Design and Implementation of Real-Time Reading System of Atmospheric Corrosion Sensor on Metal Material Using Internet of Things (IoT) Technology

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Abstract— **Corrosion is an event of destruction of metal materials due to a chemical reaction between metal with substances in its environment. This research aims to develop a system that able to read the corrosion values from the existing atmospheric corrosion sensor and used internet of things (IoT) technology concept. The reading of sensor value conducted by connecting the atmospheric corrosion sensors with the IoT system, this IoT system will measure the incoming voltage value. Prototyping method was used for system development, that each stage was communication, quick plan and modeling quick design, construction of prototype, and deployment delivery and feedback. Several sensor, controller, actuator, and system used is arduino mega 2560 as the controller, k-type thermocouple sensor, DC voltage sensor, ESP9266-01, LCD 20x4, MySQL server, and wireshark as an apps for data transmission analysis. From the results of the research that has been done, the system can read and sent the data from atmospheric corrosion sensors to the private cloud and store the data on web server in real-time.**

Keywords— *Internet of things, atmospheric corrosion sensor, arduino mega 2560, corrosion, private cloud*

I. INTRODUCTION

Metal is the main material that is widely used in infrastructure development such as buildings, factories and bridges. Metal has several types, one of which is steel. Steel is a building material that is strong, flexible and durable. Although steel has great strength, it is necessary to monitor it, because steel is a material that can be subject to corrosion. Corrosion is a chemical reaction that occurs in materials made of metals such as steel. Steel that experiences corrosion will result in a decrease in quality, because the level of steel thickness will decrease in a certain period of time, so that the safety of the building is less guaranteed.

There were many researchers have been deployed sensors to identified atmospheric corrosion using radio-frequency identification (RFID) sensors [1–3], passive wireless sensors [4], corrosion potential sensors [5], optic sensors, fibre Bragg gratings (FBGs) [6–11], atmospheric corrosion monitoring (ACM) methods [12,13], and atmospheric corrosion rate monitoring (ACRM) techniques [14].

The corrosion on metal material detection also has been developed by Nining Purwasih et all with the dry wet method by applying a 5% NaCl solution to test pieces in order to investigate the performance of ACSSM via the active dummy method [15,16]. This system was used for monitoring corrosion rate on the metal object, but in the process of monitoring corrosion, it is still using conventional process using data logger, the system shown on figure 1.
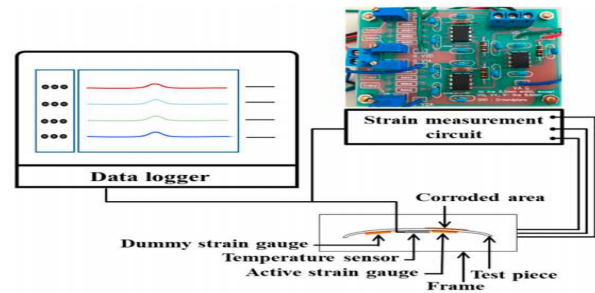

Figure 1 Corrosion sensor, Nining et al [15,16]

Therefore, more further research on this area was needed, especially for development an online tool that can measure corrosion in metal materials designed based on the internet of things (IoT) technology. Internet of Things is a concept in which certain objects have the ability to transfer data through a network without requiring human-to-human or human-to-computer interaction.

II. MATERIAL

A. DC Voltage Monitoring System

DC voltage monitoring system is a tool that is assembled from various components that function to monitor data about the DC voltage that is obtained. In this research, the monitored DC voltage comes from atmospheric corrosion sensors which can measure the tension of a metal material [17].

B. Arduino Mega 2560

The Arduino Mega 2560 is a microcontroller development board based on Arduino which uses the ATmega2560 chip [18].
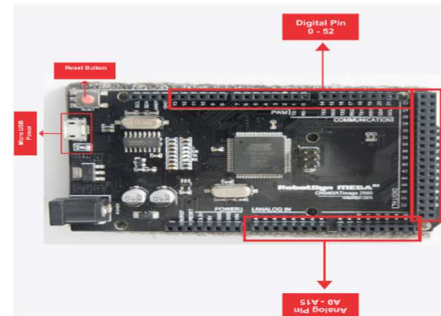

Figure 2 Arduino Mega 2560

Specifications of Arduino Mega 2560 can be seen table 1

Table 1 Specification of Arduino Mega 2560

Description	Specifications
Microcontroller chip	ATmega2560
Operating voltage	5V
Input Voltage (Recommended, via DC jack)	7V - 12V
Input voltage (limit, via DC jack)	6V - 20V
Digital I/O pin	54 pins, among them is PWM
Analog Input pin	16 pins
DC current per pin I/O	20 mA
DC current pin 3.3V	50 mA

C. DC Voltage Sensor

This an important part for detecting and measuring voltage. This module works using the principle of a resistor voltage divider, where the voltage input read at the output of this module is divided by 5 to the input voltage.
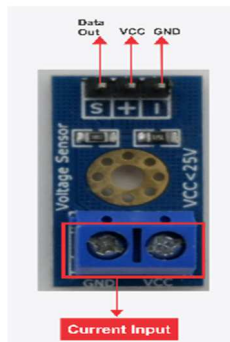

Figure 3 DC Voltage Sensor

Specifications of DC voltage sensor can be seen in the table 2:

Table 2 Specification of DC Voltage Sensor

Description	Specifications
Voltage input	0 – 25 V
Detection Voltage	0.02445 – 25V DC
Measurement Accuracy	0.00489 V
Size	25x13 mm

D. LCD 20x4

*Liquid Crystal Display (*LCD) 20x4 is a module used to display a character from a microcontroller such as Arduino. The 20x4 LCD module can display 4 lines of characters, where each line can display as many as 20 characters [19].

E. I2C

Inter Integrated Circuit (I2C) is a two-way serial communication using two special channels to send or receive data from a microcontroller. The two channels used by I2C are SDA (Serial Data) and SCL (Serial Clock) [20].

F. Thermocouple Type-K

Thermocouple (thermocouple) is a type of temperature sensor that is used to detect or measure temperature by means of two different metal conductors which are joined at the ends to give a "effect Thermo-electric". Thermo-electric occurs in a conductor metal which is given a gradient heat difference to produce an electric voltage [21].

G. ESP01

ESP-01 is one type of module Wi-Fi from ESP8266, which is an additional module that functions to connect the microcontroller to the internet network [22].

Table 3 Specification of ESP01 Module

Description	Specifications
Input Voltage	3.3 V
RAM capacity	1 MB
Frequency	2.4 GHz

Adapter ESP-01

Adapter ESP-01 is a regulator module that converts the 5 V voltage from Arduino to 3.3 V, so it is safe to use on modules that require a voltage value of only 3.3 V. The ESP01 adapter uses the help of an IC (Integrated Circuit) LD33V which does function for reduce the voltage from 5 V to 3.3 V.

H. MySQL

MySQL is a provider of online storage media (database) which is commonly used in making online system. MySQL is also a provider database that provides open access rights to its users so that users can do anything to their database. MySQL is widely used in web development because it has several advantages, one of which is the GPL license and multi- platform, can be run on specifications hardware low because it is more memory efficient, MySQL is also provided free of charge by developers to users, and MySQL can be integrated with several languages programming like PHP [23].

I. REST API

REST API is an architectural style in designing a web service where the design REST has resources that can be accessed via a unique HTTP URL address. REST also allows clients to make requests via the HTTP protocol easily using URLs [24].

POSTMAN

Postman is a REST client web-based available as an extension to Google Chrome. A tool that helps in developing REST Web Services. Postman is a powerful HTTP client for testing web services. Postman makes it easy to test, develop and API (Application Programming Interface document) by allowing users to quickly collect both simple and complex HTTP requests.

J. Wireshark

Wireshark is an application for analyzing network protocols. This program can capture various types of information [25] contained on the network used. Apart from that, this program can also record various types of packages and then select and display them in as much detail as possible.

III. RESEARCH METHODOLOGY

Prototype method is a methodology that often used in the development of an information system, including this research used this method. By using the prototype, developers and customers will each other interact during the system development [26]. The prototype method is suitable for use in system development yet fully defined in full at the beginning of the process or is a customization. In the prototype method has four stages those are; communication, quick plan and modeling quick design, construction of prototype, deployment delivery and feedback.
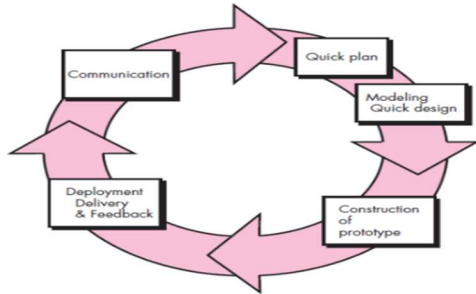
Figure 4 Prototype Method

A. Communication

At this stage, the developer and the user meet and define the entire system, identify all known needs, identify problems from the user and define the future goals of developing the system to be made.

B. Quick Plan and Modelling Quick Design

At this stage, planning and modeling are carried out quickly and are more focused on presenting the aspects that will be displayed. The design will be conducted there on the side of the device (hardware) and the software (the software). On the hardware side, an embedded system is used with a microcontroller that is connected to the sensors to be used as well as the modules to support the internet of things. Meanwhile, on the software side, there is a database that is used to store the values that have been obtained from the system.

C. Construction of Prototype

This stage is the process coding (programming) in terms of software, as well as the database to be used. Programming for the side hardware using the Arduino IDE as follows:
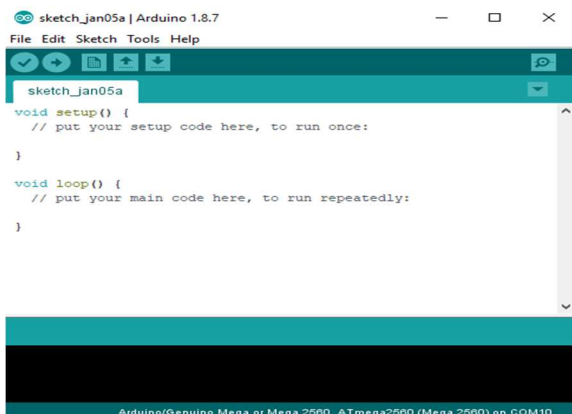

Figure 5 IDE Arduino

For the database design to be used as follows:

Figure 6 Database Design

The database used has several attributes, those are id_sensor, waktu, aktif, dummy, delta, and suhu.

D. Deployment Delivery and Feedback

Prototype will be given to the user and then evaluated by the user himself. Feedback is obtained from complaints or suggestions given after evaluating the prototypes that have been tried.

IV. RESULTS AND DISCUSSIONS

A. Communication

At this stage it is divided into 2 namely functional and non-functional requirements.

1. Functional Requirements

The system can display the values obtained by atmospheric corrosion sensors. The system can send sensor values to the private cloud that has been provided using technology Internet of Things (IoT).

2. Non-Functional Requirements

The system can be easily understood in the process of using it

B. Quick Plan and Modelling Quick Design

1. *Hardware Design;* The hardware of the system to be designed modeled as shown below:
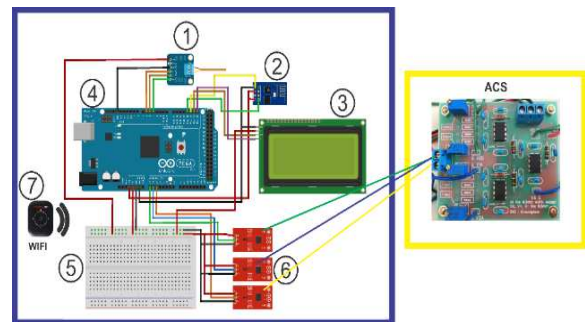

Figure 7 Hardware Design

Figure 7 shown the prototype design of the system to be designed. Number 1). K-type thermocouple sensor, 2). ESP01 module, 3). LCD 20x4, 4). Arduino Mega 2560, 5). Breadboard, 6). DC voltage sensor, 7). MiFi. Data that has been received by the system will be sent to the hosted database.

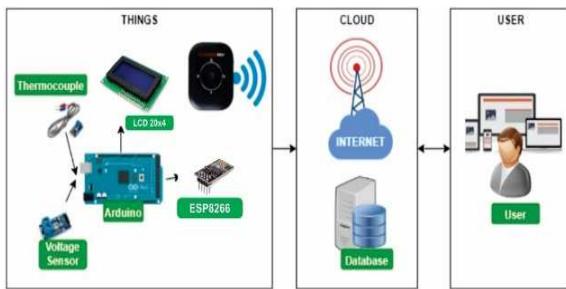The architecture of this system can be seen in the following figure:

Figure 8 System Design Architecture

Figure 8 shown the system design architecture which is divided into 3 layers, namely things (hardware), cloud (database on the internet), and users.

2. Software Design

In designing software, a database that is contained in MySQL will be designed to store the data that has been obtained by the system and an API for connecting hardware with the database. The following is the Entity Relation Ship Diagram (ERD) from the database of the system to be designed:
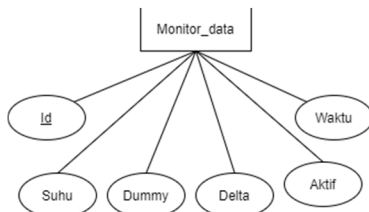
Figure 9 ERD Diagram

From Figure 9 there is an entity used, namely monitor data to store the value of the sensor. In these entities, there are attributes, namely id, time, active, dummy, delta, temperature with id as the primary key.

Then for the design of the API can be seen in the image below:
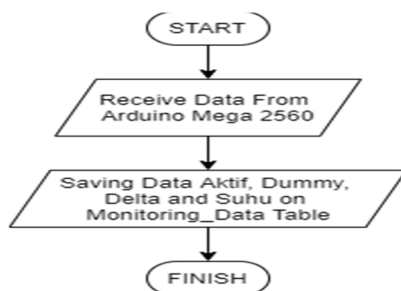
Figure 10 API Flowchart

Figure 10 shown the API receives data sent by the hardware and continues it to the database and stores it according to the predetermined table.

C. Construction of Prototype

This stage is the coding and implementation phase of the components that will be used in the system building process. The coding on the hardware uses the C language found on the Arduino IDE, then the Application Programming Interfaces (API) is designed through the laravel framework, and the database uses MySQL which is already on the hosting.
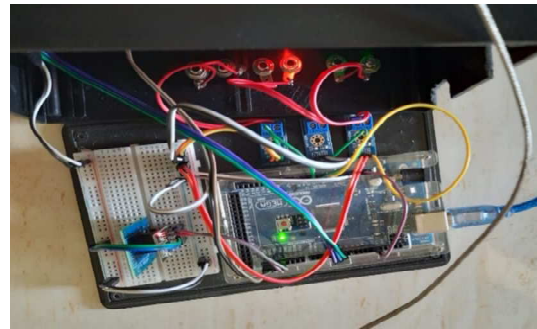
1. Hardware Implementation

Figure 11 ACS Value Reader Device

Figure 11 shows the hardware of atmospheric corrosion sensor reader. The hardware will take input data in the form of active voltage, dummy voltage, delta voltage, and temperature.
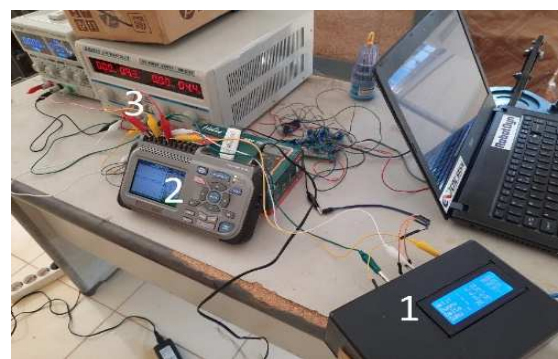

Figure 12 Hardware Implementation

Figure 12 shows the implementation of the hardware connected to the power supply as the input value giver and the MIDI logger device as a comparison for the accuracy of the value reading.

2. Software Implementation

Figure 13 Database Implementation

Figure 13 is a database implementation in MySQL. The database field was id, waktu, aktif, dummy, delta, suhu as a storage place for values sent by the hardware.
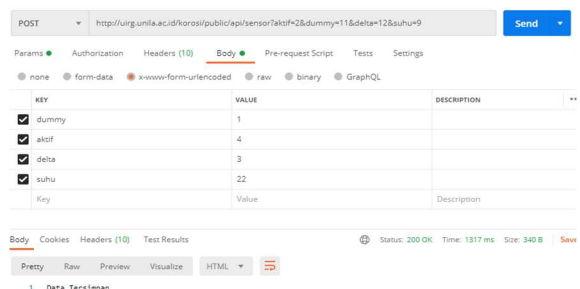

Figure 14 API Implementation on POSTMAN

Figure 14 is the API implementation that will be used. However, before connecting to the system, the API is tested using the POSTMAN application to determine the success of the API, HTTPS method also implemented for security reason.

Figure 15 API Implementation on System

Figure 15 is the API implementation on the system. From this figure, the value obtained by the hardware is successfully sent and stored in a database that has been created in MySQL.

D. Deployment Delivery and Feedback

At this stage the system that has been built will be tested using the Black Box method. Feedback is obtained from complaints or suggestions given by users after evaluating the system that has been tried. Here are the results of tests performed in accordance with the functional requirements:

Table 4 Testing Data Delivery

Cases and test result			
Data Input	Expected	Observations	Conclusion
The system receives the data voltage and temperature every second	System sends data from the sensor voltage and temperature every 1 hour and when the value exceeds the threshold limit of the maximum	Data from the system successfully entered into the database every 1 hour or when the value exceeds threshold the maximum	Successfully

Table 4 represents the results of testing to transmit data from the hardware to the database and from these tests, the system succeeded in sending the data to the MySQL database.

Table 5 Displaying ACS Value on LCD Testing

Case and Test Result			
Data Input	Expected	Observation	Conclusion
System receives the voltage and temperature of atmospheric corrossion sensor (ACS) every second	System displays the data voltage and temperature of atmospheric corrossion sensor (ACS) on the LCD	Systems display data Voltage and temperature every second on the LCD	Successfully

Table 5 shows the test to display the ACS value on the LCD with a successful conclusion.

E. Analysis

At the analysis stage there are several things that will be analyzed, namely regarding the amount of data sent from the system to the database, the time required for delivery to the database, and the security in the system. Following are the results of the analysis that has been carried out:

1. Data Sending Analysis

Analysis using the Wireshark application with the following results:

Figure 16 Data Analysis

From Figure 16 it can be seen that there are 27 frames in one transmission and the data required in one delivery is 2.747 bytes.

2. Delivery Time Analysis

In analyzing the time to send data from hardware to the database, the application is also used Wireshark in the analysis process. Results of the analysis carried out are as follows:

Table 6 Delivery Time Analysis

Deliver ed time	Last Frame (seconds)	First Frame (seconds)	Different (last frame –first frame)	Average (seconds)
1	34,067	32,863	1,204	
2	3646,448	3644,861	1,587	1,379
3	7258,469	7257,342	1,127	
4	10871,058	10869,46	1,598	

From table 6 it is known that the average time needed by the system in sending data is 1,379 seconds.

V. CONCLUSIONS

Based on the results and discussion obtained in this research, there are several conclusions: The IoT system can successfully read the DC voltage value from Atmospheric Corrosion Sensor (ACS), and sending the data to the database. The IoT system can send data without any packet loss, during the testing on lab environment. From the data analysis using wireshark application, data transmission has an average delay 1,379 seconds to the next transmission, due to an interaction with the TCP protocol which takes place repeatedly up to 27 frames.

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