

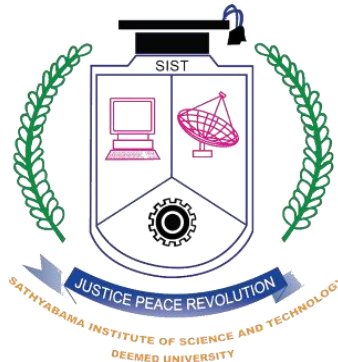
Blockchain-Enabled Supply Chain Management for Authenticating Products Using QR/Barcode

Submitted in partial fulfillment of the requirements for the award of a Bachelor of
Engineering degree in Computer Science and Engineering

By

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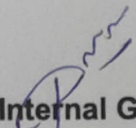
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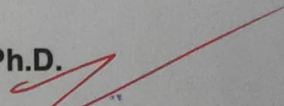
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BONAFIDE CERTIFICATE

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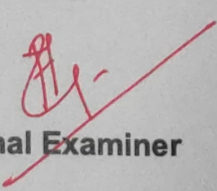

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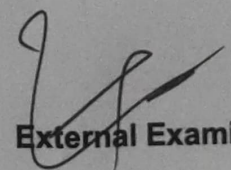
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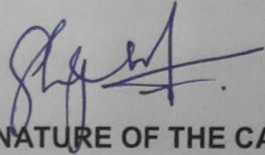

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DECLARATION

I Sanjay Krishna S R (40111134) hereby declare that the Project Report entitled "Blockchain-Enabled Supply Chain Management for Authenticating Products Using QR/Barcode" done by me under the guidance of Dr. T. Prem Jacob., M.E., Ph.D. is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in **Computer Science and Engineering**.

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ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to the **Board of Management of Sathyabama Institute of Science and Technology** for their encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my thanks to **Dr. T.Sasikala., M.E., Ph.D. Dean, School of Computing,** and **Dr. L. Lakshmanan., M.E., Ph.D. Head of the Department of Computer Science and Engineering** for providing me with necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Dr. T. Prem Jacob., M.E., Ph.D.** for his valuable guidance, suggestions and constant encouragement that paved the way for the successful completion of my project work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the **Department of Computer Science and Engineering** who were helpful in many ways for the completion of the project.

ABSTRACT

This project aims to combat the threat of counterfeit products in the global marketplace by leveraging blockchain technology. It creates a secure and transparent supply chain management system with smart contracts, QR code integration, and a user-centric approach. Manufacturers add products to the blockchain and generate QR codes for authentication. Sellers sell products, and customers verify authenticity through QR codes. A user reward system encourages participation, and the project collaborates with international organizations to strengthen counterfeit prevention. Warranty verification is also integrated to prevent fraudulent warranty claims. In summary, this project addresses counterfeiting, fosters trust in products and enhances modern commerce through innovative technologies and global collaboration. Furthermore, the project's use of blockchain technology ensures data immutability and transparency, making it extremely difficult for malicious actors to manipulate records. This creates a decentralized ledger that maintains an unalterable record of product provenance, transactions, and authenticity, which not only restores trust but also safeguards against financial losses, potential health risks, and damage to brand reputation. By embracing emerging technologies and fostering global collaboration, this pioneering effort strives to fortify the foundations of modern commerce, protecting consumers and enhancing the integrity of supply chains on a global scale. Moreover, the project's utilization of blockchain technology ensures real-time traceability, enabling stakeholders to track the movement of products at every stage of the supply chain. Through the implementation of smart contracts, the system automates processes, reducing human error and enhancing efficiency. By integrating QR code authentication, the project empowers consumers to make informed purchasing decisions, fostering a culture of transparency and accountability. Ultimately, this innovative solution sets a new standard for supply chain management, paving the way for a more secure, transparent, and trustworthy global marketplace.

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LIST OF ABBREVIATIONS

ABBREVIATION	EXPANSION
QR	Quick Response
RFID	Radio Frequency Identification
SRS	Software Requirement Specification
SQL	Structured Query Language
JS	JavaScript
API	Application Programming Interface
IOT	Internet of Things

CHAPTER 1

INTRODUCTION

1.1 COUNTERFEITING IN THE GLOBAL MARKETPLACE

In today's hyper-connected global marketplace, the exchange of goods and services has reached unprecedented levels. Yet, this incredible growth in commerce has brought with it a sinister underbelly: the proliferation of counterfeit products. These deceptive imitations not only endanger the health and safety of consumers but also cast a long shadow over the reputation and integrity of manufacturers and suppliers worldwide. The consequences of counterfeiting are far-reaching, encompassing financial losses, erosion of brand trust, regulatory liabilities, and even risks to national security. Counterfeit products are not a novel phenomenon; they have plagued industries for centuries.

The advent of modern technology and the ever-expanding reach of the internet, the production, distribution, and sale of counterfeit goods have surged to unprecedented levels. No longer confined to luxury fashion or electronics, counterfeit products span a broad spectrum, encompassing pharmaceuticals, automotive parts, food, and everyday consumer goods. The battle against counterfeit products is not only a matter of economic concern but one of profound moral and ethical importance. Every fraudulent product that makes its way into the hands of unsuspecting consumers carries the potential for harm. Whether it's a counterfeit pharmaceutical with incorrect ingredients, an imitation car part that fails during operation, or counterfeit baby formula with contaminated contents, the risks are real and terrifying.

1.2 LIMITATIONS OF COUNTERFEIT PREVENTION METHODS

Manufacturers and legitimate businesses are not the only victims of counterfeiting. Consumers pay a steep price, both financially and in terms of personal safety. Moreover, governments and regulatory bodies expend significant resources combating counterfeiting and enforcing intellectual property laws, which could be better spent addressing other critical societal issues. Traditional methods of combating counterfeits, while important, have proven to be insufficient in today's rapidly evolving

marketplace. It is within this backdrop that our project emerges, offering a comprehensive, innovative, and technologically advanced solution to this age-old problem. Our project proposes a holistic approach to combating counterfeiting by seamlessly integrating two powerful technologies: blockchain and QR/barcode systems. This marriage of technologies forms the bedrock of a supply chain management system that not only guarantees product authenticity but also ensures supply chain transparency. At the heart of this solution is the groundbreaking use of blockchain technology. Blockchain, most renowned as the technology underpinning cryptocurrencies like Bitcoin, is a decentralized, immutable ledger system. It offers unprecedented security, transparency, and trust in an era where trust is often eroded (Fig:1.1). Each product is uniquely identified and its journey from the manufacturer to the consumer is recorded securely on the blockchain. This record becomes immutable and resistant to tampering or alteration by malicious actors. It forms an indelible digital certificate of authenticity, accessible to anyone with a QR code scanner.



Fig:1.1 Blockchain in Supply Chain

The integration of QR (Quick Response) and barcode systems further fortifies the project's mission to eradicate counterfeits. QR and barcode technology has been a

staple in the world of commerce for decades, primarily used for tracking and inventory management. However, our project elevates its utility to new heights. Each product, upon leaving the manufacturer, is assigned a unique QR code or barcode.

1.3 INTRODUCTION TO BLOCKCHAIN

Blockchain technology has emerged as a revolutionary concept with the potential to transform various industries, ranging from finance and healthcare to supply chain management and beyond. At its core, blockchain is a distributed ledger technology that enables the secure and transparent recording of transactions across a network of computers, known as nodes. Unlike traditional centralized databases, blockchain operates on a decentralized network, where each participant maintains a copy of the ledger, ensuring redundancy and immutability.

The concept of blockchain was introduced in 2008 by an unknown person or group of people under the pseudonym Satoshi Nakamoto, as the underlying technology behind the digital cryptocurrency Bitcoin. Since then, blockchain has evolved beyond its cryptocurrency origins to become a versatile tool with applications across diverse domains. One of the key features of blockchain technology is its ability to provide transparency and accountability through a tamper-resistant and auditable record of transactions. Each transaction, or block, is cryptographically linked to the previous block, forming a chain of blocks that cannot be altered retroactively without the consensus of the network participants. This inherent immutability ensures the integrity of the data stored on the blockchain. Blockchain-based systems are characterized by their decentralized nature, which eliminates the need for intermediaries and central authorities, thereby reducing costs, enhancing security, and increasing efficiency. Through the use of smart contracts, self-executing contracts with the terms of the agreement directly written into code, blockchain-based systems can automate and streamline processes, facilitating trust less transactions between parties.

In recent years, blockchain technology has gained widespread attention and adoption across various industries, driven by its potential to revolutionize existing business models and processes. From supply chain management and digital identity

verification to voting systems and intellectual property rights management, blockchain-based systems offer innovative solutions to complex challenges.

However, despite its promise, blockchain technology also presents challenges, including scalability issues, regulatory concerns, and interoperability limitations. Addressing these challenges requires ongoing research, collaboration, and innovation to unlock the full potential of blockchain technology and harness its benefits for society. In conclusion, blockchain-based systems represent a paradigm shift in how data is stored, shared, and transacted in the digital age. With its decentralized, transparent, and secure nature, blockchain has the potential to drive profound changes across industries, ushering in a new era of trust, transparency, and innovation.

1.4 BLOCKCHAIN IN COUNTERFEIT PREVENTION

Blockchain technology has emerged as a powerful tool in the fight against counterfeit products, offering innovative solutions to address the growing threat of illicit trade and fraudulent goods. By leveraging the inherent features of blockchain, such as transparency, immutability, and decentralization, organizations can establish robust systems for verifying product authenticity, tracking supply chain provenance, and protecting consumer rights. One of the key advantages of blockchain in counterfeit prevention is its ability to create an immutable record of product transactions and ownership. Each product can be assigned a unique digital identity, stored as a digital token on the blockchain. This digital identity contains essential information about the product, including its origin, manufacturing process, and distribution history. By scanning a product's QR code or RFID tag, consumers can access this information and verify its authenticity in real-time, reducing the risk of purchasing counterfeit goods.

Furthermore, blockchain enables transparent and traceable supply chains, allowing stakeholders to track the movement of products from the manufacturer to the end consumer. Every transaction recorded on the blockchain is cryptographically secured and time-stamped, providing an auditable trail of the product's journey through the supply chain. This transparency not only enhances trust between supply chain partners but also enables swift identification of counterfeit products and the source of illicit trade.

Smart contracts, self-executing contracts with predefined conditions written in code, can also play a crucial role in counterfeit prevention. By automating key processes, such as product authentication, payment settlement, and warranty verification, smart contracts reduce the reliance on intermediaries and minimize the risk of human error or manipulation. For example, smart contracts can trigger alerts when a counterfeit product is detected, initiate product recalls, or enforce warranty terms based on predefined conditions. In addition to product authentication and supply chain tracking, blockchain technology can also facilitate collaboration between stakeholders in the fight against counterfeit products. By establishing decentralized networks and consortiums, industry players can share information, best practices, and intelligence data in real-time, enabling proactive measures to combat counterfeiting and protect consumer safety.

Despite its potential, the widespread adoption of blockchain in counterfeit prevention faces several challenges, including scalability issues, regulatory barriers, and interoperability concerns. Moreover, educating consumers and incentivizing stakeholders to embrace blockchain-based solutions require concerted efforts and investment. However, with ongoing research, collaboration, and technological advancements, blockchain has the potential to revolutionize counterfeit prevention efforts and safeguard consumer trust in the global marketplace.

1.5 USAGE OF BLOCKCHAIN SYSTEMS

Blockchain technology, initially developed to support cryptocurrencies like Bitcoin, has transcended its original purpose and is now being widely adopted across various industries. Its decentralized, immutable, and transparent nature has made it suitable for a plethora of applications beyond financial transactions. One notable area where blockchain is making a significant impact is in supply chain management. By leveraging blockchain, companies can establish transparent and traceable supply chains, enabling them to track the movement of goods from their point of origin to the end consumer. This technology helps verify the authenticity of products, trace their provenance, and streamline logistics and inventory management processes.

Moreover, blockchain is revolutionizing identity management by providing a secure and decentralized solution for storing and managing digital identities. With blockchain-based identity systems, individuals have greater control over their personal data, reducing the risk of identity theft and fraud. Additionally, blockchain technology is reshaping voting systems, offering increased transparency, security, and tamper resistance compared to traditional methods. By recording votes on a distributed ledger, blockchain helps prevent electoral fraud and ensures the integrity of the voting process. In the realm of intellectual property protection, blockchain offers a novel approach to safeguarding copyrights, patents, and trademarks. By creating digital certificates of authenticity on a blockchain, creators can prove ownership and protect their intellectual property from theft or infringement. Similarly, in healthcare, blockchain is improving the security and interoperability of patient records by providing a decentralized and tamper-proof system for storing and sharing medical data. This ensures patient privacy, data integrity, and seamless access to medical records across different healthcare providers.

Furthermore, blockchain technology is driving the rise of decentralized finance (DeFi), enabling trustless financial transactions without the need for traditional intermediaries like banks. DeFi platforms leverage smart contracts to offer a range of financial services, including lending, borrowing, trading, and asset management. Additionally, blockchain facilitates the tokenization of real-world assets, such as real estate and commodities, by representing them as digital tokens on a blockchain. This allows for fractional ownership, increased liquidity, and democratized access to investment opportunities.

Finally, blockchain is transforming supply chain finance by digitizing and automating trade finance processes, reducing the risk of fraud, improving transparency, and enhancing access to working capital for businesses. These examples illustrate the diverse applications of blockchain technology across various sectors, highlighting its potential to drive innovation, improve efficiency, and foster trust in digital ecosystems. As blockchain continues to evolve, its transformative impact on industries and business processes is expected to expand even further.

1.6 ADVANTAGES AND DISADVANTAGES OF BLOCKCHAIN

Blockchain technology offers numerous advantages, but it also comes with its own set of challenges and limitations. Below are some of the key pros and cons:

Pros:

1. **Decentralization:** Blockchain operates on a decentralized network, eliminating the need for intermediaries and enabling peer-to-peer transactions. This decentralization increases transparency, reduces the risk of censorship, and enhances data security.
2. **Transparency:** All transactions on a blockchain are recorded in a tamper-proof and transparent manner, visible to all network participants. This transparency promotes accountability and trust among users.
3. **Immutability:** Once recorded, data on a blockchain cannot be altered or deleted without the consensus of the network participants. This immutability ensures the integrity and reliability of the data stored on the blockchain.
4. **Security:** Blockchain uses cryptographic techniques to secure transactions and data, making it resistant to hacking and fraud. The decentralized nature of blockchain also mitigates the risk of single points of failure and cyber attacks.
5. **Efficiency:** Blockchain streamlines processes by automating transaction verification and settlement through smart contracts. This automation reduces the need for manual intervention, leading to faster and more cost-effective transactions.
6. **Traceability:** With blockchain, users can trace the origin and ownership history of assets or data, providing greater visibility into supply chains, intellectual property rights, and other critical processes.
7. **Lower Costs:** By eliminating intermediaries, reducing paperwork, and automating processes, blockchain helps lower transaction costs, making it more accessible to individuals and businesses.

Cons:

1. **Scalability:** As blockchain networks grow in size and transaction volume, they may face scalability issues, such as slower transaction processing times and

higher fees. This can hinder the widespread adoption of blockchain for large-scale applications.

2. **Energy Consumption:** Proof-of-work (PoW) consensus mechanisms, used by some blockchain networks like Bitcoin, require significant computational power and energy consumption for transaction validation. This has raised concerns about the environmental impact of blockchain mining activities.
3. **Regulatory Uncertainty:** The regulatory landscape surrounding blockchain and cryptocurrencies is still evolving, leading to uncertainty and compliance challenges for businesses operating in this space. Regulatory changes can impact the legality and viability of blockchain projects.
4. **Privacy Concerns:** While blockchain offers transparency, it also poses challenges related to privacy and data protection. Public blockchains store transaction data openly, raising concerns about the exposure of sensitive information.
5. **Governance Issues:** Blockchain networks rely on consensus mechanisms to validate transactions and make decisions, but reaching consensus among network participants can be complex and contentious. Governance issues, such as forks and disputes, can disrupt the stability and integrity of blockchain networks.
6. **Adoption Barriers:** Despite its potential, blockchain technology faces adoption barriers related to technical complexity, interoperability issues, and lack of standardization. Overcoming these barriers requires education, collaboration, and investment in infrastructure and development.

Overall, while blockchain offers promising benefits in terms of decentralization, transparency, security, and efficiency, it also poses challenges that need to be addressed to realize its full potential across various industries and applications.

1.7 ENHANCING QUICK RESPONSE SYSTEMS

Consumers, armed with smartphones or dedicated scanners, can effortlessly scan the QR code or barcode on a product's packaging. What happens next is nothing short of revolutionary. In the blink of an eye, the consumer gains access to a wealth of

information about the product's entire supply chain journey. From the factory floor to the distribution center to the retail shelf, every step is accounted for, unchangeable and trustworthy. With this knowledge, consumers can confidently verify the authenticity of the product they hold in their hands, making informed decisions about their purchases.

The implications of this technology are profound. It shatters the opaque veil that has long shrouded supply chains, allowing consumers to peer inside and gain clarity on the products they buy. It empowers consumers to differentiate between genuine and counterfeit goods without relying solely on trust in retailers. It fosters a sense of confidence and security, strengthening the bond between consumers and businesses. However, the project doesn't stop at empowering consumers alone. It takes a comprehensive approach to combating counterfeiting. An essential component of the project is its robust reward system, designed to incentivize active participation in product authentication. Users who engage with the system by scanning QR codes and validating product authenticity are rewarded with a variety of incentives, such as loyalty points, discounts, or exclusive benefits. This rewards system not only encourages vigilance but also fosters a sense of community committed to fighting counterfeits.

In summary, this project represents a pioneering effort to address the pervasive issue of counterfeiting within supply chains. It combines blockchain technology, smart contracts, QR code integration, and a user-centric approach to create a secure, transparent, and efficient system. By embracing emerging technologies and fostering global collaboration, this endeavor strives to restore trust in products, protect consumers, and fortify the foundations of modern commerce.

1.7.1 Why QR for Counterfeit Prevention

Using QR codes for counterfeit prevention offers several advantages:

1. **Easy Verification:** QR codes provide a quick and simple way for consumers to verify the authenticity of a product. By scanning the QR code with a smartphone, consumers can instantly access information about the product's origin, manufacturing details, and supply chain journey.
2. **Tamper-Proof:** QR codes can be designed to be tamper-proof, making them difficult to replicate or counterfeit. Advanced printing techniques and security

features can be incorporated into QR codes to ensure that they cannot be easily duplicated by counterfeiters.

3. **Cost-Effective:** Implementing QR codes for counterfeit prevention is cost-effective compared to other anti-counterfeiting technologies such as RFID tags or holograms. QR codes can be printed directly onto product packaging or labels without requiring additional hardware or infrastructure.
4. **Scalability:** QR codes can be easily integrated into existing product packaging and labeling processes, making them scalable for use across a wide range of products and industries. They can also be generated and distributed in large quantities at relatively low cost.
5. **Real-Time Tracking:** QR codes can be linked to a blockchain-based tracking system, enabling real-time tracking of products throughout the supply chain. This allows manufacturers, retailers, and consumers to track the movement of products from production to point of sale, reducing the risk of counterfeiting at various stages of the supply chain.
6. **Enhanced Consumer Confidence:** By providing consumers with a reliable and transparent method for verifying product authenticity, QR codes help build trust and confidence in the brand. Consumers are more likely to purchase products with QR codes knowing that they can easily verify their authenticity.

Overall, QR codes offer a practical and effective solution for counterfeit prevention, providing consumers with an accessible and reliable way to verify product authenticity while also enabling manufacturers to track and trace products throughout the supply chain.

This versatility allows brands to enhance the overall consumer experience by providing valuable information and engaging content through QR code scanning. Moreover, QR codes are compatible with most smartphones, making them accessible to a wide range of consumers without the need for specialized equipment or technology. Overall, the adoption of QR codes for counterfeit prevention not only strengthens supply chain security but also enhances consumer engagement and satisfaction, contributing to the overall success of brands and businesses.

CHAPTER 2

LITERATURE SURVEY

2.1 A SURVEY ON BLOCKCHAIN TECHNOLOGY

"A Survey on Blockchain Technology: Evolution, Architecture and Security," [1] authored by Muhammad Nasir Mumtaz Bhutta, Amir A. Khwaja, Adnan Nadeem, Hafiz Farooq Ahmad, Muhammad Khurram Khan, Moataz A. Hanif, Houbing Song, Majed Alshamari, and Yue Cao in 2021, offers a comprehensive exploration of blockchain technology. The research work delves into the architecture of cryptocurrencies, smart contracts, and general blockchain-based applications, providing a holistic perspective on these essential components of blockchain systems. It meticulously examines the various blockchain architectures in the context of cryptocurrencies, smart contracts, and other applications, shedding light on their underlying mechanisms and functionalities.

One of the notable strengths of this survey research work is its detailed coverage of blockchain and its diverse applications. It elucidates the intricacies of blockchain technology, making it an invaluable resource for readers seeking an in-depth understanding of this transformative field. Furthermore, the research work highlights significant research advances in consensus mechanisms, offering insights into key developments and application frameworks that drive the evolution of blockchain technology. However, it is worth noting that the research work has some limitations. While it provides an extensive overview of blockchain and its applications, it does not delve into the detailed concepts of hashing and all consensus algorithms. This omission may leave readers wanting a more thorough exploration of these fundamental aspects of blockchain technology. Despite this limitation, the survey serves as a valuable resource for researchers, professionals, and enthusiasts in the blockchain space, offering a comprehensive view of blockchain architecture and its diverse applications. "A Blockchain-based Management System for Detecting Counterfeit Products in the Supply Chain," [2] authored by M.C. Jayaprasanna, V.A. Soundharya, M. Suhana, and S. Sujatha in 2021, addresses the pressing issue of counterfeit products, particularly in the online and black markets. The proliferation of

counterfeit goods poses a significant challenge within the supply chain industry. The research work introduces a novel approach to tackle this problem by leveraging blockchain technology. The primary focus of this research work is on vendor-side verification using an encryption algorithm. This approach ensures that only authorized individuals with the correct private key can decrypt and access critical information. By implementing such a security measure, the research work aims to detect counterfeit products effectively at both ends of the supply chain, enhancing the overall integrity of the system.

One notable advantage of this research work is its comprehensive approach to counterfeit product detection. It not only addresses the issue at the consumer end but also emphasizes the importance of verifying the authenticity of products at the vendor or supplier level. This dual-level verification strategy enhances the effectiveness of counterfeit detection and prevention. However, the research work does have certain limitations. It highlights that using Radio Frequency Identification (RFID) technology can be time-consuming within a Blockchain-Based Management System (BCBM). The computational demands of RFID may slow down the system's performance, potentially impacting its efficiency. This limitation underscores the need for optimizing the integration of RFID with blockchain to ensure a seamless and responsive system.

In summary, the research work presents a promising approach to combat counterfeit products in the supply chain by utilizing blockchain technology and encryption-based vendor-side verification. While it offers a comprehensive solution that addresses both ends of the supply chain, the potential challenges associated with RFID integration should be carefully considered and optimized for practical implementation.

2.2 RESEARCH WORKS ON BLOCKCHAIN

"A Blockchain-based Supply Chain Quality Management Framework," [3] authored by Si Chen, Rui Shi, Zhuangyu Ren, Jiaqi Yan, Yani Shi, and Jinyu Zhang in 2018, introduces a significant contribution to the field of supply chain quality management. The research work presents a comprehensive framework that

leverages blockchain technology to enhance the quality management processes within the supply chain.

The central focus of this research work is the development of a theoretical framework that underpins the intelligent quality management of the supply chain through blockchain technology. This framework serves as a foundation for advancing theories related to information resource management in distributed and virtual organizations, particularly in the context of decentralized management. By emphasizing the role of blockchain in quality management, the research work paves the way for innovative approaches to supply chain quality improvement.

One of the noteworthy strengths of this research work is its theoretical approach to blockchain-based supply chain quality management. It provides a valuable theoretical basis for understanding how blockchain technology can be harnessed to optimize quality control processes in complex supply chains. This conceptual framework not only enhances our understanding of the subject but also opens up avenues for further research and practical applications. However, the research work does acknowledge certain limitations. It points out the challenge of designing a complex smart contract system, which may have efficiency implications. The development and implementation of intricate smart contracts within a blockchain-based system can indeed be resource-intensive and may require careful consideration to strike the right balance between complexity and efficiency.

In conclusion, this literature review offers a pivotal contribution to the field of supply chain quality management by proposing a blockchain-based framework. While it provides a theoretical foundation for decentralized quality management, the practical aspects, such as the design and efficiency of smart contract systems, warrant further exploration and optimization for real-world applications.

2.2.1 Integration Challenges

The exploration of blockchain technology within the context of supply chain management and quality control has yielded valuable insights, as evidenced by a collection of seminal literature research works. In "Blockchain and the Internet of Things in the Industrial Sector: A Survey" (2019) [4], the authors delve into the

synergistic potential of blockchain and the Internet of Things (IoT) within the industrial domain. This survey elucidates the convergence of these technologies and their applications, particularly in the realms of supply chain management and quality assurance. While it opens up promising avenues for enhanced transparency and quality control, a notable limitation lies in the need for robust integration, which can be complex and resource-intensive.

A compelling real-world case is presented in "Blockchain-Based Supply Chain Traceability: A Case of Saffron Authentication" (2018) [5]. This research work showcases the practical implementation of blockchain to authenticate saffron in the supply chain, exemplifying the technology's capacity to enhance traceability and, consequently, product quality assurance. However, the detailed design and execution of complex smart contract systems can be resource-inefficient, as mentioned in the cons, emphasizing the need for optimization in real-world applications.

2.2.2 Blockchain in Supply Chain

The research work "Blockchain in Logistics and Supply Chain: A Lean Six Sigma Approach" (2021) [6] introduces the integration of blockchain technology with Lean Six Sigma methodologies in logistics and supply chain contexts. This approach is lauded for its potential to streamline supply chain processes and improve product quality through efficient management. Nevertheless, a careful balance must be struck between complexity and efficiency when implementing intricate smart contracts, as pointed out in the cons.

Another perspective is offered in "Blockchain for Supply Chain Quality Management: A Systematic Literature Review and Research Agenda" (2021)[7]. This systematic literature review synthesizes existing research findings, offering an extensive overview of blockchain's role in supply chain quality management. It provides a structured foundation for future research, shedding light on the pros and cons of blockchain applications in quality assurance within supply chains. The need for extensive and diverse research to address this multifaceted area emerges as a prominent research agenda, marked as a potential limitation.

2.2.3 Supply Chain Traceability

"Enhancing Supply Chain Traceability with Blockchain Technology: A Literature Review" (2021)[8] emphasizes how blockchain enhances supply chain traceability and subsequently elevates product quality management. While the advantages of blockchain in traceability are evident, the research work also acknowledges the challenges associated with its implementation. This balanced view underscores the complexity of integrating blockchain into supply chain processes.

Finally, "Quality and Safety in the Agri-Food Supply Chain: Blockchain Technology and the Identification of Quality Attributes" (2020) [9] explores the application of blockchain in the agri-food supply chain, specifically focusing on the identification and management of quality attributes. This research work presents a nuanced perspective on how blockchain can be harnessed to ensure the quality and safety of food products. It highlights the potential of blockchain to revolutionize quality management in this critical sector.

In conclusion, these literature research works collectively demonstrate the multifaceted impact of blockchain technology on supply chain management and quality control. They shed light on the promising advantages, such as enhanced traceability, improved quality assurance, and streamlined processes, while also acknowledging challenges, including integration complexities and resource-intensive smart contract design. As the field of blockchain in supply chain and quality management continues to evolve, these insights serve as critical building blocks for future research and practical applications.

2.3 INFERENCES FROM LITERATURE SURVEY

Blockchain technology has emerged as a disruptive force in the domain of supply chain management and quality assurance. The collective insights from nine literature surveys reveal a compelling narrative of how blockchain's unique attributes, including transparency, immutability, and decentralized consensus mechanisms, are reshaping traditional supply chain practices. These surveys span a diverse range of topics, providing a comprehensive understanding of blockchain's transformative potential, its applications, and the challenges that need to be addressed.

The base research work, "Exploring the Role of Blockchain in Enhancing Supply Chain Traceability and Transparency," provides valuable insights and principles that are instrumental in shaping our project, "Blockchain-Enabled Supply Chain Management for Authenticating Products Using QR Technology." Here's how the base research work is useful for our project, especially in the context of expanding its application from agriculture to a wider scale using QR technology:

Conceptual Foundation: The base research work offers a well-established conceptual foundation for blockchain's role in enhancing supply chain traceability and transparency. This concept is directly applicable to our project, allowing us to understand the underlying principles that will be essential for authenticating products across a broader spectrum.

Scalability Insights: The base research work discusses the scalability challenges in implementing blockchain for supply chain management. This is particularly useful for our project as it encourages us to consider scalability solutions when applying blockchain to a wider range of products. Understanding these challenges can help us implement a scalable solution effectively.

Interoperability and Standardization: The base research work highlights the importance of interoperability and standardization in blockchain adoption. This is crucial when expanding our project to a wider scale, as it prompts us to ensure that the blockchain system we implement is compatible with various industries and products, and adheres to standardized practices.

Data Security and Transparency: The base research work emphasizes the significance of data security and transparency, which are key aspects of our project. Implementing QR codes and blockchain to authenticate products on a larger scale requires robust security measures, and the base research work provides insights into how to achieve this while maintaining transparency.

Smart Contracts and Automation: The project's emphasis on QR technology aligns with the base research work's discussion on smart contracts and automation. Leveraging QR technology in conjunction with blockchain can enable automated processes for product authentication, which can greatly benefit a broader supply chain ecosystem.

Real-World Use Cases: The base research work likely presents real-world use cases of blockchain in supply chains. These use cases provide inspiration and practical examples that can be adapted to our project's goals and implemented on a wider scale beyond agriculture.

Challenges and Solutions: By referring to the base research work's discussions on challenges and potential solutions, our project can anticipate and address issues that may arise when scaling up the blockchain-based supply chain authentication system. This proactive approach can save time and resources in the long run.

Consumer Trust and Credibility: The base research work's focus on blockchain enhancing trust and credibility in supply chains is highly relevant to our project's goal of authenticating products. Implementing these principles on a wider scale using QR technology can amplify consumer trust and enhance the credibility of products across various industries.

In conclusion, the inferences drawn from these nine literature surveys collectively underscore the transformative potential of blockchain technology in supply chain quality management. Blockchain enhances the transparency, authentication, and traceability of products, offering robust solutions to long-standing challenges. While challenges, such as smart contract complexity and integration issues, persist, the evolving landscape of blockchain in supply chains holds promise for revolutionizing the way we manage quality and authenticity in products across various industries. As the field continues to evolve, ongoing research and practical implementations will be essential to unlock the full potential of blockchain in supply chain quality management.

2.4 OPEN PROBLEMS IN THE EXISTING SYSTEM

As blockchain technology takes center stage in supply chain quality management, the synthesis of insights from nine comprehensive literature surveys reveals a series of open problems that warrant further research and innovation. These challenges present opportunities for future investigations to refine and optimize the application of blockchain in this critical domain.

Integration Complexity: While the potential benefits of blockchain in supply chain quality management are evident, complexities arise in integrating blockchain

seamlessly with existing systems and processes. The literature surveys, including "Blockchain-Based Supply Chain Traceability: A Case of Saffron Authentication" (2018) and "Blockchain for Supply Chain Quality Management: A Systematic Literature Review and Research Agenda" (2021), underscore the need for solutions to streamline the integration process. Future research should explore standardized integration frameworks and tools to reduce complexities and facilitate smoother adoption.

Smart Contract Efficiency: The design and execution of complex smart contracts within blockchain systems are highlighted as a significant challenge in several surveys, such as "Blockchain-Based Supply Chain Traceability" and "Blockchain in Logistics and Supply Chain: A Lean Six Sigma Approach" (2021). These contracts play a pivotal role in supply chain processes and quality management. Research efforts should focus on optimizing smart contract design to improve efficiency without compromising security, scalability, or transparency.

Scalability: Blockchain's scalability remains a critical concern, particularly as supply chains expand and generate vast amounts of data. "Blockchain and the Internet of Things in the Industrial Sector: A Survey" (2019) emphasizes the importance of addressing scalability to accommodate the growing volume of IoT-generated data. Research should explore innovative consensus mechanisms, sharding techniques, and network optimizations to ensure blockchain systems can scale effectively.

Interoperability: Supply chains often involve a multitude of stakeholders, each potentially using different blockchain platforms or systems. Achieving interoperability between these diverse systems remains a challenge, as highlighted in "Blockchain for Supply Chain Quality Management" (2021). Future research should aim to develop standardized protocols or frameworks that facilitate seamless communication and data sharing between disparate blockchain networks.

User-Friendly Interfaces: Enhancing user interfaces and experiences for various stakeholders in the supply chain is vital. This is particularly relevant in scenarios where consumers and non-technical personnel interact with blockchain systems. Future research should explore user-friendly design principles and tools to improve accessibility and usability.

2.5 BLOCKCHAIN PERFORMANCE

The performance of blockchain in counterfeit prevention is characterized by its ability to provide a secure, transparent, and immutable ledger for tracking and verifying product authenticity throughout the supply chain. Blockchain's decentralized nature ensures that once information is recorded on the blockchain, it cannot be altered or tampered with, making it highly resistant to fraud and manipulation. This immutability enhances the reliability of product information, as stakeholders can trust that the data recorded on the blockchain accurately reflects the history and provenance of each product.

Moreover, blockchain's transparency enables all authorized participants in the supply chain to access real-time information about the origin, manufacturing process, and distribution of products. This transparency fosters trust among stakeholders and allows for greater visibility into the supply chain, making it easier to identify and address any instances of counterfeit or fraudulent activity.

Additionally, blockchain's smart contract functionality automates various aspects of supply chain management, such as product authentication, payment processing, and contract enforcement. Smart contracts execute predefined rules and conditions automatically, reducing the need for manual intervention and minimizing the risk of errors or discrepancies in the supply chain.

However, it's essential to acknowledge that while blockchain offers significant advantages in counterfeit prevention, it is not without its limitations. Challenges such as scalability, interoperability, and regulatory compliance may impact the widespread adoption and effectiveness of blockchain in combating counterfeit products. Nonetheless, ongoing research and development efforts aim to address these challenges and further improve the performance of blockchain in counterfeit prevention initiatives.

2.6 FIREBASE AND ITS PERFORMANCE

The integration of Firebase enhances the performance of the project in several ways, primarily by providing a centralized secondary database that complements the blockchain infrastructure. Firebase offers real-time data synchronization, offline

support, and robust authentication mechanisms, all of which contribute to improving the overall efficiency and reliability of the system.

One significant benefit of integrating Firebase is its ability to reduce the transaction (gas) cost associated with repeated queries. By offloading certain data storage and retrieval tasks to Firebase, the project can minimize the number of transactions performed on the blockchain network, thereby reducing gas fees and optimizing resource utilization.

Furthermore, Firebase's real-time data synchronization feature ensures that updates made to the database are immediately propagated to all connected clients. This ensures that stakeholders, such as manufacturers, sellers, and customers, have access to the most up-to-date information about products and transactions, enhancing transparency and enabling informed decision-making.

Firebase's offline support functionality is also crucial for ensuring continuous access to critical data, even in situations where internet connectivity is limited or unavailable. This ensures uninterrupted operation of the system, mitigating the risk of disruptions or downtime that could impact the user experience. Additionally, Firebase provides robust authentication mechanisms, including user authentication and access control, to ensure that only authorized individuals can interact with the system. This helps prevent unauthorized access and malicious activities, enhancing the security and integrity of the supply chain management system.

Overall, the integration of Firebase complements the blockchain infrastructure by providing efficient data storage, real-time synchronization, offline support, and robust authentication, all of which contribute to improving the performance and reliability of the project.

Firebase offers scalable cloud infrastructure that can seamlessly handle fluctuations in user traffic and data volume, ensuring consistent performance even during peak usage periods. Additionally, Firebase's flexible pricing model allows the project to scale resources up or down based on demand, optimizing costs and resource allocation. This scalability and flexibility enable the project to adapt to evolving business needs and support future growth, ensuring that the supply chain management system remains efficient, reliable, and cost-effective over time.

CHAPTER 3

REQUIREMENT ANALYSIS

3.1 FEASIBILITY STUDIES/RISK ANALYSIS OF THE PROJECT

The development and implementation of a blockchain-based system for supply chain quality management represent a significant endeavor with far-reaching implications. To ensure the success of such a project, it is essential to conduct thorough feasibility studies and risk analyses. These processes provide critical insights into the project's viability, potential challenges, and opportunities for optimization.

- ***Feasibility Studies - Evaluating the Viability:*** Feasibility studies are essential early in the project lifecycle to determine the practicality of implementing a blockchain-based supply chain quality management system. These studies typically encompass three primary dimensions:
- ***Technical Feasibility:*** Blockchain technology, while promising, is not a one-size-fits-all solution. A technical feasibility study examines whether the chosen blockchain platform and architecture align with the project's requirements. It also assesses the availability of necessary technical resources, such as skilled personnel, infrastructure, and compatible systems. In the context of the project, the choice of technology stacks is crucial. For instance, the use of Truffle, Solidity, and Web3.js must be examined in detail to ensure they are suitable for the intended application.
- ***Economic Feasibility:*** A blockchain-based project comes with associated costs, from initial development to ongoing maintenance and scalability. Economic feasibility studies delve into these financial aspects, weighing the expenses against the expected benefits. For example, the choice of using a centralized secondary database like SQL to reduce transaction costs (as identified in the "Seller" module) should be analyzed for its long-term cost-effectiveness.
- ***Operational Feasibility:*** Operational feasibility focuses on how well the proposed system aligns with the existing operational processes of supply chain management. This assessment considers the readiness of stakeholders to

adopt and adapt to the blockchain system. It also accounts for potential disruptions during the transition and the resources required for training and support.

3.1.1 Risk Analysis: Identifying and Mitigating Challenges

While feasibility studies provide an initial green light, risk analysis goes a step further by identifying potential pitfalls, challenges, and vulnerabilities in the project. Risk analysis encompasses several key components:

- **Technology Risks:** Blockchain technology is still evolving, and unforeseen technical challenges can arise. It is vital to anticipate and mitigate potential technology risks, such as security vulnerabilities, scalability limitations, and interoperability issues. For instance, the risk of a security breach due to vulnerabilities in smart contracts (as indicated in the "Smart Contracts" module) should be addressed through rigorous code audits and testing.
- **Regulatory and Compliance Risks:** Regulatory environments for blockchain implementations vary across regions and industries. Project stakeholders must conduct a thorough analysis of the legal and compliance risks associated with supply chain quality management on the blockchain. This analysis will help navigate complex regulatory requirements, ensuring adherence to standards and legal frameworks while maximizing the system's benefits.
- **Operational Risks:** The introduction of a blockchain-based system may disrupt existing operational processes. It is essential to assess and mitigate operational risks, including challenges related to data migration, user training, and changes in workflow. Proper change management strategies can help alleviate these risks.
- **Data Privacy and Security Risks:** As highlighted in the "Data Privacy" module, data privacy and security are paramount concerns. Risks associated with unauthorized access, data breaches, and non-compliance with data protection laws should be thoroughly analyzed. Robust encryption, access control, and auditing mechanisms can mitigate these risks.
- **Market Risks:** The market landscape is dynamic and influenced by factors such as technological advancements and consumer preferences. Project

stakeholders should evaluate market risks, including shifts in consumer behavior, competition, and emerging technologies that could impact the project's success.

- **Resource Risks:** Adequate resources, including skilled personnel and funding, are critical for project success. Identifying resource risks involves assessing the availability of talent, budget constraints, and the potential need for third-party services. Contingency plans for resource shortfalls should be developed.

In conclusion, conducting comprehensive feasibility studies and risk analyses is essential to ensure the success of a blockchain-enabled supply chain quality management project. These processes provide a solid foundation for informed decision-making, risk mitigation strategies, and resource allocation. By addressing feasibility and risk considerations proactively, project stakeholders can increase the likelihood of a successful implementation that enhances supply chain transparency and quality management while minimizing potential disruptions and vulnerabilities.

3.2 SOFTWARE REQUIREMENTS SPECIFICATION DOCUMENT

A Software Requirements Specification (SRS) document serves as the cornerstone of any software development project, outlining the comprehensive roadmap for the development team to follow. In the context of our blockchain-based supply chain quality management system, the SRS document plays a pivotal role in ensuring the project's success by precisely defining the software requirements, functionalities, and constraints.

3.2.1 Defining Requirements

The SRS document meticulously delineates both functional and non-functional requirements. Functional requirements describe the specific features and operations the software must perform. In our project, this includes functionalities such as product authentication, supply chain traceability, and user interactions across the manufacturer, seller, and customer modules. Non-functional requirements encompass aspects like performance, security, and usability. Given the sensitive nature of supply chain data, security measures, data encryption, and access controls become

paramount non-functional requirements. Additionally, performance expectations, such as system response times, are critical for seamless operation.

The SRS document will include detailed use cases and user stories to capture how different actors (manufacturers, sellers, and customers) will interact with the system. Use cases help visualize system functionality from an end-user perspective, while user stories provide real-world scenarios to guide development. These artifacts are instrumental in ensuring the software meets the practical needs of supply chain stakeholders. User interfaces are the bridge between users and the system. The SRS document will specify the design, layout, and accessibility features to ensure that users across various levels of technical expertise can seamlessly interact with the blockchain system. User-friendly interfaces are essential for wide-scale adoption.

3.2.2 Scalability and Performance

Scalability requirements, as identified in "Open Problems in Existing System," will be addressed in the SRS document. It will define how the system should expand to accommodate growing data volumes and user loads. Performance benchmarks will be outlined to ensure the system's responsiveness, even as the supply chain network scales.

3.2.3 Security and Data Privacy

Given the criticality of data security and privacy, the SRS document will comprehensively detail security measures, including encryption standards, access controls, and authentication methods. It will also account for data privacy regulations and compliance measures, ensuring that the system adheres to relevant laws and standards.

In summary, the Software Requirements Specification (SRS) document serves as the foundational blueprint for our blockchain-enabled supply chain quality management system. It defines the functional and non-functional requirements, user interactions, data models, security measures, and testing protocols. By meticulously detailing each aspect, the SRS document guides the development team in building a

secure, efficient, and user-friendly system that meets the specific needs of supply chain stakeholders while adhering to regulatory standards.

The workflow of the proposed architecture (Fig:3.1) involves seamless interaction between various components, each playing a crucial role in ensuring the authenticity and transparency of the supply chain. At the core of the architecture lies the blockchain network, serving as a decentralized ledger for recording and validating transactions related to product authentication.

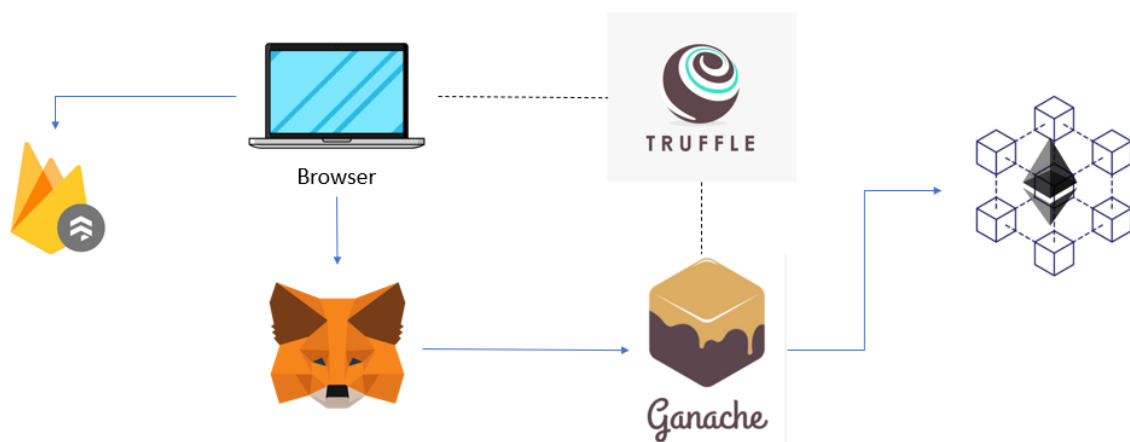


Fig:3.1 Software Architecture

Utilizing tools such as Truffle and Ganache, smart contracts are deployed on the blockchain, enabling automated processes for adding new products, recording sales, and facilitating queries. MetaMask, acting as a browser-based blockchain interaction tool, provides users with a seamless interface for accessing and engaging with the Ethereum blockchain. Concurrently, Firebase serves as a centralized secondary database, complementing the blockchain by reducing transaction costs for repeated queries. Through Firebase Authentication, users are securely authenticated, ensuring that only authorized individuals can access and interact with the system. Firestore, another component of Firebase, is leveraged as a decentralized storage solution, enhancing data management and retrieval.

The workflow seamlessly integrates these components, enabling manufacturers to add products, sellers to scan and sell products, and customers to verify purchases, all while ensuring transparency, authenticity, and trust within the supply chain ecosystem.

3.3 REQUIRED WORKFLOW

The workflow of the proposed blockchain-enabled supply chain management system is designed to seamlessly integrate various components to ensure transparency, authenticity, and efficiency in product authentication and tracking.

- The process begins with manufacturers interacting with the system to add new products to the blockchain. Using a user-friendly interface, manufacturers input product details such as name, description, and unique identifiers into the system.
- Once the product details are entered, the system generates a unique QR code or barcode for each product. This QR code/barcode serves as a digital fingerprint, linking the physical product to its corresponding blockchain record.
- The generated QR code/barcode is then affixed to the physical product, enabling seamless integration with the blockchain. The product details, along with the unique QR code/barcode, are securely stored on the blockchain, ensuring immutability and transparency.
- Sellers interact with the system by scanning the QR code/barcode of products they wish to sell. This action triggers a query to the blockchain, retrieving the product details and confirming its authenticity.
- Upon successful verification of the product's authenticity, the transaction details are recorded on the blockchain. This includes information such as the seller's identity, the buyer's identity, and the transaction timestamp.
- Customers can verify the authenticity of products by scanning the QR code/barcode using a mobile device. The system retrieves the product details from the blockchain, providing real-time information about the product's origin, manufacturing date, and distribution history.

- After verifying the product's authenticity, customers can proceed with the purchase. Once the transaction is completed, the details are recorded on the blockchain, ensuring transparency and traceability throughout the supply chain.
- To incentivize participation and encourage adherence to the system, a reward system may be implemented. Users who actively engage with the system by adding products, verifying transactions, or providing feedback may receive rewards in the form of tokens or discounts.
- The project collaborates with international organizations, regulatory bodies, and industry stakeholders to strengthen counterfeit prevention efforts. By fostering collaboration and sharing best practices, the project aims to create a unified approach to combating counterfeit products on a global scale.

Overall, the workflow of the blockchain-enabled supply chain management system ensures seamless interaction between manufacturers, sellers, and customers, facilitating transparent and trustworthy transactions while mitigating the risks associated with counterfeit products.

3.4 SECURITY REQUIREMENTS OF BLOCKCHAIN

Security requirements are paramount in blockchain-based counterfeit prevention systems to safeguard sensitive data, ensure transaction integrity, and protect against cyber threats. The following are essential security requirements for such systems:

1. **Data Encryption:** All sensitive data, including product information and transaction details, must be encrypted using robust encryption algorithms. This ensures that only authorized parties can access and decipher the data, protecting it from unauthorized access or tampering.
2. **Access Control:** Implement stringent access control mechanisms to regulate user access to the system. Role-based access control (RBAC) can be employed to assign specific permissions and privileges to users based on their roles and responsibilities within the system.
3. **Immutable Ledger:** The blockchain ledger should be immutable, meaning that once data is recorded on the blockchain, it cannot be altered or deleted. This

ensures the integrity and transparency of transaction records, preventing unauthorized modifications.

4. **Digital Signatures:** Utilize digital signatures to authenticate and verify the identity of users participating in transactions. Digital signatures provide cryptographic proof of the authenticity of transactions, mitigating the risk of identity fraud or impersonation.
5. **Consensus Mechanism:** Choose a robust consensus mechanism, such as proof of work (PoW) or proof of stake (PoS), to validate and confirm transactions on the blockchain. Consensus mechanisms ensure that transactions are verified by the network consensus, preventing double-spending and fraudulent activities.
6. **Secure Smart Contracts:** Ensure that smart contracts deployed on the blockchain are securely coded and audited to prevent vulnerabilities and exploits. Smart contracts should undergo rigorous testing and auditing processes to identify and mitigate potential security flaws.
7. **Network Security:** Implement robust network security measures to protect against DDoS attacks, malicious nodes, and network disruptions. Utilize firewalls, intrusion detection systems (IDS), and distributed denial-of-service (DDoS) mitigation techniques to safeguard the blockchain network infrastructure.
8. **Privacy Protection:** Incorporate privacy-enhancing technologies, such as zero-knowledge proofs (ZKPs) or private transactions, to protect sensitive information from being exposed on the blockchain. Privacy features ensure confidentiality and anonymity for users while preserving the transparency and integrity of transactions.
9. **Regular Audits and Monitoring:** Conduct regular security audits and monitoring activities to identify and address potential security vulnerabilities and threats. Implementing continuous monitoring and threat detection mechanisms helps detect and mitigate security incidents in real-time.
10. **Regulatory Compliance:** Ensure compliance with relevant regulatory requirements and data protection laws, such as GDPR or HIPAA, to protect user

privacy and data confidentiality. Adhering to regulatory standards helps maintain trust and credibility in the blockchain-based counterfeit prevention system.

3.5 HARDWARE REQUIREMENTS

To run a blockchain-based counterfeit prevention project effectively, the hardware requirements depend on various factors such as the scale of the project, the complexity of the blockchain network, and the computational resources needed for data processing and storage. However, here are some general hardware requirements for running such a project:

1. **Computing Devices:** High-performance computing devices such as desktop computers or servers are required to host and run blockchain nodes, smart contract execution environments, and database servers. These devices should have sufficient processing power (CPU) and memory (RAM) to handle the computational workload associated with blockchain transactions, data processing, and cryptographic operations.
2. **Networking Equipment:** Reliable networking equipment such as routers, switches, and network cables are essential for establishing and maintaining network connectivity between blockchain nodes and other system components. High-speed internet connectivity is crucial for ensuring efficient communication and data exchange between distributed nodes in the blockchain network.
3. **Storage Devices:** Adequate storage devices such as hard disk drives (HDDs) or solid-state drives (SSDs) are required to store the blockchain ledger data, transaction records, and other system files. The storage capacity should be sufficient to accommodate the growing size of the blockchain database over time, considering factors such as transaction volume and data retention policies.
4. **Backup Systems:** Backup systems and storage solutions are essential for creating redundant copies of critical data and ensuring data integrity and availability in case of hardware failures or data loss incidents. Implementing regular backup routines and disaster recovery plans helps mitigate the risk of data loss and ensures business continuity.

5. **Security Devices:** Security devices such as firewalls, intrusion detection systems (IDS), and antivirus software are necessary to protect the hardware infrastructure from cyber threats, malware attacks, and unauthorized access attempts. Implementing robust security measures helps safeguard sensitive data stored on the hardware devices and ensures the overall security of the blockchain-based counterfeit prevention system.
6. **Power Supply Units (PSUs):** Reliable power supply units (PSUs) and uninterruptible power supply (UPS) systems are essential to provide continuous power to the hardware infrastructure and prevent unexpected shutdowns or data corruption due to power outages.
7. **Cooling Systems:** Effective cooling systems such as fans, heat sinks, and air conditioning units are necessary to maintain optimal operating temperatures for the hardware devices and prevent overheating or thermal damage.
8. **Scalability Considerations:** The hardware infrastructure should be designed with scalability in mind to accommodate future growth and expansion of the blockchain-based counterfeit prevention system. Modular and flexible hardware configurations allow for easy upgrades and adjustments to meet changing demands and requirements over time.

CHAPTER 4

METHADODOLOGY OF PROPOSED SYSTEM

The proposed system represents a groundbreaking approach to supply chain quality management, leveraging blockchain technology to enhance transparency, authenticity, and efficiency across the supply chain. This visionary system offers an innovative framework designed to benefit a wide range of stakeholders, from manufacturers and sellers to end consumers.

4.1 SELECTED METHODOLOGY OR PROCESS MODEL

The choice of a methodology or process model is pivotal in shaping the success of any software development project, and in the context of our blockchain-based supply chain quality management system, the selection of Agile methodology aligns perfectly with the dynamic and evolving nature of this project.

- ***Agile Methodology:*** Agile is not merely a methodology; it's a philosophy and a set of principles that embrace flexibility, collaboration, and adaptability. This approach is ideally suited for a project that involves blockchain technology, where rapid changes, feedback loops, and continuous improvement are essential.
- ***Iterative and Incremental Development:*** Agile emphasizes iterative and incremental development, breaking the project into small, manageable units known as sprints. These sprints enable the development team to focus on specific components, fostering a more in-depth understanding and faster problem resolution. In the context of our project, this approach allows for the progressive refinement of blockchain features and functionalities.
- ***Adaptability to Changing Requirements:*** One of the core strengths of Agile is its adaptability to evolving requirements. In a blockchain-based project, where new insights and changes can emerge as the system evolves, Agile's ability to accommodate these changes without disrupting the overall development process is invaluable. This ensures that the project can respond effectively to open problems or emerging technological advancements.

- ***Stakeholder Collaboration:*** Blockchain projects often involve multiple stakeholders, from manufacturers to end consumers. Agile's focus on collaboration encourages stakeholders to actively participate in the development process, providing feedback and insights that ensure the system aligns with their needs and expectations. This collaborative approach enhances the system's usability and functionality.
- ***Blockchain-Powered Transparency:*** At the core of the proposed system lies blockchain technology, a distributed ledger system renowned for its transparency and security. The blockchain, in conjunction with QR/barcode technology, empowers consumers to access real-time information about the products they purchase. Each product is assigned a unique QR/barcode that serves as a gateway to its entire supply chain history, from its origin to the point of sale. This transparency instils confidence in consumers by enabling them to verify the authenticity of products, thereby mitigating the risks associated with counterfeit or subpar goods.
- ***Authentication and Trustworthiness:*** The proposed system introduces a robust product authentication mechanism. When a consumer scans a product's QR/barcode, the system queries the blockchain for its history. If the data on the blockchain matches the information embedded in the code, the product is verified as authentic. This authentication process minimizes the reliance on merchants and distributors for verifying product legitimacy. Furthermore, consumers can report and track any instances of counterfeit products, enhancing the overall trustworthiness of the supply chain.
- ***Efficient Supply Chain Traceability:*** Supply chain traceability is revolutionized with the proposed system. Manufacturers, sellers, and consumers alike can track the journey of a product through the supply chain with unparalleled accuracy. This traceability feature not only bolsters quality management but also facilitates the identification and resolution of issues, such as product recalls or delays. It equips businesses with real-time insights into the movement of goods, enabling them to optimize inventory management, reduce waste, and enhance overall supply chain efficiency.

- **User-Centric Design:** The system places a strong emphasis on user-friendliness. Its intuitive interfaces cater to users with varying levels of technical expertise. Manufacturers, sellers, and consumers can interact with the system effortlessly, making it accessible and practical for all stakeholders. This user-centric design encourages broad adoption and ensures that the system's benefits are realized across the supply chain.
- **Security and Compliance:** In an era of heightened data security concerns, the proposed system prioritizes security measures. Access control, data encryption, and adherence to data privacy regulations are integral components. These measures protect sensitive supply chain data from unauthorized access and ensure compliance with legal standards, thereby safeguarding the integrity of the system.
- **A Collaborative Ecosystem:** The proposed system fosters collaboration among supply chain stakeholders. Manufacturers can establish trust with consumers, and consumers can contribute to the system's accuracy by reporting counterfeit products. This collaborative ecosystem strengthens the supply chain's quality management practices and encourages transparency.

In summary, the proposed system represents a transformative paradigm for supply chain quality management. Leveraging blockchain technology establishes a new era of transparency and authenticity within the supply chain. Through user-friendly interfaces, robust security measures, and a collaborative ecosystem, it empowers stakeholders to participate in an efficient, trustworthy, and accountable supply chain network. This system not only addresses existing challenges but also paves the way for future innovations in supply chain management.

In conclusion, the selection of Agile methodology for the development of the blockchain-based supply chain quality management system is a strategic choice that aligns with the project's dynamic nature. It enables iterative and incremental development, accommodates changing requirements, promotes stakeholder collaboration, and ensures a user-centric, tested, and validated product. By embracing Agile, the project is positioned to navigate the complexities and uncertainties inherent in developing a cutting-edge solution for supply chain quality management effectively.

4.2 ARCHITECTURE / OVERALL DESIGN OF PROPOSED SYSTEM

The architecture and overall design of the proposed blockchain-based supply chain quality management system are pivotal to its success. It serves as the blueprint that guides the development and implementation of the system, ensuring that it achieves its goals of enhancing the efficiency across the supply chain.

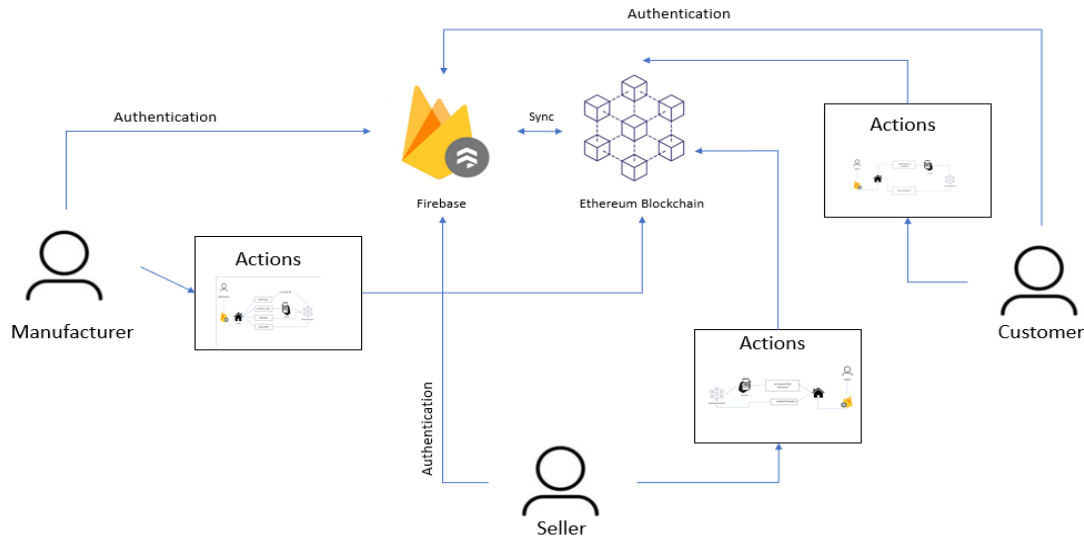


Fig:4.1 System Architecture

The proposed system's architectural (Fig:4.1) cornerstone is blockchain technology, renowned for its transparency and immutability. The system leverages a decentralized and distributed ledger to record every transaction and product movement across the supply chain. Blockchain's unique block and chain structure, as well as its cryptographic security, guarantees that once data is recorded, it cannot be tampered with. This unchangeable record ensures the authenticity and integrity of supply chain data.

The system is designed with modularity in mind. It consists of three primary modules Manufacturer (Fig:4.2), Seller (Fig:4.3), and Customer (Fig:4.4) each tailored to the specific needs of the stakeholder.

- **QR/Barcode Integration:** The system incorporates QR/barcode technology to facilitate ease of use. Each product is assigned a unique QR/barcode that consumers can scan for product verification and supply chain traceability. The QR/barcode system simplifies the interaction between consumers, products, and the blockchain.
- **Integration of Centralized Database:** To address scalability and performance challenges, the system integrates a centralized secondary database, as identified in the "Seller" module. This database, powered by SQL, reduces the gas (transaction) costs associated with repeated queries. It serves as a strategic solution to ensure efficient system operation, especially as the supply chain expands.

4.2.1 User Interfaces

The proposed system features user-friendly interfaces that cater to users with varying levels of technical expertise. These interfaces are designed to facilitate interactions between stakeholders and the system. Manufacturer, Seller, and Customer modules have distinct yet intuitive interfaces, ensuring a smooth user experience.

To accommodate the diverse technology ecosystems across the supply chain, the system is designed with interoperability in mind. It adheres to open standards and protocols that facilitate communication and data sharing between different stakeholders and blockchain systems.

Security is a paramount concern in the system's design. The architecture incorporates multiple security layers, including access controls, data encryption, and authentication. These layers safeguard sensitive supply chain data and protect against unauthorized access. The system utilizes smart contracts to automate and secure transactions. Smart contracts are integral components, automating processes such as product verification and record-keeping. However, their complexity, as mentioned in "Open Problems in Existing Systems," requires rigorous design and validation.

This modular approach streamlines development, scalability, and maintenance. It allows for efficient updates to individual modules without affecting the overall system,

promoting agility and adaptability. The system architecture of this project is designed to integrate various technologies and components seamlessly, ensuring the secure and efficient functioning of the blockchain-enabled supply chain management system. At its core, the architecture relies on blockchain technology, which serves as the decentralized ledger for recording transactions and product information. The blockchain network, powered by Ethereum, provides transparency, immutability, and security to the system.

4.3 MANUFACTURER FLOW

The manufacturer flow within the blockchain-enabled counterfeit prevention system is designed to streamline the process of adding new products to the supply chain and ensuring their authenticity throughout the distribution network. The process begins with the manufacturer accessing the dedicated platform or application associated with the blockchain system. Once logged in, the manufacturer navigates to the product management section, where they can initiate the addition of a new product to the system. To do so, the manufacturer enters relevant details about the product, including its name, description, specifications, and any unique identifiers such as serial numbers or SKU codes. After providing the necessary information, the manufacturer generates a QR code or barcode associated with the newly added product. This code serves as a digital fingerprint that links the physical product to its digital counterpart on the blockchain ledger. The manufacturer then affixes the QR code or barcode to the physical product packaging before it is distributed to retailers or other intermediaries in the supply chain. This ensures that each product is uniquely identified and its journey from the manufacturer to the end consumer is recorded securely on the blockchain.

Throughout the distribution process, the manufacturer can monitor the movement of their products in real-time using the blockchain system. They can track each product's location, status, and transaction history, allowing for greater visibility and control over the supply chain. In the event of any discrepancies or suspected instances of counterfeiting, the manufacturer can take proactive measures to investigate and address the issue.

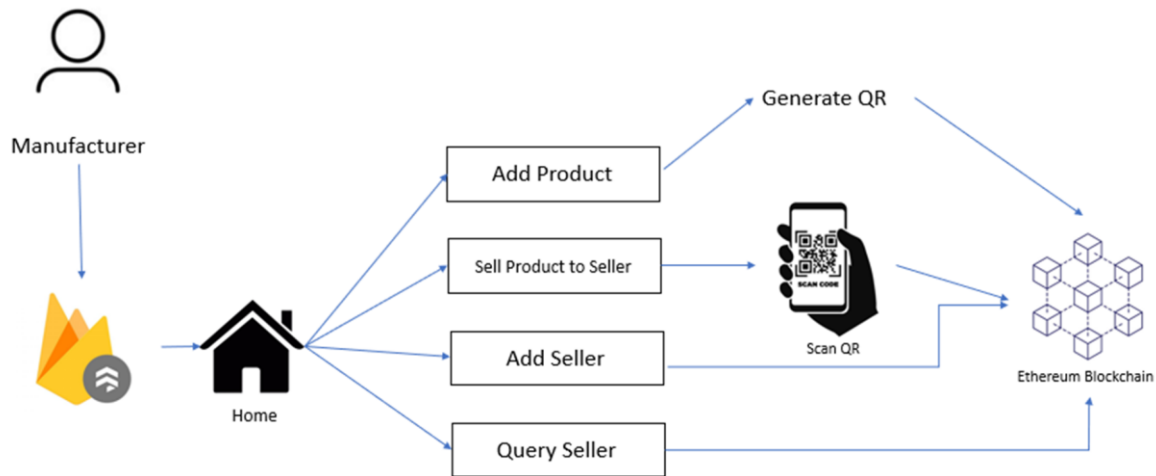


Fig:4.2 Manufacturer Flow

Overall, the manufacturer flow within the blockchain-enabled counterfeit prevention system empowers manufacturers to maintain transparency, traceability, and authenticity throughout the entire product lifecycle, ultimately enhancing trust and confidence in their brand and products.

4.4 SELLER FLOW

The seller flow within the blockchain-enabled counterfeit prevention system is designed to facilitate the efficient sale and distribution of products while ensuring their authenticity and integrity. The process begins when the seller accesses the dedicated platform or application associated with the blockchain system. Upon logging in, the seller is directed to their dashboard, which provides an overview of their inventory and sales activities. From here, the seller can initiate the sale of products by scanning the QR code or barcode affixed to each item.

Using a compatible scanning device or smartphone equipped with a camera, the seller scans the QR code or barcode of the product they wish to sell. This action triggers a query to the blockchain ledger, where the authenticity and transaction history

of the product are verified in real-time. If the product is deemed authentic based on the information stored on the blockchain, the seller proceeds with the sale transaction. The customer's purchase details are recorded securely on the blockchain, providing an immutable record of the transaction. In the event that a product is identified as counterfeit or suspicious during the scanning process, the seller is alerted to take appropriate action. This may involve halting the sale, conducting further investigations, or notifying the manufacturer or relevant authorities.

Throughout the sales process, the seller can leverage the blockchain system to track the movement of products, monitor inventory levels, and ensure compliance with regulatory requirements. Real-time updates and notifications keep the seller informed and proactive in managing their sales operations.

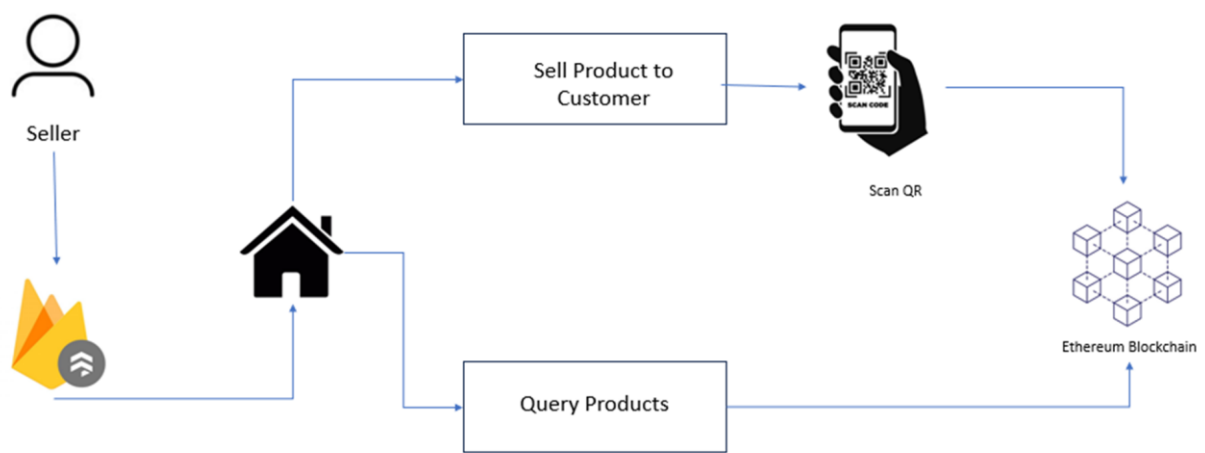


Fig:4.3 Seller Flow

By integrating blockchain technology into their workflow, sellers can enhance trust and confidence among customers, differentiate their products in the market, and contribute to the overall integrity of the supply chain ecosystem. This transparent and secure approach to product authentication benefits both sellers and consumers alike, fostering a safer and more trustworthy marketplace.

4.5 CUSTOMER FLOW

The customer flow within the blockchain-enabled counterfeit prevention system is designed to be intuitive and user-friendly, empowering customers to verify the authenticity of their purchased products seamlessly. The process begins with the customer obtaining a product with a QR code or barcode affixed to it. Using a smartphone or similar device equipped with a camera, the customer scans the QR code or barcode using a dedicated application associated with the blockchain system. Upon scanning the QR code or barcode, the application retrieves relevant information about the product from the blockchain ledger, including its origin, manufacturing details, and supply chain history. This real-time information is displayed to the customer through the application interface, allowing them to verify the authenticity of the product.

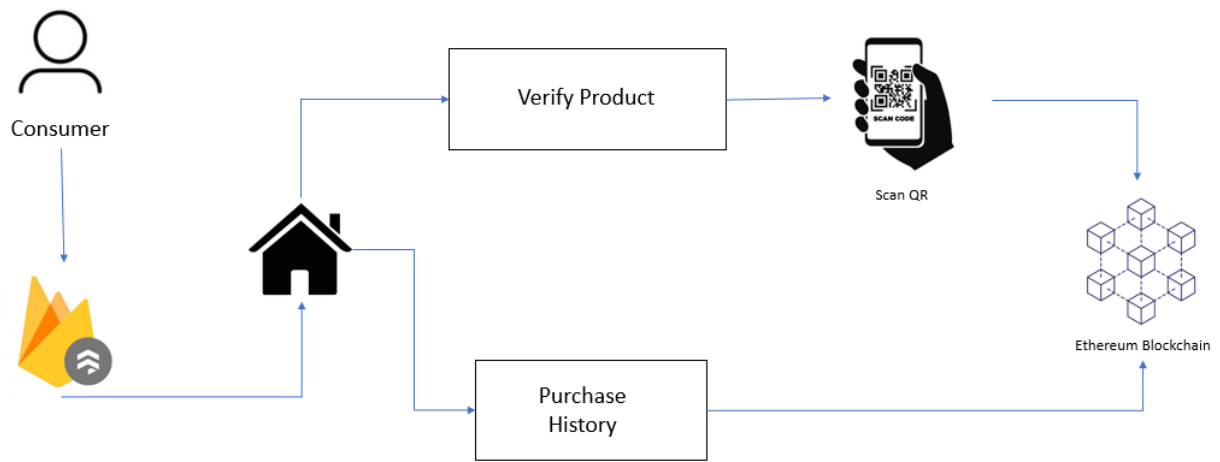


Fig:4.4 Customer Flow

If the product's information matches the data stored on the blockchain and meets the customer's expectations, they can proceed with confidence in their purchase. However, if the information retrieved from the blockchain indicates discrepancies or inconsistencies, such as a lack of records or conflicting data, the customer is alerted that the product may be counterfeit or tampered with. In the event of a potential counterfeit detection, the customer is provided with additional options for

recourse. They may choose to report the suspicious product to the manufacturer or relevant authorities, providing valuable feedback to improve counterfeit prevention efforts. Additionally, the customer may opt to explore alternative products or suppliers to ensure their safety and satisfaction. Overall, the customer flow within the blockchain-enabled counterfeit prevention system prioritizes transparency, authenticity, and trust, empowering customers to make informed purchasing decisions and safeguarding them against the risks associated with counterfeit products.

In conclusion, the blockchain-enabled counterfeit prevention system offers a comprehensive solution to combat the proliferation of counterfeit products in the marketplace. Customers benefit from a user-friendly interface that allows them to verify product authenticity in real-time, empowering them to make informed purchasing decisions and avoid counterfeit goods. Manufacturers leverage the system to track their products' journey from production to sale, ensuring supply chain transparency and protecting their brand reputation. Sellers play a crucial role in maintaining product integrity by facilitating sales and distribution while verifying product authenticity through the blockchain ledger. Together, these stakeholders contribute to a safer and more trustworthy marketplace, where counterfeit products are swiftly identified and removed from circulation. By harnessing the power of blockchain technology, this system strengthens consumer confidence, enhances brand trust, and fosters a more transparent and secure ecosystem for commerce.

CHAPTER 5

RESULTS AND DISCUSSIONS

The implementation of the product verification system, integrating blockchain technology, smart contracts, user interface development, and cloud services, has yielded significant results and sparked insightful discussions about its implications and future directions.

5.1 PROJECT INTERFACE

The project is modularized into three major parts, as discussed in the previous sections. The following images depict some of the actual user interface that all the user roles will be using.

The screenshot displays the 'Add Product' interface of the 'PROVENANCE PRO' application. The top navigation bar includes links for Home, Add Product, Add Seller, Sell Product To Seller, and Query Seller, along with a user profile icon labeled 'manufacturer'. The main form is titled 'Add Product' and contains the following fields:

Field	Value
Manufacturer ID	wTPluQysulVFU3N9L4igE7Mg3ZK2
Product Name	TEST NAME
Product SN	11
Product Brand	TEST BRAND
Product Price	999

Below the form is a yellow 'Add the Product' button. Underneath this button is a large QR code. At the bottom of the QR code is a yellow 'Download QR Code' button.

Fig:5.1 Add Product Screen

Enhanced Security: Leveraging blockchain technology for product verification has significantly enhanced the security and transparency of transactions. The immutable

nature of the blockchain ensures that product information remains tamper-proof and trustworthy.

PROVENANCE PRO Home Add Product Add Seller Sell Product To Seller Query Seller Browsersync: connected

Add Seller

Seller Name		Seller Brand	
Seller Code		Seller Phone Number	
Seller Manager		Seller Address	
Manufacturer ID	w1PluQysulVFU3N9L4igE7Mg3ZK2		

Add the Seller

Fig:5.2 Add Seller Screen

5.1.1 Improved User Experience

The development of a user-friendly interface has led to positive feedback from users across all workflows, including manufacturers, sellers, and consumers. The intuitive design and seamless navigation have contributed to an enhanced overall user experience.

- **Real-time Updates:** Integrating Firebase Firestore for real-time data storage and retrieval has enabled instant updates and notifications, enhancing the responsiveness of the system. Users can access the latest information without delay, improving efficiency and decision-making.
- **Streamlined Operations:** Automation of various processes, such as product authentication, sales transactions, and inventory management, has led to streamlined operations for businesses and consumers alike. Tasks that previously required manual intervention can now be performed efficiently through the system.

User experience (UX) plays a crucial role in the success and adoption of any technology-driven solution, especially in the context of blockchain-enabled supply chain management systems. Here are some aspects of user experience that are relevant to this project:

1. **Ease of Use:** The system should have a user-friendly interface that is intuitive and easy to navigate for all stakeholders, including manufacturers, sellers, and consumers. This includes simplifying the process of product authentication through QR/barcode scanning and providing clear instructions for each step of the process.
2. **Accessibility:** The system should be accessible to users across different devices and platforms, including desktop computers, tablets, and mobile phones. It should also be designed to accommodate users with diverse technical backgrounds and accessibility needs.
3. **Efficiency:** Users should be able to complete tasks quickly and efficiently within the system. This includes processes such as adding new products, initiating sales, scanning QR codes, and verifying product authenticity. Minimizing the number of steps required to perform these tasks can help improve overall efficiency.
4. **Feedback and Confirmation:** The system should provide timely feedback and confirmation to users after they have completed an action. For example, users should receive immediate feedback after scanning a QR code, indicating whether the product is authentic or counterfeit. Clear and concise messages can help users understand the status of their actions and build trust in the system.
5. **Customization and Personalization:** The system should allow users to customize their experience based on their preferences and needs. For example, manufacturers may have different preferences for how they organize and manage their products, while consumers may want to receive personalized recommendations based on their purchase history.
6. **Training and Support:** Comprehensive training materials and support resources should be provided to help users learn how to use the system.

effectively. This may include user manuals, video tutorials, online help forums, and dedicated customer support channels.

By prioritizing these aspects of user experience, the blockchain-enabled supply chain management system can enhance usability, satisfaction, and ultimately, adoption among its target users.

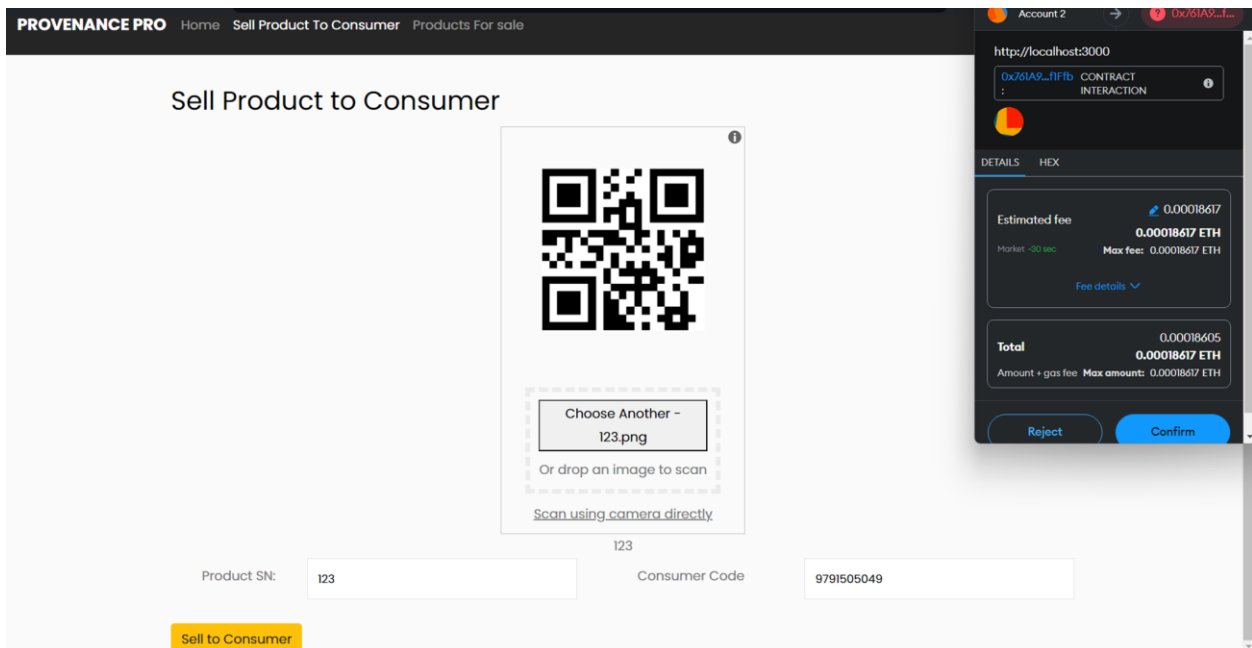


Fig:5.3 Sell Product screen

The implementation of secure authentication mechanisms and blockchain-based verification has instilled trust among users. They have confidence in the authenticity of products and the integrity of the system, leading to increased customer satisfaction and loyalty.

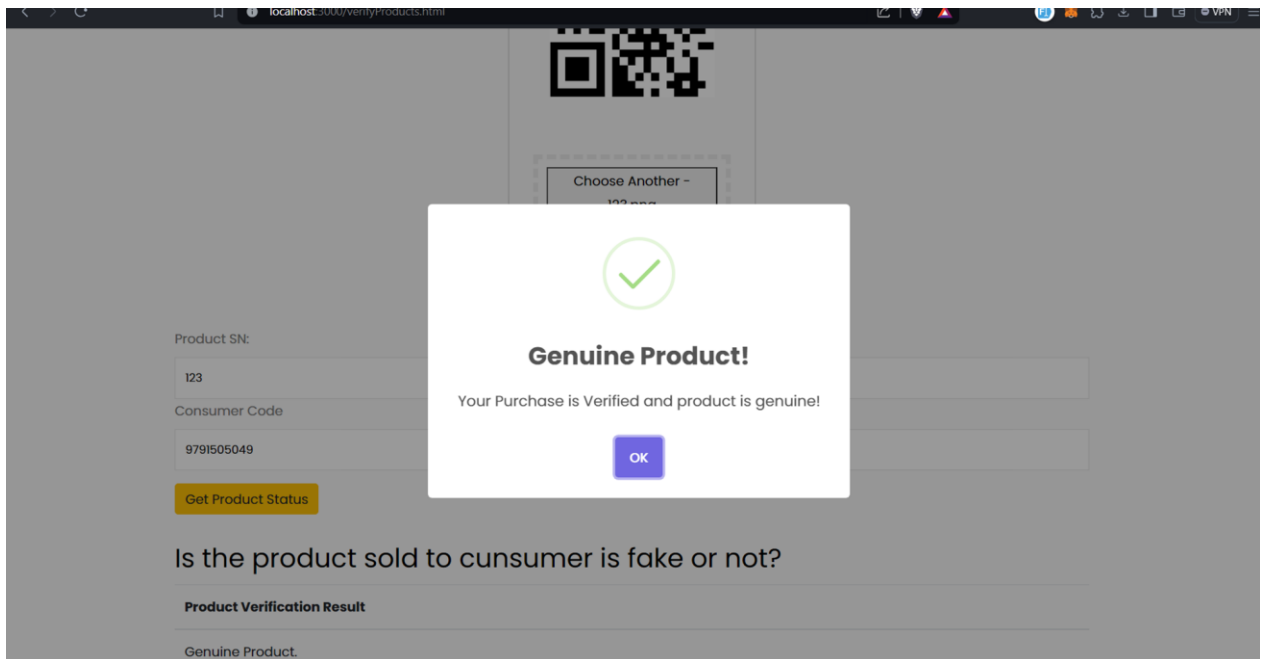


Fig:5.4 Product Verification screen

5.2 API ENDPOINTS AND THEIR USAGE

The API endpoints created from the centralized database (Firebase Firestore) open up a world of possibilities for future development. Here are some expanded ideas on how these APIs can be utilized for diverse applications:

- ***E-commerce System:*** The API endpoints can be leveraged to build a comprehensive e-commerce platform. Manufacturers can seamlessly add products, update inventory, and manage orders. Sellers, in turn, can access APIs to list products, process transactions, and monitor their sales. Customers benefit from features like browsing products, placing orders, and tracking their purchases.
- ***Online Sales Platform:*** Transforming the system into an online sales platform involves extending functionalities for sellers. API endpoints can facilitate seller-specific actions, such as managing storefronts, setting product prices, and analyzing sales performance. Integrating secure payment gateways and order fulfillment services can further enhance the platform's capabilities.
- ***Order Delivery Tracking System:*** The API endpoints can be extended to include features for order tracking and delivery management. Couriers and

delivery services can use APIs to update the status of orders in real time, providing customers and sellers with accurate information about the delivery process. Notifications and alerts can be implemented to keep all parties informed.

- ***Inventory Management System:*** The system can evolve into a robust inventory management tool for manufacturers and sellers. API endpoints can support actions such as adding new products, updating stock levels, and generating inventory reports. Integration with barcode scanning systems and IoT devices can further streamline inventory operations.

5.3 TRANSPARENCY AND TRUST

Transparency and trust are foundational principles in blockchain-enabled supply chain management systems. Blockchain technology enables unprecedented transparency by providing a decentralized and immutable ledger of transactions. In the context of supply chains, this means that every step of the product's journey, from its creation by the manufacturer to its sale to the end consumer, is recorded on the blockchain. This transparency allows all stakeholders, including manufacturers, sellers, and consumers, to access real-time information about the product's origin, authenticity, and entire supply chain history. By promoting transparency, blockchain enhances accountability and helps prevent fraud, counterfeiting, and other illicit activities within the supply chain. Transparency is a key driver of trust in supply chain management. When stakeholders have access to accurate and verifiable information about the products they are dealing with, they can make informed decisions and have confidence in the integrity of the supply chain. Blockchain technology's tamper-resistant nature and cryptographic security mechanisms further enhance trust by ensuring that the information recorded on the blockchain is immutable and cannot be altered or manipulated by any single party. As a result, blockchain-enabled supply chain management systems foster trust among all participants, leading to stronger relationships, increased collaboration, and ultimately, improved business outcomes.

In summary, transparency and trust are interdependent concepts in blockchain-enabled supply chain management. By leveraging blockchain technology to create transparent and trustworthy supply chains, businesses can enhance accountability, reduce risks, and build stronger relationships with their partners and customers.

5.4 SECURITY AND DATA INTEGRITY

Security and data integrity are paramount considerations in blockchain-enabled supply chain management systems: Blockchain technology provides robust security mechanisms to protect sensitive data and transactions within the supply chain. Through cryptographic techniques such as hashing, digital signatures, and consensus algorithms, blockchain ensures that data stored on the ledger is tamper-resistant and immutable. This means that once a transaction is recorded on the blockchain, it cannot be altered or deleted without the consensus of the network participants. Additionally, blockchain networks are decentralized, distributed, and encrypted, making them highly resistant to hacking and unauthorized access. By leveraging these security features, blockchain-enabled supply chain management systems can safeguard sensitive information, prevent fraud, and protect against cyber threats. Data integrity refers to the accuracy, consistency, and reliability of data throughout its lifecycle. In blockchain-based supply chain management, data integrity is ensured through the transparent and verifiable nature of the blockchain ledger. Every transaction recorded on the blockchain is cryptographically linked to the previous transaction, creating a chronological chain of blocks that provides an immutable record of all activities within the supply chain. This ensures that all data stored on the blockchain is tamper-proof and can be trusted by all stakeholders. By maintaining data integrity, blockchain-enabled supply chain management systems enable stakeholders to make informed decisions based on accurate and reliable information, leading to increased efficiency, transparency, and trust in the supply chain.

In conclusion, security and data integrity are fundamental aspects of blockchain-enabled supply chain management systems. By leveraging the security features of blockchain technology and ensuring data integrity throughout the supply chain,

businesses can mitigate risks, prevent fraud, and build trust with their partners and customers.

5.5 IMPACT ON COUNTERFEIT PREVENTION

Counterfeit prevention is a critical aspect of modern supply chain management, and blockchain technology has emerged as a powerful tool in combating this pervasive problem. The implementation of blockchain-based systems for supply chain management has a significant impact on counterfeit prevention through various mechanisms:

- **Immutable Recordkeeping:** Blockchain technology enables the creation of an immutable and transparent ledger that records every transaction and movement of goods within the supply chain. Each product is assigned a unique identifier, such as a QR code or barcode, which is linked to its corresponding entry on the blockchain. This immutable record ensures that the entire lifecycle of a product, from its manufacturing to its sale to the end consumer, is transparent and traceable. Any attempt to tamper with the data recorded on the blockchain is immediately detected, making it extremely difficult for counterfeiters to manipulate the supply chain.
- **Authentication and Verification:** QR codes and barcodes are commonly used as authentication mechanisms in blockchain-enabled supply chain systems. Consumers can easily scan these codes using their smartphones to verify the authenticity of a product and access detailed information about its origin, manufacturing process, and distribution history. By providing consumers with real-time access to trusted information, blockchain-based authentication systems empower them to make informed purchasing decisions and avoid counterfeit products.
- **Supply Chain Transparency:** Blockchain technology enhances transparency throughout the supply chain by providing visibility into every stage of the product lifecycle. Manufacturers, suppliers, distributors, and retailers can access a shared ledger that contains accurate and up-to-date information about inventory levels, shipment status, and product authenticity. This transparency reduces the risk of counterfeit products entering the supply chain undetected and enables stakeholders to quickly identify and address any discrepancies or anomalies.

- **Fraud Prevention:** The transparency and immutability of blockchain records act as a deterrent to fraud and counterfeiting. Blockchain-based supply chain systems use cryptographic techniques to secure data and transactions, making it nearly impossible for unauthorized parties to tamper with or alter the information stored on the blockchain. This high level of security and integrity reduces the risk of fraud and ensures that all participants in the supply chain can trust the accuracy and authenticity of the data.
- **Consumer Trust and Brand Reputation:** By implementing blockchain-based counterfeit prevention measures, companies can enhance consumer trust and protect their brand reputation. Consumers are increasingly demanding transparency and accountability from the brands they support, and blockchain technology provides a tangible way for companies to demonstrate their commitment to product quality and authenticity. By leveraging blockchain-enabled authentication systems, companies can build trust with consumers, differentiate themselves from competitors, and safeguard their brand reputation against the negative impacts of counterfeit products.

In summary, blockchain technology has a transformative impact on counterfeit prevention in supply chains by enabling immutable recordkeeping, authentication and verification, supply chain transparency, fraud prevention, and enhanced consumer trust. By leveraging the unique capabilities of blockchain, companies can effectively combat the proliferation of counterfeit products and build a more secure, transparent, and trustworthy supply chain ecosystem.

5.6 SCALABILITY AND PERFORMANCE

Scalability and performance are crucial considerations in the implementation of blockchain-based systems for counterfeit prevention and supply chain management. As blockchain technology continues to gain traction across various industries, addressing scalability challenges and optimizing performance becomes essential for ensuring the effectiveness and viability of these systems. Several factors influence the scalability and performance of blockchain solutions:

- **Transaction Throughput:** The throughput of a blockchain network refers to the number of transactions it can process per unit of time. Scalability issues arise

when the transaction throughput of a blockchain network is insufficient to handle the volume of transactions generated by supply chain operations. To improve scalability, blockchain platforms need to implement solutions such as sharding, off-chain processing, or layer-two scaling solutions like sidechains and state channels.

- **Network Congestion:** As more transactions are added to a blockchain network, network congestion may occur, leading to delays in transaction confirmation and increased transaction fees. Scalability solutions aim to alleviate network congestion by optimizing block size, transaction prioritization, and network bandwidth allocation. Additionally, implementing a consensus mechanism that can accommodate a large number of transactions without compromising security is essential for ensuring the scalability of blockchain networks.
- **Data Storage and Retrieval:** Blockchain networks store a vast amount of data, including transaction history, smart contracts, and other metadata. As the size of the blockchain grows, storing and retrieving data becomes increasingly resource-intensive, impacting overall system performance. Scalability solutions may involve implementing data pruning techniques, distributed storage solutions, or archival nodes to manage data storage efficiently and reduce latency in data retrieval.
- **Consensus Mechanisms:** The consensus mechanism used in a blockchain network significantly impacts its scalability and performance. Traditional consensus mechanisms like Proof of Work (PoW) and Proof of Stake (PoS) may have limitations in terms of transaction throughput and energy consumption. Newer consensus algorithms such as Proof of Authority (PoA), Delegated Proof of Stake (DPoS), and Practical Byzantine Fault Tolerance (PBFT) offer improved scalability and performance by reducing the computational overhead associated with transaction validation.

Addressing scalability and performance challenges requires a holistic approach that considers various technical, architectural, and operational factors.

CHAPTER 6

CONCLUSION

The blockchain-based supply chain quality management project represents a pioneering journey towards transforming the way we authenticate products and ensure supply chain transparency. In this conclusion, we reflect on the project's journey, its achievements, and the broader implications of its implementation.

6.1 SUMMARY

From its inception, this project was driven by a vision to combat the pervasive issue of counterfeit products, enhance supply chain transparency, and empower consumers to make informed purchasing decisions. Through the integration of cutting-edge technologies, the project has successfully realized this vision.

Beyond Counterfeit Detection:

While the project's primary focus was on counterfeit product detection, it has broader implications. It lays the foundation for a new era of supply chain management, one characterized by transparency, efficiency, and security. The blockchain's decentralized nature and immutability provide a robust framework for recording and verifying transactions, not limited to product authenticity alone.

Enhancing Global Collaboration:

One of the standout features of the project is its potential to enhance global collaboration. In an increasingly interconnected world, where products traverse borders and markets, the need for a unified, secure, and transparent supply chain system is paramount. The blockchain-based solution aligns with this need, facilitating global collaboration by ensuring that supply chain information is readily accessible and reliable.

Challenges and Open Problems:

However, challenges remain. The project faces issues such as the time-consuming nature of Radio Frequency Identification (RFID) in a blockchain-based system. Additionally, complex smart contract systems require further development to enhance efficiency.

Feasibility and Risk Analysis:

The project has conducted a comprehensive feasibility and risk analysis, ensuring that it remains economically viable and anticipates and mitigates potential risks. This approach safeguards the project's sustainability and resilience.

Project Management:

A robust project management plan and detailed financial planning have been essential in steering the project from its initiation through development, testing, deployment, and full-scale operations. These plans have been instrumental in ensuring that the project remains on course and financially viable.

6.2 A BLUEPRINT TO THE FUTURE:

In summary, this project serves as a blueprint for the future of supply chain quality management. Its innovative approach combines blockchain technology, QR/barcode systems, and user rewards to create a transparent, secure, and collaborative supply chain ecosystem. The project's accomplishments extend beyond counterfeit detection, providing a foundation for an interconnected global supply chain network that can be adopted across industries.

A Collective Achievement:

The success of this project is not the result of individual efforts but a collective achievement. It demonstrates the power of collaboration, innovative thinking, and the relentless pursuit of a transparent and secure supply chain. The project team, stakeholders, and all those who contributed have played a pivotal role in advancing supply chain quality management.

Looking Ahead:

As we conclude this project, we look ahead to a future where supply chain quality management is synonymous with transparency, trust, and authenticity. The journey doesn't end here; it is the beginning of a new era in supply chain management. The blockchain-based system, with its user reward feature and QR/barcode technology, will continue to evolve and adapt, providing a beacon of light in the fight

against counterfeit products and ensuring a brighter, more secure future for all stakeholders in the supply chain.

As we conclude this project on blockchain-enabled supply chain management for counterfeit prevention, it is essential to reflect on the significance of our efforts and the impact they can have on the broader landscape of commerce and consumer safety. Throughout this endeavor, we have strived to address the pressing challenges posed by counterfeit products in today's global marketplace and offer innovative solutions leveraging blockchain technology. Our project represents a holistic approach to supply chain management, combining the transparency and security of blockchain with the efficiency and accessibility of QR/barcode technology to authenticate products and ensure trust and authenticity.

By implementing a QR/barcode-based tracking system integrated with blockchain, we have empowered consumers to make informed purchasing decisions, strengthened trust between consumers and businesses, and fortified the fight against counterfeit products. The real-time access to product origin and supply chain history provided by our solution not only enhances consumer confidence but also enables businesses to protect their brand reputation and uphold their commitment to quality and authenticity. Moreover, our project's use of Firebase as a centralized secondary database has enabled us to reduce transaction costs for repeated queries, enhancing the efficiency and scalability of our system. The integration of tools like Truffle, MetaMask, and Ganache has further streamlined the development and deployment of smart contracts on the Ethereum blockchain, ensuring seamless interaction and interoperability within our ecosystem.

Looking ahead, we envision our project making a significant impact on the global fight against counterfeit products, fostering trust and transparency in supply chains across diverse industries. By continuing to innovate and collaborate with stakeholders, we can further refine and optimize our solution to meet the evolving needs of the marketplace and contribute to a safer and more trustworthy consumer experience. In conclusion, our project represents a pioneering effort to leverage blockchain technology for counterfeit prevention and supply chain management, with the ultimate goal of enhancing transparency, trust, and authenticity in the global marketplace.

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APPENDIX

A. SOURCE CODE

Products.sol

```
pragma solidity ^0.8.12;

contract product {

    uint256 sellerCount;
    uint256 productCount;

    struct seller{
        uint256 sellerId;
        bytes32 sellerName;
        bytes32 sellerBrand;
        bytes32 sellerCode;
        uint256 sellerNum;
        bytes32 sellerManager;
        bytes32 sellerAddress;
    }
    mapping(uint=>seller) public sellers;

    struct productItem{
        uint256 productId;
        bytes32 productSN;
        bytes32 productName;
        bytes32 productBrand;
        uint256 productPrice;
        bytes32 productStatus;
    }

    mapping(uint256=>productItem) public productItems;
```

```

mapping(bytes32=>uint256) public productMap;
mapping(bytes32=>bytes32) public productsManufactured;
mapping(bytes32=>bytes32) public productsForSale;
mapping(bytes32=>bytes32) public productsSold;
mapping(bytes32=>bytes32[]) public productsWithSeller;
mapping(bytes32=>bytes32[]) public productsWithConsumer;
mapping(bytes32=>bytes32[]) public sellersWithManufacturer;
//SELLER SECTION
function addSeller(bytes32 _manufacturerId, bytes32 _sellerName, bytes32
_sellerBrand, bytes32 _sellerCode,
uint256 _sellerNum, bytes32 _sellerManager, bytes32 _sellerAddress) public{
    sellers[sellerCount] = seller(sellerCount, _sellerName, _sellerBrand,
_sellerCode,
    _sellerNum, _sellerManager, _sellerAddress);
    sellerCount++;

    sellersWithManufacturer[_manufacturerId].push(_sellerCode);
}

function viewSellers () public view returns(uint256[] memory, bytes32[] memory,
bytes32[] memory, bytes32[] memory, uint256[] memory, bytes32[] memory, bytes32[]
memory) {
    uint256[] memory ids = new uint256[](sellerCount);
    bytes32[] memory snames = new bytes32[](sellerCount);
    bytes32[] memory sbrands = new bytes32[](sellerCount);
    bytes32[] memory scodes = new bytes32[](sellerCount);
    uint256[] memory snums = new uint256[](sellerCount);
    bytes32[] memory smanagers = new bytes32[](sellerCount);
    bytes32[] memory saddress = new bytes32[](sellerCount);

```

```

for(uint i=0; i<sellerCount; i++){
    ids[i] = sellers[i].sellerId;
    snames[i] = sellers[i].sellerName;
    sbrands[i] = sellers[i].sellerBrand;
    scodes[i] = sellers[i].sellerCode;
    snums[i] = sellers[i].sellerNum;
    smanagers[i] = sellers[i].sellerManager;
    saddress[i] = sellers[i].sellerAddress;
}
return(ids, snames, sbrands, scodes, snums, smanagers, saddress);
}

```

//PRODUCT SECTION

```

function addProduct(bytes32 _manufactuerID, bytes32 _productName, bytes32
_productSN, bytes32 _productBrand,
uint256 _productPrice) public{
    productItems[productCount] = productItem(productCount, _productSN,
_productName, _productBrand,
_productPrice, "Available");
    productMap[_productSN] = productCount;
    productCount++;
    productsManufactured[_productSN] = _manufactuerID;
}

```

B. SCREENSHOTS

PROVENANCE PRO Home Add Product Add Seller Sell Product To Seller Query Seller manufacturer

Add Product

Manufacturer ID	wtPluQysuLVFU3N9L4igE7Mg3ZK2	Product Name	TEST NAME
Product SN:	ii	Product Brand	TEST BRAND
Product Price	999		

Add the Product



Download QR Code

Fig B.1 Add product Screen

PROVENANCE PRO Home Add Product Add Seller Sell Product To Seller Query Seller Browsersync: connected

Add Seller

Seller Name		Seller Brand	
Seller Code		Seller Phone Number	
Seller Manager		Seller Address	
Manufacturer ID	wtPluQysuLVFU3N9L4igE7Mg3ZK2		

Add the Seller

Fig B.2 Add Seller Screen

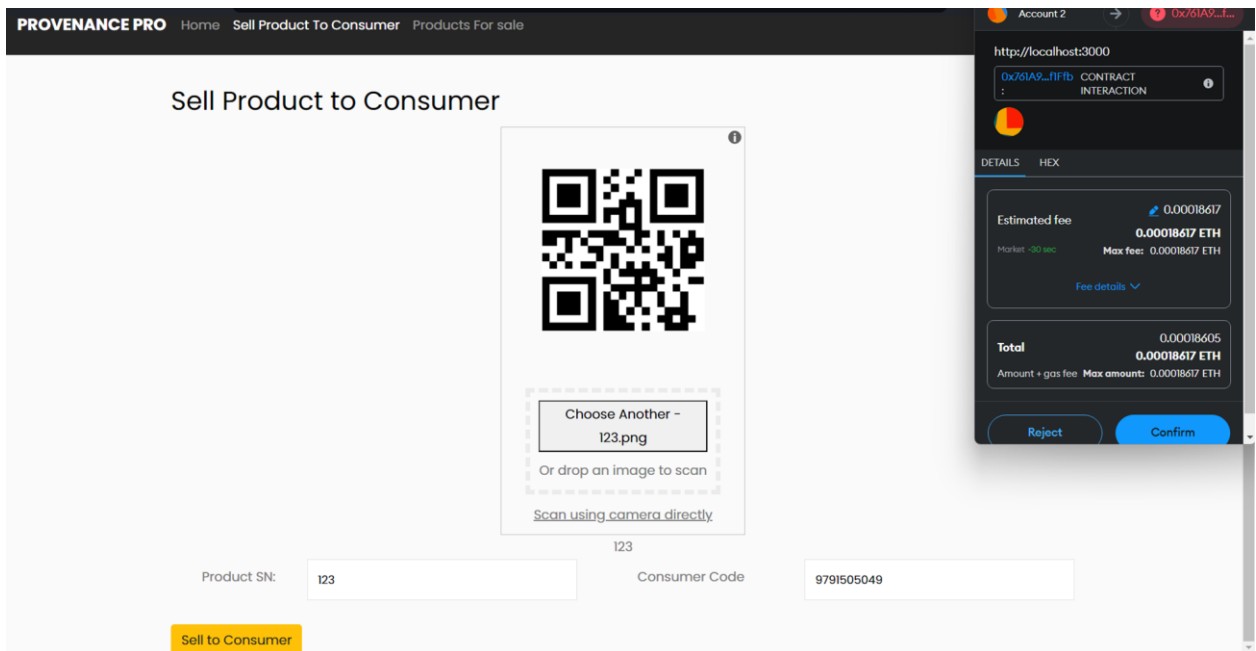


Fig B.3 Sell Product Screen

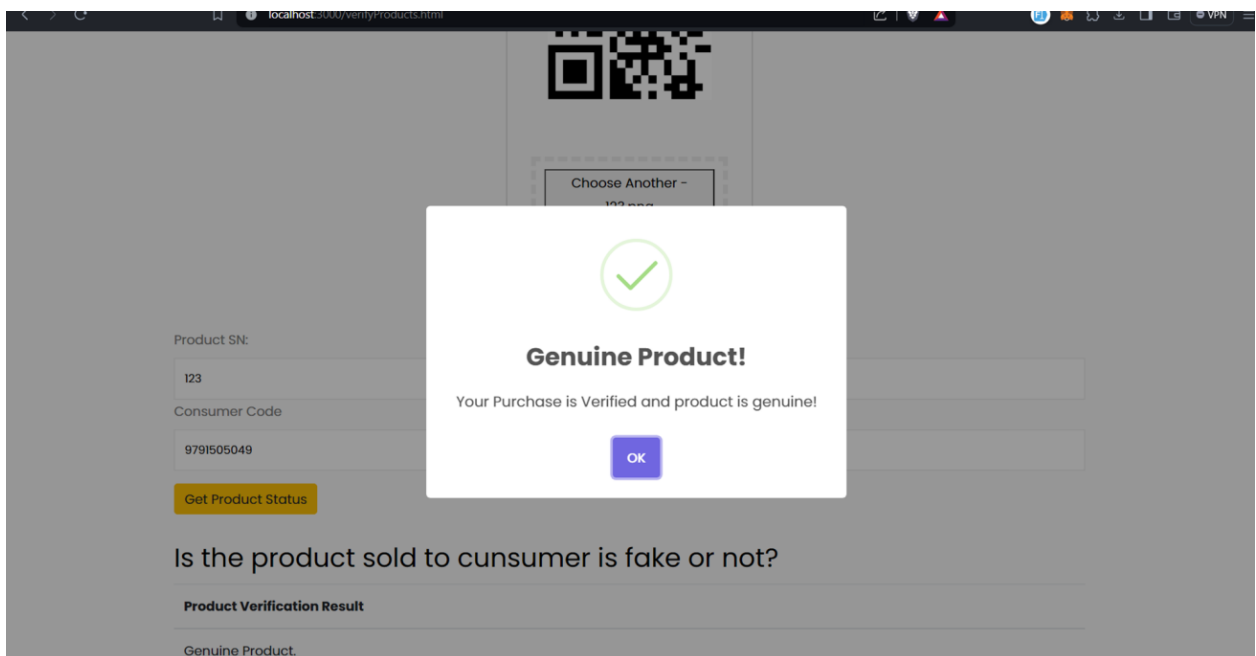


Fig B.4 Product Verification Screen

C. RESEARCH PAPER

Blockchain-Enabled Supply Chain Management for Authenticating Products Using QR with Firebase Integration

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Abstract—This research work makes use of blockchain technology to eliminate forged products in the global marketplace. It establishes a secure supply chain with smart contracts and QR code authentication. Manufacturers add products to the blockchain, Sellers sell those products to the users and register the sale in the blockchain network. Users verify authenticity through QR codes. This system combines the benefits of centralized storage system and decentralized storage techniques like blockchain. This approach fosters trust, safeguards against manipulation, and enhances supply chain integrity on a global scale.

Keywords—Supply Chain Management, Blockchain, Quick Response, Counterfeit Product Detection, Firebase

I. INTRODUCTION

Supply chain management is a critical aspect of marketplace impacting businesses, consumers, and the global economy. The effective functioning of supply chains is essential for the delivery of genuine products, cost-efficiency, and consumer trust. However, supply chains often face challenges such as counterfeit products, lack of transparency, and inefficiencies. To address these issues, this research explores a groundbreaking work that integrates blockchain technology with QR/barcode systems to authenticate products and enhance supply chain transparency.

1) The manufacturing and marketing of counterfeit or duplicate products arise significant financial, health, and safety threats to consumers, resulting in economic losses for original manufacturers and businesses. It undermines trust among business partners and consumers. To tackle these challenges, a blockchain-based system is proposed, which can identify genuine products and detect counterfeit ones. In this research work, emerging wireless technology trends, Quick Response (QR) codes, and barcodes are harnessed to combat counterfeiting. The unique feature of this research work is the incorporation of a user reward system, global collaboration, and warranty verification to enhance the capabilities of the blockchain-enabled supply chain management system.[5]

2) The primary objective of this research work is to develop a robust blockchain-based supply chain management system that allows consumers to authenticate products by scanning QR codes or barcodes. By linking these codes to a blockchain, the system securely stores product details, creating a digital ledger of product history. When a consumer scans a product, the system compares the code with the blockchain data to verify its authenticity, thereby reducing reliance on merchants for product authentication. We can also overcome the drawback of delay in the processing by integrating a centralized database to provide a seamless experience to the users.[2]

3) The System Features includes a QR/Barcode Authentication. One of the work's core features is the use of QR codes and barcodes to enable consumers to easily and efficiently authenticate products.

a) Blockchain technology serves as the bedrock of the work, ensuring data immutability and security. By recording product details on the Ethereum blockchain, the system creates an unalterable digital ledger of a product's history, bolstering trust and transparency.

b) The work's core mission is to identify counterfeit products through QR code and barcode scanning, allowing consumers to make well-informed purchasing decisions and businesses to protect their brand reputation.

c) The major drawback of the existing system is the delay in the processing of data, when the number of nodes is less or the amount of data to be processed is huge. To overcome this problem and provide quick responses to the user we have integrated the blockchain with the Firebase Firestore.

II. LITREATURE SURVEY

The foundation of this research work lies in the comprehensive analysis of the issues surrounding counterfeit products and their varied impact. The base paper provided critical insights into the challenges faced by businesses and consumers and laid the groundwork for the incorporation of blockchain technology as a potent solution. The work extends beyond the base paper's findings by integrating Firebase Firestore and providing a seamless experience to the users. These elements significantly enhance the work's facilities and contribute to its comprehensive nature.

The blockchain based supply chain management system covers the basic idea of supply chain management on agricultural products. It speaks about implementing blockchain into agricultural product management. [1][4]

The Study on Practical limitations of Ethereum Blockchain highlights the problems with the existing blockchain based decentralized system. One of the major problems that the research work highlights is the delay in the data processing by permissionless blockchain. This issue is faced by many blockchain based systems and prevent them from scaling up.[7]

The significance in the exploration of Blockchain technology as a viable solution to the forementioned issues. Blockchain is presented as a transformative technology capable of efficiently and transparently managing data. It highlights how Blockchain can streamline transaction authorization and verification without the need for intermediary third parties, thereby enhancing the overall efficiency of supply chain process [3].

The paper emphasizes blockchain's potential to enhance efficiency, reliability, and transparency in the overall supply chain while optimizing inbound processes. Identifying a lack of standard methodology in designing blockchain solutions for non-financial applications, the paper aims to address this gap. It integrates existing literature, creating a standardized methodology for designing blockchain use cases and integrating them into business strategy, with a specific focus on digital strategy. [6]

The integration of blockchain technology in supply chain management is a rapidly growing and evolving field of study. The systematic literature review approach is employed to analyze 103 review papers, highlighting the multifaceted impact of blockchain on supply chain operations. The distinctive features of blockchain, such as transparency, trust assurance, and real-time updates, make it a promising alternative for enhancing supply chain performance. The technology's potential lies in its ability to establish a synchronized network among various stakeholders, supporting information sharing, process monitoring, and decision-making across different industries. The paper aims to outline the current state of the art in this emerging field and identify key areas for future research exploration. [10]

III. EXISTING SYSTEM

The existing system in blockchain-enabled supply chain quality management faces several open challenges that demand further research and innovation. These challenges, extracted from comprehensive literature surveys, include complexities in integrating blockchain with existing systems, the need for more efficient smart contract design, scalability concerns, interoperability issues between diverse blockchain platforms, and the importance of regulatory compliance. Additionally, the existing system requires improvements in user-friendly interfaces, data privacy mechanisms, and cost management strategies. Addressing these challenges through focused research efforts will be crucial for unlocking the full potential of blockchain technology in enhancing transparency, authenticity, and overall quality in supply chains across diverse industries.

IV. PROPOSED SYSTEM

3.1 ARCHITECTURE

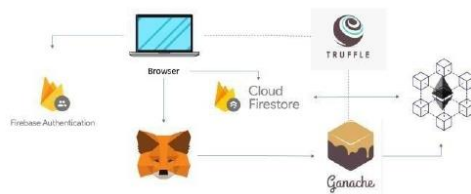


Fig. 3.1 System Architecture

The overall architecture (Fig 3.1) of the system comprises of both centralized and decentralized technologies like Firebase Authentication, Firebase Firestore, Ethereum Blockchain network, Metamask, Ganache and Truffle Suite.

Firebase Authentication is utilized for secure user authentication, Firebase Authentication ensures that only authorized individuals can interact with the blockchain-enabled supply chain management system.

Cloud Firestore is integrated as a decentralized storage solution, Cloud Firestore enhances data management and retrieval, contributing to the reliability and scalability of the project's supply chain information storage. Implementing fault-tolerant measures and ensuring redundancy in data storage can enhance system reliability.

The Ethereum blockchain network is the backbone of the project, facilitating secure and transparent transactions while making use of smart contracts for automating supply chain processes and ensuring authenticity verification through QR code authentication. [9] Blockchain facilitates the verification and traceability of multistep transactions that require verification and traceability. It can ensure secure transactions, lower compliance expenses, and accelerate data transfer processing.

Truffle is employed for smart contract development, offering a development environment, testing framework, and asset pipeline that streamlines the creation and deployment of smart contracts within the supply chain management system. Metamask serves as a crucial component for browser-based blockchain interaction, enabling users to access and engage with the Ethereum blockchain seamlessly through their web browsers, facilitating secure and user-friendly transactions.

Ganache is used for local blockchain testing, Ganache provides a personal blockchain environment, allowing developers to simulate and test various scenarios before deploying the supply chain management system to the live Ethereum blockchain.

Performance can be enhanced by optimizing the blockchain transactions. Implementing caching mechanisms, optimizing smart contracts, and utilizing efficient data structures can improve system responsiveness

3.2 WORKFLOW

In this blockchain-based product verification system, the overall workflow (Fig 3.2) seamlessly connects three key stakeholders: manufacturers, sellers, and customers. The process begins with the manufacturer, who logs into the system to manage their products and distribution network. The manufacturer has the capability to add new products to the system, initiate sales to sellers, query information about sellers, and add new sellers to the network. Sellers, in turn, log in to their dedicated space and engage in activities such as scanning QR codes to sell products to customers and querying information about their existing inventory. Finally, customers log in to verify the authenticity of their purchased products by scanning product QR codes and also have the ability to query information about their purchases.

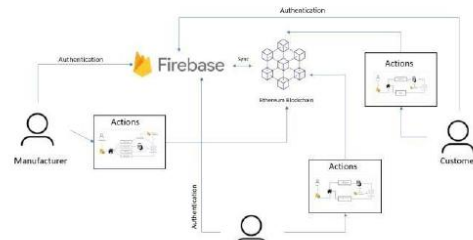


Fig. 3.2 Workflow

Manufacturers (Fig 3.3) start by logging into the system and navigating to their home page. From here, they can seamlessly add new products to the system. Additionally,

manufacturers can initiate sales to sellers by strategically assigning products. To ensure a robust distribution network, manufacturers can query information about sellers in the system. Furthermore, they can add new sellers, streamlining the process of onboarding new partners and expanding the reach of their products.

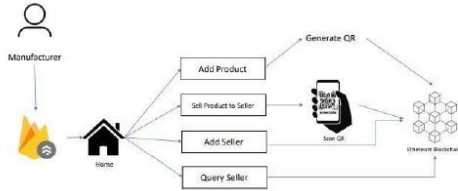


Fig: 3.3 Manufacturer workflow

Upon logging in, sellers (Fig 3.4) are directed to their home page, offering a comprehensive dashboard for their operations. Sellers engage in transactions by scanning product QR codes to efficiently sell products to customers. The system also allows sellers to query information about their existing inventory, aiding in real-time decision-making and inventory management. This streamlined workflow ensures that sellers can focus on providing quality products and efficient services to customers, fostering a trustworthy and reliable network.

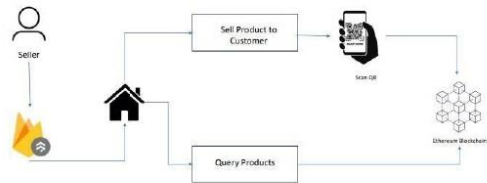


Fig: 3.4 Seller workflow

Customers (Fig 3.5), after logging into the system, access their home page, where they can effortlessly scan QR codes to verify the authenticity of their purchased products. This verification process instills confidence in customers, assuring them of the legitimacy of the products they own. Additionally, customers have the convenience of querying information about their purchases, facilitating. Overall, the customer workflow aims to enhance the consumer experience by providing a reliable mechanism for product verification and information retrieval.

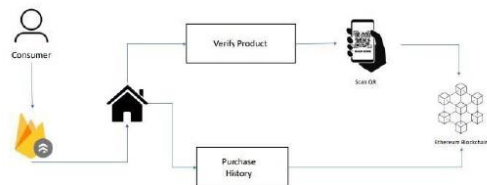


Fig: 3.5 Consumer Workflow

3.4 METHODOLOGY AND IMPLEMENTATION

The implementation of the product verification system involves a diverse approach, integrating blockchain technology, smart contracts, user interface development, and cloud services for authentication and data storage.

The system's foundation is rooted in the locally deployed Ethereum blockchain using Ganache. This provides a secure and decentralized ledger for recording and validating transactions related to product authentication. The use of Ethereum ensures transparency and immutability in the verification process.

The logic governing the interactions on the blockchain is implemented through smart contracts. The Truffle Suite facilitates the deployment of these contracts, and Solidity.js is utilized for writing the smart contract code. These contracts handle operations such as adding new products, recording sales, and facilitating queries, ensuring the integrity of the data on the blockchain.

The user interface is crafted using HTML, CSS, and JavaScript. This interface provides a seamless experience for manufacturers, sellers, and customers to interact with the system. Manufacturers can add products, sellers can scan and sell products, and customers can verify their purchases with ease, all through an intuitive and user-friendly interface.

Authentication is employed to secure the user interactions with the system. This robust authentication mechanism ensures that only authorized users can access and perform actions within their respective workflows. Firebase Authentication adds an extra layer of security to the product verification process in addition to the blockchain's immutability and transparency, addressing trust and transparency challenges prevalent in traditional supply chain systems.

Firestore, as a NoSQL database in the Firebase suite, is utilized to store and manage data related to user requests, transactions, and product information. Firebase Functions are written to interact with Firestore, providing real-time updates and seamless integration between the blockchain and the user interface. When a user places a request, it is instantly updated in Firestore, eliminating the need for users to wait for blockchain network confirmations. This asynchronous approach enhances user experience by providing immediate feedback while the blockchain processes the request in the background.

The execution combines the robust security of a local Ethereum Blockchain with the streamlined efficiency of smart contracts and a user-friendly interface, Firebase for authentication, and Firestore for real-time data updates. This holistic approach ensures a reliable and responsive product verification system for manufacturers, sellers, and customers.

I. RESULTS AND CONCLUSION

4.1 RESULTS

- a) The integration of QR/barcode technology with blockchain has proven highly effective in identifying and eliminating counterfeit products. Real-time tracking ensures swift responses to any anomalies in the supply chain.
- b) The work has successfully enhanced transparency within supply chains.

- c) Consumers and businesses can now access detailed and real-time information about a product's journey from its origin to the end consumer, instilling trust and confidence.
- d) The delay in the processing of data by the blockchain network is not affected to the users as we have integrated a centralized system which processes data instantly and makes the user session available for other activities instead of waiting for the processing time. The centralized database syncs with the decentralized network time to time.[2]

4.2 CONCLUSION

In conclusion, this research work marks a significant stride in combating counterfeit products and fortifying supply chain integrity. The integration of blockchain, QR/barcode technology, and user rewards has demonstrated not only technical resilience but has also generated positive socio-economic effects. The demonstrated success in counterfeit detection, user engagement, and supply chain transparency showcases the potential of blockchain solutions in addressing complex real-world challenges. As we progress, the scalability of this model to broader industries and its potential for continuous refinement open avenues for further exploration and innovation in supply chain management. This research serves as a testament to technology's transformative influence in guaranteeing product authenticity and fostering trust across global supply networks.

4.3 FUTURE WORKS

The API endpoints derived from the Firebase Firestore database offer a versatile framework for the development of diverse applications. By expanding these endpoints, a robust e-commerce ecosystem emerges, empowering manufacturers to manage products seamlessly, sellers to create customizable storefronts and analyze sales intricately, and customers to benefit from real-time order tracking and delivery updates. The system can evolve into an advanced inventory management tool, a comprehensive Customer Relationship Management system, and a supply chain management solution. Blockchain integration via APIs ensures secure loyalty programs, while exploring emerging technologies enhances the user experience. The platform's adaptability extends to multi-channel selling and global outreach, supporting multiple languages and currencies, creating a dynamic and future-proof system for a variety of industries.

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D. LETTER OF ACCEPTANCE

	7th International Conference on Inventive Computation Technologies ICICT 2024 24-26, April 2024 ~ Lalitpur, Nepal	icict.conf@gmail.com www.icicts.com/2024
Letter of Acceptance		
Author Name: Sanjay Krishna S R, Pon Raja Prabhu S K, T. Prem Jacob		
Affiliation Details: Department of Computer Science and Engineering, Sathyabama Institute of Science & Technology, Chennai, India Dear Author:		
It is with great pleasure that we extend our warmest congratulations to you on the acceptance of the paper titled ""Blockchain-Enabled Supply Chain Management for Authenticating Products Using QR with Firebase Integration""- PAPER ID: ICICT-188 for presentation at the 7th International Conference on Inventive Computation Technologies, scheduled to be held in Lalitpur, Nepal, from April 24th to April 26th, 2024.		
Your submission was subjected to a rigorous review process, and the result that your paper has been selected for inclusion in our conference program. We believe that your contribution will greatly enrich the discussions and knowledge exchange at our event.		
Your participation will undoubtedly contribute to the success of the 7th International Conference on Inventive Computation Technologies.		
Once again, congratulations on your acceptance, and we anticipate your valuable contribution to our conference.		
 Prof. Dr. Subarna Shakya Conference Chair - ICICT 2024		
Proceedings by 		