

Blockchain Based Platform for Supply Chain Management

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Abstract—The global supply chain market surged over \$15.85 billion in 2019 and is expected to soar past \$37.4 billion by 2027 with the additional revenue opportunity from Software as a Service (SaaS) ^[1]. It suffers from issues like the lack of transparency, information sharing, and delays in data retrieval affecting every stage of the process. In addition to the above-mentioned issues supply chains need to solve challenges such as product authentication and traceability. To tackle these problems industry needs a solution that is reliable, efficient, and transparent. Blockchain as a technology is in its early stages of evolution, but it has shown huge potential in real world implementations. The core principle of blockchain is a decentralized ledger which promotes traceability and transparency. A system for managing supply chain with blockchain as the backbone has been proposed. It will be a generic distributed application having features to register, authenticate and track products. As there are multiple use cases in supply chain management like food supply chain, pharmaceutical supply chain, automobile supply chain, etc., this generic platform can be useful in catering to multiple needs.

Keywords- Blockchain, Distributed Application (DApp), Flutter, Ethereum, Ethereum Virtual Machine (EVM).

I. INTRODUCTION

With the Industrial Revolution of late 18th and early 19th century, United States and much of Europe transitioned from labour driven manufacturing methods to machine based semi-autonomous methods. Gradually, these manufacturing methods trickled down to their colonies and much of the remaining world. On the backdrop of increased efficiency and higher production numbers ensued a dramatic uptick in almost all aspects of life. The Industrial Revolution also brought about an exponential rise in the rate of population growth leading to more demand for consumer goods. Advancement of science enabled invention of modern ways of transportation, ushering in a new era of connectivity across the world. Population growth around the world created sustained demand for commodities, thereby setting the base for rapid expansion for supply chains to almost all countries in the world. The invention of shipping containers in the 1950s and reduction in cost of cargo aviation improved connectivity for lesser developed countries in Asia and Africa. This gave rise to globalization as we know it today. Never in the last few hundred years has been the world so interconnected. For example, in India, we use petrol which has been imported from Iran or the Middle East, clothes which are probably manufactured in Bangladesh and electronics manufactured in China. According to Statista, in 2019, the global trade value of goods exported stood at a staggering \$ 19 trillion ^[2]. Globalization has also helped lower income countries carve a niche for themselves in specific products/manufacturing, thus helping the local population. Once in a century pandemic has vastly disrupted the global supply chains. The detection of Covid19 cases in Wuhan, China in November 2019 and the subsequent spread of the virus to other cities including Beijing led to lockdown like curbs being imposed throughout the country. This led to a supply shock in the world as China is the biggest exporter of consumer goods throughout the world, amounting to \$ 2.6 trillion in 2020 ^[3]. Subsequently, through air/sea route the virus spread to different countries in the world. The global economy shutdown which followed created a demand shock, while the supply from China eased due to reduction in cases. This led to a demand and supply gap throughout the world. This coupled with the ongoing Sino-US trade war has compelled enterprises to de-centralize their manufacturing and supply chains. Currently supply chains across the world have heavy use of manual process with large amounts of data which is stored across different mediums of storage. Hence, with more and more multinational companies, industries de-risking their supply chains through distribution of manufacturing to several countries, it will be imperative to ensure that these supply chains are robust and cater to growing needs to a globalized world.

This system will use the concept of a Distributed Application (DApp) based on blockchain technology to register, authenticate and track products through any supply chain. This will be a generic platform suitable to be molded for any case. The system will have a QR code-based mechanism for identification and registration of any product along with the details and user authentication through various authentication methods like email, phone number, etc. Blockchain can greatly improve supply chains through faster and more cost-efficient delivery of products. It will help enterprises enhance the traceability of their products and improve co-ordination between them and their local partners.

II. LITERATURE SURVEY

- **Sara Saberi, Mahtab Kouhizadeh, Joseph Sarkis & Lejia Shen (2018), Blockchain technology and its relationships to sustainable supply chain management, International Journal of Production Research.**

This paper explores how blockchain technology introduces transparency, security, traceability and shows promise for easing global supply chain management problems.

- **Feng Tian (2016): An Agri-food Supply Chain Traceability System for China Based on RFID & Blockchain Technology, IEEE.**

The authors of this paper propose a system based on RFID and Blockchain for the agri-food supply chain for China.

- **Reshma Kamath (2018), Food Traceability on Blockchain: Walmart's Pork and Mango Pilots with IBM, The JBBA, 47-53.**

The author of this paper discusses and reviews blockchain pilots conducted by Walmart for their pork and mango supply chains across China and Americas.

- **H. Wu et al., "Data Management in Supply Chain Using Blockchain: Challenges and a Case Study," 2019 28th International Conference on Computer Communication and Networks (ICCCN), 2019, pp. 1-8, doi: 10.1109/ICCCN.2019.8846964.**

This paper provides an analysis of technical challenges faced by blockchain-based supply chain management systems. It includes parameters such as scalability, throughput, access control, data retrieval. Practical solutions are discussed for technical challenges.

- **S. Jangir, A. Muzumdar, A. Jaiswal, C. N. Modi, S. Chandel and C. Vyjayanthi, "A Novel Framework for Pharmaceutical Supply Chain Management using Distributed Ledger and Smart Contracts," 2019 10th International Conference on Computing, Communication and Networking Technologies (ICCCNT), 2019, pp. 1-7, doi: 10.1109/ICCCNT45670.2019.8944829.**

This paper describes the use of Ethereum based supply chain management system for the pharmaceutical industry. It provides information about different smart contracts required in the making of a trustworthy system.

- **JINHUA MA, SHIH-YA LIN, XIN CHEN, HUNG-MIN SUN, YEH-CHENG CHEN, AND HUAXIONG WANG (2020), "A Blockchain-Based Application System for Product Anti-Counterfeiting", Special Section on Data Mining For Internet Of Things, IEEE Access, 77642-77652.**

This paper discusses leveraging decentralized blockchain technology to ensure customers get authentic products without relying on merchants. It uses Ethereum as the back end for developing a system that can reduce the cost of product assurance.

III. BLOCKCHAIN

Blockchain is a decentralized ledger of transactions that is duplicated and distributed across a network of computer systems. It facilitates the process of recording transactions and tracking assets. An asset can be tangibles like house, car, land, etc. or intangibles like intellectual property, patents, etc. Blockchain primarily consists of three concepts: - blocks, nodes and miners.

1. **Blocks** – A blockchain is a chain of multiple connected blocks and hence a block forms the most essential part of the technology. Each block contains a cryptographic hash of the previous block, timestamp of the current block and transaction data. The cryptographic hash is generally of a 256-bit length generated using SHA-256 algorithm. The first block of any chain is known as the genesis block. A chain link is established between the blocks through the hash which ensures that alteration of any data in one block would modify the cryptographic, thus breaking the chain. Therefore, blockchains are resistant to modification once data is recorded.

2. **Nodes** - Since blockchain is a peer-to-peer publicly distributed ledger and hence decentralization forms an integral part of the system. No single computing device owns the chain, it is instead distributed over multiple nodes over the world. A node can be any computing device that can be maintain copies of the blockchain and keep the network function. The nodes adhere to a set protocol for validation of new blocks and the network must algorithmically approve any newly mined block for the chain to be updated, trusted and verified.

3. **Miners** – Miners create news blocks on the chain through a process called mining. Since, updating a large chain requires huge computing power, miners need to compete to solve a difficult mathematical problem based on a cryptographic hash algorithm. The solution to this problem is called proof-of-work. This proof then confirms the transaction of the block and the chain is updated through the system. When a block is successfully mined the miner is rewarded financially.

Transactions on the blockchain are usually done using a set of rules known as **smart contracts**. Smart Contract is a self-executing program with terms of the agreement between the buyer and the seller written into the contract. A smart contract can define conditions for employment contracts, real estate transactions, etc. They are typically used to automate the execution of an agreement so that all the participants can know the outcome, without any intermediary's involvement or time loss.

Blockchain can be primarily divided into two types: -

- **Public Blockchain** – It is a permissionless blockchain network which is completely open -ended and anyone can participate in the network. Advantages of public blockchain is that it is more secure because the chain is distributed among a large number of nodes. Disadvantages of such a system are low privacy and high computing power required due to the size of the chain. Example can be the Bitcoin network.

- **Private Blockchain** – A private blockchain is a type of network whose control and usage lies within an organization. The organization controls the participants, set rules and maintain the ledger. A private blockchain can be run behind a corporate firewall thus ensuring increased privacy, though security is lesser due to smaller size of the chain. Example can be a private corporation running its own blockchain network to manage its supply chain, with restricted access given only to its business partners.

IV. TOOLS USED

Ethereum

Ethereum is an open-source decentralized blockchain providing ability to any program to use smart contacts. It's a public database that is updated and shared across multiple computing devices in a network. Ethereum runs on Ethereum virtual machine (EVM). EVM stores the state which is followed by all the computing nodes that are connected in the network. Every node has a copy of the state rendered by the EVM. Whenever any node in the network requests to perform any computation using EVM, the same request needs to get validated by all the peers in the network. Once the state is changed it is shared with every node and cannot be retracted.

For any user to broadcast a transaction request, they need to give some amount of fee. This fee is in terms of Ether which is Ethereum's own cryptocurrency. Every node that verifies, executes, and commits the transaction to the chain gets a reward in ether depending upon the complexity of the computation and time required. This required fee helps to prevent hackers from jamming the network on purpose.

Ethereum provides the functionality of programming the business logic using smart contracts. They are at the basic level code snippets that take parameters and perform different tasks. To create contracts and publish them publicly a fee in terms of ether is required. With different smart contracts, anyone can create DApp (Decentralized Application) having complex inner workings and can even leverage smart contracts written by someone else. Ethereum supports many languages to write the contracts like Java, Python, JavaScript, Go, Rust, etc. But solidity is the most used and maintained programming language for writing smart contracts. It gets compiled in the Ethereum compiler which then deploys the contracts on the EVM. Ethereum project stack is as follows:

- Ethereum Virtual Machine
- Smart Contracts
- Ethereum Nodes
- Ethereum Client APIs
- End-User DApp

Ganache

Ganache is a part of the Truffle suite, which is a development environment having multiple useful functionalities like testing frameworks, asset pipelines specifically for blockchains running on Ethereum virtual machine (EVM). It simplifies the process for developers to work on blockchains as developers cannot test the features or additions to applications in development on a real public blockchain. One of the challenges in blockchain development is that it is immutable. Once smart contracts are deployed on the public blockchain then it cannot be modified. Apart from this immutability issue, it costs ether to deploy every time. Instead of testing on public chain, developers can leverage the personal blockchain of ganache for Ethereum based decentralized application development. It helps in the development, deployment, and testing of DApp's in a safe and deterministic environment. It creates a private blockchain on the given node. For any write transaction in the blocks of the chain, a fee is required in terms of ether which is provided by Ganache test accounts. Each account has certain dummy ethers for testing purposes. It is useful for testing different smart contracts locally. Truffle testing framework can be used to write and run tests for given application functionalities.

Flutter

Flutter is an Open-source UI software development kit. It is used for building applications for mobile, web, and desktop. It involves coding on a single codebase for different platforms. Flutter apps are written in the Dart language and make use of many of the language's more advanced features. It has been around since 2015 when Google introduced it and remained in the beta stage before its official launch in December 2018. It enables development on Windows, macOS, and Linux. Flutter runs in the Dart virtual machine, which features a just-in-time execution engine. The central idea behind Flutter is the use of widgets. It's by combining different widgets that developers can build the entire UI. Each of these widgets defines a structural element (like a button or menu), a stylistic element (a font or colour scheme), a layout aspect (like padding), and many others. Among the advantages of flutter which makes it popular amongst developers are quick builds and hot reload. Hot reload allows to instantly view the changes applied to the code on emulators, simulators, and hardware. The changed code is reloaded in less than a second. All the while, the app is running and developers don't need to waste time on restarting it. The Foundation library, written in Dart, provides basic classes and functions that are used to construct applications using Flutter, such as APIs to communicate with the engine.

Firebase

Firebase is a mobile application development platform developed by Google. It includes services pertinent to mobile application development like analytics, databases, file storage authentication, configuration, push messaging, etc. All these services are hosted on the Google cloud platform (GCP). Firebase provides software development kits (SDK) for every back-end service which is managed by Google. There is no need to write backend which communicates with SDKs rather client application can directly connect SDKs. One of the most important aspects of any mobile application is registering users through preferred signup options like email, social media, etc. Already registered users also need to be able to log in again without any hassles. Hence, a robust user authentication system is essential for maintaining records of users and also ensuring that user details remain secure. Google provides an easy-to-use authentication service known as Firebase Authentication. Firebase Authentication allows user authentication across multiple platforms with support for different types of signup methods. Currently, we will have the provision to log in using email and password with expansion to further signup methods when required.

Firebase Authentication creates a unique UID each time a new user enters their credentials into the system. The next time any user signs in to the app, credentials entered by the user can be supplied to the Firebase Authentication which verifies those credentials and returns a response to the client.

Quick Response (QR) code

Quick response code is a two-dimensional, machine-readable matrix barcode. There are different types of QR codes like model1, model2, micro, IQR, frame, SQRC, etc.

QR code is used in various industries as it is easy to make, share, update and has universal support. A QR code is an optical tag that is machine-readable and contains data related to a given item it is associated with. It can contain data germane to location, URL, parameters for certain products, etc. It has some standard modes to store data like numeric, alphanumeric, byte/binary and kanji. The bar code generator is the tool used to convert desired data into a QR code. Bar code reader/scanner can convert the QR code into an alphanumeric format and send the data to the computer. Advantages of QR code are it can be used anywhere with anything, is quick, and inexpensive. The only challenge is it needs a proper generator and scanner.

V. SYSTEM DESCRIPTION

Supply chain is the network that includes individuals, resources, organizations, activities, and technology associated with the making and disposal of a product. The most important components of any management tool pertinent to the supply chain require registration of the product, tracking the product, and ensuring it is authenticated by the end-user. The proposed decentralized application caters to these specific requirements leveraging blockchain technology that thwarts the malicious manipulation and renders a platform that can be molded according to the business use cases.

As shown in Figure 2., the application will provide two different user types based on the role. The vendor can be a user that is associated with the manufacturing or procurement of the product. The vendor can create a new account or log in to the existing account with relevant credentials.

Data from each vendor is connected to specific unique identification given after new account creation. After successful login, the user can register the new products with their details. For registering a product user will get an option to scan a QR code that is already linked to a particular product. Once the application fetches the unique identification number for the product, the user can enter the information/data relevant to the product like origin, date of manufacturing, temperature, location, date of expiry, etc. Another user type is customer, which does not need an account to proceed with the application. The customer has the option to scan a QR

linked to a particular product to verify its authenticity. Further, customers can also check the details for that product.

Features of the proposed solution:

- Decentralized
- User-friendly interface
- Secure authentication
- Provision to register, authenticate and track products

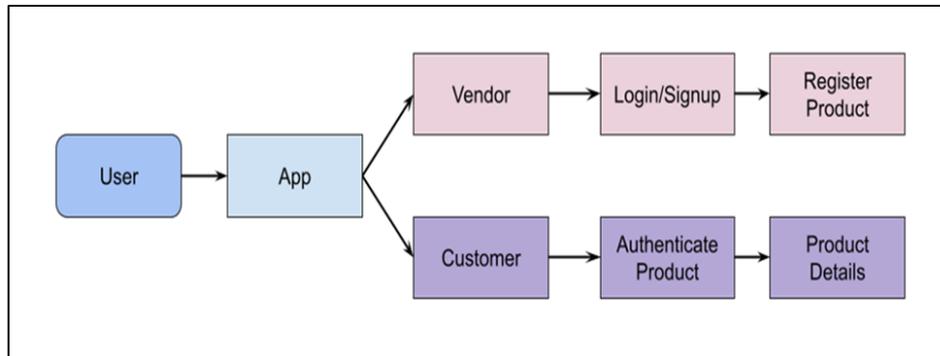


Figure 1. Project Flow

VI. TECHNICAL ARCHITECTURE

Frontend

Flutter has been used to build the end-user application. It has different libraries built for specific functionalities. This application code can be used to make Android and IOS platforms-based applications. The entire UI has been built by combining various widgets like text fields, lists, various types of buttons. These widgets have been used to register, authenticate, create account, log in users to the account and add details about the product. Each of these widgets defines a structural element (like a button or menu), a stylistic element (a font or colour scheme), a layout aspect (like padding), and many others. QR code scanner has been embedded in the application using a third-party library. This scanner can be used with the camera of the user’s smartphone.

Widgets used for building screens in the mobile application are: -

- Parent Widgets - Stack, Column, Row are the parent widgets which form the base of the app, inside which other widgets are placed.
- Buttons - Round, Flat, Raised, Outline buttons for navigation of users between multiple screens.
- List Element - Dynamic list element to display the products in the blockchain.
- Text Fields - Input elements through which we can take user email, password for signup and input details such as type of product, etc. through a form.

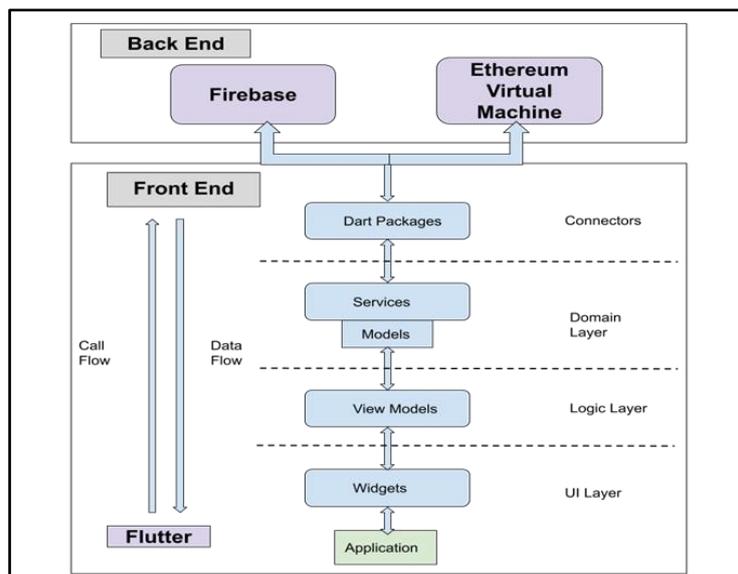


Figure 3. Technical Architecture

Backend

The two principal segments of the application are user authentication and product data storage. Firebase is used for the authentication of the users. It provides a secure way to sign up and sign in users. It assigns a unique identification to each user which can be used to store and retrieve data specific to that user. Ganache is used to create a personal blockchain for development purposes on the local network. The logic for all the functionalities is written in solidity language in terms of smart contracts. For each write transaction on the chain, a fee in terms of gas which is a unit of transaction needs to be paid as mining is required for the addition of data in the chain. Although reads from the blocks are free. Unique identification number linked to each user is stored with the given transaction on the block. All the smart contracts after compilation get converted into bytecode. The bytecode runs on a stack-based Ethereum virtual machine (EVM) in each node. The smart contract gives way to perform transactions on the blockchain network and the shared blockchain state being updated accordingly. Reads can be performed in the same manner from the blocks but take a certain delay as it needs to maintain consistency in the data. It forms an immutable, robust decentralized system.

VII. RESULTS/TESTING

Mobile Application

The image shows a mobile application interface for entering product details. At the top left, there is a back arrow and the title "Enter Details". Below the title, there are five input fields, each with a label above it: "Barcode Number" (containing "12345678"), "Date" (containing "20/05/2021"), "Temperature" (containing "10"), "Type" (containing "Vegetable"), and "Place" (containing "Pune"). At the bottom of the form is a blue rounded rectangular button with the text "SUBMIT" in white capital letters.

Figure 2. Product details form



Figure 3. Products on individual blocks

VIII. CONCLUSION AND FUTURE SCOPE

Covid-19 virus and the changing world order has put strain on the existent supply chains. It is now imperative for corporations to reinvent the supply chain in tune with the needs of the modern technological world. With recent leaps in technology, there is huge scope for new technologies such as blockchain in domains such as supply chain management, as such technologies help in ensuring transparency and traceability. The proposed solution stresses focus on supply chain management through blockchain technology by development of a generic platform which can be molded to the requirement of individual use case. There is further scope for improvement in the solution, through the integration of analytics and forecasting using machine learning models, automation of complete supply chain using Internet of Things (IOT) devices, and customizing the app for specific applications like agriculture, pharma industries.

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