MAKERERE UNIVERSITY

COLLEGE OF COMPUTING AND INFORMATICS TECHNOLOGY

DEPARTMENT OF COMPUTER SCIENCE
SCHOOL OF COMPUTING AND INFORMATICS TECHNOLOGY

PRODUCT TRACING SYSTEM

GROUP 7

A Project Report Submitted to the School of Computing and Information technology for the study in partial Fulfilment of the requirements for the Award of the Degree of Bachelor of Science in Computer Science of Makerere University.

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DECLARATION

We as group 7 hereby declare that this report, written in partial fulfillment of the requirements of the award of a Bachelor of Science in Computer Science degree at Makerere University, is our very own authentic work and the content of this document has never been submitted to any institution. Note however, that Citations, Quotations and References to other people's work or sources of information where used have been duly made.

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DEDICATION

We dedicate this to our parents who made the greatest choice putting us in school, providing financial support in every level of academia to where we have reached.

ACKNOWLEDGEMENT

We would love to acknowledge the Almighty God for enabling us to come this far with this work. We have seen His mighty hand at work in this project right away from the start.

We also acknowledge our supervisor madam Mariette Katarahweire for her guidance and constant supervision as well as for providing necessary information regarding the project and also for their support in completing our project.

TABLE OF CONTENTS

LIST OF FIGURES

ABBREVIATIONS

CSS - Cascading Style Sheets

DAPP – Decentralized application.

Enum - Enumeration.

EPCs – Electronic Product Codes.

GB – Giba Byte.

HTML - Hypertext Markup Language

HTTP – Hyper Text Transfer Protocol.

IOT – Internet of things.

JS – Java Script.

NFC – Near Field Communication.

QR – Quick Response.

RAM – Random Access Memory.

RFID – Radio Frequency Identification.

SCs – Smart Contracts.

UI – User Interface.

UML – Unified Modeling Language

UNBS – Uganda National Bureau of Standards.

UV – Ultra Violet.

Web – Website.

ABSTRACT

Our project is a product tracing system project that traces the flow of a product as it gets from the farmer to the final consumer using the Ethereum blockchain technology and validating the origin of that product.

In chapter One of this document contains the Introduction and Background of the subject matter from where all the parts build from. It briefly highlights what product tracing is all about as well as what blockchain technology is all about.

It furthermore gives a revelation and insight in the matter summarizing the question why blockchain? as the problem statement into detail defines the scope and the objectives for this project. The scope is subdivided into two parts namely: Geographical scope and the Technical Scope where by the former is the location constraint whereas the latter what the project puts more emphasis on.

It also gives the significance of this project.

As the journey continues, we go into Chapter Two which is all about the literature review. It is then partitioned into different sections for example: Introduction, the approaches to Track Products, the challenges, the advantages, the differences between blockchain and centralized architecture, the limitations and then a summary of a proposed system.

Chapter three gives the methodology used while data was obtained. It goes on to expound on the research methods we used like Surveys and the data collection methods/tools like questionnaires, study of analogous systems and so on.

Chapter Four talks about the Analysis and Design whereas chapters 5 and 6 talk about the results and conclusion respectively.

CHAPTER ONE

1 INTRODUCTION

The trade in substandard goods is growing and is affecting the sales and profits of companies. It also exposes consumers to the potentially fatal risks associated with buying substandard products especially agricultural products like grapes, coffee, vegetables among others.
This project addresses this issue by implementing a blockchain product tracing system based on the Ethereum blockchain technology to identify and trace products and validate their origins.

Product tracing is the ability to trace potentially contaminated products, the consumption of which may cause an adverse health impact, through the supply chain. It provides numerous benefits such as the ability to investigate and troubleshoot issues related to a component or ingredient. [1]
This becomes crucial during unforeseen events like recalls, it enables the source of the problem to be swiftly identified and rectified, and also allows a given company in a supply chain to distance itself from the problem and highlight that their products were not affected.

Blockchain [2] on the other hand is a distributed, decentralized ledger technology controlled by smart contracts and regulated by a consensus protocol and can be used to trace the origin of goods as we explain in the coming chapters.

1.1 Background

Counterfeiting is a massive economic problem that results in billions in lost revenue each year globally. It exposes individuals and corporations to heightened health and safety risks and its reach affects every stage of the product life cycle, from the manufacturing floor to the point of sale.
This drives up costs, erodes revenues and damages company reputations and brands.

In Uganda, a survey noted that 54% of goods in circulation are fake this implying that it is estimated that the nation could be losing up to Shillings 6 trillion to counterfeits and substandard products every year. [3]
Not only that but the nation itself loses its innocent picture “For God and my Country” to the outside world in the name of “FAKE.”

And so, several strategies are being enforced to handle this problem like laboratory testing, market surveillance, receiving and handling complaints from the affected parties. However, these have not been very effective with Uganda National Bureau of Standards (UNBS) citing challenges like inadequate resources resulting in understaffing, lack of vehicles, inadequate facilitation and operational funds. [4]

Much as there has been companies that have been put in place to trace out products and deal away with fake products in the supply chain, for example the TruTrade Africa [5] it’s not been in position to provide an avenue where a stakeholder can trace their products hence the necessity of the product tracing system.

1.2 Problem Statement

A report in 2015 by the Global Entrepreneurship Monitor ranked Uganda as the top entrepreneurial country in the world [6]. Entrepreneurs expect to earn a living while facing fair competition, but many businesses find themselves having to deal with problems like substandard and counterfeit alternatives that pose a threat to revenues and brand reputation.

This project however solves the problem through a Blockchain 2.0. Within a supply chain, a blockchain ledger can automate contract compliance between entities through smart contracts and track products from production to distribution. The ledger can then eliminate supply chain ambiguities and create transparency which ensures that businesses and customers get the quality for which they pay for.

1.3 Scope

Geographical scope

Our project will majorly focus on products manufactured and distributed within Kampala district as it is the capital city and thus where majority of economic activity takes place. The main products to focus on will be on agricultural products coffee in particular.

Technical Scope

Using block chain to record and store transactions that take place throughout the supply chain process, from the moment the product is produced to the moment it reaches the final consumer.

OBJECTIVES

Main Objective

- To develop a prototype/system that enables customers to identify substandard products for a specific company brand in the post supply chain and also be in position to track and trace their product right from the manufacturer.

Specific Objectives

- To analyze the strengths and weaknesses of the existing product tracking systems.
- To develop and deploy a fully functioning tracking system that uses blockchain technology in order to track products perhaps reduce the counterfeiting problem in the chain if any.
- To test and validate the developed system.

SIGNIFICANCE

Blockchain has been called a pillar of the Fourth Industrial Revolution, comparing it to technologies such as the steam engine and the internet that triggered previous industrial revolutions.

It has the power to disrupt existing economic and business models and may prove particularly valuable in emerging market economies [7]. Blockchain has been used for crypto currencies like Bitcoin, but many other possible uses are emerging, such as energy markets, digital identity, supply chain, health care and financial services.

One of the mentioned applications, Bitcoin, has not only been effectively solving the double-spending problem but also it can confirm the legitimacy of transactional records without relying on a centralized system to do so. Therefore, any application using Blockchain technology as the base architecture ensures that the contents of its data are tamper-proof.

As we describe a decentralized Blockchain system with products anti-counterfeiting, in that way manufacturers can use this system to provide genuine products without having to manage direct-operated stores which in turn can significantly reduce the cost of product quality assurance.

Enterprises only need to pay very low transaction fees, and they no longer need to worry about the possibility of obtaining counterfeit products.

And thus, with the Blockchain architecture provided by Ethereum it can be used to record product ownership on the Blockchain. By using Block chain’s traceably and transparency properties, and the assurance that each record cannot be forged on the Blockchain, consumers don't need to fully rely on trusted third parties to safely know the source of the purchased product.

CHAPTER TWO

2 LITERATURE REVIEW

Introduction

A Blockchain is a distributed [8], or decentralized, ledger for recording transactions among multiple parties in a verifiable, tamper proof way. [9] Data is stored in blocks that are all linked to each other, time stamped and can't be forged. The term 'Blockchain' is derived from the 'blocks' of validated and immutable transactions and how they are linked together in a chronological order to form a chain.

When paired with Internet of Things (IoT) [10] technologies, Blockchain provides the ability for the various stakeholders within the supply chain to access a product's entire history, from the point of production up to the moment a customer buys the product.

2.1 General approaches to track products in the supply chain.

Overt.

These include packaging technologies which are visible in the product itself for example holograms, color shifting inks, security threads, water marks etc. The advantage of these approaches is that they can be checked by the end consumers however they are not immune to duplication by malicious third parties. [11]

Covert.

These [12] are applied on the product itself and they include UV, bi-fluorescent and pen-reactive ink as well as digital watermarks and hidden printed messages. [13] They help to identify counterfeits in the supply chain and are especially efficient combined with overt technologies. Their disadvantage is that they are only identifiable with special equipment with isn't easily accessible to the general consumer.

Track and Trace.

This includes Radio Frequency Identification (RFID) [14] tags, Electronic Product Codes (EPCs), QR Codes, Bar Codes and Near Field Communication (NFC) based solutions. [15] The tag or barcode is included on the product by the manufacturer. Distributors and retailers alike scan the identification enabling them to check the history and authenticity of the product.

Challenges faced by current product tracking systems using centralized architecture.

However, these solutions are built with centralized architecture. They require dedicated applications or authentication servers to integrate with these tags involved so as to perform writing, reading and validating features on the data stored in these tags with the product identifier (PID) and its metadata stored for purposes of validation at later stages.

A security analysis [16] was performed on the NFC assisted approaches threats were identified and grouped into physical NFC tag threats and system threats as listed below:

Physical NFC tag threats:

Tag Cloning.

Each NFC tag has a unique identifier which if exposed to attackers, data stored in a tag could easily be cloned into another tag. [17]

Tag disabling.

Malicious parties can take advantage of the wireless nature of NFC Systems in order to disable tags, from any further interaction with the tags, temporarily or permanently changing the state of NFC tags.

Tag's data modification.

Tags use writable memory and so one can take advantage of the feature to modify or delete valuable data from memory of any involved tags, during the reading and writing process.

The NFC system threats include the following:

Man-in-the-middle relay attack.

A device is placed between a legitimate NFC tag and a mobile application with a dedicated backend database which is in a logged in state. Unauthorized access to sensitive information related to transactions or the supply chain as a whole can be obtained. [18]

Tracking and tracing.

Information related to queries sent and responses received from an NFC tag at various locations may be used to obtain login data, via brute-forcing or dictionary attacks, giving the attacker unrestricted access to the web applications.

Denial of Service attack (DoS).

This involves jamming the system with noise interference, blocking radio signals, removing or even disabling NFC tags, causing different system components or the entire system to work improperly. [19]

All in all, centralized product anti-counterfeiting and traceability systems rely on a centralized authority to combat counterfeit products which results in single point for processing, storage and failure and the potential attacks via manipulating the security threats identified in the threat analysis as shown earlier.

ADVANTAGES OF A BLOCKCHAIN BASED TRACKING SYSTEM.

Some of the major areas the value of Blockchain can be assessed in the supply chain industry:

Replacing slow, manual processes: Supply chains currently handle large, complex data sets and many of their processes are slow and rely entirely on paper.

Automation of transaction processes: Many functions can be automated through a smart contract, in which lines of computer code use data from the Blockchain to verify when contractual obligations have been met before payments are issued to the various stakeholders.

The smart contract can be programmed to assess the status of a transaction and automatically take actions such as releasing payment, recording entries in the ledger and catching exceptions or errors.

Auditing: Each block is encrypted and distributed to all participants in the supply chain who maintain their own copies of the Blockchain. Each party can review the status of a transaction, identify errors, and hold counter parties responsible for their actions.

No participant can overwrite past data thus ensuring a complete, trustworthy and tamperproof audit trail.

Blockchain technology stands out as the best alternative to better prevent risks and overcome threats with vulnerabilities associated with centralized architectures. It offers transparency, decentralization, trustworthiness, accountability and security for product information within the supply chain.

Comparisons with centralized architecture are summarized in the table below:

A Table showing differences between blockchain and centralized architecture

BLOCKCHAIN ARCHITECTURE	**CENTRALIZED ARCHITECTURE**
New data is added when a consensus among all parties is reached.	New data is added by administrator account without consensus.
Old data is immutable and cannot be changed and tampered with.	No restrictions on data modifications.
Distributed and decentralized in nature	Single point of failure and control
Peer to peer structure	Client-server architecture
Cryptographic verification	Cryptography is only an add-on
Availability and resiliency increases with the number of peers	Backups are manually implemented

2.2 LIMITATIONS OF BLOCKCHAIN BASED SOLUTIONS.

Manageable system integration model.

Not every user of the blockchain system and stakeholder in the supply chain possesses the technical knowledge to maintain a copy of the system components. A manageable model is needed to help promote adoptions of the decentralized Blockchain solution in place of the less efficient centralized counterpart that is already widely used in the supply chain industry [20].

Limited scalability.

Decentralized solutions can take longer times to compute the same set of operations as compared to the centralized models. This is due to the fact consensus is needed among multiple parties and more steps are involved to update representations of the product records. However, this is offset by the increased integrity and security of the product information [21].

Data integrity.

Situations can occur where a party enters false information onto the Blockchain. A wholesaler can simply create an entry for a counterfeit and it will be immutable and go undetected. Trust in each involved party's integrity is essential for a Blockchain ledger to have its desired effect [22].

2.3 SUMMARY OF PROPOSED SYSTEM.

Based on the review of the current solutions being implemented, the proposed Blockchain system will consist of the following features:

Web platform to access product tracking data with an easy to use, sleek, intuitive user interface to ease the adoption process by the various stakeholders in the supply chain.

A tamper proof, self-executing smart contract that allows decentralized automation by facilitating, verifying and enforcing conditions of an agreement between various stakeholders.

Ethereum based private network that acts as a distributed database for product information.

CHAPTER THREE

3 METHODOLOGY

Introduction

This chapter explains in detail the selected research methodologies we used to achieve the objectives of the project. It describes the tools instruments techniques and major technologies we employed in the research study area, data collection, analysis, design, implementation and testing of the system

3.1 Data Collection Techniques

The purpose of data gathering is to collect sufficient, relevant, and appropriate data so that a set of stable requirements can be produced [23]. Even though a set of initial requirements existed, data gathering will be required to expand, clarify, and confirm the initial requirements.

This would all be helping us to get to the root of the matter [24].

The basic techniques we used for data gathering allowed us to effectively and systematically collect information about our study area, these included questionnaires, focus group discussions, studying documentation and interview, we also had to study some analogous systems which was really so helpful. [25]

Some of them, such as the focus group discussions, required active participation from stakeholders, while others, such as studying documentation, required extensive research work on the side of the developers.

Using Surveys and Questionnaires

We used surveys and questionnaires and we found that most people had actually been duped and also the available systems were not efficient hence the necessity of this system.

This helped us form a database from which to infer how best we can solve the problem to achieve the objectives of the system, and this method was used because of its benefits.

Surveys are relatively inexpensive [26] and they are useful in describing a large population ensuring a more simple but accurate sample. Lastly surveys are dependable in that respondents answer with more candid and valid answers.

Surveys helped us to obtain both the farmers and the customer’s opinions on existing systems and many of them weren’t effective.

In this technique, questionnaires as a tool were sent to the respondents who were required to fill in appropriate data which was analyzed and processed to provide requirements for the system.

For this research, open-ended questions were used since they give the respondent the ability to respond in their words.

It helped us find out the issues in those systems the customers, famers and the other players in the chain were displeased with.

This technique was used because it is relatively economical and inexpensive. It was possible to cover a large number of people scattered [27] over a wide area.

Interviews

With this one the communication between the interviewer and the person being interviewed could either be structured or non-structured.

The tools that were used included interview guide, papers, and pens for this research, it was carried out with different stakeholders from different farms and responses about how they currently deal with coffee right from the farms or plantations to the final consumer.

This technique was used because it is time-saving, less costly, increases the knowledge base of the system since views and ideas are exchanged, flexible since its framing depends on the situation and in-depth analysis since detailed information can be collected which enables proper analysis of a problem.

Studying Analogous Systems

Rules and procedures on how the work was achieved are written down in manuals and these are a good source of data about the steps involved in an activity and any regulations governing a task. [28] This gives a good foundation on how to start out one that’s unique and different [29].

This method was used because it helps to prevent research problems such as plagiarism, falsification and data duplication.

It also helps to identify the missing gap in the researches made before thus enabling one to develop a new project with new functionality. The Internet was the major tool we used in this.

Focus Group Discussions

This technique helped in permitting alternative ways of obtaining information from stakeholders. [30]

It also helped in easy identification of the stakeholders’ feelings, perceptions, because focus groups utilize qualitative data collection methods.

The technique captures real-life data in a social setting; it is flexible, generates quick results and costs little to conduct.

Data Analysis

After data collection exercise we analyzed the data collected to eliminate inconsistencies, to sieve out useful data and to update system requirements. The data collected through questionnaires was quantified by coding the responses before doing Quantitative [31] analysis. Qualitative methods were employed at some extent especially during analysis of information and documentation reviews.

System Implementation

This is the stage at which the physical realization of the system was implemented. This was done through a number of implementation tools and technologies such as: HTML, Java Script, Meta mask, Solidity, Infura, CSS, Truffle, Node Js, Bootstrap

These technologies are defined below adapted from Wikipedia the online encyclopedia:

Hypertext Markup Language (HTML) is a predominant markup language used for designing web pages.

Cascading Style Sheets (CSS) a style sheet language used for describing the presentation of a document written in a markup language.

Bootstrap is a front-end framework used for designing an interface for the user. Bootstrap includes HTML and CSS based designs templates for forms, buttons, tables and many more.

JavaScript is a text-based scripting language that's interpreted by a client system to perform tasks in various settings. JavaScript was originally conceived as a means for making web pages dynamic making it possible for users interact with them and receive something in return.

MetaMask is a software cryptocurrency wallet used to interact with the Ethereum blockchain. Allows users access their Ethereum wallet through a browser extension or app which can be used to interact with decentralized applications.

Solidity is an object-oriented programming language for writing smart contracts. It is used for implementing smart contracts on various blockchain platforms most notably Ethereum.

NodeJS is an open-source, cross-platform, back-end JavaScript runtime environment that runs on the V8 engine and executes JavaScript code outside a web browser.

Infura is a blockchain node infrastructure service that allows apps and developers to get data from, and broadcast transactions to the Ethereum blockchain.

Truffle is a framework for building, testing and deploying applications on the Ethereum network.

System Testing and Validation

This process helped us in executing the system to evaluate its functionality using carefully planned test strategies.

The system was uploaded to an online server and published as a prototype for user testing and validation. Initial resources were uploaded onto the system. This was meant to encourage many stakeholders to visit the system, open up accounts and upload more resources.

Validation measures were enforced by testing the prototype with invalid data and procedures to check its way of handling exceptions. Security considerations were then implemented for scenarios where the prototype had failed to handle the exceptions satisfactorily.

CHAPTER FOUR

4 ANALYSIS AND DESIGN

4.1 Design

The system is a web application that will help people get more information about the products they purchase. The information is stored in smart contracts, which are a core component of a blockchain.

A blockchain is an immutable database which only supports append operations and heavily relies on cryptography. Information once added to a blockchain cannot be changed which ensures the integrity of the data in the Blockchain. The data in a blockchain is stored in terms of blocks and each block consists of data, a hash of the data and hash of previous block.

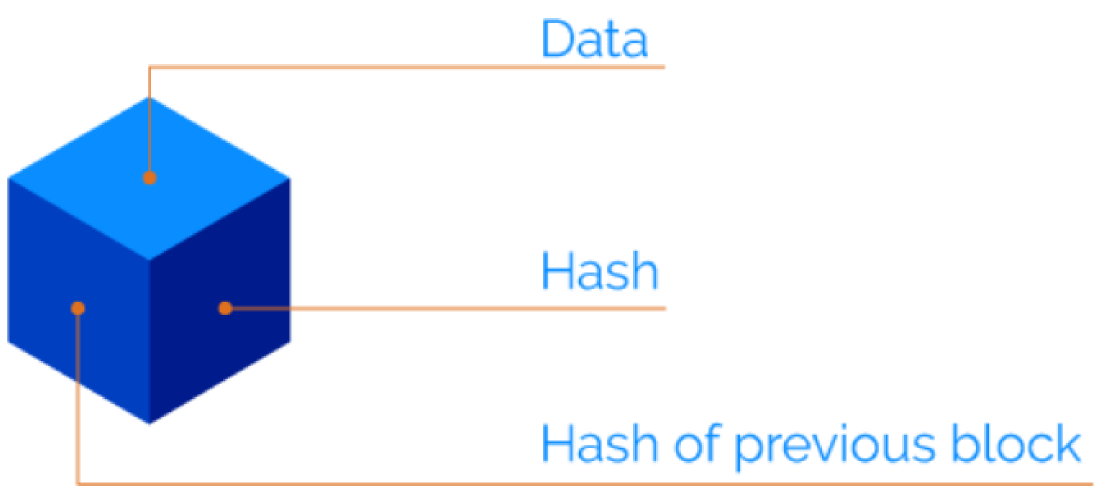

Figure 1: Structure of a block

Ethereum:

A smart contract is important because it defines the rules and conditions for querying a ledger and generating new transactions that are recorded on it. Smart contracts describe, in code, the lifecycle of one or more business objects that are stored on the ledger. It describes how they are created, updated, and queried.

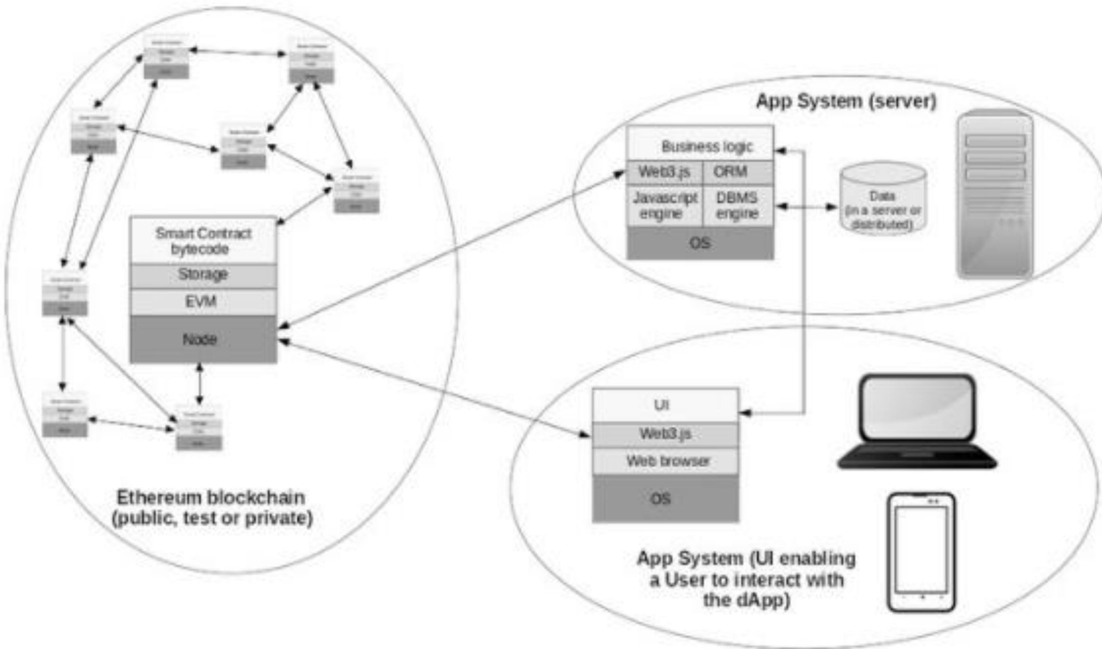

Figure 2: Typical architecture of an Ethereum DApp

The figure 2 above shows a basic architecture for an Ethereum Decentralized application(dApp). The App system is shown on the right while the core blockchain system and its Smart Contracts (SCs) are shown on the left.

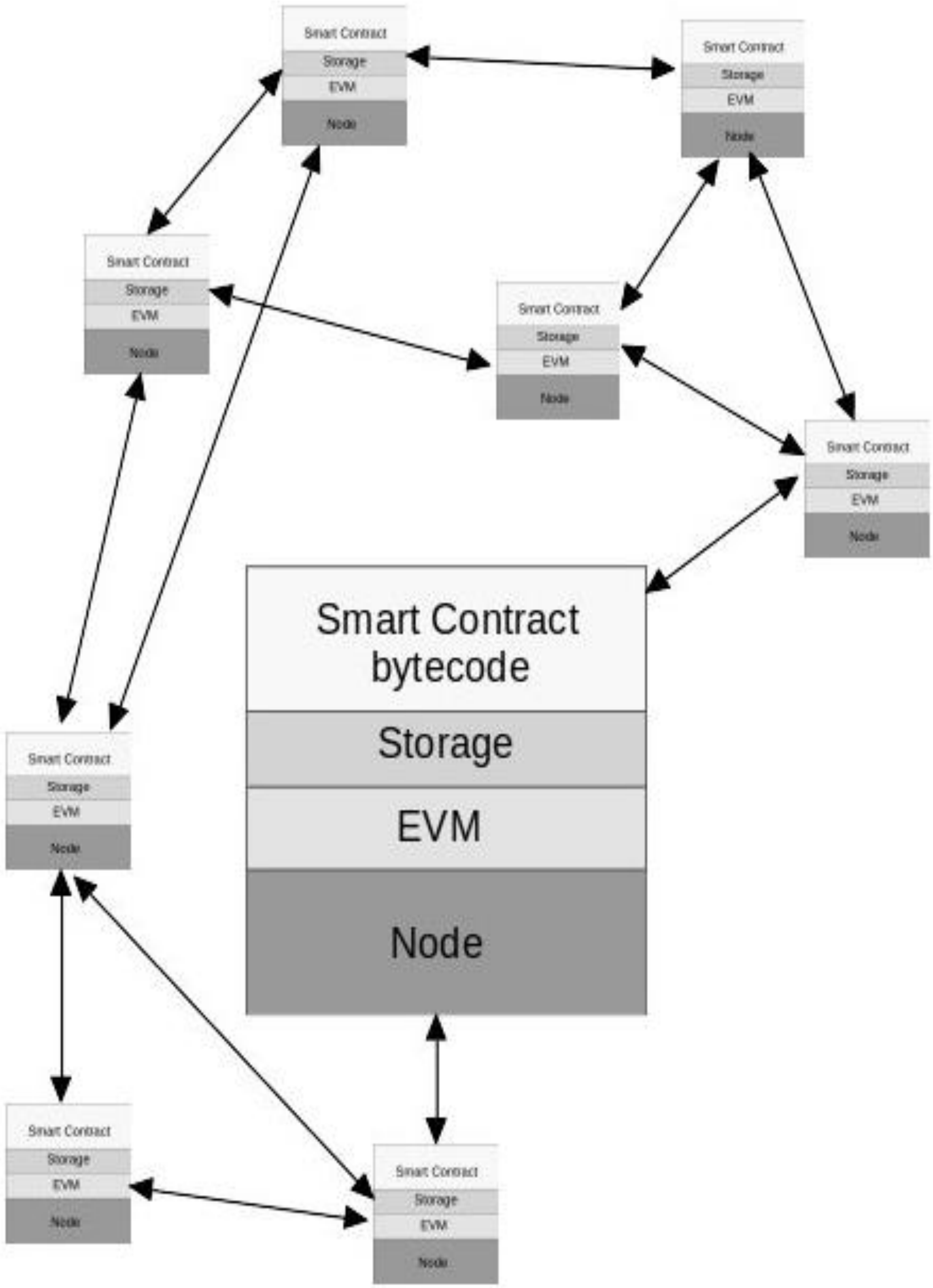

Figure 3: Ethereum VM and Smart Contracts

From figure 3, we can see that a typical Ethereum dApp consists of a software system running on mobile devices and/or on servers, possibly on the Cloud, exchanging information with users and external devices, which we call "App System". Its User Interface (UI) typically runs on a Web browser. It can have a server component, to store data that cannot be stored in the blockchain, and to perform business computations.

In Ethereum, the App System typically communicates with the blockchain using the "web3.js" JavaScript library, which manages the creation and dispatch of transactions.

The Ethereum Virtual Machine executes the smart contract byte code, which runs on all the Ethereum nodes on the blockchain. Most Ethereum smart contracts, like the ones used by our system are written in a high-level language called solidity.

The results of executing a smart contract must be the same regardless of the node they run in. This is because SCs run in an isolated environment. They do not get information from sources external to the system and cannot autonomously initiate a transaction.

They can only change state and send messages to other contracts but cannot have their contents changed, which renders them immutable. The state of a smart contract at any given time is permanently stored in the blockchain. Immutability is an important characteristic of blockchain systems which will ensure data integrity for our system.

4.2 SYSTEM ARCHITECTURE

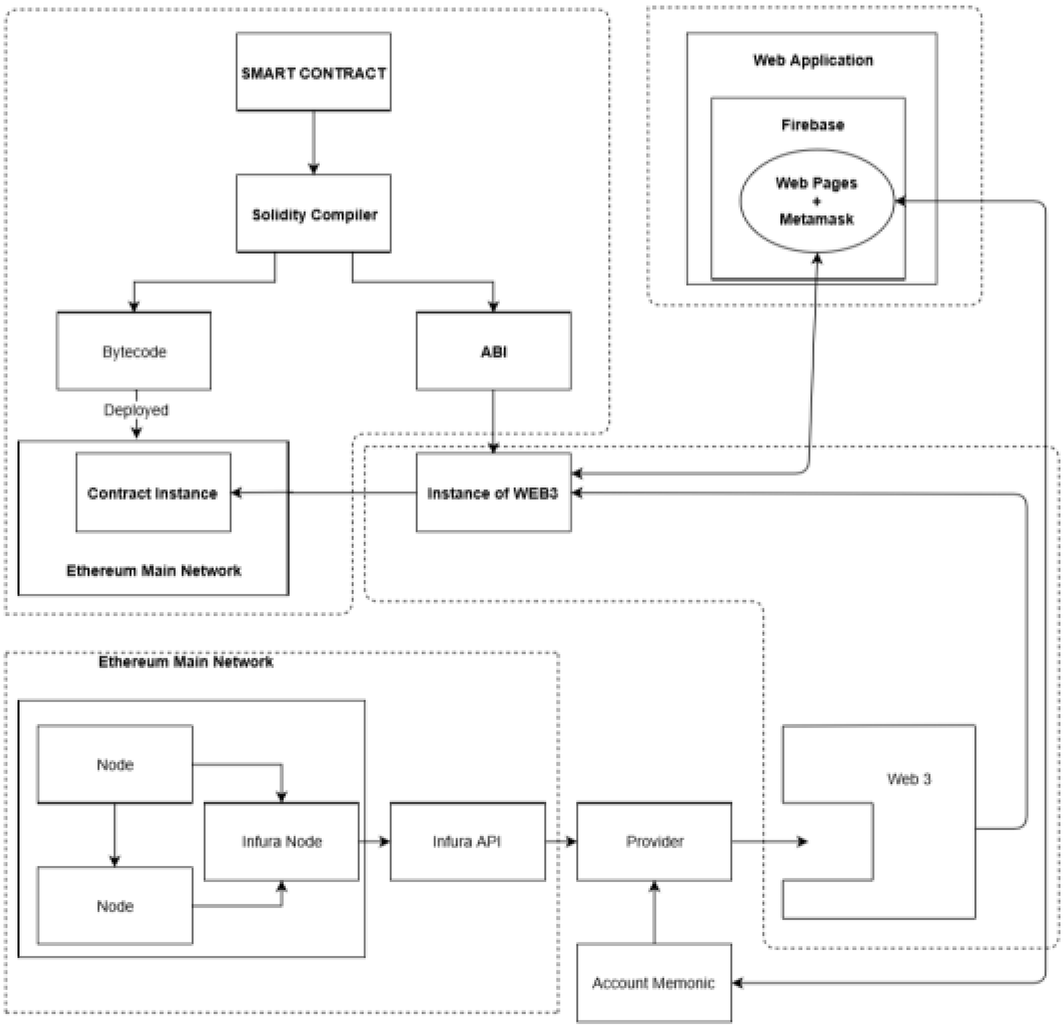

Figure 4: System architecture showing the overall structure of the system.

Smart contract:

A smart contract is a program that runs at an address on Ethereum. A smart contract is like a class. A contract contains state variables, functions, function modifiers, events, structures, and enums.

Contracts also support inheritance. Inheritance is implemented by copying code at the time of compiling. Smart contracts also support polymorphism. They will also automate a workflow, triggering the next action when conditions are met.

Web3

- Web3 is a JavaScript library.
- web3.js is a collection of libraries that will allow us to interact with a local or remote Ethereum node using HTTP.

- Web3 bridge between solidity and the JavaScript which means it helps us to interact with the Smart Contract from the front end of the web application.

Metamask

- Metamask is a wallet for keeping Ether, which is a is cryptocurrency developed by Ethereum. Metamask interacts with the Ethereum blockchain and is a service which is used with regular browsers, such as Chrome, Firefox, Internet Explorer, etc.
- Ether transaction on Ethereum's main network defines the compatibility with Ethereum blockchain.
- We cannot interact with the Ethereum blockchain with our regular browser because the regular browser does not contain any Ether.
- Metamask injects the web3 JavaScript library into the browser.

Infura

- To do the transaction in the Ethereum network we need to be a part of a network
- Infura has a running node which is a part of the Ethereum network.
- We need to connect to the running node with our web application so that we can interact with the Ethereum network.
- Infura provides nodes for 4 networks, one is the main network node and three test network nodes Rinkbey, Kovan, and Ropsten.
- Infura provides secure and easy access to the Ethereum network.
- When we sign up on the infura website it gives us a token, and it is used to connect to the corresponding Ethereum network.

4.3 UML DIAGRAMS

Use case: Coffee supply chain

Use case diagram

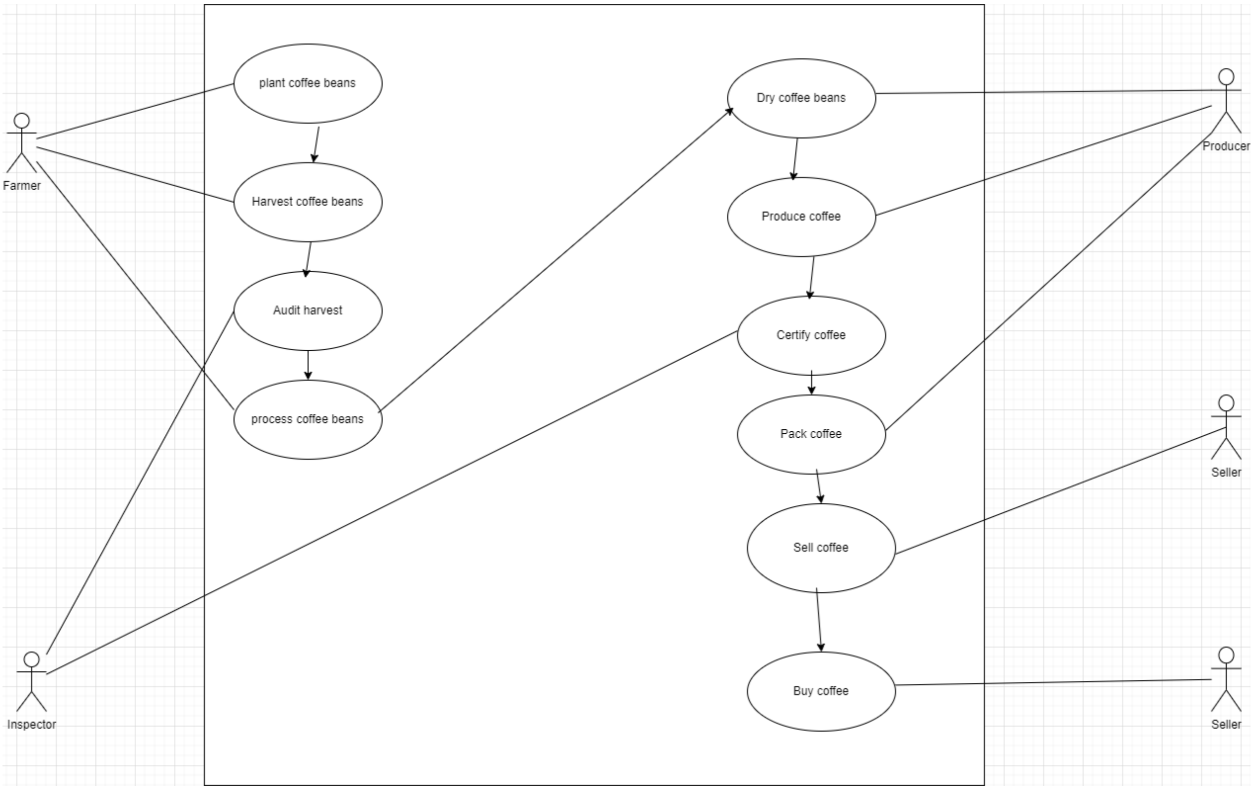

Figure 5: Use case diagram showing the actors on the system and the actions they can perform.

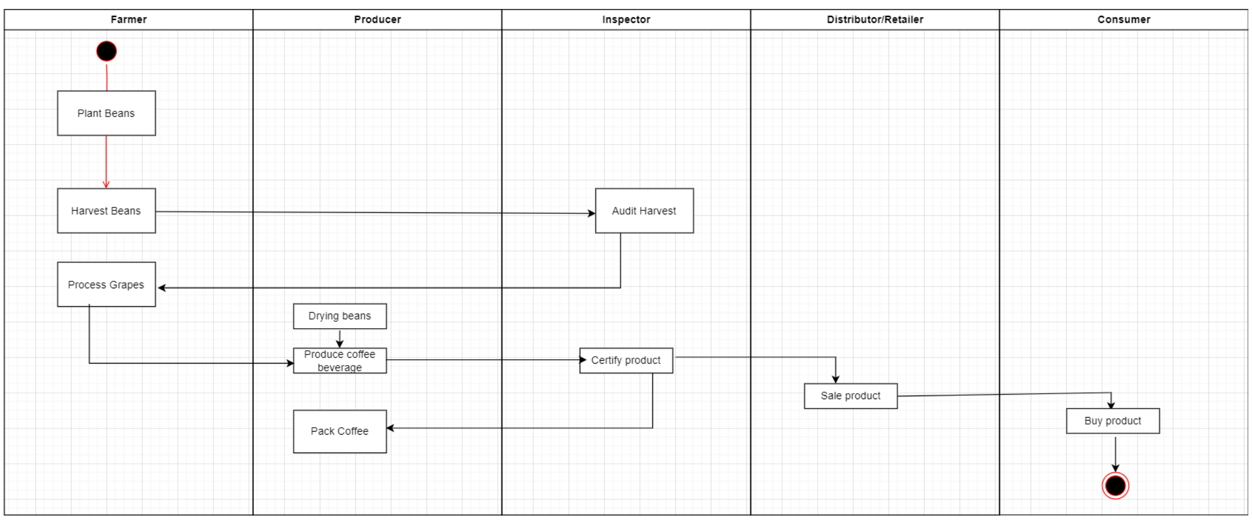

Figure 6: Activity Diagram depicting the behavior of the system.

Our use case is a coffee supply chain. We have 5 user groups for the supply chain.

The Farmer: The farmer plants the coffee beans, whereby they provide critical information about the beans planted and the type of fertilizers used. The farmer may also process the coffee beans.

The farm inspector: Upon harvesting, the farm inspector audits the harvest, to check for the quality of the coffee and also to confirm whether the right guidelines were followed with regards to the fertilizers used. This is one before the beans are processed. The inspector also inspects the final product, which is the coffee beverage. The inspector then provides a stamp and also enters information into the system.

The producer: The producer turns the processed coffee into the final product, which is the coffee beverage.

The distributor: The distributor purchases the certified coffee from the producer

The consumer: the consumer purchases the product from the distributor, and can see the history of the product.

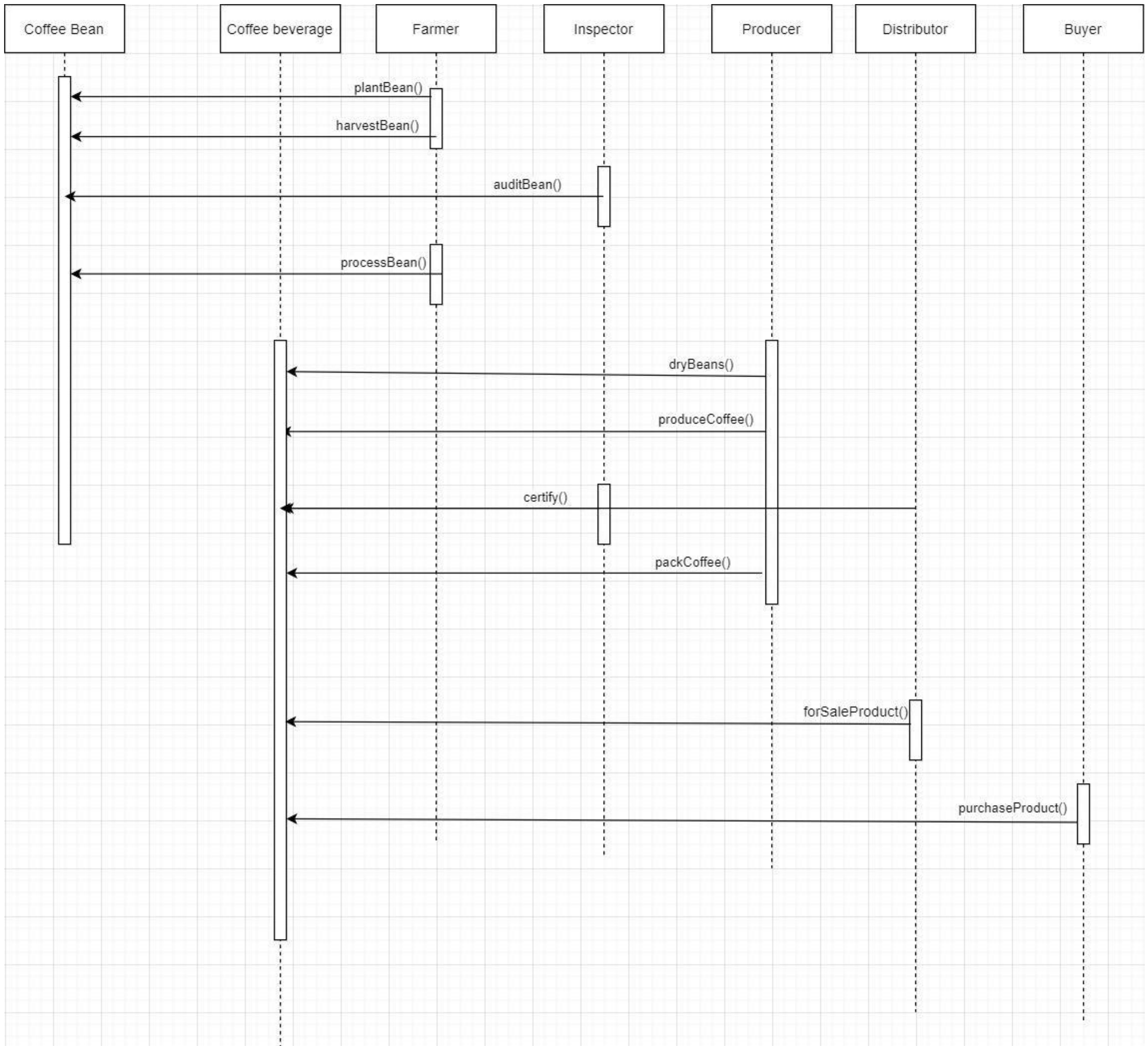

Figure 7: Sequence Diagram showing the order in which the entities work together.

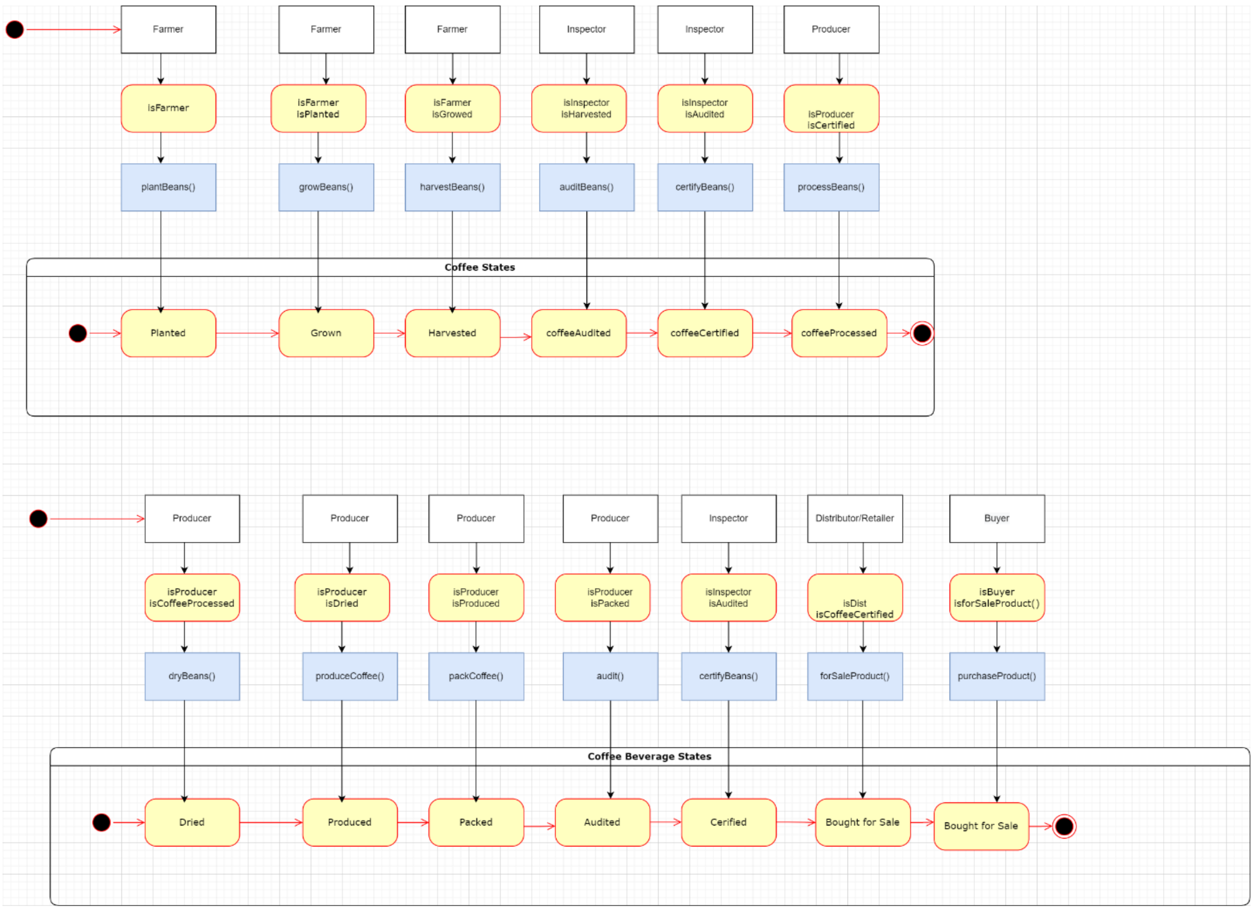

Figure 8: State Diagram showing the states in which the system can be at any given time.

4.4 Intended users of system

Functional Requirements.

The proposed system should be able to meet the following functional requirements:

- Authentication of a user through their Blockchain account addresses.
- The owner of the smart contract should be able to create new user roles.
- The system should display all details of all transactions processed with a time-stamp and the users involved.
- The system should display the actions available for each specific user role
- The Blockchain should provide each user with minimum 100 Ether to carry out transactions.

Non-functional requirements.

- The system should be responsive where validation of any transaction does not exceed 10 seconds.
- Users of the system should have technical knowledge of how Ethereum Blockchain works and how to test and deploy smart contracts.

- The system should have a friendly user interface that makes it easy for users to carry out transactions.
- The system should be portable if the hardware requirements are met.

System requirements.

The various stakeholders in the supply chain must have access to the following:

- Computer with at least 4GB RAM and an active reliable Internet Connection on Windows 10.
- Google Chrome Internet Browser.
- Metamask browser extension to link their Blockchain account addresses to the application front end.
- Ganache local Blockchain software installed on the computer.
- Truffle software for testing and deploying the smart contract to the blockchain.

CHAPTER FIVE

5 RESULTS

System Analysis and design

After the data collection exercise, system analysis and design process were conducted where collection and interpretation of facts, identification of the problems, and decomposition of a system into its components are put into action. During this process, future updates were also considered to make sure that they will be compatible with the system.

System Analysis

From the findings during data collection, system analysis was conducted to study the product tracing system. Concerns and requirements of the system from the views of the stakeholders from different firms were also put into consideration.

The requirements were categorized into functional and non-functional that describe what the system should do and how the system should work respectively, from which we were able to tell the specifications of the system.

5.1 System Design

Process Modeling

This was achieved through the use of sequence diagrams. Such diagrams help so much in depicting how sequence messages can be exchanged between the objects needed to carry out the functionality of a scenario. They are designed using a language called the Unified Modeling Language (UML). And also, we used the activity and state diagrams for this in the supply chain as denoted in Figure 5, Figure 6and Figure 7.

System Architecture

The kind of architecture we used was the Ethereum Virtual Machine.

It executes the smart contract byte code, which runs on all the Ethereum nodes on the blockchain. Most Ethereum smart contracts, like the ones used by our system are written in a high-level language called solidity.

Data Processing

Data got from respondents is processed using a tool called SPSS (**S**tatistical **P**ackage for the **S**ocial **S**ciences), which is software for editing and analyzing all sorts of data.

These data may come from basically any source: scientific research, a customer database, Google Analytics or even the server log files of a website.

SPSS can open all file formats that are commonly used for structured data such as spreadsheets from MS Excel, plain text files (.txt or .csv), relational (SQL) databases and Stata and SAS.

This tool was chosen because of the several benefits it comes with, which include:

- Ability to easily adapt to data from experiments
- It is user-friendly
- It has a point and click interface which allows you to assemble code quickly
- You can save the code in the form of a syntax file and re-use it when needed and share it with others.

CHAPTER SIX

6.1 CONCLUSION

An Ethereum based system was designed and tested to track coffee from the stages from production up to the point of purchase by the consumer.

Five roles in the supply chain were defined namely; Farmer, Producer, Inspector, distributor/Retailer and Consumer. Their respective actions were tested and implemented and all the transactions were recorded on the Blockchain in a transparent immutable manner.

However, the system was constrained to work in a test environment and not tested in a production environment with multiple users. Future work will involve deploying the smart contract to a live Blockchain environment and also integration with IoT sensors in the supply chain to track the product in real time.

There is considerable room to improve supply chains in terms of end-to-end traceability, speed of product delivery and coordination. For supply chains where participants are not known or trusted Blockchain can be a powerful tool for addressing some of these issues because it adds trust, transparency and traceability.

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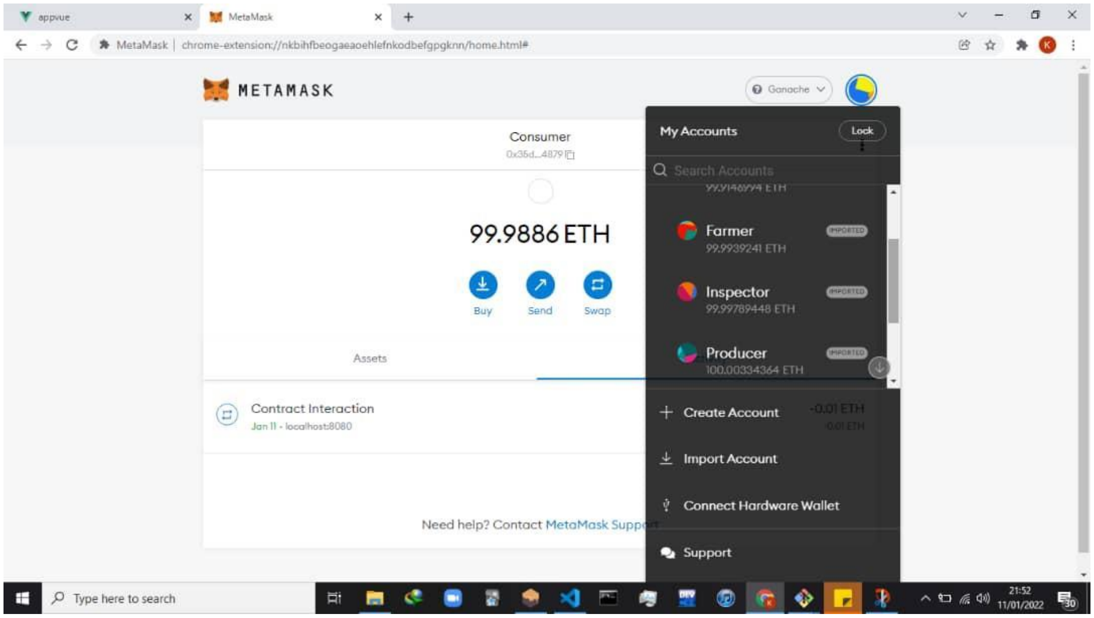
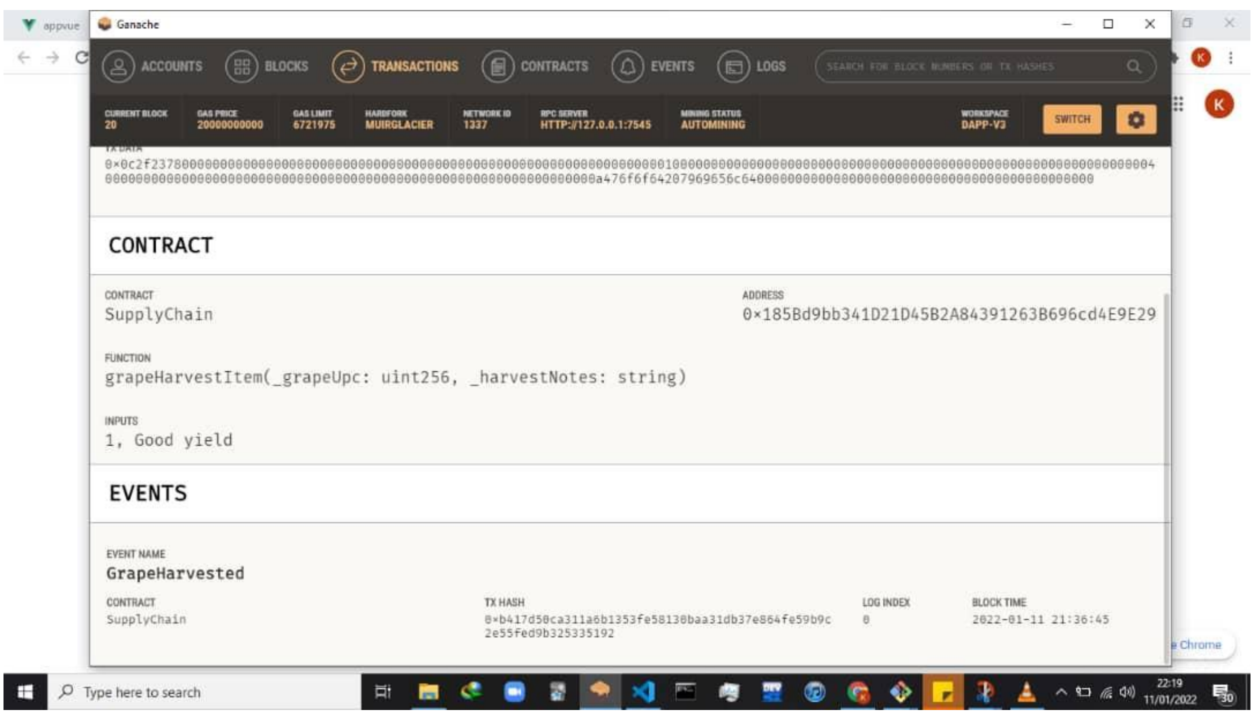
APPENDICES



*Appendix SEQ Appendix * ROMAN I: Screenshot of the prototype*



*Appendix SEQ Appendix * ROMAN II: Each Transaction recorded on the Ganache local blockchain with all relevant details.*