A Secure Accounts Payable Platform for Goods Trade using Ethereum Blockchain

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ABSTRACT

Blockchain technology has the potential to make commodity trading easier, cheaper, and more transparent. It can be used in any process that involves transactions and data exchange. Blockchain permanently verifies and records the transaction data on a secure distributed ledger trusted by all entites in the system. It establishes a system in which parties can communicate directly with one another without the use of any intermediaries. In goods trading, shippers purchase products from suppliers, and carriers convey the items as part of the goods trade supply chain transaction. Suppliers and carriers provide invoices to shippers. The supply chain organisations are primarily motivated to adopt blockchain-based accounts payable systems in order to eliminate process redundancies, decrease the number of disputes among transacting participants, and speed up the accounts payable processes through improvements to claim generation and blockchain-based dispute resolution. This paper outlines a blockchain-based accounts payable system that produces claims for deficiency in products after delivery and adjusts payments for carriers and suppliers accordingly with additional features such as authentication and payment processing. The main objective here is to automate the goods trading process and ensure transparency in transactions for all the involved entities and to satisfy non functional requirements like integrity, scalability and security of the built blockchain system. We simulate the proposed system using the Ethereum blockchain.

Keywords— Blockchain technology, ethereum blockchain, ganache, smart contract

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Chapter 1

INTRODUCTION

Goods trade is a part of the supply chain process which involves buying of goods of a shipper from a supplier and the delivery of goods from the supplier to the shipper through the carrier. The goods trade process may cause disputes at various different stages of the process due to mistakes of any of the entities involved. This can be either due to the goods being damaged, lost or defective. In such a situation, there is a need for a system trusted by all entities involved which stores the transaction and logistics data safely and securely. Blockchain-based accounts payable systems can be used by supply chain organizations to eliminate the process redundancies and reduce the number of disputes among the transacting participants. This allows easier dispute reconciliation as at each point of time, the current status of the goods is recorded in the blockchain. Invoice processing can be accelerated as the dispute process can take place before the delivery of goods to the shipper.

In a typical supply chain goods trade, shippers initiate a trade transaction by sending suppliers a purchase order (PO) containing information about the requested goods. Suppliers send commercial invoices (CIs), which include terms and information on how much the shipper must pay for the products, along with dispatch advices (DAs), which explain how the goods are packed. Cross-border freight movement may be involved in international trade. The shipper's products receiving team determines whether or not the received items can be accepted when the freight arrives at the delivery centre at the destination. The receiving team reports any damages to the received products or differences between the quantity/price of the received goods and the PO via receiving advice (RA). The various carriers involved in the movement of freight each issue a separate invoice for their services. The shipper's accounts payable team must process the invoices once it has access to the carriers' and the supplier's invoices. First, the accounts payable team submits a claim in the form of claim advice for the disparities noted in RA. The accounts payable team then generates payment advices (PAs), where each PA captures the net amount owed by the shipper to either the supplier or the carrier, depending on who is responsible, after subtracting the amount captured in claim advice from the relevant invoice.

1.1 Motivation

Blockchain enables a transparent and end-to-end tracking in the supply chain by providing a decentralized immutable record of all transactions. This transparency can help reduce fraud for high value goods. All parties i.e the suppliers, shippers and carriers would have the same information and hence reduce communication errors. In addition to this, a distributed ledger of all relevant information may save the huge amount of time it currently takes in manual checking of credit purposes.

1.2 Contributions of this Project

In this paper, we propose a blockchain-based accounts payable system with capabilities to fulfill the needs of the supply chain network participants related to invoice processing. The system allows the shipper, supplier, and carriers to raise disputes on the generated claim advices & payment advices and reconcile the disputes before payment processing with audit trails. The system is implemented using the ethereum blockchain. Ethereum is a decentralized public blockchain with functionality for smart contracts. Smart contracts are programmes which can be stored on the blockchain which are triggered when some predetermined conditions are met. The following summarises the format of the rest of the paper. In Chapter 2, we go through most of the recent works that have developed blockchain based systems in the goods trade domain. After describing the proposed work and model architecture in Chapter 3, we demonstrate the experimental setup and results in Chapter 4. Finally, we conclude with the inferences obtained in Chapter 5.

Chapter 2

LITERATURE REVIEW

2.1 Background of Literature Survey

Dursun et al. (2020) researched about the possible improvements of using blockchain technology in agricultural and automotive manufacturing domain. Potential developments in this area were discussed and some solutions for the same were also proposed. The problems in the traditional supply chain management were put forward and its corresponding blockchain solution and advantages were proposed. Agi and Jha (2022) used Decision-Making Trial and Evaluation Laboratory (DEMATEL) method to extract logic from data collected from 37 French experts about the impact of the enablers and their interdependencies. The main focus of the authors here was to conduct a theoretical research model to know about the adoption of blockchain technology in supply chain organizations. The limitations of this paper were prominently related to the biased respondents belonging only to the region of France. In (Chiu and Koepp, 2019), various trading environments and about all parties based on national and international trade that will be involved in the trading system. Several equilibriums are shown which should be maintained for system to be in stable state. Few equilibriums are also shown that should be maintained to avoid disputes of any form. Other principal risks along with scenarios are shown.

Narayanam et al. (2021) worked on building a block chain based goods trade platform which generated claims based on the goods received or accepted by shippers and handled the settlement of disputes amongst the parties if any. An e-invoicing platform which used blockchain technology was proposed by Narayanam et al. (2020) for global trading. This research was based on the fact that multiple suppliers and carriers are involved in global trade and the real-time tracking of invoices is necessary which can be automated securely using blockchain technology. Researchers have also worked on supply chain management systems which involve the use of block chain. Some of the works include (Shahid et al., 2020; Caro et al., 2018) in which the authors have made use of the IPFS (Interplanetary file storage system) for storing all the blockchain transactions in agric-foods supply chains.

2.2 Outcome of Literature Survey

The literature review talks about the problems that standard supply chain faces. Problems that need to be addressed are easy auditing, timely updating of records so that the system's integrity doesn't get hampered, and providing security from various types of intrusions. Another big problem these chains need is proper inventory management. Untimely update of the status of inventory results in numerous discrepancies, which later leads to disputes between the participants in that supply chain. Biasness that could arise in developing such management systems. This biasness could be due to participants on which initial surveys, are done to design a blueprint of a system belonging to a particular region.

Other than that, Various generalized equilibriums must be maintained for the system to be stable. If these equilibriums are not maintained, it could lead to disputes. Several measures are expected to be taken while designing such procedures to avoid disputes, for example change in the price of an item should not affect the prices of past orders. E-invoice generation and live tracking features can be extended to blockchain-based supply chain management systems.

2.3 Problem Statement

To build a blockchain based accounts payable system to simulate trading of goods amongst enterprises and settle disputes in the generated claims.

2.4 Research Objectives

(1) To build a blockchain system capable of generating and processing invoices.

(2) To add capabilities of payment processing to the system.

(3) To enable authentication to make the system secure.

(4) To enable transparency amongst the involved entities and provide flexibility in choosing roles in goods trade.

Chapter 3

PROPOSED METHODOLOGY

3.1 Methodology

The complete model architecture of the proposed goods trade blockchain system is visualized in Fig. 3.1.1. The process starts when the shipper has a requirement of certain goods. The shipper initiates the transaction by placing a purchase order (PO) to the supplier. A purchase order basically comprises of the list of goods as per the requirement of the shipper with some quantity associated with each of the goods. The purchase order enlists all of this data along with the price at which the order was placed.

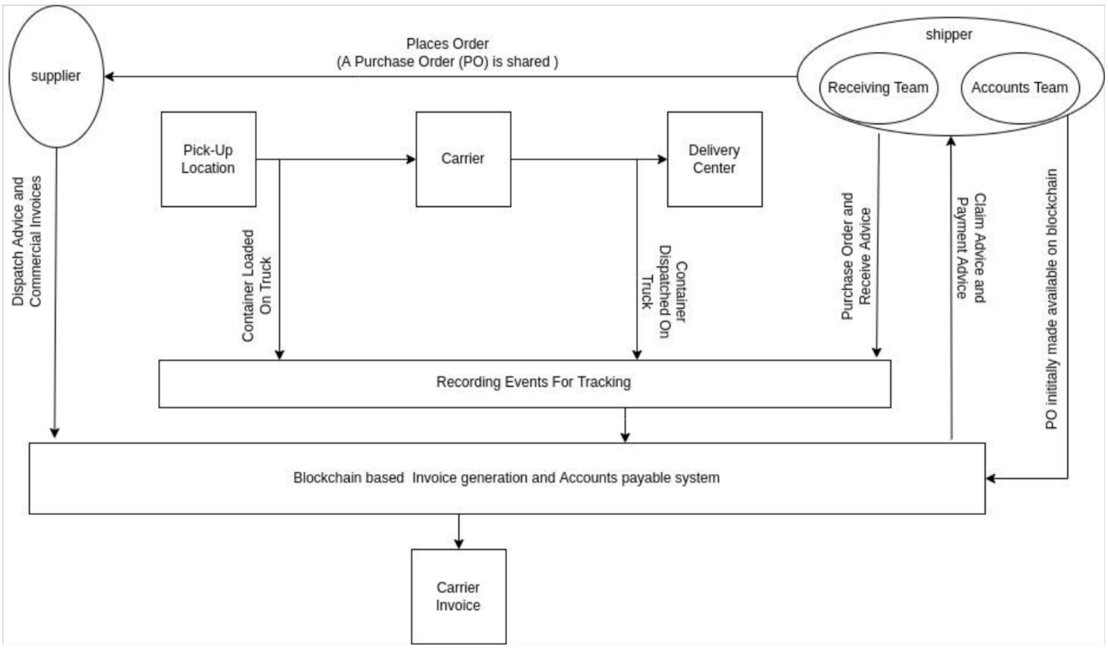


Figure 3.1.1: Workflow

The purchase order is then forwarded to the supplier who generates a dispatch advice (DA) and commercial invoice (CI) which lists all the order details with the amount the shipper owes to the supplier. The supplier then assigns a carrier to deliver the goods to the shipper. The status of the goods at every point of time is also recorded so that the shipper has the access to view the current status of the goods in transit. Once the goods are delivered to the shipper, the shipper's accounts payable team verifies the invoices and ensure there are no discrepancies in the negotiated prices or in the amount of goods requested.

For claim advice generation by the shipper's accounts payable team, various inequalities are used which should hold true to ensure there is no disputes. Such inequalities help in settling disputes in a few cases even before goods actually reach shipper. For example if seller has made short delivery i.e. has not sent goods as per Purchase Order (PO) he/she can update the Recipient Advice(RA) on network and shipper needs to pay according to it. If there is transport damage, seller can request for dispute settlement with carrier and can update advices and invoices accordingly. Claims can be categorised, disputes can be raised and settled as per the category and participants involved. The accounts payable team typically computes the claim amount by exercising methods such as 2-way, 3-way, or 4-way matching,

- Two way matching: The quantity as per supplier's invoice (CI.Q) $\geq$ Purchase Order Quantity (PO.Q). This ensures that the quantity of goods in the suppliers commercial invoice is more than or equal to that in the purchase order preventing short delivery. The price of goods while purchasing of goods is the less than or equal to that of the suppliers claims.

- Three way matching: The commercial invoice quantity (CI.Q) $\leq$ Quantity dispatched by the supplier/quantity received by the shipper (DA.Q). 3-way matching ensures that the goods received by the shipper is atleast as much as that requested by them in the purchase order.

- Four way matching: Commercial invoice quantity (CI.Q) $\leq$ Quantity accepted by the shipper after the verification by shipper's goods receiving team (RA.Q). 4-way matching is used to ensure that the shipper pays no more than the price of the goods which they accept.

3.1.1 Building the Blockchain System

A decentralized application is developed using solidity smart contracts and Remix IDE to deploy the contracts on the Ganache local blockchain environment. For interaction with the smart contracts, we use web3.js with javascript. web3.js is a collection of various libraries/modules that allow us to interact with the Ethereum node. Metamask is used to connect to the ethereum network. Metamask serves as the abstraction layer required to interact with the ethereum blockchain. Application Binary Interface (ABI) represents the structures and the functions that are to be used in order to interact with contract on the binary level. The ABI provides the indications to the caller of a particular function to encode information in the format of mentioned variable declarations and function signature. This is often termed as Application Binary Interface Encoding. A web3.eth.Contract is passed with ABI and contract address as arguments and helps in interacting with the smart contracts on the ethereum blockchain. Javascript is used to interact with the deployed Ethereum smart contract. Basically inputs are accepted from the front end and using various modules of web3 inputs are sent to contracts and values if any, to be returned are received.

3.1.2 Payment Processing

Invoice generation

Once the order is placed, the invoice for the same can be generated easily using a single click of a button which downloads the PDF of the placed order. In case of partial acceptance of orders by shipper, the invoices get automatically updated after the delivery of the order by carrier to the shipper.

Automated payment processing

The payment processing is automated where the amount of ether to be paid by the shipper is visible to the shipper on their dashboard. The shipper only needs to click on the 'Pay' button for their placed order.

3.1.3 Authentication using Private Key

To ensure the security of the Ethereum blockchain, authentication using private key is enabled into the application. An image is used as a private key in this context. This type of authentication helps preserve the integrity of the system in case the MetaMask wallet of any entity is compromised. The user will not be able to login to the accounts payable blockchain system if an image different from private key is used for authentication.

3.1.4 Transparency and Flexibility

Live Tracking

The live tracking feature is incorporated so that all the entities' accounts payable system have access to the current status of the goods of a particular purchase order. The goods pass through various states during transportation like 'Placed', 'Shipped', 'Passed to carrier' and 'Delivered'. The 'placed' state indicates that the order has been place by a supplier. The 'passed to carrier' activates when the supplier assigns a carrier for delivery.

Multiple suppliers and shippers

The application also supports the existence of multiple shippers placing orders. An entity can act as a shipper, supplier and a carrier. Furthermore, multiple suppliers can host their products where in all the shippers can view their products.

Partial Orders

The shipper can accept a part of the order i.e less quantity of goods that that received from the carrier. The invoices for the same are updated accordingly once the goods are delivered by the carrier to the shipper.

Chapter 4

EXPERIMENTAL SETUP AND RESULTS

4.1 Setup

The development tools used for building the decentralized application of the blockchain system are listed below,

- Ganache: Ganache provides a private blockchain that can be used to test and develop ethereum based decentralised application. Ganache can be used for the complete development cycle and we can also deploy our applications in a secure and deterministic manner on ganache.
- Remix IDE: Essentially, smart contracts are blockchain-based algorithms that execute when certain criteria are met. They are often used to automate the implementation of an agreement so that all parties can be certain of the conclusion right away, without the need for an intermediary or additional delay. These smart contracts are written in solidity which is an object-oriented and high level language. In order to compile and deploy these contracts we have used remix ide.
- Metamask: Users can store Ether and other ERC-20 tokens in MetaMask, a cryptocurrency wallet. Decentralized applications, or dApps, can be communicated with using the wallet. We can import private key of a test account to perform simulation on the application.

To enter the blockchain system, the very first step is to start the local ganache environment. Once the ganache environment is up and running, the next step is to compile the smart contracts using any solidity compiler. The Remix IDE is used to compile and deploy the smart contracts. The smart contract on Remix is then connected to the local ganache environment. After deploying the smart contract, we update the ABI and the contract address to ensure the javascript backend uses the exact specifications of the deployed contract. Next, we connect the MetaMask wallet to the ganache environment and import the necessary accounts that are to be used for the transactions using their respective private keys. Ideally, a minimum of three accounts are imported to represent the three primary entities: shipper, supplier, and carrier. More accounts can be used as per requirement. The final step is to start the decentralized application on the localhost.

4.2 Results and Discussion

4.2.1 The Developed Blockchain System

Figure 4.2.1 shows the current products offered by the supplier and also addition of new products by the supplier. Seller has to pay some ether because of gas required to update to the products. Supplier is also provided with an option to change the price for listed products. The case where the price of ordered products which are to be unaffected has been handled.

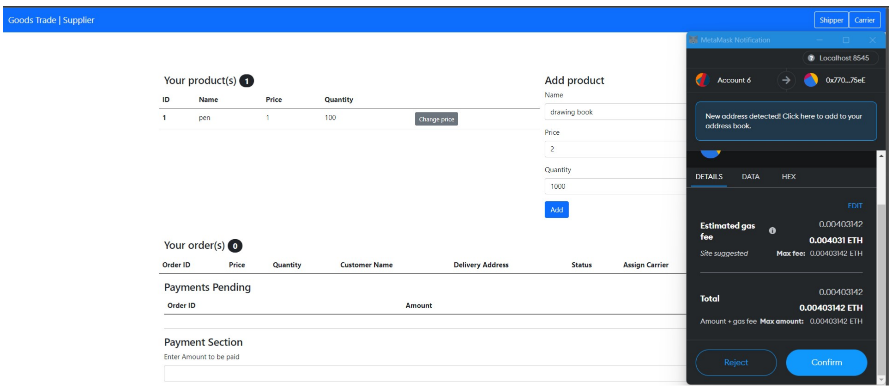


Figure 4.2.1: Products offered by supplier and adding new product by supplier

Fig. 4.2.2 shows all the items currently available to shipper. These are the products listed by different sellers and and also shows the shipper buying a particular product. Since this requires the updation of data on chain therefore seller has to pay some ether for this.

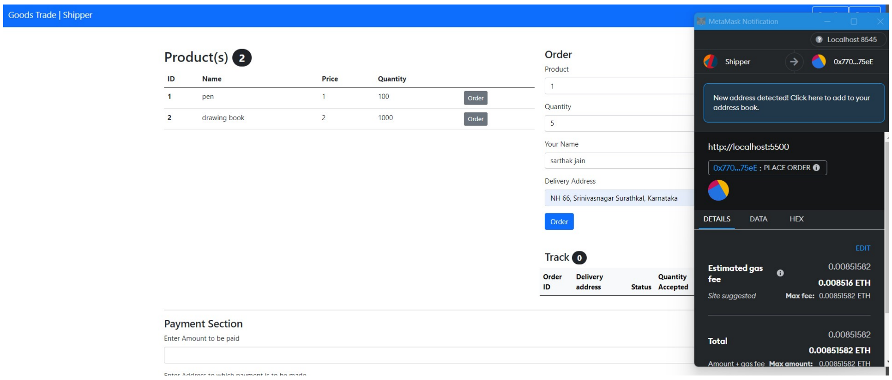


Figure 4.2.2: List of products available to shipper and buying of product

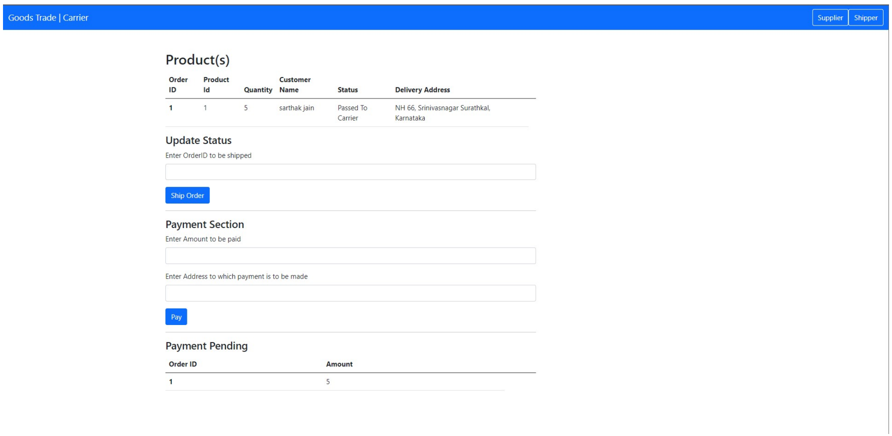


Figure 4.2.3: Carrier Page

Figure 4.2.3 shows the list of order that particular carrier is suppose to deliver. It also shows the payment status of that order, carrier will only hand over the product to shipper when pending payment corresponding to that order becomes zero. Due to this carrier can not make fake delivery claims.

4.2.2 Payment Processing

A pay button is provided to shipper to make direct payment. Shipper is also given option to generate invoice. A invoice in PDF format can be directly generated. Invoice can be generated by shipper at any stage of the process. A sample generated invoice is shown in Fig. 4.2.4. It contains information such as customer address, carrier address, delivery address, id of the product ordered as well as the pending payment.

INVOICE FOR ORDER : 1

id : 1

product_id : 1

quantity : 1

customer_name : novo tech

status : Delivered

delivery_address : tikamgarh road mahroni

customer_address :0x154c79daDf282e8E44be0c836d0e47D99117dCCe

carrier_address :0x5B38Da6a701c568545dCfcB03FcB875f56beddC4

price : 3

pending_payment : 0

Figure 4.2.4: Generated Invoice

4.2.3 Authentication using Private Key

The first step when entering the system is user authentication as shown in Fig. 4.2.5. The user chooses an image as password and signs its hash using private key. The hash corresponding to the specific user is stored on blockchain to provide additional security from metamask wallet compromises.

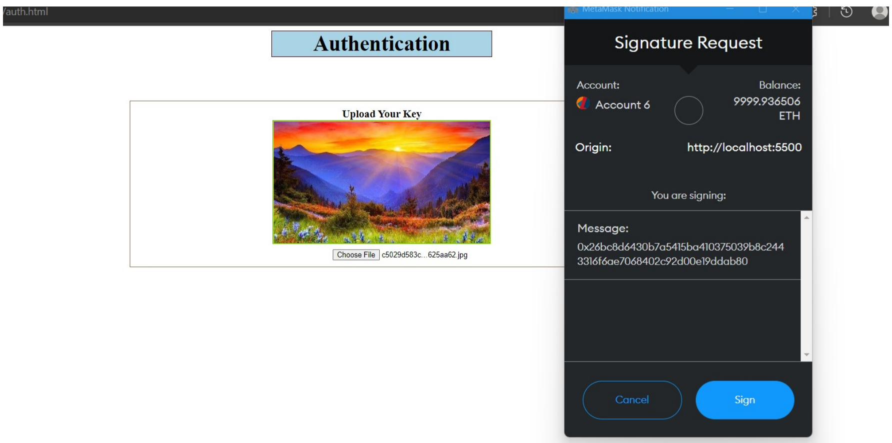


Figure 4.2.5: Signing image using private key and setting it as password

Fig. 4.2.6 shows the alert displayed on user's screen when trying to authenticate using wrong image pass key. Successful authentication requires uploading the same image each time.

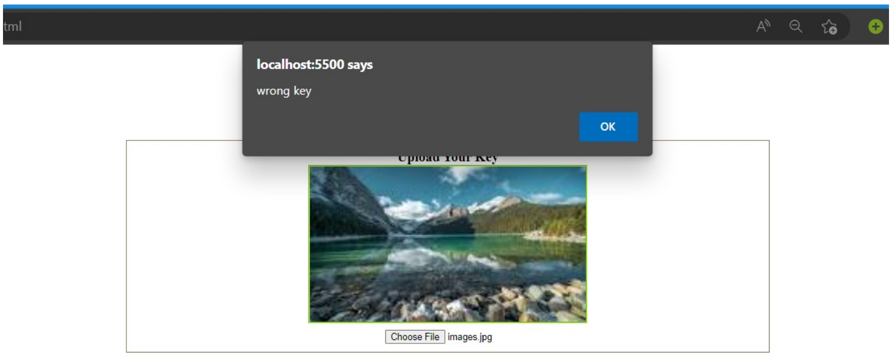


Figure 4.2.6: Uploading invalid image

4.2.4 Transparency and Flexibility

Figure 4.2.7 shows live tracking of the order placed by the shipper. Status changes based on the stage product is currently on. It also shows the pending payment and the amount to be paid along with the address to which payment is to be made.

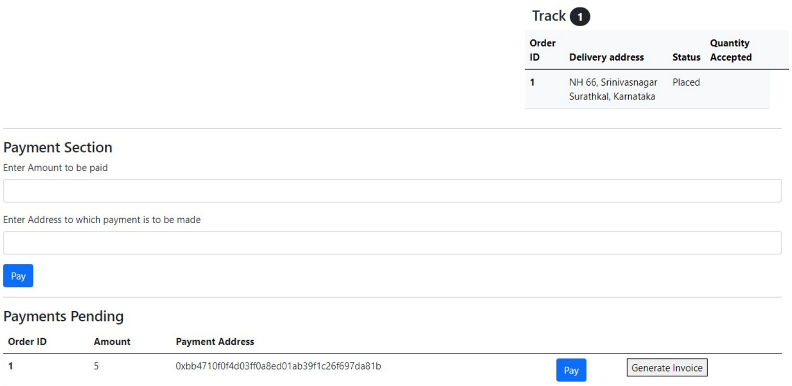


Figure 4.2.7: Live tracking of order, pending payments and invoice generation

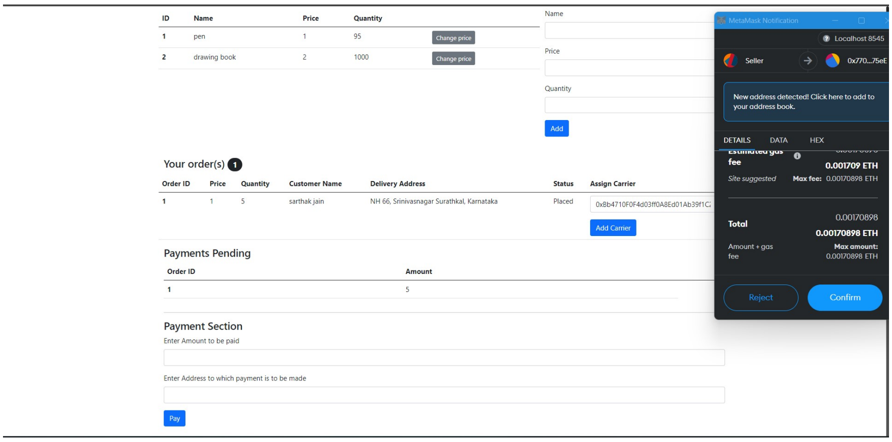


Figure 4.2.8: Assigning carrier to particular order by supplier and pending payments of supplier

Figure 4.2.8 shows the assignment of carrier to particular order. Carrier is entity responsible to deliver the goods to the shipper. It also shows pending payments corresponding to the orderID. A supplier can assign a carrier by adding their public key to the input.

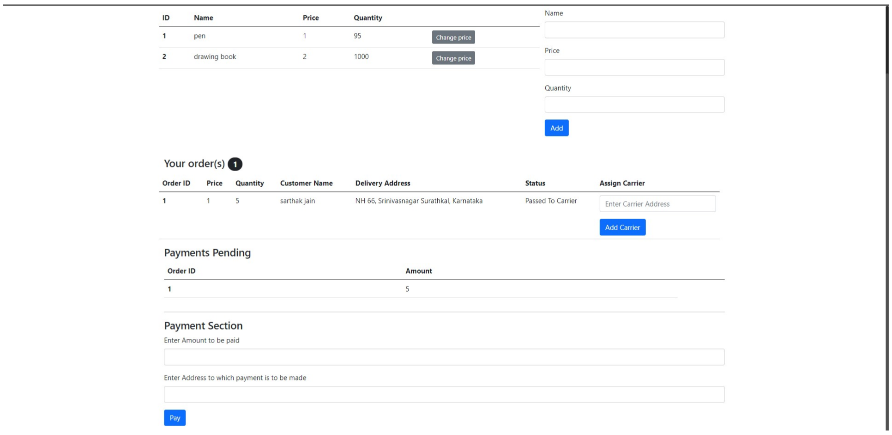


Figure 4.2.9: Changing of status to passed to carrier

Figure 4.2.9 shows the change in status when the goods is passed to carrier by the seller. This status is visible to shipper and carrier of that particular order. Such change in status serves as a transparency to all the entities and makes the system reliable and trustworthy.

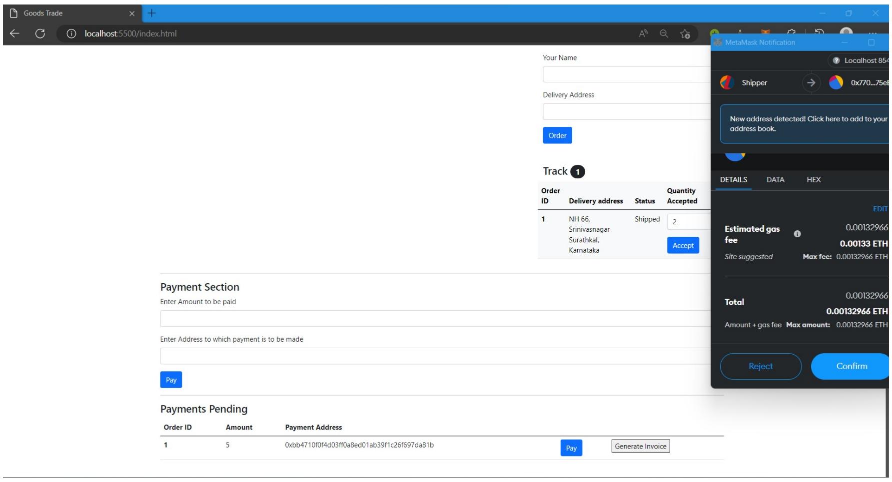
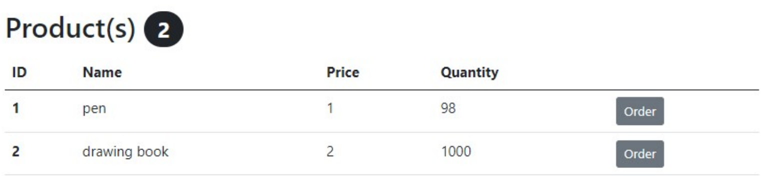


Figure 4.2.10: Partial acceptance of order by shipper

Figure 4.2.10 At any stage if shipper wish to partially accept or completely reject the order he/she can directly update the value of quantity accepted and can make payments updates accordingly. Inventory will also be added with items returned accordingly on the price that particular product is being offered by the seller.



Product(s) 2

ID	Name	Price	Quantity	
1	pen	1	98	Order
2	drawing book	2	1000	Order

Figure 4.2.11: Inventory updation after return of particular order

Figure 4.2.11 show updation of inventory with items returned made available for selling. Bill of shipper is also updated accordingly.

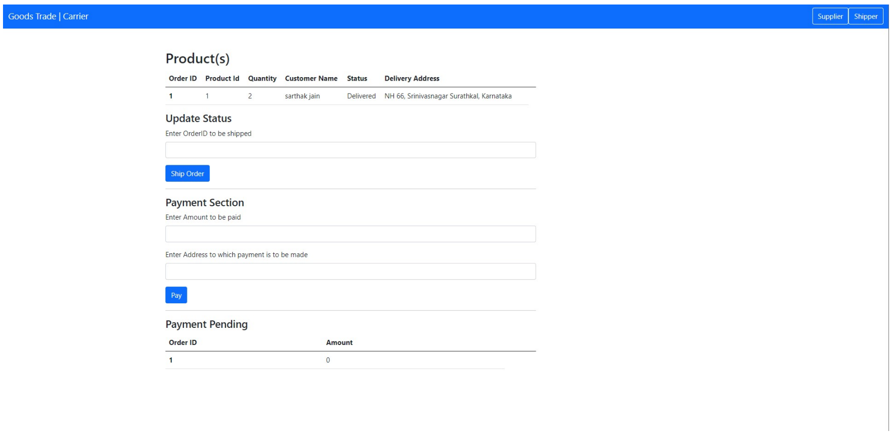


Figure 4.2.12: Carrier updates status to delivered

Figure 4.2.12 show the status being update to delivered by the carrier once the amount to be paid for that order becomes zero. Shipper cannot change quantity accepted after order is marked delivered. This ensures there arises no case of lesser payment by shipper. Invoice and delivery status is also updated accordingly.

Chapter 5

CONCLUSIONS

Blockchain-based accounts payable platform enable various supply chain organizations to securely perform trade by eliminating process redundancies and also makes auditing easy as data stored on the blockchain is immutable. It also helps in easy dispute resolution and prevention due to pre-agreed conditions in the smart contracts. This also enables payments to various trade entities without using any intermediate payment processor. It makes the process even more transparent. Various conditions are pre-agreed upon by all the entities involved in the trade that prevents any dispute. Each phase is accompanied by an update of the current order status, which helps all the participants involved in trade to live track the order. Metamask provides a secure wallet and can act as a provider to connect the application to the blockchain. Additional security is added by adding image hash-based authentication. This method prevents unwanted activities when the wallet gets comprised. Hash is signed on the client side. Even when the network is compromised, the intruder is not be able to regenerate the passkey. Such a system easily supports a large volume of transactions and can be extended across different fields of trade. The easy and intuitive user interface of the decentralized application makes the process much simpler for the users. Automatic inventory updates also take place, which avoid one product being sold twice to customers. The invoice generation feature is also integrated with the application. This application provides a platform for enterprises to trade goods with added security.

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