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Article

A Blockchain Use Case in Cold Chain to Minimize the Risk of COVID-19 Infection

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Abstract: The world is facing an unprecedented socio-economic crisis caused by the novel coronavirus infection (COVID-19). It is also spreading through the import and export food supply chains. The Chinese authorities have discovered the COVID-19 virus in various imported frozen meat packages. Traceability plays a vital role in food quality and food safety. The Internet of Things (IoT) provides solutions to keep an eye on environmental conditions, product quality, and product traceability. These solutions are traditionally based on the centralized architecture, which does not guarantee tamper-proof data sharing. The blockchain is an emerging technology that provides tamper-proof data sharing in real-time. This article presents Hyperledger Fabric-based blockchain use case and a quick reference guide to develop the blockchain network for tracking and tracing the supply chain to minimize the risk of COVID-19 in the frozen meat supply chain.

Keywords: Cold supply chain; Meat Supply Chain; Food Safety; COVID-19; Blockchain; Hyperledger Fabric

1. Introduction

The novel coronavirus was declared a pandemic on March 11, 2020, by the World Health Organization (WHO) [1]. Countries around the world implemented full or partial lock down to prevent the pandemic from spreading. It resulted in the closure of most businesses, social institutes, and social gatherings around the world. The food supply chains are essential to life. They must continue the normal operations to feed the nations worldwide during the pandemic. Researchers review the COVID-19 pandemic impact on the food industry in great detail [2–5]. This pandemic disrupts the food supply chains worldwide [6]. The center of diseases and prevention of the United States of America reported 16,233 COVID-19 cases and 239 deaths among the US workers in 115 meat and poultry processing facilities in 19 states [7]. China is one of the biggest importers of frozen meat, mainly from New Zealand, Australia, and Brazil. The Chinese authorities found coronavirus traces on beef, and its packaging from Brazil, Bolivia, Australia, and New Zealand [8,9]. The traces of COVID-19 were also found on pork's packaging from Argentina [10]. The Chinese authorities sealed the whole warehouses, canceled the companies' import licenses, and banned imports from various companies. It is badly impacting the labor in China and overseas.

Several rules and regulations have been developed and published in private and government sectors to support the food industry and prevent the infection from spreading. The Chinese State Council also released a circular to prevent COVID-19 infection risk in cold chain foods [11]. The traders exporting meat products to China need to double down on ensuring their meat products' high quality and their record proving COVID-19 prevention compliance [12]. The tracking and traceability is the core component to sustain the food supply chains. The one core goal of supply chain traceability is to track and trace the healthy environmental conditions on the facilities, workers' health, and secure custody of commodities from farm to distributors to ensure food safety and increase the customer's trust in their brand.

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The vast majority of traditional supply chain information systems are insufficient to provide transparency, and audit-ability [13]. Several research and development communities and organizations focused on using the Internet of Things (IoT) to provide better information and monitoring facilities to capture the data from the environment and living things to increase food safety standards [14,15]. IoT technology innovations heavily rely on centralized and cloud-based solutions. These solutions are not enough to provide trusted data and information to cope with the current risks of COVID-19 infection due to the lack of transparency, data lock-in, and audit-ability [16]. In food supply chain management, in terms of food safety, maintain trust and reliability, the throughout supply chain's visibility and data tamper-proofing is an important issue [17]. It is a big challenge to ensure associated data in the food supply chains from origin to destination. This data is essential to prevent COVID-19 and other foodborne illness risks, food integrity issues, and issuing various food certificates. Blockchain technology is emerging as the core technology of transparent tamper-proof data sharing.

We have already published several articles to track and trace the food package from origin to consumer and deployed blockchain technology in Hubei Government China's food safety project, with an alliance of food producers and distributors in China and overseas [17–20]. We used a design-based research approach with the concept of mindful use of information technology [17]. The detailed workflow of our developed methodology based on a design-based research approach is given in Figure 1.

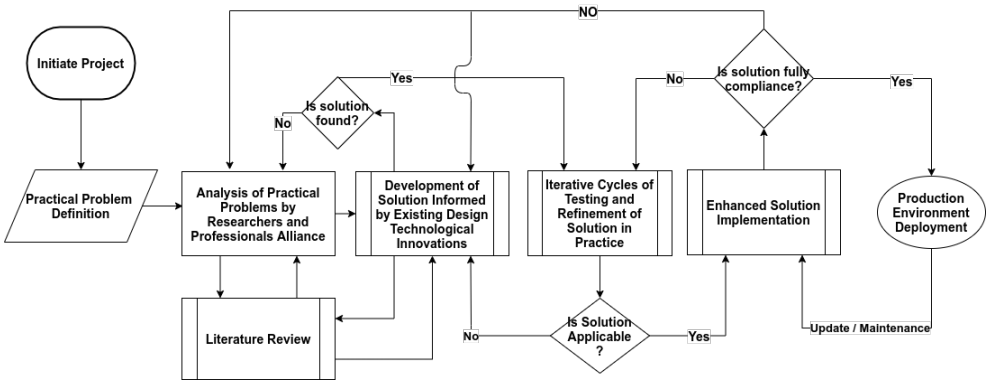

Figure 1. Research Methodology

The rest of this paper is organized as follows. Section 2 provides a quick overview of blockchain technology and the COVID-19 impact on the food industry.

2. Background Studies

2.1. Overview Blockchain Technology

Bitcoin originated from the world's first blockchain-based application [21]. A blockchain is a distributed database consisting of blocks of information integrated with the cryptographic hash function. Hash function processes are given data through a sequence of complex mathematical transformations and output a fixed string of characters called a hash value [Figure 3]. The hashing process is designed that even the tiniest change in the data will result in a completely different hash. In Figure 2, we have a chain of three blocks. The use of hash only is not enough to protect the tampering. Computers these days calculate billion of hash per second. We can effectively tamper with the block and recalculate all the hashes of the other blocks. It is where proof of work comes in handy. It slows down the creation of new blocks. It makes it very hard to tamper with the block as tampering with one block will also require proof of work for the current and all following blocks [22].

The blockchain's security comes from its creative use of cryptography, a hashing function, and peer-to-peer networking. When someone joins the blockchain network, it needs to gets all the blockchain into the system. The system can verify that everything is in order. When someone creates a new block, it sent it to the rest of the network. Each node

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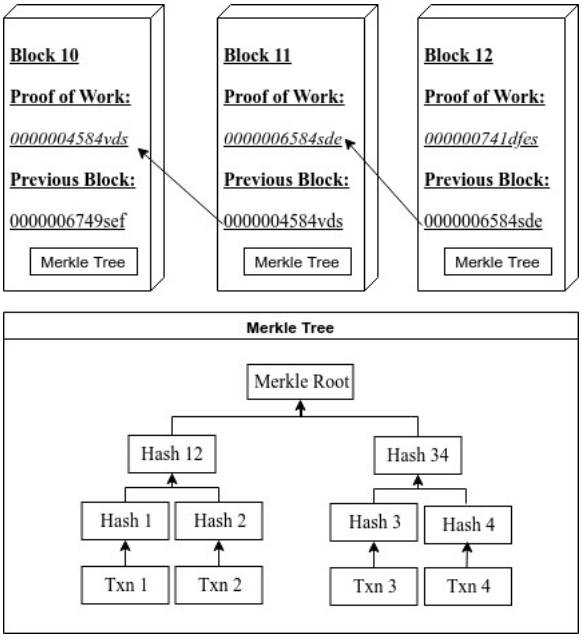

Figure 2. Blocks forming blockchain using hash signature

```
String     : Hello World
SHA256 Hash: A591A6D40BF420404A011733CFB7B190D62C65BF0BCDA32B57B277D9AD9F146E
SHA512 Hash: 2C74FD17EDAFD80E8447B0D46741EE243B7EB74DD2149A0AB1B9246FB30382F2
             7E853D8585719E0E67CBDA0DAA8F51671064615D645AE27ACB15BFB1447F459B
MD5    Hash: b10a8db164e0754105b7a99be72e3fe5

string     : hello world
SHA256 Hash: B94D27B9934D3E08A52E52D7DA7DABFAC484EFE37A5380EE9088F7ACE2EFCDE9
SHA512 Hash: 309ECC489C12D6EB4CC40F50C902F2B4D0ED77EE511A7C7A9BCD3CA86D4CD86F
             989DD35BC5FF499670DA34255B45B0CFD830E81F605DCF7DC5542E93AE9CD76F
MD5    Hash: 5eb63bbbe01eeed093cb22bb8f5acdc3

string     : Hello world
SHA256 Hash: 64EC88CA00B268E5BA1A35678A1B5316D212F4F366B2477232534A8AECA37F3C
SHA512 Hash: B7F783BAED8297F0DB917462184FF4F08E69C2D5E5F79A942600F9725F58CE1F
             29C18139BF80B06C0FFF2BDD34738452ECF40C488C22A7E3D80CDF6F9C1C0D47
MD5    Hash: 3e25960a79dbc69b674cd4ec67a72c62
```

Functions.PNG

Figure 3. Hash values generated by different Hashing Algorithms

then verifies the block validity. If everything is valid, every node adds it to its blockchain. So all the nodes in the network reach a consensus. They agreed upon which block is valid and which block is invalid. Blocks tampered with will be rejected by other nodes of the network. To successfully tampering with the public blockchain, we need to calculate all the proof of work and need more than 50% control of the peer-to-peer network, which is almost impossible to do. To study blockchain in detail with its various aspects, architecture, and working, can be referred to [23]. Table 1 is referring to blockchain enable supply chain solutions.

2.2. Covid-19 and Food Contamination

Zenia et al. has analyzed the Covid-19 impact on the food industry concerning the food safety recommendations from various governmental and public organizations [2] and is a basic document on existing literature in our use case. It is reassuring to say that despite the worldwide spread of COVID-19, there is no evidence of transmission of this infection via consumption [24–26]. Therefore, as stated by public health agencies worldwide, there is no evidence that food poses a risk to public health concerning COVID-19. The main transmission of COVID-19 is through respiratory droplets of the infected [25]. These droplets may quickly fall on the floor and surfaces. The Center for Disease Control and Prevention provides the latest information on COVID-19. The COVID-19 virus survived on cardboard and hard surfaces for up to 72 hours in an experimental setting. Thus it is more likely that the infected food worker will spread the virus from person to person or through droplets on the surface of the food processing plant and food packaging [26]. COVID-

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19 is an issue of occupational safety and ensures that the workers are healthy and not contaminate the food through infected droplets on the surfaces, food, and packaging [27]. The companies need to implement strict measures for employee health screening, daily disinfecting the surfaces, surroundings, proper use of personal protection equipment by the workers, and effective laundry monitoring. Training and effective communications with the workers are equally important. According to the requirements of the state council's China "Work Plan for Prevention and Comprehensive Disinfection of Imported Cold Chain Food," the General Administration of Customs, Ministry of Transportation, Health Commission, and General Administration of Market Supervision are monitoring bodies for the implementation of this plan throughout China. The import process workflow is described with the help of the flow chart in Figure 4.

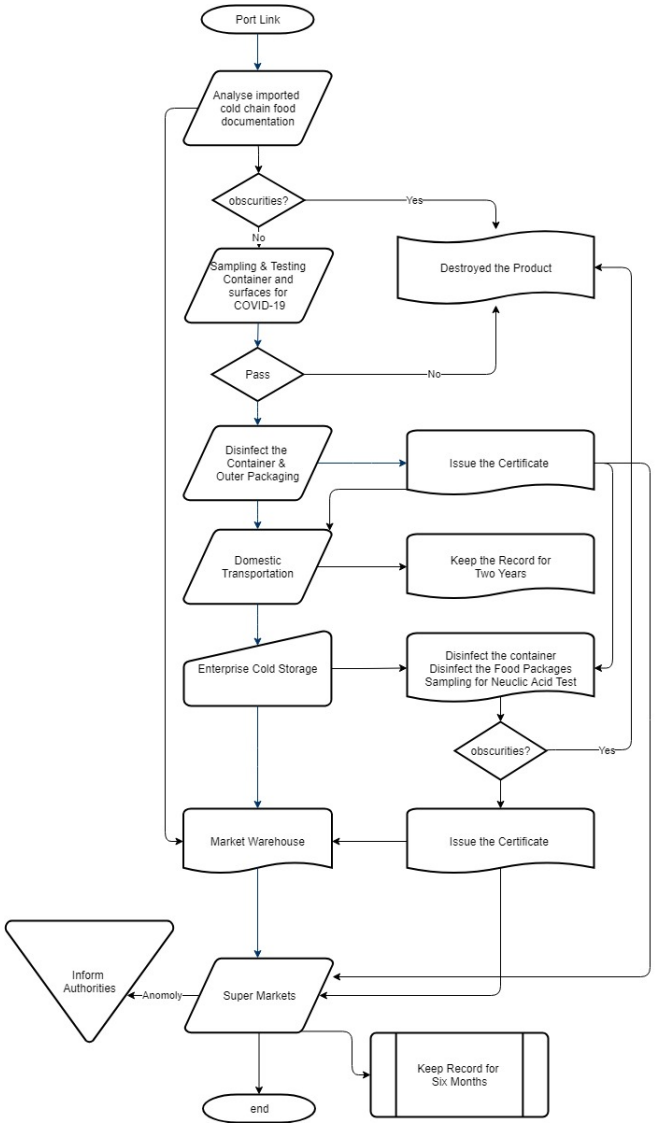

Figure 4. The import process of cold chain products

3. Blockchain-based Solution for Importers/Exporters

The beef supply chain is comparatively linear [Figure 5]. The supply chain after the COVID-19 pandemic included many actors than before. There are very high chances of lack of trust due to the legal regulations and pandemic control legislations. The blockchain is a single source of truth in a trustless environment. The logical illustration of the blockchain system based on Hyperledger Fabric is given in Figure 6.

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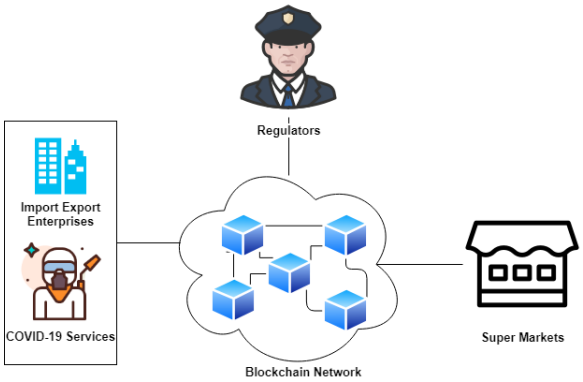
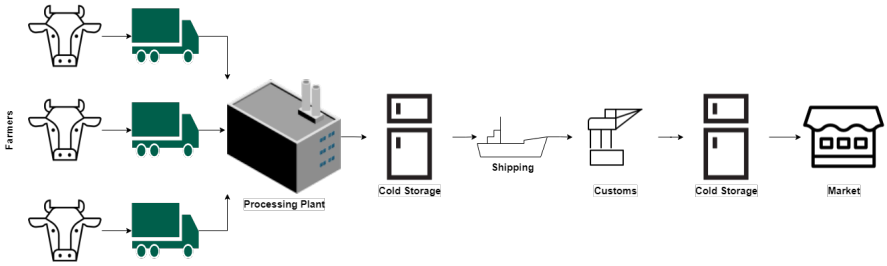


Figure 6. The logical overview of the system



Supply Chain.png

Figure 5. The overview of the beef supply chain

The Figure 7 is illustrating our farm management systems. The digital data about the feeding and animal breed age and health is digitally available to feed to the blockchain. The processing plant is monitoring and recording every employee's health with identification twice a day at the start and end of the shift and uploading it at the blockchain with a specially designed smart contract. The thermal cameras at the entry-exit and different locations of the plant are also continuously monitoring the employees' health. The plants are strictly applying the food safety recommendations. The plant's live feed is available to the importers to keep and eye on the plant's safety conditions. The food packages are carefully packed and completely disinfected with recommended chemicals, including the container. The enterprise is also responsible for disinfecting once again at the port before closing the container and updating the certificate from port authorities on the system. Suppose any anomaly is found in the health of the employees working on the specific batch of the production. In that case, the production will be returned without acceptance. The flow chart in Figure 4 is explaining the domestic operations. All the data will be uploaded on the food safety blockchain system designed for the Hubei Food Safety Authorities.

3.1. Blockchain Network Architecture

Cold chain management requires a large number of reconciliations between different departments. Our proposed use case provides a real-time and tamper-proof trail of transactions to all the essential departments with high integrity. Moreover, it is incredibly flexible and cost-efficient as it does not require some particular infrastructure and costly servers. Figure 8 is an overview of our proposed blockchain protocol stack. The Hyperledger Fabric blockchain uses Smart Contracts called Chain Code. The chain code can ensure the transparency of the rules for everyone, and relevant criteria should trigger interventions. In a blockchain network, the chain codes are the functions that took input in the form of transactions and send notifications to the network's participants to monitor and notice any violation of the rules. The Hyperledger Fabric is a fully permission-ed network. Each component of the system requires to carry its own identity, including users and operators. So no attempt of violation can be hidden in any way.

The following subsections briefly describe all the layers in the proposed architecture.

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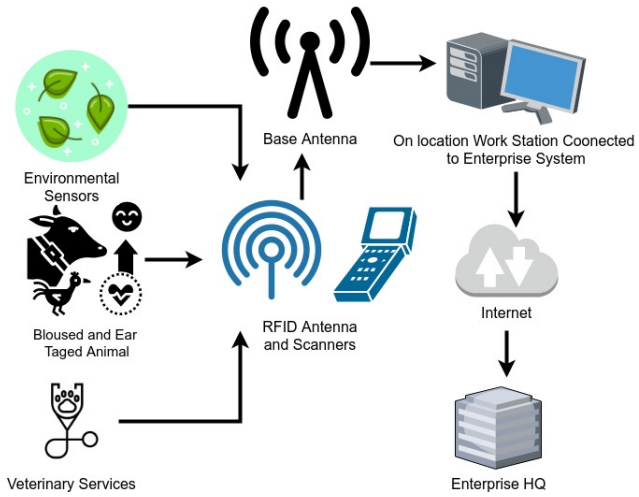

Figure 7. Farm Management System

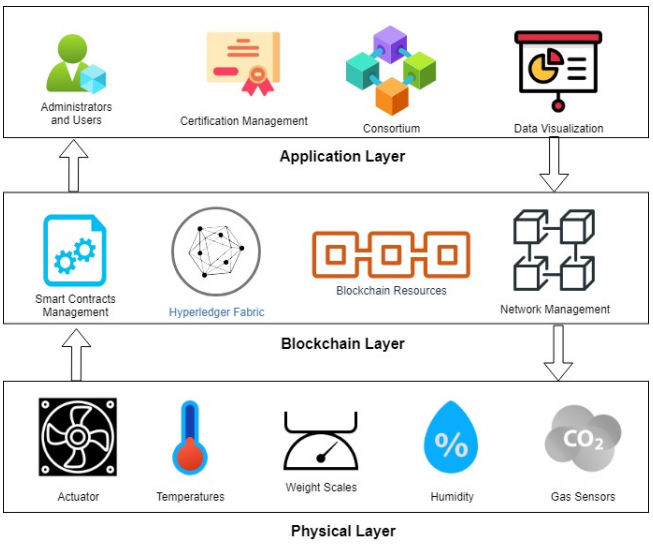

Figure 8. An overview of the Protocol Stack

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3.2. Application Layer

The application layer consists of Administrators and users, Certification Management, Consortium Formation, and Data Visualization. Hyperledger Fabric is a consortium-oriented blockchain platform. The consortium is consists of relevant departments and enterprises. According to the government policy, the consortium makes policies to conduct its operations and update its smart contracts to carry on all the operations.

In the consortium, all the participating entities have a role assigned to it with a mutual understanding of the consortium members. The role cannot be changed without the mutual consensus of the participants of the consortium. The first step is to define the network configurations in the form of the policies. With these policies, we can create the first component of the network, which is called orderer. The orderer serves as the administration point for the rest of the network. The orderer uses the system channel to communicate with the rest of the system components. The orderer needs to configure with the help of the network configuration. We can retrieve certification from the certification authority to give the identifies to the system components. The certification authority issues an x509 certificate for identity. Each endpoint needs its own identity to recognize the other components from a particular organization or have a specific role in the network. It is why there is usually more than one certification authority in a network. The fabric provides its own CA, which calls the fabric CA. The network configurations depend greatly on generated certificates. It is where policies define which certificate is needed to perform a particular task.

3.3. Blockchain Layer

The second step is to create the channel. For this proposed network, we are just going to implement the one channel that is shared by all of the three organizations. The channel is providing the communication mechanism for the members of the consortium to communicate. The channel configuration creates a channel, and this configuration is completely separate from that of the network configurations. The organizations will now join the network on the channel as a peer. The peer is a bridge between the fabric network and the real world. Organizations are connected with their peers to get access to the network. It is also a place where the ledger is stored. Remember that it is distributed to all of the peers connected to a particular channel. Every channel has one ledger, and every participant has a copy of the ledger. The ledger is logically stored on the channel, but it is stored on the connected peer nodes. At this moment, we have our channel created, and we have connected all of our participants to the channel. We also have a ledger to store the information. We still need smart contracts to interact with the ledger.

The Hyperledger Fabric blockchain uses Smart Contracts called Chain Code. The chain code can ensure the transparency of the rules for everyone, and relevant criteria should trigger food reserves interventions. In a blockchain network, the chain codes are the functions that took input in the form of transactions and send notifications to the network's participants to monitor and notice any violation of the rules. The Hyperledger Fabric is a fully permission-ed network. Each component of the system requires to carry its own identity, including users and operators. So no attempt of violation can be hidden in any way. The chaincode is deployed on all the peer nodes. The chaincode is not connected to the channel, but it is hosted on the peer nodes. Now our network is ready where all of the three organizations have an equal right on the network.

3.4. Physical Layer

The data has become the most value able resource, surpassing the oil. The internet of things is the pillar of industry 4.0 and agriculture 4.0. The increasing use of different intelligent technologies such as machine learning, cyber-physical systems, and the internet of things is transforming human life completely dependent on the data produced by nearby things and information generation. The world's technological advancements are now directly proportional to global automation driven by the internet of things and some other

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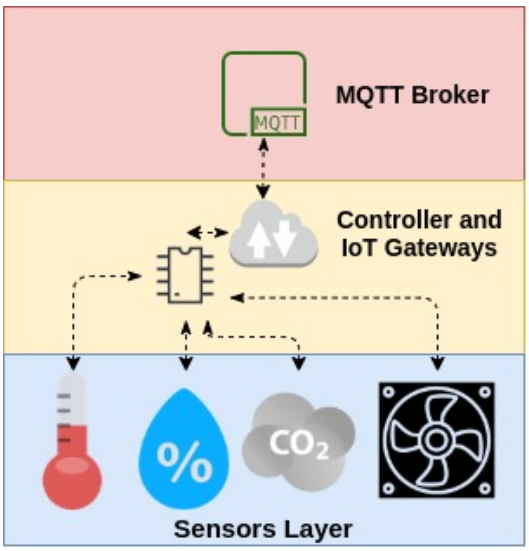
physical systems. The systems will provide the foundation of our critical infrastructure, form the basis of emerging and future smart services, and improve our life quality in many areas. While the internet of things takes care of the connections between objects and machines to the internet, cyber-physical systems are machines in which a mechanism is controlled or monitored by computer-based algorithms. These connected things will interact with each other and make decisions autonomously. One of the data sources that feed the algorithms comes from the smart sensors systems. The internet of things generally refers to the network of all these sensors having the ability to collect the data from its environment and feed that data to the algorithms on the processing nodes anywhere globally through the internet or its local area network [Figure 9].



stack.jpg

Figure 9. IoT Layer Architecture

4. Blockchain Network Integration

We developed a technological stack to integrate the existing enterprise architecture with a blockchain network behind the scene. Figure 10 refers to our technology stack to develop blockchain-based applications. It provides the required functionality to integrate the blockchain network with the existing enterprise network to load data to/from the blockchain network. The Hyperledger Fabric provides a flexible architecture to develop the user interface to interact with the blockchain [Figure 11]. The front end of the application can be developed as a traditional web application. A desktop application or a custom middle care can be created using the provided application development kits by Hyperledger Fabric.

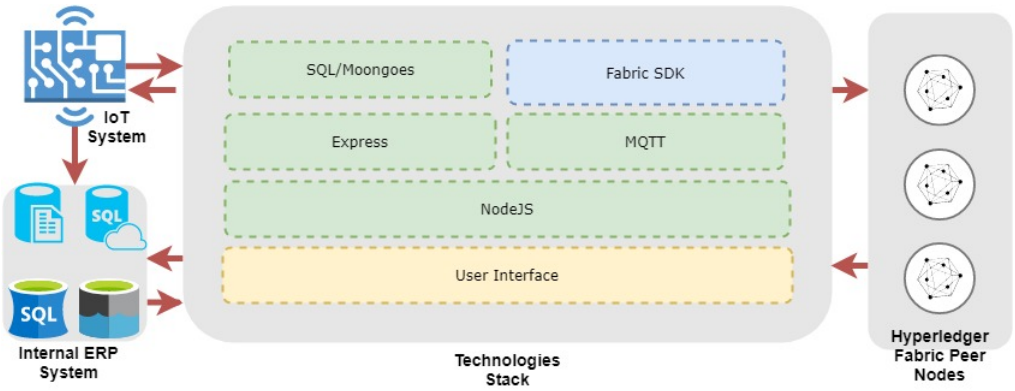


Figure 10. Blockchain Technological Stack to Developed Blockchain Network

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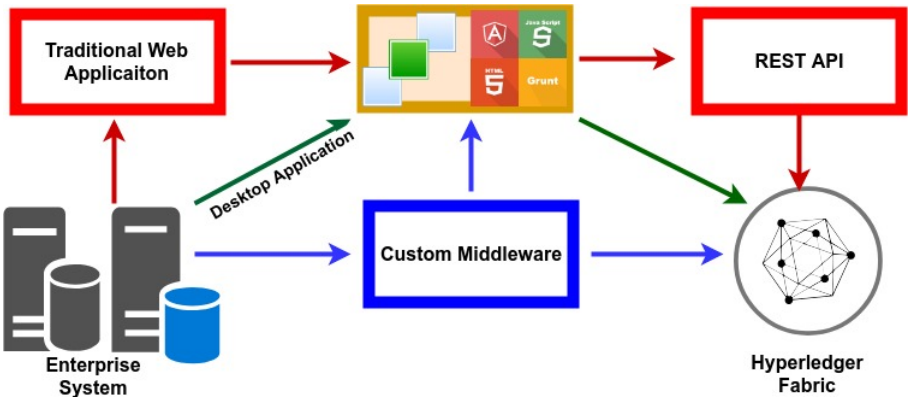

Figure 11. Blockchain Technological Stack to Developed Blockchain Network

5. Conclusion

This paper defines a blockchain technology use case and a quick reference guide to design a blockchain network for the food industry to quickly reconcile the documentation and required data with legislation authorities to import cold chain products to certify the quality of the final product. This information is also useful for Food Control Authorities to prevent potential food safety hazards. It also enhances healthy competition between companies to improve product quality continuously. We are developing a common products code and protocol to create a national products recognition database. It needs to develop a system where the different blockchains can transfer the data on each other or can be merged.

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Data Availability Statement: Data sharing is not applicable for this article.

Conflicts of Interest: The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript.

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Nir Kshetri	5G in E-Commerce Activities	[29]
Cen et al.	Improving Business Process Interoperability by Shared Ledgers	[30]
Edwards et al.	*Blockchain meets the supply chain*	[31]
Alzahrani et al.	Block-Supply Chain: A New Anti-Counterfeiting Supply Chain Using NFC and Blockchain	[32]
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Feng Tian	A Supply Chain Traceability System for Food Safety Based on HACCP, Blockchain & Internet of Things	[34]
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Table 1: Application of Blockchain in the Food Supply Chain

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