ArmChain - A Blockchain Based Sensor Data Communication For the Vehicle as a Mobile Sensor Network

Alviansyah Arman Yusuf, Dwi Kurnia Basuki, Sritrusta Sukaridhoto, Yogi Putra Pratama, Fariz Bramasta Putra, Heri Yulianus
Department of Informatics and Computer Engineering
Politeknik Elektronika Negeri Surabaya
Surabaya, Indonesia
Email : alviansyah.arman@gmail.com, dwiki@pens.ac.id, dhoto@pens.ac.id, yogiputrapra@gmail.com, farisbram@gmail.com, heri4n@gmail.com

Abstract*—The Internet of Things (IoT) is widely used in various aspects such as industry, manufacturing, health, agriculture and others. One of the uses of IoT is as an environmental monitoring system. In its application, IoT-based environmental monitoring systems are composed of one or more sensors placed in various locations and connected to each other using certain protocols. The problem arises when thousands of IoT devices connected together in one network and using the server-client connection model which raises several works in the synchronization process and access control management. This kind of network depends on a server as the center of control management that work as storing and distributing data from the sensor so that any data comes from the server is considered correct. To overcome this problem, it is proposed an IoT system that uses Blockchain technology which is a distributed data structure that forms blocks that do not require central authority and verification from third parties. From the experiments conducted can be evaluated that blockchain communication is much slower compared to MQTT communication protocol in terms of speed. The data transmission between node is measured with an average delay of 200ms. This system also visualizes data in graph with a high mobility data collection using vehicle so that it can be used to be an alternative of public participatorial measurement.

***Keywords*— Internet of Things, Blockchain, Distributed Network, Vehicle as a Mobile Sensor Network, Air Quality Measurements.**

I. Introduction

The Internet, an innovation originating from several government-funded computer network projects has been running for the past 40 years which is now a source of access to information and has produced several other innovations in the communication protocol used by the public. Internet of Things (IoT) is one of the developments of the internet that is oriented towards personal, professional, and community life. IoT is a term for electronic devices, with various functions, sizes, and uses that are connected to the Internet [1]. In term of connecting and communication between devices, there are many protocols available. MQTT is one of the most popular among the other.

Implementing VaaMSN using these ways, facing some issue like scalability and security. In scalability [2], the problem occurs when a massive sensor node joining the network because VaaMSN in public participatory means a lot of public users will connect and participate in monitoring the environment. Using the traditional centralized server-client model are not practical to challenge this problem. Some security problem [3] relies on the three-layer basic architecture of the IoT. On the perception layer, the attack mainly focused on data collection such as Node Capture Attack a.0nd Malicious Code Injection. On the network layer, the attack related to the wireless connection of the IoT such as Denial-of-Service and Unauthorized Access. On the application layer, the attack is related to the users such as Phishing Attack because these layers are in the top of the architecture providing operations to the users.

Blockchain is an emerging data structure technology behind Bitcoin, a digital currency that uses a public, full transaction history to keep track of transactions made between nodes. It is called public and full transaction history because the transaction history is shared between every peer and contains every transaction [4].

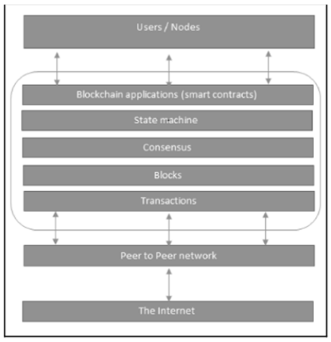

Fig 1. Structure of a Block

It is decentralized, meaning that the data is not stored in any single location. Various version of the blockchain is available across the internet. They can be open to everyone (public) or for a limited group (private). The financial institution, Companies in shipping, manufacturing, consumer goods, automotive and healthcare, are exploring uses for the technology. In this proposed system, we use the blockchain to store and manage the sensor data in a decentralized way. Prior to describing the decentralized access control, we need to discuss the Blockchain as data storage.

This section of the paper has four purposes: Section 1 present the introduce about background problem in this paper, the related works, and a previous study of the research presents in section 2. Section 3 presents the details of the system was built, Section 4 presents the results and discussion of the system of our research.

II. Related Works

The study and previous works have developed public participatory monitoring for air quality. Building a citizen community for monitoring air quality with effective use of the offline facility. As the community grows, the data is supplied timely and highly sourced data become available [5] . Another research on public participatory monitoring is the bus as a Mobile Enterprise Sensor Bus (M-ESB) service in China that supports two main requirements: to support the urban physical environment and to improve road conditions. The M-ESB system uses the mobility of the bus to expand the range of sensors, sensor data obtained from buses on different routes can be combined to form a sensor network that covers the entire city [6]. The road pothole detection system [7], [8] was also using the VaaMSN system. Yogi [9] proposed MQTT Protocol for the data communication between the collar and the basestation. The research on blockchain use-case on supply chain was published by Miguel Pincheira et al. [10] using Ethereum blockchain to develop a decentralized system for agricultural food supply chain management called AgriBlockIoT that features transparency and traceability asset. Meanwhile, research conducted by Ali Dorri et al. [11] build an IoT architecture based on blockchain for handling security and privacy issues while considering the resource of many connected IoT devices. Faris Bramasta et al. [12] using the API system for the speech recognition and obtaining the ICD database. The research on real-time environment monitoring was published by Berlian, M. H et al. [13] using big data in the implementation.

III. System Design

The proposed system is consisting of VaaMSN, which is a vehicle carrying an air quality sensor, the Blockchain System, and Data Visualization. The system shows in Figure 1.

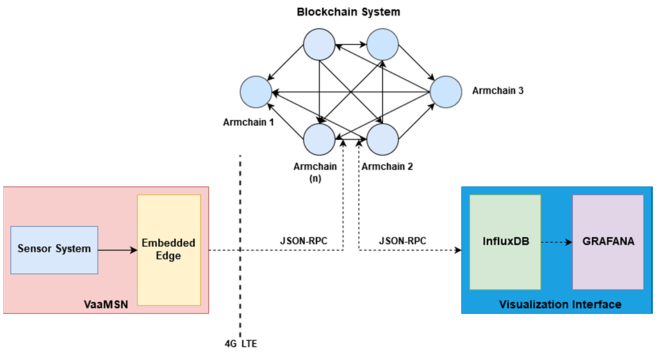

Fig 2. ArmChain Architecture Diagram

A. Air Quality Sensor System

This system is the "thing" in term of IoT. The air quality sensors consist of Sensirion SPS30 to measure Particulate Matter 2.5 and 10, Sensirion SHT-31 to measure T/H, GPS Sensor Ublox Neo 6M, and an arduino mega 2560 microcontroller.

All three sensors are processed by the microcontroller. The measurement is started every 5 second and collected through the defined port. Before the data is sent to the embedded edge [14], it must be converted to the ppb or ppm units. for the air quality. The converted data then sent to the embedded edge through serial communication with some formatting

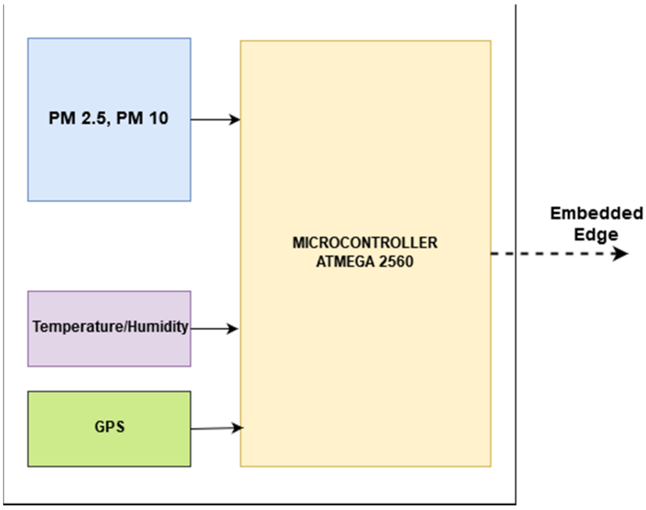

Fig 3. Diagram of The Air Quality Sensor System

B. Embedded Edge

This part is used to receiving data from the sensor system. The system will wait until the data has arrived from the serial port. After that, the data format is checked and parsed it to the JSON object [15]. This JSON object contains data such as timestamp, latitude, longitude, PM2.5, PM10, temperature and humidity that will be sent to the blockchain system by using JSON-RPC [16]. By using JSON object, we can provide bulk data operation and transaction to the blockchain. For connecting to the internet, we must provide a 4G-LTE cellular connection by using WiFI modem.

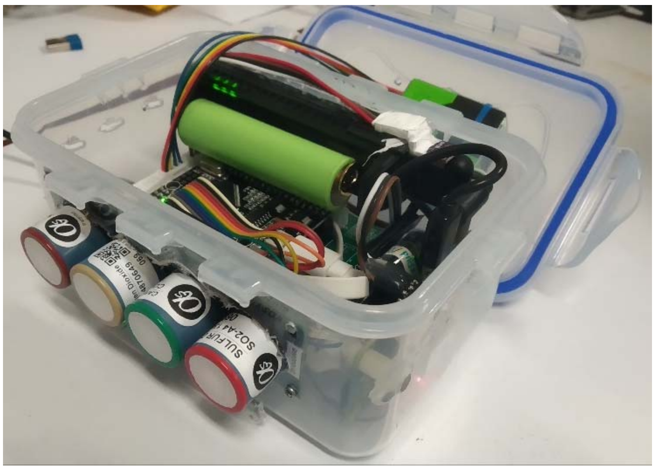

Fig 4. VaaMSN Device Including Sensor and Embedded Edge

C. Blockchain System

This the main part of the system. this blockchain system consists of several computers installed in the blockchain client and connected to each other, also called nodes [17]. This node is built on a computer with a 64-bit Ubuntu Linux operating system with a minimum specification of 1GB of RAM and 1GB of disk space. The node is then installed the client blockchain and will make a connection with the chain that has been made. For the blockchain system to work, the initial chain needs to be created by nodes that have special access rights. After the initial block has been successfully created, other nodes can make connections with the chain. In order to connect to the blockchain network, the new node will request access rights to the initial chain-making node.

The existing node then gives access rights to the new node through the address listed. After access rights are granted, the client node will be able to connect to the chain on the blockchain network. After the blockchain network is formed, the data exchange process can be done. The data sent by the sensor system is a String plain text type. After the data is successfully sent from the sensor system to the blockchain system, the data will automatically be duplicated to each node in the blockchain network as the main function of the blockchain itself. The process of interaction between sensor systems with the blockchain system uses a remote procedure call (RPC). RPC on the blockchain system can be used for various administrative settings, wallet settings, and queries regarding data on the blockchain

To be able to access the blockchain system with RPC, the sensor system must post HTPP through the node address and the port specified on the client which can be seen in the file configuration that appears during initial chain creation. In making a request, a basic authentication header that contains a username and password is needed from the chain created. The process of sending data received from the sensor starts with converting the data into JSON Object format, after that it performs the HTTP post request [18] along with the specified header then determines the request address using the node address and the RPC port listed in file configuration. Every time there is data received, the blockchain system will write it into the last block. This update block process occurs every 10 seconds. If there is no transaction, the number of blocks will not increase. With this distributed data principle, if one node is disconnected from the blockchain network, the other nodes can still provide data. The breakdown of one node does not cause the blockchain network to stop unless all nodes are interrupted until there are no nodes left. The active node will carry out data transactions continuously and when the broken node is successfully connected again with the blockchain network, then the node will synchronize the missed blocks as long as the node is disconnected so there is no difference in data between nodes.

D. *Blockchain Node and Data Visualization*

This system is deployed with three cloud server that works as the blockchain node called Armchain 1, Armchain 2, and Armchain 3. Each node running the blockchain client, influxdb [19] service, and grafana [20] service. The blockchain RPC are connected through port 7178 with IP address corresponding to the node address. To visualize the data, InfluxDB will read streams on blockchain and then store it by time series. This process done automatically by detecting any change on number of transaction inside stream on the blockchain. For example, if the last number of transaction is 100, and then it change to 101 it will trigger the program to read the latest transaction and write it to InfluxDB. The visualization process is done using grafana service that runs on port 3000. Grafana will visualize the data that already stored in the InfluxDB every certain interval. This will show a graphical interface at the dashboard in the form of gauge, table, graph, and maps.

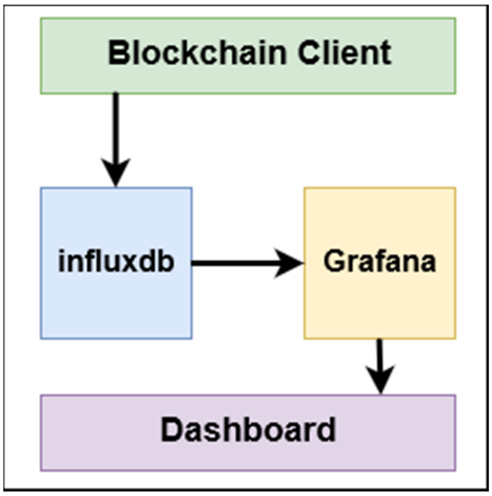

Fig 5. Diagram of Blockchain Node

Measuring the air quality on this research is referred to the Indonesian Air Quality Standard Index (ISPU), this rule is used by the current Republic of Indonesia government [21] to convert the air pollutant concentration into air quality index value. This index is categorized according to health impact. As shown in table 1. The index based on the measurement of five air pollutant including sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), particulate (PM_{10}), and ozone (O_3). To obtain this index, require computation of air pollutant concentration over a specified averaging period. The value is calculated using formula provided in [21]. Although, there is another way to obtain more accurate index range category by using classification method with Decision Tree [22].

Table I. INDONESIAN AIR POLLUTION STANDARD INDEX

ISPU (Index Value)	**Range**
0-50	Good
51-100	Moderate
101-199	Unhealthy
200-299	Very Unhealthy
300-500	Dangerous

IV. Result And Discussion

A. *Blockchain Data Communication Performance*

The Blockchain communication in this occurred between node. In this case, there are three nodes that connected each other. There are Armchain 1, Armchain 2, and Armchain 3. All three nodes are located in the same region. The data transferred between them are JSON encoded string containing sensor measurement value which its sizes approximately 200 bytes. This data include air quality sensor measurement and the timestamp of the data. To evaluate the time performance, we measured the time elapsed between each node. When the data is published from Armchain 1, the received time is calculated on the Armchain 2 and Armchain

3. The time is measured using epoch [23] UNIX timestamp in nanosecond.

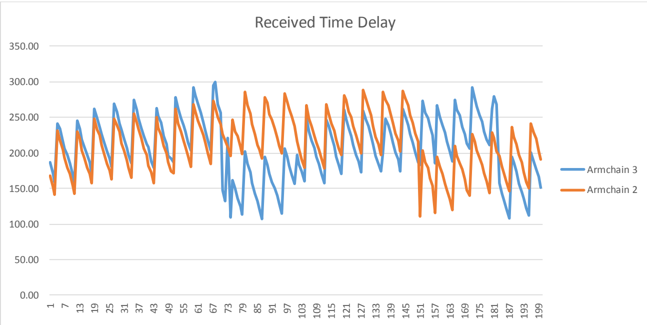

Fig 6. Transmission Time Evaluation

The transmission time of blockchain communication between node is displayed in Figure 6 calculated from the delta between send and received time of 200 data in a millisecond unit. By calculating the mean of the data, it can be concluded that the Blockchain data communication performance has an average delay of 212.12ms on Armchain 2 and 207.01ms on Armchain 3. In contrast to MQTT protocol conducted by Lars D¨urkop (2015) [24] In accordance with the research conducted by V. Altukhov (2014) [25] , the transmissions time of blockchain protocol is slower compared to MQTT that has average delay of 40ms.

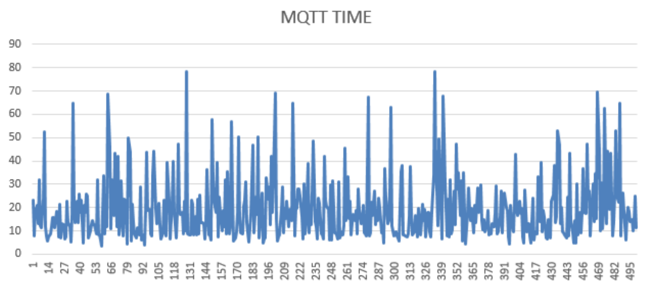

Fig 7. MQTT Transmission Time

During the test displayed in Figure 7 The transmission time of MQTT communication between calculated from the delta between send and received time of 500 data in a millisecond unit. By calculating the mean of the data, it can be concluded that the MQTT data communication performance has an average delay of 19.29 ms. The compared transmission time between MQTT and Blockchain is shown in Figure 8 below.

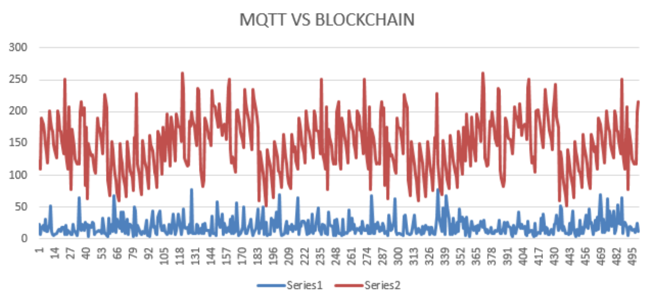

Fig 8. MQTT Vs Blockchain

B. *Data Visualization*

This visualization system helps to provide an integrated view across numerous sensor measurement. The numerical data from the sensor is translated into a language that easy to understand and analyze by presenting on visual language. The visualization dashboard can be accessed from 'http:[node_address]/armchain/?chain=arm1&page=visualization.

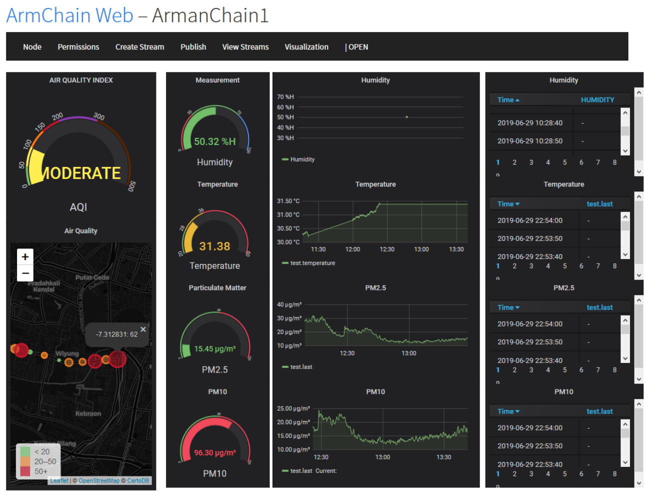

Fig 9. Visualization Dashboard

Figure 7 shows a graphical display of air quality data measured on a current sensor runtime.

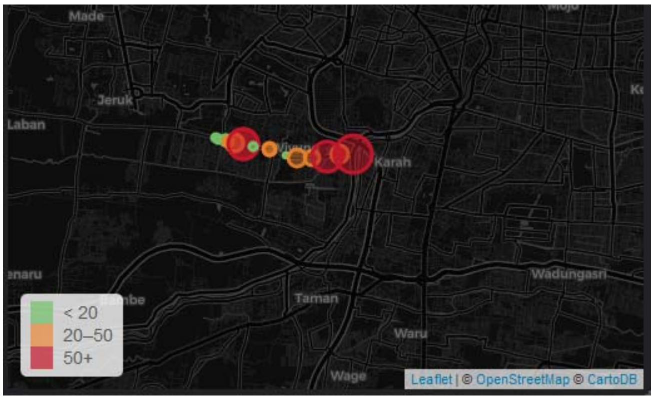

Fig 10. Air Quality Heat Map Visualization

Figure 8 shows a heat map view of air quality index over the road.

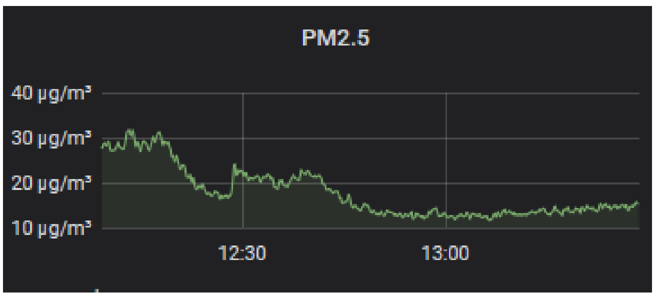

Fig 11. Graph Visualization

Figure 9 shows a graph view of Particulate Matter data show based on time measured. This visualization shows that the data collected from VaaMSN can be received to the visualization dashboard using blockchain communication protocol.

V. Conclusion

In this section, we conclude our work and focus on the aspects that we faced in the course of our development. During the implementation phase of our project, we can implemented a communication protocol using blockchain. During testing the transmission time using blockchain, the average time between node is 212.12 milisecond. While the transmission time of the data using MQTT in between node has an average delay of 19.29 millisecond. This can be said that the MQTT protocol is much faster than blockchain in term of communication speed. The visualization of the data using Grafana and InlfuxDB is successfully displayed on web interfaces with the webserver hosted on each node.

Acknowledgment

This research is funded by KEMERISTEKDIKTI from “Penelitian Terapan Unggulan Perguruan Tinggi” in 2019 scheme with the number: T/140/E3/RA.00/2019 and the title is “Implementation Vehicle as a Mobile Sensor Network terintegrasi dengan Smart Environment Monitoring and Analytics in Real-time(SEMAR) system sebagai Pemantauan Permukaan Jalan dan Lingkungan untuk mendukung Smart City”.

References

[1] M. H. Miraz, M. Ali, P. S. Excell, and R. Picking, “A review on Internet of Things (IoT), Internet of everything (IoE) and Internet of nano things (IoNT),” in Proc. Internet Technol. Appl. (ITA), Sep. 2015, pp. 219–224.

[2] S. H. Hashemi, F. Faghri, P. Rausch and R. H. Campbell, "World of Empowered IoT Users," 2016 IEEE First International Conference on Internet-of-Things Design and Implementation (IoTDI), Berlin, 2016, pp. 13-24.

[3] J. Lin, W. Yu, N. Zhang, X. Yang, H. Zhang and W. Zhao, "A Survey on Internet of Things: Architecture, Enabling Technologies, Security and Privacy, and Applications," in IEEE Internet of Things Journal, vol. 4, no. 5, pp. 1125-1142, Oct. 2017.

[4] Nakamoto, Satoshi. 2009. Bitcoin: A Peer-to-Peer Electronic Cash System. Cryptography

[5] Qijun Jiang, Frank Kresin, Arnold K. Bregt, et al., “Citizen Sensing for Improved Urban Environmental Monitoring,” Journal of Sensors, vol. 2016, Article ID 5656245, 9 pages, 2016.

[6] L. Kang, S. Poslad, W. Wang, X. Li, Y. Zhang and C. Wang, "A Public Transport Bus as a Flexible Mobile Smart Environment Sensing Platform for IoT," 2016 12th International Conference on Intelligent Environments (IE), London, 2016, pp. 1-8.

[7] A Mochamad Rifki Ulil et al 2019 IOP Conf. Ser.: Earth Environ. Sci.239 012034.

[8] Rasyid, A., Yusuf, A. A., Falah, M. F., Panduman, Y., Albaab, M. R. U., Basuki, D. K., ... Yudianto, F. (2019, September). Pothole Visual Detection using Machine Learning Method integrated with Internet of Think Video Streaming Platform. . In 2019 International Electronics Symposium (IES).

[9] Pratama, Y. P., Basuki, D. K., Sukaridhoto, S., Yusuf, A. A., Yulianus, H., Faruq, Putra, F. B. (2019, September). Designing of a Smart Collar for Dairy Cow Behavior Monitoring with Application Monitoring in Microservices and Internet of Things-Based Systems. In 2019 International Electronics Symposium (IES).

[10] C. Xie, Y. Sun and H. Luo, "Secured Data Storage Scheme Based on Block Chain for Agricultural Products Tracking," 2017 3rd International Conference on Big Data Computing and Communications (BIGCOM), Chengdu, 2017, pp. 45-50.

[11] A. Dorri, S. S. Kanhere, and R. Jurdak. (Aug. 2016). ‘‘Blockchain in Internet of Things: Challenges and solutions.’’ [Online]. Available: https://arxiv.org/abs/1608.05187

[12] Putra, F. B., Yusuf, A. A., Yulianus, H., Pratama, Y. P., Humairra, D. S., Erifani, U., Basuki, D. K., Sukaridhoto, S., Budiarti, R. P. N. (2019, September). Identification of Symptoms Based on Natural Language Processing (NLP) for Disease Diagnosis Based on International Classification of Diseases and Related Health Problems (ICD-11). In 2019 International Electronics Symposium (IES).

[13] Berlian, M. H., Sahputra, T. E. R., Ardi, B. J. W., Dzatmika, L. W., Besari, A. R. A., Sudibyo, R. W., & Sukaridhoto, S. (2016, September). “Design and implementation of smart environment monitoring and analytics in real-time system framework based on internet of underwater things and big data”. In Electronics Symposium (IES), 2016 International (pp. 403-408). IEEE.

[14] C. Pahl, S. Helmer, L. Miori, J. Sanin and B. Lee, "A Container-Based Edge Cloud PaaS Architecture Based on Raspberry Pi Clusters," 2016 IEEE 4th International Conference on Future Internet of Things and Cloud Workshops (FiCloudW), Vienna, 2016, pp. 117-124.

[15] B. Lin, Y. Chen, X. Chen and Y. Yu, "Comparison between JSON and XML in Applications Based on AJAX," 2012 International Conference on Computer Science and Service System, Nanjing, 2012, pp. 1174-1177.

[16] J. Sáenz, J. Chacón, L. De La Torre, A. Visioli and S. Dormido, "Open and Low-Cost Virtual and Remote Labs on Control Engineering," in IEEE Access, vol. 3, pp. 805-814, 2015.

[17] Y. Yuan and F. Wang, "Blockchain and Cryptocurrencies: Model, Techniques, and Applications," in IEEE Transactions on Systems, Man, and Cybernetics: Systems, vol. 48, no. 9, pp. 1421-1428, Sept. 2018.

[18] D. Li, Y. Lyu, J. Gui and W. G. J. Halfond, "Automated Energy Optimization of HTTP Requests for Mobile Applications," 2016 IEEE/ACM 38th International Conference on Software Engineering (ICSE), Austin, TX, 2016, pp. 249-260.

[19] Influx DB—Time Series Database. Accessed: July. 27, 2019. [Online]. Available: https://www.influxdata.com

[20] M. Brattstrom and P. Morreale, "Scalable Agentless Cloud Network Monitoring," 2017 IEEE 4th International Conference on Cyber Security and Cloud Computing (CSCloud), New York, NY, 2017, pp. 171-176.

[21] Head of Environmental Impact Control Agency, Perhitungan Dan Pelaporan Serta Informasi Indeks Standard Pencemar Udara [Calculation And Reporting As well as Information on Air Pollution Standard Index]. Indonesia: of Environmental Impact Control Agency.1997.

[22] F. Panduman, Yohanes Yohanie Fridelin , Besari, Adnan Rachmat Anom , Sukaridhoto, Sritrusta , Budiarti, Rizqi Putri Nourma , Sudibyo, Rahardhita Widyatra, Nobuo, “Implementation of Integration VaaMSN and SEMAR for Wide Coverage Air Quality Monitoring,” Telkomnika Indones. J. Electr. Eng., vol. Vol 16, No, 2018.

[23] IEEE Standard for Information Technology--Portable Operating System Interface (POSIX(R)) Base Specifications, Issue 7," in IEEE Std 1003.1-2017 (Revision of IEEE Std 1003.1-2008) , vol., no., pp.1-3951, 31 Jan. 2018

[24] L. Durkop, B. Czybik and J. Jasperneite, "Performance evaluation of M2M protocols over cellular networks in a lab environment," 2015 18th International Conference on Intelligence in Next Generation Networks, Paris, 2015, pp. 70-75.

[25] Altukhov, V., and E. Chemeritskiy. "On real-time delay monitoring in software-defined networks." Science and Technology Conference (Modern Networking Technologies)(MoNeTeC), 2014 First International. IEEE, 2014.