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Gemstones Supply Chain Management through Blockchain Mechanism

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The provenance of gemstones significantly enhances their value. However, both conventional supply chain management and digital systems are susceptible to counterfeiting, loss, and theft. Blockchain has emerged as a suitable technology to store tamper-proof records of gemstones allowing the storage of immutable journey of gemstones. This research article shows how the blockchain-based Ethereum network can be used for managing the supply chain of gemstones. Mining details, cutter information, digital certificates, proof of ownership, quality, and sales history of gemstones can be arranged in a two-tiered blockchain network to allow multiple organizations to securely share specific information within the organization and publicly. We cover the major supply chain exchanges for gemstones and end users with Ethereum smart contracts. We present that our suggested decentralized architecture-based solution can overcome many limitations in terms of immutability, traceability, verifiability, and security which exist in both conventional and digital supply chain management systems. Test scripts or smart contracts are publicly deployed on the Ethereum network.

Keywords: Gemstones; Blockchain-Based Gems Authentication; Blockchain; Decentralized Gemstones Supply Chain Management.

Introduction:

Transparency and traceability including tracking and tracing (from mine to market and market to mine) of gemstones, like precious pearls and diamonds, is an increasingly critical issue in the gemstones industry, as shown by novel reports and research [1][2][3]. The convoluted and mangled nature of the gemstone industry worldwide means that limited data and information are typically provided about the supply chain process and how gemstones are mined and manufactured [4][5][6]. Transparency is achieved through the traceability of gemstones, which helps address supply chain issues in a more comprehensible and well-documented manner. Increasing traceability and transparency helps to improve the social and environmental impact of a supply chain [7]. In traditional verification process of gemstone value and quality is done through paper-based certification. Legacy systems have many limitations and problems with trusted third parties. Paper-based gemstone certification has limited information that describes gemstone properties, such as type, color, and weight [8].

Centralized authority controls a paper-based centralized system and issues certificates to the gemstones. End-users must have to trust a central entity. Traditional centralized management systems are unable to maintain records from gemstone mining to end-user purchases. When dealing with fine gemstones, sellers and end users verify the accuracy and authenticity of historical records to ensure the gemstones' high value. Traditional management systems also leave end users without information about the gemstones' natural origins. Ensuring authenticity and transparency is particularly difficult when trading gemstones, especially diamond jewelry. Trust plays a mighty role in gemstone jewelry trading, making it extremely challenging in the open market [9].

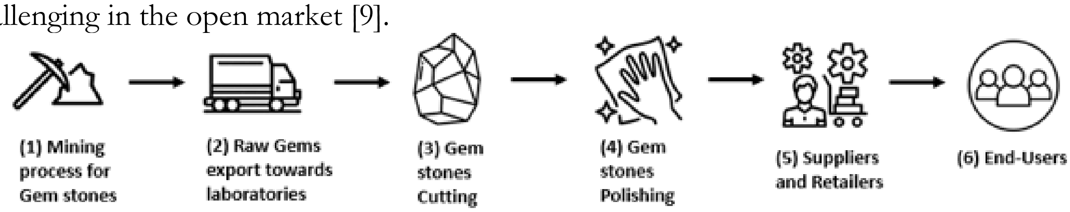

Figure 1: Traditional Gemstones Supply Chain Systems.

Blockchain technology can overcome limitations in terms of security and transparency that exist in traditional gemstone supply chain management systems. In blockchain data and a list of transactions in encrypted form are kept in the block of distributed public ledger [10]. Blockchain operates on a decentralized architecture, eliminating the need for a central or third-party entity to maintain or verify transactional records. Transactional customization in a blockchain is done with the implementation of smart contracts [11]. Smart contracts are algorithms that execute during the management process of transactions. Blockchain technology serves as a secure storage of data in many fields such as managing vehicle records, health care, educational records, land records, supply chain management systems, and many more [12][13][14][15][16][17]. Blockchain technology has many features like immutability, decentralization, distributed ledger, transparency, and security. Through blockchain technology, end-users can access authentic information at any stage of the gemstone supply chain [18][19]. To facilitate gemstone supply chain management through blockchain technology, hash key values are deployed to create a digital gemstone information certificate [20]. Digital gemstone certificates consist of a group of unique public and private hashes. Private hash key values cannot be exchanged for another [21]. Traceability in blockchain ownership and digital record authenticity is achieved using public hash key value [22]. Similarly, hash key values can be useful to encrypt the features of gems in terms of quality assurance, identification, and also information to end-users about authentic gemstone organizations.

This research paper proposes a blockchain-based decentralized solution for gemstones with a digital gemstone certificate throughout the gemstone supply chain management process. The suggested method makes use of the Ethereum blockchain network. Smart contracts are developed and deployed to manage gemstone supply-chain processes for different organizations and history records of diamond jewelry. We sum up our contributions to the effort as follows:

- A decentralized distributed system that distributes digital gemstone certificates in terms of encrypted key values to provide single or multiple organizational gemstones proof of ownership and supply chain management.
- We incorporate logistic digital gemstone certificates to each organizational gemstone to manage and trace the ownership of gemstones jewelry and permit the decentralized selling of jewelry set with gemstones. After end-user gemstone purchases, logistic certificates are transferred.
- We demonstrate the approach of our proposed system by presenting the system architecture for single or multiple organizations and illustrating the interactions among end-users and gemstone organizations in architecture diagrams.
- We lay out and define smart contracts to manage to issue logistic non-fungible tokens for gemstone supply chain management. Further, we implement and deploy our proposed work on an Ethereum blockchain-based network.

Objectives:

This work aims to be able to track the life of gemstones using blockchain starting from mining to the finished product and then further keeping track of the ownership of the gemstones and any changes that are made to them. The objectives of this study are as follows:

- To support gemstone institutions, the organizational industry strengthens, from mining to finished product and ownership verification
- To raise the gemstone supply chain productivity without any interruption of centralized authority
- To provide a secure digital platform development to increase innovation capacity
- To improve gemstone industry marketing and branding in a secure and validated manners
- To strengthen policies for increased competitiveness

Novelty Statement:

In this paper, we have proposed a consortium-based blockchain for tracking gemstones. Multiple vendors keep their gemstone supply chain management information in their private ledgers. Once the supply chain process is complete, information about gemstones from multiple vendors is stored in an immutable, publicly distributed ledger. This allows end users to interact directly for purchasing purposes. The majority of current solutions rely solely on theoretical research and perform research only for a single vendor but we have developed and put into action our solution on the Ethereum blockchain network for multiple vendors to achieve genuine, real-time tracking and verification of gemstones. The layout of this document is as follows: related work is presented in section II and challenges faced by the diamond supply chain industry. Section III contains our proposed system architecture and methodology part. Section IV describes our proposed system implementation. Proposed system testing, valuable results, and analysis are in sections V and VI. Section VII summarizes and concludes our work in this paper.

Literature Review:

This section discusses current advancements in diamond gem supply chain management systems. Traditional systems often have security vulnerabilities and limitations. While some digitalized systems for diamond gem supply chain management exist, these typically operate under centralized authority architectures.

Blockchain Technology-Based Jewelry Application Security Issues:

Blockchain-based jewelry application focuses on jewelry tracking implementation in a decentralized manner [4]. Initially, jewelry information is collected such as type, weight, and photo. A transaction is produced in the block of the distributed ledger and unique hash key values are assigned to jewelry. Information about jewelry's new shape in the blockchain is updated after melting, cutting, and polishing. Jewelry application only has information about jewelry design and type it does not contain information about the end-users. Blockchain technology-based jewelry applications completely based on informative documentation facilitate jewelry companies and organizations. However, these applications do not maintain a comprehensive record of ownership history nor do they directly benefit end-users. This research has many gaps in terms of authenticity and security and it is based on only research there is no real-life implementation [23].

Designing and managing a decentralized architecture becomes increasingly challenging as more entities and processes are added to the blockchain system. A DAM (Diamond Accountability Model) was introduced by Kank et al. which is based on decentralized architecture [24]. Researchers present a three-level architecture for diamond jewelry. Researchers call these levels as end-user level, operational level, and coordination level. The second level of the architecture is based on cyber-physical systems. Data exchange and manipulation tasks are performed in cyber-physical systems or operational level. Many organizations are part of the Gemstones Accountability Model and have their cyber-physical systems to generate information and data. Blockchain is used for prevention and storage purposes at an operational level. Before the exchange of information and data at the coordination level, the coordinates check the end-user's authenticity. For verification purposes, smart contracts are designed and deployed. Generally, the proposed research work can be implemented to check gemstone accountability with limited partners and CPS but this work requires more enhancement in terms of privacy, security, development, and deployment.

Vision for Gems and Jewelry Industry:

The gem and jewelry sector is collaborating across geographies and industries to inaugurate itself as a pre-eminent, world-class, highly competitive, powerhouse for precious gem cutting and jewelry manufacturing. To achieve this vision, the industry is upgrading the processes used in mining and jewelry production through the use of better skills and technology; training workers to increase productivity throughout the supply chain; encouraging research and development to gain a secure supply chain process, and diversifying its product line to realign supply with the demands of both domestic and foreign markets; setting and enforcing quality standards; and maintaining a supportive legislative environment. This research aims to be focused on achieving many objectives based on gemstone supply chain security.

Methodology:

Gems Supply Chain Management through Blockchain Mechanism:

In this section, we described the design and architecture of our proposed blockchain-based research on gem supply chain system management. Ethereum platform is employed to supply non-fungible tokens to each transaction (financial or non-financial) in the gems supply chain management system and stores data on a publicly distributed ledger. The gem record is updated after each sell and buy transaction in a distributed ledger. A block in blockchain technology includes a header, body, and footer. The block header contains the preceding block's public hash key value that maintains linking with the previous block and accomplishing a chain. With this mechanism, no external entity can breach the chain or alter any transaction within the blockchain network. The body of the block contains transaction information or data in encrypted form and the footer contains a private hash key.

Proposed System Architecture:

The Ethereum-based smart contracts (algorithms) help keep the data of the gems and jewelry supply chain in a secure, transparent, and ownership-traceable manner. In the proposed research work our main focus is on creating smart contracts on each phase of a supply chain that support non-fungible token functions. Once smart contracts are deployed they become immutable and we can share gems and jewelry records with all the nodes of a blockchain network. Gem design is calculated in the initial phase of the supply chain according to the shape and size of the gem. Different types of computer-based software are used for design calculation, in our research we used GemCad for accurate gems design structure. Gem-cutting operations are performed and its information is stored on a distributed ledger with non-fungible tokens. In our proposed system the first node called the miner captures network transactions to validate and execute them. The miner has list of blocks in the distributed ledger but the miner itself cannot change, update, delete, or alter any transaction after smart contract call operation execution. Entities in the system can use a decentralized application front end for smart contract function deployment.

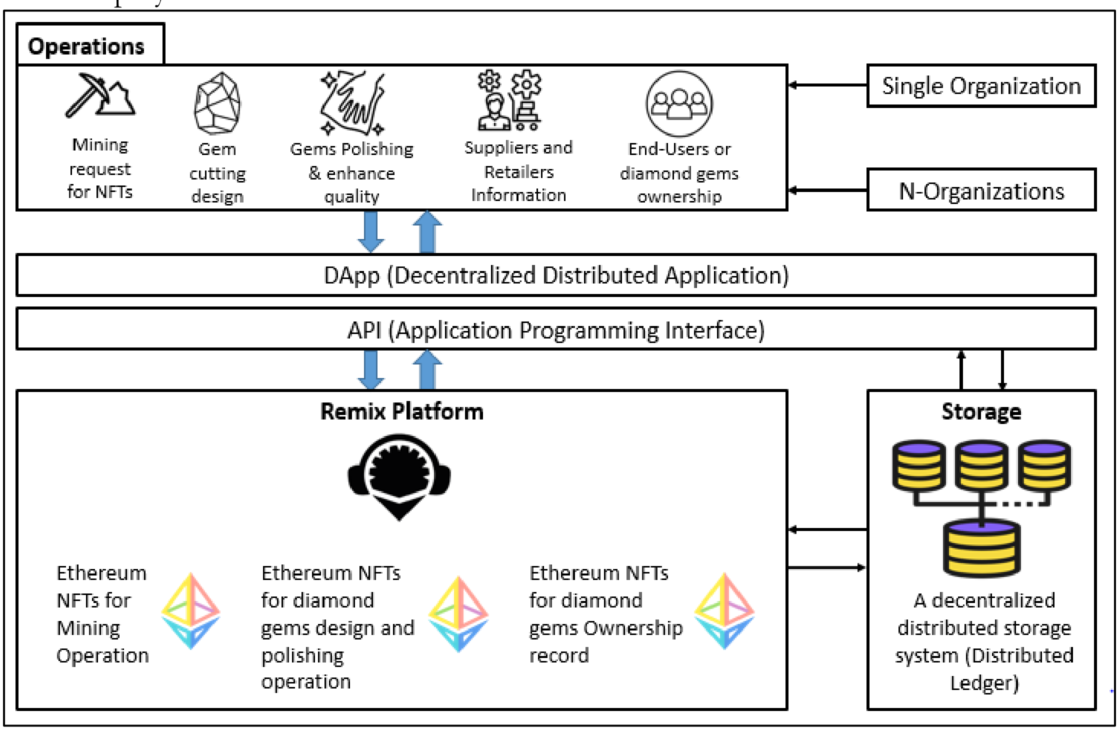

Figure 2: Gems and Jewelry Supply Chain Management through Blockchain Technology-Based System Architecture

There are five major operational data that a single or multiple organization wants to deploy on a secure blockchain-based network. In the proposed system architecture front end of the decentralized distributed application is connected with Ethereum smart contracts through application programming interface. Each organization can put gems supply chain operational records on the network like mining, cutting, polishing, and ownership details. These records are encrypted and kept in a block of the blockchain network's distributed ledger. Different types of hashing algorithms are used for the encryption of data in blockchain like SHA-256. End-users are also the part of the system, when end-users purchase gems or jewelry through a decentralized application then gem ownership records automatically update in the ledger. Figure 2 displays the system's intricate architecture.

As said in the paragraph before, there are a total of five main operations in the gems and jewelry supply chain management process. All operations interact with Ethereum smart contracts and have a specified role. The proposed system operations role is summarized below:

Mining:

The jewel adornment organizations are mindful of precious gemstone collections with the mining operations. Different government and private organizations obtain permission from country authorities and perform mining operations. Gems that organizations collect from mining operations are in raw form and have different attributes. Gems collection details submission in the proposed architecture is also the responsibility of respected organizations.

Design and Cutting:

Different types of techniques and tools are used to determine the appropriate and accurate shape of gemstones. Raw gems are collected from the mining process and the next step is to determine the exact shape of gems based on gems attributes like length, width, quality, etc. GemCad software can be used for authentic and accurate gemstone design. GemCad is computer-added design software that can generate design diagrams for gemstones. Gem diagrams can be scaled with GemCad to adjust their dimensions, making them taller, fatter, shorter, or skinnier, to fit certain pieces of rough. It allows the facility to organizations to create new designs according to end-users requirements. GemRay is computer design software that uses ray tracing techniques and provides a rough imagination on paper for cutting gems. GemRay provides the facility to prediction that how gems will look and also calculate cutting angles. Government and private gems and jewelry organizations will provide gem quality, design, and cutting information in immutable manners in the proposed system.

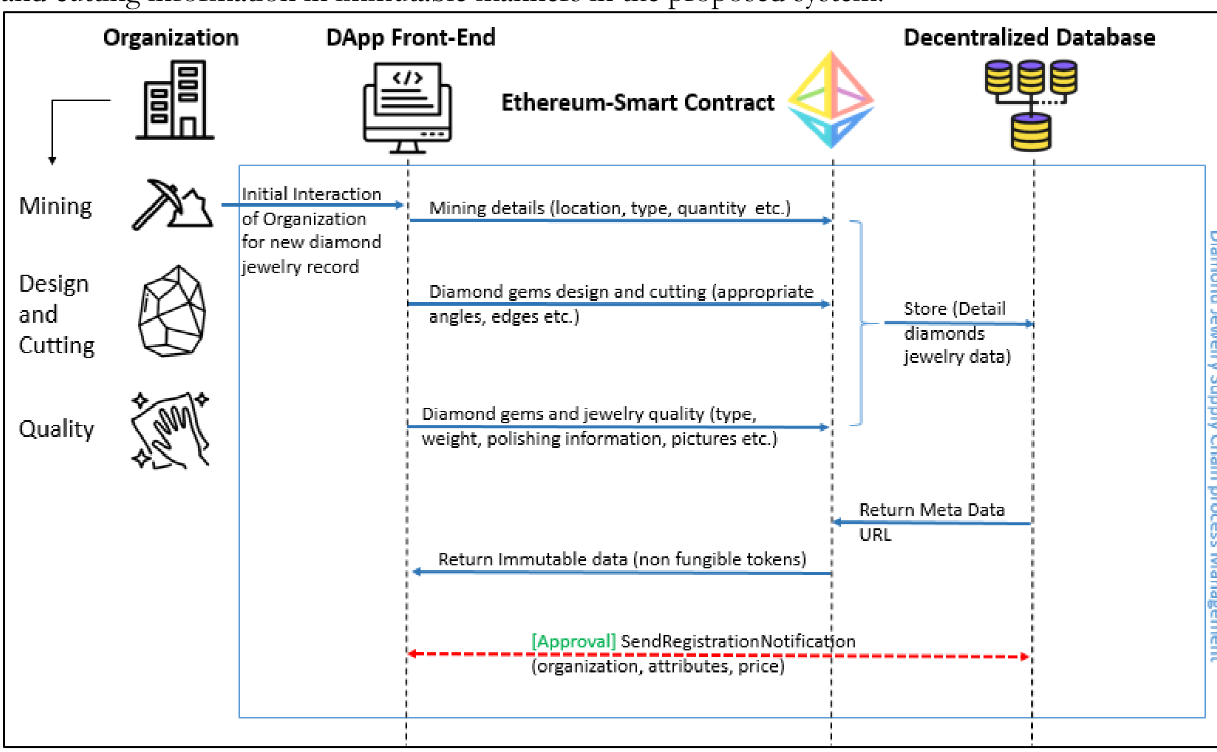

Figure 3: Flow Diagram of Organizations System Interaction.

Gems Polishing:

This operation is included in a proposed framework fair for recognizable proof of adornment quality data since each precious stone adornment has its possess traits. Adornment costs moreover depend on the traits of the gems. So within the proposed framework, each gemstone property data is additionally put away permanently.

Retailers:

True retailers are part of the system, can purchase jewelry from organizations, and get non-fungible tokens. Organizations transfer digital ownership of gems and jewelry to retailers in the system.

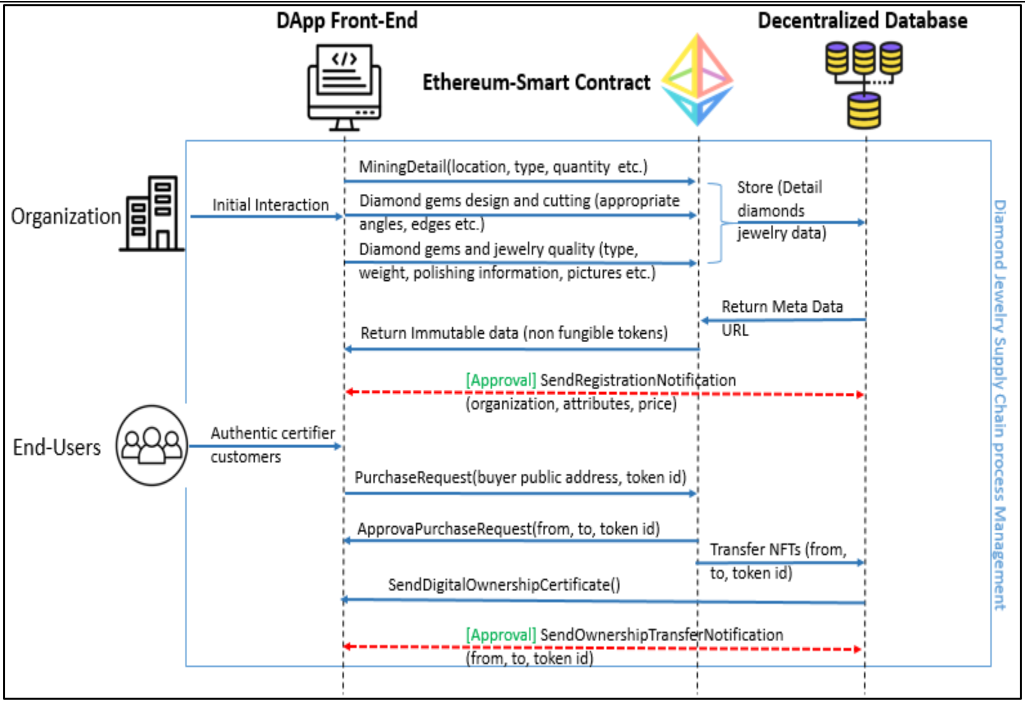

Figure 4: Flow Diagram of End-User Gemstones Buying Operation from Organizations through Proposed System.

End-Users:

End-users are also part of our systems and only authentic end-users in the system can buy gems products. Authentic end-users can access a whole detail of the gemstone supply chain process but cannot perform any change, update, delete, or alter operations. After an end-user makes a successful purchase, they end up the unused proprietor of precious gems and its record will consequently overhaul within the framework as a successful transaction.

Gemstones Supply Chain Management Organizational Operations Interactions with the Proposed System:

Authentic public and governmental organizations' interaction with the proposed system is done through a decentralized application front end. Organizations submit supply chain operations like mining, design, cutting, and polishing through a front-end user interface. In the back end, the organization performs calling functions with Ethereum smart contracts. The sequence of Figure 3 and Figure 4 shows the flow of system organizational interaction. The organization needs to deploy the supply chain operation through the front end. Ethereum smart contracts provide digital certificates against operational information. Next, the operational digital certificates that are immutable are kept in distributed ledger blocks. Attributes such as gem identification number, design, cutting angles, type, weight, quality, and price are displayed on the decentralized application front end in immutable manners through non-fungible tokens. Gems registration is approved in authentic and validated manners.

Figure 4 presents buying and selling details to complete the process of supply chain management from manufacturer to end-user. In our proposed system gems' complete details like type, quality, weight, etc are displayed in immutable manners using the front end. End-users can access organizational data but cannot perform change, delete, update, or alter any gem data. Interested end-users or buyers generate an event as a buying request. End-user buying requests are approved through Ethereum smart contracts. Transfer non-fungible tokens from seller to buyer or customer. Finally, an event triggered to announce at the front end that non-fungible tokens ownership has been changed from seller to end-user. Gems ownership rights are updated with a new owner.

Experimental Setup:

In the experimental setup, organization supply chain operations data placement was described through various functions and smart contracts. The front-end user interface was designed in React.js and connected with the Ethereum platform using an application programming interface (API). Algorithms or smart contracts, in blockchain terms, were written in the Solidity programming language. In our proposed system, single organizations or multiple organizations directly interacted through a front-end interface. Single and multiple organization interaction with our proposed system is shown in Figures 5 and 6 below:

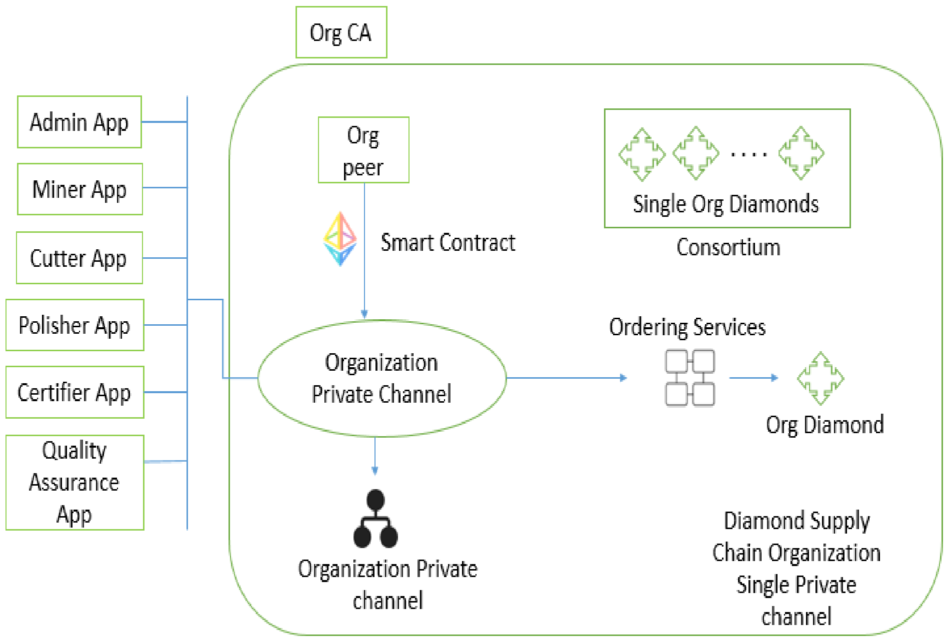

Figure 5: Single Organization System Interaction.

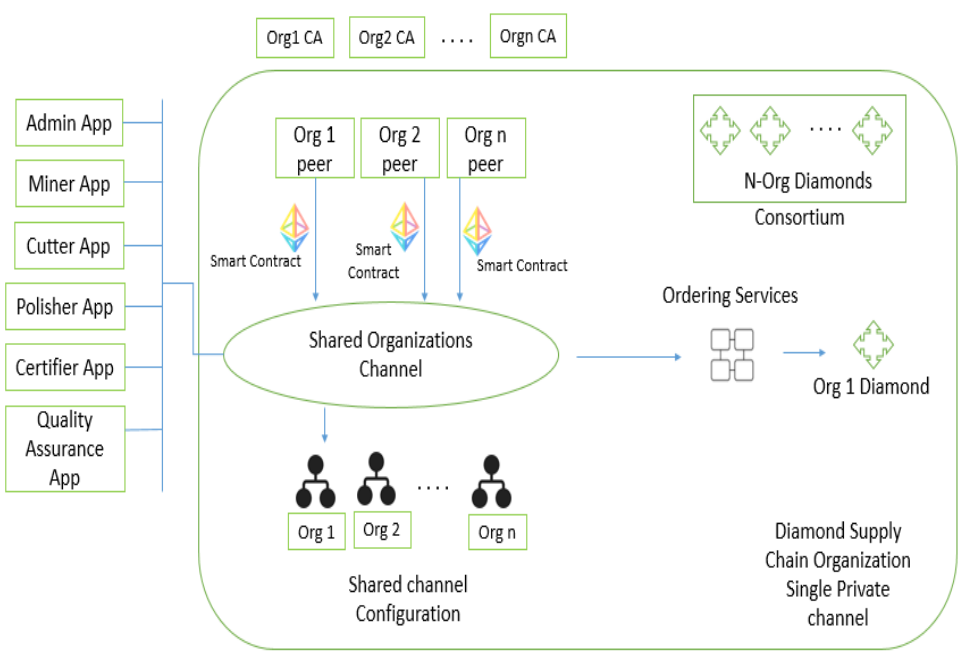

Figure 6: Multiple Organization System Interaction.

The first algorithm describes the process of a single or multiple organization's authentic registrations in the proposed system. The organization is responsible for adding complete details of gemstones. Organization registers with respective serial numbers and hash keys in terms of non-fungible tokens are mapped to an organization.

Algorithm 1 Organizational NFTs

(1) Input: SNorg, NFTorg, IPFS
(2) SNorg: Ethereum hash address of Organization
(3) NFTorg: Non-fungible tokens for Organization
(4) IPFS: IPFS for Organizational Data
(5) Modifier: Generate tokens for authentic Organization
(6) Call Generate-function(NFTs)
(7) Call Set-Token (NFTorg, IPFS)
(8) Map SNorg ⟶ NFTs
(9) Return OrgNFTs

Similarly, an organization registered its fine gemstone data. Pre-defined function calls for gems and registration and non-fungible tokens providence. When the function is prompt at the end to apprise all the authentic organizations and end-users that a new gem has been added.

Algorithm 2 Fine gemstone registration

(10) Input: DSN, DNFT, IPFS
(11) DSN: Hash address for Gems
(12) DNFT: Non-fungible tokens for Jewelry
(13) IPFS: IPFS for Organizational Data
(14) Modifier: Generate tokens for jewelry from OrgNFTs
(15) Call Generate-function(NFTs)
(16) Cal Set-Token (DNFT, IPFS)
(17) Map DSN ⟶ NFTs
(18) Return DNFTs

In the same organizational registration manners, end-users are also getting NFTs from the system. End-users also have serial numbers and register to get NFTs. End-users are the system entity that can perform only buying operations. End users do not perform any gemstone addition operation in the proposed system.

Algorithm 3 End-user NFTs

(19) Input: SNuser, NFTuser, IPFS
(20) SNuser: Ethereum hash address of End-user
(21) NFTuser: Non-fungible tokens for End-user
(22) IPFS: IPFS for Organizational Data
(23) Modifier: Generate tokens for authentic End-user
(24) Call Generate-function(NFTs)
(25) Cal Set-Token (NFTuser, IPFS)
(26) Map SNuser ⟶ NFTs
(27) Return UNFTs

In the final algorithm, the main operation is performed in the proposed system. If the end-user performs any buying operation, then the gem is delivered after a successful payment transaction. In the system, the gemstone is associated with the respective end-user to update gemstone ownership.

Results:

Smart Contracts Validation:

In the smart contract validation section, we specifically described the testing of smart contract functionalities in a web server environment. Non-fungible tokens were assigned for organizations, end-users, and gemstones as well. Mainly three necessary functionalities were tested, including organization and its gemstone product registration, end-user authentication, and ownership transactional record operations. The solidity programming language was used to develop smart contracts deployed on an Ethereum-based network using REMIX IDE. These smart contracts were compiled through Remix virtual machines, which served as the main network in our experimental work. The main network retrieved actual transactional values regarding latency and transaction costs, allowing for the calling of any public or private function. In Ethereum, transaction costs were incurred for each smart contract, necessitating calculations based on variables, functions, or complexities within the contracts. The Remix IDE calculated deployment costs for all smart contracts on the network.

Algorithm 4 Gemstone ownership transfer

(1) Input: DSN, DNFT, SNuser, NFTuser, Approved
(2) Approved: End-User Decision on organizational gemstone product
(3) If Approved, then
    Amount transfer from End-user to Organization
    Call Transfer-function (DNFTs, SNuser, IPFS)
    Amount Verification
    DNFTs ⟶ SNuser
(4) Else
    Event Emit
(5) End

In the initial smart contract, we endeavored to integrate various authentic public and private organizations within the gem system. Non-fungible tokens were assigned to these authentic organizations, and their information was stored in encrypted form within blocks of a distributed ledger. Smart contracts were deployed in the same fashion as organizations for End users. Authentic end-user gets non-fungible tokens as well. Figure 7 describes the smart contract that is deployed on a distributed encrypted network of Ethereum. End-users in the proposed system can perform only buying transactions they cannot change, update, delete, or alter operations in the system. Organizations are responsible for adding gemstone products to the system. When an organization adds products then is responsible for adding complete product supply chain information like mining, design, and other quality attributes. Smart contracts for products are also compiled and deployed on the Ethereum network, only authentic gemstone products are displayed to end-users with their complete ownership records.

The last important and necessary smart contract for ownership transfer was also deployed on the Ethereum network. In the proposed system, when an end-user performs a purchase, ownership of the product is transferred to that end-user. Product ownership records automatically update in the public distributed ledger to complete the supply chain process.

The results that were extracted from the deployment of smart contracts are displayed in the below figures. Hash key values in terms of hashing address are assigned through smart contract deployment. SHA-256 hashing algorithm is used for this purpose. Figure 7 and Figure 8 show the hashing address for the organization and end user respectively. Figure 10 expresses the ownership transfer in terms of the hashing address. It shows a public hashing address of the organization and end-user in between the buying transaction takes place.

```
// SPDX-License-Identifier:   GPL-3.0

Pragma solidity >=0.8.2 <0.9.0;
contract organization
{
        string request= 'Organization_Name';
        function registration () public view returns (string
        memory)                         infinite gas
        {
                return request;
        }
        function Organization_NFT () public view returns
        (address msgSender)        385 gas
        {
                return (msg.sender);
        }
}
```

Smart Contract 1: Authentic public and private organizations registration

```
// SPDX-License-Identifier:   GPL-3.0

Pragma solidity >=0.8.2 <0.9.0;
contract EndUser
{
        string request= 'EndUser_Name';
        function Registration () public view returns (string
        memory)                         infinite gas
        {
                return request;
        }
        function EndUser_NFT () public view returns
        (address msgSender)             385 gas
        {
                return (msg.sender);
        }
}
```

Smart Contract 2: End-User Registration

```
// SPDX-License-Identifier:   GPL-3.0

Pragma solidity >=0.8.2 <0.9.0;
contract Ownership
{
        string request= 'Product_Ownership transfer';
        string newbuyer = '0x4B20993Bc481177ec7E8
                          f571ceCaE8A9e22C02db';
        function UpdateLedger () public view returns
        (string memory)                  infinite gas
        {
                Return request;
        }
        function NewOwner () public view returns (string
        memory)                          infinite gas
        {
                Return request;
        }
        function Organization_NFT () public view returns
        (address msgSender)              385 gas
        {
                return (msg.sender);
        }
}
```

Smart Contract 3: Gems addition in the system

```
// SPDX-License-Identifier:   GPL-3.0
Pragma solidity >=0.8.2 <0.9.0;
contract Org_Product
{
        string OrgProduct= 'Product_Name
                           Mining_Detail
                           Cutting_Angles
                           Diamond_Jewelry_Attribute
                           s';
        string request= 'Organization_Name';
        function Registration () public view returns (string
        memory)                          infinite gas
        {
                Return request;
        }
        function Product () public view returns (string
        memory)                          infinite gas
        {
                Return request;
        }
        function Organization_NFT () public view returns
        (address msgSender)              385 gas
        {
                return (msg.sender);
        }
}
```

Smart Contract 4: Gems ownership transfer

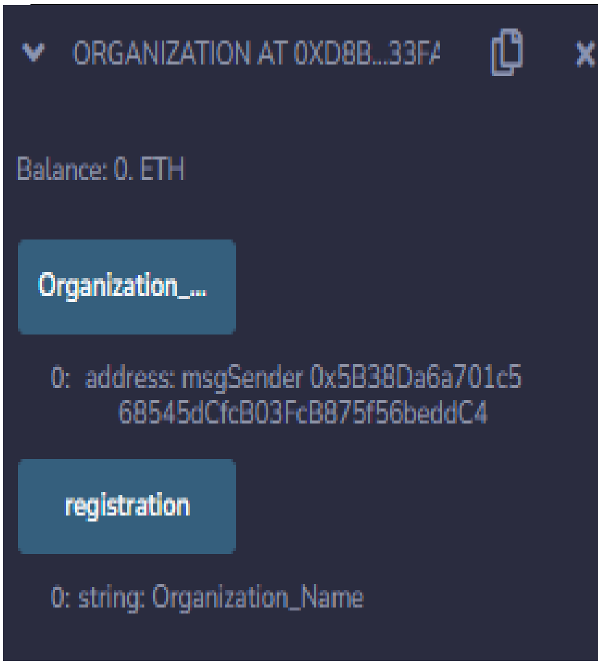

Figure 7: Organizational registration smart contract results

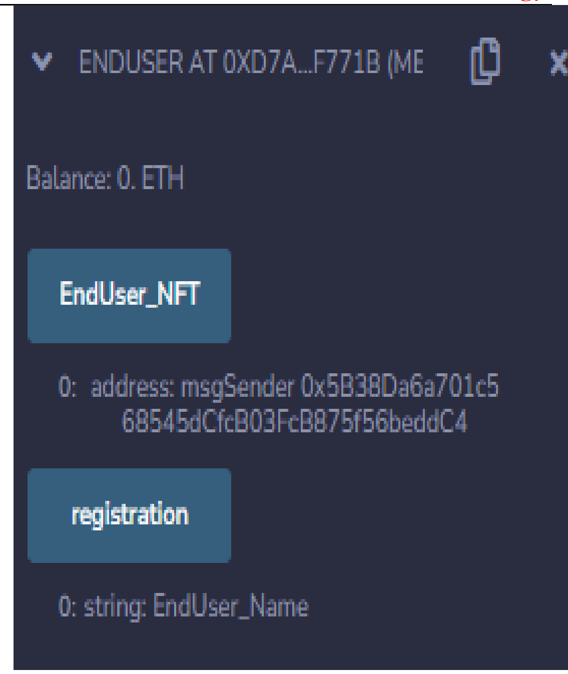

Figure 8: End-user registration smart contract results

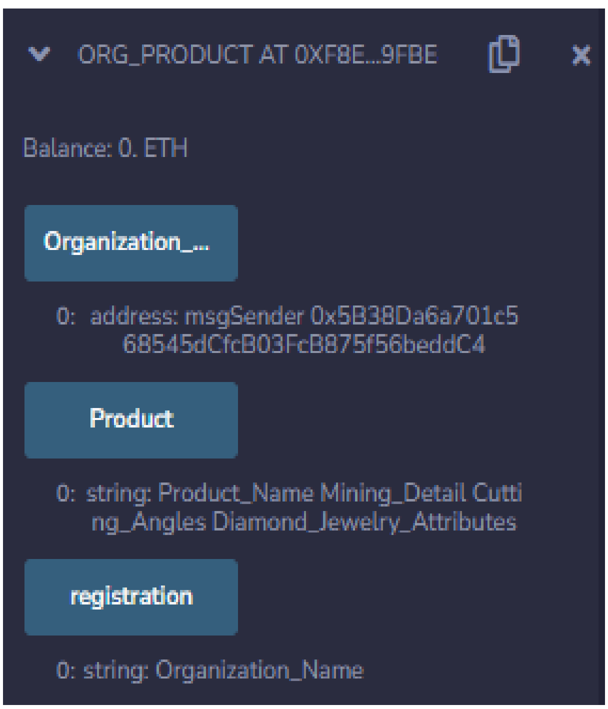

Figure 9: Smart contract for organizational product registration

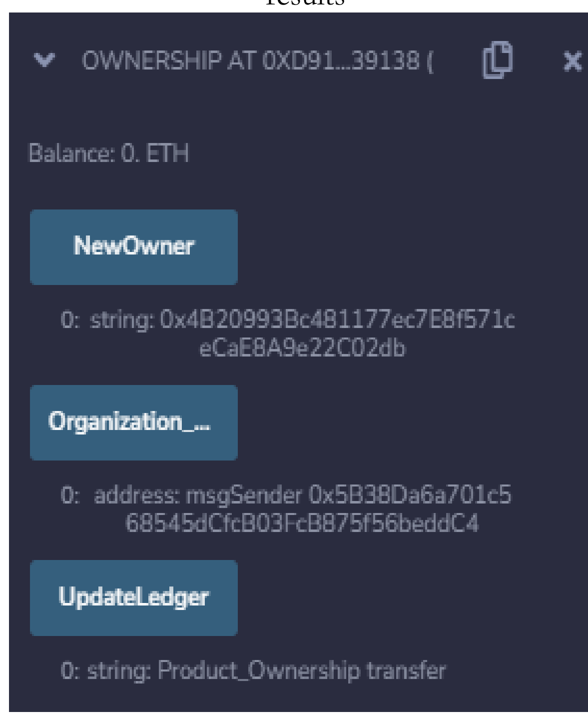

Figure 10: Ownership transfer in terms of the hashing address

Analysis:

In the analysis section, we present the security and cost analysis for our proposed decentralized architecture-based supply chain process management for gems. A well-known security threat that occurs in traditional supply chain management processes is elaborated and discusses how decentralized architecture eliminates those threats. Table 1 illustrates blockchain technology features that address traditional gemstone supply chain challenges.

Table 1: Blockchain Technology Characteristics that Address Traditional Gemstone Supply Chain Challenges

Characteristic	Description
Immutability	Gemstones supply chain process complete information is stored in the ledger that is distributed. Data is distributed among all the nodes of the system in encrypted form. So any entity of the system cannot be changed, deleted, or updated in any data in the blocks.
Decentralization method	In a traditional supply chain all the entities of the system are too much depend on the centralized authority. Blockchain removes dependency and provides the facility of direct communication between the entities of the system. In decentralized architecture gemstones, retailers and customers can perform direct communications and financial transactions with each other.
Transparency	Data is distributed among all the nodes of the system in encrypted form. So any entity of the system cannot be changed, deleted, or updated any data in the blocks. In the gemstones supply chain transparency mitigates the fraud of insurance.
Traceability	Gems can be traceable throughout the process of the supply chain.
Security	Blockchain makes gemstone supply chain and financial transaction data highly secure and robust.
Provenance	All the history of the gemstone supply chain and end users is stored in the highly secure distributed ledger of the blockchain.
Distributed ledger	A distributed ledger is the most important part of the blockchain. All the gemstone supply chain information, trading, and financial transaction data are stored in the distributed ledger.
Digital wallet	Digital wallet removes the deficiency of banks, and provide us with the facility of direct financial transactions between the entities of the system.

Cost Analysis:

In this section of the paper, we discussed the cost analysis of supply chain management. Ethereum platform provides the facility of public decentralized architecture so each transaction on Ethereum network requires gas for completion. Ethereum has a digital currency called "ether". Ether is used to purchase gas in the Ethereum platform. Each transactional cost in Ethereum depends on the complexity of smart contracts. Smart contracts consist of functions or methods. There are two types of functions in solidity smart contract and we have to specify function accessability. The view function can only provide the facility of read operation, we don't need to provide gas for the execution of the view function. In the case of pure function, we have to provide gas for the function execution. In pure function, we can perform read, write, or update operations.

Limitations and Challenges:

In the gems supply chain industry, the traditional supply chain has a lot of security holes and limitations. Some of them are illustrated in Table 2 and 3:

Table 2: Transaction Summary for Gemstone Ownership Transfer

Key points	Transaction Status
Status	0*1 Valid transactional
From	0x5B38Da6a701c568545dCfcB03FcB875f56beddC4
To	0x4B20993Bc481177ec7E8f571c⬇CaE8A9e22C02db
Input	Gems ownership transfers transactional information

Transactional Cost	Algorithm cost: O(n)
GAS(Cost)	407

Table 3: Gas Costs for Computational Transactions to Deploy Smart Contracts on Ethereum Network

Computational Transaction	Cost Gas
Organization Registration	385
End-User Registration	385
Organization Product Registration	407
Ownership Transfer	407
Total	**1584**

Comparison of Previous Solutions:

To better understand how our proposed solution successfully fulfills the objective of gemstone supply chain traceability and authenticity, we evaluated our approach against existing solutions. This evaluation focused on research advocating for blockchain-based technical solutions. Table 4 presents the comparison of our proposed solution with existing solutions mostly existing solutions are only based on theoretical work but we implemented and deployed our solution on the Ethereum blockchain network to gain real-time gemstone traceability and authenticity. Table 4 presents comparison between proposed and existing solutions.

Table 4: Summary of Blockchain Implementations.

	Proof of Ownership	Implemented	Deployed and Tested	Real-time Environment
Tracing manufacturing processes using blockchain-based token compositions	Yes	No	No	No
Blockchain for the diamond industry	Yes	No	No	No
Digital Assets Using Blockchain and Smart Contracts	No	No	No	Yes
Our Solution	Yes	Yes	Yes	Yes

Gems Origin and Ownership History Authenticity:

Trust related to the authentication of the gem's origin and ownership history is the major issue in the gemstone supply chain industry. Traditional supply chain mechanisms don't maintain the record of gems ownership. Customers show a lack of interest in buying gems due to the providence of non-authentic information.

Authentic Sources of Gemstones:

Buyers in terms of retailers and customers always want to get authentic and legal information related to gems resources.

Lack of Trust in the supply chain system:

Traditional gemstone supply chain mechanisms are based on paperwork. Therefore, the supply chain mechanisms documentation can easily be changed, updated, and deleted.

Customers and Bank's Fraudulent Claims:

In the past few years, different banks around the globe have claimed too many fraudulent gemstones. Customers and banks have nothing for the identification of gems. Banking lack of a tracking mechanism directly impacts the banking reputation and centralized architecture.

Conclusion:

This study presents a decentralized architecture-based solution for the gems industry. Traditional gemstone supply chain processes that produce and sell valuable items like gems and jewelry need to mitigate security effects. The proposed decentralized architecture-based solution consists of four algorithms (smart contracts) that are publically deployed on the Ethereum network. In particular, we created four smart contracts that govern the interaction between whole gems and jewelry supply-chain operations. The urged solution is efficient, secure, and authentic against different types of cyber-attacks like MITM attacks. We calculate a cost that is enough to deploy smart contracts on the network. In this paper, we presented security and cost analysis as well. Entities of the system cannot perform change, delete, update, or alter any transactions, however, the proposed system provides authenticity to both gemstones organizations and end-users. Reliability, security, verifiability, and traceability are the characteristics of our solution. With the end-user gems buying operation ownership record updated as well that cannot be changed, updated, or altered. In the future, we plan to commercialize our decentralized web and mobile-based applications with international stockholders.

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