Blood Supply Chain Management Using Blockchain Technology

Nasurudeen Ahamed N (nasurudeenahamed@presidencyuniversity.in)
Presidency University

R VIGNESH
Presidency University

Research Article

Keywords: Blockchain, Supply Chain, Hyperledger, Hyperledger Fabric, Cold Chain

Posted Date: July 29th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1888116/v1

BLOOD SUPPLY CHAIN MANAGEMENT USING BLOCKCHAIN TECHNOLOGY*

NASURUDEEN AHAMED N†

School of Computer Science and Engineering, Presidency University,
Bengaluru, Karnataka, India‡
nasurudeenahamed@presidencyuniversity.in

R VIGNESH

School of Computer Science and Engineering, Presidency University,
Bengaluru, Karnataka, India
vigneshr@presidencyuniversity.in

Abstract: The blood supply accessible for blood bonding diminishes and requests increments. In any case, existing brought together blood the board frame-works have impediments in that they need itemized blood data and, additionally, data isn't reflected continuously. To take care of this issue, this paper presents an inventive blood cold chain framework dependent on blockchain innovation. Blockchain is one of the arising innovations in use in numerous businesses like (Medical/Smart cities/Voting/etc..,). In this paper, we talk about blood supply the board utilizing blockchain innovation. The proposed framework plans to expand data permeability by recording the general data on the blood supply to the conveyed record. Since we need to utilize the consent blockchain that implies hyperledger texture every one of the exchanges is straightforward so we can keep away from the specialists and stop the blood to sell in the bootleg market. In this strategy, we utilized the savvy contract for a con-sent network that implies cold chain (Go Language/Java) code to be composed so third people cannot mess with the information. Data in the proposed blood cold chain framework can't be produced or altered, also, data recorded and partook continuously is kept straightforward.

Keywords: Blockchain; Supply Chain; Hyperledger; Hyperledger Fabric; Cold Chain.

1. Introduction

In, the current era every human gets aware to give a blood donation. Because blood donation is not a donation it lives or saves someone's life. So, Many NGOs and governments give advertisements and awareness shows to impress the youngsters and volunteers to give their blood as a donation. In, all over the world blood (Kim et al., 2020)donation for a commercial purpose is strictly prohibited. Due to this much awareness, we get struggle to get

blood in some emergencies. So, we supply the blood from the donation camp to reach the appropriate customer through the hospital. That means we have to use the blood supply chain(Mousavi et al., 2021). But, anyway, some problems also arise in this blood supply chain. As of now, the blood production network framework has issues with supply time and data on the board because of the brought-together structure. However, changes in the blood supply locale may cause irreconcilable situations between blood sources, evasion of jobs of clinical establishments, responsibility, and cost issues.

This investigation means to plan and execute a fresh blood store network framework dependent on blockchain innovation to work on the above issues. Blockchain innovation makes it hard to manufacture and distort data, permitting the framework to be overseen straightforwardly continuously. What's more, blockchain-based shrewd agreements (Griggs et al., 2018) can save time and effort identified with report preparation and have a component of accelerating execution. To take care of the stockpile time issue by utilizing these benefits, blood exchanges between medical clinics are planned and executed as savvy contracts in crisis circumstances. So, we mentioned the following methods of contribution:

- Blockchain.
- Supply Chain Management (Food / Medical /Oil etc.)

2. Blockchain

Blockchain is an emerging technology nowadays. So, we integrated many business applications. Because, it is a Decentralized, Conveyed, and Changeless Record. Blockchain Network we can split into three parts as follows:

- **Block**: Each Block for Create Transactions and all transactions are recorded.
- **Chain**: Each Block is linked in a chain manner that is hash code created and connected for every node.
- **Network**: All Blockchain are connected through hash code (chain) and composed in the network.

In the Blockchain Structure, the very first block is called as “Genesis Block “and then generates the next block in the blockchain network. Blockchain Connected the blocks and verified every block before starting the transaction in the blockchain network. The previous block is connected in a way of cryptographically addressed a securely. All, Transactions made in Blockchain are very secure and transparent.

Because we used in cryptography method. Moreover, all the changes we made in transactions it's updated automatically in the ledger. All Blocks are exchanged the data in the form of a Merkle tree. The purpose of increase the trust in the blockchain.

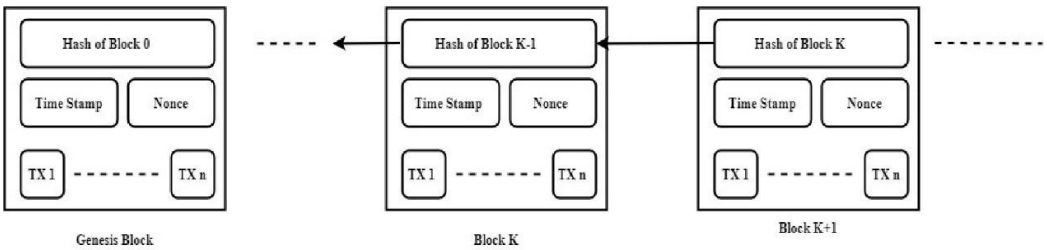

Fig. 1. Basic Blockchain Architecture

The above Fig. 1. represents the form of the Merkle tree structure and all the data exchanges used in this above structure. In, this structure block header contains Timestamp and Nonce. The Timestamp is described when the block is added (Time and Date), and Nonce is described how many iterations are going for the validated block. The Block Body contains the transactions. All Transactions stored in the Block forever belong to the block body in the above-mentioned basic Blockchain structure(Kshetri, 2021).

3. Medical Supply Chain Management

Supply Chain is a sequential process of taking products from origin to destination at the correct time. There are many industries are running in the supply chain (Food Sector / Healthcare Sector / E-Commerce). Here we, take an Example of the Healthcare Supply Chain Process(Fertier et al., 2021). In, the Health Care Supply Chain We can take the drugs from supplier to patient.

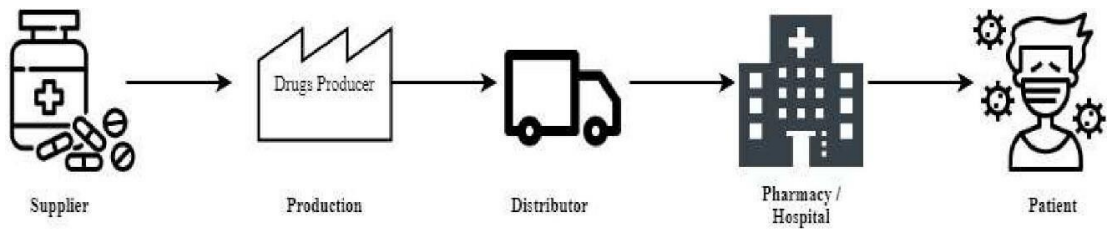

Fig. 2. Traditional Medical Supply Chain.

The above drug supply chain talks about the traditional method Fig. 2. In the above method, we can take the drugs from the supplier to reach the patient. In the same way, we can take all healthcare products in a traditional supply chain from suppliers to reach the patient. In, Health Supply Chain is a very huge process and many types of the supply chain in healthcare supply chain management(Jamil et al., 2019). For, example Drug Supply Chain, Plasma Supply Chain, and Blood Supply Chain. In this paper, we discuss how we integrate the blockchain method in blood supply chain management.

4. Blockchain Integrated in Medical Supply Chain Management

For taking advantage of the entire interaction of medication and clinical items development from providers to patients. Since all exchanges are recorded onto the record, and each hub in the blockchain(Chen et al., 2021) keeps a record of the exchange it is not difficult to check the beginning of the medication, the merchant, and the wholesaler in a flash. Besides, the disseminated record of the blockchain permits medical care authorities and doctors to check and validate the qualifications of providers. Every one of the progressions is refreshed consequently in the record**.**

Below Fig. 3. describes the blockchain integrated into medical supply chain management. It was shown to overcome the traditional supply chain method through the emerging blockchain method. So, it's very easy to update the transaction ion distributed and decentralized from supplier to patient.

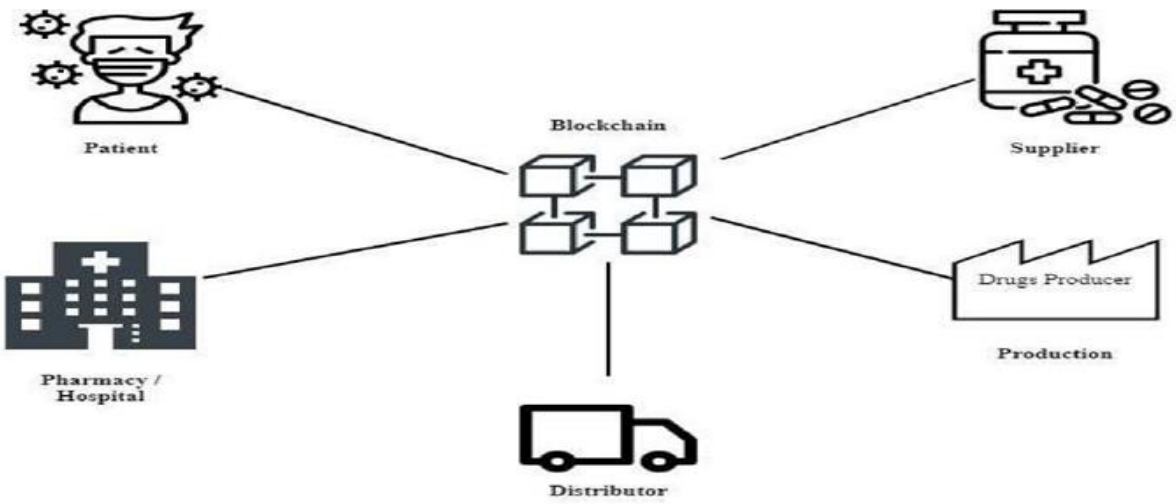

Fig. 3. Blockchain Integrated with Medical Supply Chain.

5. Proposed Work

In this paper, we propose a blood production network framework configuration utilizing private blockchain innovation. We talk about plan situations and models, explicitly for crisis blood demands. The main thing for emergency clinics that unexpectedly need blood is a prepared blood supply. Nonetheless, if the blood donation center that provisions the blood is a long way from the emergency clinic, challenges of supply occur. These hardships can be tackled by utilizing excess blood from different medical clinics that are nearer. In this manner, we planned a framework for direct, crisis situation blood trade between close-by emergency clinics. Utilizing blockchain innovation, the significant exchange records are recorded and partaken progressively(Chen et al., 2021).

The Blockchain consists of three types:

I. Public Blockchain
II. Private Blockchain
III. Consortium Blockchain

In the **Public Blockchain** name itself, we identified whoever can join this network (Example: Ethereum).

Private Blockchain is only authorized persons can join and communicate in this network (Example: Hyperledger Fabric).

Consortium Blockchain consists of both two Public and Private Blockchain Networks. In Our, proposed work we have to describe the private blockchain (Hyperledger Fabric).
The difference between both Permissioned and Permissionless is mentioned in Table 1.

Table 1. Difference between Permissioned and Permissionless.

Permissioned	**Permissionless**
Prohibitive admittance to the Organization.	Open admittance to the organization.
Light agreement calculations.	Complex agreement calculations.
Agreement with restricted adaptability.	Versatile agreement.
No need for motivational components	Motivating force instruments.

5.1. *Hyperledger Fabric*

It is an open-source blockchain stage from The Linux Establishment, which is given by IBM as "Blockchain as an Administration". It is focused on organizations. Hyperledger works with shrewd agreements by interfacing all applicable gatherings together. The texture is a sort of private or permissioned blockchain. A few associations or government offices "own" the hubs, who license the hubs to speak with one another. Personalities and jobs of individuals are known to other individuals(Shuaib et al., 2021).

Hyperledger Texture follows a measured plan that permits the combination of pluggable modules for its distinctive foundation parts (e.g., agreement calculations). Notwithstanding, client characterized agreement calculations can be attachment and-play when required. Texture upholds chain codes like ETH (Ethereum) shrewd agreements. Hyperledger Fabric follows an Execute-Order-Submit model, in which exchanges are at first executed on the arrangement of validators characterized in the underwriting strategy mentioned below Fig. 4.(Abu-elezz et al., 2020)(Johari et al., 2021)

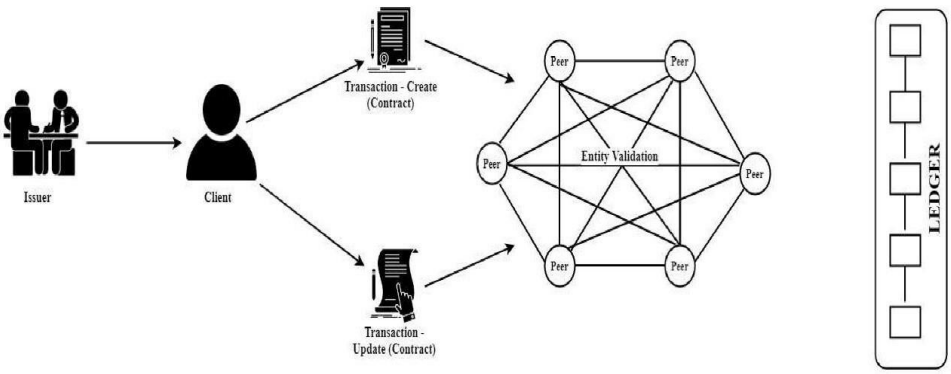

Fig. 4. Hyperledger Fabric Architecture.

This methodology further develops adaptability by lessening blockage time forestalls non-determinism in agreement code, and empowers the private execution of exchanges between a bunch of members.

The versatility of Hyperledger Fabric likewise relies upon how quickly the equipment of the elaborate companions executes the approval pipeline of exchanges(Tanwar et al., 2020).

Hyperledger Fabric doesn't need costly mining calculations to submit exchanges, so it can help assemble blockchains that can increase with less latency. Following are the critical components of a regular Hyperledger organization:

- Records store a chain of squares that keep all unchanging verifiable records of all state advances.
- Hubs are the coherent elements of the blockchain.

There are three sorts:

I. Clients are applications that follow up in the interest of a client to submit exchanges to the organization.
II. Peers are elements that submit exchanges and keep up with the record state.
III. Orderers make a common correspondence channel among customers and companions; they additionally bundle blockchain exchanges into blocks and send them to submitting peers.

5.2. *Components of Hyperledger Fabric*

The List of Hyperledger Fabric Components is the below:

I. Chain Code.
II. Peer.
III. Channel.
IV. Orderers.

5.2.1. *Chain Code*

Chaincode is like a keen agreement in different organizations, like Ethereum. It is a program written in a more significant level language that executes against the record's present status information base. In, Figure 5(a) talks about the two different organizations sharing the data with the help of a keen argument. Coding Language: Go.

5.2.2. *Peer*

Peer the organization is generally addressed by a bunch of companion hubs or just friends mentioned in Figure 5 (b). Each companion saves a neighborhood duplicate of the record for each channel and may run chaincode cases

locally. Accordingly, peer hubs are answerable for furnishing customer applications with admittance to the record and the chain code of their channels.

5.2.3. *Channel*

Channel is a devoted line of correspondence between a few friends. It's a consistent construction framed by a mix of companion hubs. Each channel has its own free blockchain state with a totally autonomous record. So we get as many separate blockchains as there are channels mentioned in Figure 5 (c). On the off chance that a friend gets to various channels, it will have a different duplicate of the record for each channel.

5.2.4. *Orderers*

Orderers are requesting administration give a common correspondence channel to customers and friends, offering a transmission administration for messages containing exchanges talks in Figure 5 (d). Orderers are liable for guaranteeing nuclear conveyance, everything being equal, or agreement of exchanges inside each channel.

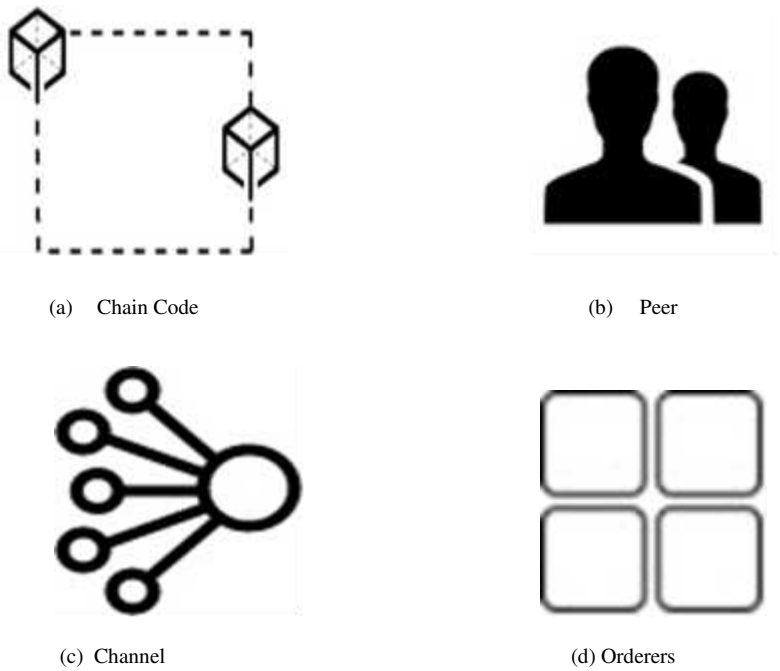

Fig.5. Hyperledger Fabric Components.

5.3. *Decentralized Version*

Blockchain gives a circulated record or information base which is divided between all members in the organization depending on the agreement component. The requirement for an outsider verifier is wiped out, making the framework secure and totally decentralized. Any exchange which brings about an adjustment to the Blockchain record is carefully marked, checked, and approved by excavator hubs which keep a copy of the record. This makes totally decentralized, secure, time-stepped, and shared carefully designed records.

Blockchain innovation has been used in numerous businesses like money, medical care, inventory network, coordination, archive the executives, and bookkeeping(Nizamuddin et al., 2019).

Because of its hearty and decentralized foundation, blockchain innovation is applied to deal with issues identified with trust, proficiency, protection, and information sharing. This innovation kills the prerequisite of an outsider exchange authority by utilizing the capability of cryptography to give dependable answers for the elements taking an interest in the chain. Example: Hyperledger Fabric. Hyperledger Fabric supports the Decentralized Application for writing the code language is either Go or Java both executed in containers.

In hyperledger fabric for the decentralized application written in the language in Go. This is like Ethereum smart contract. That means we enter the code for legal agreement from supplier to consumer without any intercept of a third party. In the proposed blood supply chain management, we have to create the chain code (Contract) for the blood donation camp to direct the deal to the hospital. with this method, we can easily avoid the third party involved in this blood to sell on the black market.

Algorithm 1: Create Smart Contract (ChainCode) for BloodDoantion

```
Procedure contract Blood camp
string public patient name;
function Blood camp() public
patient name =" XXXX";
function set (string  name) public
patient name =name;
function patient() constant returns (string)
return patient name;
End Procedure
```

The above Algorithm 1 (Contract) creates for exclusive blood donation camp for the hospitals. Whenever the emergency purpose for a particular patient. This contract is executed through the hospital to the appropriate patients. So, this way we can avoid the third party. Moreover, all the transactions occur decentralized so it's visible to everyone participating in this network. One more advantage of this permission network blockchain utilizes this blood supply chain we can easily monitor the temperature of blood and blood types. And how it's utilized all the things are we can easily store in a distributed manner.

Algorithm 2: Smart Contract (Chain Code) for Blood Temperature

```
Procedure class Blood
```

"blood id": "Blood123"

"blood type": "B Positive"

"unit": "350"

temperature

"transaction-id" : "123456"

"centigrade": "4"

"timestamp" : "2021-03-07 13:10 IST"

End Procedure

The above Algorithm 2(Contract) is defined for blood storage, generally, our human blood has to maintain a cool place and we have to maintain it on certain days. Generally, patients or people don't know what the temperatures they are maintaining are and how many days our blood is preservative. So, all the things are stored in the permission blockchain in a decentralized manner in the chain code (contract) creation.

6. Blood Supply Chain Using Blockchain Through Decentralized Storage

Completely decentralized blockchain arrangements ideally use decentralized capacity frameworks, like Interplanetary Record System (IPFS). IPFS stores a record in a distributed organization of public hubs, and gives content-based tending in light of the file's SHA-256 message digest, making it simple to set up associations between the blockchain and the capacity. Interplanetary File System (IPFS) IPFS is a distributed storage worker that consequently returns a hash of the transferred file(Nizamuddin et al., 2019).

IPFS framework is cultivated also, and safeguarded by the gathering of medical care suppliers, for example, clinics. It utilizes a substance tending to a strategy where the location is inferred from the substance of the document. Each document is hashed into a hash string and each hash string is remarkable to distinguish the record. Anybody can discover the complete record put away in IPFS by means of the hash line of the document on Blockchain. IPFS makes it conceivable to disseminate an enormous volume of information with high productivity(Kumar et al., 2021).

IPFS is shared; no hubs are favored. IPFS hubs store IPFS objects in nearby capacity. Hubs interface with each other and move objects. These articles address documents and different information structures. The IPFS Protocol is partitioned into a pile of sub-conventions liable for various usefulness:

- **Personalities** - oversee hub character age and verification.
- **Organization** - oversees associations with different companions, employments different fundamental organization conventions.

- **Directing** - keeps up with data to find explicit companions and items. Reacts to both nearby and re- bit inquiries.
- **Trade** - an original square trade convention (BitSwap) that administers effective square dispersion. Demonstrated as a market, feebly boosts information replication. Exchange Techniques swappable.
- **Items** - a Merkle DAG of content-tended to im- changeable items with joins. Used to address arbitrary data structures, for example, document progressive systems and communication frameworks.
- **Documents** - formed record framework progressive system motivated by Git.
- **Naming** - A self-guaranteeing variable name framework.

The below is Fig.6. explains the proposed framework of the blood supply chain using blockchain technology. in this hyperledger fabric that means a permission blockchain network, so only authorized persons can be involved in this network. the doctor knows the patient blood type and blood unit. so, in our proposed work all the things we have uploaded are in decentralized storage.so, it's very transparent to see those who are participating in the permission network. doctor able to see all blood types and its satisfied from the doctor, fetch the blood from the blood camp to the destiny patient. in this method, everyone has to satisfy the blood types and centigrade to maintain the blood and how many days are preserved(Zhou et al., 2021) (Madine et al., 2020).

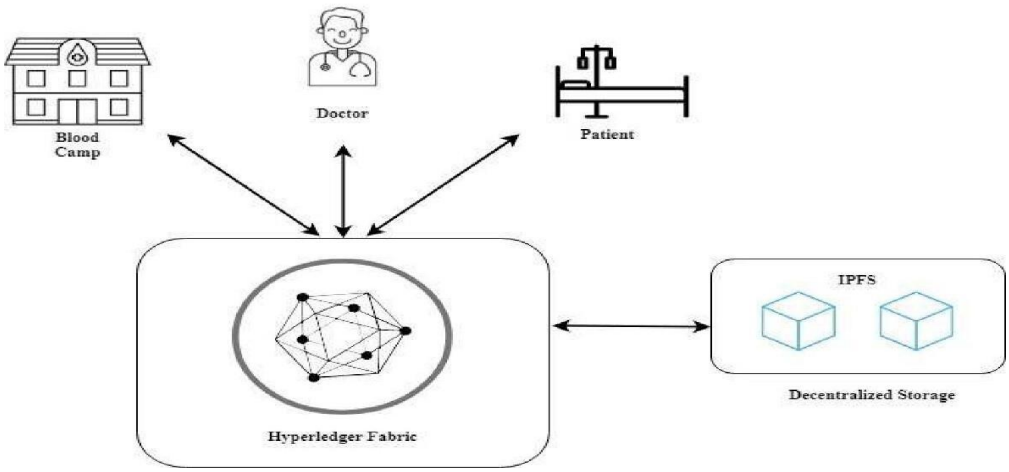

Fig.6. Blood Supply Chain Using Hyperledger Fabric through Decentralized Application.

The below Fig. 7. sequence diagram represents accessing the blood from the blood camp to the appropriate patient. In this modern technology, we have to utilize this emerging (blockchain) technology. This sequence diagram tells about decentralized transactions and transparency for this blood supply chain. Initially blood camp gives the information about blood for example (Blood Type, Blood Temperature), to decentralized storage. Whenever the doctor or hospital approaches decentralized storage like IPFS to gather the blood information. When it's suitable for the appropriate client, the doctor directly approaches the blood camp, then the blood camp accepts the request for that hospital or doctor to start the distribution to the particular hospital. Eventually, the patient gets suitable blood(Zhuang et al., 2020)(Griggs et al., 2018).

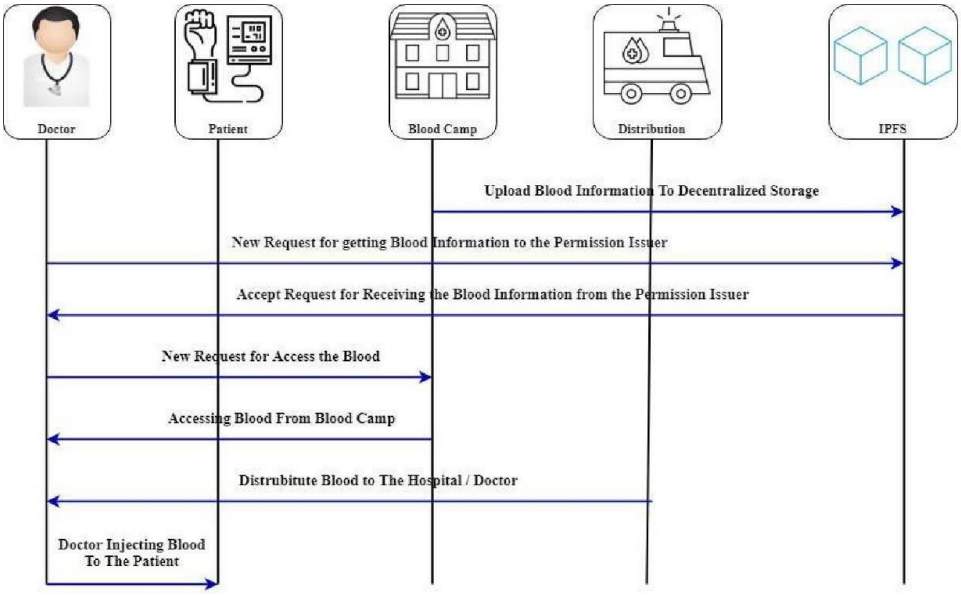

Fig.7. Sequence Diagram of Accessing Blood

7. Results and Simulation

In this section, we develop the hyper ledger fabric (private channel) tool in blockchain for patients. So, all blood types and blood units, etc. everything in blood-related data is stored in a separate block. so, all records are stored and shared decentralized. easy to track the flow of the blood supply chain. Moreover, data cannot change in anyone. because we develop the hyper ledger fabric tool as a private channel for this blood supply chain.

A channel is a private "subnet" of correspondence between two or more explicit organization individuals to perform private and classified exchanges. The correspondence inside the channel is confined and secured, and exchanges and information on the channel are apparent just to channel individuals in Fig. 8.

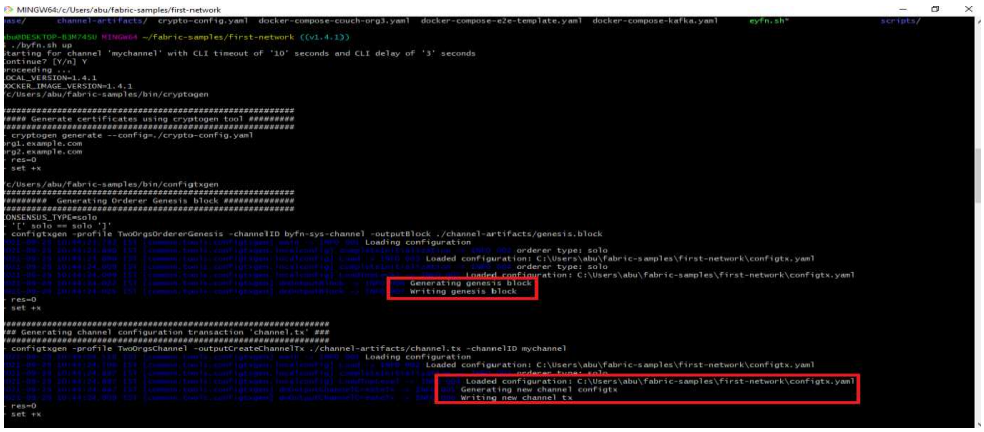

Fig.8. Generating New Channel for Patients

Once, Channel Generated all records are kept private and we can fetch them whenever we want. So, after creating the channel Doctor or Patient can monitor either the hospital or blood camp location and Vehicle(Ambulance) location, blood type, how many patients are waiting, etc., In Fig. 9. describe the navigation of the Patient, Hospital, and Blood Supplier(Camp) Location.

Fig.9. Navigation Map for Flow of Blood Supply Chain.

The Fig.10. describes the schedule allocation of the blood supply chain. That is the source of blood and destination, kind of vehicle we can use, priority, the total number of orders, etc., all the things we stored in the separate block.so, whenever we can fetch the data.

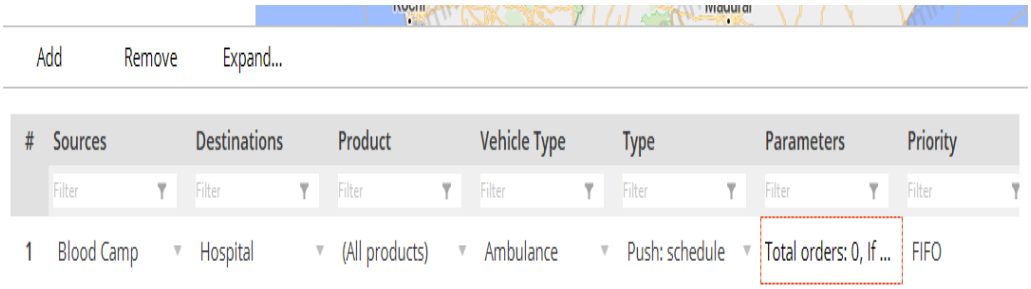

Fig.10. Schedule Allocation for Blood Supply.

Assuming an association approaches the Blockchain network, it can make and keep a private channel with certain different individuals. Individuals (associations) characterize and structure a channel to permit specific hubs to run private and classified exchanges, which different individuals from a similar organization can't see and access. Each channel incorporates hubs, a typical general record, chain codes on the channel, and at least one requesting administration.

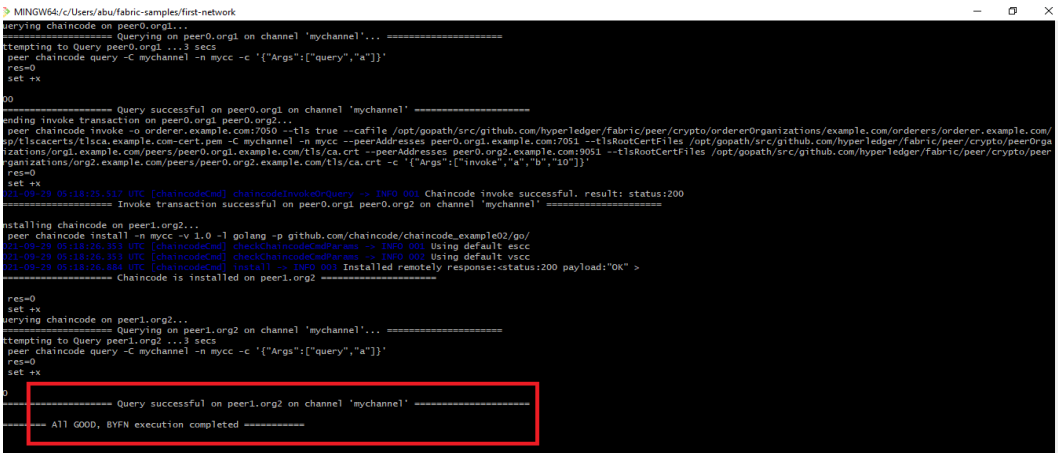

Figure 11. Fabric Channel Execution Completed.

In the above Fig.11. talks to communicate privately regarding the blood supply chain for the appropriate patient through the hyper ledger fabric(private). after, sending the blood to the proper destination hyper ledger fabric execution is successfully completed. But, data is stored in the block forever. Hyperledger Fabric has developed fundamentally as of late and presently represents a large portion of the highlights that organizations can depend on. Hyperledger Fabric is intended for corporate use from the beginning. It is the most dynamic of any remaining Hyperledger projects, and the local area assembled around the stage is continually developing. Accordingly, it has effectively executed in the blood production network on the board.

8. Conclusion

We proposed a decentralized structure and sharing of patient blood reports. The advantages and highlights of Blockchain, and the IPFS document framework used in this blood production network are the executives. The proposed framework is decentralized, secure, and strong, taking out the reliance on the confided-in outsider. Due to the conveyed also, decentralized qualities of blockchain and IPFS, all blood and data about the blood are put away in this decentralized storage.so, it's extremely straightforward, and with the approved individual in the hyper record texture to give the consent to get to the blood and after the endorsement from the guarantor, the specialist can without much of a stretch access the blood from the blood camp. In this proposed work we need to keep up with all blood data (Blood Type/Blood Temperature/Days to Preserve).so, in this strategy to stay away from the outsider and sell the human blood in the underground market. What's more, we intend to create a high-level Blockchain-based model to forestall Blockchain assaults, for future work, we intend to examine more savvy production networks on the board like 4.0 or inventory networks the executives 5.0.

Declarations

Ethical Approval

Not Applicable

Competing of Interests

Not Applicable

Authors' contributions

I would like to express my very great appreciation to Vignesh R to guide me. I (Nasurudeen Ahamed N) am very happy to write this manuscript with Implementation.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Availability of data and materials

Not Applicable

Acknowledgments

I would like to express my very great appreciation to Vignesh R to guide me.

References

Abu-elezz, I., Hassan, A., Nazeemudeen, A., Househ, M., & Abd-alrazaq, A. (2020). The benefits and threats of blockchain technology in healthcare: A scoping review. *International Journal of Medical Informatics*, *142*(February), 104246. https://doi.org/10.1016/j.ijmedinf.2020.104246

Chen, M., Malook, T., Rehman, A. U., Muhammad, Y., Alshehri, M. D., Akbar, A., Bilal, M., & Khan, M. A. (2021). Blockchain-Enabled healthcare system for detection of diabetes. *Journal of Information Security and Applications*, *58*(February). https://doi.org/10.1016/j.jisa.2021.102771

Fertier, A., Martin, G., Barthe-Delanoë, A. M., Lesbegueries, J., Montarnal, A., Truptil, S., Bénaben, F., & Salatgé, N. (2021). Managing events to improve situation awareness and resilience in a supply chain. *Computers in Industry*, *132*. https://doi.org/10.1016/j.compind.2021.103488

Griggs, K. N., Ossipova, O., Kohlios, C. P., Baccarini, A. N., Howson, E. A., & Hayajneh, T. (2018). Healthcare Blockchain System Using Smart Contracts for Secure Automated Remote Patient Monitoring. *Journal of Medical Systems*, *42*(7), 1–7. https://doi.org/10.1007/s10916-018-0982-x

Jamil, F., Hang, L., Kim, K. H., & Kim, D. H. (2019). A novel medical blockchain model for drug supply chain integrity management in a smart hospital. *Electronics (Switzerland)*, *8*(5), 1–32. https://doi.org/10.3390/electronics8050505

Johari, R., Kumar, V., Gupta, K., & Vidyarthi, D. P. (2021). BLOSOM: BLOckchain technology for Security Of Medical records. *ICT Express*, *xxxx*, 2–6. https://doi.org/10.1016/j.icte.2021.06.002

Kim, S., Kim, J., & Kim, D. (2020). Implementation of a blood cold chain system using blockchain technology. *Applied Sciences (Switzerland)*, *10*(9). https://doi.org/10.3390/app10093330

Kshetri, N. (2021). Blockchain and sustainable supply chain management in developing countries. *International Journal of Information Management*, *60*(May), 102376. https://doi.org/10.1016/j.ijinfomgt.2021.102376

Kumar, R., Tripathi, R., Marchang, N., Srivastava, G., Gadekallu, T. R., & Xiong, N. N. (2021). A secured distributed detection system based on IPFS and blockchain for industrial image and video data security. *Journal of Parallel and Distributed Computing*, *152*, 128–143. https://doi.org/10.1016/j.jpdc.2021.02.022

Madine, M. M., Battah, A. A., Yaqoob, I., Salah, K., Jayaraman, R., Al-Hammadi, Y., Pesic, S., & Ellahham, S. (2020). Blockchain for Giving Patients Control over Their Medical Records. *IEEE Access*, *8*, 193102–193115. https://doi.org/10.1109/ACCESS.2020.3032553

Mousavi, R., Salehi-Amiri, A., Zahedi, A., & Hajiaghaei-Keshteli, M. (2021). Designing a supply chain network for blood decomposition by utilizing social and environmental factor. *Computers and Industrial Engineering*, *160*(May), 107501. https://doi.org/10.1016/j.cie.2021.107501

Nizamuddin, N., Salah, K., Ajmal Azad, M., Arshad, J., & Rehman, M. H. (2019). Decentralized document version control using ethereum blockchain and IPFS. *Computers and Electrical Engineering*, *76*, 183–197. https://doi.org/10.1016/j.compeleceng.2019.03.014

Shuaib, K., Abdella, J., Sallabi, F., & Serhani, M. A. (2021). Secure decentralized electronic health records sharing system based on blockchains. *Journal of King Saud University - Computer and Information Sciences*, *xxxx*. https://doi.org/10.1016/j.jksuci.2021.05.002

Tanwar, S., Parekh, K., & Evans, R. (2020). Blockchain-based electronic healthcare record system for healthcare 4.0 applications. *Journal of Information Security and Applications*, *50*. https://doi.org/10.1016/j.jisa.2019.102407

Zhou, Y., Zou, T., Liu, C., Yu, H., Chen, L., & Su, J. (2021). Blood supply chain operation considering lifetime and transshipment under uncertain environment. *Applied Soft Computing*, *106*, 107364. https://doi.org/10.1016/j.asoc.2021.107364

Zhuang, Y., Sheets, L. R., Chen, Y. W., Shae, Z. Y., Tsai, J. J. P., & Shyu, C. R. (2020). A patient-centric health information exchange framework using blockchain technology. *IEEE Journal of Biomedical and Health Informatics*, *24*(8), 2169–2176. https://doi.org/10.1109/JBHI.2020.2993072