Blockchain-Based Medical Record Management System (BBMRMS)

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***Abstract*— BBMRMS is a system that can increase the security of the electronic medical records with the cryptographic and decentralized technique. The system is designed with apply Java Programming language on Apache Netbeans platform. The immutable characteristics of blockchain technology which cannot be change subsequently is appropriate for medical records which should be non-editable. Furthermore, BBMRMS can also increase the interoperability of medical records between different healthcare facility and reduce the risk of exchange the medical records electronically with the traceability and transparency features provided by blockchain technology. Hyperledger Fabric Framework had been implemented to deploy a consortium blockchain network for BBMRMS.**

Keywords—BBMRMS, blockchain technology, cryptographic technique, decentralized technique, electronic medical records, healthcare facility, Hyperledger Fabric Framework.

I. INTRODUCTION

The rapidly growth of the advance technology where the Blockchain technology had been improving the way how people store and access critical data such as medical records in nowadays (Dashtizadeh & Juremi, 2023). According to research in (Gillum, 2013), the precursor of the modern medical records was first discovered in Berlin and Paris by the early 19th century. As 1960s, the medical records are moving toward digitalization and begin the paperless medical records which can develop into electronic medical record credit to the new technologies and maintaining method. The evolution of medical records into electronic medical records had improve the medical records become more accessible, portable and comprehensive. At the same time, there are some side effects come along with the application of electronic medical record in different healthcare facility which included different aspect such as security issue, reliability of data, maintenance issue, accessibility and etc.

Blockchain technology is an emerging method to store information with a decentralised database where it is link together with lots of blocks with cryptography where each block contains information of its previous blocks then formed into a chain and managed by a network of users with a cryptographic validation. As known from (Vazirani, 2020), the blockchain technology was traditionally used to manage cryptocurrency transaction records, but it can also be utilized in different aspects in healthcare such as medical record management as it can introduce integrity and ensure that will only one validated version of events is stored in blockchain database which can't simply change subsequently without getting the agreement from other nodes or blocks. Hence, the blockchain technology had the potential to be apply in enhancing the current method to store and share the medical record.

With the investigating the security, accessibility, confidential issue, processing time and the record keeping of medical data, we will see how the blockchain technology can improve the efficiency, consistency and security of the current medical record management system.

II. LITERATURE REVIEW

A. Introduction

Blockchain technology is an emerging technology that used to store authentic and confidential data in a secure decentralized database. It applies cryptographic techniques to allow each user on the network to validate the information without existing of third-party. According to journal (Hao Sen Andrew Fang, 2021) because the characteristics of blockchain technology in data access, control, transparent, security and ownership to end users, it is suitable to utilize in medical industry such as store electronic medical records which contain patient's private medical information and data.

Medical records are a record which contain valuable patient information such as patient's privacy and medical history that should keep in a confidential manner (Qiao et al., 2023). According to research in (Xiaolan He, 2021), the complicated handwritten medical records are replacing by the electronic medical records which emerged because of the advanced development of internet technology and improvement in medical information. It is a digital document based on the application of the medical information system in different healthcare facility. If the patient goes to the same healthcare facility in future, electronic medical records can easily retrieve and collect the medical information of the patient in the system

In the research of (Nir Menachemi, 2011), one of the potential drawbacks of electronic medical records is the risk of patient privacy violation due to the health information exchanged electronically. Furthermore, it is difficult to trace the electrical medical record from different healthcare facility as all the medical records can only save in the medical information system of the associated healthcare. This is also

causing the duplication and redundant data of the electronic medical records which save a copy in different healthcare facility. So, it is hard to trace the medical history and transaction of the patient and will lead to data inaccuracy issue.

Therefore, it is important to develop a blockchain based medical record management system which provide a secure and structure method to keep the medical records in order to increase the accessibility and accuracy of the medical information then ease the process of sharing and grant permission on the medical records of patient.

B. Electronic Medical Records

As mentioned by (Thomas, 2009) medical records is important to the management of patient which it can help the doctor to prove on the treatment or diagnosis and helping in analysis the result of treatment. At 1990s, due to the growth of technology, the usage of electronic hardware such as computer had become more familiar, powerful and affordable. Internet provided an easier and faster access to the medical record information with the use of web-based HER. (Inform, 2020)

According to (Xiaolan He, 2021), the electronic medical record emerged as the result of the advanced technology, and it is rapidly replacing the complicated hand-written medical records which has become an essential part of the healthcare facility. An electronic medical record included all health information and treatment process of the patient.

As stated in the study of (Benedictis, 2020), electronic medical record had been counted as the key element to improve the quality and safety of healthcare, reduce the adverse process for patients, improve the clinical research and achieve the best clinical performances. Electronic medical record reduce the extra coft of Hospital Acquired Condition (HAC) by 16% and reduce the death due to HAC by 34% as mentioned in the study of (Firdaus, 2019) Furthermore, electronic medical record could also be beneficial on tracking patient's allergic history or diseases history. With the information provided in electronic medical record, the decision making on diagnosis can be supported. In these cases, the accuracy of the information is essential as it will affect the decision of doctor on medicine selection or treatment selection.

The usage of electronic medical record not only brings advantages, but it also leads to some drawbacks. The maintenance cost for electronic medical record might be a bit higher than the traditional medical records system as it need to continuously upgrade the software and replace the old hardware in accordance with (Collum, 2011).

C. Blockhain Technology

Blockchain Technology are well-known with cryptocurrency, but the blockchain concept is appropriate to apply on solving medical record problem such as the security of the record and patient's information in accordance with (Alaa Haddad, 2021). Blockchain is an emergence technology which introduced with Bitcoin in year 2008.

Fig. 1. Image of Bitcoin

Blockchain is a shared database which apply decentralized technique and all the information will be stored in a block. The aim of a blockchain is to store digitalized information in distributed way but not be able for edit and emphasized to be immutable. In general, blockchain is a database which is only encourage for reading and appending data.

With the decentralized technique, there is no one have the full control over the information stored in the block or the storing operation as it allows the user on the network with the cryptographic proof to validate the information in the block without 3rd party needed. So, every transaction in the blockchain network will be verified by the consensus of the majority network participants before it can proceed. (Leila Ismail, 2020) This verified process are achieve though an algorithm called consensus algorithm.

The first ever block in the chain is known as genesis block which called as the Block 0. The block will combine with a generated data which known as hash value through a cryptographic technique called hashing. Each block will contain the hashing value of the previous block and link together in sequential manner just like a chain.

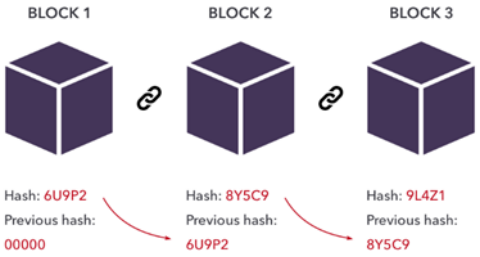

Fig. 2. Sample of Blockchain

Blockchain technology can be described as a combination of distributed ledger cryptography technologies and consensus protocols as stated in the study of (Leila Ismail, 2020)

Due to different demand of the market, there are several types of blockchain which is private, public and consortium. (Wang, 2021)

Private Blockchain: Private blockchain is a permissioned blockchain which is controlled by a single organization. There is not necessarily grant each node in the blockchain with equal right to perform functions. Therefore, private blockchain is known as a partially decentralized as public node is restricted to access the private blockchain.

Public Blockchain: Public blockchain is the opposite of the private blockchain which is permissionless and fully decentralized. Public blockchain allow all the nodes to have the same rights to access and perform functions such as validate data in a block or create a new block in the blockchain.

Consortium Blockchain: While consortium blockchain is a permissioned blockchain but controlled by a group of

organizations rather than just governed by only one organization. Therefore, it is more decentralized compare with Private Blockchain which is known as partially decentralized.

For the project BMMRMS, Consortium Blockchain will be chosen as the blockchain network to utilize. This is because:

- Consortium Blockchain is immune or free from monopoly as it is control by the members which defines their own rules or authority with endorsement policy rather than prof of work or proof of sake.
- No transaction fees need in comparison with public blockchain.
- The information is not revealed to public but only the members in the same consortium network has the right to view. So, consortium blockchain can be used to store data which require higher level of privacy such as medical record.

More efficiency and faster on transaction speed compared with public blockchain.

III. PROBLEM STATEMENT

A. *Security Risks on Misuse of Medical Record*

The misuse of medical records is not only revealed on paper-based medical records but also occurs in electronic medical record. According to the research from (Harande, 2018), the medical records of patients are just like a treasure trove to hackers as the medical records contains patients credential information such as patient name, address, contact, medical history, or even financial and payment information which is enough for hackers to blackmail, set up a line of credit or take out a loan under name of the patient. Furthermore, hackers also could sell out the credential data for profit on the black market. Those credential information could be used to create fake IDs that used from purchase medical equipment or medicine such as drugs, illegal organ trading or file a false insurance claim.

B. *Lack Standard in format and data accuracy due to variability of data input*

Medical Records of patient are required with the latest information and data after a treatment, diagnosis, medicine redemption or there is a major change to the general health. According to (R.S.Evans, 2016), there is necessary to have a standard for medical records such as the consistent syntax and data format in order to prevent the ambiguity of data element definition in medical record. In research from (André Henrique Mayer, 2020), the medical record of patient leave scattered across various healthcare facility as life event then take the record from one provider and give it to another. As the medical records are owned by the healthcare facility or different doctors, it is difficult and challenging for the medical record updating and medical record sharing with the medical community or different healthcare facility. In that case, different healthcare facility probably will have various copy of medical record with unique format according to the healthcare facility. This will cause the duplication of medical record for the same patient in different healthcare facility and the data of medical record is inaccurate and in different format due to the interpretation, diagnosis, and treatment from different doctors.

C. *Accessibility / Lack of interoperability between different healthcare facility*

The data ownership and liability on the medical records always been a critical challenge in electronical medical records. After research on a few medical records management systems, those medical records are kept with the healthcare facility and patients have the right to access a copy of their own medical record. The records will only share electronically after the healthcare facility get the grant permission from the patients. This policy of the medical record can protect the data of the patient from unauthorized access, but it is inconvenient for patients as the patient need to request the medical record every time if the patient want to go to a new healthcare facility or used it to file an insurance claim and report a lawsuit as critical evidence. This shows that the current medical records management system has a barrier on the interoperability of the medical records and didn't have a proper way to access the needed patient's information effectively when it is urgent or emergency (Maribel Cifuentes, 2015). The lack of coordination of data exchange and management in medical record reason that the medical records are fragmented instead of cohesive. (André Henrique Mayer, 2020)

IV. AIMS AND OBJECTIVE

This research aims to propose and develop a Blockchain based Medical Record Management System to improve the security of the electronic medical records in order to protect privacy of both doctors and patients meanwhile also ensure the data accuracy and data tracing.

The objectives are:

- To develop a proposed blockchain based system to improve the security of electronic medical records.
- To determine an appropriate format to update the electronic medical records from different healthcare facility for ensure the accuracy of the data & information in patient's medical record to prevent data duplication.
- To identify a suitable method for a secure authorized access to electronic medical record from different healthcare facility with grant permission from patient.
- To increase interoperability of medical record between patient, doctor and data requester
- To track all the medical history such as diagnosis, medicine, treatment, vaccination of a patient from electronic medical records for reduce unnecessary research, consultation, diagnosis due to time limit if an emergency arises

V. RESARCH METHOD

A. *Target Users*

The target user of the system will be

- Patient

- Doctor
- Data Requester (Healthcare Facility, Family, Medical Insurance Company)

B. Programming Language Chosen

The developer has decided to choose Programming language is the most essential tools for the project development. After careful consideration, the developer had chosen Java programming language with version Java 17 for the development BBMRMS project. This is because Java programming language is compatible to the tools to be implement in the project, Hyper Ledger Fabric with using SDK. Furthermore, Java provide a write once, run anywhere features. Therefore, the developer has not worried on the compatibility of the programming language with the hardware selection. Last but not least, Java emphasied on object-oriented programming and this is providing a good maintanability for the project to be improve in the future.

C. IDE (Interactive Development Environment) chosen

An Interactive Development Environment is a software that provides comprehensive features to developer for software development. The developer had decided to choose one IDE from Eclipse and Apache Netbeans.

Eclipse is a free java-based IDE with offer customized IDE functionality and the current version of Eclipse is version 4.22.0. According to the research from (Shoba.S.A, 2016),Eclipse is recommended to use for java application development as it contains base workspace and able to customize the environment due to the extendable plug-in system in Eclipse. As stated in the study from (Wyatt Spear et al., n.d.), Eclipse can be beneficial on system development with its extensibility and portability. Because of the Eclipse is free and open source, the developer is able to modify and expand the features as needed for the system development with plugins provided by Eclipse.

Furthermore, Netbeans is also one of the free java-based IDE that support multiple development such as desktop system, mobile application, web application and etc. In Netbeans, there is various type of tools and features provided for an all-inclusive software development life cycle from the establishment of idea to the deployement of the application which run on a modular architecture concept . (CompareCamp, n.d.). In addition, Netbeans also supported on multiple operation system such as Windows, Linux, Machintoch and etc. This can ensure that the developer will not facing any issue on the Netbeans interface or architectures not compatible if user migrate between different oeprating system during the development of the system. Not only that, Netbeans also have the native support for Gradle, Maen and Ant build automation tools which can help the developer to build application more efficiently. More importantly, Netbeans had a better support on Maven compare with Eclipse as mentioned by (Software Testing Help, 2022)

After going through research on several Java Interactive Development Environment, the developer had chosen Netbeans as the IDE for the development of project BBMRMS. The version of the Netbeans IDE selected by the developer is version 13 which is the latest version.

D. Libraries/Tools chosen

- *Hyperledger Fabric*

Hyperledger Fabric is a distributed ledger platform that was designed for enterprise grade which offer versatility and modularity for a wide set of business use cases. It is aimed as a basis for developing project or solutions with modular architecture. Hyperledger Fabric provided a secure and scalable platform that support private transactions and confidential data. This architecture leading to a new era trust, accountability and transparency for business with the help of Hyperledger Fabric. Furthermore, Hyperledger Fabric offered multi language smart contract support such as GO, JavaScript and Java. The version of Hyperledger Fabric that applied for this project is **Hyperledger Fabric 2.2 LTS**.

- *Docker*

Docker is an open-source platform that design for developing, building, running, testing and deploying the application more quickly. This is because it allows the developer to separate the application from the infrastructure (Docker, n.d.) Furthermore, Docker provide a lightweight and clean environment for developer to test the application without needed for complex orchestration. For example, Docker provide a critical feature called as container which is a lightly isolated and secure environment that allow Docker to package the code or software into standardized units and run. The containers contain every resource that the software needs to run such as system tools, code, libraries and etc. (Amazon Web Services, n.d.) Docker can run on many containers concurrently on a given host and no need to be dependent on what is currently installed on the host. With docker, the delay between code development and running the code in real production can be reduce by the developer.

E. Database Management System Chosen

The database management system chosen is Microsoft Access. Microsoft Access is a type of relational database which can help provide database management service with cost-effective compare with other database solution such as Oracle that need high cost to install and maintain the database. In comparison with other database, Miscrosoft Access also as a quick and easy way to create and manage database in the case where developer has time limit on this project.

Moreover, Microsoft Access can be used in multiple scenarios and platform with the Access Connector Library. (YIITBOX, 2020) For example, it allow the developer to store the data in SQL server and manipulate the data with SQL query. Microsoft Access also store many data formats

F. Operating System Chosen

Operating system is a system software that control the resources and the processing capability of a computer. According to (Isaac Odun-Ayo et al, 2021), the operating system act as an interface between the developer and the computer device. It serves as a communication bridege between the computer hardware and application software. After careful consideration, the developer had chosen Microsoft Windows operating system with the version Windows 10. Windows is a well-known operating system which introduced by Microsoft at November 1985. One of the

biggest advantages is Windows provided Graphical User Interface (GUI) and customization on the layout of GUI depends on user preference. Furthermore, the Split Screen features that offer by Windows will increase the efficiency on the tasks. For example, the developer can split the screen to enable multiple view on the opened window and max up to 4. This can ease the process of development as the developer no need to keep on switching the screen when they need to refer on project requirements in document or other references. Furthermore, the developer can seek for advice or support from Microsoft Support with a quick response when the developer had any issue on the usage of OS or compatibility on software application. Therefore, Windows operating system is the most suitable OS for developer to develop on the project BBMRMS.

VI. SYSTEM DEVELOPMENT METHODOLOGY

After conducted research and analysis, Waterfall Methodology was chosen for the development of Blockchain-Based Medical Record Management System. Waterfall Methodology is the most well-known and oldest SDLC model according to the study of (Eason O. K., 2016). It is a methodology that divide the system development life cycle into a set of pre-defined different phases with linear-sequential flow as proposed by the pioneer of software development, Winston W. Royce in 1970. There are 5 phases in Waterfall Methodology which is Analysis, Design, Implementation, Testing and Maintenance. The phases in this methodology are constructed in logical series that follow down-hill pattern just like a waterfall (K.SARAVANAN, 2017) and each phase in the methodology must be completed before the next phase can start. This is because the end point or outcome of each phase is act as the starting point for the next sequential phases and it is dependent to the previous phase. Hence, there will be no overlapping between each phase and there is not going back to the previous phase once it is completed.

A. Phases in Waterfall Methodology

The diagram below shows the phases in Waterfall Methodology. The phases started with Analysis phase, then follow with Design phase, Implementation phase, Testing phase and end with Maintenance phase.

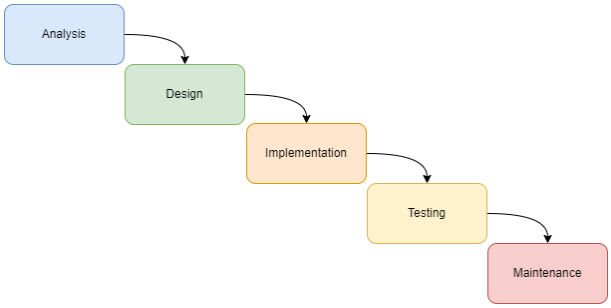

Fig. 3. Diagram of Waterfall Methodology

- **Analysis** – Analysis phase is a phase to define both functional and non-functional requirements as the behaviour of the system and produce a complete description of each behaviour which are going the be developed in the project. (Aroral, 2021) The completed description is also known as the Software Requirement Specification (SRS). For example, the functional requirements may include purpose, scope of the project, perspectives to the system, software attributes, database requirement, user involvement, system functions and etc. While for the non-functional requirements which defines the quality attribute of the system, it consists of requirements such as the limitations of the system, security, performance, quality of deliverables and etc.

- **Design** – Design phase is a phase that design the solution to meet the requirements of the project and defining the architecture of the whole system. It include the planning process and problem-solving process for the software solution to be apply in the system. (Aroral, 2021) For example, the developer and the system designer are required to identify and design a solution which includes the data structure, algorithm design, logical diagram scheme, system data flow, system architecture design and others. The completion of design phase will provide an overview of the overall system.

- **Implementation** – Implementation phase is a phase that involved the understanding of business requirements and implement the design idea that define in the previous state into a solid execution program through programming and deployment. (Aroral, 2021)This is also the phase where the real coding process start and compiled the written code into the operational application. The programmer code and develop the system based on the project specifications and requirements.

- **Testing** – Testing phase is a phase where verification and validation process carried out to test the system for any fault and failures and ensure the system is fulfil the requirements of the project. If there is any system faults or bugs are found in this phase, correction process are taken or redefined accordingly. According to (Aroral, 2021), verification process is the process to evaluate the delivered system to identified whether the system satisfies the requirements at the start while validation process is the process to evaluate the system during and at the last part of development process to determine whether the system satisfies its specific requirements.

- **Maintenance** – Maintenance phase is a phase that carried out the process of improving the system. After the testing phase is done, the system is release and deploy to the market. As claimed by (Aroral, 2021), maintenance phase is to modify the system after deployment and delivery to refine the output, fix the error, enhance the system performance and quality. The maintenance process could include the process such as increasing system reliability, accepting new user requirements based on user's feedbacks, adaption of system to the system environment and etc.

B. Advantages of Waterfall Methodology

Progression is easily measure. The linear-sequential concept in Waterfall Methodology can deliver clear and well-defined phases. So, it is easier for developer to manage the progress or achieve the project milestone follow the project schedule due to the rigidity of the methodology.

Project duration and cost are predictable. Due to the needs of static requirements at the early stage of project, the cost needed, and project duration can be estimated.

Client involvements are not required. After the requirement phase in the methodology, the customer intervention is minimal, and the developer are not required to have meeting frequently with client for feedbacks.

Can avoid delay on project deliver. Each phase in the methodology is processed once and the phase need to be completed before the next phase can start. Therefore, the deadline for all tasks in each phase are clearly state at the beginning of project to avoid any delay on the next phase. Besides, client is not allowing to add or make changes on requirements after the requirement gathering phase and this could ensure the final project to deliver on time without changing requirement at the final stage of project.

Good quality control on every process. The developer only allows to start the next phase if the current phase is completed in perfect and deliver a good output. In addition, the developer will need to have a review on the process at the end of the phase to ensure that the current output as predicted before proceeds to the next phase.

***Emphasis on detailed and good documentation*.** Waterfall Methodology required a detail documentation for all process and output of each phase before proceeding to the next phase which can provide more understanding on the tasks that completed.

C. Disadvantages of Waterfall Methodology

***No able to handle frequently changes in requirements after requirement gathering phase*.** As the output of a phase act as the starting of the next sequential phase. It will cost lots of time and resources for requirement changes in previous stage and repeat the process again.

***Can't include client's feedback within the development*.** There is not complete and working project until the late stage of the project development. Hence, client didn't have any chance to provide any valuable feedbacks until the project is complete.

***Low efficiency on progress*.** As Waterfall Methodology rigid to no overlapping of phases during the development and this could reduce the work productivity as the phase need to be complete first before the next phase can start.

***Lots of documentation*.** It may consume lots of time on massive documentation needed in Waterfall Methodology.

D. Justification of Selecting Waterfall Methodology

After conducted a study to determine and compare the strengths and weakness of Waterfall Methodology, Agile Methodology and RAD Methodology, Waterfall Methodology was chosen as the system development methodology for the project of Blockchain-Based Medical Record Management System (BBMRMS). First of all, the project BBMRMS is limited to the time constraints which is 8 months. Due to the time limitation, it is important to measure the progression of project BBMRMS. Next, the scope and objectives of the project are clearly stated at the early stage of planning and the developer had a clear depiction on what the final system should be. (Akshita Dubey, 2015) So, the project duration and cost of project BBMRMS can be predictable. The requirements of project BBMRMS are define clearly during the early stage and there is no needed on frequently changes on project requirements. Hence, the project time and cost can be sav with no resources needed for requirement changes. Moreover, this project doesn't involve any clients and there is no need for the participation of clients to provide feedback. Last but not least, the project required detailed documentation and Waterfall Methodology also emphasis on a good documentation for all the process in each phase.

VII. RESEARCH METHOD

After completed the investigation to various research method and prudent consideration on different aspect, the developer had chosen Quantitative Research Method and Questionnaires as the data collection method for this project. As mentioned by (Apuke, 2017), quantitative research method is a method that deals with quantifying and analysing data to get a result for certain research. In quantitative research, it utilizes and analyse numerical data with using specific arithmetical techniques to answer questions like How, What, When, Why, Where and etc. Quantitative research are usually used for large sample and the sample is considered as the representative of a specific population. (André Queirós, 2017). In other word, the result taken from the representative sample act as a comprehensive view of the entire population. The main aim of quantitative research is to collect measurable data to formulate the statistics with the help of mathematical technique in order to discover the pattern and relationship of the data information in the research. In accordance with (Bala, 2017), questionnaires is a research methos that provide a set of closed-ended or multiple choices questions and collect answers in gathering data information from participants. Furthermore, questionnaires is cheap and easy to carry out for the developer to acquire large amount of information in quick and efficient. According to (Yaddanapudi, 2019), questionnaire has the minimal ethical concerns, and it is non-interventional. But questionnaire also hidden risk which is the low participant rates, and the participant may lie to make exaggeration due to the social desirability. Therefore, it is important to design the questions painstakingly and validate the questions before distributed to the participants.

A. The strength of Questionnaires

According to the medical and paramedical research from (Aithal, 2020), questionnaires is suitable to use to collect quantitative data information from participants such as patients, health-care professionals, relatives and others.

Due to the pandemic of covid-19, most of the data collection process had been conducted through online platform to reduce the chance of direct contact. So, questionnaires will be the best data collection for the project BBMRMS during this pandemic.

Questionnaires does not require any face-to-face meetings for data gathering. The potential participants of the questionnaire in this project are the participants who had basic understanding on the purpose & usage of medical record and age is above 18 years old which consider as a large amount of participant. The developer can distribute the questionnaires to potential participants through internet channel such as e-mail, instant messaging, posting on social media and others. This can help the developer to hand out the questionnaire to large number of participants with less time consuming.

Furthermore, distributed questionnaire through internet can also ensure the generalization of the data collection. For

example, the developer can collect information from different age category to identify the acceptance of people on blockchain technology according to the age. This can ensure the developer have more accurate and generalized data collection.

Moreover, the standardized of the format of the questions can ease to process of statistic calculation to find out the relationship between the data and data pattern. Lastly, there is no limitation on the research time and research location. The participants can complete the questionnaire anytime and anywhere with internet.

B. Design the Questionnaires

First, the targeted participant for the questionnaire of project BBMRMS will be the participant who had basic understanding on the purpose & usage of medical record and age above 18 years old. The number of targeted responses for this questionnaire is 50 participants.

The questionnaire of project BBMRMS will be conducted using Google Form and distributed to potential participant through link. The reason of apply Google Form as the tools for questionnaire is because the requirement is low which only need a Google account and it is free to use. In agreement with (Raju, 2016), Google Form provide a user-friendly interface for designing the questionnaires. For example, it offer various type of data capturing method such as check boxes, scale, multiple choice options, text input, image and others. Next, the responses management of Google Form is great. The developer can get notified by email if there is any new responses and the responses can be view in one glance according to the questions in the response's summary. After collected all the responses, Google Form provide a data visualization function which can view the statistics of data in different visualized form such as pie chart, bar chart and etc. Not only that, but all the responses can also be viewed in Microsoft Excel form and export as a csv file. Microsoft Excel is a tool that provide predefined formula or the formula that create by the developer to perform statistics calculation on the data collection and generate the output in different graphical representation. This will ease the process of analyse the data collection as the developer can use all the features that provided by the Microsoft Excel to get a more accurate result.

The aim of this questionnaire to collection information and opinion from participant on the current security and accessibility of the medical record management system then identified the acceptance of participants on the BBMRMS project. There are 4 sections in this questionnaire which comprise questions and information such as the introduction of this questionnaire, demographic profile of the participants, electronic medical record, and blockchain technology. The objective of each question and information will further explain accordingly to the section at this part of document.

VIII. DATA ANALAYSIS

Based on the analysis conducted by the researcher, majority of the participants in the questionnaire is male, from the age group 18-24 years old and the education level is 78%. According to the responses in section 2 about the electronic medical records, the developer can conclude that overall participants has 2-5 medical records in total, with rating of 4 on the rate of importance the medical records, only review when they need the medical record, didn't have experience to request medical record before, rate for 5 as requesting medical records is a time consuming process, rate for more than 30 minutes needed to request for a medical records when urgent, rate for 4 as become the "communication bridge" between the healthcare facility, choose for both patient and healthcare facility should take care thee ownership and responsibility of the medical record, rate for 5 as agreed on the medical record is safe within the healthcare facility and finally rate for 5 as the participants concern on the credential information be utilized by criminals for illegal purposes.

While for the section 3, the majority of the participant choose for cryptocurrency as the first thing come to the mind when heard the term "blockchain", rate for 4 for the understanding of blockchain technology, vote for yes as the participants believe that the security of medical records can be improve if not kept within the healthcare facility but manage by our own, choose for yes as the participants concern on the shareable medical record with own permission, rate the highest preference for the benefit to of blockchain technology is the security and the least is the transparency, rate for 5 on the acceptance on adoption of blockchain technology in medical record system and answer "no concern" or "no suggestion" for the last two questions.

IX. SYSTEM ARCHITECTURE

A. Features: Accessibility

BBMRMS allow user to register with using username, email address and password. Then, the user can apply the username and password to access the system. The is restriction on the duplication of username and email address. Hence, username and email address exist uniquely in the database. After login into the system, the system will show the main screen with preloaded dashboard panel to user. There are several navigation panels as a side menu provided to user for switching screen more efficiency and smoothly. Those navigation panel allow user to switch page between Dashboard, Patient Profile, Record and Transfer Record Page. There is a logout navigation panel locate at the bottom of the side menu.

B. Features: Patient Information

User of BBMRMS are allowed to perform several features to manipulate the patient information that retrieved from database. When navigate to the patient profile page, the patient information will display in the table form to user. First of all, user can search the patient with using the search bar and the result will display in the table form to user. Next, user are able to add new patient profile if there is not existing related patient information in the database. User can also select and view the patient's profile in detail with select the patient from the table before navigating to view page. In the view page, the user are allowed to update the patient profile information. There is also a add new record function in the patient profile features. This is because the user had to select a patient to create a new record. It is impossible to create a record without select a patient, as a record must belong to a patient and record cannot exist without patient profile.

C. Features: Record Information

For record information features, as the medical record is confidentiality and non-editable characteristics, there is no update and delete features designed for the record information features. The user can only search the record with the search bar and then select the record to view in detail. It is necessary

to design a feature for user to view record in detail as the medical records contains lots of information that not able to display all in the table.

D. Features: Record Sharing

There is two features designed for record sharing which is send the record with email and download the record as PDF format. First, the user will be required to select the record that need to transfer from the table and choose for the transfer methods. In transfer with email method, the user are required to provide the email address, password of the email address and also the recipient email address. While for save record as PDF method is just simple as click the download as pdf button. In both transfer method, the system will display again the record information to user again before sending for confirmation and verification purpose. Lastly, BBMRMS will send a message to notify patient that the record had been shared to others once the process of record transfer in complete.

E. Features: Hyperledger Fabric

For Hyperledger Fabric features, the consortium network are built with using docker tools for the demonstration of real time network. For BBMRMS, there is 4 nodes will be created which is 2 peer nodes from 2 organizations (1 organization has 1 peer node), 1 orderer node and one CLI node. Furthermore, in order to establish a communication between two organizations, the developerhad create one channel between the 2 peer nodes. After that, a chaincode (smart contract) which act as the rule of the channel will deploy to the channel. Both peer node has to install the chaincode first and then endorse the chaincode according to endorsement policy. Hence, both peer node can invoke the chaincode after endorsement process complete.

F. System Design

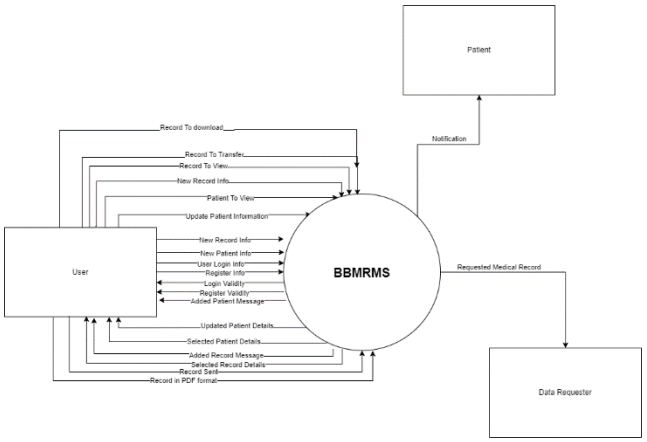

Fig. 4. Context diagram of BBMRMS

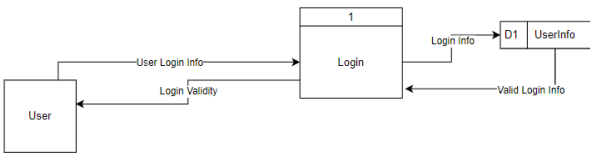

Fig. 5. DFD level 1 diagram for login

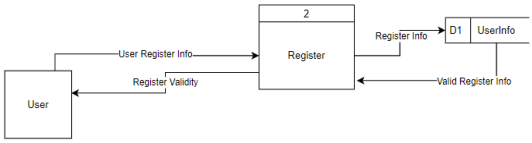

Fig. 6. DFD level 1 diagram for register

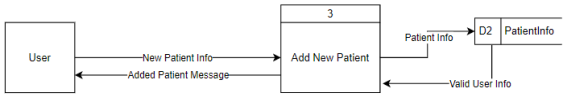

Fig. 7. DFD level 1 diagram for add new patient

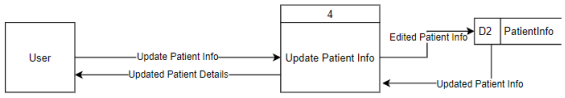

Fig. 8. DFD level 1 diagram for update patient info

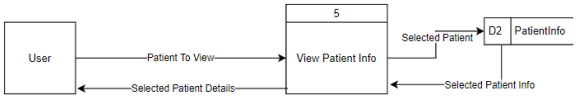

Fig. 9. DFD level 1 diagram for view patient info

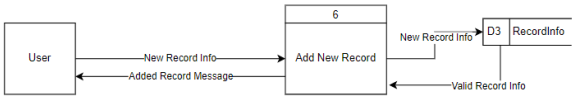

Fig. 10. DFD level 1 diagram for add new record

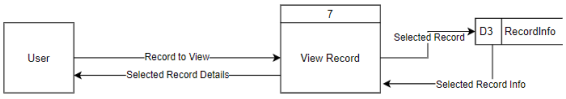

Fig. 11. DFD level 1 diagram for view record

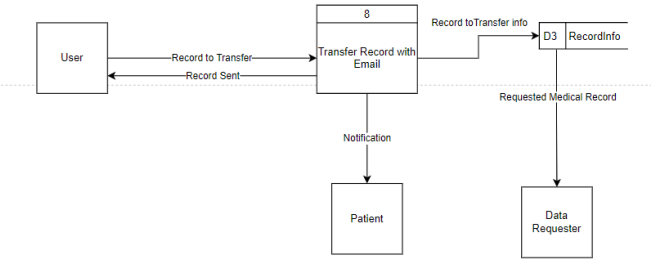

Fig. 12. DFD level 1 diagram for transfer record with email

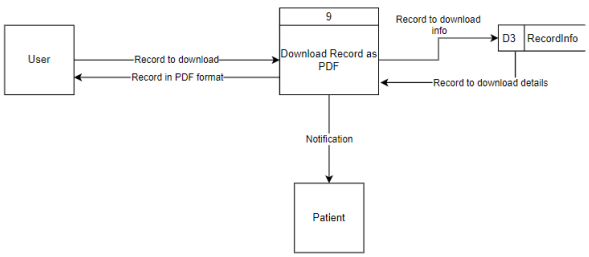

Fig. 13. DFD level 1 diagram for download record as PDF

G. Database Design

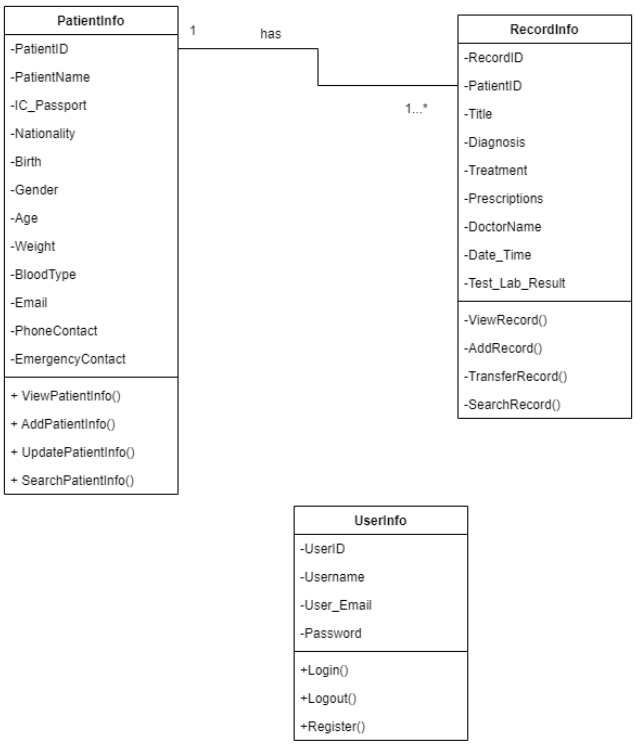

Fig. 14. Class Diagram of BBMRMS Project

X. PROJECT PLAN

The testing chosen to be conduct is the unit testing and user acceptance testing. There are 50 test case for the unit testing according to each page and expected result of each case. If the test case didn't output expected result, the test status of the test case is considered fail. In other word, if the test case output the expected result, then the test status is considered pass. Although unit test is time consuming process, but it can help to discover the bugs and errors of the system.

Furthermore, 3 users have been selected from different background such as student, healthcare facility staff and developer to test BBMRMS so that the result of testing will reduce the possibility of bias of background. All the user acceptance test are conducted with Face-To-Face Conversation Method.

After all test is done, the developer will review on the result of unit test and feedbacks from user acceptance test to make improvement on the system.

XI. SYSTEM VALIDATION

After conducting unit testing for the BBMRMS project, there is not serious bug and failure explore during the test except for few spellings error and pointed wrong GUI destination for certain page. The overall system performance is good, and the GUI interaction works smoothly. All data retrieved from database and input variable had been validated and verified. The percentage of code churn is low after conducted the unit testing. Next, the developer had carried user acceptance testing with 3 users from different background and occupation which included healthcare facility staff, junior developer and student. The overall feedback from 3 user on BBMRMS is good. Most of the user agree on the clean and clear GUI of BBMRMS is learnability and easy to use which can also reduce the training time and cost needed by the healthcare facility. Furthermore, the information in the dashboard should add on more statistical data so that the user can get all required information from dashboard with one sight. Next, one of the users suggest the email should be protected and required permission such as password to retrieve information from the email.

XII. CONCLUSION AND RECOMMENDATIONS

After conducting research throughout the BBMRMS project from determine problem statement, solution planning, blockchain implementation and project deployment, the developer have a deep understand on the concept of blockchain technology especially on consortium based blockchain network with using the Hyperledger Fabric framework.

After conducting the elicitation technique which questionnaire, the developer realizes that most of the patients rarely or not even check the medical record often. Most of the patient will only check the medical record in the case scenario such as insurance clamming, lawsuit, police report, treatment in new healthcare facility. This is because medical record and health care record is not same but just similar. There is too much terminology on medical record while the healthcare record has less jargon word which is more understandable by patients who didn't have related knowledge.

Last but not least, according to the result from unit testing, the rate of the code churn is below 25% which represent that 75% of sources code is function effectively. Furthermore, the recipient who take part in the questionnaire and user acceptance testing provide a good response and feedback to the developer which can help the developer to have deeply understanding on what patient needs and how the BBMRMS can be improved in the future.

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