Interim Report

Supply Chain Management using Blockchain and Non-Fungible Tokens

*Increasing Transparency & Traceability*

<table>
<thead>
<tr>
<th>Group Member</th>
<th>UID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agarwal, Siddharth</td>
<td>3035555482</td>
</tr>
<tr>
<td>Bera, Navoneel</td>
<td>3035551735</td>
</tr>
<tr>
<td>Lohia, Suyash</td>
<td>3035550406</td>
</tr>
</tbody>
</table>

Supervisor: Dr. Yuen, John

Date of Submission: 22/01/2022
Abstract

Rapid globalisation and advancing technologies have connected the world, leading to businesses constantly trying to improve their supply chain for customer satisfaction and financial growth. Current solutions lack traceability and transparency with companies facing a 20% loss in goods every year. This report offers a potential solution by providing a blockchain-powered platform comprising a web and mobile application that utilises the power of NFTs. The supply chain member will transfer and accept the goods through the application that inherently conducts this process through tokenization of goods into NFTs. The Ethereum Blockchain is used because of its immutable nature, decentralisation and support of NFTs which further assist in the traceability of ownership. The businesses will be able to track the goods through another web portal offered as a part of the platform. The consumers will also be able to view and trace the origin of products at a store through the mobile application. Certain limitations have been identified in the platform, the key one revolving around the traceability of homogeneous goods from different suppliers. The current progress has revolved around research regarding the technical implementation, development of the mobile application for the supply chain members, and the tokenization of products into NFTs. The next steps involve integration of the application with the NFT tokenization process and creating the web dashboard for the supply chain managers. The report highlights the implementation, feasibility as well as the schedule for project development. Additionally, future plans include integration with Enterprise Resource Planning to create a trusted and traceable supply chain management system with features of accounting and smart analytics.
Acknowledgement

We would like to express our gratitude to the supervisor of this final year project, Dr. John Yuen, for his guidance and support. We are also thankful to the Department of Computer Science, HKU for providing us with this opportunity.
List of Figures

Figure 1. Anatomy of blockchain 10
Figure 2. High-level overview of the product workflow 13
Figure 3. Overview of Tokenization structure 14
Figure 4. Frontend Project Structure 17
Figure 5. Backend Project Structure 18
Figure 6. Database User Model 18
Figure 7. Minted NFT containing metadata 19
Figure 8. NFT Transfer logs 19
List of Tables

Table 1. Schedule 16
Abbreviations

**API**: Application Programming Interface  
**dApp**: Decentralized Application  
**ERP**: Enterprise Resource Planning  
**MERN**: MongoDB, Express, React, Node  
**NFT**: Non-Fungible Tokens  
**SaaS**: Software as a Service  
**SCM**: Supply Chain Management  
**UI/UX**: User Interface/ User Experience
# Table of Contents

List of Figures 3
List of Tables 4
Abbreviations 5

1. Introduction 7
   1.1 Background 7
   1.2 Objective 8
   1.3 Scope and Deliverables 8
   1.4 Outline 8

2. Literature Review 10
   2.1 Technology Review 10
      2.1.1 Blockchain 10
      2.1.2 NFT - Non-Fungible Tokens 11
   2.2 Related Works 11

3. Proposed Methodology 13
   3.1 Application Workflow 13
   3.2 Implementation & Feasibility 13
      3.2.1 Blockchain: Ethereum 14
      3.2.2 Backend: Express, NodeJS & Solidity 15
      3.2.3 Database: MongoDB 15
      3.2.4 Frontend: React Native & ReactJS 15

4. Project Progress 16
   4.1 Schedule 16
   4.2 Technical Research 16
   4.3 Mobile Application Development 17
      4.3.1 Major Screens 17
      4.3.2 Frontend Development 17
      4.3.3 Backend Development 18
      4.3.4 Database Development 18
   4.4 Tokenization of Goods 19

5. Discussion 20
   5.1 Limitations 20
   5.2 Challenges 20
   5.3 Next Steps 20
   5.4 Future Plan 21

6. Conclusion 22
References 23
1. Introduction

With rising globalisation and advancing technologies, businesses across the world are becoming increasingly connected [1]. Supply chain management (SCM) plays an integral role in this and needs to suffice the needs of the companies for their better growth. Additionally, the end consumer also benefits from the supply chains since the product reaches them faster. Hence, a trusted SCM platform that improves on existing solutions is required.

1.1. Background

A supply chain does not solely consist of a producer (company) and consumer (customer). It can be defined as a network of different “entities” that are involved in the transfer or movement of goods and services from a source to the end consumer [2]. This can include different kinds of producers as well as suppliers. For example, Wellcome will need to interact with different kinds of manufacturers and suppliers for its vast variety of products. Hence, for efficient management, all the entities need to collaborate and cooperate with each other.

Successful SCM increases customer satisfaction, reduces operating expenses and improves the financial position of a company [3]. In the current competitive scenario, SCM seems to be becoming increasingly necessary. There has been a paradigm shift from “store versus store” to “supply chain versus supply chain” [4]. Alongside the consumers, businesses also want the goods readily available, authentic and cost-effective. Consequently, a robust management system which manages risk, is traceable, and provides “visibility” to all members of the chain is becoming essential [5].

The importance of the SCM market can also be quantified through its market size. From being worth 15.85 billion USD in 2020, it is expected to double in size by 2026 [6]. Any loss of goods incurred in the supply chain can have a drastic impact on the business. According to [7], companies suffer around 20% loss in their inventory every year due to mismanagement and untraceability of their products in the supply chain. Therefore, businesses across the world are investing highly in their supply chains to improve their processes.
1.2. Objective

This project aims to develop a substitute for the current SCM systems which provides traceability and transparency, not only to the companies involved but also to the consumers. It will be a blockchain-based application that will utilise Non-Fungible Tokens (NFTs) for tracking the goods being transferred in the supply chain. A web application will be developed to serve the companies specifically as well as a mobile application to cater to the needs of both consumers and companies.

From the perspective of the companies, the application will provide a one-stop shop to improve the SCM. The management can track every product on the application with each good being an NFT and present on the blockchain. The consumer will not only be able to view the products in a particular store through the mobile application, but also have these two advantages: first, trace the origin of items to confirm ethical sourcing practices are met and second, confirm the authenticity of luxury goods to combat the circulation of counterfeit goods in the supply chain.

1.3. Scope and Deliverables

In order to fulfil the objectives, the team aims to deliver the following: An implementation of the blockchain so that tokenization and transfer of goods become possible; An easy to use web interface for companies to input and track the goods; A user-friendly mobile application for companies to transfer goods and consumers to view them. With a mobile and web application based on blockchain that utilises NFT for certified exchange of goods, the project will provide a trusted, transparent, and reliable alternative to all stakeholders of the supply chain. Although the scope of this project will be to complete the aforementioned deliverables, the team’s vision is to provide additional features, such as accounting and data analytics, as a SaaS (Software As A Service) platform which can help revolutionize the supply chain.

1.4. Outline

The purpose of this report is to present a technologically driven solution for SCM. It first specifies the problems in SCM followed by introducing a blockchain-powered application that will be beneficial to both producers and consumers. Having highlighted the scope of the project, it expands upon the technology behind the solution which then leads on to the
proposed implementation of the product. Furthermore, it gives an account of the current progress and limitations of the project. Lastly, it describes the future improvements and plans of the project.
2. Literature Review

To further understand the importance as well as the need of the solution, this section elaborates upon core technical components of the application followed by an explanation of related works in the field of SCM.

2.1. Technology Review

The project primarily utilises two technical components: Blockchain and NFT. The following section expands upon related findings of these technologies.

2.1.1. Blockchain

Blockchain is a digital ledger that acts as a shared database of all the transactions (data being injected on the blockchain) [8]. There is not just one location where data is stored but rather multiple locations because of which it is known as a “decentralised” database. Furthermore, all these transactions are immutable and non-editable. An additional feature of blockchain is inbuilt security since it makes use of cryptography [9].

All features can be accredited to the anatomy of the blockchain (Fig. 1). It consists of many blocks, the first one being the genesis block. All blocks have a hash value that represents their uniqueness. Apart from the first block, each of them also contains the stored data and the hash value of the previous block [10]. Consequently, if any data is tampered with, the hash value of the block changes, the chain breaks and the participants of the network can identify this issue. Since blockchain is distributed and based on a majority consensus, a hacker will require a massive amount of computational power to modify the blockchain [9].

![Fig. 1. Anatomy of blockchain](image)
In our project, the exchange of goods needs to be recorded and maintained for all members of the supply chain at multiple locations but having the same information. A member should have a record of the previous transactions but not be able to tamper with them. The importance of SCM for a business also demands the system to be secure. All of these requirements are fulfilled by the aforementioned features of the blockchain.

2.1.2. NFT - Non-Fungible Tokens

Fungibility of an item means it can be exchanged or replaced (For Example: Gold, currency) [11]. NFT is a unique non-fungible token and has a particular owner [12]. It is a digital unit of data stored on a few blockchains like Ethereum and Hyperledger, representing digital or real-life data. Like the concept of blockchain, the record of ownership of NFTs is immutable. Additionally, no two NFTs can be the same and cannot be interchanged. For example, the Mona Lisa is a piece of art that is unique. There can be multiple replicas that can be bought by many people, however, there is only one original owned by one party.

NFTs enable one to “buy and sell ownership” of items, the record of which is on the blockchain [11]. For the purposes of this project, all the products of the supply chain will be tokenized as NFTs and stored on the blockchain. Subsequently, through each step of the chain, the ownership of the product will be transferred by agreement between both parties. Additionally, the companies can trace the ownership of any product easily.

2.2. Related Works

There has been an advent of many technological solutions for SCM such as Enterprise Resource Planning (ERP) and the use of blockchain technologies. According to the Harvard Business Review [13], ERP is a tedious and expensive process with each member of the supply chain requiring a separate system. It further states how the members can only trace the goods with whom they have immediately interacted.

Blockchain has the power to solve the problems of ERP systems by providing traceability and a uniform solution [14]. There are giants like IBM who have developed a solution for SCM using blockchain. Their partnership with TradeLens (a company trading globally) wherein all trade transactions are continuously updated on the blockchain successfully reduced the
companies’ shipping time by 40% [15]. Nevertheless, blockchain solutions have limitations. Firstly, they are powered by “smart contracts” which provide traceability across all members but it is a difficult process [16]. Secondly, data stored on them can also be false data that has been added without mutual agreement.

To overcome the above limitations, this project aims to use NFTs along with blockchain technology wherein each product acts as an NFT. As mentioned earlier, since NFTs dictate ownership, they will be easily traceable. Moreover, the exchange of NFTs will require the participation of two members (sending and receiving) preventing the issue of false data.
3. Proposed Methodology

This section details the workflow of the application followed by explaining and justifying the technology implementation.

3.1. Application Workflow

Business management will input the goods required on the web interface. These goods can be based on different units (weight, quantity). During the transfer of goods, the first member of the supply chain needs to select the goods being transferred on the mobile application. The application, linked to the blockchain, will tokenize these goods into an NFT. In the entire supply chain, as physical goods are transferred, the relevant members will transfer or accept the NFT through the application, thereby relieving or taking ownership of the goods. If there is any loss of goods, the stakeholder can refuse to accept the NFT and the company is immediately informed regarding this event. Consequently, the company will be aware of the loss of goods at the actual step of the supply chain. Additionally, the transfer of NFT will allow the companies to track the goods through the web application (Fig. 2).

![Fig. 2. High-level overview of the product workflow](image)

3.2. Implementation & Feasibility

The following section provides an overview of different technologies. These are presented in an orderly manner discussing each technology's implementation and feasibility.
3.2.1. **Blockchain: Ethereum**

Blockchain forms the base of the application. We needed to decide between a custom or an existing blockchain. After extensive research, Ethereum was chosen. This was based on its support for NFTs, extensive library functions and built-in features of smart contracts and state databases. A lower fee for each transaction was also taken into consideration.

The modules for tokenization of goods and further transactions based on it have been built using the truffle suite on top of a node.js framework. Truffle is a development environment utilizing the EVM (Ethereum Virtual Machine) as a basis. The environment specializes in smart contract development and it features numerous functionalities that help dApp developers tremendously.

The code base contains different sections responsible for the tokenization of goods (Fig. 3):

- **Assets**: Contains any image, gif or other form of media to be associated with the NFT.
- **Contracts**: Contains all solidity files used to make migrations and interact with the blockchain network.
- **Data**: Contains the metadata for each NFT to be minted. All files are in JSON format.
- **Scripts**: Helper javascript files used to interact with third party services essential to create the NFT.

![Fig. 3. Overview of Tokenization structure](image)
3.2.2. **Backend: Express, NodeJS & Solidity**

The backend server will be created using Express, a Javascript framework based on NodeJS, a server-side programming language with vast built-in functionality. Solidity, an Ethereum supported language, will be on the server to create and execute contracts on the blockchain for NFT creation and transfer. We will be storing metadata about the goods such as type and quantity in the NFT. Homogenous items can also be grouped into one NFT thereby saving gas fees. The backend will not only interface with Ethereum and MongoDB libraries such as web3.js but also provide an application programming interface (API) for the frontend.

3.2.3. **Database: MongoDB**

MongoDB is a non-relational database that will be used to store information regarding users of the applications. It will be populated by the backend for each supply chain and used for verified access to the mobile application. The products of a supply chain will also be stored on it. It is highly flexible and has seamless integration with NodeJS and Express.

3.2.4. **Frontend: React Native & ReactJS**

With the backend being javascript driven, the frontend was also chosen of the same language. The mobile application will be created in React Native while the web application will be developed in ReactJS. React Native is a cross-platform library (allowing us to create both Android and iOS apps using a shared codebase) that will call the backend API for facilitating the NFT tokenization and exchange for companies. Consumers will have a separate interface to view the list of products and trace their origin. The web application will use the backend API to provide CRUD (Create, Read, Update, Delete) operations for product entry. It will also provide additional features for tracking packages and goods. Both the libraries have reusable components and a vast developer community.
4. **Project Progress**

This section introduces the development plan of the project. It then states the current progress of the application followed by discussing next steps.

4.1. **Schedule**

The project is divided into six different stages where each stage is considered an iteration to adhere to an Agile development process (Table 1). Every stage marks the completion of an important task essential for starting future tasks. The team is currently completing Stage 4.

*Table 1. Schedule*

<table>
<thead>
<tr>
<th>Stage</th>
<th>Task</th>
<th>Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>Research on the feasibility of different blockchains with respect to throughput and gas fees and further study on various NFT standards</td>
<td>4th - 29th October</td>
</tr>
<tr>
<td>Stage 2</td>
<td>Develop a module to tokenize goods based on information</td>
<td>1st - 15th Nov</td>
</tr>
<tr>
<td>Stage 3</td>
<td>Develop a pipeline to create and transfer NFTs across a blockchain network</td>
<td>16th Nov - 30th Dec</td>
</tr>
<tr>
<td>Stage 4</td>
<td>Develop a web and mobile interface which allows the initialization, transfer and tracking of NFTs</td>
<td>3rd Jan - 14th Feb</td>
</tr>
<tr>
<td>Stage 5</td>
<td>Build an interface for consumers using which the origin can be tracked and the authenticity can be verified.</td>
<td>15th Feb - 14th March</td>
</tr>
<tr>
<td>Stage 6</td>
<td>Test the entire product in iterative sprints and improve the UI/UX of interfaces.</td>
<td>15th March - 15th April</td>
</tr>
</tbody>
</table>

4.2. **Technical Research**

On account of the complexity of the project, the team decided to conduct research regarding the technologies used in the project. The primary step was to analyse blockchain and its current solutions for SCM. Thereafter, the concept of NFTs was explored. This research directed the team towards making decisions for development. Firstly, we decided to build upon existing blockchain solutions that are robust for both extensibility and ease. Secondly,
since NFTs are majorly supported on two blockchain platforms, Ethereum and Hyperledger, we analysed the two and selected Ethereum owing to an extensive developer community.

4.3. **Mobile Application Development**

Adhering to the methodology, the mobile application for the supply chain members has been created. ([Demo Link](#))

4.3.1. **Major Screens**

Six screens have been created for the mobile application. Each screen corresponds to a core functionality of the application. First, the ‘Login’ screen allows both supply chain members and consumers to access the application. Second, the ‘Profile’ page acts as a hub for the various features of the application. Third, the ‘Create’ page allows users to create and tokenize shipments. Fourth, the ‘Transfer’ page allows users to transfer tokens to other users in the supply chain. Fifth, the ‘Sent Shipments’ page allows users to track the status of the tokens they have initiated for transfer. Finally, the ‘Requested Shipments’ page allows users to view and accept or reject tokens transferred to them.

4.3.2. **Frontend Development**

React Native has been used to create the frontend of the aforementioned screens. Redux, which is a state management library, has been used to keep a global state which contains useful information such as current username, login state, and authentication token. The code is highly modular (Fig. 4) and ‘App.js’ forms the entry point. Individual elements in the components folder are composed to create screens. The navigation folder contains the structure of the navigation stack.

*Fig. 4. Frontend Project Structure*
4.3.3. **Backend Development**

The backend was developed using the Express framework using a modularised structure for better development (Fig. 5). The ‘server.js’ file sets up the process and connects with the database. The ‘models’ folder contains the schema of the database whereas the ‘routes’ folder houses different routes for all API calls made from the frontend.

![Fig. 5. Backend Project Structure](image)

4.3.4. **Database Development**

Two models have been created on the database. The ‘products’ model contains a list of the names of all products in a supply chain. The ‘users’ model maintains user information and details of all shipments in hand or in the transfer process (Fig. 6). Each of them contains every product’s name and quantity. The ‘sentShipments’ are shipments pending to be approved by the receiving user. The ‘reqShipments’ refers to the shipments which the current user needs to either accept or reject and continue the transfer process.

```javascript
username: "jado"
password: "2001"

currentShipments: Array
  0: Object
tokenId: "abc123"
  products: Array
    0: Object
      name: "Apples"
      quantity: 100
    1: Object
      id: ObjectId("61db8546f5222da4506ae381")

sentShipments: Array
  0: Object

reqShipments: Array
  0: Object
```

![Fig. 6. Database User Model](image)
4.4. Tokenization of Goods

The creation and transfer of NFTs play a major role in the application workflow. The NFTs are the goods being transferred in the supply chain. Consequently, the team prioritized the task of developing a module that will store the information of the products as an NFT on the blockchain. The module was created using the Truffle Suite with tools like Ganache and Truffle. Ganache is a personal Ethereum blockchain that provides free testing and Truffle is a development framework for Ethereum which assists in creating and executing the module. The team initially minted the NFT on a personal blockchain network which was setup using Ganache CLI. Thereafter, the team minted NFTs on the Rinkeby network, an online test network which is a clone of ethereum mainnet used by developers for testing (Fig. 7).

The transfer process was also performed on the Rinkeby network (Fig. 8). This process of tokenization forms the basis for the future development of the application.

Fig. 7. Minted NFT containing metadata

Fig. 8. NFT Transfer logs
5. Discussion

This section discusses the limitations and challenges faced by the application and lays out the future plan for the project.

5.1. Limitations

The biggest limitations are the environmental impact and cost of the solution. Both the creation and transfer of NFTs requires large amounts of gas fees and electricity. However, these could be mitigated with the expected launch of Ethereum 2.0 in June 2022. Furthermore, tokenization is conducted for the goods selected by the members of the supply chain which creates the possibility of human error and rogue actors. Apart from this, if the quality of goods degrades in the supply chain due to external factors like weather, the application can detect the point of degradation but not determine the exact reason for it.

5.2. Challenges

Operational challenges arise in implementing the blockchain. All the team members are new to blockchain and hence self-learning and research will play a crucial role in overcoming this challenge. From a technical perspective, tracing homogenous products in a store arriving from different supply chains is the biggest challenge. This creates a problem for both consumers and businesses and can lead to the misrepresentation of information.

5.3. Next Steps

Having completed the mobile application for supply chain members and the NFT transfer module, the coming semester will firstly involve their integration. Thereafter, a web dashboard for company management will be created that will enable them to add new products to be transferred as well as track products across different supply chains. Additional screens for the end consumers will also be developed. To accomplish this, new database models will be required. Lastly, the team will perform integration testing for improving both functional and visual features.
5.4. **Future Plan**

Apart from the current objective and deliverables, the team believes in a wide scope of the application. The primary task post the completion of the project will be to remove the current limitations and challenges. Hardware solutions like QR codes could be used to tackle traceability of homogeneous goods as well as reduce human error. Integration with existing ERP solutions to provide accounting, inventory management, and especially smart analytics could assist in recommending both natural and man-made reasons for degradation of goods whilst also decentralising the existing ERP solutions.
6. Conclusion

SCM has developed into an industry of billions of dollars that needs to improve every day to handle the rising complexity. A successful SCM leads to customer satisfaction and a better financial position. Current solutions are either tedious or lack traceability or both. This report presents a potential solution to this problem in the form of a blockchain-powered platform.

The application aims to provide transparency and traceability in the supply chain by combining the traceability of ownership offered by NFTs with the immutable and decentralised nature of blockchain. The product comprises a web application that is utilised by companies to enter the products they exchange. In the supply chain, the first member selects the products to be transferred through the mobile application. These are tokenized into NFTs and stored on the blockchain. Every successive member will transfer or accept the NFT through the application, thereby relieving or taking ownership of the goods. The business management can review and track each step through the web application which can detect any inconsistency. Once it reaches the final store, the consumers can view all the products in that store, trace the origin of the product and hence be able to verify its authenticity. Ethereum is used as the preferred blockchain for its compatibility with NFTs whereas the MERN stack is used for smooth internal and external integration for all applications. The current progress has involved research on implementation and feasibility of technologies, the development of the mobile application for supply chain members, and tokenization of products into NFTs.

The project is limited by operational inefficiencies such as human error during selection of goods and degradation of the quality of goods. Additionally, the creation and transfer of NFTs impact the carbon footprint. Lastly, traceability of homogeneous goods reaching one store from different suppliers can lead to incorrect tracking.

Owing to the rising demand for technologically advanced SCM, future work will involve mitigating the limitations by reducing human effort. Additionally, integration with ERP systems would assist in providing features of accounting and smart analytics in a trusted and decentralised manner.
7. References


