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# MONITORING SYSTEM DESIGN BASED ON INTERNET OF THINGS (IOT) AT THE XYZ COMPANY DATA CENTER

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**ABSTRACT**

XYZ company is an engaged consumer electronics and mobile communications company. The use of information technology plays a significant role in this company to run business. Therefore, XYZ companies need to change the DC environment due to the utilization of information technology to adapt to the increasingly competitive competition. The new solutions are going to expect to benefit from a more efficient IT budget. Currently, there is a monitoring system on the DC that provides alerts in the form of indicators that are difficult to be accessed by PT XYZ because of the location is far from the DC; it is indeed challenging to analyze the cause of the server when experiencing downtime or failure. Monitoring is currently in the form of reports provided by DC service providers. Furthermore, this study aims to design a monitoring system using temperature, humidity, and voltage sensors on DC-based Internet of Things (IoT) to identify the air condition and energy consumption used for maximum server performance. The device used is a DHT11 sensor as a temperature and humidity sensor. The voltage sensor operated here is ZMPT101B, which serves to read voltage values, on the microcontroller side using Arduino that serves to process data read from the sensor. The entire process performed by IoT that is going to be sent by ethernet shield to the database server and visualized using Grafana as a monitoring dashboard. This study explains how IoT is able to measure the temperature, humidity, voltage, and availability service providers offer. The method used for availability measurement is AST to classify the DC tier used. The new solution expected that this research could be an input for companies in monitoring DC SLA offered by service providers to meet the company's needs.

**Keywords:** *Internet of Things, Data Center, Availability Service Time, Monitoring, Micro-Controler*

## 1. INTRODUCTION

Information Technology (IT) has become a significant need for every company. IT presence has facilitated business processes, data transmission, and information needed to support business continuity. Increased internet usage as one of the current IT utilization can increase energy consumption in Data Center (DC).

DC is a facility that runs services and applications provided by the internet, enterprise systems, and others. DC is also one of the most critical aspects of an IT company's operations because it consumes enormous power [1]. Therefore, companies need to make sure the DC they have is working safely and optimally. Various equipment in DC produces heat so high that it can cause a down on servers and equipment. Mistakes that occur in maintaining such equipment can disrupt the running of the company's business. As the core infrastructure of big data, DC will become more critical. DC is a complex infrastructure that includes computers, networks, and storage systems and includes redundant communications, controls, monitoring, and security devices. DC plays an essential role in ensuring the sustainability of IT infrastructure and providing the necessary assurances for information security [2]. DC must comply with several conditions according to ANSI/TIA-942-A (Telecommunication Infrastructure Standard for Data Center). They are temperature must be 18 - 27°C (64-81°F) dry bulb temperature, maximum humidity rate in 60%, maximum due point in 15°C (59°F), maximum temperature changes in between 5°C (9°F)/ hour, the maximum relative voltage is 338V and minimum relative voltage is 180V.

Another important thing to note is that an officer must be in the server room if they want to turn on the server or check whether the server room

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temperature is enough to work optimally. Problems arise because the server space is usually located quite far away and must always lock for security reasons. So it takes a control system and monitor that can turn on the server remotely while monitoring the server room's temperature [3].

Previous research conducted to monitor DC focuses only on DC room temperature, as it did [2]. His research proposes a green DC air conditioning system assisted by cloud engineering consisting of three sub-systems: the AC system on DC, the cloud management platform. AC systems on DC include environmental monitoring, air conditioning, communication, ventilation, and temperature control. At the same time, the cloud platform provides data storage, analysis, big data predictions, and top-level applications. This study suggests that the study can significantly reduce DC energy consumption without reducing the cooling effect of DC. [3] Also, conduct research on temperature monitoring systems with IoT and Message Queue Telemetry Transport (MQTT) communication protocols applied to telemetry systems to obtain temperature changes in real-time and accurately. [4] researching IoT systems as one solution to monitor various points in DC. The study focused on colocation servers to monitor the temperature associated with ESP8266 to provide temperature data via SMS and email. This system makes it easier for DC management to decide if a situation does not run normally immediately. Therefore, in this study, researchers will implement it in a case study at XYZ company by monitoring the temperature, humidity, and voltage in the DC room to maximize server performance.

To monitor servers located in DC can take advantage of the Internet of Things (IoT). IoT has become a field of research since the development of internet technology and other communication media. IoT is one of the results of researchers who optimize several tools such as sensor media, radio frequency identification (RFID), wireless sensor networks, and other smart objects that allow humans to interact with all equipment connected to the internet network easily.

In recent years' services on the internet, mainly cloud services, have penetrated lives, businesses. It is expected to grow even more using big data, artificial intelligence (AI), IoT in the future. Especially in recent years, high-performance servers called high-performance computing (HPC), which are used for big data and AI, rapidly increase. Despite its high processing capacity, the amount of electricity and heat consumption also generated increases, and as the amount of heat increases, the energy needed for cooling also increases. In addition, with the rapid growth of mobile networks, the number of internet-connected devices is increasing, and the explosion of data generated by these devices poses significant challenges for computing and data storage. The rapidly growing big data industry is accelerating technological evolution and application innovation. Governments have realized that big data plays an essential role in economic development, public services, and national security.

The importance of DC monitoring system certainly also applies to XYZ company as a company engaged consumer electronics and mobile communications company, and companies need to change their DC environment. DC needs change to respond to increasingly competitive competition. They need to implement new technologies that are expected to benefit lower costs and increased revenues. In the past, DC was used primarily to support internal functions. However, today they are used to support end-user applications and content.

In this study, the monitoring system that will be designed will be used to measure the temperature in DC as an impact on increased energy consumption, so that cooling in the DC room is important to note to maximize server work and monitor voltage to maximize server performance. A server room temperature monitoring system is helpful for monitoring server room temperature in an agency or company [5]. A sensor placed in the DC room will be monitored for temperature. However, only a sensor integrated with a server room provides warnings in sound and light in the existing monitoring system. The current server room temperature monitoring system requires a considerable administrator role, as the administrator must be in the location where the system works. The existing system creates time and place inefficiencies, especially for server room administrators. Existing systems are also independent / run independently, which there is currently no connection between systems in every server space in an agency. It makes the arrangement and control of the entire server space less effective so that the old system is less suitable for application to an agency or large-scale company such as XYZ company.

In addition, this monitoring system will also monitor Service Level Agreements (SLA) offered by service providers, such as downtime and power failure. Downtime and power failure have a significant negative impact on the company. There are four most common causes of DC operating outages: systems, networks, databases, and

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applications. The most common outages include [6], i.e., there can be problems such as operational errors, user errors, third-party software errors, software problems developed internally, inadequate change control, and lack of automated processes. The usual problems often occur for the network side, such as overperforming, peak load problems, and inefficient bandwidth. In databases, problems that often arise are running out of disk space and excessive performance. The last common thing that often occurs is the application problems encountered, such as application errors, inadequate change control, and not dichotomized applications.

In this monitoring system, there will be the utilization of IoT sensors in DC in the form of temperature, humidity, and voltage sensors. So that the data can be used to monitor the SLA of DC service provider XYZ company to ensure the SLA is offered.

## 2. RELATED WORKS

In related research by [7] was developed a technique and method for real-time measurements based on the fusion of embedded sensors and systems, with connectivity to the communication network in the generation of a dedicated database, for information processing with open software and hardware resources for temperature and humidity monitoring in a DC and located in a region of humid tropical climate, in the south-southeast of Mexico, specifically in the TECNM-Villahermosa. IoT was implemented based on adaptive models, applied in DC, which continuously monitors the temperature and humidity behavior, which results in significant benefits to the institution, organizations, and consequently to its customers, achieving greater productivity and avoiding losses by reducing failures in computer equipment, which will contribute to the saving of energy supplies and the preservation of natural resources. This research used IoT formed by a network of seven DHT22, Arduino Uno (Rev3), and Ethernet shield card. The system's design incorporates a shield-type Ethernet card, set in the embedded system Arduino Uno, to which an Unshielded Twisted Pair (UTP) is connected and has the functionality in its firmware to write an IP to communicate through the TCP/IP protocol with other network devices. The system work from DHT22 initialization, MAC address and IP assignment of the Ethernet shield card, the function that receives temperature and humidity of the endpoint sensors, a function of data sending to the web service, loop cycle function, data reading, sending information to the communication center for sending to the database, and visualize the data in mobile and web interface. Six of the seven temperature sensors implemented in the DC are within the standard's optimum range. Only the sensor placed in the hot aisle exceeds the upper limit. However, it is necessary to maintain the humidity ranges since as the temperature increases, the humidity decreases. The final average temperature range was 18.097◦C - 21.224◦C from the measurements obtained, which meet the ASHRAE standard. On the other hand, the average humidity range 48.82%-55.71% RH is within the range rule. The development monitoring system allowed to observe that in specific periods the values of humidity exceed the norm ranges; it is recommended that the institution acquire a team dehumidifier or implement a cooling system suitable for the DC.

Internet of Things has been increasingly implemented in many sectors of industry. As research on [4] was developed a monitoring system in the DC with ESP8266. The ESP8266 is loaded with the firmware program written in C++ that does all the interfacing with sensors, processing the sensor data and interfacing with cloud platform and finally uploading the data to the cloud platform ideally once every one minute. As the prototype system is deployed at a setup, the live data is monitored over the cloud dashboard. The dashboard continuously presents the live data. It also sends out a mail to the defined email. A continuous test run of more than 24 hours shows the steady performance of ESP8266. This system adds up value to the existing on-site monitoring system available at DC. It provides much comfort to the higher authority of DC management to monitor the parameters from remote anytime with the help of the dashboard.

Periyaldi [3] also conducted research using IoT to monitor DC. This research uses a temperature sensor and Raspberry Pi as MQTT Client. The Raspberry is connected via the internet with the Slimline PC as the MQTT broker in the NOC room. Slimline PC also functions as a Monitoring Server to process the data on the MQTT broker connected to the Monitoring Platform. The design of the server room temperature monitoring system is beneficial for monitoring the server room temperature.

Rodriguez [8] developed a wireless sensor network for data-center environmental monitoring to improve energy efficiency and optimal data-center performance at Argonne National Laboratory. They used networked wireless nodes with temperature and humidity sensors. A 24-hour

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test run at Argonne's DC has demonstrated that the wireless networked environmental monitoring solution is easy to integrate and manage with the existing IT infrastructure while delivering better visibility into the DC 3D temperature and humidity distribution.

*Table 1: Summary Of Literature Review in Previous Work*

| Research | Topics | Parameter | Method |
|---|---|---|---|
| [7] | IoT implementation on DC to monitor temperature and humidity | temperature and humidity | Web service |
| [3] | Implementation of IoT-based server room temperature monitoring system with MQTT | temperature | MQTT |
| [4] | DC temperature monitoring with WSN and cloud based ESP8266 | temperature | Web service |
| [1] | Energy efficiency at DC and temperature with IoT | temperature | Zigbee |
| [2] | Green data center IoT with cloud technique at temperature | temperature | Wired & Zigbee |

In the recent research, temperature and humidity are important factors that can ensure proper server function and performance in the DC. Based on previous research on DC monitoring, various techniques that used in monitoring temperature, including using the Internet of Things (IoT) using Raspberry Pi and Arduino based on the Cloud, SMS Gateway, MQTT, Web, Thermal Management, and Wireless Sensor. In this study, in addition to monitoring temperature and humidity to monitor SLA of DC also conducted research on monitoring voltage to monitor the level of availability of the DC, using ethernet shield so that the process of sending data to the database server can be stable, so that with the results of monitoring carried out can provide input on the customer side and the DC if the monitored SLA is below than offered by the service provider.

## 3. RESEARCH METHODOLOGY

### 3.1 Research Framework

Figure 1 is a framework in this study that begins with understanding the background of XYZ company activities. Company XYZ uses several application systems that can be accessed 24 hours and integrated with branch offices spread throughout Indonesia for the business to run smoothly. However, some applications cannot be accessed for 24 hours non-stop on some occasions, so that these constraints can hamper the process of business activities in XYZ company. The hardware, applications, and data have been placed on dc colocation tier III vendors used by XYZ company.

To determine objectives and scope in this research, necessary to understand and identify problems from the background. From the conditions that have occurred in DC XYZ company, the need for an IoT-based monitoring system to monitor the status of DC in collaboration with XYZ company, it is necessary to know the SLA of DC offered by the service provider has met the needs of XYZ company. Observations were made to find out the initial condition of the DC service provider. Through the stages of literature studies, search for literature sources regarding DC monitoring system research and IoT that have been done before and make comparisons to distinguish previous research. Data collection and analysis are needed to determine the design of the IoT and monitoring system used on the XYZ company server.

In the early stage, monitoring systems and IoT design is used by testing and calibration first before direct testing of DC service providers. After testing on DC, it takes an analysis of validation results from the system's design that has been made by the availability serviced time (AST) method to perform tier classification on the DC. The provision of research results in the form of conclusions and suggestions based on the results of AST analysis is expected to be helpful for the company to meet the

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needs of XYZ company, service provider, vendor, or another researcher. This monitoring system is also expected to be implemented by the service provider and facilitate the operator's work on DC service providers. XYZ company itself is expected to streamline the business with measurements and parameters that this monitoring system can provide.

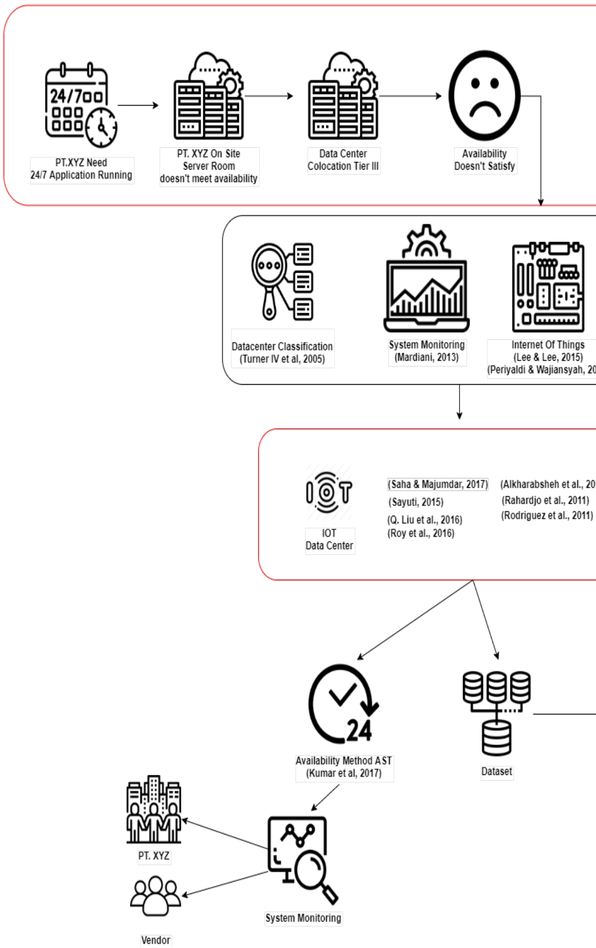


*Figure 1: Research Framework*

The study was conducted on DC providers co-operating with XYZ company, where XYZ hired a service co-location on DC to store hardware equipment, data, and applications used by the company. The selection of places based on the facilities and services offered by the service provider meets the criteria of the XYZ company. DC vendor has Tier III certification from Up Time Institute. Tier III has an availability of 99,982% of total downtime below 1.6 hours per year. DC in general, server racks have a two-row section, cold aisle that serves to get cold air into the server rack components. The back row is a hot aisle that serves to release hot air, as in Figure 2.

*Figure 2: Data Center Location*

### 3.2 IoT Architecture

The IoT architecture in Figure 3 is a reflection of IoT design techniques on DC monitoring systems. Design starts by connecting the power supply as a power source for the Arduino Uno and actuator. After creating the C++ language program on Arduino IDE 1.8.15, the program upload into Arduino Uno memory. Ethernet Shield is connected to Arduino Uno as a data aggregator to the Application Server and processed to the Remote Database Server. Before running the program in Arduino IDE 1.8.15, the DHT11 temperature and humidity sensor & ZMPT101B voltage sensor will

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read the voltage as a sensor that shows the power side on the Active / ON rack server that will be the input on the Arduino Uno connected through the Arduino Uno analog port.

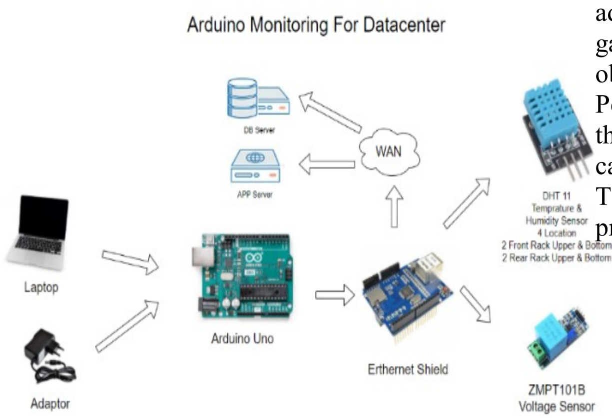


*Figure 3: IoT Architecture*

### 3.3 Hardware Design

The image in Figure 4 is a scheme of tools used as the specifications have been described in the previous chapter. The tools used are one Arduino Uno, four DHT11 Sensors, one ZMPT101 sensor used to measure voltage, and one Ethernet Shield. The use of four DHT11 sensors is used to obtain a diversity of temperature and humidity data in DC that is useful for researchers and objects studied so that data at each location can be monitored for temperature and humidity.

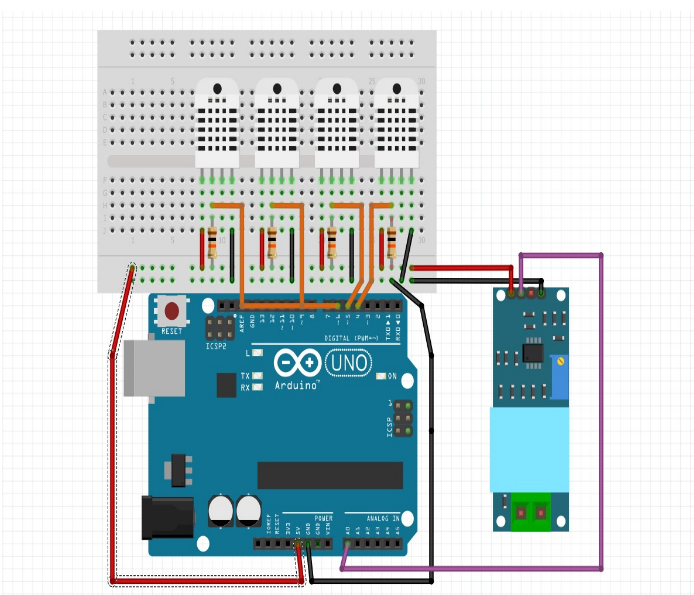


*Figure 4: Arduino Hardware*

The hardware IoT process in this study is described in Figure 5. The hardware IoT process begins by initializing the parameters and library used on the tool, followed by running ethernet shield modules to obtain Internet Protocol (IP) addresses, Domain Name Services (DNS), and gateways. Read the DHT11, ZMPT101B sensors to obtain temperature, humidity, and voltage data. Performing TCP communication to the server, if the connection is available, the result of data capturing by the sensor will be sent to the server. The final process is to delay intervals and loop programming code.

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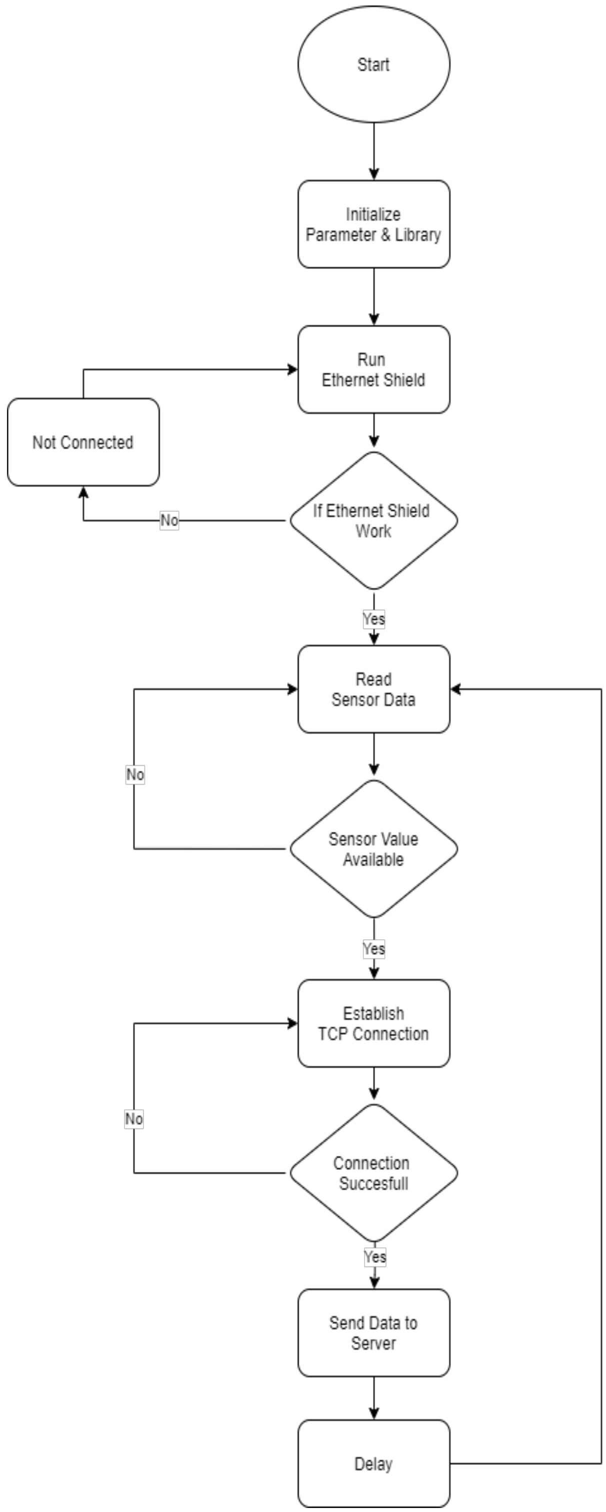


*Figure 5: IOT Hardware Flowchart*

#### 3.3.1 Arduino IDE

Arduino Integrated Development Environment (IDE) is a cross-platform application that uses the Java programming language and is derived from the IDE for processing programming languages and wiring projects. It is designed to introduce programming to other newcomers who are not yet familiar with software development. [9].

#### 3.3.2 Arduino Uno

Arduino Uno is an ATmega328-based microcontroller board. Arduino Uno differs from all previous boards in that it does not use FTDI USB-to-serial driver chips. In contrast, the Atmega16U2 feature (Atmega8U2 to R2 version) is programmed as a USB-to-serial converter.[10].

The module has 14 digital input/output pins (6 can be used as PWM output), six analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection power plugs, ICSP headers, and reset buttons. Here are the specifications of the Arduino Uno R3 board

Arduino Uno is a microcontroller that makes it easy to prototype microcontroller programming with high-level programming language C++ and Arduino Uno supported by Arduino IDE software in the programming process.

#### 3.3.3 Ethernet Shield

Ethernet shield is based on the Wiznet W5100 Ethernet chip. Wiznet W5100 provides IP networks that support TCP and UDP connections. The Ethernet Library is used to write programs so that the Arduino board can connect to the network by using the Arduino Ethernet Shield [11]. Figure 6 shows the Ethernet Shield adds the ability of Arduino boards to connect to internet networks, making it possible to send and receive data from anywhere in the world with an internet connection.

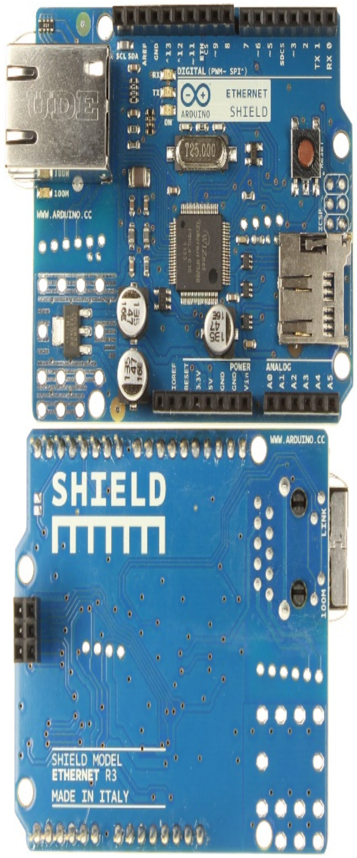


*Figure 6: Ethernet Shield*

### 3.3.4 DHT 11 Temperature & Humidity Sensor

DHT11 is a temperature and humidity sensor that produces a calibrated digital output. DHT11 can interact with any microcontroller output such as Arduino, Raspberry Pi. DHT11 is a humidity and temperature sensor that provides high reliability and long-term stability, suitable for this research.[12].

DHT11 sensor, in general, has a calibration feature of temperature and humidity reading values that are quite accurate. The storage of calibration data is contained in the OTP program memory, also called calibration coefficients. Specifications of the DHT 11 have Input voltage 5 Vdc, Temperature range 0-50°C error ± 2° C and Humidity 20-90% RH ± 5% RH error. As seen in Figure 7, DHT11 has four pins that have functions for dc power sources on pins 1 and 4. Pin 3 is used to get sensor reading results to be connected to the microcontroller

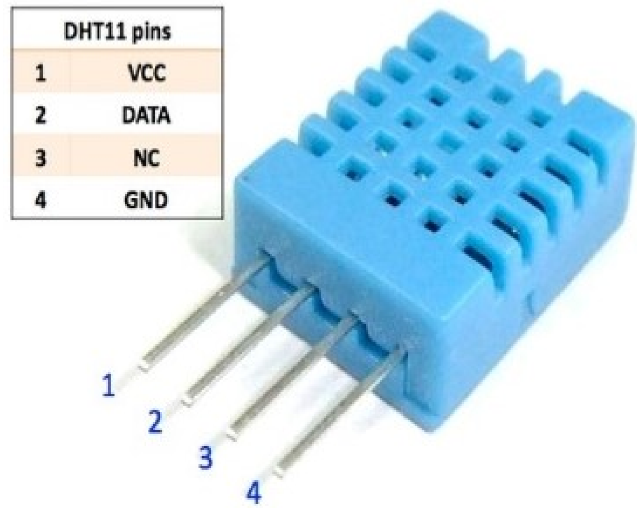


*Figure 7: DHT11*

### 3.3.5 ZMPT101B Voltage Sensor

The ZMPT101B Voltage Sensor is a voltage sensor made of ZMPT101B voltage transformers with high accuracy, good consistency for voltage and measurement power, and can measure up to 250V AC [13]. The ZMPT101B Voltage Sensor is an easy-to-use sensor with a multi-turn trim potentiometer to adjust AC and DC output.

ZMPT101B has six pins that function on pins one, three, and four as DC resources and two as a reader analog sensor connected to a microcontroller. Pin five and pin five functions to read the voltage of AC electricity as in Figure 8.

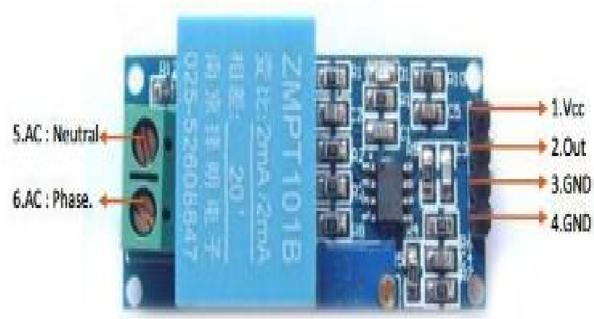


*Figure 8: ZMPT101B Voltage Sensor*

### 3.4 Monitoring System Design

Research monitoring system architecture can be seen in Figure 9. The monitoring system architecture in this study consisted of two layers, namely the device layer, web layer, and database. The division into two layers is considered necessary to explain the architecture of this monitoring system comprehensively.

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The Web Application Layer and database aim to collect and display data from the device layer that will be sent on the database side. On the device layer, this runs consists of Arduino sensors where several sensors are installed. Arduino will be in the contents of the firmware so that the sensor can work properly and the existing data can be sent over via WiFi modules installed on the Arduino board.

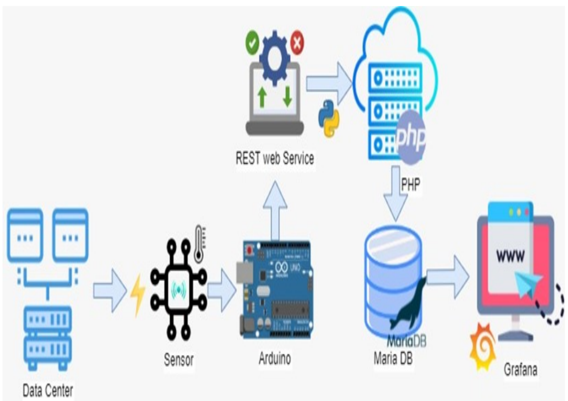


*Figure 9: System Monitoring Architecture*

### 3.4.1 REST Web Service

Communication between Arduino and the server uses Representational State Transfer (REST) web service. REST is a standard web-based communication architecture with resources between REST servers to communicate with REST clients. It takes a REST web server as an endpoint of data from Arduino to the server. The REST server will communicate with the database server to store the data received from sensor readings carried out by the IoT circuit. Data – data sent to rest servers in the form of JSON format as in Table 1.

*Table 2: JSON Table*

| Data | Data Type | Description |
|---|---|---|
| id | BIGINT | ID data |
| tem1 | DECIMAL (5,2) | Temperature Sensor “frontupper” |
| hum1 | DECIMAL (5,2) | Humidity Sensor “frontupper” |
| tem2 | DECIMAL (5,2) | Temperature Sensor “frontbottom” |
| hum2 | DECIMAL (5,2) | Humidity Sensor “frontbottom” |
| tem3 | DECIMAL (5,2) | Temperature Sensor “backupper” |
| hum3 | DECIMAL (5,2) | Humidity Sensor “backupper” |
| tem4 | DECIMAL (5,2) | Temperature Sensor “backbottom” |
| hum4 | DECIMAL (5,2) | Humidity Sensor “backbottom” |
| avg_tem | DECIMAL (5,2) | Temperature Sensor Average |
| avg_hum | DECIMAL (5,2) | Humidity Sensor Average |
| Volt | DECIMAL (5,2) | Status voltage |
| Status | TINYINT | Sensor Status |
| update_time | DATETIME | Timestamp |

### 3.4.2 Grafana

Grafana is a web application-based interactive visualization tool that focuses on data analysis and monitoring that can accommodate various databases and have alert systems [14]. Grafana was developed by Torkel Ödegaard in 2014. Grafana development refers to a time-series database and capable of compatibility with a wide variety of existing databases. The primary purpose of grafana is to facilitate access for users to view and analyze a data set.

The user interface owned by grafana is based on the third version of kibana. Grafana has a variety of templates that are interactive and have alert notifications as a complement to data analysis. Many companies often use Grafana to load data from databases into a comprehensive dashboard, thus making it efficient in analyzing data.

## 3.5 Calibration Tools

Before testing on DC, the sensor used in the study had to be calibrated. Calibration is the activity of establishing a relationship, under certain conditions, between a quantity value indicated by a measuring instrument or measurement system or a value presented by a measuring material or reference material with a corresponding value related to the applicable standard. The two sensors that will be calibrated are DHT11 and ZMPT101B. The sensor has three results: temperature, humidity, and voltage. The DHT11 sensor will read the temperature and humidity. Calibration of Temperature and humidity will use the HM 16 Beurer tool as in Figure 10. This tool has an accuracy of up to 0.1 ° C so that it is capable of set calibration on IoT

Journal of Theoretical and Applied Information Technology
31st October 2021. Vol.99. No 20


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Figure 10: Beurer HM16

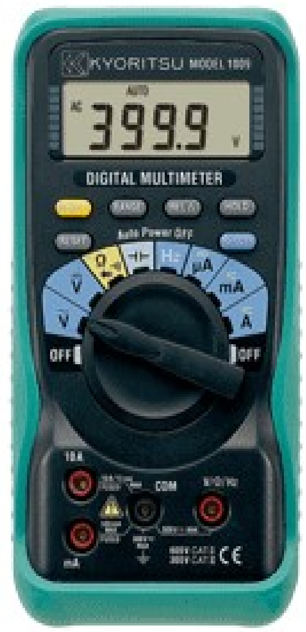


Figure 11: Kyoritsu 1009

Kyoritsu 1009 multimeter is an electric voltage gauge used to calibrate the ZMPT101 sensor used in this IoT. Kyoritsu is a Japanese company that manufactures electrical measurement devices of international standards so that professionals widely use them. Electrical measurement tools become the main products offered by this company: accuracy, durability, and after-sales service to attract consumers.

Kyoritsu 1009 multimeter has a display screen of up to 4000 counts. This tool also has an auto and manual range selector that can make it easier for users, as in Figure 11. Test the range of resistance continuously that can provide a voice to warn the user. Direct current measurement can reach 10A for AC and DC. This current limit is suitable to test the IoT tool to be designed.

### 3.6 Agreed Service Time Analysis

Agreed Service Time (AST) is the expected time of operation of a service. For example, if the level of service obtained stipulates that the user must access the system for 24 hours, the AST is 24 hours / 1,080 minutes / 64,800 seconds per day. downtime is the amount of time unavailability of service access during the AST period. According to [15], availability is the time seen in a percentage that signifies the availability of services within the network. The equation can calculate availability value as in (1).

$$Availability = \frac{AST - DT}{AST} \times 100 \quad (1)$$

All test results and findings obtained from this study will be concluded whether data from sensors placed on all four sides of the rack server has met the SLA standards offered by DC providers have Tier III standard

1. The AST offered by Tier III DC standard of 99.982% per year is 96 minutes downtime tolerance at one year.
2. The temperature and humidity offered by DC service providers are 22° C and 55% RH on humidity so that the server can work optimally.

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## 4. RESULT AND DISCUSSION

IoT prototype results that have been made for the monitoring system on DC. As in Figure 12, the circuit consists of Arduino Uno, Breadboard, Ethernet shield, DHT11 sensor, and ZMPT101B sensor. The circuit is assembled using a casing made of transparent ABS in order to be able to monitor the Arduino board easily. The number of DHT 11 sensors used amounted to four sensors. The ZMPT101B sensor is one sensor. one Breadboard sensor, one Arduino board, and one ethernet shield.

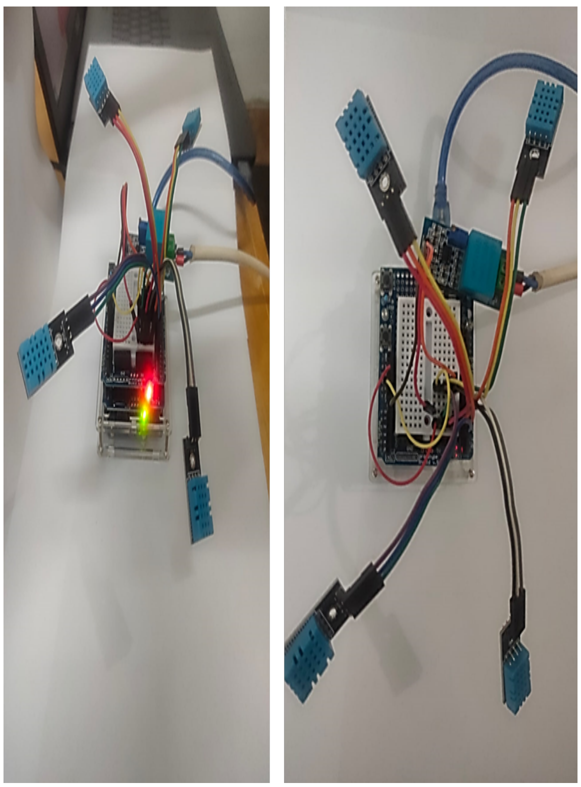

*Figure 12: IOT Prototype*

An activity diagram is a design of the flow of activity or workflow in a system to be run. Activity diagrams are also used to define or cluster the system flow display. Activity diagrams have components with specific shapes connected by arrows. The arrow leads to a sequence of activities that occur from start to finish. This research activity diagram is in Figure 13.

The monitoring system has four layers in this activity diagram: sensor, service, network, and application. The initial activity measures the temperature, humidity, and voltage in the DC captured by the sensor. The next activity is to read the data on the sensor and can be received by the IoT. The next step is the data sent to REST web service and then sent through the network layer into the MariaDB database. In the final step, Grafana will show the data.

Unified Modeling Language (UML) is an architectural system that works in Object-Oriented Analysis / Design (OOAD) with a consistent language for determining, visualizing, constructing, and documenting pieces of information used or generated in a process called artifacts [16]. UML can also be defined as the standard language for system visualization, design, and documentation or the standard language for writing software designs. UML has several modeling diagrams: use case, activity, sequence, component, and class diagrams. A use case diagram is a UML diagram model used to describe the expected functional agreement of a system [16].

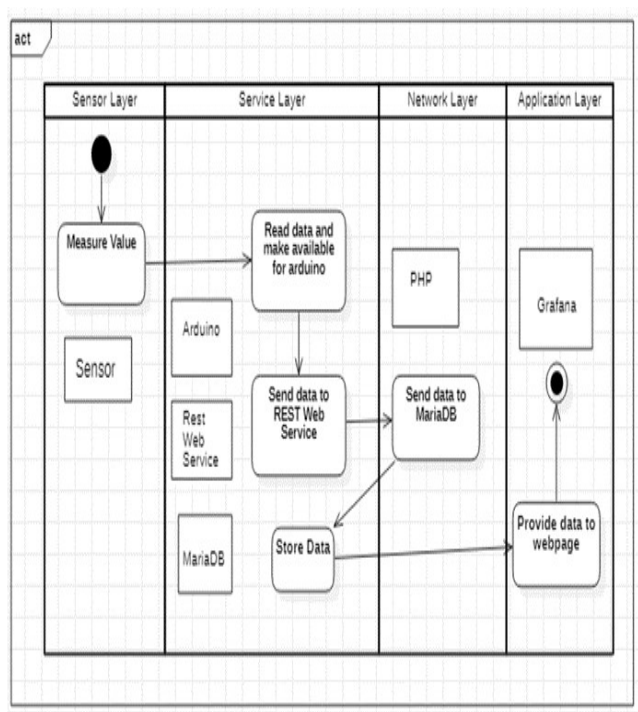


*Figure 13: Activity Diagram*

A class diagram describes a group of objects with the same property, behavior (operation), and relationships in Figure 14. So that the class diagram can provide a global view of a system, this is reflected in the existing classes and their relationship with each other. This study's class diagrams are divided into six classes: Sensor, IoT, PHPWebService, DC, Grafana, and Tier Classification. Sensor Class has three attributes: sensor id, position, and type. The class sensor also

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has a capture operation to capture temperature, humidity, and voltage data.

IoT Class has four operations: initialize, captured, connect, and send data. Initialize on IoT is to initiate variables on IoT to work on IoT. This operation initiates so that IoT can capturing the data (capture) from the sensor, connecting to the database (connect), and sending data (send data) to the database. The PHPWebService class has the operation to receive data from IoT and capture it. DC Class has a position, temp, hum, volt, time, and date attributes and has captured and calculate operations.

Grafana Class has six attributes: user id, name, username, password, email, and organization. Grafana class also has a show, password change, and notify operations. In the show operation, grafana displays data results from DC monitoring in interactive data to make it easier for users to assess data. Notify is also in grafana operations to provide initial warnings to users and executives to streamline their performance.

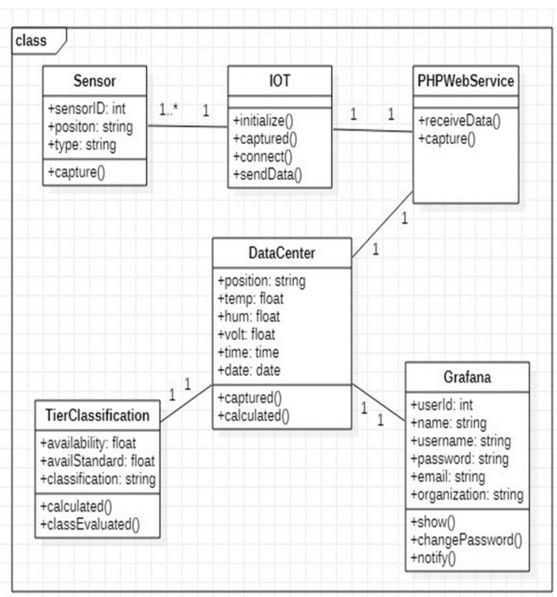

*Figure 14: Class Diagram*

Use Case Diagram is an overview of the user's interaction with the system by performing functions that the system can accept. In the use case diagram intended in this study, there are two: the use case diagram IoT and the use case diagram web application. Use case diagram of the IoT in this research can be seen in Figure 15. Actor in the IoT use case is identified as a user that is every user who can access dashboard monitoring, administrator as a user or act as an administrator to manage users who can access the dashboard, Arduino as a microcontroller to measure and transmit sensor temperature, humidity, and voltage data. The last actor is a Grafana, a dashboard system that accepts and displays parameters from the sensor to be seen and accessed by the user.

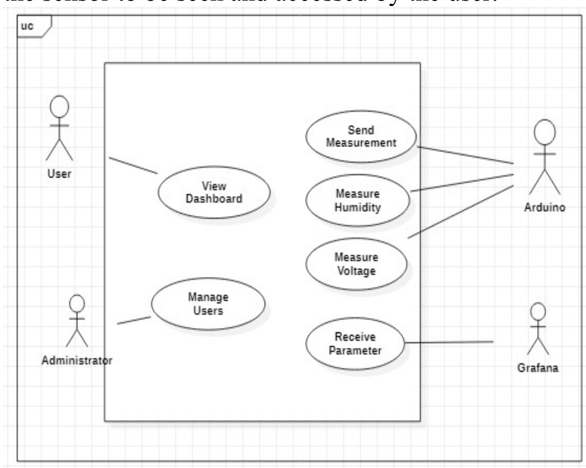

*Figure 15: Use Case IoT Hardware*

The use case of the application web diagram can be seen in Figure 16. Actors in this diagram are identified as several actors: executives who act as company officials who can receive dc tier classification notifications and reports. These users act as users who play a role in monitoring dashboard monitoring. Administrators have access to manage various users for the determination of access rights at each level. Arduino is a microcontroller that does not transmit sensor measurement data to the database server. Grafana as a visualization for dashboard systems and web service as a parameter receiver of a microcontroller.

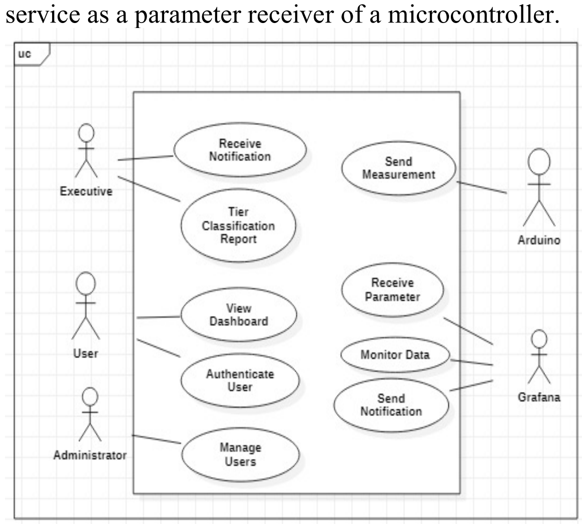

*Figure 16: Use Case Application*

DHT 11 sensor testing that can measure temperature and humidity will test before being

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placed in DC. The sensor is tested to ensure that the sensor is calibrated correctly. The calibration method is used with the IoT sensor comparing with Beurer HM 16 Thermo Hygrometer. Figure 17 shows data captured by the first and second DHT 11 sensors. On the LCD screen, sensor one reads T1:29.40, H1:67, T2:29.50, and H2:68.0. The temperature sensor one has a value of 29.40 ° C, Humidity Rate one has a value of 67.0%, temperature sensor two has a value of 29.50 ° C, and Humidity Rate two has a value of 68.0%. Seen in Beurer HM 16 in Figure 17 shows a temperature value of 29.7 °C and a humidity rate of 67%.

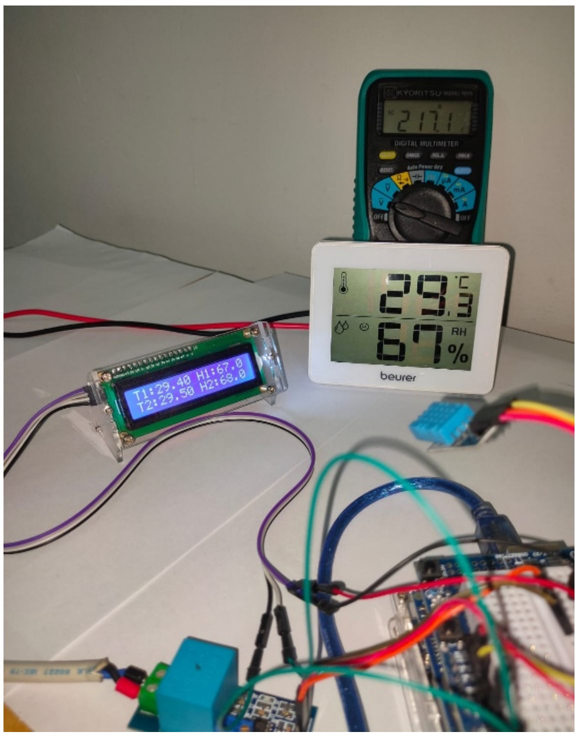


*Figure 17: DHT11-1 and DHT11-2 Calibration*

In Figure 18, the LCD screen shows that sensor one reads T3: 29.60, H4: 68.0, T4:29.50, and H4:68.0. Temperature sensor one has a value of 29.60°C, humidity rate three has a value of 68.0%, temperature sensor two has 29.50° C, and humidity rate four has a value of 68.0%. Beurer HM 16 in Figure 18 shows a temperature value of 29.7°C and humidity of 67%.

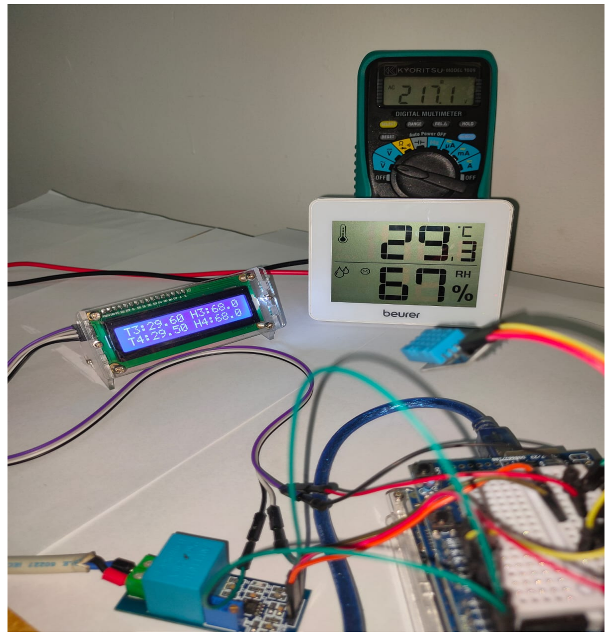


*Figure 18: DHT11-1 and DHT11-2 Calibration*

ZMPT101B sensor calibrating in Figure 19 to measure voltage tested before being placed in DC. The sensor is tested by correctly calibrating whether the sensor is calibrated. The calibration method was used with the voltage sensor comparison value with Kyoritsu 1009 multimeter. Figure 19 shows that the LCD screen shows data captured by the ZMPT101B sensor worth 217.59V, as shown in the Kyoritsu 1009 multimeter device worth 217.1V.

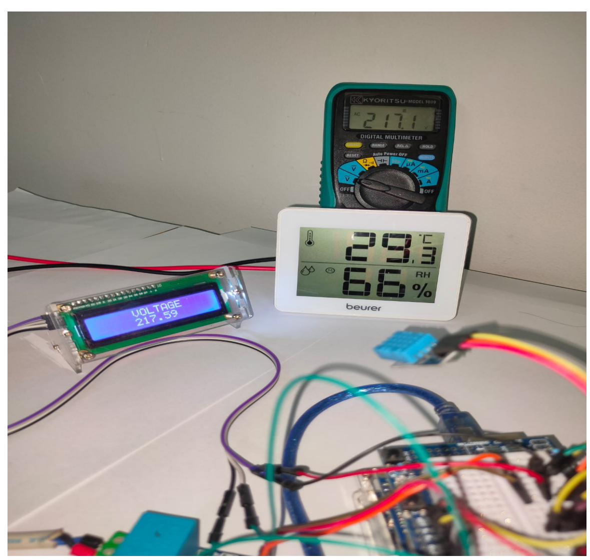


*Figure 19: DHT11-3 and DHT11-4 Calibration*

Figure 20 shows sensors located in the cold aisle. The DHT 11 sensor is placed at the top and bottom of the server rack. It aims to get different measurement results as a comparison for temperature and humidity values.

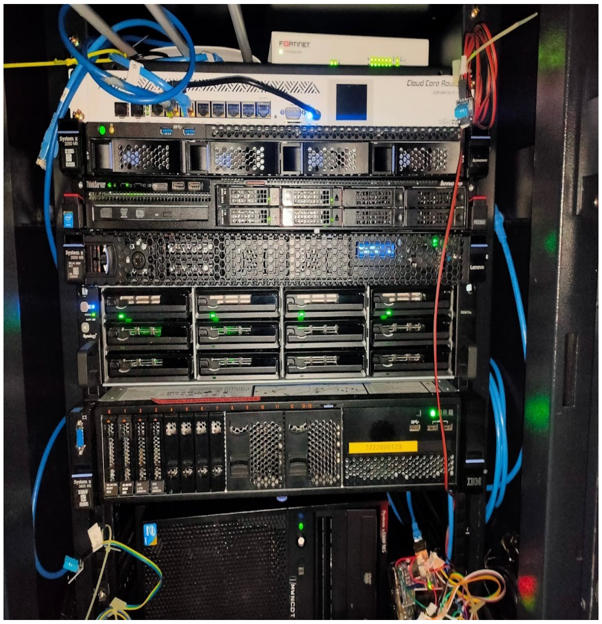

Figure 20: IoT placement on the cold aisle

In Figure 21, DHT 11 sensor is placed at the top and bottom of the server rack on the hot aisle. It aims to get different measurement results as a comparison for temperature and humidity values. So that later, it will be known the best position to put the server to work optimally.

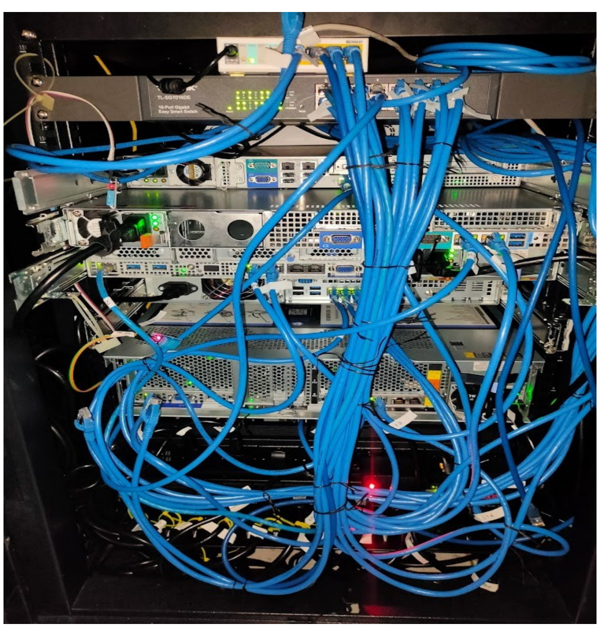

Figure 21: IoT placement on the hot aisle

Grafana is a dashboard software that has interactive visualization and rich features. This software provides different widgets, for example, time series, tables, text fields for a single metric. Grafana also supports many data sources, such as Graphite, Elasticsearch, InfluxDB, OpenTSDB.

The advantages of Grafana have many features. The quick Range selection makes navigating in the series precise and easy. Features in grafana have the zoom and auto-refreshing functions and settings that range that were often used before. The templates used in grafana are also the main attraction. Grafana templates define arrays, where they dynamically fill values automatically depending on the data and status of the Grafana [17]. The dashboard for the monitoring system is seen in Figure 22, which displays temperature, humidity, voltage, and availability.

Grafana supports many channel notification systems such as email, telegram, slack, and webhook to integrate with other applications easily. The monitoring system will send Figure 23 examples notifications to an administrator in an email temperature and humidity measurements outside the predetermined limit or malfunctions such as downtime.


Figure 22: Grafana Realtime Dashboard

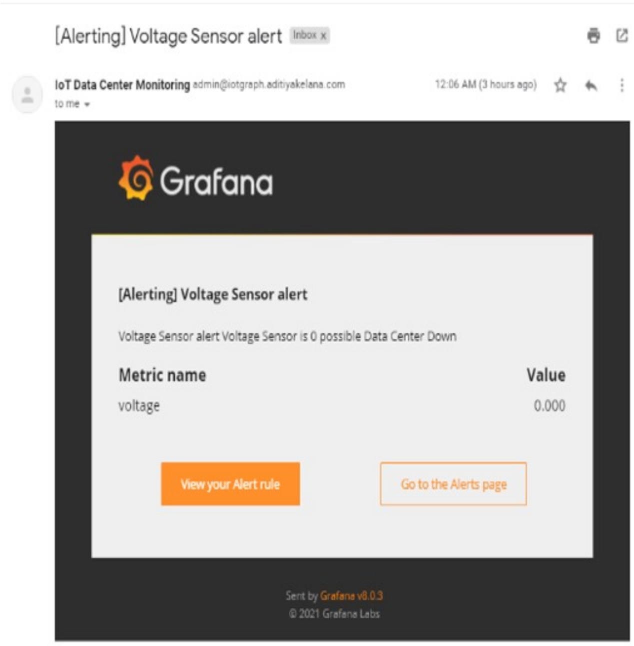


*Figure 23: Grafana Notification*

In this test, the monitoring system can work as previously designed. After the test process on the dashboard, data from several sensors showed the results of temperature measurements, humidity voltage, and AST calculations read well. The monitoring system managed to provide notifications to users, as in Figure 24.


*Figure 24: Grafana Dashboard*

The result temperature data is divided into four data variables, namely temp1, temp2, temp3, and temp4, as shown in Table 2. The average of the four variables is 25.95 ºC. Temp1 variable has 25.39 ºC of temperature average, Temp2 21.77ºC temperature average, Temp3 has 30.15 ºC of temperature average, and temp4 has 26.49 ºC of temperature average. The average temperature of the ideal location is in the front-bottom position of DHT-11-2 (temp2) because it is close to the SLA offered, which is 22 ºC, so it is recommended for XYZ company to place a critical server in that position so that performance is maintained because other positions have not met the SLA offered by the DC service provider.

*Table 3: Temperature Average Result*

| Sensor | Location | Average (ºC) |
|---|---|---|
| DHT11-1 | Front–Upper | 25.39 |
| DHT11-2 | Front–Bottom | 21.77 |
| DHT11-3 | Back– Upper | 30.15 |
| DHT11-4 | Back– Bottom | 26.49 |

The resulting humidity monitoring data is divided into four data variables, namely hum1, hum2, hum3, and hum4, as shown in Table 3. The average data of the four variables is 30.64 %RH. hum1 has an average humidity of 31.18 %RH, hum2 has an average humidity of 40.18 %RH, hum3 has an average humidity of 22.62 %RH, and hum4 has an average humidity of 28.58 %RH. In the SLA offered, the average humidity will be maintained at 55%. However, the research results on the monitoring system show an average humidity of 30.64 %RH, so it met the offer of the SLA from the DC vendor. The average value of voltage captured by the monitoring system is 230.52V, which is met the SLA offered by the DC service provider.

*Table 4: Humidity Average Result*

| Sensor | Location | Average (%RH) |
|---|---|---|
| DHT11-1 | Front–Upper | 31.18 |
| DHT11-2 | Front–Bottom | 40.18 |
| DHT11-3 | Back– Upper | 22.62 |
| DHT11-4 | Back– Bottom | 28.58 |

This research took data from 1 May 2018 until 1 May 2019. The monitoring system captured several downtime from the DC service provider within one year of testing, as in Table 4. From the downtime that occurred, the availability calculated by the monitoring system was 99.792%. In the DC Vendor SLA, Tier III is the category offered. Tier III must have a minimum availability value of 99.982%. However, from the calculation of the monitoring system on DC the availability value is 99.792% which is clustered in the Tier II category.

*Table 5: Downtime occurs in DC provider*

| Date | Downtime Minute |
|---|---|
| 17/05/2018 | 130 |
| 18/05/2018 | 5 |
| 19/05/2018 | 20 |
| 28/05/2018 | 220 |
| 29/05/2018 | 160 |
| 07/06/2018 | 5 |
| 27/06/2018 | 185 |
| 06/07/2018 | 35 |
| 27/09/2018 | 10 |
| 11/10/2018 | 5 |
| 21/10/2018 | 20 |
| 04/02/2019 | 5 |
| 07/02/2019 | 90 |
| 08/02/2019 | 170 |
| 25/02/2019 | 5 |
| 30/03/2019 | 5 |
| 09/04/2019 | 5 |
| 11/04/2019 | 10 |
| 23/04/2019 | 5 |
| 24/04/2019 | 5 |

## 5. CONCLUSION

The Implementation of a monitoring system based on IoT was working well. After one year of testing data retrieval. The performance in reading temperature and humidity with continuous precision was confirmed. Grafana's interactive design as a data visualization makes it easier for users and executives from XYZ company to monitor data. The multi-user account in grafana make this monitoring system usefull in organisazion subject. This system can be accessed anywhere and anytime. The system will immediately report executives via email if any malfunction or temperature and humidity did not meet the requirement of the SLA.

This monitoring system not only measures the humidity and temperature but also measures the voltage, so this system is able to calculate the total of availability in the DC. From the measurement, the temperature shows between 21.77 oC – 30.15 oC and the temperature average were 26.49 oC; the humidity range in 22.62% - 40.18% RH the humidity average was 28.58 %, and the final average of voltage was 230.5 V. Based on ANSI/TIA-942-A the temperature of back-upper sensor does not meet the requirements because it is in range of average 30.15 oC. However, the total average of the four sensors has passed the requirement. The SLA of DC offers a constant 22 oC temperature, but only the front-bottom meets the offer from the final temperature average. From all the data results of the monitoring system Availability marked in 99,792%, the DC is clustered to Tier II category. This research is limited to the room environment in the DC room in the first basement level in server rack number DC-JK2-192.C from May 2018 until May 2019 that XYZ company used. The server rack represents the real condition of SLA that DC offered to XYZ company.

The Availability is automatically counted by the system, make this system suitable for improving the business performances of XYZ company. Simplify decision-making for XYZ company executives because the system can show all the historical data and simple analysis, even the early notification warning. Hopefully, this system can help the DC service provider manage the DC environment and optimize the DC. Officers can maintain the cooling system of DC easily by checking the temperature anywhere and anytime. This research can propose the future work of:

1. Legislation and current requirement of installment of the DC.
2. Variables construction in environment monitoring system.
3. Artificial neural network to predict temperature and humidity in the DC.
4. Internet of Things 4.0
5. Transforming data via the Internet of Things device.
6. Machine learning for DC classification.

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