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A Data Provenance System for Myanmar Rice Cycle based on Ethereum Blockchain

by

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(이더리움 블록체인 기반의 미얀마 쌀 유통관리 시스템)

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A dissertation

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Abstract

The existing system of the Myanmar rice cycle is still relying on a third party to manage every rice data from several organizations. It is hard to supervise continuously due to the unreliability of information provided by organizations. Thus, the original data of the rice cycle is difficult to be utterly trusted since it can be manipulated by irresponsible parties. Moreover, the current system does not preserve a proper incentive for the involved parties. Therefore, in this thesis, we leverage the Ethereum blockchain to be adopted in order to tackle the aforementioned issues. The purpose is to increase trust between parties while transferring rice from the producer to customers. Our proposed scheme allows customers to check and trace information about the Myanmar rice cycle information. Furthermore, the authorized parties are also rewarded by the government through Ethereum smart contract features. Eventually, our scheme achieves traceability in the Myanmar rice chain and may leads to the complete digitization and automation of the rice cycle information.

한국어로 요약한 논문

초느엔진랏

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요약

미얀마 쌀 주기의 기존 시스템은 여전히 제3자에 의존하여 여러 기관의 모든 쌀 데이터를 관리하고 있다. 조직에서 제공하는 정보의 신뢰성이 떨어져 지속적으로 감독하기 어렵다. 따라서, 쌀 주기의 원래 데이터는 무책임한 당사자들에 의해 조작될 수 있기 때문에 완전히 신뢰받기 어렵다. 더욱이, 현행 제도는 관련 당사자들에게 적절한 동기를 부여하지 않는다. 따라서, 본 논문에서, 우리는 앞서 언급한 문제를 해결하기 위해 채택될 이더리움 블록체인을 활용한다. 목적은 생산자에서 고객에게 쌀을 이전하는 동시에 당사자 간의 신뢰를 높이기 위한 것이다. 우리가 제안한 계획은 고객들이 미얀마의 쌀 순환 정보에 대한 정보를 확인하고 추적할 수 있게 해준다. 게다가, 허가된 당사자들은 또한 이더리움 스마트 계약 기능을 통해 정부로부터 보상을 받는다. 결국, 우리의 계획은 미얀마 쌀 체인에서 추적가능성을 달성하고 쌀 순환 정보의 완전한 디지털화와 자동화를 이끌 것이다.

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Chapter 1. Introduction

1.1 Background

According to the society is becoming more consuming, and most people in the developed countries have high consumer power and standard of living. Consumer goods, from essentials to entertainment goods, are continuously produced and ordered in large quantities. There are multiple "stakeholders" acting as crucial business participants such as farmers, manufacturing plants, distributors, retailers, and consumers in the food supply chain. These traders prefer to selectively provide the food information, which is beneficial to them in the trading process to make a high profit. This concern is quickly leading to food fraud and food safety problems. Any document that is difficult to check because of the information providers' inaccurate in the supply chain, regulatory agencies find it difficult to gather reliable and accurate information to implement oversight.

The digital world has changed the way people buy and consume things. Consumers want customizable and tailored products to meet their needs also a streamlined shopping experience and transparency in product cost. These needs have created new opportunities and new challenges in existing supply chains. The challenges are to manage expectations, improve operations, build a better network of suppliers, and track or investigate an asset or product in geographically dispersed supply chains that are becoming separate and more complex. A supply chain refers to “a network of all the resources, activities, and technologies of the individual organizations involved in creating and selling a product” [1]. These include multiple processes, from sourcing and raw materials by suppliers, through design and production by manufacturers, to shipment of the final product to consumers, and it can even include logistical support after delivering a discount. Supply Chain Management (SCM) arranges all of these steps and organize the personnel, processes, and technologies required for smooth operation. Due to the multiple supply chain networks, there are many challenges combined with managing supply chains.

By using the blockchain app, we can guarantee data can be heard, authenticated, available, and stable. Moreover, the blockchain due to being decentralized in nature, it ensures that no third party is involved, and the blockchain acts as a distributed registry, whereby the client can read, write and broadcast information to their peers on the networks. It was derived from the popular cryptocurrency Bitcoin [3]. Smart contract software that can be written powerfully from Ethereum [4]. Go or Python, and Java run on top of the blockchain and contain a set of rules that must be fully populated for a transaction to take place. It is self-executing, verifiable and tamper-proof, and requires no third-party control.

1.2 The Scope

The Ethereum platform emerged in July 2015, relatively new and is still undergoing many experimental changes. With the ability to build decentralized applications with smart contracts such as logic programming running on the decentralized Ethereum blockchain. It has since gained popularity among researchers who are looking to integrate this new platform with the release one and conduct huge different experiments and offer their views on different use cases and how it can help overcome some challenges. This research is to analyze the Ethereum blockchain and supply chain. Also, ensure food safety in the supply chain and some opportunities to forward it by adopting blockchain technology. This study will help notice the chance of nowadays blockchain technology and the demand that accompanies these probabilities. The purpose is to establish a framework trustable and traceability in the Myanmar rice cycle supply chain throughout the blockchain and smart contracts. It would help to figure out the drivers of mainstream blockchain adoption in the Myanmar rice cycle supply chain, possible business models, and strategic considerations.

1.3 Outline of the thesis

The structure of this thesis is divided into six chapters as follows:

Chapter 2: We define the problem definition, state the research questions.

Chapter 3: We discuss the literature review.

Chapter 4: We introduce a proposed approach.

Chapter 5: We show performance and analysis.

Chapter 6: We discuss the conclusion and future work

Chapter 2. Problem Definition

2.1 Problem Statements

In Supply Chain Management (SCM), the life cycle of a product can be roughly divided into the many phases that the product goes through, from raw material until the product ends up in the hands of the consumer. Starting with raw materials, most products undergo iterations of processing and shipping, traveling from place to place, while being transformed into successively more refined versions and changing owners. This is valid for any product in any type of industry, and even the simplest of products that may not require any processing must be shipped from their place of origin to the place where they will be sold [5].

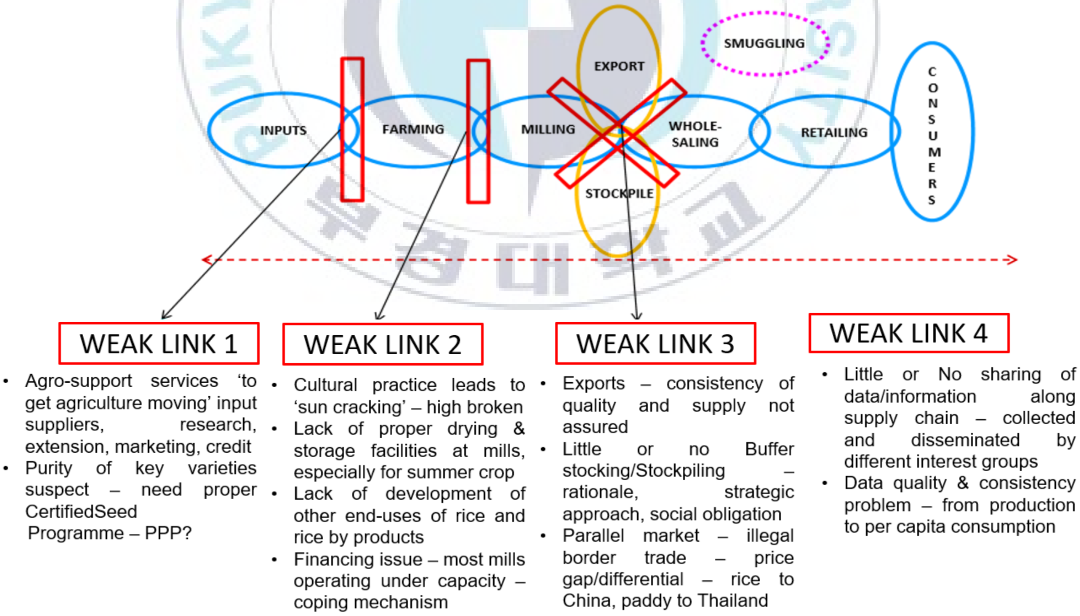

FIGURE 2.1: Weak Links in the Myanmar Rice Supply Chain (Strength of a chain is determined by the weakest link) [22]

Weak link 1: Input supplies need to be improved, especially seeds and fertilizers. Need for PPP in certified production. Insufficient existing local production, need to invite FDI in this area, given Myanmar's oil.

Weak link 2: Regarding rice quality, rice mills face high fractures due to proper post-harvest technologies. Likewise, the purity of the rice varieties was a constraint for the rice mills interviewed. Suitable drying, grinding and storage facilities are required. Rice bran oil and other end users of rice products and very limited products.

Weak link 3: constant quality and supply for exports. Internal price and supply volatility problems require adequate rice stocks to be doubled as a buffer. Border trade not properly monitored and managed.

Weak Link 4: Lack of quality, consistency, and transparency even in basic data and information along the rice supply chain. Challenging for policy makers and investors.

In this thesis, weak links 1 and 2 are out of the scope of blockchain and beyond blockchain technology. Our scheme can recover problems of weak links 3 and 4. In weak link 3 quality and supply for exports, this fact is important when transport rice products to the end-users. Our scheme supported blockchain technology to enhance rice quality and safe products when transfer to the consumer. Moreover, border trade is not properly monitored and managed to rice products. Therefore, we used a blockchain platform to monitor rice products.

For weak link 4, our rice product’s quality, consistency and transparency are important when sell to the consumers. If something problem appears in the rice product, the consumer can check and trace by own self. Transparent is also open because our schemed used blockchain technology. In our scheme, every parties can see the information along the rice supply chain. Therefore, our scheme is consistent, and every party can trust each other about our rice product’s quality to achieve transparency toward building a trustiness system.

2.2 Research Questions

As we discuss effective problems in problem definitions, this section takes us to basic research questions:

1. Why do we consider using Ethereum blockchain?
2. What approach to be used to overcome the weakness of the current Myanmar rice cycle system?
3. How can Ethereum blockchain provide data provenance?
4. How to give distributive incentives to the parties?
5. How to achieve transparency toward building a trustiness system?

Chapter 3. Literature Review

3.1 Decentralized Technology

3.1.1 Essential Blockchain

The blockchain was developed for Bitcoin, which is a decentralized transaction and data management technology that implements consumers and sellers to store and exchange value without the need for traditional agents. It is an original technology that has the possibility to disorder current industrial and common systems and establishes transparency, profitable, and safety system, and Blockchain technology is a form of distributed ledger that benefits the characteristics of a broad peer-to-peer network, peers and colleagues to certify and accept transactions. The distributed ledger has historical, cryptographically signed, immutable transaction records that can be linked from anywhere on the network. Considering blockchain copies are distributed globally across the network, authentic network records cannot be changed without the approval network. Permanent distribution increases trust, and immutable distribution also increases reliance on the network.

In addition, transactions of specific users and larger network participants with access true can be displayed and tracked, which makes the exchange of values decentralized and transparent. The digital signature of data records secures the data protection of the transaction information saved in the blockchain. According to their study published in the Gartner Research Journal, Valdes and Furlong [7] defined the following key characteristics of blockchain technology that are common to all blockchains.

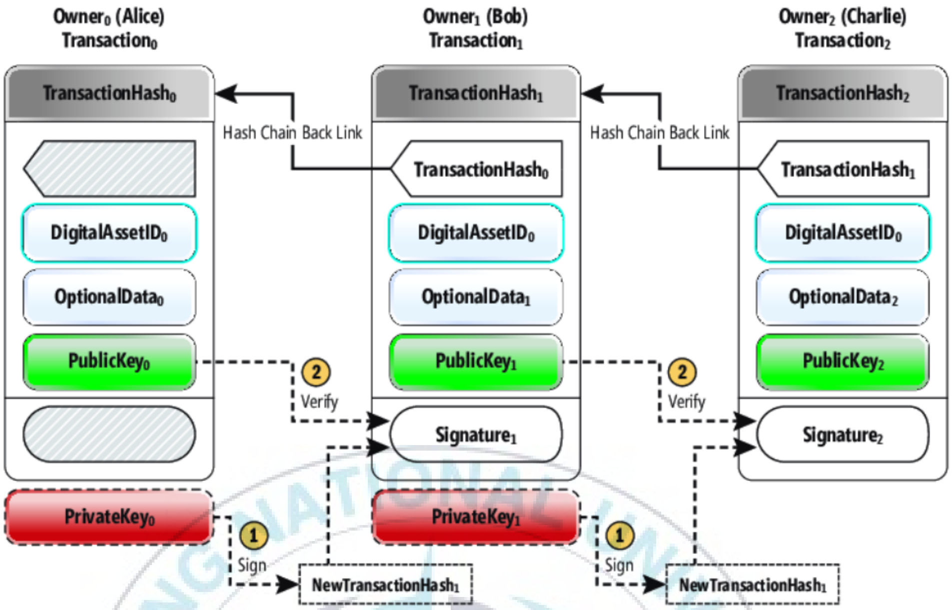

FIGURE 3.1: Hash Chain Transaction on Blockchain (Satoshi Nakamoto) [20]

3.1.2 Public Blockchain and Private Blockchain

Bitcoin has decentralized and developed permissionless, so anyone on the network can participate in the proof-of-work mining process and access a copy of the ledger. However, this method of governance was inefficient because it did not satisfy economies of scale in processing. The high risk of a single group of miners forming most of the consensus threatens the integrity of the trustless consensus process. Private or licensed blockchains are created with a different value proposition than Bitcoin or the public blockchain. Private blockchains are useful when the integrity of the audit trail is no longer relevant and the exchange of data between sectors needs to be consistent for efficient operation and a new market structure.

TABLE 3.1: Common Types of Blockchain

	Public Blockchain	Private Blockchain	Hybrid/Consortium
Overview	Fully decentralized with no central authority; “proof-of-work” or “proof-of-ownership” is used to ensure record authenticity	A central authority acts as a trusted intermediary to control and ensure record authenticity	Quasi-centralized where a consortium of entities controls the record authenticity.
Permission	Permissionless – anyone can read and write	Permissioned – write permissions are centralized to one entity	Permissioned – selected participants can make changes
Transaction verification	Records are verified by majority of the “miners” reaching consensus on the authenticity	Central authority verifies transactions	Transactions are verified by the consortium
Data storage	Records are distributed, a copy of the entire record is available to all uses of the peer-to-peer network	Records are stored by the central authority.	Records are distributed throughout the consortium.
Transaction cost	Low cost for transactions	Transaction cost dictated by one entity.	Transaction cost agreed to by the consortium

On the public or permissionless blockchain, anyone can participate in any capacity. It accepts anyone to approve new blocks during the mining process, as, in the case of a private or licensed blockchain, only certain parties can share in the network. Processing or mining is limited to specific network members or organizations. Despite the fact, the cost of verification is zero, the cost of networks is still important as the private blockchain still relies on trusted parties.

3.2 Conventional Supply Chain and Issues in Myanmar

In the conventional supply chain system, most data are recorded by each company in a centralized ledger that is stored locally. When general ledger information is not conducive to the development of the business itself, it can be falsified privately. As a result, mistrust between companies has become increasingly prominent, due to the high possibility of altering the data within the company, the information between the nodes of the supply chain is inconsistent, leading to the is inconsistent, leading to the process traceability of the product is easily interrupted [9].

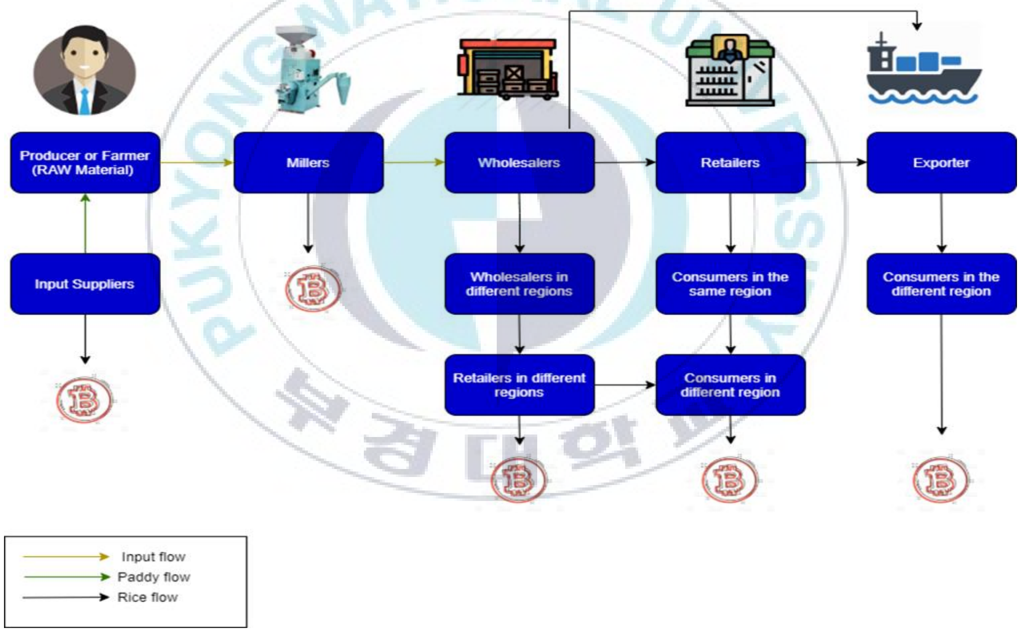

FIGURE 3.2: The Parties in the Models

We upgrade our scheme based on "The impact of environmental uncertainty on the performance of the rice supply chain in the Ayeyarwady Region, Myanmar [13]. In this paper, the parties' rice supply chain is used without blockchain. Our scheme base of this paper and this paper is from 2019, the latest one of our country's rice value chain. In this scheme, all the parties are controlled by the government. Hence, our thesis scheme based on this paper, and we adopted blockchain technology in our scheme.

The rice supply chain involves the activities of the parties to bring rice products from the farm to the final consumer. Supply chain activities link inputs from suppliers, farmers, processors, retailers, and consumers, and establish relationships that allow the supply chain to function effectively [13]. The agricultural supply chain includes all functions, such as input supply, production, post-harvest, storage, processing, marketing and distribution, food service and consumption of specific agricultural products.

The rice supply chain in Myanmar has been studied by Wong and Wai (2013) [13]. The structure of the rice supply chain is illustrated in Figure 3.2. Farmers buy inputs such as seeds, credit, etc. from suppliers of inputs for paddy production. Most collectors buy paddy from farmers with financial support from millers. The miller buys rice and grinds it into rice. They carry out different activities that add value such as transportation, processing, grading, and packaging. The millers store and distribute the rice mainly to wholesalers. The wholesalers deliver the rice in turn to retailers to supply domestic consumers or to exporters who supply consumers in foreign countries. The supply chain is fragmented because there are too many different parties at different stages and too many stages between the farmer and the end consumer.

3.3 Decentralized Supply Chain as a Solution

The blockchain is a permanent and immutable record that is created by overlaying data encrypted in chronological order. This distributed ledger technology has very important features such as decentralization, traceability, tamper checking, and crypto security. Moreover, smart contracts can be built based on the blockchain [12], allowing transactions to be conducted securely between mutually untrusted parties. In particular, the application of blockchain technology in the supply chain industry will promote its more perfect development. As a distributed ledger database, the blockchain stores data in the form of blocks. The blocks are links arranged chronologically by the hashing algorithm to ensure that the contents of the block cannot be changed. Each node in the network maintains a local copy of the blockchain ledger, which increases the cost of tampering with data. This unique data storage method can effectively solve the data problem that can be easily modified in the supply chain. Therefore, information about upstream and downstream organizations can be transparent and consistent, and all participating organizations jointly maintain a ledger to prevent malicious node attacks.

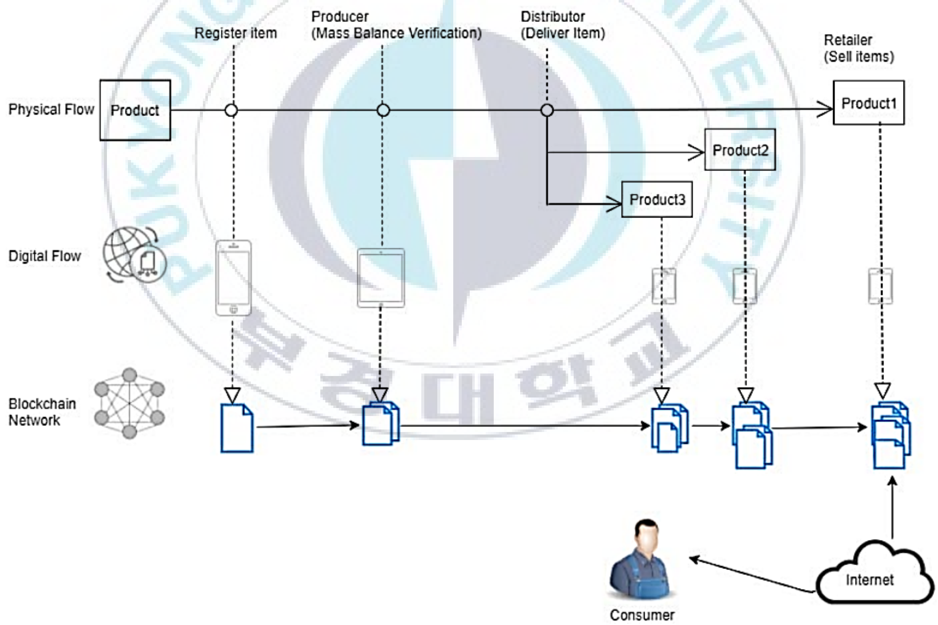

FIGURE 3.3: Traceability for Supply Chains [21]

In our previous research, we have described "A Preliminary Approach to Blockchain Technology in the Supply Chain System" [21]. n the traceability model, data information such as data provenance, lot number, industry and process data, expiration dates, storage temperatures, and shipping details are digitally linked to products when moving from origin to destination, as shown in Fig. 3.3 Traceability means to trace all processes from raw material to end product by using the Ethereum smart contract. Once the data is added to the new block, it rests consistently on the blockchain always.

Often in business and business, decentralization refers to the ability to enter a market and change value between peers without the intervention of an outside middleman who is likely to control and restrict barriers to entry. A decentralized supply chain would provide a smooth means of sharing business value between companies, even among the smallest players in the industry. Decentralization is defined as the transfer of power from a central location or authority. As a concept, it is not new; However, as a business model, it's a strong idea.

This is especially needed in the supply chain industry, which has historically suffered from many problems hindering its efficiency. The main obstacle is that supply chains today are unable to become fast-moving, which addresses an important problem in a market in which they must be able to rapidly and continuously change their configurations to meet the ever-changing dynamics of supply and demand. Another major drawback is that connection methods tend to be very heavy, with some companies still relying on manual paperwork. As a result, data storage is secured in special systems that do not allow collaboration.

The solution to many of these recurring problems in the supply chain primarily involves people. By creating networks of qualified individuals and decentralized and independent organizations, tremendous value can be created for businesses, supply chains and customers. These networks align economic incentives so that everyone thrives, based on their contribution to temporal skill and intellectual property. The new vision of decentralization has the potential to radically transform the supply chain [10].

Food companies can use blockchain to bring transparency to their supply chain process. Blockchain has the potential to add an extra layer of security to the food industry.

1) Decentralized Network

All parties in the supply chain have access to the same data. A majority consensus manages any data alterations.

2) Transparent Transactions

Blockchain keeps each data record linked to connected sensors with unique and unchangeable identifiers, so that the entire history of each asset can be tracked from the time of production.

3) No Intermediaries

Smart contracts can automate various tasks that traditionally require human involvement, as well as cut out the third-party, making supply chain management more profitable.

4) Trusted Environment

The blockchain maintains a permanent record of all supply chain histories, ensuring tamper-proof digital document tracks and building trust among network participants.

5) Secure Operations

Encryption keys protect every bit of data, with any corruption attempt instantly visible to the entire network. Private blockchains allow separate permissions to be set.

6) Interoperable Networks

Blockchain connects suppliers, distributors, manufacturers, and retailers into a single ecosystem where all parties have access to the same data.

3.4 Platforms Used

3.4.1 Essential Ethereum Blockchain

Presentation of a practical way to implement a supply chain application based on an Ethereum blockchain. There has been a lot of research recently into this application to PoCs and large companies are already experimenting with this possibility for their operations. Walmart is even already adapting a supply chain based on blockchain technology. Using blockchain offers the benefits of a more transparent and efficient tracking of the technology's inherent origins. [11] There are two types of accounts on the Ethereum blockchain:

1) External Accounts (EOAs): EOAs have an Ethereum address that is controlled by a private key. A person can open EOA at will. EOAs can not only send and receive ether, but also create and activate contracts.

2) Contract Accounts: These are accounts to which code is assigned. Each contract that is provided for the Ether and the network has its own account that contains a unique Ethereum address. However, unlike an external account, a contract account does not have a private key with which it is contracted. A very important concept in Ethereum is the concept of fees. A fee is charged for every calculation made as a result of a transaction on the Ethereum network. This fee is paid in a denomination called "gas". The Ethereum blockchain requires Ethereum gas to run the way a car uses gasoline to store the lights on. All transactions on the Ethereum network cost a certain amount of gas, depending on the current appeal for gas and the size and speed of the contract you want to execute. Probably, performing transactions over the Ethereum network is like driving a car. If we do

not use sufficient gasoline, the transaction won't find its way from one party to the other.

Gas is a very important innovation in the blockchain society. Like a car, Ethereum runs on gas. Each line of code that the network must implement takes gas. Gasoline is running out and the code has stopped working. So how much gas do we need to implement one line of code? They are predefined amounts for every action we want to take in our code. Example: Sending ether from one address to another requires 21,000 units of gas.

3.4.2 Main Point of Ethereum Blockchain for Myanmar Rice Cycle

We use Ethereum platform with the following 3 questions:

1) Differences between Ethereum and any other platforms such as Hyperledger Fabric. Ethereum is more suitable for our scheme in terms of architecture, types of transaction, visibility, and to name a few.
2) We use Ethereum to provide a reward for the parties when they successfully submit a transaction.
3) Ethereum platform provides immutable incentive that can solve dispute between parties.

We conclude and explain with the table based on the above 3 questions and why we have to consider Ethereum blockchain in our thesis.

TABLE 3.2: Considering Ethereum Blockchain

For Question 1	For Question 2	For Question 3
Ethereum: Public and private, and permissionless. In transaction privacy, no transaction privacy. All transactions are posted to the public ledger visible to all participants. **Hyperledger**: Private and permissioned. In transaction privacy, privacy is available when transacting across channels.	Hyperledger is not cryptocurrency-based but Ethereum is based on cryptocurrency. To give incentive for every parties whenever they submit the transaction through smart contract.	Provenance + Immutable incentive

3.4.3 Smart Contract

The programming ability of the Ethereum platform relies on its ability to create and execute smart contracts. The term "smart contract" was introduced by Nick Szabo in 1996, when he described it as "a set of promises, specified in digital form, including the protocols within which the parties keep those promises" [6]. A smart contract is a digital contract that executes itself when predetermined conditions are met. These code-based contracts allow you to execute agreed actions (such as payments) automatically, immediately and without intermediaries once the term of the contract has expired [8]. For example, a smart contract could be used to release payment to a courier when the customer confirms receipt of the package. The smart contract is an agreement between the parties involved in a transaction that holds each party accountable for their role in the transaction. Smart contracts define the rules and penalties related to a transaction like a traditional contract, but they also ensure that the contract is respected.

3.4.4 Ethereum Virtual Machine (EVM)

Ethereum is a protocol for the open and distributed execution of a virtual machine. This virtual machine is known as the Ethereum Virtual Machine (EVM). Programs on EVM are known as Ethereum Smart Contracts. The EVM is a complete Turing virtual machine as defined above. The only limitation of the EVM that a typical Turing Complete machine doesn't have is that the EVM is inherently gas-bound. Thus, the total amount of computation that can be performed is inherently limited by the amount of gas supplied. In addition, the EVM has a stack-based architecture. A batch machine is a computer that uses a last-in and last-out batch to store temporary values. The size of each stack element in the EVM is 256 bits and the stack have a maximum size of 1024.

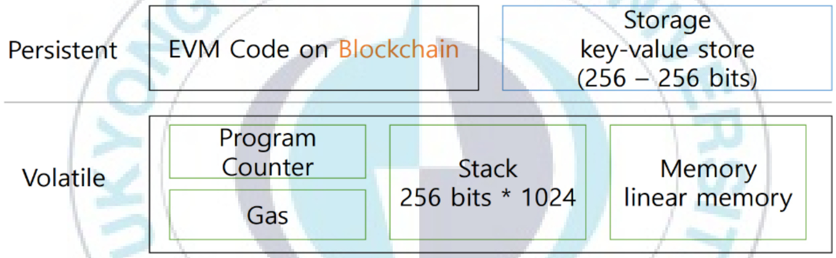

Figure 3.4: Ethereum Virtual Machine (EVM) [13]

3.4.5 Metamask

Blockchain wallets can store the user's private key, not just manage the blockchain account balance, and create transactions on behalf of the user to transmit. In this sense, wallets are the simplest approach to the general user blockchain network. *Metamask* is the most representative web wallet extension program that runs in the browser and currently supports Chrome, Firefox, Opera and Brave Browser and supports the creation and linking of Ethereum accounts, electronic signature, and the generation of transactions. Users can easily access smart contracts on the blockchain by using *Metamask* in the browser.

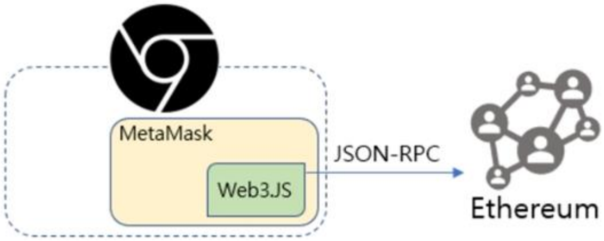

FIGURE 3.5: JSON-RPC Connection in browser by web3 [15]

In order for users to access the Ethereum network, they must participate in the network as a blockchain node via the Ethereum client. Because this approach reduces user access, *Metamask* uses the Infura API [14], which is a cloud service that allows wallet users to access the network. This allows users to connect to the Ethereum network, enter into smart contracts, and get results without having to run the contract themselves. Ethereum supports the standard web3.JS API for communicating with the Ethereum network using JSON-RPC in web applications. *Metamask* has its own browser running.

3.4.6 Ganache – Truffle Suite

Ganache allows you to create a private Ethereum blockchain to run tests, execute commands and inspect the status by checking the operation of the chain. It gives the possibility to perform all the actions we would do on the main chain without the cost. Many developers use it to test their smart contacts during development. It provides useful tools such as advanced mining controls and a built-in block explorer.

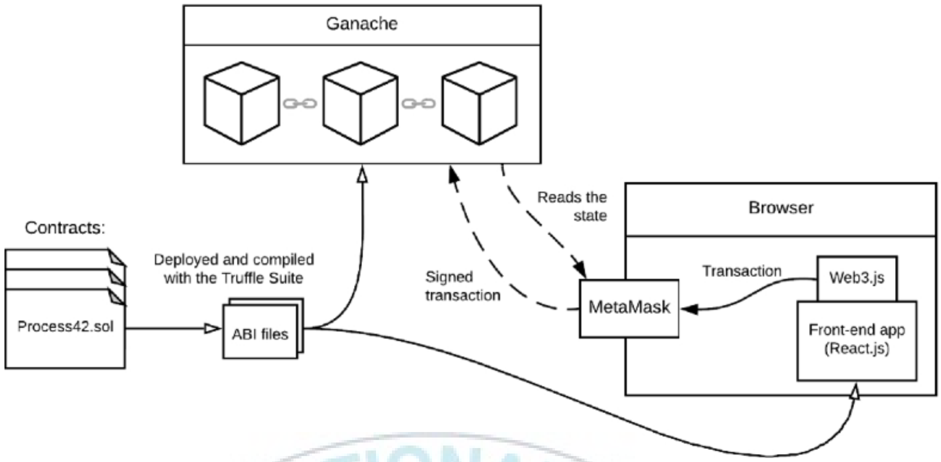

FIGURE 3.6: Overview of communication with a local blockchain [17]

In the Fig 3.6 In Fig, the contract is our smart contract that has two functions. They are the update function and revenue function. The update function is updating rice information to the smart contract, as well as the revenue function is the government gives the reward the same ether to every party. Additionally, contract ABI is when user *Truffle* the easiest way to get a contract ABI, that just to read JSON files. Then, in the *Ganache*, we can see a list of transactions everything in there. Then, *Metamask* is the manage the party's entities wallets public and private key, that came from *Ganache*.

Truffle is a development environment, test framework, and deployment pipeline for Ethereum DApps or any blockchain that uses the EVM to make life as a developer easier. *Truffle* is operated in the terminal and therefore has a number of useful commands that we can use in different phases of the development of a DApp [20]. In other words, *Truffle* is a development environment, test framework, and asset pipeline rolled into one. It is based on Ethereum Blockchain and was developed to enable the smooth and seamless development of DApps. With *Truffle* we can compile and deploy smart contracts, insert them into web apps and develop front-end for DApps. Today, *Truffle* is one of the most widely used IDEs for the

Ethereum blockchain. The *Truffle* suite consists of its core elements:

- *Truffle* – The actual development environment that integrates compilation, testing, and deployment of Smart Contracts.
- *Ganache* – It is a locally deployed Blockchain simulator. *Ganache* has a graphical user interface that can simulate Blockchain networks and test smart contracts live without requiring us to set up real test networks or use a remote network.

Chapter 4. Proposed Approach

4.1 Our Proposed Scheme

The Ethereum smart contract has the potential to transform safety of rice product into an integrated smart system that guarantees the quality of rice product delivered to the end consumer. Our proposed scheme and solution focus on the usage of smart contracts executed autonomously on the public Ethereum blockchain platform. The smart contract functions are implemented by multiple mining nodes that are globally distributed, and the execution outcome is agreed upon by all mining nodes. It is worth nothing that it is the mining nodes that make up the blockchain network.

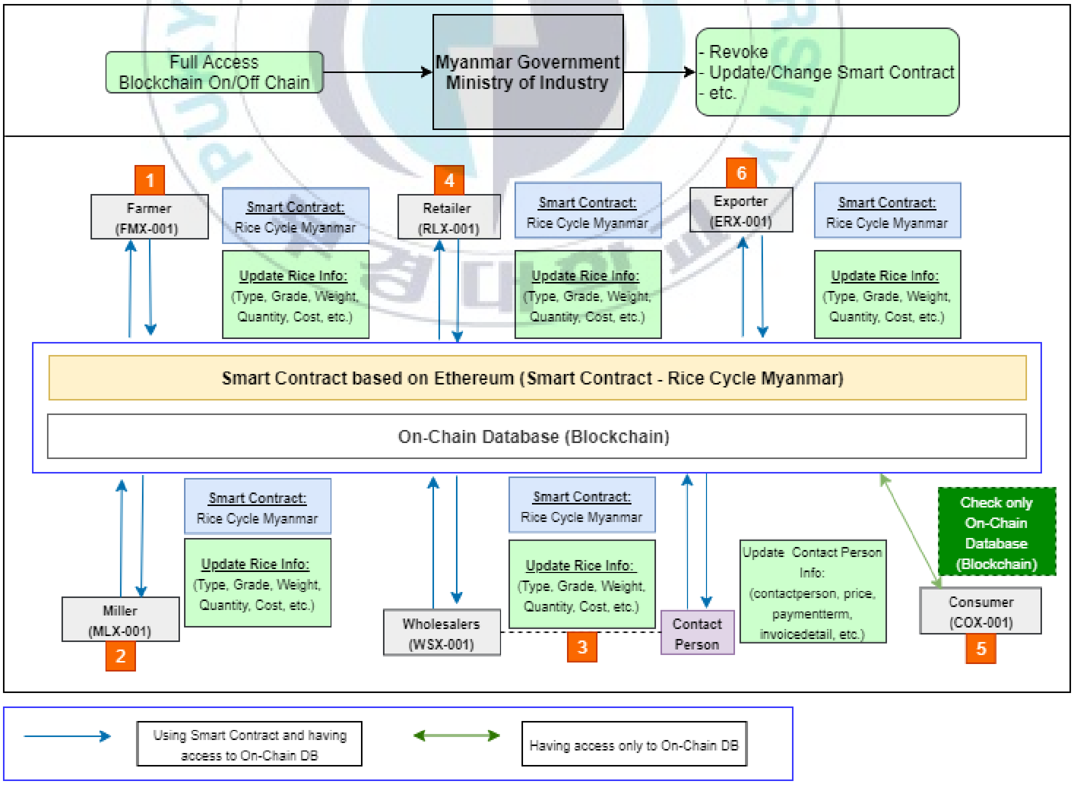

FIGURE 4.1: The parties and roles in Myanmar Rice Cycle

A mining node can be any computer machine that collects, validates, and executes transactions. The nodes also store the data and results of these transactions in a ledger that is replicated and synchronized by all mining nodes. In the blockchain, smart contracts receive transactions in the form of function calls and trigger events to allow participating entities to continuously monitor, track and receive alerts when violations occur. Thereby, it eventually helps restore optimal conditions and respond to violations that occur within the rice cycle chain. Our solution focuses on the rice supply chain to be in this case.

In figure 4.1 illustrates an overview of the system architecture of the proposed rice supply chain. The main participating parties include Farmer, Miller, Wholesalers, Retailer, Consumer, and Exporter. The blockchain has the EVM executing the smart contract and every parties must update the information to the Ethereum Smart Contract. The Ethereum account basically consists of the Ethereum account (EA) with public and private keys which are used to cryptographically and digitally signed. It validates the integrity of the data within a transaction and associate each transaction with a specific EA.

In our scheme, the whole system is assumed generated by the Ministry of Industry of the Government of Myanmar. The Ministry of Industry of the Government of Myanmar has full access to blockchain on/ff-Chain and government can revoke, update/change smart contract. Meanwhile, Farmers, Millers, Wholesalers, Retailers, and Exporters use smart contracts based on Ethereum and have access to the on-chain database. The consumer only has access to the chain database. In our scheme, we use public Ethereum with a fixed number of parties.

1. Farmer: The farmer updated the rice information in the Ethereum-based Smart Contract (Smart Contract - Rice Cycle Myanmar) and On-Chain Database (Blockchain).
2. Miller: The miller determines the type and quality of the rice and buys the

rice from the farmer. In addition, all information is stored on the smart contract and blockchain platform.

3. Wholesalers: A wholesaler is generally a store that buys end products from Miller. It is an entity that is involved in the process of distributing rice products to the general population.
4. Retailer: The retailer purchases finished rice products from the wholesaler usually in batches with traceable identifiers and sells them to consumers in small quantities. In our diagram, we have divided two branches of the wholesaler, the first entity is the retailer and the second entity are the exporter. The local lot of the retailer and exporter is a foreign lot.
5. Consumer: The consumer is the end user who buys and consumes the product from the retailer. The consumer will only verify the Blockchain on the database.
6. Exporter: The exporter also buys finished rice products from wholesalers and will then transport them overseas.

4.2 Algorithms

This chapter explained the smart contract algorithm functions.

The first algorithm in Algorithm 4.2 is for adding a new user, it can only be executed by the owner of the contract (Government). It is embedded by government account address, which is used for authentication every time the user invokes the function within the contract.

```
Algorithm 1:   AddNewUser
Input: addNewUser
Ouptu: bool
If msg.sender is not the contract owner then
       throw;
       end
else
If addNewUser exist then
       return false;
else
     authorizeUsers[addNewUser] = true;
     return false;
End
```

Algorithm 4.2: Add New User

The second algorithm 4.3 is for creating rice information. It is invoked only with the owner of the contract allowed to add the items listed in the algorithm, such as rice type, rice grade, weight, quantity, and cost. The first argument is to check the address of the owner, if indeed exist. The last argument is to add data to the blockchain using a mapping that will allow us to look up a specific item retrieve necessary information.

```
Algorithm 2:     CreateRiceInformation
Input: farmer[id], ricetype, enum ricegrade,
weight, quantity, cost, timestamp (date)
Ouptut: Items added with captured timestamp
If msg.sender is not the contract holder then
    throw;

else
   mapping CreateItem (id) and add it to the index
     variable data collection

return true;
```

Algorithm 4.3: Creating Rice Information

The third algorithm as can be seen in algorithm 4.4 is for searching the rice information stored on the blockchain. The first argument checks the valid user address, then do the looping of all records by using Ids created in the second function and returns the searched results.

```
Algorithm 3:   SearchRiceInformation
Input: itemId
Ouptut: searchResult
searchResult ⇐ Index[itemId,keywords];
get Index[itemId,keywords] length of array len;
for unit i=0; itemid; i++ do
    return itemId;
return searchResult;
```

Algorithm 4.4: Searching Rice Information

The last algorithm as can be shown in algorithm 4.5 is for the revenue mechanism that have been uploaded onto the blockchain. In terms of the input, we have to update the ids, names, and descriptions. The revenue mechanism sends 0.25 Ether by authorized parties (the amount of Ether is adjustable, and it can set freely by the Government).

```
Algorithm 4:   Revenue Mechanism
Input: itemId, name, description
Ouptut: searchResult
If msg.sender 0.25 ether then
    throw;

else
   send 0.25 ether
    return true;

End
```

Algorithm 4.5: Revenue Mechanism

4.3. Data Information of Myanmar Rice Cycle from Authorized parties

In this section talked about the data information of Myanmar rice cycle from authorized parties. In Myanmar rice cycle, six authorized parties are included, and each party connected and to trace the information of rice product. These data input information can see in Appendix A. There are six authorized parties:

1) Farmer
2) Millers
3) Wholesalers
4) Retailer
5) Consumer
6) Exporter

For the first party, “Farmer”, we have to enter the ID, organization, rice variety, rice variety, weight, quantity, cost and the address of the miller. The second party "miller" is the important septum in rice processing. In this party, miller ID, organization, rice type, rice type, received weight, output weight, quantity, cost, and miller address must enter data from millers.

In the third-party provider, "wholesalers" have to enter the ID, organization, rice variety, rice variety, received weight, order quantity, product name, shipping data, dealer address and contact person of the wholesaler. These are the important data of the “wholesalers” party. The closest “Retailer” is one of the “Wholesalers” branches and a local branch. Input data are dealer ID, receipt data from wholesaler, order number, organization, order quantity, rice type, weight, rice type, product name, price, invoice details and consumer address.

The end-user ‘Consumer’ can check all rice data information of each party, and input data are consumer ID, order number, farmer organization, miller organization, wholesalers organization, retailer organization, rice type, rice grade, order quantity, weight, and price. If something error happened in the rice product, the consumer can check it by self. The last one ‘Exporter’ is the branch of the wholesaler and this party *transfer* to a foreign country. Input data are consumer ID, order number, wholesaler organization, order quantity, rice type, invoice detail, weight, price, shipment date, payment method, and shipping address detail. These are the *data, information on* the Myanmar rice cycle from authorized parties.

Chapter 5. Analysis and Performance Evaluation

Evaluation

This chapter is based on an evaluation of the proposed method, in addition to testing the performance results of the transaction, the gas used and the total ether comparison between the authorized parties and the government. We analyze the cost of the contract from the moment of the transaction fee implemented, as well as the cost of the invoked functions, we use the truffle and ganache, we debug and test. For cost assumptions, we used the *Metamask* plugin that was integrated with remix IDE online to estimate the cost.

5.1 Implementation

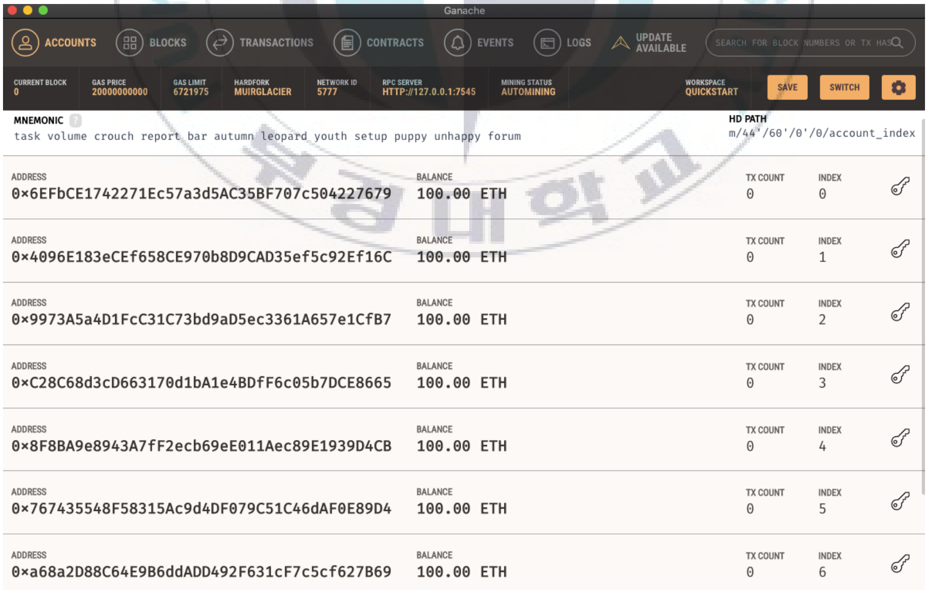

FIGURE 5.1: Ganache GUI

Figure 5.1, this is like only to provide private address and private key from *Ganache*. The government, the farmer, the millers, the retailer, the wholesalers, and the exporter, these actors are getting the private keys from *Ganache*. Then, the default setting balance has100 ETH (ether) that we can see the gas price, gas limit in the above figure, there are from the *Ganache*. The gas price is '20000000000' and the gas limit is '6721975'.

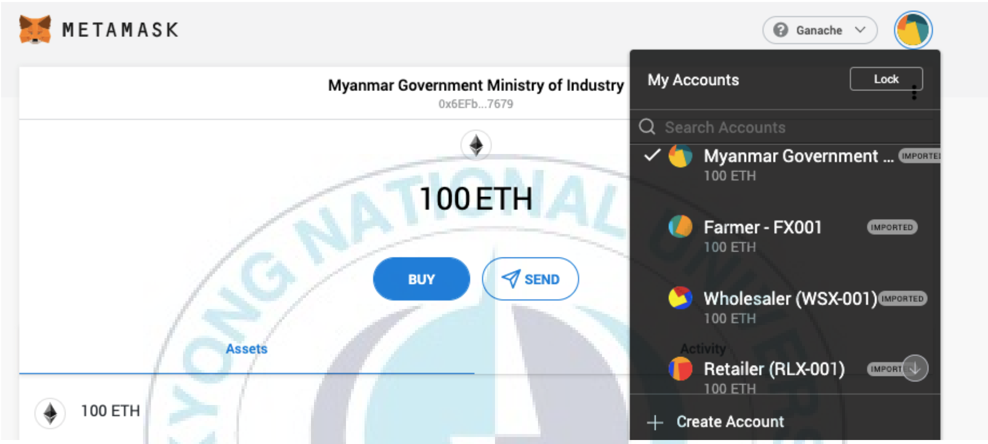

FIGURE 5.2: Metamask

In Fig 5.2, *Metamask* manages a wallet of *the parties*, and the entities derived from the *Ganache* eventually copy the private key to the *Metamask*. *Metamask* will manage the entire wallet of party entities. From Fig 5.1 we copied the private key and import to a private key in the *Metamask* from the account, import, copy/paste, and we need farmer, wholesaler, retailer, exporter, and all parties' processes are same.

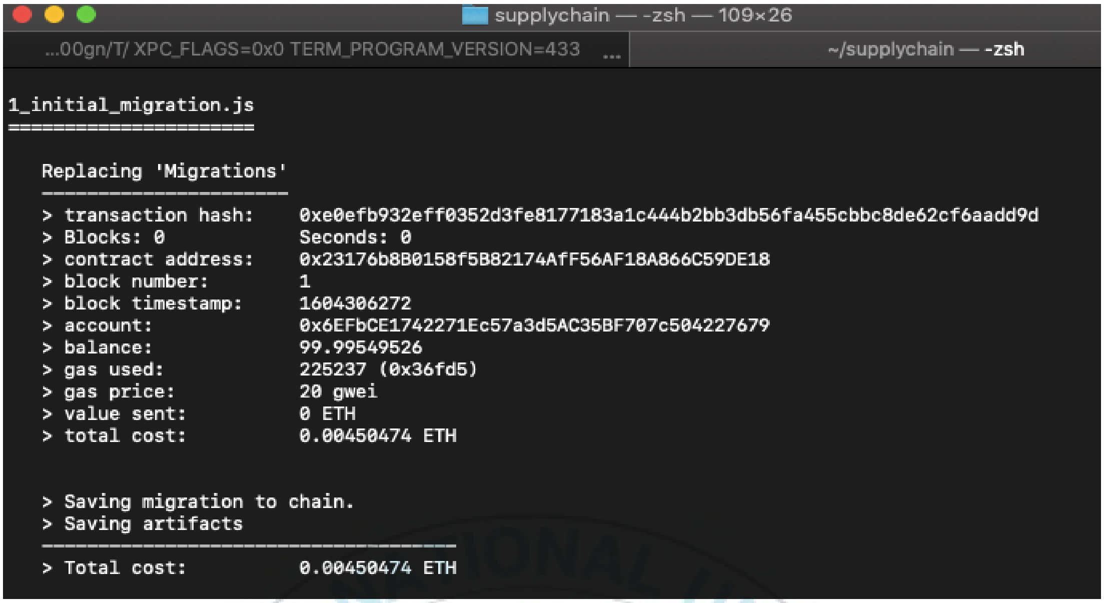

FIGURE 5.3: Migrate for the smart contract

Fig 5.3 is for the migrate of the smart contract and the first one is ‘transaction hash’, second is blocks ‘0’ this is genesis block and the next one ‘contract address’, in order to apply the smart contract and they used the kind of gas. Hence, in the Fig we will see ‘gas used’ and ‘gas price’ and the ‘total cost’ is ‘0.00450474 ETH’.

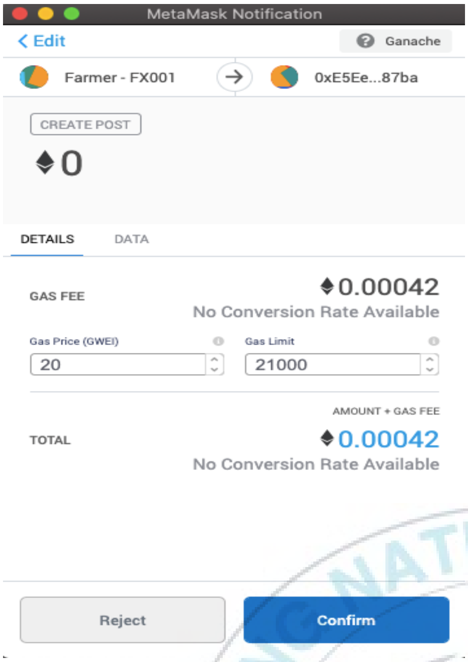

FIGURE 5.4 (A): Transaction of Farmer

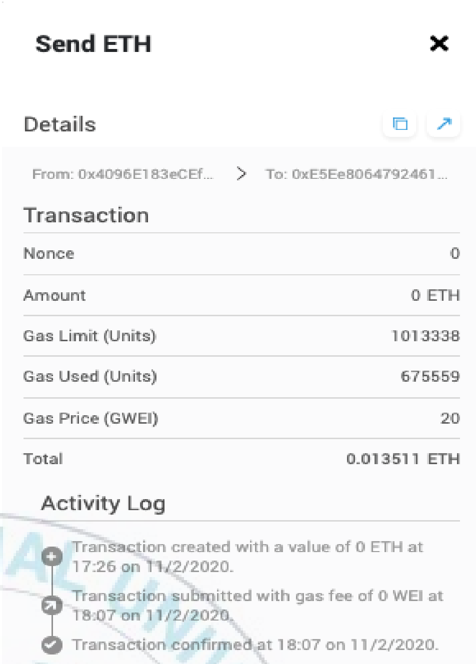

FIGURE 5.4 (B): Complete Transaction Form

Fig 5.4 (A) is for the transaction and the 'Farmer' will put the data. The data we described input the data as description and input enter the web and submit. To submit it and they needed the gas fee total is '0.00042'. Fig 5.4 (B) is the complete transaction form that used the gas. We could see the 'Gas limit' '1013338', the 'Gas Used' '675559', 'Gas Price' '20' in Fig 5.4 (B), and the 'Total' ether is '0.013511' ETH.

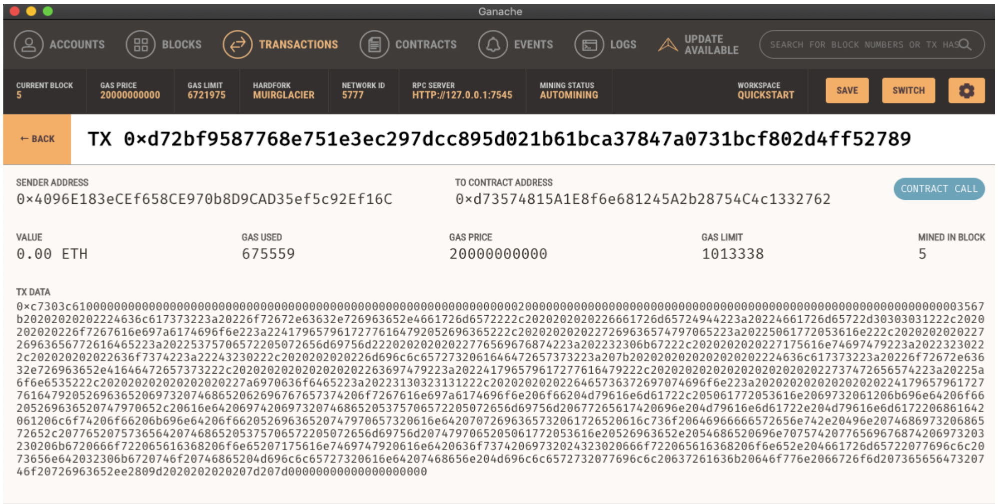

FIGURE 5.5: Transaction View

Fig 5.5 and 5.6 are also the same transaction, but it can see from Ganache. In the Ganache showed that value, gas used, gas price, gas limit, and mine in the block, we could see everything in here. In this transaction, the mined in the block is 5, block '0' is genesis block, block '1' is migrated smart contract, block '2' is framer transaction, and block '5' is a smart contract it will invoke to the data. We can see everything in the Ganache about Transaction.

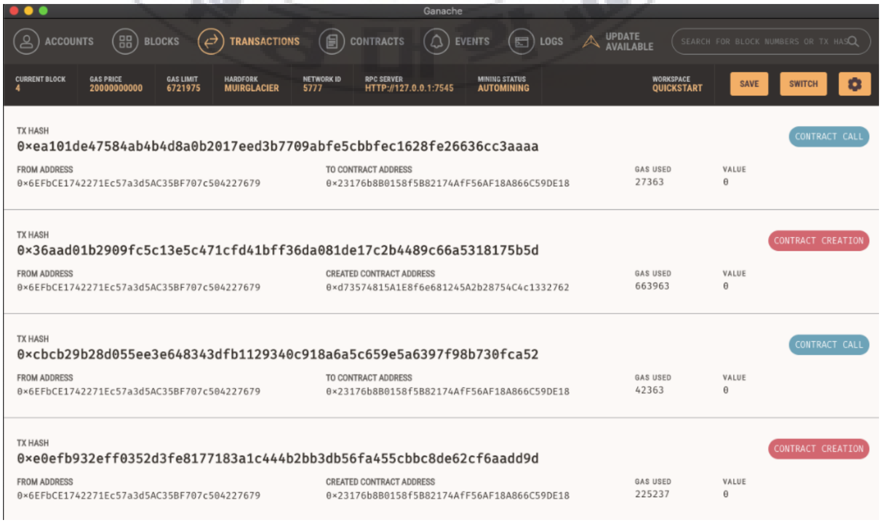

FIGURE 5.6: Transaction from Ganache

5.2 Performance Results

In the table 5.1, the largest one is the farmer that the data size is '936' bit data size. It comes from farmer data characters' words '117' and gas limit of farmer and government are automatic and the gas used we can see from Fig 5.4 (B) by the farmer, if the data are big, the gas used will be used a lot. Moreover, the government gas used is the same for all parties because the government gives the same '0.25' ETH to every party and the size of data is the same. The total ETH for the transaction of the farmer has automatically calculated then the government for transactions is the same for all parties.

TABLE 5.1: Performance result of Transaction

Transaction No	Data size (bits)	Gas Limit (units)		Gas Used (units)		Total (ETH)	
		Auth. Parties	Govern.	Auth. Parties	Govern.	Auth. Parties	Govern.
1. Farmer (FMX-001)	936	1013338	6721975	675559	117987	0.01351	0.00729
2. Miller (MLX-001)	512	1013338	6721975	636564	117987	0.01113	0.00729
3. Wholesalers (WSX-001)	760	1013338	6721975	656123	117987	0.01226	0.00729
4. Retailer (RLX -001)	800	1013338	6721975	665521	117987	0.01324	0.00729
5. Exporter (ERX-001)	624	1013338	6721975	643598	117987	0.01104	0.00729

The retailer is the second-largest data size that comes from '95' character words. It is equal to '800' bit. Gas limit of retailer and government is automatic, the retailer is '665521' this is the second largest one for gas used because retailer data size is the second largest one. The total of Ethereum transaction is automatically calculated.

The smallest one is a miller which data size is '512' bit like '64' character words. If the data size is small, the gas used is lesser. All the other processes are the same as from other parties' processing.

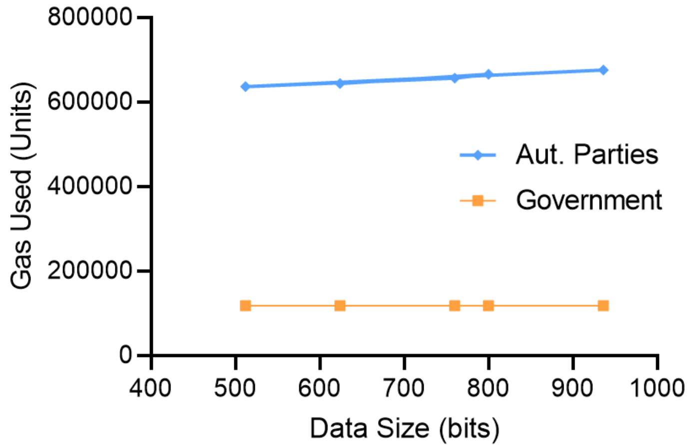

FIGURE 5.7: Gas Used Comparison between Authorized Parties and Government

In the Fig. 5.7, showing that gas used of authorized parties and government. The authorized parties gas used are higher, the gas used are depended on data input size. If the data input sizes are bigger, the gas used of authorized parties are also will be higher. In the Fig. 5.7, described with arrow line to authorize parties' gas used. In the other side, the government's gas used are stable.

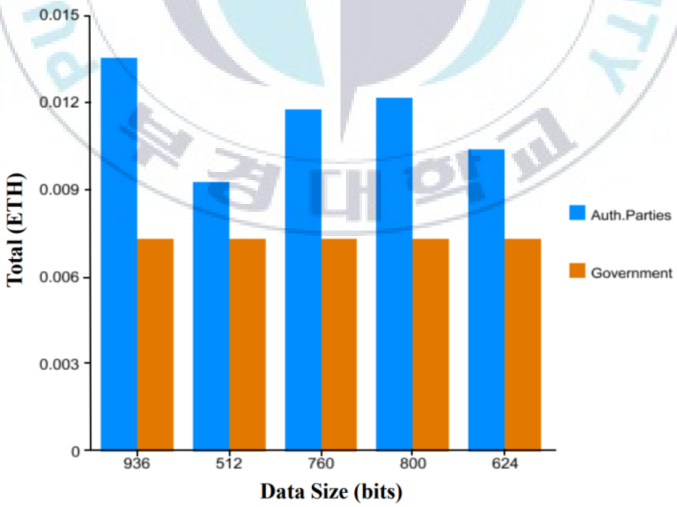

FIGURE 5.8: Total Ether Comparison between Authorized Parties and Government

In the Fig. 5.8, showing that the total Ethereum of authorized parties and government. The authorized parties' total Ethereum is different because they are depended on data size. The government of total Ethereum are similar because the government gave the same amount of ether to each party.

TABLE 5.2: Public Private Key of Authorized Parties

Auth. Parties	Account Address	Private Key
Government	0x6EFbCE1742271Ec57a3d5AC35BF707c504227679	de2ac421d6923f91ada606e3db36e2ddb3bf77f6f5d943c60334b09ab757ae89
Farmer	0x4096E183eCEf658CE970b8D9CAD35ef5c92Ef16C	952ed3cdce15a44bf4a74ca511a2c68bac0f4c6
Miller	0x9973A5a4D1FcC31C73bd9aD5ec3361A657e1CfB7	e7f8654fddf91f92bc16fab82c70b1904b882cc4bb4de3bea67265ce3e0ed64d
Wholesalers	0xC28C68d3cD663170d1bA1e4BDfF6c05b7DCE8665	c5c85aafd80c28abf76ea0df41d2edbc74c026ef018eed888780908a3157f3b4
Retailer	0x8F8BA9e8943A7fF2ecb69eE011Aec89E1939D4CB	3243eaa7593b9fdf8e819e7cfcbcfdd7df28d26fbc04e73ea4e80534f5b14019
Exporter	0x767435548F58315Ac9d4DF079C51C46dAF0E89D4	6858f8084d3354c9ec8a71de142b27dce36aae06cfc75620f752f58c3cb1bcba

Fig 5.6 Gas Used comparison between authorized parties and government and Fig 5.7 Total ether comparison between authorized parties and government, both Figs based on the above table 5.1. Both Figs showed that Gas Used and Total ETH of comparison between authorized parties and government. Fig 5.6 shows that Gas Used (Unit) and Data Size (bits) between authorized parties and government. Fig 5.7 shows that Total ETH and Data Size (bits) between authorized parties and the government.

5.3 Comparison Research Papers

In the following table, we have compared our proposed scheme with the previous research papers. We used eight major issues and compared to each previous research article based on the following facts.

1. Data provenance: to keep track of original data from current data.
2. Quality control: to maintain the quality of the rice.

3. Traceability for public: the process of tracking the origin and route of rice products and their inputs from the raw product of the supply chain to final consumption.
4. Immutable rice cycle information: no one can change the information of the rice data.
5. Relying on third-party in managing every transaction: all informational data is based on third parties.
6. Information transparency: transactions are transparent and rice information can be updated and validated in real time. All transactions can see the parties involved in the data flow.
7. Process Consistency: let the government know when the parties are doing the right things and make changes when they are not.
8. Party reputation (Recorded): as you give each party the reward, the party's reputation increases. The above facts are the main problem when we considered and compared with the research papers of our proposed scheme.

TABLE 5.3: Comparison research papers

Variables	**Conventional Approaches**		**Our Proposed Scheme**
	Oo, S, P., and Usami, K. (2020) [23]	**Thuzar Linn and Broos Maenhou (2019) [13]**	
Data Provenance	✗	✓	✓
Quality Control	✓	✓	✓
Traceability for Public	✗	N/D	✓
Immutable Rice Cycle Information	✗	✗	✓
Relying on Third-Party in Managing Every Transaction	✓	✓	✗
Information Transparency	N/D	✓	✓
Process Consistency	✓	✗	✓
Party Reputation (Recorded)	✗	✗	✓

N/D: Not Defined

Chapter 6. Conclusion

This research builds on the current rice supply chain in Myanmar without blockchain technology. There are different types of parties in the rice value chain, i.e. farmers, millers, wholesalers, retailers, consumers, and exporters, and we build trust between the parties. In the current Myanmar rice cycle, we found that there are some problems: the flow of data is controlled by a single entity, which means they are dependent on third parties. Therefore, they can change everything on the web, so we can't fully trust the quality of the rice. The next problem is hackable, it can be hacked. The last is that they have no incentives for the parties involved. That is why, in our thesis, we have solved these problems using blockchain technology.

Blockchain technology provides immutability data on Myanmar rice cycle information, in this case no one can change the data and we can trust the quality of the rice. In addition, the transparency of the data flow allows everyone to see the information in which the party is involved in the flow. Furthermore, it incentivizes decentralized parties involved and eliminates dependence on third parties, so they don't rely on third parties.

Ethereum blockchain as a solution to provide an immutable data source for the Myanmar rice cycle. Decentralized revenue is provided successfully, and it can motivate authorized parties to act honestly. Information can only be updated by authorized entities, but the stored data is available to the public. Eventually, our proposed scheme can be gradually adopted to address the current issues of the Myanmar rice cycle.

Chapter 7. Appendix

A. Input Data

Farmer


```
{
    "$class": "org.cc.rice.Farmer",
    "farmerID": "Farmer-0001",
    "organization":"Ayeyarwady Rice",
    "ricetype": "Paw San",
    "ricegrade": "Super Premium"
    "weight": "20kg",
    "quantity": "20",
    "cost":"$20",
    "millers address": {
        "$class": "org.cc.rice.Address",
        "city": "Ayeyarwady",
        "street": "Zone5",
        "zipcode": "10211",
    "description":
        "Ayeyarwady Rice is the biggest organization of
Myanmar, Paw San is a kind of Rice type, and it is the
Super Premium great in Myanmar. Myanmar had a lot of kind
of Rice types and prices are also different. In this here,
we used the Super Premium type Paw San Rice. The input
weight is 20 kg for each one quantity and cost is $20 for
each one. Farmer will send 20kg to the Millers and then
Millers will crack down from seeds to rice.”
    }
}
```


Millers


```
{
    "$class": "org.cc.rice.Farmer",
    "millersID": "Farmer-0001",
    "organization":"Ayeyarwady Rice",
    "ricetype": "Paw San",
    "ricegrade": "Super Premium"
    "receiveweight":"20kg",
    "issueweight": "17kg",
    "quantity": "20",
```

```
    "cost":"$30",
    "millers address": {
        "$class": "org.cc.rice.Address",
        "city": "Yangon",
        "street": "East",
        "zipcode": "11211",
    "description":
        "The millers received 20kg weight from the
farmers. When the millers crack down the seeds, the issue
weight was 17 kg for each one. Rice cost was $30 for each
one."
    }
}
```

Wholesalers

```
{
    "$class": "org.cc.rice.Wholesalaers",
    "wholesalersID": "wholesalers-0211",
    "organization":"Golden",
    "ricetype": "Paw San",
    "ricegrade": "Super Premium",
    "receiveweight": "17kg",
    "orderquantity": "10",
    "productname": "CC Paw San"
    "shipmentdata": "9/15/2020"
    "retailer address": {
        "$class": "org.cc.rice.Address",
        "city": "Yangon",
        "street": "East",
        "zipcode": "11211",
    }
    "contactperson": "Mr.Kang",
    "contractedprice": "$500",
    "paymentterm": "30% immediately. End of the month",
    "invoicedetail": {
        "$class": "org.cc.rice.Address",
        "city": "Yangon",
        "street": "East",
        "zipcode": "11211",
    "description":
        "Wholesalers received rice weight 17 kg from the
millers and quantity is 10. Wholesalers produced named CC
Paw San and noticed the shipment data and retailer
address. Wholesalers have to know the contact person's
```

```
information detail for the payment. Wholesaler has two
branches one is for local and one is for foreign country.”
    }
}
```


Retailer


```
{
    "$class": "org.cc.rice.Retailer",
    "retailerID": "retailer-0628",
    "receive_date_from_wholesaler": "9/18/2020”,
    "ordernumber": "28",
    "organization":"Top",
    "orderquantity": "2",
    "ricetype": "Paw San",
    "weight": "10kg",
    "ricegrade": "Super Premium",
    "productname": "CC Paw San"
    "price": "$140",
    "invoicedetail": {
        "$class": "org.cc.rice.Address",
        "city": "Yangon",
        "street": "North",
        "zipcode": "11211",
    }

    "consumeraddress": {
        "$class": "org.cc.rice.Address",
        "city": "Yangon",
        "street": "North",
        "zipcode": "11211",
    “description”:
        “Retailer received rice from the wholesaler and
noticed receive date from wholesaler, order number etc.
When retailer resell to the consumer, price changed and
have to noted detail of invoice and consumer address.
Retailer is a branch of wholesaler and it transport to
only local.”
    }

}
```

Exporter


```
 {
"consumerID": "2343"
"ordernumber": "16"
"wholesalerorganization": "Golden",
"orderquantity": "3",
"ricetype": "Paw San",
"invoicedetail": {
        "$class": "org.cc.rice.Address",
        "country": "Korea",
        "city": "Busan",
        "street": "Yong-so-ro",
        "zipcode": "48507",
    }
"weight": "20kg",
"price": "$240",
"shipmentdate": "9/19/2020",
"paymentmethod": "paypal",
"shipping_address_details": {
        "$class": "org.cc.rice.Address",
        "country": "Korea",
        "city": "Busan",
        "street": "Yong-so-ro",
        "zipcode": "48507",
 "description":
        "The exporter is a branch of wholesaler and it transports to foreign country. Therefore, exporter have to notice detail of consumer, order number, shipment date, payment method and shipping address details."
    }
```

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Glossary

Acronyms

DApps	Decentralized Applications
EA	Ethereum Account
EOAs	Ethereum Owned Accounts
EVM	Ethereum Virtual Machine
FDI	Foreign Direct Investment
PoCs	Proof of Concepts
PoW	Proof of Work
PPP	Purchasing Power Parity
SCM	Supply Chain Management

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