Fog computing architecture based blockchain for industrial IoT

Su-Hwan Jang[1], Jo Guejong[1], Jongpil Jeong[1]✉, and Bae Sangmin[2]

[1] Department of Smart Factory Convergence, Sungkyunkwan University, Gyeonggi-do, 16419, Republic of Korea
{korjsh,jejewind,jpjeong}@skku.edu
[2] Markate Incor.,, Gyeonggi-do, 13522, Republic of Korea
baesm@markate.net

Abstract. Industry 4.0 is also referred to as the fourth industrial revolution and is the vision of a smart factory built with CPS. The ecosystem of the manufacturing industry is expected to be activated through autonomous and intelligent systems such as self-organization, self-monitoring and self-healing. The Fourth Industrial Revolution is beginning with an attempt to combine the myriad elements of the industrial system with Internet communication technology to form a future smart factory. The related technologies derived from these attempts are creating new value. However, the existing Internet has no effective way to solve the problem of cyber security and data information protection against new technology of future industry. In a future industrial environment where a large number of IoT devices will be supplied and used, if the security problem is not resolved, it is hard to come to a true industrial revolution. Therefore, in this paper, we propose block chain based fog system architecture for Industiral IoT. In this paper, we propose a new block chain based fog system architecture for industial IoT. In order to guarantee fast performance, And the performance is evaluated and analyzed by applying a proper fog system-based permission block chain.

Keywords: Industrial IoT · Block chain · Hyperledger Fabric.

1 Introduction

This system, also known as Industrial Automation and Control Systems (IACS) or Operational Technology (OT), is well established today. The system is used in a variety of industries, including manufacturing, transportation and utilities, and is sometimes referred to as a cyber-physical system (CPS).

Internet of Things (IoT) [1] was first used in 1999 and has been applied to devices connected to the Internet in consumer, home, business and industrial environments [2]. Although IoT has a large body of literature to define its uses and typical components, little is known about how these apply in industrial settings. Therefore, IIoT, which is to be applied in industrial environment, is conducting researches on CPS in real time and IoS is used to provide inter-organizational

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and inter-organizational services by participants in the value chain. And it is said to be the core of Industry 4.0 as it is utilized [3].

Industry 4.0 is also referred to as the fourth industrial revolution and is the vision of a smart factory built with CPS. The ecosystem of the manufacturing industry is expected to be activated through autonomous and intelligent systems such as self-organization, self-monitoring and self-healing.

The Fourth Industrial Revolution is beginning with an attempt to combine the myriad elements of the industrial system with Internet communication technology to form a future smart factory. The related technologies derived from these attempts are creating new value. However, the existing Internet has no effective way to solve the problem of cyber security and data information protection against new technology of future industry. In a future industrial environment where a large number of IoT devices will be supplied and used, if the security problem is not resolved, it is hard to come to a true industrial revolution.

Currently, Internet technology is a centralized data processing process, which has the advantage of being able to be designed for each purpose in each industrial environment, but it has a disadvantage that it is very vulnerable because of centralized processing on a central server. Methods to address these drawbacks are also very limited and issues of performance load can not be avoided. So, to solve the problem, the system structure must change fundamentally. In other words, the goal of this paper is to study the need to reorganize the centralized structure into a distributed structure.

In this paper, we propose the necessary technologies and systems to build IoT - based smart factories for manufacturing companies and set the scope of the study to derive conclusions about the proposed structure through performance evaluation and analysis.

2 Related Work

2.1 Industrial IoT

There are a lot of IoT definitions in academia, but I will try to understand them through three related definitions.

1) The definition of IoT is “an infrastructure group that interconnects connected objects and allows access to management, data mining and generated data”. Linked objects are “specific functions by which sensors or actuators can communicate with other devices”[4].

2) “The Internet of Things is broadly referred to broadly as the extension of network connectivity and computing capabilities to objects, devices, sensors, and items that are not generally considered to be computers. These smart objects. They often need to have connectivity to remote data collection, analysis and management functions.”[5].

3) “IoT represents a scenario in which all objects or ’objects’ are embedded in the sensor and can automatically communicate status with other objects and automated systems in the environment. Each object represents a node of

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the virtual network, And continuously transmits large amounts of data to the periphery."[6].

As IoT is defined and evolved, more and more applications are being made to apply this technology in the industry. IIoT is also called the "industrial internet" in GE. How it is called, IIoT differs from other IoT applications in that it focuses on connecting machines and devices in industrial sectors such as oil and gas, power facilities, and medical care. The initial definition of IIoT has been introduced in many literature[7, 8], using industry specific IoT technology in industrial environments. One of the recent studies for the IIoT environment has implemented hierarchical fog server architecture. This approach seeks to decentralize the fog server architecture to reduce communication latency and increase throughput.

IIoT in smart factories is one of the most mentioned industrial business concepts in recent years.The term IIoT refers to the Internet for industrial objects. In a broader sense, it is to connect devices in transportation, energy, and industrial sectors and sensors and other devices in vehicles to the network. The meaning of IIoT actually varies. The IIoT system is simple enough to leave home text like a connected mousetrap, but it can track and share large amounts of information, from a fully automated mass production line to maintenance, productivity, ordering and shopping, It can be as complex as it is. Currently, the level of application of IoT in industrial automation is not high overall.[9] IoT solutions for industrial automation are still evolving. The fog-based approach can meet the requirements of modern industrial systems. Most existing research, however, focuses on a centralized computing architecture that uses cloud computing to monitor data and manage control processes in industrial automation. Most of the existing approaches and solutions from the cloud computing point of view for industrial automation are focused on higher than the field level.

2.2 Fog Computing

The concept of fog computing connects these two environments as a kind of distributed network. " Fog complements the middle between data that needs to be pushed to the cloud and local analysis, " said Morchiang, Dean of the College of Engineering at Purdue University and Fogg and Edge Computing researcher. The OpenFog Consortium, a group of research institutes and companies that support the standard development of fog technology, is committed to delivering fog computing to the computing community, "distributing computing, storage, control, networking services and resources from anywhere in the cloud- System-level horizontal architecture " cite ref10-1

With the fog computing framework, companies have new options for processing data wherever they are for optimal data processing. It is particularly useful in areas where data must be processed as quickly as possible. For example, there is a typical manufacturer whose connected equipment has to respond to an accident as soon as possible.

Fog computing creates a network connection with less delay between the device and the analysis endpoint. This reduces the amount of bandwidth required

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by sending data to the data center or to the cloud. It can also be used when the bandwidth connection to send data is difficult and needs to be handled close to the data generation site. It is also an advantage that security can be applied to the fog network from the divided network traffic to the virtual firewall to protect it.

Fog Computing is still in the early stages of commercialization, but its use cases are diverse. First, ConnectedCada. The emergence of semi-automatic and autonomous vehicles is driving up data generated by vehicles. In order for the vehicle to operate independently, local data such as the surrounding environment, driving condition, and driving direction must be analyzed locally in real time. Other data can be sent by the manufacturer to improve vehicle maintenance or track vehicle usage. The fog computing environment enables communication from both the edge (in-vehicle) as well as the endpoint (manufacturer) for all this data.

Smart cities and smart grids are also good places to apply fog computing. Like connected cars, utility systems are also increasingly leveraging real-time data for efficient operation. This data may be located in a remote area, so it is necessary to process it near the place where it was created. Data may need to be collected from multiple sensors. In both cases, the fog computing architecture presents a good solution.

Real-time analysis is used at a variety of locations, from manufacturing systems that need to respond to events as soon as they occur, to financial institutions that use real-time data to provide information necessary for transaction decisions or to monitor fraudulent transactions. Placing fog computing here makes data transfer between the data generation site and the various places where the data needs to be moved more smoothly.

The 5G mobile connection expected to be launched after 2018 is expected to spread more rapidly to fog computing. According to Andrew Anders, senior vice president of technology planning and network architecture at CenturyLink, 5G technology requires very dense antenna placement. The distance between the antennas should not exceed 20 km. In this case, by creating a fog computing architecture that includes a central control between the antenna points, it is possible to manage applications running on this 5G network and support connectivity to back-end data centers or the cloud.

The fog computing fabric has various components and functions. There are various wired and wireless granular collection endpoints, such as fog computing gateways and ruggedized routers and switching equipment that accept data collected by IoT devices. Gateway and customer premises equipment (CEP) for edge node access may also be included. At the higher end of the stack, the fog computing architecture may touch the core network and routers, and ultimately, the broadband cloud services and servers.

The Open Fog consortium, which is developing a reference architecture, introduced three objectives of fog framework development. First, the fog environment must be horizontally scalable. This means that you will support multiple vertical industry use cases. Second, it must work across the continuum from cloud to

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things. Third, it must be a system-level technology that extends across the network protocol from the object through the network edge to the various network protocols.

The Difference between Fog Computing and Edge Computing Helder InTunes, a senior member of Cisco's Corporate Strategy Innovation and an openfog consortium, explained that Edge Computing is a component or subset of fog computing. He thinks " fog computing is the way data is processed from where it was created to where it is stored. Edge computing only refers to processing near the point at which data is generated. Fog computing not only covers its edge processing, but it also includes the network connections needed to bring that data from the edge to the endpoint. "

2.3 Blockchain

Satoshi Nakamoto has laid the foundation for block-chain technology by presenting a solution for distributed trust among unauthorized entities [11]. The first decentralized virtual currency is a bit coin. That is, the bit coin is a cipher and the block chain is a technique that supports bit coin. Cryptography is a digital currency that runs on a block chain, and many virtual currencies based on the current block chain are created, creating a huge virtual money market. Especially, they are interested in the block chain technology in the financial market, and they are investing heavily. For example, a block chain of bit coins means "not centralized", that is, not controlled by a single central authority. While the centralized system structure, the bank issues the currency, the bit coin has no central authority. Instead, the block chain of bit coins is maintained and credible by the network of people known as miners. In other words, building a block - chain - based distributed network means that a financial institution does not have to devote much effort to security and authentication for reliability.

Block Chain Technology is a revolutionary technology that will lead the next generation Internet, attracting a lot of interest from the industry and rapidly expanding its influence with the emergence of ethereum, hyperledger, ripple and R3. In addition, competition for technology and platforms is getting hotter as a start-up company that provides block chain solutions in various fields such as virtual currency, asset management, shared economy, IoT, health, and logistics.

To connect an industrial IoT to a block-chain platform, it must create a module that will integrate IoT and block-chain functionality. This module stores information in the smart space of the IIoT and replicates information from the block chain into signed transactions. Also, it will be possible to create contracts that can be automatically processed under appropriate conditions. The best platform for this kind of integration is Hyperledger Fabric / Burrow[12].

They provide a fault-tolerant consensus mechanism as well as a basic infrastructure for creating and processing smart contracts. Using these platforms, it is possible to create both types of block-chain networks, both private and public.

A public block chain is an etheric, bit coin that we commonly know. Anyone can join a block chain to produce a block, a node, or a transaction. "Anyone" has the advantage of creating a huge network, so you can have high security. But

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you have to use complex logic circuits to keep that “everyone” in a state of trust. And because of this, Public Block Chain has the disadvantage that Transaction Per Second (TPS) is much lower than the existing network.

A private block chain is the key to building a reliable chain of chains without having to have complex logic circuits, such as public block chains, by limiting who or what can participate in the block chain. And since only limited users are involved, it is easy to modify the software maintenance, so that the structure of smart contract can be changed and developed so that it can be used immediately in the current system.

For example, in the financial sector, the transaction record should not be open to everyone. But a third-party supervisory authority must have the authority to see it. A public block chain is a very challenging environment to implement. However, the private block chain can be easily implemented with the freedom to modify and set permissions for smart contracts. It's a technology that banks can use without having to change the existing banking laws.

2.4 Hyperledger

Hyperledger is a block-chain open source project hosted by the Linux Foundation. The goal is to create block chain technology that can be applied across industries such as finance, IoT, logistics, manufacturing, and technology industries. In addition to hyperledger, there are other block-chain platforms such as R3, Ripple and Ethereum. Hyperledger is special for the following reasons.

1) an environment suitable for implementing a corporate business as a private block-chain platform;

2) a technology standard that can be adopted universally for various industries, unlike other platforms specialized in finance is.

Hyperledger is committed to mass-producing enterprise block-chain technology. These include distributed ledger framework,smart contract engine,client library,a graphical interface,other utilities, and sample application. This hyperledger umbrella strategy drives the rapid development of Distributed Director technology elements while strengthening the community by reusing common infrastructure elements. Incubating projects are divided into two major divisions. One is the Hyperledger Framework and the other is the Hyperledger Tool.

Hyperledger consensus

In the HLF, several nodes execute first, verify the result, and process the steps applied to all nodes separately. In the Execute phase, the peers execute once and compare the results to each other. Then, in the order step, the order is sorted and transmitted to all peers. Finally, each peer applies the requested contents in order and validates them. At this last step, the update is finally made to the ledger. This Execute-Order-Validate step itself is an agreement. But to be precise, it is a bit different from the block chain algorithm we think. Since Kafka, which is often called the HLF's algorithm for solving, is actually used only in the Order stage, it is not an accurate expression.

In other words, HLF is a structure in which consensus occurs in duplicate. In the Execute and Validate phase, it performs its own Endorse process according

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to the endorsement policy defined in the network. It is not an algorithm, but an agreement is determined according to the 'policy' defined in the network. In the intermediate Order step, the assigned orderers in the network sort the submitted transactions in the Kafka method and the agreement between the orderers is made.

Kafka is not strictly an algorithm for block chain aggregation. Kafka is a distributed messaging system developed by Linkedin, specializing in real-time large-volume log processing. So while the other agreement algorithms are BFT - which verifies the content to be delivered - Kafka is a Crash Fault Tolerance (CFT). It ensures that only the sequence is stacked up correctly. HLF is a block chain based on genuine "consensus." The use of Kafka seems to have resulted from the architectural troubles to improve the performance of HLF. In the first 0.x HLF, PBFT was installed as a standard. Nevertheless, criticism of performance (TPS) was constantly raised, and HLF developers would have to take measures against it. It is still a powerful but effective way to reach consensus. Kafka was an attractive solution in that it could quickly deliver messages in a pull-sub-structure, minimizing the burden on the receiving peer and improving speed. Although BFT verification can not be done, it is the problem of solving the problem by using the characteristic of Permissioned Blockchain to block the risk first in the CA and further supplementing the endorsement policy without any holes.

HLF can also satisfy the requirement for BFT verification between organizations. The algorithm for HLF's consensus is modular, as developers can choose which approach to consent - note that the application of this approach is only in the Order stage. The BFT verification method that HLF basically provides is SBFT. 1.3 release criteria Although not included, it was included in the 2018 roadmap released earlier this year and was announced to be available from the 1.4 release.

Hyperledger framework

FABRIC: Hyperledger Fabric (HLF) [13, 14] is an open source project for the Hyperledger umbrella project. It is a modular, permissible block-chain platform designed to support pluggable implementations of various components such as order and membership services. With HLF, clients can manage transactions using chain codes, peers, and order services. Chaincode is the smart contract of HLF [15]. It consists of distributed code in a network of HLF run and validated by the peer to maintain the ledger, conforms to the state of the database (modeling as a key / value store) and warranty policy, and the order service generates a distributed ledger block The order of each block is also determined.

SAWTOOTH: Sawtooth is a modular platform for distributed branch construction, deployment and execution. We have successfully completed a healthcare-related POC with Intel-led projects.

IROHA: Iroha is a distributed led development project focused on mobile application development. C ++ design-based, Byzantine Falut Tolerant consensus algorithm. Japanese companies such as Soramitsu, Hitachi, and NTT Data are leading.

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INDY: Indy is a certification-specific project. Provides tools, libraries, and reuse components for creating and using independent digital identity records based on block chains. The best thing is that you can use it across other 'silos' such as admin domains, applications, and so on.

BURROW: A smart contract interpreter based on the Ethereum Virtual Machine (EVM) provides a built-in block-chain client.

Hyperledger tools

COMPOSER: Hyperledger Composer is a tool that you have heard once if you are interested in developing a block chain. It is the first tool released in the Hyper Leisure project, allowing you to build a block-chain business network. It also allows the contract to flow between the smart contract and the ledger.

CELLO: Cello enables an as-a-service deployment model in a block-chain ecosystem. It is an orchestration tool that minimizes the effort of creating, managing, and deleting a block chain network.

EXPLORER: Hyperledger Explorer is a tool that allows you to quickly and easily view blocks, transactions, related data, network information, chain codes, transaction families, and other information in your ledger.

QUILT: It enables interoperate between led systems with the payment protocol ILP. That is, it allows the transfer of values between the Distributed Ledger and the General Ledger.

CALIPER: Hyperledger Caliper generates reports that contain various performance indicators such as Transactions Per Second (TPS), transaction latency, resource utilization, and so on. The results you create in Caliper are used to build the framework in other Hyperledger projects and help you choose the block chain implementation that suits your specific needs.

3 Proposed architecture

In this paper, we design a fog computing model based on the permissible block chain for future Industrial IoT as shown in figure 1. Key requirements are fast exchange of data and reliable exchange of data based on low throughput and low latency. The basic flow is to create a private key on the edge device and register it with the fog node / server. Then, in the fog, the authority for the transaction of the edge device is checked by referring to the registered public key, and the initial leisure is distributed. And requests the ordering service to distribute the registered transactions to all the peers. When processed, records are added to the world state, and the peers in the same channel can request transactions such as query and resource exchange of data of the newly registered edge device.

Figure 2 shows the functions to be operated in the proposed model by dividing each layer. In the edge stage, edge functions include functions such as real-time processing, small-scale data storage, and gateways. In the fog group, functions such as control, routing, data analysis, data preprocessing and virtualization are included. Algorithm of logic, block chain. Deep learning is included. By building a block-chain network with cloud and fog nodes, the nodes of each layer share a distributed ledger.

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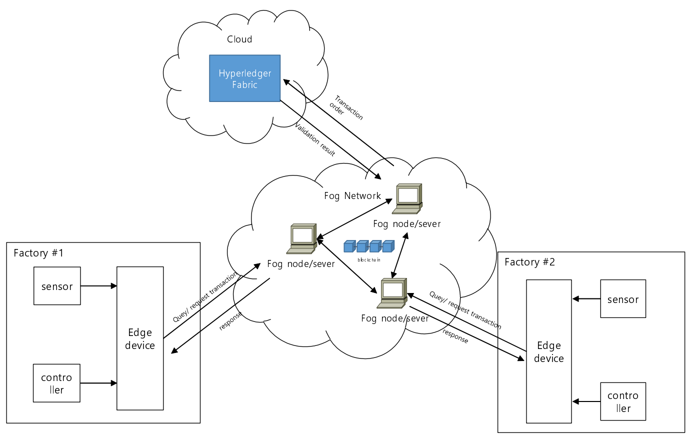

Fig. 1. Blockchain based Industrial iot fog computing proposal model

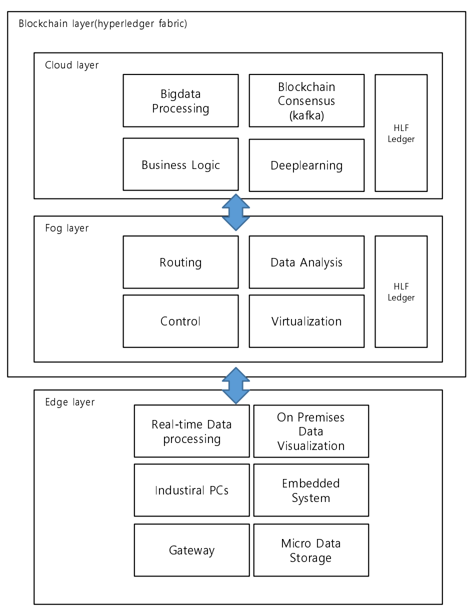

Fig. 2. Blockchain based Industrial IoT fog computing Proposal Model Feature architecture by layer

Figure 3 shows the actual configuration of Figure 1 with hyperledger and fog computing. orderer in the cloud because security and network stability must be guaranteed. It is essential that each fog node below it can be guaranteed stability

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and speed in a block-chain network if the orderer is distributed in the cloud and supports clustering services even if the geographical location is far away. In this paper, we have placed Endoser peers in the fog node for security of the network and deployed them as brokers of IoT device groups. The combination of these layers creates the following service and network features: The ordering service adds a block to the chain through a consensus algorithm. The more the orderer gets and the more complex the algorithm becomes, the better the stability. But the slower the speed, It handles this task with a Fog node to maintain each block chain data, and acts as a network so that the edge device can query the desired data or maintain a connection. In an industrial local network, in a local network connected by wifi and ethernet, the edge receives signals from sensors, controllers and other devices and processes them in real time.

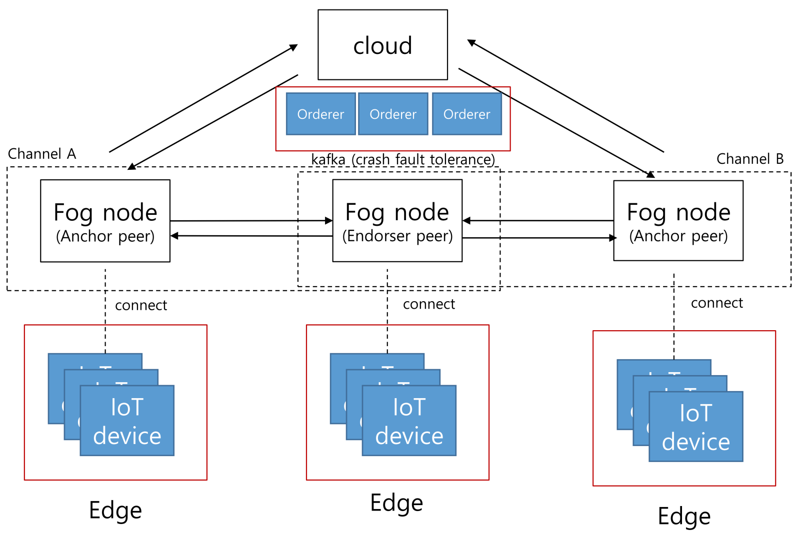

Fig. 3. Blockchain based Industrial IoT fog computing architecture

4 Evaluation

The scenarios for designing a model for evaluating performance in the Permission Block Chain based fog computing architecture are as follows.

(1) When an ordering service is established at the fog node, the evaluation of the corresponding throughput delay time and the like of the number of each authors is carried out.

(2) When an ordering service through a VM is established in the cloud, the evaluation of the corresponding throughput delay time and the like of the number of each node is performed.

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For the performance evaluation, the orderer is AWS EC2 t2.micro Ubuntu server 16.04 LTS (HVM), SSD Volume Type Variable ECU, 1 vCPUs, 2.5 GHz, Intel Xeon Family, 1 GiB memory, EBS only) Core i5-7200U CPU @ 2.50GHz 2.71GHz Ubuntu server 16.04 LTS (VirualBox) It is 8GB RAM. The performance of each virtualization instance of the Endoser peer is vCPU 2, 4 GB RAM. The block chain network is composed of Hyperledger Fabric v1.3, the sample chain code (smart contract) is installed in the network, and the chain code is operated by communicating with the REST-server through HTTP communication. In the experiment, 350 threads in the block-chain network are all executed in less than one second, and each thread repeats the next operation (HTTP Request, etc.) 20 times. TPS stands for Transactions per Second, which means the number of transactions processed per second. As a result, response time was 7209 ms, minimum 537 ms, average 4665 ms, and TPS was calculated as about 48 TPS through 7000 sample data. Figure 4 shows the TPS graph over time.

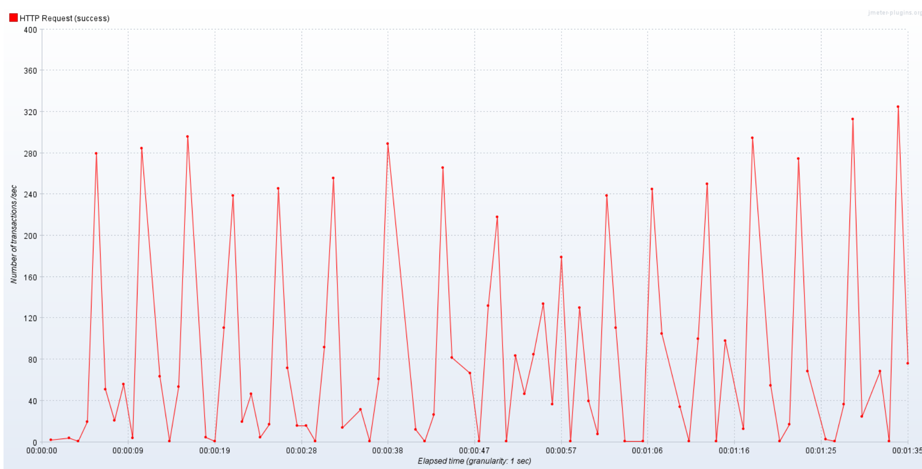

Fig. 4. TPS of fog architecture based on hyperledger for elapsed time

Figure 5 is a graph of Active Threads according to each elapsed time. we can see that there is some delay in the network when a thread group starts and ends an HTTP request. Other than that, we reliably handled threads in a block-chain network.

Figure 6 shows the response time to the blockchain network. I have placed the ordering service in the cloud to see if the network is stable. It can be seen that even though the orderer instance is the minimum specification, it supports a relatively stable network. It is analyzed that it can be used very appropriately in environments where high throughput and real-time environment are not required.

Figure 7 shows the throughput graph of a hyperledger fabric based fog network over time. Throughput is calculated as requests/unit of time. The time

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Fig. 5. Active Threads of fog architecture based on hyperledger for elapsed time

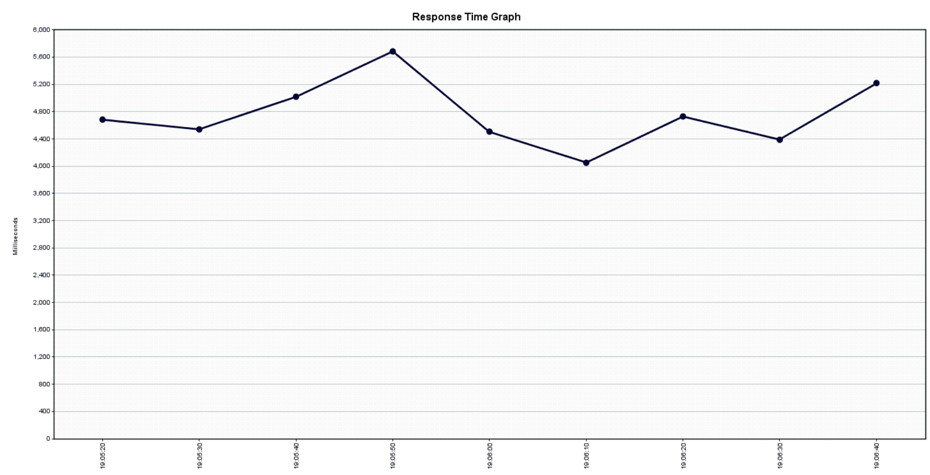

Fig. 6. Response Time of fog architecture based on hyperledger for elapsed time

is calculated from the start of the first sample to the end of the last sample. This includes any intervals between samples, as it is supposed to represent the load on the server. The formula is: Throughput = (number of requests) / (total time).we can see that the throughput is much lower than the bytes are received.

By placing orderer in the cloud as shown in the above figures, we can confirm that the performance is stable. Therefore, if orderers are configured with higher performance instances in the cloud, it can be seen that the block-chain network can also achieve high performance.

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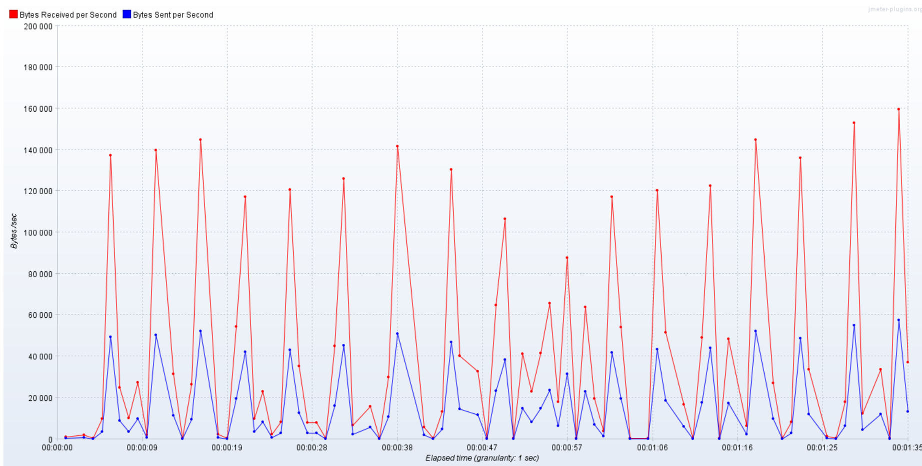

Fig. 7. Response Time based on elapsed time for HTTP request

5 Conclusion

In this paper, we propose a system architecture that can prevent data forgery by converting existing centralized database method to distributed type based on block chain. By dividing the proposed system structure into cloud, fog, and edge, we proposed a way to organically operate the IIoT ecosystem. We also investigated whether the performance of the block - chain network agreement algorithm can be guaranteed by using public cloud resources. Resolves data validation and security based on Hypeledger block chain platform in IIoT environment (permissioned blockchain), Resolves performance load issues by not connecting IIoT devices directly to block-chained networks, Orderer is ported to the cloud to ensure stability, security and scalability. We propose that smart contract and transaction verification proceed to process in fog node to obtain network latency and throughput performance. In the future research, challenges will include research into network configuration for cost savings in the cloud, and optimization of cloud and fog node instancing performance to maximize the performance of the block-chain network hyperledger. Finally, we hope to analyze the performance and consistency of the model by applying it to actual industry environment.

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