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Blockchain Technology in Healthcare Industry and Implementation of Secure Cryptographic Technique

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Abstract

Blockchain is a decentralized technology for maintaining privacy, security, auditability, and tracking. Mainly Blockchain technology is implemented in cryptocurrency and tokenization. But there are various domains and industries also available where we can implement the goodness of Blockchain. Among them, Supply Chain Management (SCM) in the healthcare industry is a crucial domain. The weak or compromised SCM in the healthcare industry may impact various levels of stakeholders. Therefore, we need to investigate the practical implementation of Blockchain-based supply chain management in the healthcare industry. In this paper, we review recent development in the actualization of Blockchain-based SCM in the healthcare industry using the collected academic articles. The review includes relevant articles based on SCM and Blockchain applications in the healthcare industry. The aim of this review is not only limited to studying Blockchain technology and its applications in the healthcare industry but also preparing a plan for their actualization. Therefore, by the conclusion of the conducted review, we propose a model for future implementation and simulation. That is because there are significantly fewer implementations of Blockchain technology available for healthcare, and most of the work is only limited to the scope of review and a conceptual model. Finally, the conclusion as a summary of this review and future plan has been disclosed.

Keywords: Blockchain technology, supply chain management, large scale data handling, tacking, review, Blockchain modeling n healthcare.

INTRODUCTION

How important healthcare infrastructure is, we learned this lesson from COVID-19. The entire world is suddenly starting to suffer from this pandemic and due to this a significant negative impact on supply chain management we have seen. Additionally, the shortage of life-saving medicines and black marketing of drugs and equipment is also a huge issue during this pandemic. The only reason is the compromised, conventional and outdated technique of supply chain management. This motivates us to design and develop an effective methodology to deal with such kind of future crisis. In this context, this paper is focused on planning and designing the smart healthcare infrastructure to deal with the issues involved in supply chain management in the healthcare industry.

Healthcare becomes an expensive and sensitive issue in recent years. It includes various levels of risk, which is ranging from end patient safety to the end of the drug manufacturer, hospital, drug or equipment distributor, and other stakeholders. Therefore risk management with effective supply chain management is the key demand of the healthcare industry. The compromised supply chain may increase the chances of duplicate product supply, and can negatively affect the reliability, maintainability, tracking, and monitoring of healthcare products. In this context, we need an effective, efficient, auditable, and secure solution to fulfill this demand. As a solution, we have only one way to deal with issues is the implementation of Blockchain technology in healthcare supply chain management. Basically Blockchain is a shared and unchallengeable ledger. That provides the ability to capture or record the transactions and also track resources assets in a business network. The asset can be tangible (physical like cash) or intangible (digital like copyrights). This will reduces the risk and increase the transparency in movement of assets. It also reduces the misuse and fake asset utilization.

In this paper, we first extract and summarized the recent literature, which is publically available through Google scholar. This literature is mainly based on supply chain management and the healthcare industry as an application of Blockchain technology. Next, we highlight the key findings of the conducted study and based on which we have formulated the problem domain of our future research work. Further a supply chain management system in the healthcare domain has been proposed for implementation and their simulation. Finally, the conclusion and future work has been discussed.

I. RELATED WORK

This section explores the applications and utility of Blockchain technology in healthcare industry and also in supply chain management. Therefore, 48 recent articles are downloaded from Google Scholar and selected most relevant 24 articles. An overview of the studied literature is discussed in this section.

A. Essential Keywords

During study of articles some frequently used abbreviations are identified are reported in table 1.

Table 1 Keywords

Keyword	**Description**
RFIDs	Radio-frequency identification
SCM	supply chain management
BCT	Blockchain technology
IoT	Internet of things
IoHT	Internet of Healthy Things
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analysis
DApps	Decentralized Apps

EHRs	electronic healthcare records
PHR	Personal Health Records

B. Related Study

This section involves a brief overview of the studied articles based on Blockchain implementation in supply chain management and healthcare industry.

A. Hasselgren et al [1] was review, assess and synthesize publications utilizing Blockchain to improve processes and services in healthcare. Literature search on the topic was conducted in October 2018. 39 publications fulfilled the criteria. The result indicates that EHR and PHR are the most targeted areas. Access control, interoperability, provenance and data integrity are issues in this field. Ethereum and Hyperledger fabric seem to be the most used platforms. This study shows that the endeavors of using Blockchain in the health domain are increasing.

In recent years, no clear framework has defined whether a supply chain should implement Blockchain. ***J. Aslam et al [2]*** attempts to fill this gap by a framework for supply chain networks. First, identified the supply-chain practices of the oil industry, and then analyzed the impact on performance. Results show that the SCM practices positively impact operational performance. They also identified different Blockchain features and influence on supply chain practices. They guide managers and decision-makers to evaluate their current supply-chain practices and understand the relationship, and how features can improve supply-chain.

A. Tandon et al [3] review on Blockchain applications in the healthcare. It incorporates 42 articles presenting implications and gaps of Blockchain for improving healthcare processes. The findings indicate that Blockchain is used to develop advanced interventions to improve the standards of handling, sharing, and processing of medical data and records. The application is undergoing an evolution in the healthcare industry where it has added significant values. The findings also suggest that the limitations pertain to model performance, and costs of implementation. A framework is presented to address areas for future researchers, including regulatory compliance, architecture, and data protection.

Blockchain can be applied to SCM, such as logistics, quality assurance, inventory management, and forecasting. One of the functions is to improve the transparency, traceability and auditability of materials flow throughout the supply chain from suppliers, manufacturing, warehouses/distribution centers, to customers. ***J. M. Song et al [4]*** focuses on the impact of Blockchain on supply chain traceability through the industry applications, and its future direction.

Supply chains have become complex, to ensure transparency throughout supply chain. The approaches came up, adopting the immutable, decentralised, and secure characteristics of Blockchain to increase transparency, security, authenticity, and auditability. ***F. Dietrich et al [5]*** investigates recent publications combining Blockchain and SCM and classifies them to be map on the Blockchain. The increase of supply chain transparency is identified as the objective of recent projects. Most of the publications deal with simple supply chains and products. Few approaches dealing with complex parts of supply chains. Currently no example

exists which increasing the transparency of manufacturing supply chains, and enables the mapping of assembly processes, auditability of assets, and implementation.

The information gathered can then be used to improve patient safety and provide after-market analysis to improve efficiency. ***L. Bell et al [6]*** outlines work within the areas of pharmaceutical traceability, data sharing, clinical trials, and device tracking.

G. Blossey et al [7] intend to combine these two perspectives on BCT in SCM to summarize a current state of the art and to derive avenues for further research. Thus, a framework of use case clusters of BCT in SCM is developed according to the features of BCT. The framework is used to analyze 53 applications of BCT in SCM derived from literature review and a dataset of Blockchain-driven innovations in SCM. They identify five use case clusters of BCT in SCM which clearly extend the scope of applications such as product tracking and tracing.

G. J. Katuwal et al [8] review use cases of Blockchain in healthcare: patient data management, pharmaceutical research, SCM, prescription management, billing claims management, analytics, and telemedicine. Found that most of the projects are limited as white-papers, proof of concepts, and limited user base. They observed that the quantity, quality, and maturity of the projects are increasing and discuss technical, regulatory, and business challenges.

M. Prokofieva et al [9], conducting a review to produce new evidence, and identify applications in healthcare. The review looks at the professional and academic open-sourced journals to recognize the potential of Blockchain in healthcare information disseminations, and to segregate issues for the implementation and development of Blockchain applications. They identify major applications that present opportunities and challenges for the future advancements for the benefits of researchers.

B. Esmaeilian et al [10] provide an overview of Blockchain and Industry 4.0 for advancing supply chains. First, extracted the literature, evaluate the capabilities of Industry 4.0 for: (1) IoT-enabled energy management; (2) smart logistics and transportation; and (3) smart business models. They expand capabilities for increasing sustainability, under: (1) design of incentive mechanisms and tokenization to promote green behavior; (2) enhance visibility across the product lifecycle; (3) increase systems efficiency while reducing development and operational costs; (4) foster sustainability monitoring and reporting performance.

A. Batwa et al [11] is identified and explore applications of Blockchain in SCM and a framework for analysis. They address conflicting opinions regarding hype of Blockchain and clarify applications. That helps supply chain practitioners appraise the applications before it is too late to use. The framework was developed based on a review articles, and examined with semi-structured interviews. Findings suggested that traceability and supply chain finance seemed to be the most applicable applications in SCM. Light was also shed on applications such as: compliance with standards, supply chain integration and digitalization of the transactions.

Blockchain with IoT system provides benefits such as connecting the link between the flows in the supply chain to improve the efficiency, makes the system transparent that can reduce the code of conduct violation, the immutable properties to trace the products. So far the implementation rate is very low because of the lack of knowledge and understanding. ***S. Aich et al [12]*** highlight the difference between the conventional and Blockchain based supply chain and the benefits in different sectors. Also highlight the problems by using the conventional supply chain and the solutions provided by the Blockchain. They help the people to understand the benefits of the Blockchain in their fields and implement it to improve the efficiency.

Effective SCM is a challenge, but in healthcare there is added complexity and risk in healthcare can impact patient safety and health outcomes. A solution for improving security, integrity, data provenance, and functionality is Blockchain. ***K. A. Clauson et al [13]*** provide overview of opportunities and challenges with Blockchain adoption and deployment, focus on the pharmaceutical supply, medical device and supplies, IoHT, and public health. A review was conducted to identifying and characterizing stakeholders. Most Blockchain initiatives remain in proof-of-concept or pilot phase and unrealized to improve the health supply chain.

With the growth of aviation domain, there has been demand in aircraft for airlines. SCM teams deal with complex networked supply chains for spare part purchase and delivery. All parts come with certain life expectancy, specific requirements and maintenance attributes. With thousands of spare parts, hundreds of parameters, and number of manufactures distributed globally. ***Y. Madhwal et al [14]*** use a scenario to demonstrate the necessity of decentralized system based on distributed data-driven application, it not only assist in maintaining inventory but also to monitor the performance, usage, etc. This will help to achieve a transparent network of supply chain and reduce the risk of availability. These technologies will help to analyse the supply, demands, availability and methods to procure them.

Globalization of supply chains makes their management and control difficult. ***S. Saberi et al [15]***, Blockchain and smart contracts are examined with application to SCM. They investigate how Blockchain can address and aid sustainability. Examine how Blockchain, a disruptive technology that early in its evolution, can overcome potential barriers. Four Blockchain adoption barriers are: inter-organizational, intra-organizational, technical, and external. They propose future research and directions that can overcome barriers and adoption of Blockchain.

It is crucial to study how technology accompanied with a system for smart contracts can support and challenge the healthcare for all actors and assets. The contributions of ***M. Kassab et al [16]*** are: (i) report the results of review to identify, extract, evaluate and synthesize the studies in healthcare; (ii) summarize and categorize benefits/challenges; (iii) provide a framework that will facilitate new research; and (iv) establish the state of evidence with assessment.

C. C. Agbo et al [17] review of the ongoing research in the application of Blockchain in healthcare. The methodology is based on the PRISMA and a mapping process, in which a search protocol is used, to identify, extract and analyze relevant publications. The review shows that a number of studies have proposed different use cases of Blockchain; however, there is a lack of adequate prototype implementations and to characterize the effectiveness of use cases. They highlights the state-of-the-art in the development of applications, their limitations and the areas of research.

Smart contracts are built atop Blockchain to support on-chain storage and enable DApps. Programmable Blockchain in the healthcare is a solution to resolve key challenges, such as gapped communications, inefficient clinical report delivery, and fragmented health records. ***P. Zhang et al [18]*** provides evaluation metrics to assess Blockchain based DApps in terms of feasibility, capability, and compliance.

A. Fusco et al [19] aim to validate Blockchain in healthcare, and suggest a trace-route for a COVID19-safe clinical practice. The use of Blockchain in combination with artificial intelligence allows the creation of generalize predictive system to the containment of pandemic risk. An analysis of the adoption of a Blockchain-based prediction model is underline opportunities and limits to its adoption. Blockchain could play a role in future healthcare: It may work to improve COVID19-safe clinical practice. The concepts, and clinical workflow, from different Blockchain-based models have been reported and discussed.

Traditional Healthcare data management systems suffer from single point of failure, data privacy, centralized data stewardship, and vulnerability. Most of the works suffers from high energy consumption, limited scalability, and low throughput. ***L. Ismail et al [20]*** propose lightweight Blockchain architecture for reducing computational and communication overhead using network clustering and maintaining a ledger per cluster. The use of canal, allows secure and confidential transactions. The solution is avoiding fork and demonstrate the effectiveness in providing security and privacy. Also discuss how we address the identified threats. The results demonstrate that architecture generates 11 times lower traffic. The ledger update is 1.13 times faster. Architecture shows a speedup of 67% in ledger update and 10 times lower traffic.

According to ***H. S. Chen et al [21]*** research about Blockchain and healthcare is currently limited, but Blockchain is on the brink of transforming the healthcare system; through its principles, Blockchain can improve accessibility and security of patient information, and can therefore overturn the healthcare hierarchy and build a new system in which patients manage their own care.

M. Hölbl et al [22] review, Blockchain research in the field of healthcare. The aim is to reveal the applications and to highlight the challenges and directions. First, background is discussed, followed by a description of the methodology used. Next, an analysis of the results is given, which includes an overview, gathered data and properties, and the results.

S. E. Chang et al [23] explore the status, applications, and future directions of Blockchain in SCM. A survey is done to understand the trajectory of research and benefits, issues, and challenges. A corpus comprises 106 articles to provide an overview and smart contracts. The diverse applications in various sectors have received attention. Four major issues: traceability and transparency, stakeholder and collaboration, supply chain integration and digitalization, and common frameworks, are critical. Traditional activities involve several intermediaries, trust, and performance issues. The Blockchain can be leveraged to disrupt supply chain operations for better performance, governance, and automation.

Traditional SCM suffer from a wide scope of issues such as lack of information sharing, delays for data retrieval, and unreliability in product tracing. Although there are some studies from the perspective of logistics, the underlying technical challenges are not clearly identified. ***H. Wu et al [24]*** provide an analysis of opportunities, requirements, and principles of designing Blockchain based SCM. They summarize and discuss four challenges: scalability, throughput, access control, data retrieval and review the solutions.

II. REVIEW SUMMARY

Blockchain is one of the most studied technologies in recent years. Additionally, there are a significant amount of benefits when we utilize this technology with different services and applications. However, there are a number of studies are done in recent years in order to explore the applications of Blockchain technology at different industry levels. But the scope of these studies is limited only to the review, applications, ideas of implementation and deployment, framework design, and conceptual or theoretical overview of the implementation of Blockchain in different industries. In addition, when we explored the implementation of Blockchain in healthcare and SCM then we found in healthcare is mostly used for data sharing, managing health records, and access control. It is also found that technical details about the used Blockchain are not given in most of the articles and do not present any implementation. Even an implementation of the model has no details about Blockchain.

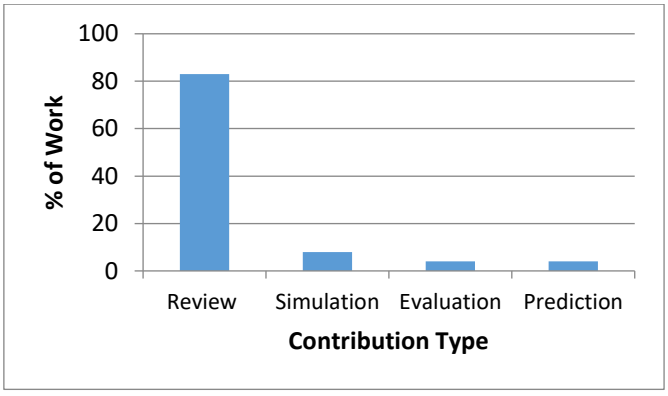

Figure 1 work trend using the Blockchain technology

According to the conducted review, we have found that 83% of the work is dedicated to delivering reviews of the implementation of Blockchain and supply chain management systems. 8% contributed to the simulation of the prototype model, 4% of the work was focused on designing and identifying the evaluation parameters, and the remaining 4% of

techniques are utilizing this technology as the predictive model with secure data analysis. Based on the contributions figure 1 demonstrates the % of work carried out using Blockchain technology in the field of supply chain management and the healthcare industry. In addition, the summary of the studied literature has been discussed in table 2.

Table 2 Review Summary

Ref	Type	Domain	Target Issues	Contribution
[1]	Review	Healthcare	-	Review, assess and synthesize publications utilizing Blockchain.
[2]	Review	SCM	No framework has defined where a supply chain implements Blockchain.	Measuring the impact on implementing the Blockchain in SCM performance.
[3]	Review	Healthcare	Implications and gaps of Blockchain for improving healthcare processes.	Presents a review on Blockchain applications in healthcare. It incorporates 42 articles.
[4]	Review	SCM	Impact of Blockchain on supply chain	Traceability through the applications, and future direction.
[5]	Review	SCM	Supply chains become complex, to ensure transparency of supply chain.	Investigates recent publications combining the Blockchain and SCM and classifies them to be map on the Blockchain.
[6]	Review	Healthcare	Data gathered can be used to improve patient safety and market analysis.	Outlines work in the areas of pharmaceutical traceability, data sharing, clinical trials, and device tracking.
[7]	Review	SCM	Combine perspectives of BCT in SCM	Summarize current methods and derive research avenues. A framework of use case clusters is developed.
[8]	Review	Healthcare	Fragmented data affecting research and services, half of trials are never reported, cost of drug is increasing, and fake medicines are a problem.	Review use cases of Blockchain in: patient data management, pharmaceutical research, SCM, prescription management, billing claims management, analytics, and telemedicine.
[9]	Review	Healthcare	Capabilities and applications have to extended beyond crypto-currencies	Conducting a review to produce new evidence, and identify applications in healthcare.
[10]	Review	SCM	Energy management, smart logistics, smart business models	Design of incentive mechanisms and tokenization, enhance visibility of product lifecycle, increase systems efficiency and reducing costs, monitoring and reporting.
[11]	Review	SCM	Address conflicting opinions hype of Blockchain and clarify applications.	Identified and explore applications of Blockchain and framework for analysis.

[12]	Review	SCM	So far the implementation rate is very low because of the lack of knowledge and understanding.	Highlight the difference between the conventional and Blockchain based supply chain and the benefits in different sectors.
[13]	Review	Healthcare	SCM challenge, in healthcare there is added complexity and risk in impact patient safety and health outcomes.	Overview of opportunities and challenges with Blockchain adoption and deployment, focus on pharmaceutical supply, medical device and supplies, IoHT, and public health.
[14]	Simulation	SCM	Need to deal with very large amount of data.	Demonstrate necessity of decentralized system based on distributed data-driven application, to assist maintaining inventory and monitor performance, usage, etc.
[15]	Review	SCM	Globalization of supply chains makes management and control difficult.	Blockchain and smart contracts are examined with application to SCM.
[16]	Review	Healthcare	How technology used with a system for smart contracts and challenges for all interrelated actors and assets.	(i) Review to identify, extract, evaluate and synthesize studies (ii) summarize and categorize benefits/ issues; (iii) Framework for new research; (iv) establish evidence.
[17]	Review	Healthcare	Health informatics researchers and practitioners are struggling to keep pace with research progress	Review of application in healthcare. Methodology is based on PRISMA and a mapping process, in which a search protocol is used, to identify, extract and analyze.
[18]	Evaluation matrix	Healthcare	gapped communications, inefficient report delivery, fragmented records	Provides evaluation metrics to assess Blockchain based DApps in terms of feasibility, capability, and compliance.
[19]	Predictive system	Healthcare	pandemic has impacted risk management	Validate Blockchain in healthcare, and suggest route for safe clinical practice. Creation of generalize predictive system. Analysis of adoption of a Blockchain-based prediction model.
[20]	Modeling	Healthcare data management	Most of works focused on permission-less network suffers from high energy usage, scalability, and low throughput.	Lightweight Blockchain architecture to reduce overhead by network clustering and maintaining ledger per cluster. Avoid forking and demonstrate the security and privacy.
[21]	Review	Health care	Research about Blockchain and healthcare is currently limited, but it can transform the healthcare system;	Blockchain can improve accessibility and security of patient information, and can healthcare hierarchy and build a system in which patients manages own care.
[22]	Review	Health care	Need for patient-centric approach to connect	Reveal applications, challenges and directions. Indicate that Blockchain research

			disparate systems and accuracy of EHR.	is used for data sharing, managing health records and access control.
[23]	Review	SCM	Traditional activities involve intermediaries, trust, and performance issues.	Explore status, applications, and future directions. Understand the trajectory of research and benefits, issues, and challenges.
[24]	Review	SCM	Lack of data sharing, delays for data retrieval, unreliable product tracing. Issues are not clearly identified.	Opportunities, requirements, and principles of designing SCM. Discuss challenges of scalability, throughput, access control, data retrieval and solutions with case study.

III. PROPOSED WORK

The healthcare industry is a large domain and involves a number of actors and activities. In this context, a combined system to demonstrate the working of healthcare industry is a complex task. Therefore, in order to demonstrate the effectiveness of the Blockchain in healthcare industry we proposed to simulate the entire implementation work in three modules:

- **Study of cryptographic technique for secure data storage and communication:** In this phase a cryptographic technique has been implemented and their performance analysis has been carried out.
- **Implementation of a Blockchain based system in the scenario of patient admission, billing and insurance claim:** The implementation of cryptographic technique has been performed for Blockchain based billing and insurance claim management.
- **Implementation of privacy preserving data sharing scheme for patient between different departments and doctors:** in this scenario we have proposed to implement a privacy preserving patient record sharing system which share and disclose the limited data among different departments and doctors.

A. Proposed Cryptographic Model

The proposed model for performing the experiment with the cryptographic system is demonstrated in figure 2. In this diagram two models are described, first model is developed with the SHA1 and AES algorithm. Additionally the second model is made with the help of MD5 and AES algorithm.

Model 1: The model initiated with accepting data. In this experiment we have used text files for encryption and decryption. The file is read first and then passes it into the SHA1 algorithm. The SHA1 algorithm generates a 256 bit hash code as output. In order to improve the security we have prepare a bit discarding process. The bit discarding process remove alternate bits from the input hash code. After elimination of unwanted bits the hash size becomes 128 bit. This 128 bit hash code is used as key for encryption. Therefore, the generated 128 bit key and data bytes are produced into AES encryption algorithm which is used for generating the final encrypted data. During this process we also measure the time and memory usages of the system which is reported into next section.

Model 2: The second model is based on the MD5 and AES algorithm. In this model the data is given as input to the system. The text is read first and then passes into MD5 algorithm. The MD5 algorithm generates 128 bit hash code. This hash code is used as the key for the encryption algorithm. After that, data bytes and MD5 generated hash key is produced to the AES algorithm. The AES algorithm produces the final encrypted data. Additionally, the performance of the method has been measured.

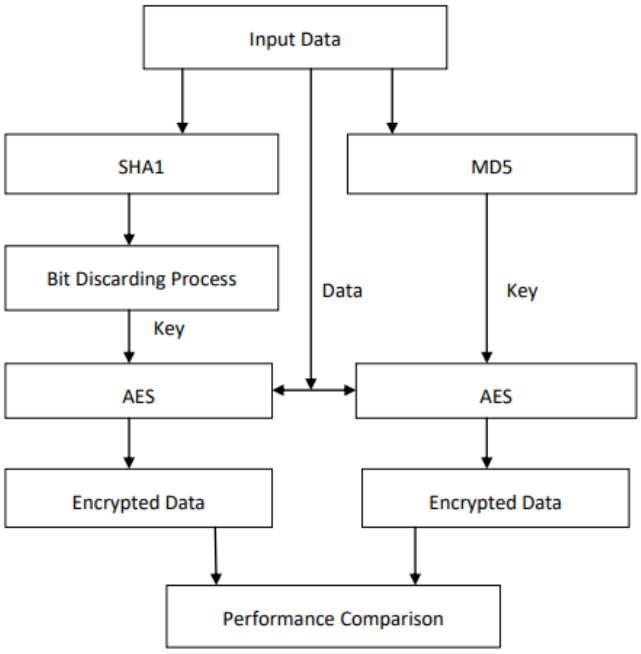

Figure 2 Proposed Cryptographic Model

This section provides an overview of the proposed cryptographic models. These two models are implemented with the help of JAVA technology and their performance has been measured and reported in next section.

B. Results Analysis

The implemented cryptographic models are evaluated in order to measure the performance. There are two parameters are evaluated namely time consumption and memory usage.

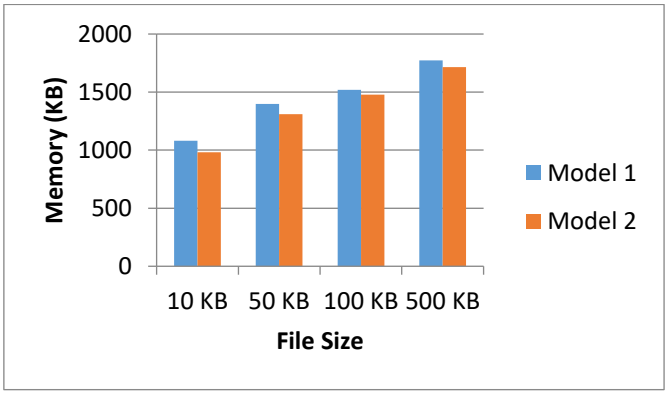

Figure 3 Memory Usage

The memory usage of the models is demonstrated in figure 3. The memory usage of an algorithm is calculated using the following formula in JAVA technology.

$$memory\ Usage = total\ assigned - free\ memory$$

The experiment has been carried out with the increasing size of text files additionally measured memory in terms of kilobytes (KB) are measured. The measured memory usage is demonstrated in figure 3. In this diagram X axis shows the file size and Y axis shows the memory in terms of KB. According to the obtained results the model 2 is efficient as compared to model 1, even with the increasing amount of file size for encryption. But model 1 is more secured than model 2.

Next parameters are time consumption for encryption. The time consumption is measured using the following formula.

$$time\ consumption = end\ time - start\ time$$

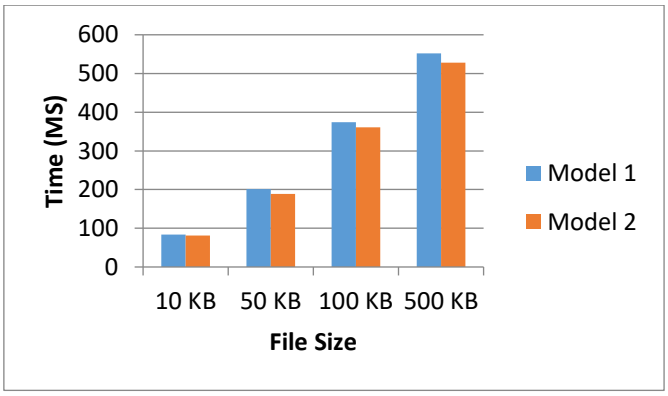

Figure 4 Time Consumption

The time consumption of both the models is measured in terms of milliseconds (MS). Additionally in figure 4 the measured time is reported in Y axis and X axis shows the file size used for experiments. According to the results the proposed models 1 and model 2 is compared in terms of time consumption. Among them model 2 is time efficient then model 1 but the model 1 is more secure technique as compared to model 2.

IV. CONCLUSION AND FUTURE WORK

The Blockchain is one of the secure technologies, which is effective to secure the data and track the modifications on the data. Therefore, it has wide areas of applications in different fields and levels. In this context to find opportunity of implementing the Blockchain technology recent contributions in the field of applications made with the Blockchain has been explored more specifically in implementation of supply chain management and in field of healthcare industry. During the investigation we have found there are very limited amount of work is available for actualization of Blockchain technology in both the fields. According to the conducted review work we have found 83% of the work is limited to the scope of review of technology, 4% of the work is contributed as the simulation of the work, 4% of the work is contributed for identifying the evaluation parameter and remaining 8% of work is

based on implementation of the work. Therefore, we have planned three scenarios of the work for practical implementation. Among three scenarios in this paper we have implemented one cryptographic technique for secure data communication additionally their performance is also evaluated. According to the obtained results we have concluded that the AES and SHA1 based cryptographic model is secure as compared to AES and MD5 based technique, because the SHA1 based technique implement a bit discarding process for designing more secure key for encryption. In near future we have implementing two other experimental scenarios based on healthcare industry to demonstrate the security and monitoring improvement in process involved in healthcare system.

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