity has decreased, as shown in Figure 9

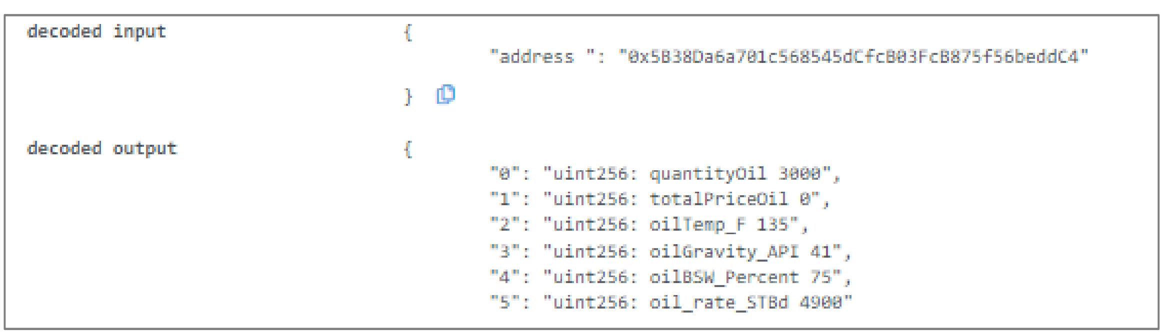

Figure 9: The Sender's Account Balance of Oil Quantity has Decreased

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We also query the recipient's account and find that their balance of oil quantity has been increased, as shown in Figure 10.

```
decoded input            {
                              "address ": "0xAb8483F64d9C6d1EcF9b849Ae677dD3315835cb2"
                         }

decoded output           {
                              "0": "uint256: quantityOil 2000",
                              "1": "uint256: totalPriceOil 160000",
                              "2": "uint256: oilTemp_F 135",
                              "3": "uint256: oilGravity_API 41",
                              "4": "uint256: oilBSW_Percent 75",
                              "5": "uint256: oil_rate_STBd 475"
```

Figure 10: The Recipient's Account Balance of the Quantity of Oil has Increased

4.2 Cost Analysis

4.2.1 Transaction cost analysis

When performing function in Ethereum smart contracts, they have a cost, which is the price of gas, which is the fee collected by miners on blockchain networks, The more complex the function that is called the higher the cost and the blockchain customer can choose the appropriate cost the higher the price of gas the faster the transaction will be confirmed, The remix IDE was used to know the cost of the Function at the price of gas and is a simulation of reality in cost estimation, This section aims at estimating the price of gas and converting it in US dollars, whether in the case of fast, medium or slow transactions. In the following table, it shows the cost of calling the job in our system at the gas price and converting it to US dollars and the hypothetical prices in Nov 2023, which are variable prices every period, respectively 14, 15 and 17 gwei. The cost of executing any function does not exceed $0.58 for a low transaction, $0.58 for a medium transaction, and $0.70 for a quick transaction[13]. Table 8 shows transaction costs after testing our proposed model.

Table 8: Transaction Cost Analysis

Method name	Execution gas cost	Slow execution (USD)	Avg. execution (USD)	Fast execution (USD)
setUserAccount	98452	2.555	2.737	3.102
mintOil	120218	3.120	3.343	3.788
setTransferOil	47483	1.232	1.320	1.496
sendOil	126096	3.272	3.506	3.974
mintGas	161703	4.196	4.496	5.096
setTransferGas	45685	1.185	1.270	1.439
sendGas	168864	4.382	4.695	5.321

4.2.2 Cost analysis between the traditional system and the Ethereum blockchain model

Cost analysis in the traditional system and our blockchain-based model, assuming that we want to work on sharing a stock of oil of around 2000 barrels in a single operation, will involve estimating approximate costs. Costs may vary from one company to another based on several factors such as location, circumstances, and surroundings. Sharing the stock with others incurs several costs, including:

- **In the traditional system:**
    - ✓ Communication and coordination costs: These are costs that companies may need to allocate for communication and coordination, such as salaries, commissions, and general expenses. They are estimated to be between $200 to $300 per operation, with an average of $250 per operation.
    - ✓ Administration and human resources costs: These costs include recruitment, training, salaries, and other benefits. They can be estimated to range from $50 to $150 per operation, with an average of $100.

- ✓ Mediation costs: These are the commission fees for intermediary companies, ranging from 1% to 2% of the quantity. Calculating based on 2000 barrels, with an average rate of 1.5% at a barrel price of $80, amounts to approximately $2400.
- ✓ Audit and verification costs: These are costs for verifying transactions and reports, ranging from $30 to $60 per operation, with an average of $45.

- **In our blockchain-based model:**
  - ✓ Blockchain fees **:**Transaction registration costs on the blockchain These are the costs of adding transactions to the blockchain network, such as registering the inventory transaction, which costs around $3.3, registering the contract transaction, which costs around $1.3, and registering the oil transfer transaction. The total cost of transactions is approximately $8. In addition to the costs of maintaining and developing the blockchain, which range from $35 to $45 with an average of $40, there are also training costs for blockchain, which range from $20 to $30 with an average of $25.
  - ✓ Communication and coordination costs: These are costs that companies may need to allocate for communication and coordination, such as salaries, commissions, and general expenses. They are estimated to be between $200 to $300 per operation, with an average of $250 per operation.
  - ✓ Administration and human resources costs: These costs include recruitment, training, salaries, and other benefits. They can be estimated to range from $50 to $150 per operation, with an average of $100.

Table 9: Cost Analysis Between the Traditional System and the Ethereum Blockchain Model

Cost	Traditional System (USD)	Ethereum Blockchain Model (USD)
Blockchain fees	0	73
Communication & coordination	250	250
Administration & HR	100	100
Mediation costs	1100	0
Audit & verification	45	0
Total cost	1495	423

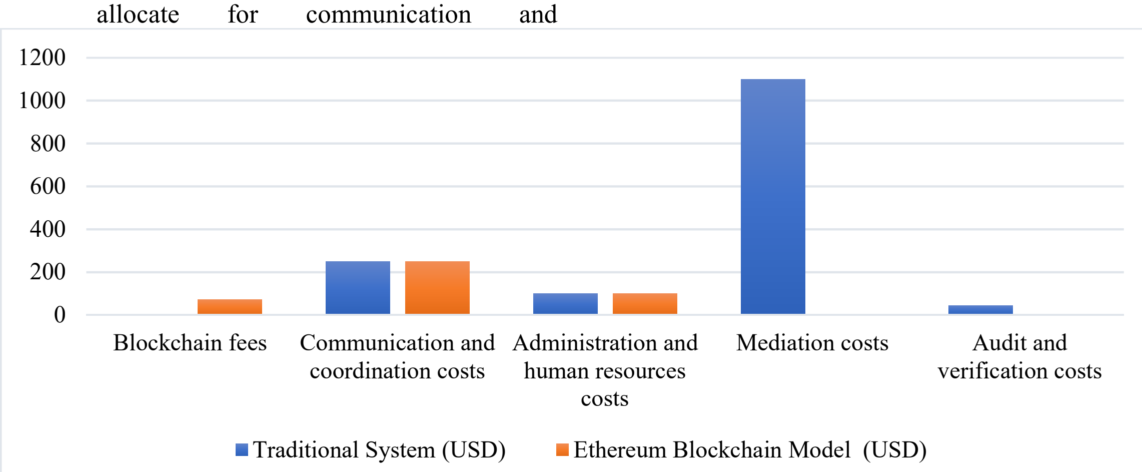

Figure11 : Chart Cost Analysis Between the Traditional System and the Ethereum Blockchain Model

4.3 Data Integrity

When constructing smart contracts correctly, it leads to entering data in a standardized format. In our proposed system, we have created smart contracts that include conditions for adding only important data, such as the total transferred quantity, rather than momentary data. This is because blockchain is used to verify data more than it is used for data storage, which ultimately ensures the integrity of oil and gas data. Furthermore, the data is stored on a decentralized distributed network, which prevents data loss. The data is recorded on the blockchain network in an encrypted form, making any changes or deletions in the data detectable. Therefore, it can be said that the use of blockchain provides assurance for the integrity of oil and gas data in the supply chain.

4.4 Advantages of Using Blockchain in our Proposed Model

The advantages of using blockchain technology in the oil and gas industry are presented as follows:

4.4.1 Security analysis

A blockchain three core characteristics are transparency, immutability, and encryption; it also has the ability to recognize data manipulation. Every transaction is logged on the blockchain, and the outcomes of this recording give the blockchain transparency, consistency, and dependability, the log data is accessible to all blockchain participants and cannot be modified or erased [14]. The risk of network attacks can be significantly decreased if blockchain technology is used to store crucial data in a decentralized fashion [15]. Hacking a system based on blockchain technology is not feasible and cost-effective because potential attackers have to crack every block, as well as copy the database on every computer and equipment in the network. This requires an attacker with unique computing resources which are not currently available [16]. Prior to adding data acquired, the majority of the network's machines must offer a consensus confirmation of the transaction; this confirmation must be obtained from at least 51% of the system's machines [17]. The security of the entire system can be further enhanced by the consensus procedure and checking the consistency of the data recorded in the distributed ledger [18]. Blockchain systems use cryptographic hash functions to ensure the security and veracity of the ledger system by hashing the block sent by a P2P network member and determining whether it still fits the pattern for the next block, the network can easily demonstrate that the calculating device actually found a coded solution to the function [17]. When oil or gas data is sent from IoT sensors, it is encrypted and, the quantity is sent from the sender to another receiver, the quantity is reduced from the sender and the quantity is added to the receiver, and this data cannot be changed after it is recorded on the Blockchain network. Because the data on the Blockchain network is immutable and legitimate data is encrypted to guarantee its integrity, no one on the network can alter the data after it has been entered to the ledger.

4.4.2 Without a third party

Some of the difficulties businesses have when a third party is involved. [19]. By using Blockchain databases, data integrity may be easily achieved, eliminating the need for Trusted Third Party Auditor (TTPA) roles [20]. With blockchain technology, participants can authenticate transactions without the need for a central clearing authority, establishing confidence and harmony in direct communication between two parties without the involvement of a third party [21] when sending quantities of gas or oil from one sender to another receiver, there is no third party guarantor for this process because one of the security factors is to get rid of the third-party trusted broker and replace the consensus algorithms by the validators in the Blockchain network to verify the transaction, and if the transaction is valid, it is stored on the Blockchain network.

4.4.3 Monitoring the chain in real-time

Transactions between parties in the blockchain system are recorded and stored in real time and monitored instantly [22] Companies are rushing to develop methods for developing near-real-time predictive analytics, data mining skills, and are extending their data storage infrastructure and resources due to the high rate of data expansion [23]. The real-time transparency and cost reductions made possible by blockchain technology help manufacturing companies become more profitable and competitive, which in turn ensures the industry's long-term viability [24]. Oil and gas data is recorded from IoT sensors and transmitted in real time, and because of that, saving time and effort in carrying out various tasks, as well as saving money in case of gas or oil leakage and early detection, also saves labor that performs these tasks because system performs these tasks.

5. Conclusion

This paper addresses the importance of monitoring and controlling the distribution of oil and gas among various entities. It discusses the significance of contracting between different parties in the oil and gas supply and distribution chain to save time, costs, ensure accuracy, and data integrity. The proposed solution combines blockchain and distributed systems to enhance data integrity, transparency, stability, and accuracy. We leverage blockchain technology to ensure the security of critical data. The algorithms, smart contract designs, and flowcharts for these contracts are also created and tested, along with transaction cost analysis. The advantages of using blockchain technology in the oil and gas

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process are discussed, including system security in terms of transparency, stability, and encryption. Additionally, data integrity is addressed through recording only valid and essential transactions, encrypting them, and making them immutable. Specific conditions have been added to smart contracts where quantities of oil and gas are collected and only the total quantity is stored on the blockchain network. This has led to a reduction in transaction costs on the network. Well as reducing the cost, we analyzed the cost per transaction, in terms of Blockchain fees, communication & coordination, administration & HR, mediation costs, and audit & verification, as it became clear that in the traditional system it costs about 1495 dollars, but in proposed model per transaction it costs about 423 dollars, saving about 1072 dollars per transaction. It is also noteworthy that there is no third party involved in transaction recording because consensus algorithms rely on it. Auditors in the blockchain network are responsible for verifying the validity of transactions and recording them. Real-time transaction processing is also discussed.

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