ABSTRACT_ Today’s a large number of blood donation management systems fall short in providing traceability, immutability, transparency, audit, privacy, and security features. Also, they are vulnerable to the single point of failure problem due to centralization. In this paper, we propose a private Ethereum blockchain-based solution to automate blood donation management in a manner that is decentralized, transparent, traceable, auditable, private, secure, and trustworthy. The proposed solution stores non-critical and large data off-chain using the decentralized storage of the InterPlanetary File System (IPFS). We present the system architecture, sequence diagrams, entity-relationship diagram, and algorithms to briefly explain the working principles of our blood donation management solution. We evaluate the performance of our solution in terms of efficiency and effectiveness through performing security analysis. We make our smart contract code publicly available on Github1.

1. INTRODUCTION

BLOOD is one of the most crucial fluids in the human body. It contributes in aiding the organs with the essential and valuable substances required for living. Since the demand for blood surpasses all other medical necessities, governments often educate their citizens on the importance of blood donation through organizing awareness programs. The number of donors in the years 2018-2019 were estimated to be 136,908 donors, contributing to a total of 216,639 donations. In general, every 56 days, mostly healthy individuals give blood donations. [3]. The World Health Organization (WHO) estimates that the annual amount of blood donations collected is 112.5 million units which is approximately 50 million liters per year [4]. Yet, the shortage of blood donors has risen with the emergence of new diseases, raising the need to enable reliable and efficient blood donation management [5]. Patient Blood Management (PBM) is a vast and challenging task. The restrictions and gaps occurring with the current blood management system limit the efficient performance of the supply chain. Hannon et. al [6] reported that the blood component wastage rates usually run from 1% to 5%, and that the amount of disposal is not shared or visible to clarify the reason behind it. Thus, any improvement or development is a significant factor in providing effective healthcare worldwide. Figure 1 illustrates a typical flow process of
blood donation. First, donors have three options to donate blood. Option 1, through healthcare centers where blood units are transported to the nearest blood bank. Option 2, through mobile blood collection units. Option 3, directly through blood banks. After that, separation, testing, and storage are operated on each donated blood in the blood bank. The separation process is based on separating whole blood units into components of red cells, platelets, and plasma through centrifuges. Next, testing is performed to verify the blood type and indicate any infectious diseases. When test results are established, units proper for transfusion are then labeled and stored either in refrigerators and freezer lockers or in walk-in cool and freeze rooms [7]. According to the Food and Drug Administration (FDA) and the American Association of Blood Banks (AABB) standards, red blood cells are stored in refrigerators at 6ºC and have an expiration date of 42 days. As per the FDA requirements, plasma is frozen in freezers for up to one year, and platelets are stored for up to five days at room temperature [8],[9]. Subsequently, blood units are packaged and loaded to transporters based on doctors’ orders for their patients’ treatment. Finally, after healthcare centers receive blood units, they further transfuse to patients [10]. Blood-related information might range from blood type to blood state, to the donor’s health record, when the donor donated the blood, and other related readings. Despite the benefit of interblood bank transfers, hospitals commonly fear the chance of receiving the wrong blood, or even worse, blood infected with hepatitis, HIV, or other similar diseases [11]. Several risks are associated with carrying infective donated blood in the supply chain. An epidemic in the late 80s occurred because polluted blood infected with HIV was carried out in the supply chain [12].

Nonetheless, counterfeiting and forgery of medicinal products are considered as another concern in the supply chain, where a falsified illegal copy of an original product can be replaced with the original product itself. This results in the possibility of replacing the blood with another type or attaching a false label to cover up the existing effective blood [13]. These are major obstacles in the supply chain management system which caught the attention of researchers and other interested parties.

Blockchain-based technology in the blood supply chain can assist in reducing the aforementioned risks. The emerging technology possesses several solutions for the verification of the origin of the donated blood. This can be made possible by tracing the source information of the donors in a trusted manner throughout the stages of the supply chain. Several countries across the world have emphasized the importance of traceability and mandated its existence in healthcare supply chains.

2.LITERATURE SURVEY
2.1 “FeelGood: A Blood Donation System Based on Smart Contracts,” [Accessed on: March 20, 2021]. [Online]. Available: system-based-on-smart-contracts/

We propose a private Ethereum blockchain-based solution to automate blood donation management processes in a manner that is fully decentralized, traceable, transparent, auditable, private, secure, and trustworthy. We integrate the private Ethereum blockchain with the decentralized storage of the Interplanetary
File System (IPFS) to overcome the storage limitations. We develop two smart contracts along with algorithms to implement functionalities and define rules regarding blood donation management. We evaluate the proposed blockchain-based blood donation management solution and the developed smart contracts using the security analyses. Also, we compare our proposed approach with the existing solutions. Our proposed blockchain-based blood donation management solution is generic and can be customized to meet the needs of other industrial applications with minimal modifications and efforts.

2.2 Kim, S., Kim, J., & Kim, D. (2020). Implementation of a blood cold chain system using blockchain technology. Applied Sciences, 10(9), 3330. doi:10.3390/app10093330

As the population structure changes due to lower fertility rates and rapid aging, the blood supply available for blood transfusion decreases and demand increases. In most countries, blood management information systems, led by national institutions, operate centrally. However, existing centralized blood management systems have limitations in that they lack detailed blood information and, moreover, information is not reflected in real time. To solve this problem, this paper presents an innovative blood cold chain system based on blockchain technology. The proposed system aims to increase information visibility by recording the overall information on the blood supply and providing detailed blood information such as blood consumption and disposal to the distributed ledger. In addition, this paper proposes direct blood transactions between medical institutions in cases of emergency. Currently, blockchain technologies are being actively employed in the supply chain management and medical fields in addition to financial systems. Particularly, private blockchain techniques with limited participants are relatively fast and reliable, making them suitable for B2B (Business-to-Business) transactions. Therefore, the proposed system is based on the architecture of Hyperledger Fabric, a private blockchain technology implemented by the Hyperledger Composer tool. Information in the proposed blood cold chain system cannot be forged or tampered with, and information recorded and shared in real time is kept transparent. In addition, allowing for B2B blood transaction in special circumstances will minimize the blood supply time and enable patients to be transfused quickly. Moreover, the surplus blood of medical institutions will be used to increase the usage rate relative to the supply amount.

2.3 Hannon, T. (2015). Waste not, want not. American Journal of Clinical Pathology, 143(3), 318-319. doi:10.1309/ajcpm8facvc0rprg

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3.PROPOSED SYSTEM
This paper proposes a blockchain-based blood donation chain management system to address the aforementioned issues. The main contributions of this paper are as follows:

The system proposes a private Ethereum block chain-based solution to automate blood donation management processes in a manner that is fully decentralized, traceable, transparent, auditable, private, secure, and trustworthy.

The system integrates the private Ethereum block chain with the decentralized storage of the Interplanetary File System (IPFS) to overcome the storage limitations. The system develops two smart contracts along with algorithms to implement functionalities and define rules regarding blood donation management.

The system evaluates the proposed block chain-based blood donation management solution and the developed smart contracts using the security analyses. Also, we compare our proposed approach with the existing solutions. The proposed block chain-based blood donation management solution is generic and can be customized to meet the needs of other industrial applications with minimal modifications and efforts.

3.1 IMPLEMENTATION

Admin
In this module the Admin will authorize Blood Donors and Blood bankers and view all the files Blood details and will do the following operations such as View Blood Donors And Authorize, View Blood Bankers And Authorize, View Hospitals And Authorize, Add Blood Groups, View All Blood Donors Trans, View Blood Donor Details By Blockchain, View Patient Details By Blockchain, View Donated Details By Blockchain.

Hospitals
In this module the Hospitals will collect all blood from the donors and provides to the patients and will do the following operations such as Register and Login, View Blood Donors, Feed Patient Detail,
View Blood Banker & Req Blood, View Blood Detail, View Patients.

**Blood Bankers**

In this module, Blood banker has to register to both the hospitals and Admin in order to get the blood from the donors and will do the following operations such as Register and Login, View Blood Donors, View Blood Detail Request, View Req And Sale Bottle, View Blood Available.

**Blood Donor**

In this module, Blood donor has to register to both hospital and Blood banker to get Blood and will do the following operations such as Register and Login, Provide Blood to Hospitals, Provide Blood to Blood Bankers.

4. DISCUSSION

This section discusses the generalization aspect of the proposed private Ethereum blockchain-based blood donation management system. Generally, Ethereum-based solutions discuss and analyze the costs involved in the solution implementation and execution; however, because our solution is built on a private Ethereum blockchain, the gas price is set to zero; therefore, no costs are involved. We present the security analysis of the proposed approach. Finally, we conduct a comparison with the existing blockchain-based solutions.

5. CONCLUSION

In this paper, we have proposed a blockchain-based blood donation management system that traces the origin of the blood in a transparent, private, secure, trustworthy, auditable, and decentralized manner. The proposed solution employed the smart contract feature of the private Ethereum blockchain to record and log events automatically. We integrated the private Ethereum blockchain with the IPFS to deal with the limited storage issue. We tested and validated the functionality of our solution using the Remix IDE. Our developed smart contracts’ code has been made available on the Github repository. We conducted the security analysis to show that the proposed blood donation management solution is robust and secure enough against major security vulnerabilities and attacks. In addition, we compared our proposed approach with the existing solutions. In the future, we aim to deploy and test our solution on the real Ethereum network and build an end-to-end DApp. Furthermore, violation monitoring will be added to further enhance the security of the blood cold supply chain.

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