DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

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COUNTERFEIT PROTECTION IN SUPPLYCHAIN USING BLOCKCHAIN

A project submitted

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by

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CERTIFICATE

This is to certify that the report entitled **"COUNTERFIET PROTECTION IN SUPPLYCHAIN USING BLOCKCHAIN"** submitted by Mohammad Adnan Muzafar (2019001743), Aman Bhargava (2019601326), Anupriya Jha (2019573254) to Sharda University, towards the fulfilment of requirements of the degree of **"Bachelor of Technology"** is the record of bonafide final year Project work carried out by them in the **"**Department of Computer Science & Engineering, Sharda School of Engineering and Technology, Sharda University**"**.

The results/findings contained in this Project have not been submitted in part or full to any other University/Institute forward of any other Degree/Diploma.

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ABSTRACT

Counterfeit protection in the supply chain is a pressing issue for businesses worldwide, as it poses a significant threat to consumer safety and can damage a company's reputation. In response, researchers have conducted a systematic review of available technologies and found that blockchain-based solutions offer several advantages over traditional methods. Blockchain technology enables the use of REST APIs (Application Programming Interface), which provide a safe and transparent method to track products through the supply chain. This technology also enables the use of smart contracts to facilitate automatic ownership transfers once certain conditions are met, resulting in a more efficient and reliable process. Additionally, the traceability offered by blockchain technology provides an added layer of security to the supply chain by allowing stakeholders to track the product's origin and journey, which is particularly important for products that are subject to counterfeiting or fraud. Implementing a blockchain-based supply chain management system can improve efficiency and transparency by providing real time information about the movement of goods. This enables stakeholders to optimize their processes and make informed decisions about inventory management and distribution. Furthermore, it helps to reduce waste and minimize costs associated with lost or misplaced items. The benefits of increased security, efficiency, and transparency are significant and can help companies gain a competitive edge in the marketplace. As the threat of counterfeiting continues to grow, it is crucial that businesses invest in advanced technologies like blockchain to protect their supply chains and ensure the safety and authenticity of their products. This research paper provides an in-depth analysis of the advantages of blockchain-based solutions and their potential to revolutionize the way supply chains are managed and protected while providing a Hyperledger based Blockchain which incorporates a QR based Anti-Counterfiet mechanism as well. The system described in the question involves generating unique identification numbers (UIDs) and associating them with products during the manufacturing process. A QR code is then generated for each product, which is covered with scratchable film. Upon purchase, the user can reveal the QR code, which contains a web link with a unique PIN, to access information about the product's supply chain journey through the exposed REST API which points to the Hyperledger. This paper also highlights the need for businesses to adopt innovative technologies to stay ahead of the competition and safeguard their customers' trust.

Keywords *– Blockchain, supply chain, counterfeit protection, REST API, smart contracts, QR, Hyperledger traceability etc.*

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INTRODUCTION

1.1 Problem statement

A blockchain based solution to solve the counterfeit protection in supply chain with increased tracking and transparency.

1.2 Project Overview

Blockchain technology, as exemplified by Bitcoin, features a public-transaction ledger, decentralized-transaction verification, a peer-to-peer network, and a fixed-currency circulation. The supply chain industry is ripe for transformation through new technologies, with blockchain offering promising opportunities for improvement. Integrating blockchain technology in supply chain management can enhance transparency and traceability, reducing administrative costs. By tracking vital information such as quality, date, certification, location, and price, participants can improve compliance, increase material supply chain traceability, reduce losses from counterfeit product sales in the grey market, and strengthen their reputation for ethical manufacturing [1]. Consumers are increasingly demanding transparency in food products, with over 90% considering it a significant factor in their purchasing decisions. They expect manufacturers to provide the necessary information, and companies that encourage social responsibility can increase their revenue by at least 55% [2]. Blockchain technology can also reduce fraud for high-value goods such as diamonds and medications. The Organization for Economic Cooperation and Development estimates that counterfeit goods contribute to approximately $450 billion in yearly commerce, and up to 30% of medication in developing countries is believed to be fake, resulting in significant fatalities and lost revenue [3] . Firms can leverage blockchain technology to better understand how raw and manufactured goods move through the supply chain, reducing losses due to grey market and counterfeit commerce, and increasing consumer confidence [4]. Overall, blockchain has the potential to transform the supply chain industry and offer significant benefits to organizations that embrace it.In this project, we will explore the issue of counterfeit protection in the supply chain and discuss how blockchain has been employed to combat this problem. We will first give a brief history of the situation of counterfeiting along with blockchain, its impact on supply chains, and the current methods used to combat counterfeiting [5]. We will then

discuss the benefits of these technologies in management of supplychain and explore some of the problems associated with implementing blockchain solutions [6]. Finally, we will propose a solution for employing blockchain to protect supplychains from counterfeiting. Counterfeiting has been a persistent problem throughout history, with the rise of globalization and e-commerce leading to an increase in counterfeit goods in the supply chain. This has led to significant financial losses for companies and has also posed a threat to consumer safety. Blockchain technology offers a solution to these issues by providing a secure and open method of tracking products through the supply chain. By using blockchain-based solutions, companies can make sure that all parties involved have access to accurate and up-to-date information, thereby minimizing the risks of counterfeiting and other fraudulent activities [7]. Moreover, the traceability offered by blockchain technology provides an added layer of security to the supply chain by allowing stakeholders to track the product's origin and journey. This is particularly important for products that are subject to counterfeiting or fraud. In addition, the use of blockchain technology can also result in cost savings and increased efficiency in supply chain management [8]. The further sections describe the existing technologies in depth while providing some limitations that they face while also providing a solution to tackle the issue of counterfeit in supplychain.

1.3 Contribution

The proliferation of counterfeit goods in the market has made it difficult to verify the authenticity of products, even for low-cost items. Existing approaches such as RFID-based solutions are too expensive, and traditional unique identifier systems can be easily cloned by counterfeiters. To address this issue, a blockchain-based anti-counterfeit method is proposed, which would also enable product tracking and traceability. This method involves creating a QR code from a unique identifier linked to the product, which can be scratched off and scanned by the consumer for validation. By displaying blockchain-verified data, consumer confidence in the authenticity of the product can be increased, and intermediaries or counterfeiters would be unable to steal or copy the QR code or unique identifier. The adoption of blockchain solutions requires collaboration among all stakeholders in the supply chain, which can give way to ecosystems which are more cooperative as well as play a role in remapping the interactions of different stakeholders. By enabling parties to exchange information, this improved transparency may also give development and performance

assessment more weight.

The key contributions of this project are:

- The aim of the project is to develop a blockchain based counterfeit protection system for supply chain.
- To develop a Hyperledger based solution consisting of a shared, permanent, and permissioned record of supply data in which the participants can be connected across the entire supply chain for tackling the problem of counterfeits.
- Increased traceability, trackability and security for the supply chain.
- To further research about the implementation of blockchain in the area of ownership rights.

1.4 Expected Outcome

Backend REST API developed on top of a Hyperledger based Blockchain, which will help the manufacturers and the customers to track and trace the supply chain from the start to finish so that the chance of any counterfeit entering the supply chain is minimized. All while adding extra security to the traditional supply chain practices by introducing the idea of a scratchable QR. We also hope to extend the backend application to a mobile app for better user experience.

1.5 Hardware and Software Specifications

Table 1.5.1 *Hardware Specification*

S.NO	Hardware	Usage
1.	Processor I5/I7/I9	• It is highly recommended to use the latest generation of Intel core processors.
2.	DDR4 RAM	• 16GB RAM is required for this project. • It is highly recommended to use DDR4 RAMs due to their high cores and memory management.

3.	Storage	• Solid State Drive (SSD) is required for this project as they make the operating system fast and response time low. • In addition to that processing time is also reduced by the use of SSDs. • It is highly recommended to SSDs of capacity more than 500GB. • NVMe SSDs are also highly recommended for storage and processing speeds.

Table 1.5.2 *Software Specification*

S.NO	Software	Usage
1.	Hyperledger	• An umbrella project for open source blockchains and related technologies.
2.	Solidity	• Solidity is a programming language specifically designed for creating smart contracts on blockchain systems, with Ethereum being one of its most prominent use cases. It is an object-oriented language that enables developers to write complex logic and implement functionality within the blockchain network.
3.	Integrated Development Environment	• It is highly recommended to use Visual Studio Code as the development environment • VS CODE from extensive resources along with support for many languages. • It also provides auto code completion which speed ups the development.

4.	Backend Technology 1. Node.js 2. Fabric SDK 3. Docker 4. Typescript	• Node.js is a runtime environment for JavaScript that is used on the backend of web applications. • NoSQL databases, which stand for "not only SQL," differ from traditional relational databases in how they store data. • Docker is an open platform that allows for the creation, distribution, and execution of software applications. It enables the separation of applications from their infrastructure, resulting in faster software delivery. • TypeScript is an extension of JavaScript that provides enhanced developer environment and allows for the inclusion of type safety in software development.

1.6 Non-Functional Requirements

These non-functional requirements are required to understand constraints put on the system. These are estimated but not actually calculated or estimated using different measures.

Table 1.6.1 *Non-Functional Requirements*

S.NO	Non-Functional Requirement	Usage
1.	Capacity	• The current requirement of storage of the project is estimated to be more than 1GB. • It can scale up in future depending upon the number of functionality added to the project.
2.	Compatibility	• The minimum requirements of the application to run is estimated to be more than 4GB of RAM and 32GB of storage. • This is right now only being developed for android operating system.
3.	Robustness	• The project has not undergone testing phase hence failure time is yet to be calculated

4.	Scalability	• The project has not been yet tested for heavy working conditions
5.	Usability	• The user interface is being developed as simple as possible • User testing is yet to commence.

1.7 Summary

In this report, we aim to bring to light the current phase and advances in the development of the project. The problem that we are tackling has been defined in the report followed by the overall definition of the problem along with an insight into the technical need of the project. This report also provides information regarding the already done work in tackling the problem. The methodology is proposed in this report along with system design and analysis followed by the results obtained to date and conclusions with the respective code and output snippets.

LITERATURE SURVEY

2.1. Background

Blockchain technology is a decentralized system that maintains a tamper-proof and continuous record file as a database through decentralization. Initially developed for Bitcoin [9], the process of adding new blocks to the blockchain involves acquiring and confirming data first. The consensus process of blockchain, which is a ProofOfWork (POW) approach, uses Bitcoin for instance. Each node participates in the chain based on how efficiently they can process information in order to solve the challenging but straightforward SHA256 math issue. And the one to solves the problem fastest respectively applies the fresh statistics for the block. Each node connects to the remaining nodes connected through the network, after saving and updating all the information accordingly on the Blockchain. The node examines the incoming transactions against the information recorded on the Blockchain to which it has access, adds them to the new block, and safeguards the editing and access rights with regard to the recently added block. Blockchain technology's primary features are its impenetrable security and anonymity, distributed structure, and ability to maintain untraceability and transparency.

Companies may have more control over the creation of outsourced contracts by employing blockchain solutions. It can lower data transmission or communication failures by giving all players in a certain supply chain access to the same information. Spending more time delivering goods and services while improving quality, reducing prices, or both entail spending less time on data review. By limiting or eradicating the effect of counterfeits, this can increase trade and customer confidence.

Furthermore, using blockchain-based-solutions one can achieve a dependable examination of supply-chain data, simplify administrative procedures and minimizing expenditures. Tasks involving human inspections for conformity or credibility that may currently take several weeks can be sped up by using a blockchain-based-solution that contains all relevant data. Setting new benchmarks for traceability and proactively managing the supply chain may help a business become a leader in ethical production. By providing information about the chain of distribution, data that has been blockchain-validated can boost public confidence in the government. Transparency may give construction and quality checks more weight when it comes to the information shared between all the supply-chain players.

2.2 Existing Work

2.2.1. Existing Systems Used Against Counterfeiting

Counterfeit protection in the supply chain is an important issue that has gained attention in recent years. Various systems have been developed to address this problem [10]. Some of the systems that are already present in the market are –

RFID (Radio Frequency Identification) is a technique that locates and tracks items using radio waves. It is commonly used in supply chain management to track the movement of goods from production to delivery. Readers and tags are the two major parts of an RFID system. RFID tags are little gadgets that contain a microchip and an antenna. The microchip stores data about the product, and the antenna allows the tag to communicate with RFID readers. RFID readers are devices that emit radio waves and capture data from RFID tags.In supply chain, affixed to items or their packaging are RFID tags. As the products move through the supply chain, RFID readers capture data from the tags and transmit it to a central database. This allows companies to monitor the location and movement of products in real time, ensuring that they are delivered at the appropriate time and location.RFID technology has several benefits for the supply chain management. It improves visibility and transparency, enabling companies to track products more accurately and efficiently. It also helps to reduce errors and increase efficiency, as manual data entry is no longer necessary. Additionally, RFID technology can be used to prevent counterfeiting, as tags can be programmed to contain unique data that cannot be replicated. Yet, RFID technology may also have certain negative aspects. One concern is privacy, as RFID tags can be used to track individuals as well as products. Additionally, the cost of implementing an RFID system can be high, which may be a barrier to adoption for some companies. Overall, RFID technology is a powerful tool for supply chain management, enabling companies to track and monitor commodities throughout the supplychain with ease and accuracy. [11].

Barcodes are a widely used method of tracking products in the supply chain. A barcode is a set of parallel lines and gaps with various lengths that serves as a visual representation of data. Usually, a defined format is used to encode the data, such as the European Article Number (EAN) or the Universal Product Code (UPC). Barcodes are easy to implement and provide a simple way to identify products. To read a barcode, a scanner is used to capture the data encoded in the lines and spaces. After that, this information may be sent to a central

database and utilised to follow the progress of goods along the supply chain. Barcodes have several advantages for the supply chain management. They are relatively inexpensive to produce and can be printed on a wide variety of materials, making them suitable for use on a range of products. Additionally, barcode scanners are widely available and can be integrated with other systems, such as inventory management software, to improve efficiency and accuracy. However, there are also some limitations to using barcodes. One potential drawback is that barcode can become damaged or unreadable, which can result in errors and delays in the supply chain. Additionally, barcodes are limited in the amount of data they can encode, which may be a constraint for companies that require more detailed information. Overall, barcodes are a widely used and effective method of tracking products in the supply chain. While they have some limitations, they are a cost-effective and reliable solution for many companies. [12].

QR codes are a kind of 2-dimensional barcode that have a larger data storage capacity than standard barcodes. They are often used in marketing and advertising to provide customers with additional product information or to direct them to a website or social media page. Also, in supply chain management, QR codes may be used to authenticate goods and follow their progress. QR codes can be scanned using a smartphone or specialized scanner, and the information encoded in the code can be transmitted to a central database for tracking and monitoring purposes. Overall, QR codes offer a versatile and flexible solution for businesses looking to improve their supply chain management and marketing efforts. They are easy to implement and can provide valuable data for companies and customers alike. [13].

Holograms are a type of three-dimensional image that can be used to authenticate products. They are difficult to replicate, making them an effective tool for preventing counterfeiting. Holograms can be placed on the packaging or the product itself and can include a range of information, such as a company logo or a serial number. When viewed under certain lighting conditions, holograms produce a distinctive and unique image that cannot be reproduced using traditional printing techniques. Overall, holograms are a valuable tool for businesses looking to protect their products and prevent counterfeiting in the supply chain. [14].

Watermarks are a type of design or pattern that can be added to a product or packaging to authenticate it. They are created by altering the texture or color of the material in a specific way to create a unique, identifiable mark. Watermarks can be difficult to reproduce and can be used to prevent counterfeiting by making it easy to distinguish between genuine and fake

products. Watermarks are often used on high-value items, such as currency, passports, and certificates, but can also be employed in supplychain to authenticate products and prevent fraud. Overall, watermarks are a valuable tool for businesses looking to protect their products and ensure the integrity of their supply chain [15].

Tamper-evident packaging is a type of packaging that is designed to show if a product has been opened or tampered with. It is used to prevent counterfeiters or other unauthorized individuals from accessing the product and altering it. Tamper-evident packaging can take a variety of forms, such as seals, tapes, or labels that break or change color when the package is opened. It can also include special closures, such as shrink-wraps or blister packs, that make it difficult to access the product without leaving visible evidence of tampering. Tamper-evident packaging is particularly important for products that require a high level of security, such as pharmaceuticals, food, and electronics. It can help ensure that these products remain safe and effective throughout the supply chain, from manufacturing to end-users. By providing a clear indication that a product has been tampered with, tamper-evident packaging can also help to deter counterfeiters and other criminals from attempting to alter or adulterate products. [16].

Track and trace systems are an essential tool for companies to monitor the movement of products throughout the supply chain. These systems enable companies to track products from their origin to their final destination, providing visibility into every stage of the supply chain. Track and trace systems use a variety of technologies, such as barcodes, RFID, and GPS, to monitor the movement of products and capture data related to their location, condition, and other key attributes. Track and trace systems can be used for a variety of purposes, such as monitoring the temperature and humidity of perishable goods, ensuring the authenticity of products, and improving inventory management. By enabling real-time monitoring of product movement, these systems can help companies optimize their supply chain operations, reduce waste, and improve customer satisfaction.Overall, track and trace systems are an essential tool for companies looking to boost effectiveness and efficiency of their supply chain management. They provide valuable data and insights that can be used to optimize operations, reduce costs, and ensure the timely delivery of products to customers [17].

Authentication labels are a type of label that is used to provide a quick and easy way to authenticate products. These labels can take many forms, including holographic labels, QR

codes, and other types of specialized labels that are difficult to replicate. Authentication labels can be placed on the product itself or on its packaging and can include a range of information, such as a company logo, serial number, or other identifying information.Authentication labels are particularly important for high-value products, such as luxury goods or pharmaceuticals, where counterfeiting is a significant concern. By providing a quick and easy way to authenticate products, these labels help ensure that customers receive genuine products and that businesses can protect their brand reputation.In addition to providing authentication, authentication labels can also be used to provide customers with additional information about the product, such as its origin, ingredients, and other relevant details. This can enhance the general customer experience and foster client loyalty and trust. Overall, authentication labels are a valuable tool for businesses looking to authenticate products and protect their brand reputation. [18].

Although these techniques have shown to be somewhat useful, they still have major drawbacks. Blockchain technology is emerging as a promising solution to address these limitations and provide more secure and reliable counterfeit protection in the supply chain [19].

2.2.2. Counterfeit Food Products in the Supply Chain

Food safety is a major global concern and there is an urgent need for technological solutions to complement legal measures. Blockchain-based traceability solutions offer an effective way to address the limitations of traditional tracing systems as they are decentralized as well as tamper-safe. Feng Tian [20] gave a blockchain and RFID-based tracking system for agricultural supply chains that successfully ensured food safety by collecting and sharing real data on various aspects of the supply chain. Wang Keke [21] developed an alliance blockchain-based traceability system that uses IPFS to hash data and validate it through a blockchain alliance model. The Wharton Chain also created an anti counterfeiting traceability solution that uses RFID and blockchain-technology.

To overcome the shortcomings of existing anti-counterfeiting traceability technologies such as data silos, manipulation, and center-based storage, Lu et al [23] developed a blockchain and Internet of Things-based food anti-counterfeiting traceability system that uses blockchain's decentralized storage and unchangeable properties to record traceability data. The system also makes use of the Internet of Things technology to ensure the legitimacy and trustworthiness of the blockchain's source data, resulting in lower communication costs,

greater security, and faster transaction times.

Arena et al. [24] introduced a blockchain-based application called "BRUSCHETTA" for better tracing and certification of the supply-chain of extra-virgin olive oil (EVOO) in Italy. The system records the entire manufacturing process and offers a way to certify EVOO using blockchain. However, in contrast to the suggested alternative, the procedure is slightly complex.

2.2.3. Counterfeit Drugs in the Supply Chain

It takes time for drugs to be developed and approved for use, from drug discovery to pharmaceutical research and development. However, the pharmaceutical industry's current supply chain management system is outdated, does not allow manufacturers and regulatory agencies access to or control over the distribution of drugs, and cannot withstand the 21st century's cyber-security issues. Drug fraud is an important global issue that is growing increasingly dangerous for public health, particularly in developing countries. These counterfeit goods may have been produced in an unhygienic manner, include dangerous materials, and result in potentially significant health problems. [25] According to estimates, between 10 and 15% of the world's medicine supply consists of fraudulent drugs. 30% of the market for drugs is made up of products sold in developing countries [26]. One of the largest and fastest growing criminal sectors in the world, counterfeiting is valued at about 600 billion dollars annually, according to the International AntiCounterfeiting Coalition (IACC) [27].

A blockchain-based innovative product ownership management system was proposed by Pham et al. [28] as a means of preventing medicine fraud and improving the usability of medication management. Small-scale tests showed that the article's recommended method can operate well in the actual world. This study provides the technology research foundation for the blockchain for drug traceability.

According to Zhu et al. [29], a blockchain-based anti-counterfeiting of medicines leverages autonomous uploading from each node to collect, register, and store data along the whole pharmaceutical supply chain, from manufacturer to client. Blockchain's non-modifiability, consensus mechanism, and traceability are essential for pharmaceutical anti-counterfeiting. The full piece of data can be hashed into a fixed-length hash result when the information is uploaded, making it impossible to tell it apart from the original data and challenging to decode by calculation [30].

Therefore, a simple hash operation was carried out, and the result was compared to the hash value already recorded on the blockchain to determine whether the data on the medications was still intact. If the two values are the same, the medication information is not altered. The non-modifiability aspect of blockchain effectively prevents any changes or forging at any node in the medication supply chain, hence ensuring the uniqueness, validity, and integrity of the data that is present.

The need to retain a database for future statistics while enhancing trust, transparency, traceability, and visibility may be summed up as the main objective and characteristics of the blockchain-based anticounterfeit system for the pharmaceutical industry. A suggested approach is to create a secure and reliable network that only authorised parties are allowed to join. On the backend, all essential transactions are stored on a permissioned blockchain; once data is entered into the blockchain, it cannot be changed. They have also developed an easy-to-use smartphone software that users will use to complete blockchain transactions [31].

2.2.4. Counterfeit Luxury Items in the Supply Chain

The majority of businesses strive to control how effective their supply chains are, but luxury brands have additional challenges from grey market, knockoff, and counterfeit items. The market for luxury products alone accounts for 60–70% of all counterfeit transactions [32]. Blockchain technology may be able to overcome these issues, as well as help firms manage their supply chains more effectively and guarantee the origins and traceability of expensive items. Therefore, it is essential to do research on the conditions and utility affecting the deployment of blockchain technology in order to enhance supply chain management and prevent fraud in the luxury market.

Dan et al. [33] proposed the usage of the EPC Internet-of-Things to stop the theft of expensive products. Although product information may be retrieved, information security is a worry since the data are exchanged over a network, and the cost is prohibitive for little goods like cosmetics and skin care products because each product has to be implanted with an RFID microchip.

According to Hochholdinger et al. [34], physical and chemical examination of markings or traces can have the effect of preventing watch fraud as well as provide a method to identify where the appropriate parts were manufactured, allowing for a certain amount of traceability. Regular consumers must seek expert guidance since the process is so complex in order to provide accurate results. The process's traceability is also erratic and somewhat dependent on

chance.

The most recent methodology and approach for garment traceability were presented by Perez et al. [35], although the data flow structure is not fully explained. This enables the logistics chain to trace all suppliers and clients. Due to the unavailability of some IoT technologies, consumers cannot access the transaction data on the blockchain directly, as suggested by Kumar et al. [36] for confirming and tracing the garment supply chain.

Boissieu et al [37] suggested a qualitative method based on grounded theory. Twelve participants were interviewed in semi-structured interviews about their work on blockchain applications in the luxury sector. This study suggests that luxury companies build private blockchain networks gradually, starting with a select number of outside vendors.

2.3 Case Studies

Blockchain technology is a distributed ledger system that keeps a tamper-proof record of data and records transactions. It is a decentralized technology that makes it possible for participants to conduct safe and open transactions without the use of middlemen [38]. Blockchain has potential applications in a range of industries, including supply chain management. In supply chain management, blockchain can be used to track the provenance of products and verify their authenticity. This is achieved through the creation of a digital ledger that records the movements of products through the supply chain [17]. This ledger can be accessed by authorized parties, including manufacturers, distributors, and consumers, allowing for traceability and transparency in the supply chain. Real-life examples of systems based on blockchain in supply chain management include the following;

Walmart's Food Traceability System - It is a blockchain-based system that enables the monitoring of food goods from their point of origin to the shelves of retail establishments. The system is made to ensure that food items are secure and of the highest calibre while also enabling transparency and traceability across the supply chain. The mechanism of the system involves the use of blockchain technology to create a digital ledger that records the movement of food products throughout the supply-chain. This ledger can be accessed by authorized parties, including Walmart, suppliers, and consumers, allowing for transparency and traceability in the supplychain [39]. The system operates by assigning a special identification to each food item, which is subsequently stored on the blockchain. This identifier includes information about the product, such as the origin, the date of production,

and the date of delivery. The movement of the goods is tracked on the blockchain as it moves through the supply chain, enabling real-time tracking of the product's origin [40]. The system also includes a mechanism for monitoring the quality of the product. This is achieved through the use of sensors and other monitoring devices that track the temperature, humidity, and other environmental conditions that the product is exposed to during transport [41]. If the product is exposed to conditions that are outside the acceptable range, an alert is triggered, and action can be taken to address the issue. In the event of a safety issue, such as a food recall, the system allows for quick and efficient identification of the affected products. This enables Walmart to remove the products from store shelves and notify consumers of the issue [42]. Overall, Walmart's Food Traceability System demonstrates the power of blockchain in the management of supply chain. By providing traceability and transparency in the supplychain and ensuring the safety and quality of food products, the system helps in building trust among the producers of food and their consumers, which is critical in today's globalized food market.

De Beers' Diamond Traceability System - It is a system that enables the tracking of diamonds from the mine to the retailer which is based on the blockchain. The system is developed to provide traceability and transparency in the diamond supplychain and ensure that diamonds are ethically sourced and conflict-free. The mechanism of the system involves using blockchain technology to create a digital ledger that records the movement of diamonds through the supplychain. The blockchain is immutable, meaning that after recording of information once, no kind of alteration or deletion is allowed. This results in a tamperproof record of diamond movements.Each diamond that is mined is assigned a unique identifier that is recorded on the blockchain. The identifier includes information about the diamond's origin, including the mine where it was extracted and the date of extraction. This information is then passed along to the next stage of the supply chain, such as the diamond cutter, who adds additional information to the blockchain.[43] As the diamond traverses throughout the supplychain, its movement is recorded on the blockchain, allowing for real-time tracking of the diamond's provenance. This enables De Beers to ensure that the diamond has been ethically sourced and conflict-free and that it has not been used to fund illegal activities or human rights abuses. The system also includes a mechanism for verifying the authenticity of diamonds. Each diamond is given a unique digital certificate, which is recorded on the blockchain. This certificate includes information about the diamond's

physical characteristics, such as its cut, carat weight, and color, as well as its digital identifier. Consumers can use this certificate to verify the authenticity of the diamond, ensuring that they are purchasing a genuine diamond.[44] Overall, De Beers' Diamond Traceability System demonstrates the potential of blockchain in supplychain logistics. By providing transparency and traceability in the diamond supply chain, the system helps to build trust between consumers and diamond producers, which is critical in today's globalized diamond market.

Maersk's TradeLens Platform - A blockchain-based platform for digitizing the global supply chain, has been studied extensively. Haughton et al. [45] presented a case study on its design, and De Marco et al. [46] presented a case study for employing blockchain technology in logistics for food traceability. The platform utilizes a shared digital ledger that records the transfer of commodities throughout the supplychain and assigns a unique digital identifier to each shipment. Parties involved in the shipment can update the digital ledger with relevant information, providing real-time traceability, tracking, and transparency of the shipment. Moreover, aside from facilitating the sharing of data related to shipping documentation, invoices, and other relevant information, the platform includes a mechanism for automating customs clearance. The use of algorithms of machine-learning and artificial intelligence in this process helps to reduce time and cost while improving accuracy and reducing the risk of errors [47]. The platform's use of blockchain technology ensures that all data is saved securely as well as in a tamper-safe manner, enhancing trust between parties involved in the supply chain.

IBM's Food Trust Platform - The blockchain based IBM Food Trust technology offers a safe and transparent means to monitor the origin of food items across the supply chain [48]. The platform is designed to increase trust between the producers of food, retailers, and consumers by providing a safe and failproof way to share data about food products. The mechanism of the Food Trust platform involves the use of a shared digital ledger that records the movement of food products through the supply chain. Each food product is given a unique-digital-identifier (UID) that is saved on the blockchain, along with other relevant information such as the origin, processing, and shipping information. As the food product moves through the supply chain, each party involved in the supply chain can update the digital ledger with relevant information, such as the current location of the food product, the temperature at which it is stored, and any other relevant information related to its safety and quality. The platform also includes a mechanism for verifying the authenticity of food

products. Each food product is given a unique digital certificate, which is recorded on the blockchain. This certificate includes information about the food product's physical characteristics, such as its origin, processing, and shipping information [49]. Consumers can use this certificate to verify the authenticity of the food product, ensuring that they are purchasing a genuine and safe product.The Food Trust platform also includes a secure data-sharing mechanism that enables parties to share data in a transparent and secure manner. This includes sharing data related to food safety, quality, and other relevant information. The platform uses blockchain technology to ensure that all data is stored in a tamper-proof and secure manner, protecting the privacy and security of all parties involved [50]. Overall, IBM's Food Trust platform demonstrates the potential of blockchain technology in the food industry. By providing transparency, traceability, and authenticity in the food supply chain, the platform helps to improve the safety and quality of food products, increase trust between parties involved in the supply chain, and ultimately, improve the overall consumer experience.

These examples demonstrate the effectiveness of blockchain when used for supply chain management. By creating a transparent and secure system for tracking the provenance of products, blockchain can help to prevent counterfeit goods, reduce waste, and ensure the quality and security of products in the supply chain.

Moving forward this section discusses a few proposed methodologies in the area of food, drugs and luxury items counterfeit protection using supply chain.

2.3.1. A Comprehensive Methodology for Detecting Counterfeit Food Items

Bext360, a startup based in Denver, Colorado, has raised $1.2 million in investment to transform the global coffee supply chain by utilizing cutting-edge technologies such as the internet-of-things, blockchain, and artificial intelligence. The aim is to enhance the flow of coffee and offer more income and equality to coffee growers.

One of the key ways the company is improving supply-chain visibility for coffee beans, which is the 2nd-largest traded commodity globally, is by leveraging blockchain. Bext360 uses a distributed, decentralized system that records information about transactions in real-time and allows all participants to examine the payment history at any time. To achieve this, Bext360 records timestamps, values, or quantities in the Stellar network, which is a decentralized, distributed system that facilitates real-time transactions. This allows for the

accurate processing of payments and credits, and all participants in the transaction, including farmers, co-ops, and companies, can access the data openly through Stellar's network. Farmers can also receive payments in real-time, ensuring they receive fair-trade payments. This approach helps to improve transparency as coffee beans move through the supply chain, which in turn helps to ensure that farmers receive fair compensation for their efforts [51].

2.3.2. A Comprehensive Methodology for Detecting Counterfeit Drug

PharmaCrypt is a blockchain-based anti-counterfeiting technology that enables the recording and time-stamping of every stage of the pharmaceutical supply chain. By scanning the bar code, every commodity transaction can be accurately recorded and time-stamped as the medication moves through the supply chain [52]. The ledger created by PharmaCrypt ensures the safety and security of the product by providing a reliable record of all transactions. The system is built on the AWS-created Ethereum blockchain, and it uses smart contracts to facilitate the creation and transfer of items across different accounts. With features such as bar code scanning, asset generation, asset transfer, and the ability to view scanned items, the system is designed to operate efficiently while meeting stringent security requirements. Overall, PharmaCrypt represents a major step forward in ensuring the safety and security of pharmaceutical products as they move through the supply chain.

2.3.3. A Comprehensive Methodology for Detecting Counterfeit Luxury Items

A logistics company has developed a blockchain-based cloud solution to digitally verify diamonds and prevent tampering with supply chain records. Ethical sourcing of diamonds requires strict certification criteria, but false certificate reports and insurance claims can undermine the measures put in place to prevent fraud. To avoid such issues, the logistics company has developed a unique diamond identification system that uses over 40 diamond attributes, including color and clarity, to create distinct IDs for each diamond. This helps to prevent fraud and ensures that the diamonds meet the necessary certification criteria. The blockchain technology used by the logistics company provides transparency between diamond certification companies and international diamond suppliers for the certification process. The technology also ensures immutability and security of the supply chain data, making it impossible for anyone to tamper with the data. To date, the logistics company has successfully digitized over a million diamonds using this technology, which is a major step

forward in ensuring the ethical sourcing of diamonds and preventing fraud in the diamond industry [53].

2.4 Gap Analysis

Counterfeit goods in supply chains can lead to a range of real-life crises that can impact businesses, consumers, and even public safety. Here are some examples:

i. Health Risks: Counterfeit pharmaceuticals, medical devices, and other healthcare products can pose serious health risks to consumers. These products may not contain the correct ingredients, may be contaminated, or may not have been produced under safe conditions. As a result, patients who use counterfeit healthcare products may experience adverse effects, and in extreme cases, fatalities can occur.

ii. Economic Losses: Counterfeit goods can lead to significant economic losses for businesses. These losses may include lost sales, lost profits, and damage to brand reputation. In some cases, businesses may also face legal liabilities for selling counterfeit products.

iii. National Security Threats: Counterfeit goods can also pose a national security threat. For example, counterfeit electronic components can compromise the safety and reliability of critical infrastructure, such as military equipment, airplanes, and power grids.

iv. Environmental Hazards: Counterfeit goods can also lead to environmental hazards. For example, counterfeit pesticides may be toxic to the environment and wildlife, while counterfeit electronic products may contain hazardous materials that can harm the environment if not properly disposed of.

v. Human Rights Violations: Counterfeit goods are often produced using forced or child labor. In some cases, the profits from counterfeit goods may also fund criminal organizations or terrorist activities.

These crises demonstrate the importance of preventing counterfeit goods from entering the supply chain and highlight the need for effective solutions to combat this problem. Counterfeit goods are a growing problem in supply chains, and they have negative impacts on both businesses and consumers. Counterfeit products are those that are falsely labeled or packaged to appear as genuine products, but they are not. These products can be found in various industries, including pharmaceuticals, consumer goods, electronics, and luxury goods.

The existing environment for preventing counterfeit goods in supply chains involves a range of methods, including product authentication, serialization, and anti-counterfeit technologies. However, these methods have limitations, and counterfeiters have become increasingly sophisticated in their methods.

Product authentication involves the use of unique identifiers, such as serial numbers or barcodes, to verify the authenticity of products. However, counterfeiters can reproduce these identifiers, making it difficult to detect fake products.

Serialization involves assigning a unique code to each product, which is recorded in a database. This allows tracking of products through the supply chain, making it easier to detect and remove counterfeit products. However, serialization requires a substantial financial input and can be difficult to implement in complex supply chains.

Anti-counterfeit technologies include features such as holograms, watermarks, and special inks that make it difficult to reproduce packaging and labeling. However, these technologies can be costly to implement, and counterfeiters can often replicate them with relative ease.

Blockchain technology offers a potential solution to these limitations. By creating a tamper-proof digital ledger that records the movements of products in the supplychain, tracking the provenance of products and verifying their authenticity can be done using blockchain. This can make it more difficult for counterfeiters to bring fake items into the suppl-chain.

However, implementing the technology of blockchain and incorporating it in supply chain management has its own challenges, including technical complexity, interoperability, and standardization. These challenges must be addressed to realize the full potential of blockchain in combating counterfeit goods in supply chains.

Counterfeit products can have a significant impact on consumers and the economy. Existing methods for preventing such products have limitations that make them vulnerable to manipulation and fraud. Common methods like product authentication and serialization rely on unique identifiers such as serial numbers or barcodes to track products through the supply chain. However, these identifiers can be easily replicated or tampered with, making it difficult to ensure the authenticity of products.To combat these limitations, new and innovative methods are being developed. For instance, some companies are exploring the use of blockchain in order to create a secure, tamper-proof system which will aid in the tracking of products. Others are exploring the use of machine learning algorithms to analyze patterns

of counterfeiting and identify potential risks. While these new methods are promising, there is still a long way to go in developing comprehensive and effective solutions for preventing counterfeit products.

Counterfeit pharmaceuticals are a major problem worldwide, particularly in developing countries where regulations and enforcement may be weak. These fake drugs can contain harmful or ineffective ingredients, posing a significant threat to public health. Current methods for preventing counterfeit pharmaceuticals, such as product authentication and serialization, have limitations that make them vulnerable to manipulation and fraud. For example, serial numbers and barcodes are easy to be replicated and tampered with, making it tough to guarantee the authenticity of pharmaceutical products. To combat this issue, various initiatives are being taken globally. Some countries have implemented stricter regulations and enforcement mechanisms, while others are exploring innovative solutions, such as blockchain technology or chemical tracing methods, to create more secure and tamper-proof systems for tracking drugs. However, these solutions require significant investment and collaboration among industry stakeholders, regulatory bodies, and technology providers. The fight against counterfeit pharmaceuticals is ongoing and requires a multifaceted approach. Raising awareness among consumers and healthcare professionals about the dangers of counterfeit drugs, investing in regulatory infrastructure and technology, and improving supply chain transparency are just a few strategies that can help combat this problem. Ultimately, protecting public health and ensuring the safety and effectiveness of pharmaceuticals is a global responsibility that requires collaboration and commitment from all stakeholders.

As a result, there have been numerous cases where counterfeit drugs have entered the market, causing serious harm to patients. For example, in 2012, a counterfeit drug scandal in China caused at least 80 deaths and led to widespread public outrage[54]. Blockchain-technology has been proposed as a potential solution to this problem. A blockchain-based solution can present a more safe and transparent way for verifying and tracking the authenticity of pharmaceutical products in the supplychain, helping to prevent any spread of counterfeit drugs and protecting public health [55].

2.5 Existing work Summary

Table 2.5.1 *Existing work summary*

Ref.	Authors	Year	Findings
[20]	Feng Tian	2016	• Prior to examining the benefits and drawbacks of using RFID and blockchain technology in the construction of the agri-food supply chain traceability system, we first examine the usage and development condition of these technologies.
[21]	K. K. Wang, Z. D. Chen, and J. Xu	2019	• Presented an effective alliance block chain-based traceability system for ensuring the safety and quality of agricultural goods.
[22]	J. Lawrence Carter and Mark N. Wegman	1979	• There are three appropriate classes of hash functions that are presented. Improvements to the limits of numerous algorithms are made possible as a corollary of the ability to examine the cost of storage and retrieval without caring about the distribution of the input.
[23]	Yi Lua, Peng Liac, and He Xua	2022	The system proposed uses blockchain technology's decentralised storage and unchangeable properties to record traceability data. The findings demonstrate the system's greater security, decreased transaction latency, and reduced communication expense.
[24]	Antonio Arena, Alessio Bianchini, Pericle Perazzo, Carlo Vallati and Gianluca Dini	2019	• BRUSCHETTA, a blockchain-based application for the certification and traceability of the supply chain for extra virgin olive oil (EVOO).
[25]	Jeremy Wilson and Roy Fenoff	2009	• The major goal of evidence-based anti-counterfeiting methods should be to

			comprehend and protect the pharmaceutical supply chain from counterfeiters.
[26]	World Health Organization	2010	• WHO and Interpol working together to solve the issue of counterfeiting.
[27]	E Roxanne, D K Lisa and P W George	2013	• Fashion ad Luxury counterfeit problems are discussed and explored.
[28]	H. L. Pham, T. H. Tran, and Y. Nakashima	2019	• To prevent drug cloning and increase the system's practical usability, a revolutionary Blockchain-based product ownership management technique has been proposed.
[29]	P. Zhu, J. Hu, Y. Zhang, and X. Li	2020	• The suggested solution provides a complete record of the medication circulation process while doing away with the need for centralized institutions and outside organizations.
[30]	A. Hafid, A. S. Hafid, and M. Samih	2019	• Developed a mathematical model to evaluate the security of blockchain protocols based on sharding. In order to validate our concept, we also examine popular sharding protocols including, Zilliga OmniLedger, and RapidChain.
[31]	I. Haq and O. Muselemu	2018	• The pharmaceutical industry will utilise the planned system to trace the pharmaceuticals from their manufacture until they are given to patients. The impact a medicine has on a patient is documented after use in a database for statistical purposes.
[32]	Y. Wang, J. Lin, and T.-M. Choi	2020	• Carefully analysed the most representative articles on counterfeiting and the grey market in the operations literature for this study.
[33]	A. I. Dan, W. X. Ran, D. Hu, X. Xu, and S. E. Pan	2012	• Discusses steps customers may take to avoid purchasing counterfeit goods, such as employing plainclothes detectives and forming dedicated

			teams to detect and deal with the problem.
[34]	S. Hochholdinger, M. Arnoux, O. Delémont, and P. Esseiva	2019	• The purpose of this study was to identify the various kinds of connections that can be made between counterfeit watch specimens, to thoroughly analyse the information these connections revealed, to examine their complementary nature, and to gain insight into the intelligence that can be generated from these bits of knowledge.
[35]	J. B. Pérez, A. Queiruga-Dios, V. G. Martínez, and M. Rey	2020	• In addition to proposing a framework for ready-to-wear clothes that allows for supply chain transparency, the purpose of this study is to offer more current traceability systems for the garment sector.
[36]	T. K. Agrawal, V. Kumar, R. Pal, L. Wang, and Y. Chen	2021	• With the distributed ledger being used to record and validate supply chain transactions, the suggested solution can help supply chain parties develop a technology-based trust.
[37]	E. de Boissieu, G. Kondrateva, P. Baudier, and C. Ammi	2021	• Blockchain technology is suggested in this paper as a means of disintermediation, traceability, and transparency in the market for luxury goods. The knowledge gap, the large number of third parties participating in the production process, and the inclination toward quick returns on investment are some of the challenges faced by luxury firms integrating this technology into their ecosystem.
[51]	D. Takahashi	2017	• Technology for streamlining vital global commodity supply chains is created by bext360. Its "bext-to-brew" platform is using blockchain, IoT, artificial intelligence, and machine learning to revolutionise the coffee business.
[52]	N. Saxena, I.	2020	• Drugs will be tracked and traced as they move

	Thomas, P. Gope, P. Burnap, and N. Kumar		through the supply chain using a Blockchain-powered application dubbed "PharmaCrypt," which will upload the data collected to a distributed Blockchain ledger to verify the drug's validity.
[53]	Everledger	2016	• A worldwide digital ledger called Everledger is used to track and safeguard precious objects like diamonds throughout their existence. Over 1,500,000 diamonds have been digitally protected on the blockchain by Everledger, which is also bringing its technology to the worlds of fine wine and great art.

2.6 Summary

This chapter provides an introduction to the use of blockchain technology in supply chain management, including the history and development of blockchain. It explains how blockchain's decentralized and tamper-proof nature makes it an ideal technology to combat counterfeiting in various industries, including agriculture, pharmaceuticals, and luxury items. The chapter also discusses the challenges and limitations of existing anti-counterfeiting traceability solutions and how blockchain can provide a more comprehensive and efficient solution. Several studies propose blockchain-based solutions that integrate other technologies like RFID and IoT to create a secure and trustworthy supply chain.

SYSTEM OUTLINE

This chapter gives an overview and describes how we can implement blockchain to protect the supply-chain from counterfeits.

3.1. Overview

To address the limitations that have been discussed in the previous section, in this paper we have discussed a blockchain-based solution that can enhance the effectiveness of these methods. Blockchain technology provides a way to keep the flow of data, transparent and tamperproof, which gives way to effective storing and sharing of data, making it an unrivaled solution for preventing counterfeit products. This blockchain-based solution can involve the use of a computerized ledger which can record the entire supply chain history, from the origin all the way to its final destination. Each product can be assigned a unique digital identifier, which is recorded on the blockchain along with other relevant information, such as its manufacturing date, shipping information, and any other relevant information related to its quality and authenticity. As the product moves through the supplychain, each player involved in the supply chain can update the ledger with relevant information, such as the current location of the product, the temperature at which it is stored, and any other relevant information related to its safety and quality. This ensures complete traceability and transparency throughout the supplychain, making it difficult for counterfeits of the products to enter the market. In addition, the blockchain-based solution can also include smart contracts that automate the authentication and verification process of products. These contracts can be programmed to trigger specific actions when certain conditions are met, such as verifying the authenticity of a product based on its unique digital identifier.

Overall, this blockchain-based solution can enhance the effectiveness of existing methods for preventing counterfeit products by aiding with a transparent as well as tamper-proof way to verify and track the authenticity of products in the supply chain. By leveraging the power of blockchain, the solution provides greater safety and confidence with respect to the products being produced and consumed, ultimately benefiting businesses and consumers alike.

3.2. Implementation

The system in question involves the use of blockchain-technology to create a tamper-proof digital ledger that records the movements of products in the supplychain. This ledger can

help in tracking the origin of products and verify their authenticity, making it more difficult for counterfeiters to introduce fake products into the supply chain. Retail plays a really important role in our economy and it brings in a lot of revenue every day. It also provides a variety of products to the costumers at different locations, and at different prices. However, the relation between the customer and the manufacturer is greatly affected by the existence of counterfeits which take place of the original ones. Hence, monitoring and keeping a track of what's happening in the supply chain becomes crucial to improve customer experience as well as tackling with the counterfeit issue. The tracking, monitoring as well as tracing of the flow of products from start to end in the supplychain would allow the end user to confirm the genuineness of the producers while also allowing them to differentiate between the real products and their counterfeits. Systems based on Blockchain are viewed to be a solution for putting this into practice. In the said system, organizations like the retail store, manufacturers, distributors, and wholesalers, could be created and managed using the enterprise based blockchain Hyperledger Fabric, which in turn will result in a would create a trustworthy messaging channel that enables tracking of any product at any stage, from its origin to its end user, hence minimizing any chance for a counterfeit to take its place.

The solution is for a straightforward supply chain network that complies with business needs. For this reason, two organizations are maintained which are; Org1, referring to the manufacturer (one end point), and Org2, refering to all the possible end nodes (points) in the supply chain like wholesalers, distributors, and retailer. Data flow begins at the manufacturer where the original goods are generated and ends when the finished goods are purchased in retail establishments mapped in the chain. Figure 3.2.1 depicts the structure of the two organizations within the chain.

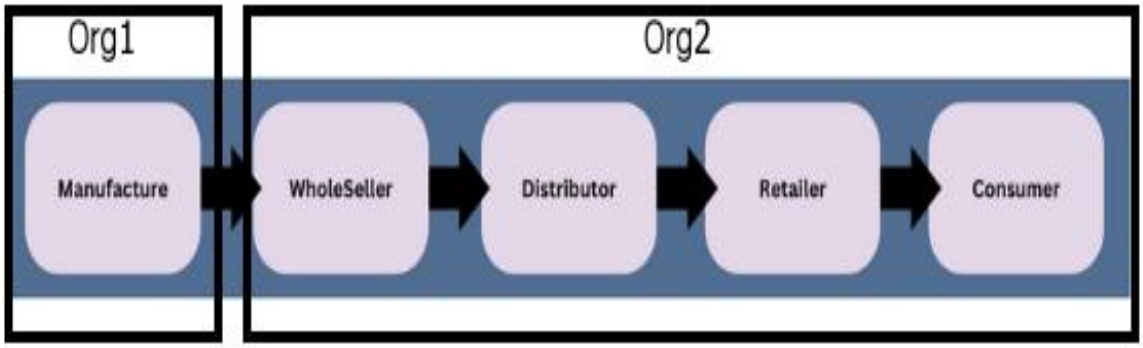

Figure 3.2.1. *Structure of the two organization within the supply chain.*

The blockchain-based hyperledger solution would enable every organisation to run a single endorser and commit a peer node to validate transactions, and only voting would determine which node will become admin or whether to let a new member join the supply chain and the decision that receives more than half of the votes would be put into effect. The system would be created to protect the supply chain from counterfeits. The task of upholding the aforementioned regulations will fall to the system administrator. And in order to build the Raft process, orderer nodes must only be in odd numbers. To make the data and system more trustworthy and solid, data that has been placed into the ledger will remain there indefinitely. Finally, any member shown to be acting maliciously must be permanently banned from the system, thus ensuring that the products remain original through the supply chain. With respect to the above proposed system, the module for Create, Get, ShipTo and GetHistory operations have been developed centered around the products that will move across the supplychain. The input and output description of these modules is given in Table 3.2.1. Moreover, the main idea is to incorporate this blockchain-based hyperledger solution with a physically accessed secure QR mechanism. This incorporated system is designed so as to provide consumers with a secure and seamless way of verifying the authenticity, and traceability of their purchased products. By generating unique identification numbers (UIDs) and associating them with products during the manufacturing process, each product is given its own identity that can be easily traced and verified. To protect the QR code containing the web link and unique PIN, a scratchable film is applied to conceal it from view. When the consumer purchases the product, they can scratch off the film to reveal the QR code and access the supply chain journey of the product through the company's website. This process ensures the verification of authenticity and traceability by the consumer for the product they have purchased, as well as providing a means of preventing counterfeiting by invalidating the QR code upon use. The manufacturing unit is responsible for generating the UIDs and QR codes, and applying the scratchable film to cover them. This innovative system offers an exciting new level of security and transparency in the manufacturing and supply chain industry, providing consumers with greater confidence in their purchases and companies with a means of ensuring the integrity of their products.

Table 3.2.1 *Operation Description*

Operation	Input	Output
Create	UID	None
Get	UID	Product Information
ShipTo	UID and the next node address and infomation	None
GetHistory	UID	Product Supply Chain History

3.2.1. Module for Create

A product instance must be created using the Create operation. A batch can include a product, in which case the batchQuantity value won't be null. In addition to accepting the product object itself, it also accepts an array of component products, which may be empty if the product is not made up of any other products. A few validation tests must be performed to ensure that the needed fields are not empty and are in an acceptable format because this operation does not return anything.

3.2.2. Module for Get

A specified product is returned by its UID after a get operation. Additionally, UID shouldn't be empty.

3.2.3 Module for ShipTo

The ShipTo action enables you to update a product's internal location by designating it as sent to a different location properties i.e., location.previous and location.current. There shouldn't be a void at the new location.

3.2.4 Module for GetHistory

A product may be retrieved together with the parent products that it is made of of using the GetHistory function. Both manufacturere and tranist roles should have access to the

"ShiptTo" function as both should be able to move a product from one place to another. All system roles, including retail employee and customer have access to the "GetProduct" and "GetProductWithHistory" services. The back end, which supplies information for the user's Web interface where they may examine product details and the supply chain, is supposed to play the latter function.

3.3. Summary

This chapter proposes a blockchain-based solution to protect the supply chain from counterfeit products. The system involves using a tamper-proof digital ledger to record the movements of products in the supply chain, which can help in tracking the origin of products and verifying their authenticity. Organizations like the retail store, manufacturers, distributors, and wholesalers could be managed using the enterprise-based blockchain Hyperledger Fabric, resulting in a trustworthy messaging channel that enables tracking of any product at any stage. The system also incorporates a physically accessed secure QR mechanism to provide consumers with a secure and seamless way of verifying the authenticity and traceability of their purchased products. The proposed system could enhance the effectiveness of existing methods for preventing counterfeit products and provide greater safety and confidence to businesses and consumers alike.

SYSTEM DESIGN & ANALYSIS

4.1 Methodology

Conventional supply chain models often suffer from incomplete information transparency and a lack of interoperability, leading to erroneous reports and difficulties in determining the real value of goods. To address these challenges, blockchain technology offers a game-changing alternative that provides a transparent, immutable, and secure decentralized system. In order to create a successful supply chain system using blockchain, several areas can be improved. These include:

1. Keeping track of every item in the supply chain.
2. Verifying and certifying the products in the chain.
3. Information about the whole network is shared amongst supply chain members.
4. Improved auditability is offered.

The development of these components is typically done using Solidity with the Hyperledger Fabric network, middleware APIs using Node, Docker, and Node.js for SDK. To illustrate the flow and the players involved in the supply chain that can use the system, Figure 4.1.1 is provided.

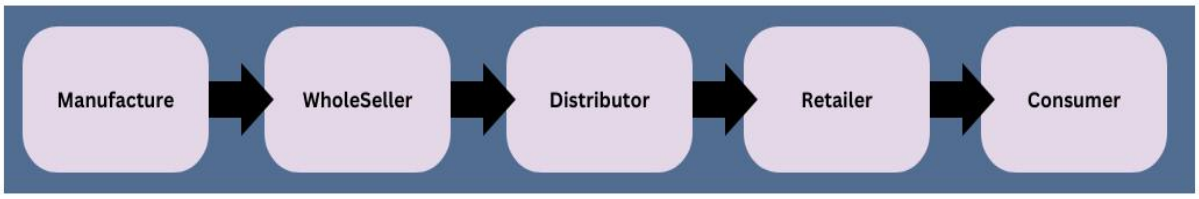

Figure 4.1.1: *Players in the Supply Chain.*

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4.2 Performance Requirements

Performance requirements of a project defines how the project should perform once it is live. In our project we have defined few performance requirements as follows:

- The system should enable a more secure API authentication as to how to store the information, thus increasing security.

- The system should be cost effective and well suited to traditional supply chain needs while protecting it from counterfeits.
- The operations should be run over the docker environment while efficiently make use of the system resources.
- The system should be reliable in case anything goes wrong.

4.3 Application Flow

The application's workflow follows a structured sequence designed to ensure efficient operation and reliable service. The steps involved in this sequence are as follows:

- User Enrolment: The first step in the process is the enrolment of users into the application. This is a vital step that makes sure that only the authorized personnel may have access to the system.
- Product Development: Once enrolled, only the manufacturer is authorized to create new products. This ensures that the product development process is centralized and that all products meet the organization's quality standards.
- Product Delivery to Wholesalers: After the products are developed, they are delivered to wholesalers. This step ensures that the products are distributed in an organized and efficient manner.
- Product Delivery to Distributors: From the wholesalers, the items are then delivered to the distributors. This step helps to ensure that the products are available at various locations, making them easily accessible to retailers.
- Product Delivery to Retailers: The retailers obtain the products from the distributors. This step ensures that the retailers can get the products they need to meet user demand.
- Order Placement: Users may place orders directly through the application. This step ensures that users have a convenient and reliable means of ordering products.
- Order Delivery: Once the goods are delivered, users can confirm receipt by marking them as "Delivered." This step provides users with a means of verifying that they have received the products they ordered.

By following this structured sequence, the application is able to deliver reliable and high-

quality service to users. The application is designed to ensure that all stakeholders involved in the process have a clear understanding of their roles and responsibilities, thereby promoting effective collaboration and minimizing errors.

The data flow for a product called "product1" with the unique identifier "1" can be visualized in Figure 4.3.1.

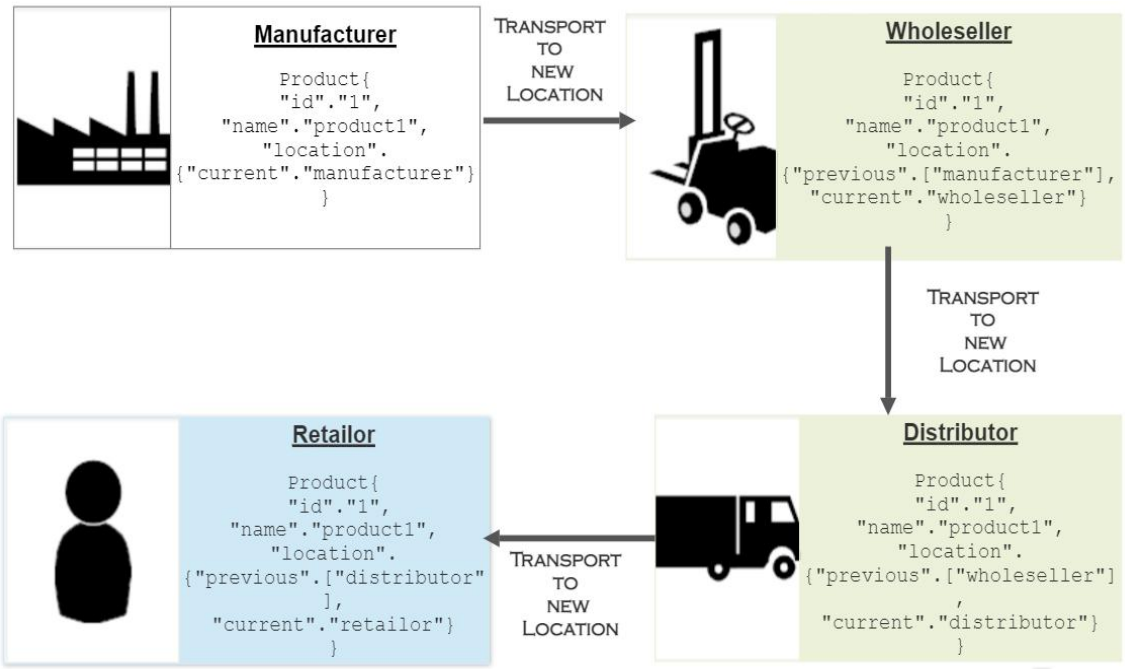


Figure 4.3.1: *Data Flow Diagram*

The flow begins at the manufacturer node and proceeds through various nodes until it reaches the retailer. The manufacturer node is responsible for creating and developing the product. Once the product is ready, it is sent to the wholesaler node, where it is organized and prepared for distribution to the distributor node. From the distributor node, the product is transported to the retailer node, where it is made available for purchase by users. Users can then place orders for the product through the application, and the order information is transmitted back through the distributor and wholesaler nodes until it reaches the manufacturer node. This flow of data ensures that all stakeholders involved in the product's lifecycle have access to the necessary information, enabling them to make informed decisions and provide efficient service. It also ensures that the product's data is properly tracked and managed, minimizing errors and promoting transparency. Overall, this data flow

is a critical aspect of the application's operation, ensuring that users have access to high-quality products and reliable service.

4.4 System Architecture

The proposed system architecture is characterized by a hierarchical structure that aims to ensure secure and efficient data flow among different organizations. Specifically, each organization is assigned its own peer node, which serves as the interface between the company and the distributed ledger network. To add transactions to the ledger, an orderer (O) node is linked to the same channel as the peer nodes, thereby allowing for the seamless integration of new transactions into the existing data flow.

Notably, the user interface for each organization is equipped with a unique user certificate that is created by the fabric-ca binaries and used to sign transactions. This feature enhances the security and authenticity of the transactions, as only authorized users with the appropriate user certificates can sign and execute transactions within the network.

The overall architecture of the system is illustrated in Figure 4.4.1, which depicts the flow of data from the producer or supplier, with more information about the product being addedand saved at each stage of the transaction. At each level of the transaction, data is appended to the existing blockchain, creating an immutable record of the transaction history.

User roles within the network are defined based on the access to chaincode functionality. Managers have full access to all functions within the network, whereas employees are restricted to limited view access only. This hierarchical access structure ensures that sensitive data and functions are accessible only to authorized personnel, enhancing the overall security and integrity of the network.

The current scope of the system is limited to two entities, namely the seller and the supplier. The network is used to log the exchanges between the two businesses in each one's own ledger, providing a secure and transparent means of tracking and verifying transactions. Future iterations of the system may incorporate additional entities, expanding the scope and potential use cases for the system.

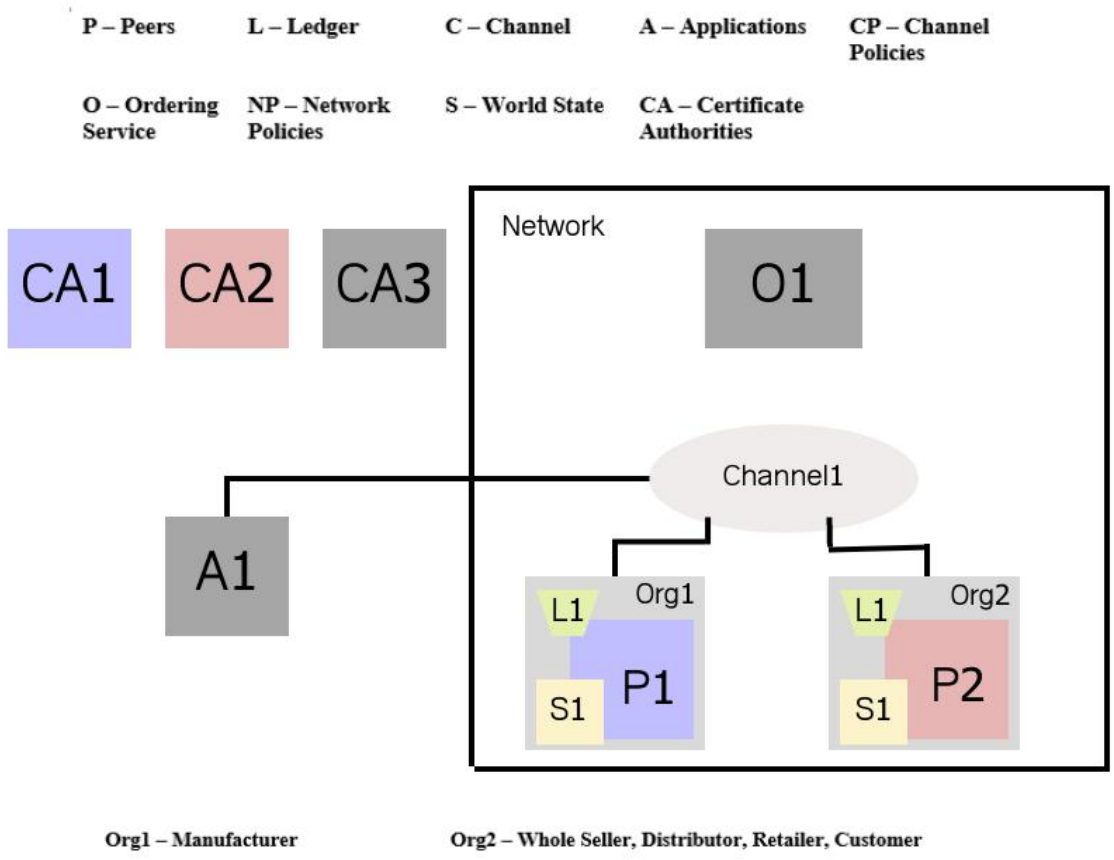


Figure 4.4.1: *System Architecture*

4.4.1. Architecture Flow

- A Docker Kubernetes Service is created by the blockchain operator.
- On a Docker Kubernetes Service, users build a Hyperledger Fabric network, and the network operator instals and instantiates the smart contract.
- The Fabric SDK is used by the Node.js application server to communicate with the deployed network on the local or cloud platform where Hyperledger is running.
- The Node.js application API is used by the React UI to communicate and send network transactions.
- To update and query the blockchain ledger and state, the user interacts with the supply chain application's web interface.

4.5 Development and Testing process

The backend of the project has been developed and testing for the above-mentioned APIs have also been carried out but creating the organizations and performing CRUD operations using the same.

4.6 Summary

This chapter discusses a proposed blockchain-based supply chain management system. The system aims to address issues of incomplete information transparency and a lack of interoperability in traditional supply chain models. The system's architecture is hierarchical, with each organization assigned its own peer node to interface with the distributed ledger network. Transactions are signed using unique user certificates to enhance security and authenticity. The application flow involves user enrollment, product development, delivery to wholesalers, distributors, and retailers, order placement, and delivery. The data flow for a product is tracked and managed at each stage, ensuring transparency and minimizing errors. The system's performance requirements include cost-effectiveness, resource efficiency, and reliability. The system components are developed using solidity with the Network - Middleware APIs using Node, Node.js for SDK, Docker and Hyperledger Fabric. The system aims to monitor all items during the run of the the supply chain, confirm as well as validate the items of the chain, exchange data among the players of the supply chain, and provide enhanced auditability.

RESULTS AND OUTPUTS

5.1 Developed Model Backend Output

The backend for the project has been developed. We have been able to achieve the goal of this project by developing the backend of the project. The developed project is shown as below.

5.1.1. Get Product API

Retrieves information about the product over the local host. In this case the local host is https://localhost:3003/getProduct/:id

Parameters used by this API are mentioned in the Table 5.1.1.1.

Table 5.1.1.1: *Get Product API parameters*

Parameters	Type
productId	string

The API code is given in the Figure 5.1.1.1.

```
app.get('/getProduct', network.connectToNetwork, async (req, res) => {
    try{
        const contract = req.contract;
        const productId = req.query.id.toString();

        const result = await contract.evaluateTransaction('getProduct', productId);
        const response = JSON.parse(result.toString());
        console.log(response);
        res.json({ result: response });
    } catch(error) {
        console.error(`Failed to evaluate transaction: ${error}`);
        res.status(500).json({
            error: error
        });
    }
});
```

Figure 5.1.1.1: *Get Product API code*

The output of the above given API snippet is given in the Figure 5.1.1.2.

```
{
    "result": {
        "barcode": "123",
        "batchQuantity": 1000,
        "category": "drugs",
        "componentProductIds": [],
        "expirationDate": "2023-06-24T18:00:400.511Z",
        "id": "1001",
        "locationData": {
            "current": {
                "arrivalDate": "2022-11-28T18:00:58.511Z",
                "location": "sharda, greater noida, delhi ncr, india"
            },
            "previous": []
        },
        "misc": "{}",
        "name": "paracetamol",
        "placeOfOrigin": "greater noida, delhi nce, india",
        "productionDate": "2021-06-24T18:25:43.511Z",
        "unitPrice": "10.00",
        "unitQuantity": 30,
        "unitQuantityType": "mg",
        "variety": null
    }
}
```


Figure 5.1.1.2: *Get Product API code output.*

5.1.2. Product Exists API

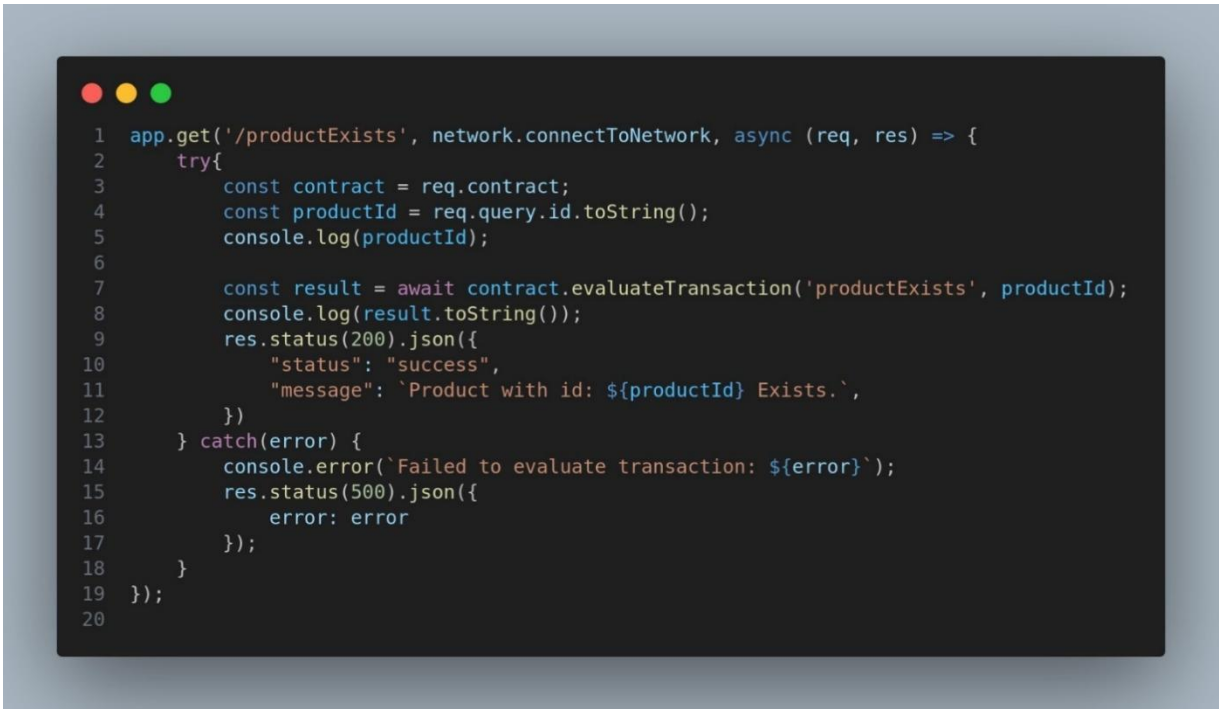
Verifies if a product exists or not over the local host. In this case the local host is http://localhost:3003/productExists/:id

Parameters used by this API are mentioned in the Table 5.1.2.1.

Table 5.1.2.1: *Product Exists API parameters*

Parameters	Type
productId	string

The API code is given in the Figure 5.1.2.1.



```
app.get('/productExists', network.connectToNetwork, async (req, res) => {
    try{
        const contract = req.contract;
        const productId = req.query.id.toString();
        console.log(productId);

        const result = await contract.evaluateTransaction('productExists', productId);
        console.log(result.toString());
        res.status(200).json({
            "status": "success",
            "message": `Product with id: ${productId} Exists.`,
        })
    } catch(error) {
        console.error(`Failed to evaluate transaction: ${error}`);
        res.status(500).json({
            error: error
        });
    }
});

```

Figure 5.1.2.1: *Product Exists API code*

The output of the above given API snippet is given in the Figure 5.1.2.2.

```
{
    "exists": "false"
}
```

Figure 5.1.2.2: Product Exists API code output

5.1.3. Create Product API

Creates a new product, over the local host. In this case the local host is https://localhost:3003/createProduct

Parameters used by this API are mentioned in the Table 5.1.3.1.

Table 5.1.3.1: *Create Product API parameters*

Parameters	Type
locationData.previous	array
locationData.current	object

Variety	string
unitQuantityType	string
unitQuantity	number
unitPrice	string
productionDate	string
placeOfOrigin	string
Name	string
Misc	object
expirationDate	string
componentProductIds	array
Category	string
batchQuantity	number
Barcode	string
productid	string

The API code is given in the Figure 5.1.3.1

```
app.post('/createProduct', network.connectToNetwork, async (req, res) => {
    try{
        const contract = req.contract;
        const productJson = JSON.stringify(req.body);

        const result = await contract.submitTransaction('createProduct', productJson);
        const response = JSON.parse(result.toString())
        console.log(result, response)
        res.status(200).json({
            "status": "success",
            "message": "Successfully Created A Product.",
            "data": productJson
        })
    } catch(error) {
        console.error(`Failed to evaluate transaction: ${error}`);
        res.status(500).json({
            error: error
        });
    }
});
```

Figure 5.1.3.1: *Create Product API code*

The output of the above given API snippet is given in the Figure 5.1.3.2.

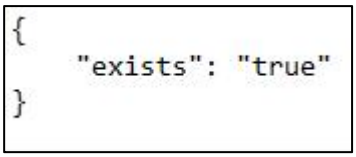


Figure 5.1.3.2: *Create Product API code output*

5.1.4. Ship To API

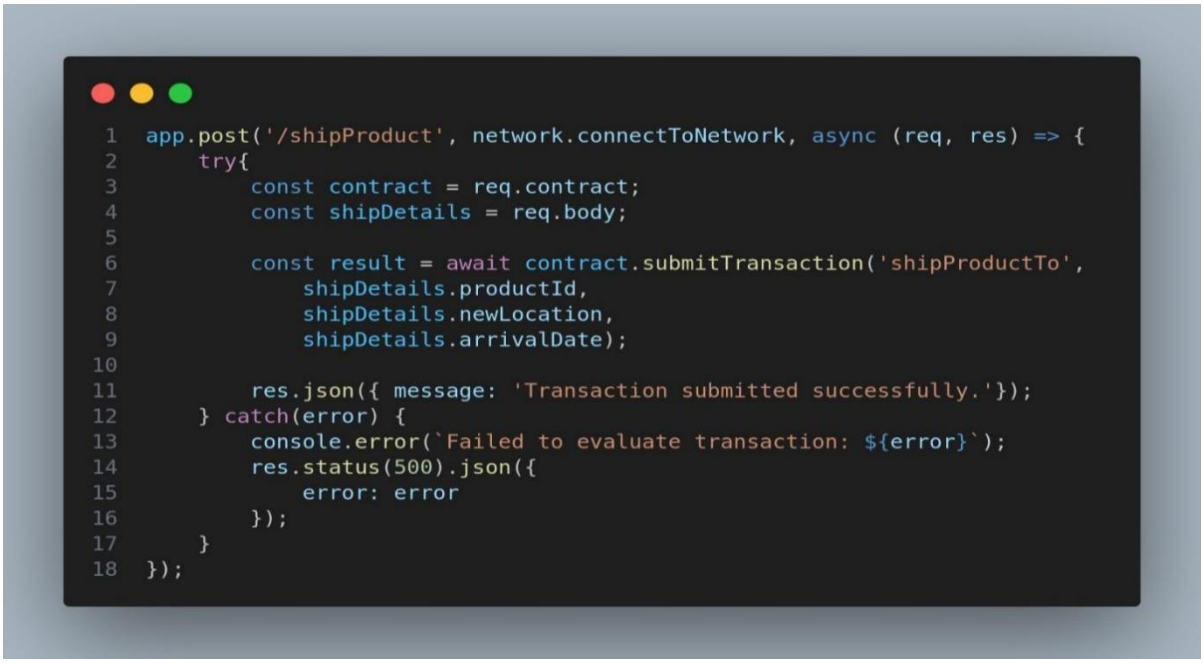
Updates the product location to the next one. In this case the local host is http://localhost:3003/shipTosts/:id

Parameters used by this API are mentioned in the Table 5.1.4.1.

Table 5.1.4.1: *ShipTo API parameters*

Parameters	Type
productid	string
newLocation	string
arrivalDate	String

The API code is given in the Figure 5.1.4.1.



```
app.post('/shipProduct', network.connectToNetwork, async (req, res) => {
    try{
        const contract = req.contract;
        const shipDetails = req.body;

        const result = await contract.submitTransaction('shipProductTo',
            shipDetails.productId,
            shipDetails.newLocation,
            shipDetails.arrivalDate);

        res.json({ message: 'Transaction submitted successfully.'});
    } catch(error) {
        console.error(`Failed to evaluate transaction: ${error}`);
        res.status(500).json({
            error: error
        });
    }
});
```

Figure 5.1.4.1: *ShipTo API code*

The output of the above given API snippet is given in the figure 5.1.4.2.

```
{
    "status": "Transaction submitted.",
    "txId": ""
}
```

Figure 5.1.4.2: ShipTo API code output

5.1.5. Get Product with History API

Retrieves information about the product over the local host. In this case the local host is https://localhost:3003/getProductWIthHistory/:id

Parameters used by this API are mentioned in the Table 5.1.5.1 below.

Table 5.1.5.1: *Get Product with History API parameters*

Parameters	Type
productId	string

The API code is given in the Figure 5.1.5.1.

```
app.get('/getProductWithHistory', network.connectToNetwork, async (req, res) => {
    try{
        const contract = req.contract;
        const productId = req.query.id.toString();

        const result = await contract.evaluateTransaction('getProduct', productId);
        const response = JSON.parse(result.toString());
        console.log(response);
        res.status(200).json({
            "status": "success",
            "message": "Successfully fetched product history",
            "data": response.locationData
          })
    } catch(error) {
        console.error(`Failed to evaluate transaction: ${error}`);
        res.status(500).json({
            error: error
        });
    }
});
```

Figure 5.1.5.1: *Get Product with History API code*

The output of the above given API snippet is given in the Figure 5.1.5.2.


```
{
    "result": {
        "barcode": "1234567890",
        "batchQuantity": 1000,
        "category": "Fruits",
        "componentProductIds": [],
        "expirationDate": "2022-06-24T18:25:43.511Z",
        "id": "1001",
        "locationData": {
            "current": {
                "arrivalDate": "2021-07-07T01:11:18.409Z",
                "location": "Waterloo, ON"
            },
            "previous": [
                {
                    "arrivalDate": "2021-06-30T18:00:58.511Z",
                    "location": "Markham Farm, Marham, ON, Canada"
                }
            ]
        },
        "misc": "{}",
        "name": "Apples",
        "placeOfOrigin": "Markham, ON, Canada",
        "productionDate": "2021-06-24T18:25:43.511Z",
        "unitPrice": "$5.00",
        "unitQuantity": 300,
        "unitQuantityType": "mg",
        "variety": null,
        "componentProducts": []
    }
}
```


Figure 5.1.5.2: *Get Product with History API code output*

5.1.6. Location Model

This is the model for recording the previous and current location.

The code for the Location Model is given in the figure 5.1.6.1.

```
import { Object as FabricObject, Property } from 'fabric-contract-api';
import { ProductLocationEntry } from './product-location-entry';

@FabricObject()
export class ProductLocationData {
    @Property('previous', 'Array<ProductLocationEntry>')
    previous: ProductLocationEntry[];

    @Property()
    current: ProductLocationEntry;
}
```

Figure 5.1.6.1: *Location Model code*

5.2 Proposed UI Screens

As part of an additional outcome of our project, we have also started the development of the mobile application "Hyper Supply," which aims to provide a user-friendly and interactive interface to supply chain players in Org2. The application targets wholesalers, distributors, retailers, and consumers as end-node points in the supply chain. "Hyper Supply" offers an easy-to-use interface for requesting data from the backend APIs, thus improving transparency, accountability, and efficiency in the supply chain, leading to increased customer satisfaction.

As of now we have built the UI screens using whimsical for the application comprises six screens, including a login screen. After the user logs in, the app prompts them to scan a QR code to obtain more information about the product. The app then verifies the availability of the product in the supply chain by hitting the productExistsAPI. Next, the user is directed to a product options page displaying the name of the scanned product. The product options include the Details Screen, displaying product details, the Location Screen showing the current location of the product, and the History Screen, displaying node-by-node supply chain history of the product by hitting the getProductWithHistory API. The Ship Screen is used to ship the product to a new location, hitting the shipTo API. Finally, the Scan Screen takes the user back to the scan QR screen.

The "Hyper Supply" application interface has been designed to enhance user experience and

facilitate access to critical information about products. We believe this application will contribute to increased transparency, accountability, and efficiency in the supply chain, ultimately leading to improved customer satisfaction. Please refer to Figure 5.2.1 for the screenshots of the different screens available in the application for a product named "Apple Jam."

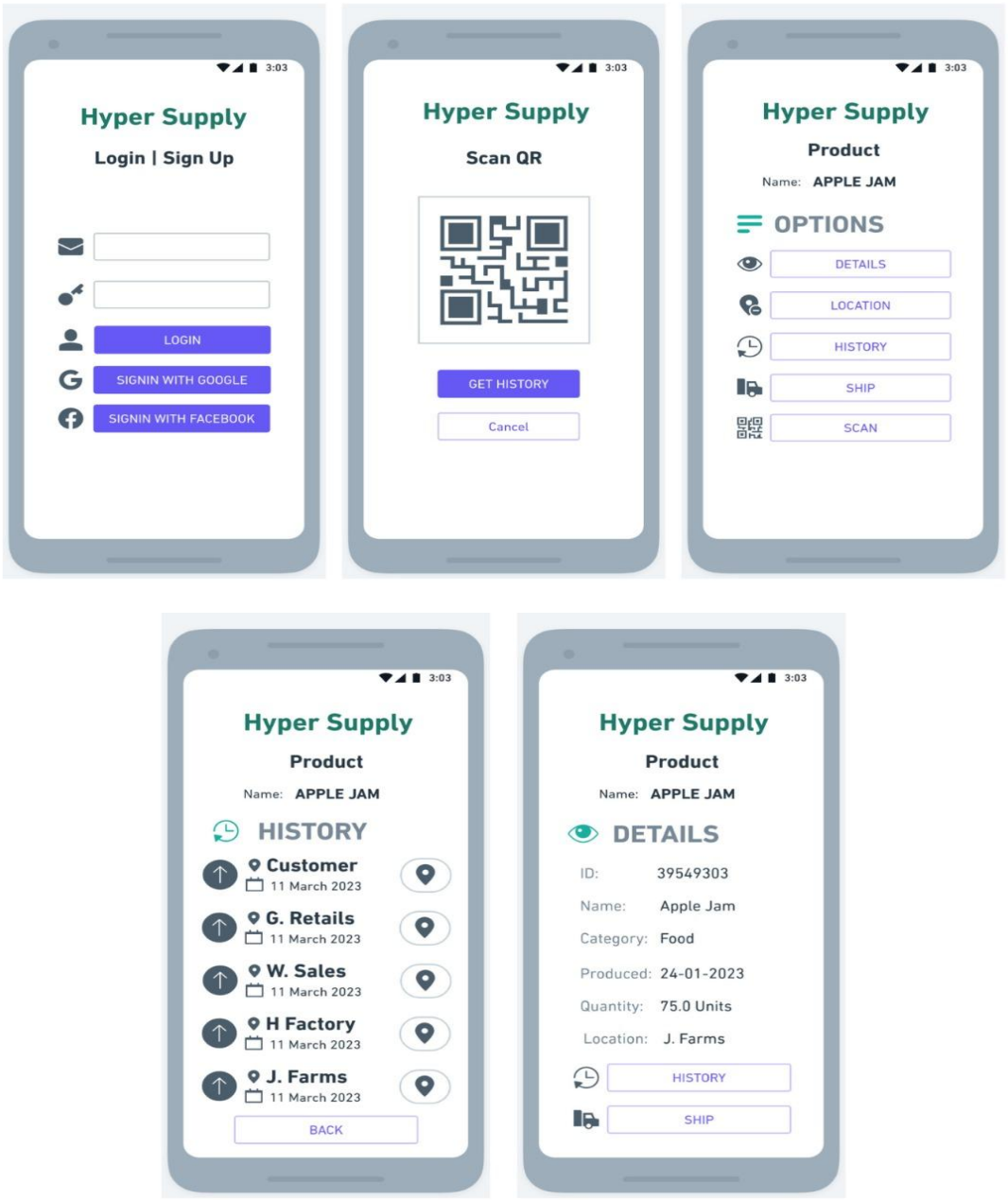


Figure 5.2.1: *Mobile App Screens*

5.3 Summary

In this chapter, the backend for a supply chain management system has been developed, including APIs for retrieving product information, verifying product existence, creating new products, updating product locations, and retrieving product history. Additionally, a mobile application called "Hyper Supply" has been designed to provide a user-friendly and interactive interface for supply chain players. The application includes six screens, including a login screen, product options screen, details screen, location screen, history screen, ship screen, and scan screen. The "Hyper Supply" application is aimed at improving transparency, accountability, and efficiency in the supply chain, leading to increased customer satisfaction.

CONCLUSION

6.1 Conclusion

A thorough analysis of the current technologies for supply chain anti-counterfeit protection has shown that blockchain-based solutions have several benefits over conventional ones. One such benefit is the usage of REST APIs, which enable the user interface of the application to communicate with the blockchain network powered by Hyperledger. This makes it possible to track items securely and openly along the supply chain, ensuring that all parties have access to the most recent and accurate data.

Additionally, the system can support ownership transfers automatically whenever certain conditions are satisfied thanks to the usage of smart contracts. This represents a substantial advancement over earlier techniques, which were sometimes prone to mistakes and delays. The transfer of ownership is rapid and safe with a supply chain management system built on a blockchain, making the process more dependable and efficient. Because it enables stakeholders to trace a product's origin and progress through the supply chain, the traceability afforded by blockchain technology also adds an extra degree of security to the supply chain. This is crucial for goods that are vulnerable to fraud or counterfeiting. A blockchain-based supply chain management system can increase efficiency and transparency in supply chain operations in addition to enhancing security. Stakeholders can optimise their operations and choose wisely when it comes to inventory management and distribution by receiving real-time information about the flow of items through the supply chain.

In conclusion, the adoption of a supply chain management system built on blockchain technology has the potential to completely alter how we organise and safeguard our supply chains. A more dependable and trustworthy supply chain will result from the advantages of greater security, efficiency, and transparency for both enterprises and consumers.

6.2 Future Scope

While a blockchain-based supply chain management system offers numerous advantages, there are also areas for future improvement and expansion. One such area is the development of a user-friendly user interface (UI) for Rest API. A well-designed UI can enhance the accessibility and usability of the system, making it easier for stakeholders to interact with and utilize the system effectively.

Another area for improvement is scalability. As the volume of transactions and data increases, the scalability of the blockchain-based supply chain management system must be improved to ensure efficient and effective management of the supply chain. This may require the adoption of new technologies or the use of innovative approaches to handle large volumes of data and transactions.

Privacy and security are also critical areas that must be addressed to ensure the success of a blockchain-based supply chain management system. Advanced encryption and access control measures can be implemented to protect sensitive data and prevent privacy and security breaches. This is particularly important for products that are subject to counterfeiting or fraud.

To address the issue of physical tampering of products, a solution based on a QR code protected by a scratchable film could be implemented. This would allow stakeholders to authenticate products and identify any incidents of tampering.

A blockchain-based system could be further developed to encompass ownership rights and sale/purchase records of various industries, like real estate and automobiles. By doing so, stakeholders within these sectors could enjoy the perks of enhanced security, transparency, and efficiency that such a system provides.

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ANNEXURE I

I1. 7th Semester Outcome

Conference: Accepted/ Presented/ Published

M. A. Muzafar, A. Bhargav, A. Jha and P. Nand, "Counterfeit Protection In Supplychain Using Blockchain: A Review," 2023 International Conference for Advancement in Technology (ICONAT), Goa, India, 2023, pp. 1-6, doi: 10.1109/ICONAT57137.2023.10080465.

Abstract: Supply chain is a network to connect participants across the supply through a permissioned, permanent and shared record of food system data. In this paper, we provide a review on blockchain based solutions that solve the tracking and tracing of products in the supply chain so that any product can be traced back to its root. Building a product tracking system is an effective way to solve the counterfeit issues. A proposed method of implementing Hyperledger in the anti-counterfeit protection of supply chain using blockchain is also suggested.

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2023 International Conference for Advancement in Technology (ICONAT)
Goa, India. Jan 24-26, 2023

Counterfeit Protection In Supplychain Using Blockchain: A Review

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Abstract— **Supply chain is a network to connect participants across the supply through a permissioned, permanent and shared record of food system data. In this paper, we provide a review on blockchain based solutions that solve the tracking and tracing of products in the supply chain so that any product can be traced back to its root. Building a product tracking system is an effective way to solve the counterfeit issues. A proposed method of implementing Hyperledger in the anti-counterfeit protection of supply chain using blockchain is also suggested.**

***Keywords*— Supply Chain, Blockchain, Hyperledger, Counterfeit, API etc.**

I. Introduction

Bitcoin is the first use of the Blockchain in the real world. Public transaction ledger, decentralized transaction verification and peer-to-peer network, and fixed currency circulation are all features it contains. New technologies across the supply chain are offering promising opportunities for improvement.[1] In addition to boosting supply chain transparency and traceability, blockchain technology offers the potential to reduce administrative costs. Participants may improve supply chain management by integrating blockchain technology by tracking data such as quality, date, certification, location, price and other important specifics. An organization's reputation as a leader in ethical manufacturing may be strengthened by having this data within blockchain, which could enhance compliance along with visibility over outsourced contract making, increase material supply chain traceability, reduce losses from grey market and counterfeit product sales, and increase traceability of the material supply chain. In a study, over 90% of consumers cited transparency in food products as a significant deciding factor and expected manufacturers to provide the necessary information. Consumers would allegedly pay at least 55% more for goods and services from companies that encourage social responsibility. [2] The transparency of blockchain technology may help reduce fraud for pricey goods like medications and diamonds. The Organization for Economic Cooperation and Development estimates that counterfeit goods contribute to about $450 billion in annual commerce. [3] Additionally, it is believed that 10 to 30 percent of the medication provided in developing countries is fake, resulting in huge numbers of fatalities and billions of lost revenues globally. [4] The technology may help firms better understand how the raw and manufactured goods are moved via each member of the chain, as well as reduce gain losses due to the grey market and counterfeit commerce and increase consumer confidence.

These days, the market is flooded with fake goods, so there is no way to know if the water bottle on our tables is authentic. A current technique, such as an RFID-based approach, would simply be too expensive to be used on low-cost goods. There are also mechanisms in place on the market where a product has a unique identifier attached to it or imprinted on it. To check the product's authenticity, the user would send the uid to the manufacturer for confirmation, but in those situations as well, gaming the system would be as easy as cloning the uid on the counterfeit product. We suggest adopting a blockchain-based anti-counterfeit method to address this issue. The technique would also aid in product tracking and traceability. This procedure applies to any tangible goods on the market that the producer has linked to a UID. A QR code would be created from this UID and adhered to the goods or printed on it. A film that can be scratched would conceal this QR code, which could then be exposed to the user for validation. By scanning the QR code, the consumer will be able to verify the product's authenticity and have access to its supply chain history. Additionally, it would undermine its originality and indicate that the product was intended for consumer purchase. This would make it impossible for any intermediaries or agents of counterfeiting to steal or copy the product's uid or QR code. By displaying data that has been blockchain-verified, the public's confidence in the government can rise. The goal is to expose REST APIs that allow user interface of the application with the layer of hyperledger blockchain network.

Transparency can help give the construction and quality testing more weight by allowing parties and other supply chain partners to share information. In order to adopt blockchain solutions, all stakeholders engaged in the chain must collaborate, which may be viewed as an opportunity to create more cooperative ecosystems and remap stakeholder interactions.

II. Literature Review

A. Background

Blockchain is a decentralised system, referring to a technology solution that maintains a failproof and continuous record file as a database using decentralisation. This system was formerly primarily put in place with Bitcoin [5]. The process of adding new blocks to the blockchain entails

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• Manufacturer
- Product{"id", "1", "name", "product1", "location", {"current","manufacturer"}}
Transport to new location
• Wholeseller
- Product{"id", "1", "name", "product1", "location", {"previous","manufacturer"}, "current","wholeseller"}}
Transport to new location
• Distributor
- Product{"id", "1", "name", "product1", "location", {"previous","wholeseller"}, "current","distributor"}}
Transport to new location
• Retailor
- Product{"id", "1", "name", "product1", "location", {"previous","distributor"}, "current","retailor"}}

Fig. 3. Data Flow Diagram.

V. Conclusion and Future Scope

A systematic review of previous done work on the said topic was conducted along with a questioner-based survey and a proposed method of implementing Hyperledger in the anti-counterfeit protection of supply chain using blockchain is suggested. The main aim is to expose REST APIs that allow user interface of the application with the layer of Hyperledger blockchain network.

We will build a mobile/web-based user interface so that the general user may be able to visually interact with the system, as the system as of now is designed to work using the Rest API only. To tackle the physical tampering of products a physical scratchable film QR based solution could also be implemented. Moreover, we plan incorporate the system to handle the ownership rights and sell/purchase records of other areas like real estate and automobiles.

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Figure I1.1: *Conference Paper*

I2. Conference Paper Published

The conference paper was presented by Mohammad Adnan Muzafar (2019001743) on 26th January 2023 in online mode. Figure I2.1 shows the screenshot of IEEE Xplore.

Date Added to IEEE Xplore: 03 April 2023

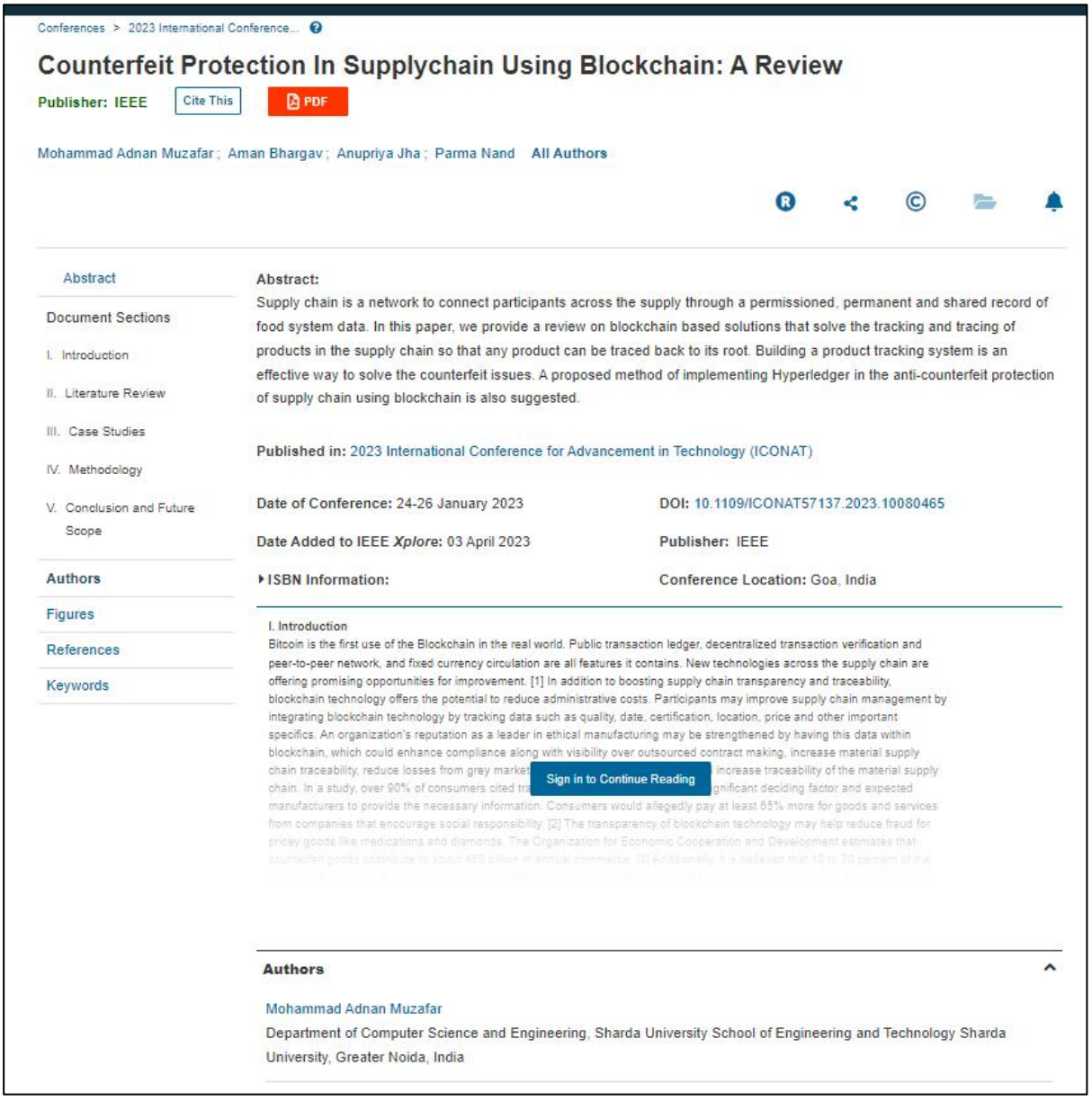

Figure I2.1: *ICONAT Conference Published Screenshot*

I3. 8th Semester Outcome

Journal: Submitted/Communicated

Submitted To: International Journal of Performability Engineering

Title: Securing the Supply Chain: A Comprehensive Solution with Blockchain Technology and QR-Based Anti-Counterfeit Mechanism

Journal URL: http://www.ijpe-online.com/

Securing the Supply Chain: A Comprehensive Solution with Blockchain Technology and QR-Based Anti-Counterfeit Mechanism

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Abstract— *Counterfeit protection is a serious concern for businesses, as it can compromise consumer safety and damage a company's reputation. To address this issue, researchers have conducted a review of available technologies and found that blockchain-based solutions offer several advantages over traditional methods. The use of REST APIs enables secure and transparent tracking of products through the supply chain, while smart contracts facilitate automatic ownership transfers. The traceability provided by blockchain technology allows stakeholders to track a product's origin and journey, improving security and transparency. Implementing a blockchain-based supply chain management system can also improve efficiency and reduce costs associated with lost or misplaced items. This research paper advocates for businesses to invest in advanced technologies like blockchain to protect their supply chains and ensure the safety and authenticity of their products. The system described in the paper involves generating unique identification numbers (UIDs) and associating them with products during the manufacturing process, with QR codes and scratchable film for consumer access. While also emphasizing the need for businesses to adopt innovative technologies to stay competitive and maintain customer trust.*

Keywords— *Blockchain, supply chain, counterfeit protection, REST API, QR, Hyperledger, traceability etc.*

I. INTRODUCTION

Counterfeiting is a significant and growing problem in supply chains worldwide. According to a report by the International Chamber of Commerce, the value of global counterfeiting is expected to reach $4.2 trillion by 2022 [1]. Counterfeit products are prevalent in various industries, including luxury goods, pharmaceuticals, electronics, and even food products. They can be difficult to identify, and they pose severe risks to public health, safety, and the environment. Counterfeiting can also damage the reputation of legitimate businesses, harm consumers, and cause significant economic losses [2]. To combat counterfeiting, there has been a growing interest in using blockchain technology in supply chains. Blockchain is a distributed ledger technology that enables secure and transparent record-keeping. Blockchain technology's inherent resistance to tampering provides a reliable way to authenticate products and trace their origin and journey through the supply chain. By using blockchain, businesses can track products from their source to their final destination, creating an immutable record of every transaction along the way [3]. Moreover, blockchain technology can help mitigate supply chain risks by reducing the reliance on intermediaries, enhancing transparency and accountability, and enabling real-time tracking of goods. Blockchain technology can also facilitate trust between supply chain partners by providing a shared, tamper-proof record of transactions, reducing the potential for fraud and errors [4][5]. Blockchain technology offers the potential to enhance supply chain resilience by providing a secure and transparent way to track products through the supply chain. Despite its potential benefits, the use of blockchain in supply chains is still in its early stages and faces several challenges [6][7]. These include interoperability issues, regulatory uncertainty, and the need for significant investment in technology infrastructure and talent. However, with the increasing prevalence of counterfeiting and the growing demand for transparency and accountability in supply chains, blockchain technology presents a promising solution for protecting supply chains against counterfeiting [8]. Blockchain technology allows for the use of smart contracts to facilitate automatic ownership transfers once certain conditions are met, resulting in a more efficient and reliable process. Moreover, the traceability offered by blockchain technology provides an added layer of security to the supply chain by allowing stakeholders to track the product's origin and journey [9]. By using blockchain-based solutions, companies can ensure that all stakeholders have access to accurate and up-to-date information, thereby minimizing the risks of counterfeiting and other fraudulent activities. In addition to the security benefits, the use of blockchain technology can also result in cost savings and increased efficiency in supply chain management by automating several processes, such as inventory tracking and product authentication [10].

This paper examines the issue of counterfeit protection in the supply chain and how blockchain technology can be used to combat this problem. It provides an overview of the history of counterfeiting and its impact on supply chains, as well as the current methods used to address it [11]. Blockchain technology provides a secure and transparent method of tracking products through the supply chain, minimizing the risks of counterfeiting and fraudulent activities [9][12]. It also offers cost savings and increased efficiency in supply chain management [13]. However, there are challenges associated with implementing blockchain solutions, such as interoperability issues, regulatory uncertainty, and the need for significant investment in technology infrastructure and talent [14]. This paper proposes a solution for using blockchain technology to protect supply chains from counterfeiting. The solution involves creating a decentralized network where all stakeholders in the supply chain can access and verify product information, ensuring transparency and accountability. By adopting this solution, companies can enhance their overall resilience and protect their brand reputation while improving collaboration between partners.

Figure I3.1: Conference Paper

I4. Journal Paper Submitted

The journal paper was submitted on 11th April 2023 on the official IJPE website.

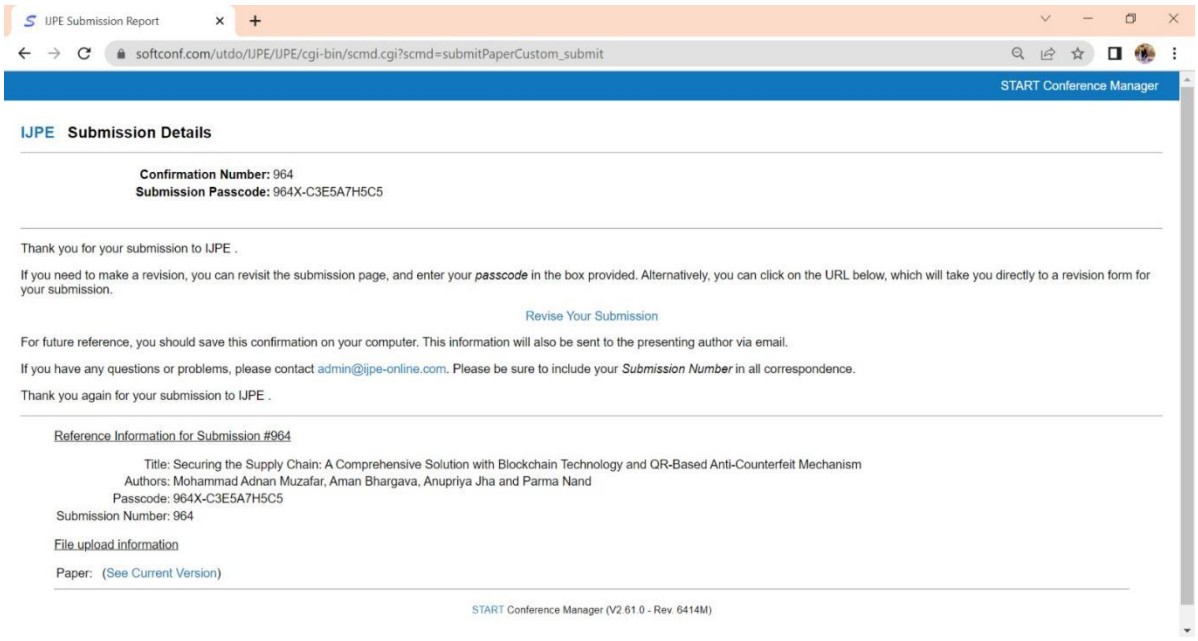
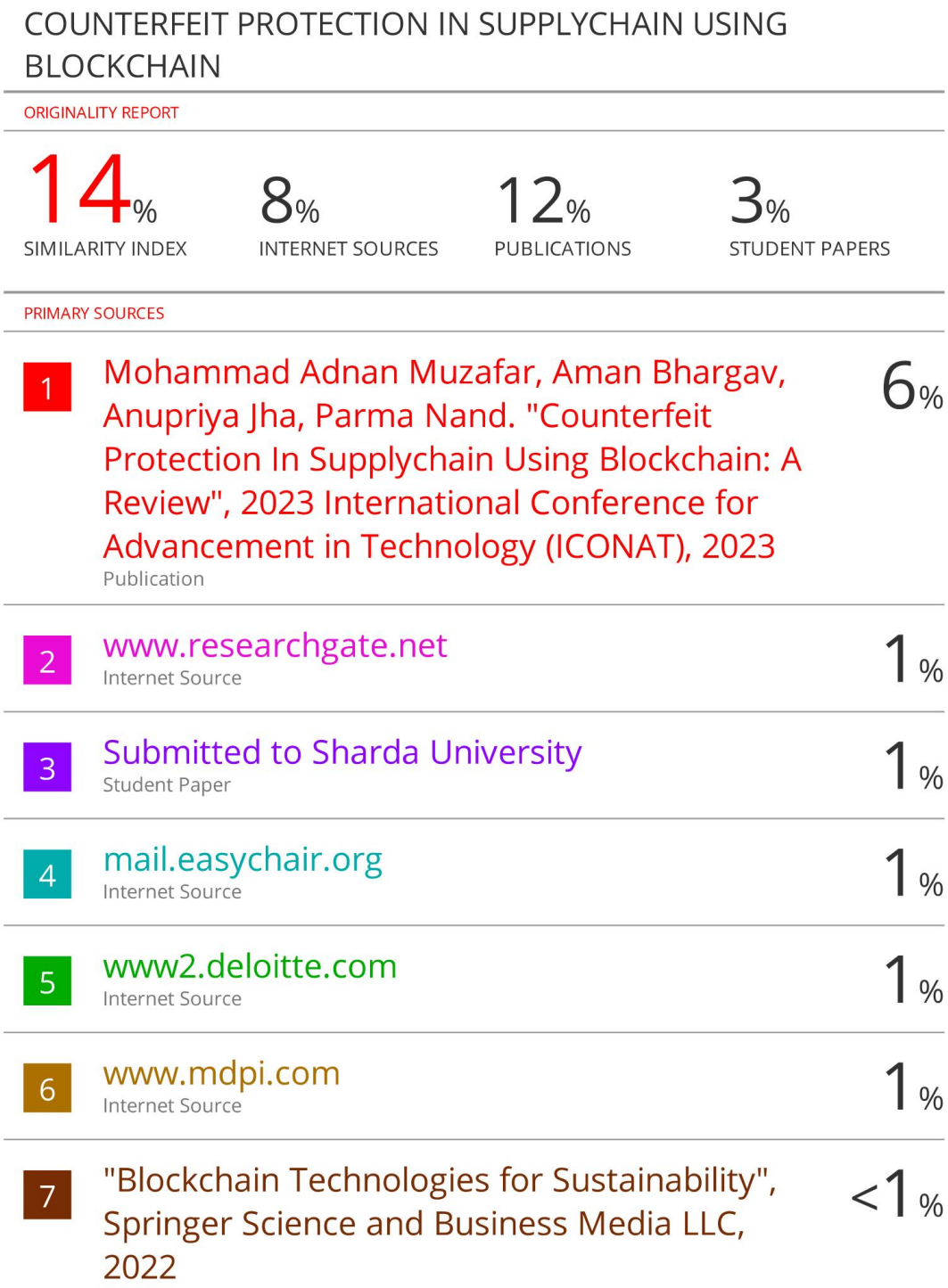


Figure I4.1. Journal Paper Submission Proof Screenshot

ANNEXURE II



COUNTERFEIT PROTECTION IN SUPPLYCHAIN USING BLOCKCHAIN

ORIGINALITY REPORT

14%	8%	12%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Mohammad Adnan Muzafar, Aman Bhargav, Anupriya Jha, Parma Nand. "Counterfeit Protection In Supplychain Using Blockchain: A Review", 2023 International Conference for Advancement in Technology (ICONAT), 2023 Publication	6%
2	www.researchgate.net Internet Source	1%
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6	www.mdpi.com Internet Source	1%
7	"Blockchain Technologies for Sustainability", Springer Science and Business Media LLC, 2022	<1%

Figure 1.1: *Plagiarism Report*