

A survey and conceptual of Internet of Things system for remote healthcare monitoring



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ABSTRACT

Introduction: Healthcare monitoring is a part of medical treatment. This research aims to increase the interoperability of the healthcare monitoring process. So that user does not need to go to the hospital and check their condition with the doctor directly.

Methods: This was a qualitative study. The sample was doctors, inpatients, and outpatients. We proposed a concept of Internet of Things platform architecture that could monitor and record patient health. The features we provided are monitoring, immutable data recording using NoSQL database and blockchain by implementing Change Data Capture, and data analytics.

Result: In this research, we proposed the Matter protocol for data communication. Matter protocol opens the possibility of increasing Internet of Things interoperability. On the other hand, implementation of blockchain could increase the security in the data at rest step, we also increase traceability by implementing Change Data Capture in the NoSQL database and store all data to the blockchain.

Conclusion: Our proposed conceptual system could be used for building healthcare monitoring using an Internet of Things system that needs high interoperability and low energy consumption. The outpatient activity could be monitored in their own house or anywhere, and the patient does not need to go to the hospital to check their health.

Keywords: Thread network, Matter protocol, IEEE 802.15.4, Internet of Things, Blockchain, Wireless Sensor Network.

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INTRODUCTION

The growth of the population affected the healthcare sector. Remote Healthcare Monitoring (RHM) can decrease hospitalization and increase the efficiency and security of the healthcare treatment process.¹ The E-health industry is facing the trend of IT technologies with implications. It is called a new era of global computing.²

The Internet of Things (IoT) is an embedded system (things) that can transfer and receive data through the Internet. IoT can bridge the physical and information systems or virtual worlds.³ The rapid growth of IoT technology stimulates the growth of IoT platforms, and the existence of the media would be able to create unique IoT systems according to user needs. An IoT platform is a set of technologies that provide the infrastructure to build and orchestrate applications according to the required features.⁴ IoT has been used in several sectors. Nowadays medical field also utilizes this technology for patient

convenience. The deployment of IoT in the medical industry revolves around various sensors, medical devices, artificial intelligence, diagnostic, and sophisticated imaging equipment. These innovations raise living standards and productivity in established and emerging sectors and civilizations.^{5,6} One of the benefits that we can see was during the COVID-19 pandemic.⁶

During the COVID-19 pandemic, there were several efforts to minimize contact with patients using technology. Understanding how established and emerging IoT technologies can support health systems to deliver safe and effective care in either a complementary or alternative way during times of crisis or health issues is becoming increasingly important as global leaders consider policies that could increase access to technology-supported health services in response to (and considerations post) the current COVID-19 crisis.⁷

All COVID-19 patient-related information is stored in the cloud, which

can help provide proper attention. This technology can capture the daily activity of a person and make alerts about health problems even though IoT allows for better patient care during the COVID-19 pandemic through real-time monitoring features. Unfortunately, due to improper information about health, there were several people died.⁶

This research aims to increase the interoperability and security of the healthcare monitoring process. The proposed system could be implemented for outpatient and inpatient. By using Matter protocol, we could increase the interoperability. Our proposed system is integrated with blockchain network to record the data.

METHODS

This was a qualitative study. We propose a system that will be applied to the medical service. The sample was doctors, inpatients, and outpatients.

The proposed system is created by

Table 1. Comparison of Healthcare Internet of Things (H-IoT) System

Reference	Criteria			
	Application	Data Abstraction	Data Accumulation	Edge Computing
Things Board	HTTP, MQTT, CoAP	ThingsBoard Core Service	Cassandra	Rule Engine
Azure IoT	HTTP, MQTT, AMPQ	Azure Stream Process	Azure Storage	Data Transformation
SEMAR	HTTP, MQTT	Data Filtering	MongoDB	Data Aggregation
OpenHAB	HTTP, MQTT	JS Transformation	Influx DB, Mongo DB, RRD4J	Plugin Function
Proposed system	Matter, MQTT, HTTP, CoAP	Data Transformation	MongoDB and PostgreSQL	Data Quality and Data Validator

Note: *detailed information about the proposed system is explained below.

comparing several IoT for healthcare platforms. This section will reach and explain our IoT healthcare monitoring system concept. We also investigated several IoT platforms related to healthcare based on seven layers architecture. This research could be used for implementing a healthcare monitoring system using the Internet of Things.

Study Procedures

We collected all of the Healthcare Internet of Things (H-IoT) Systems to compare them. All of the data are provided in Table 1. After all the H-IoT(s) were collected, we proposed the concept for healthcare monitoring based on the Thread network that can be implemented in outpatient or inpatient scenarios. The design system is shown in Figure 1. All of the applications will be enforced to the inpatient and outpatient. The proposed H-IoT monitoring system’s detailed procedure is explained in detail below.

Preparing The Proposed System for H-IoT Monitoring System.

The design system in Figure 1 implemented the IoT in seven layers of architecture. The physical devices send the data to the design system’s cloud service or input segment. We provide MQTT and Matter for data communication protocol. We could implement plug-in functions such as data validator, filter, and transformation in the data process segment. The data will be stored in MongoDB. To get the change of data event, we use Debezium for change data capture implementation to turn the updated and processed data event into Kafka topics. The Kafka topic will be consumed by the blockchain so that the blockchain can save that data automatically. In the data visualization, we will present the data from the

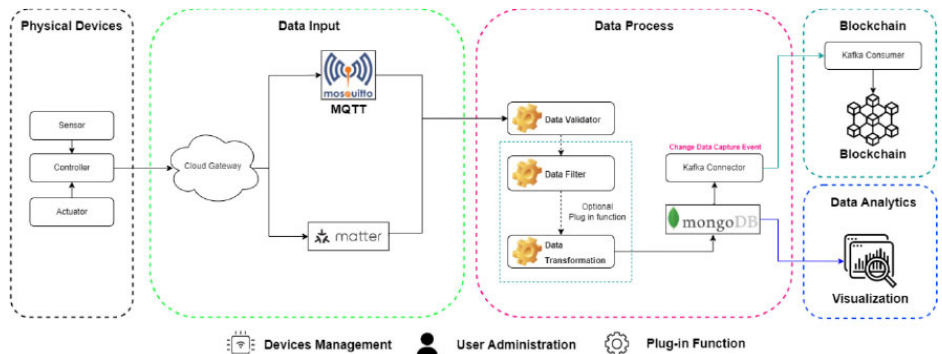


Figure 1. The proposed system for Healthcare Internet of Things monitoring system.

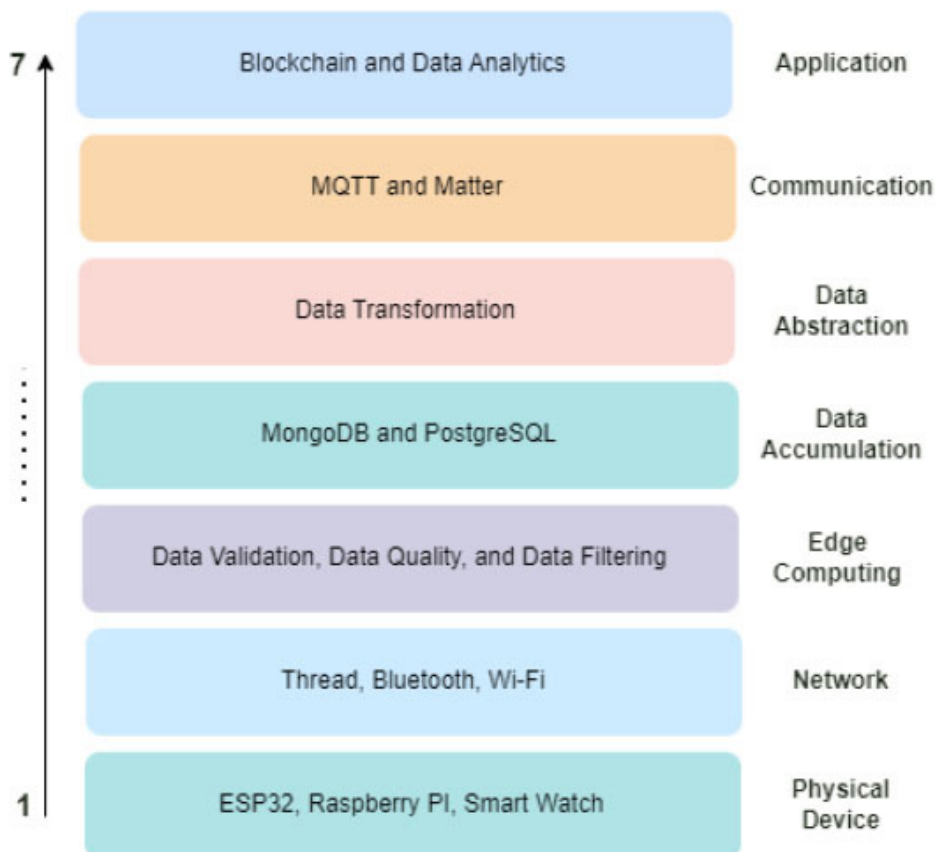


Figure 2. Seven layers architecture of the proposed system.

database (MongoDB). We provide several technology and method on each layer, as shown in Figure 2.

We could implement the proposed system in an inpatient or outpatient scenario. We provide several

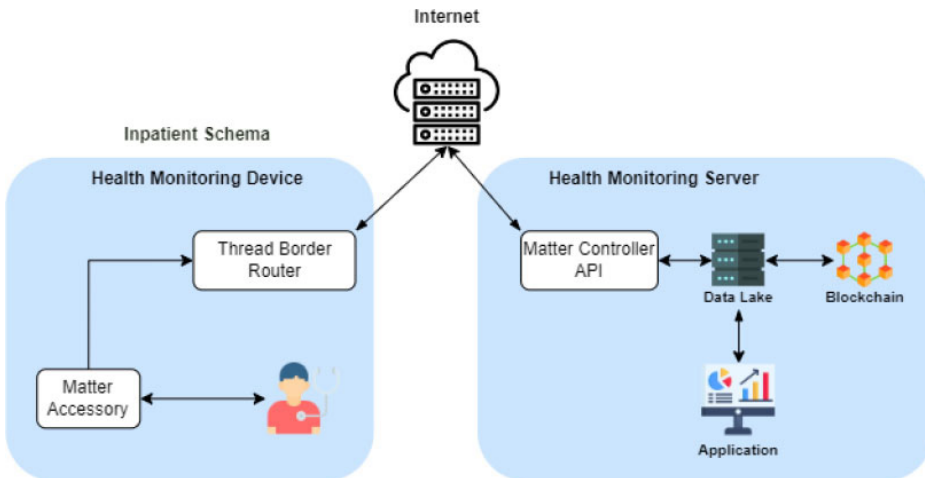


Figure 3. Healthcare Internet of Things implementation in inpatient scenario.

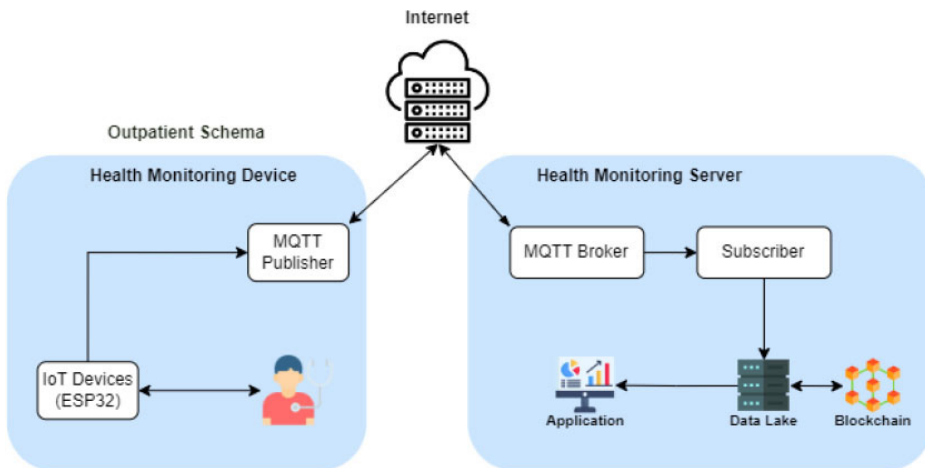


Figure 4. Healthcare Internet of Things implementation in inpatient scenario.

Table 2. Comparison of blockchain consensus

Consensus	Criteria				
	IoT Compliant	Basic Concept	Energy	E-Health Support	Example
PoW	No	CPU	Very High	Medium	Bitcoin
DPoS	Partial	PoS	Medium	High	Bitshare
PBFT	No	67% Node	Low	High	Hyperledger
PoA	No	PoW-PoS	Medium	Low	Bitcoin
dBFT	No	PBFT	Low	Low	Neo

communication protocols in the data input, MQTT and Matter. The detail of the two methods will be explained in the subsection below. HTTP and CoAP will be used for half-duplex communication, HTTP for high bandwidth data and CoAP for low bandwidth data.

Implementation of Proposed Healthcare Internet of Things in Inpatient Scenario

In the inpatient scenario, the doctor must monitor the patient in the room

or hospital space. We could implement WPAN (Wireless Personal Area Network) in this scenario. The thread network could be used to minimize energy consumption. Thread network supports Matter protocol as an application layer protocol, and we could monitor the patient through a different platform. In this research, we could use Google Nest Hub 2nd generation as a border router to register the IoT device to the thread network. The step of this scenario will be explained below:

1. Matter accessories (things) will sense patient health, such as body temperature, blood pressure, and heart rate.
2. The Matter accessory will send the data through the thread border router (Google Nest Hub 2nd generation).
3. In the Health Monitoring Server, Matter Controller could get and save the data from a border router connected to the server or the internet.
4. Data will be saved in the blockchain and visualized on the platform or as REST API.

Implementation of Proposed Healthcare Internet of Things in Outpatient Scenario

Implementation of IoT in outpatient scenarios will increase the effectiveness and efficiency of medical treatment or processes because patients can bring the devices anywhere. In this research, we implement MQTT for data communication. The step of the outpatient monitoring scenario will be explained below.

1. IoT devices act as MQTT publishers; they will publish the data to the broker on the server.
2. On the Health Monitoring server, we build subscribers to automatically subscribe to the data from the MQTT broker and save the data to the database.
3. The data will be saved in the blockchain and visualized on the platform or as REST API.

Blockchain Implementation

To increase data security, we provided blockchain as an immutable database. Blockchain will get the data using Debezium to get change data events. If there is an updated data in the data lake, it will automatically store on the blockchain. To combine the data lake with blockchain, we used Kafka to capture the data change in the data lake. So that, all database activity would be recorded and stored to the blockchain.

To implement blockchain, we investigated what consensus that fits for IoT system. The investigation result is presented in Table 2.

We will use PBFT-based consensus from that comparison because it is good

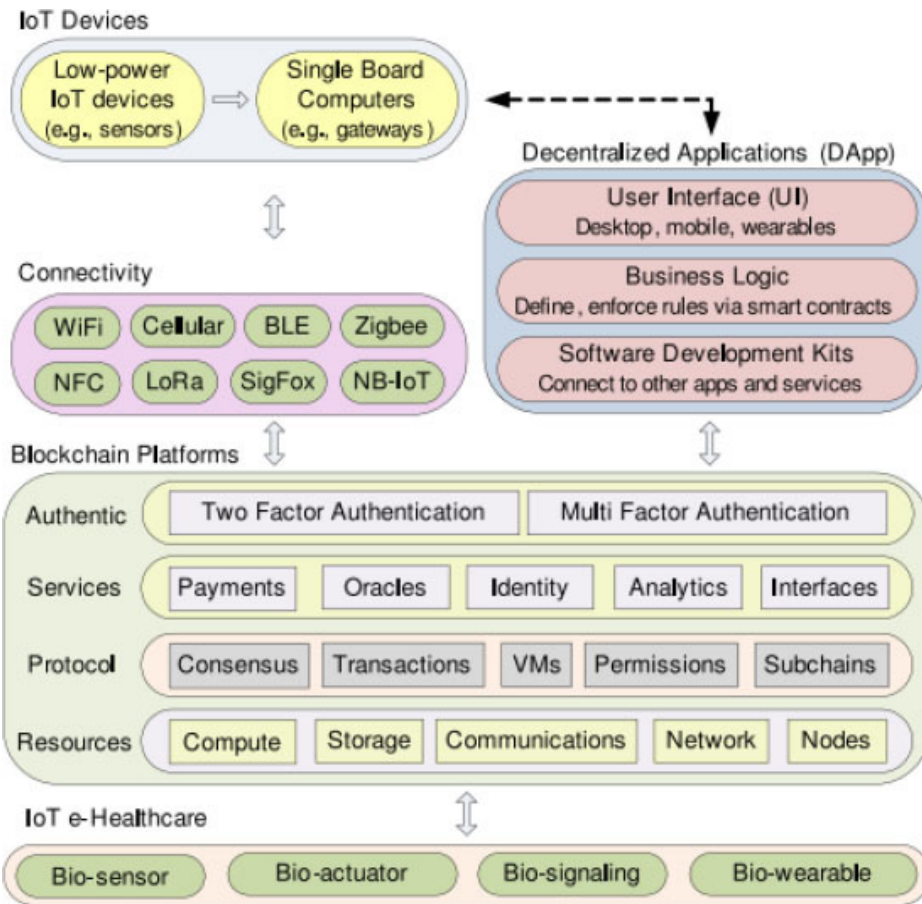


Figure 5. Blockchain implementation in Healthcare Internet of Things (H-IoT).⁸

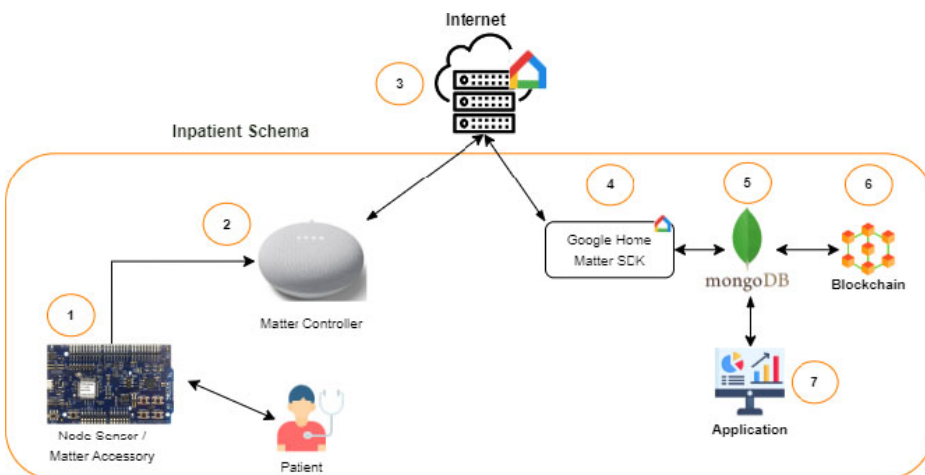


Figure 6. Hardware and software requirements for the inpatient proposed system.

for private blockchains.⁸ To build a private blockchain, we will use Hyperledger Besu for the blockchain framework to support PBFT consensus. Ray, Partha, et al. provide the architecture of blockchain implementation for IoT healthcare.⁸ The architecture can be seen in Figure 5.

RESULTS

This paper proposed conceptual of Healthcare Internet of Things (H-IoT) system for building a remote healthcare monitoring system for outpatient and inpatient activity. To increase the interoperability of system we propose implementation of Matter protocol as an

application layer for low-bandwidth data that support multi fabric that means Matter accessory or device is able to connect with multiple and different platform.

Our study found that the Matter protocol was suitable for local area monitoring or inpatient activity. For outpatient healthcare monitoring, we use MQTT as a data communication protocol. Our proposed system could be used in outpatient and inpatient activity. Our proposed system could be a reference to build interoperability, flexibility, and security in healthcare monitoring system.

Implementation of blockchain also playing a role in the proposed system. It can make our system secure and have high traceability. Blockchain implement hash function to hash the data, in our system blockchain will be integrated with NoSQL database by using Change Data Capture Kafka connector so that blockchain could record the data based on the event or data changes.

DISCUSSION

Using the H-IoT beneficial technology development for the medical field. It makes the patient reach the health facility easier.⁹ MQTT protocols could be used for inpatient or outpatient scenarios. Meanwhile, in this research, we implement MQTT for the outpatient procedure. Due to the capability of MQTT, IoT devices could connect to the broker on the server directly. The matter could be used for an inpatient scenario because Matter implements 6LoWPAN (Wireless Personal Area Network) and must connect with a thread border router. To implement the Matter protocol, we could use Google Nest Hub 2nd generation to communicate with Google Home or Google Assistant API.¹

From the result section, we provide the design system with specific hardware and software requirements. The inpatient scenario will be implemented using the Matter protocol with a thread network. The design system can be seen in Figure 6.

The outpatient schema will be implemented using the MQTT protocol. We build an MQTT subscriber to subscribe data from the node sensor automatically. If the broker enters new data, it will automatically save to MongoDB and blockchain. The design system can be seen

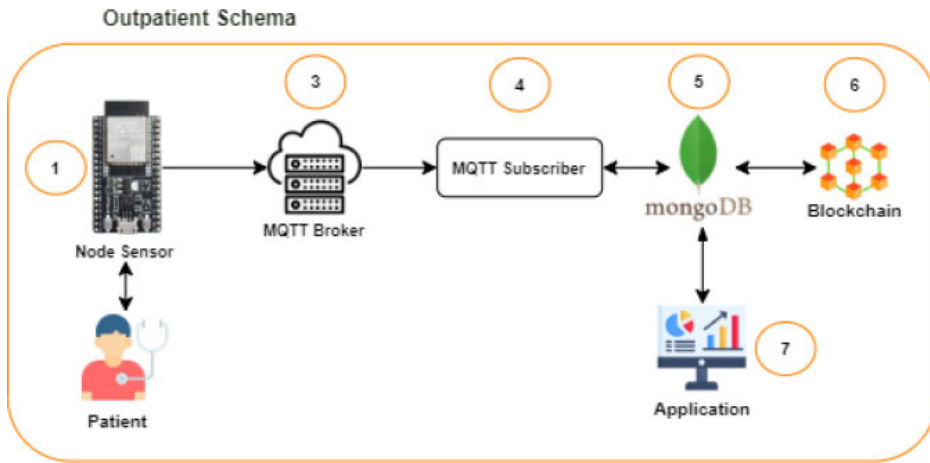


Figure 7. Hardware and software requirements for the outpatient proposed system.

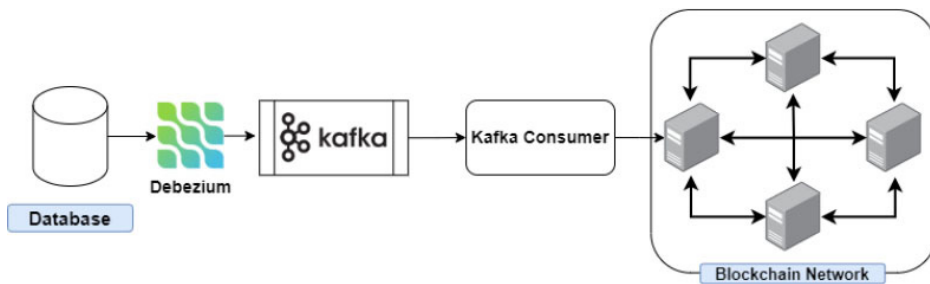


Figure 8. Change Data Capture (CDC) mechanism integrated with blockchain.

as Hyperledger Besu. Hyperledger Besu is a blockchain that is existed on top of Ethereum. Blockchain implementation aims to increase security. By implementing Change Data Capture (CDC) in the data lake or database with blockchain we could increase the traceability because we could trace the data change even though the database admin manipulates the data in a database. Figure 8 shows how blockchain works in the proposed system.

There is related research that implement blockchain and Change Data Capture in open-source hospital management system (OpenEMR).¹² They used Hyperledger Fabric for the blockchain development. To integrate the OpenEMR with blockchain network, they used Kafka as message broker and debezium as connector to watch the data changes to the OpenEMR database, then the data will be consumed by Kafka consumer service and triggering the blockchain API. The proposed system by this research could be seen in Figure 9.

CONCLUSION

We have compared several Healthcare Internet of Things (H-IoT) systems based on seven layers architecture. Then, we proposed the Healthcare Internet of Things (H-IoT) concept for monitoring outpatient and inpatients. Our system leverages MQTT and Matter protocol as communication protocols at the application layer. MQTT will be used for inpatients or outpatients who need middle to high bandwidth. Matter protocol will be used for inpatients in the hospital. It will increase interoperability and decrease energy consumption. In addition, we implement blockchain as an immutable database so that it could increase the security level of our proposed system.

In the future, we will focus on implementation and testing the proposed system. The Matter protocol implementation will use google nest hub 2nd generation and google home Matter SDK. To accelerate the development process, we will use agnostic open-source Internet of Things (IoT) platforms such as Home Assistant. In Home Assistant, we could implement your services, such as MQTT, HTTP, and plug-in functions as data abstraction and edge computing.

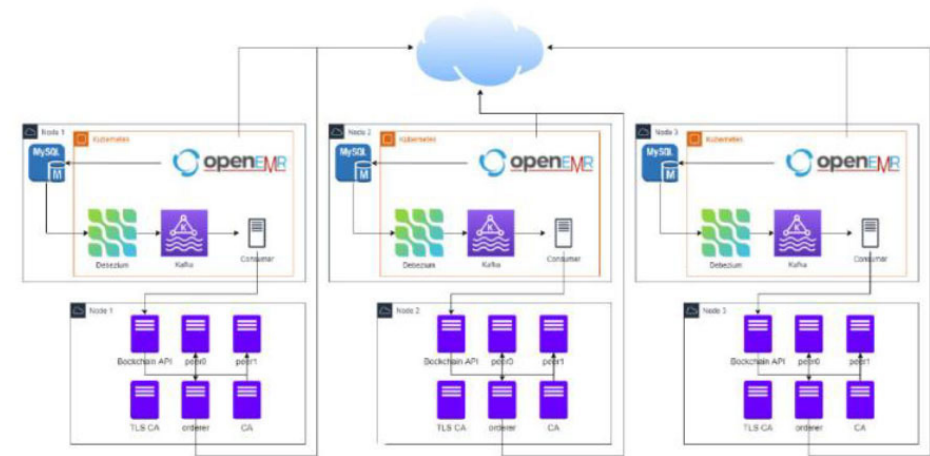


Figure 9. Implementation blockchain network in hospital management system.

in Figure 7. We will use IBFT consensus for the blockchain implementation, which requires a minimum of 4 node validators.¹⁰

Additionally, MQTT is constrained by the requirement for a third protocol to complete the MitM scheme. Typically, lower layers like RPL or 6LoWPAN are supported alongside MQTT. When the attacker is in the middle of the communications, they can access MQTT-SN data. However, for this attack, it is first necessary to compromise the communications by

attacking these protocols. The effects of this strike can be widespread: First, it may compromise confidentiality; second, it may compromise integrity because the attacker may change the messages; and third, it may compromise availability because the attacker may interfere with communication.¹¹

Furthermore, we also integrate IoT systems with blockchain as data accumulation. We built blockchain by using layer 2 blockchain technology such

DISCLOSURES

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This research has no budget.

Conflict of Interest

The authors declare that no financial or other interests could influence our action regarding research efforts, manuscript development, and decisions.

Author Contribution

All authors contributed to manuscript preparation, ideation, and revision. Hence, we could submit it for publication.

Ethical Clearance

The institution has approved this study

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