An IoT-Based Real-Time Weather Monitoring System Using Telegram Bot and Thingsboard Platform

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Abstract—The advancement of technology, particularly in the field of IoT, encourages automation in the field of meteorology, particularly the observation of real-time meteorological data. Meteorological data is required, particularly in specific areas such as mining regions; this data can be utilized to enhance worker safety and environmental management in connection to dust and poisonous gases, runoff during the rainy season, and chemical discharges into waterways. By assembling an ESP32 microcontroller with SHTC3, BMP180, wind speed, wind direction, and tipping bucket sensors, it is possible to create IoT monitoring devices that measure the primary components of weather parameters, including temperature, humidity, air pressure, wind direction, wind speed, and precipitation. Protocols for data transfer via MQTT, WebSocket, and HTTP requests make use of the most recent open source platforms, especially Thingsboard and Telegram Chatbot. BMKG's National Digital API is used to augment sensor data in real-time with weather forecast information. The weather monitoring device is effectively utilized, and the user may request real-time data whenever and wherever it is required from their mobile phone.

Keywords—IoT, sensors, weather parameters, Thingsboard, Telegram

1 Introduction

Weather is a condition of the atmosphere that emerges at a specific time and location [1]. Weather consists of various parameters that observe as the basis for weather predictions by considering atmospheric conditions' physical and dynamic phenomena. Automation and density of weather observation networks are needed to obtain real-time weather data that can be utilized in various sectors, for example, transportation, infrastructure development, agriculture and forestry, marine and fisheries, spatial planning, health, tourism, defense and security, water resources, energy resources and mining, industry, and disaster management. They also play an essential role in transportation, especially air transportation, hydrology, and many others [2].

The invention leap in the world of technology, particularly the Internet of Things, has created opportunities for developing various internet-connected devices. The more significant part of this technology innovation aims at measuring and managing diverse activities effectively. A sophisticated environmental monitoring system can manage and track the consequences of environmental changes on people, plants, and animals. IoT Based Real-Time Weather Monitoring is one of the applications an intelligent environment aims to achieve by leveraging embedded intelligence to make the environment interactive with other goals. Human needs necessitate various monitoring systems, which depend on the data collected by sensor devices.

Weather monitoring stations are created with the aim of collecting and monitoring weather data at a location. In the research conducted by Medilla, the weather monitoring station was designed using an IoT platform. The components used are the ESP8266, Arduino Mega, DHT-11 sensor, BMP180 sensor, and FC-37 sensor. In this study, the MPL115A system algorithm was also used to predict weather conditions by calculating changes in air pressure values. The weather parameters measured by this tool are temperature, humidity, and air pressure [15].

The implementation of a system for monitoring environmental parameters using the IoT has been tentatively tested by Mabrouki to verify air and weather parameters. The system provides a low energy consumption solution for the establishment of a station weather system, To protect the general well-being from contamination, this model provides an effective and minimal effort response for continuous observation [28].

This study will describe the use of Internet of Things technology in a real-time weather monitoring system with more complete sensor to capture more weather parameter. Weather parameter data will obtain by using a microcontroller connected to the SHTC3 sensor, BMP180, wind speed anemometer, wind direction anemometer, and tipping bucket rain ombrometer. Those are temperature, humidity, air pressure, wind speed and direction, altitude, and precipitation. Internet of Things technology has made it simple to visualize real-time data through platforms such as things board and Telegram Bot. The device can display real-time weather data through a web dashboard and chatbot using the Telegram application on the user's cell phone. This monitoring system's design integrates with tomorrow's weather forecast data obtained from the BMKG National Digital Forecast API data to enrich the information for the users. Weather conditions may be readily viewed using the online dashboard and the Telegram chatbot application by using an open source platform. It will benefit observations at particular sites that call for information on local meteorological parameters. The Internet of Things rapid growth has benefited businesses in numerous ways, including enhanced market research and corporate strategies. Similarly, by introducing automated services, the Internet of Things has enhanced the lives of individuals [3].

2 Materials and methods

2.1 Research procedures

The research methodology that was used for this paper is illustrated in Figure 1. It consists of three major stages: the planning stage, the development stage, and the implementation stage.

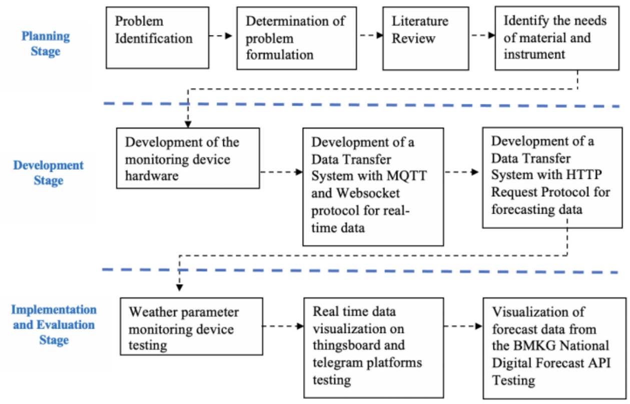

Fig. 1. Research Stages Workflow

Stages of planning. In the planning stage, the following processes carry:

1. Identify problems in monitoring weather parameter data in real-time teams and expectations and opportunities for solutions.
2. Determine the formulation and limitations of the problem and the objectives to be resolved through this research.
3. Conduct a literature study on the design of IoT tools for observing weather parameter data and implementing IoT communication protocols for real-time data. Literature study is critical to know the history and weaknesses of the previously used methods.
4. Collect the instrument materials needed in the research.

Stages of development. After carrying out the next planning stage, the development stage, which includes:

1. Manufacturing of IoT Weather Parameter Monitoring Devices: includes microcontrollers, sensors, wiring, and other fittings that will assemble into weather parameter observation devices.
2. Create a data transfer system by implementing a platform that employs the MQTT and Websocket communication protocols. In this study, Thingsboard and Chatbot display observation data captured by an IoT-based automatic monitoring device for weather parameters.

3. Create a data transfer system based on the HTTP request communication protocol to retrieve weather forecast data from the BMKG National Digital Forecast API. This forecast data will be displayed on the dashboard menu and can be querries on the telegram chatbot.

The device will be connected using wifi. Wireless systems are low cost, low power, easily expansible, and reconfigurable. [4]

Stages of implementation. The research will produce three systems from this research after the development process. Weather monitoring devices to get real-time data on temperature, humidity, air pressure, wind speed and direction as well as precipitation, Dashboard Monitoring and Weather Forecasting as a result of designing the MQTT protocol architecture and HTTP request to display real-time weather parameter data and tomorrow's weather forecast, as well as a Telegram chatbot in the form of live chat as a result of the Websocket protocol architecture design and HTTP request to display real-time weather parameter data and tomorrow's weather forecast. The primary focus of the most recent technological innovations is on the ability to control and monitor various activities. These are developed to fulfill human requirements. This technology mainly monitors and controls various activities effectively and efficiently. If the prescribed levels of parameters are exceeded, it is necessary to have an effective environmental monitoring system in place in order to monitor and evaluate the conditions [5]. In the implementation phase, it will carry out the following actions:

1. Test of the hardware monitoring devices.
2. Test of real-time data visualization on the things board dashboard and telegram platforms.
3. Test of forecast data visualization on the things board and telegram platforms.

Data flow. The process that describes the flow of data from the sensor to the display on the dashboard and thingsboard is illustrated in Figure 2, which is a diagram of the process. The data will be read by sensors installed in the Internet of Things devices. These sensors can detect temperature, pressure, humidity, wind speed and direction changes, and precipitation. Then, the collected data will be processed through the MCU node and sent using an internet connection. Each feature in IoT devices requires different energy capacities, distance requirements, and bandwidth. So, it is crucial to have stable internet connectivity to apply IoT technology optimally. Next, the data will process by the software. This process is quite vital because it will determine the reaction of the device [6].

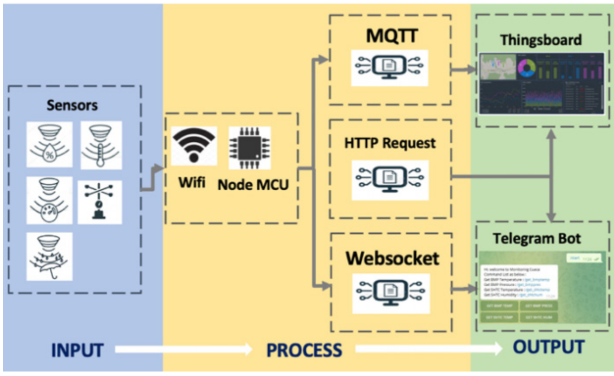

Fig. 2. Diagram of Data Retrieval Process

In this study, the communication protocols for data transfer are MQTT, WebSocket, and HTTP requests. The things board and telegram platform use to display real-time data as sensor readings on weather parameters output. Meanwhile, weather forecast data will obtain from the National Digital Forecast API from BMKG, which connects via the HTTP request communication protocol.

2.2 Research instruments

For this study, the microcontroller used to create the monitoring system hardware was a Node MCU ESP-32, containing five sensors. This instrument comprises the SHTC3, BMP180, Wind Speed Sensor, Wind Direction Sensor, and Ombrometer Tipping Bucket Precipitation Sensor. MQTT, WebSocket, and an HTTP request are the protocols utilized in the communication process. The real-time data will be presented using a thingsboard built on an open platform and a bot for the Telegram messaging service.

3 Result

3.1 Development of an IoT monitoring device

The IoT-based home automation system implements using wifi enabled ESP32 microcontroller. It also used a two-channel relay module capable of controlling two appliances individually for interfacing the appliances to facilitate communication between the devices and the microcontroller [7]. In this study, the microcontroller was assembled with SCHT3 sensors, BMP180, wind speed, wind direction, precipitation sensor and LCD 20x4 I2C as shown in Figure 3 for the detailed wiring.

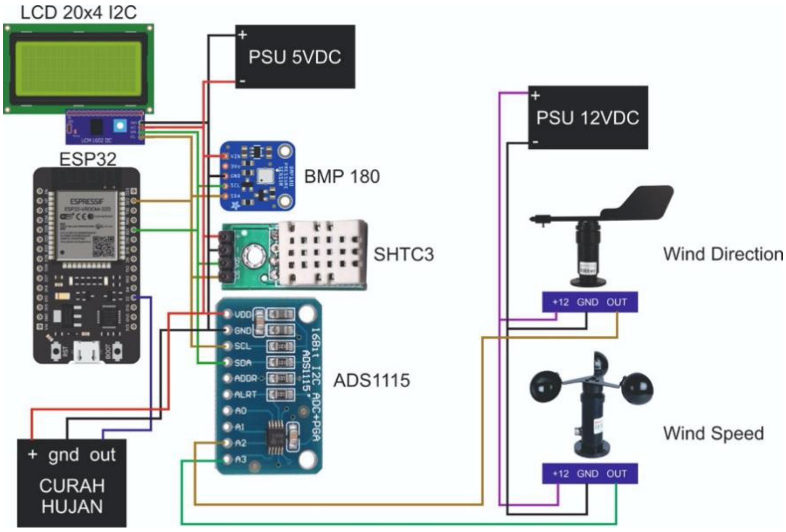

Fig. 3. Diagram of Device Wiring

SHTC3 and BMP180 sensors can directly connect to the ESP32, but for the ombrometer, wind speed and wind direction must connect via ADS1115. This ADS1115 module is an ADC module to convert Analog to Digital signals with 16-bit precision. The wind direction and wind speed sensor both are made of metal. The wind direction's signal output are between 0-5 voltage, it has a measuring range from 0 - 360 azimuth degree. The wind speed sensor's signal output are between 0-5 voltage and it has 3 cups for measuring the speed. The tipping bucket rain sensor is created using a 3D printer, each tip counts 0.7 mm of the precipitations. The process of wiring the sensor to the ESP32 microcontroller is illustrated in Figure 4. After the wiring has been completed successfully, the obtained data can be viewed on the LCD screen as shown in Figure 5.

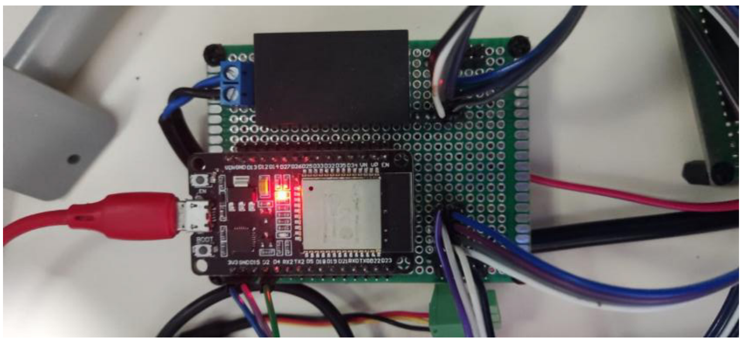

Fig. 4. Wiring Process of Hardware Device

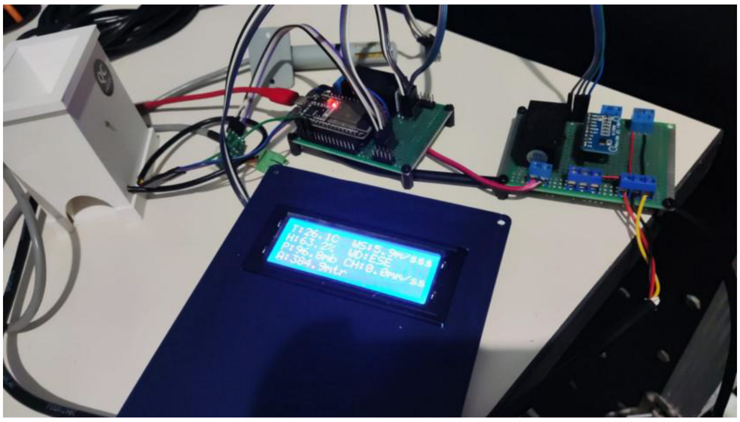

Fig. 5. LCD Display Testing

3.2 Development of IoT transfer data system

The proposed system is accessible by the user and subject to the user's control via the user interface using a smartphone or computer from anywhere in the world. The user interface creates using two different platforms. The MQTT, WebSocket, and HTTP request is the communication protocol for enabling communication between the software and hardware. The home automation system is low-cost and based on a reliable and scalable IoT platform that can remotely switch on or off any home appliance and monitor weather data over the internet. The Figure 6 shown decision flowchart of data collection from the sensor until the device can display the data.

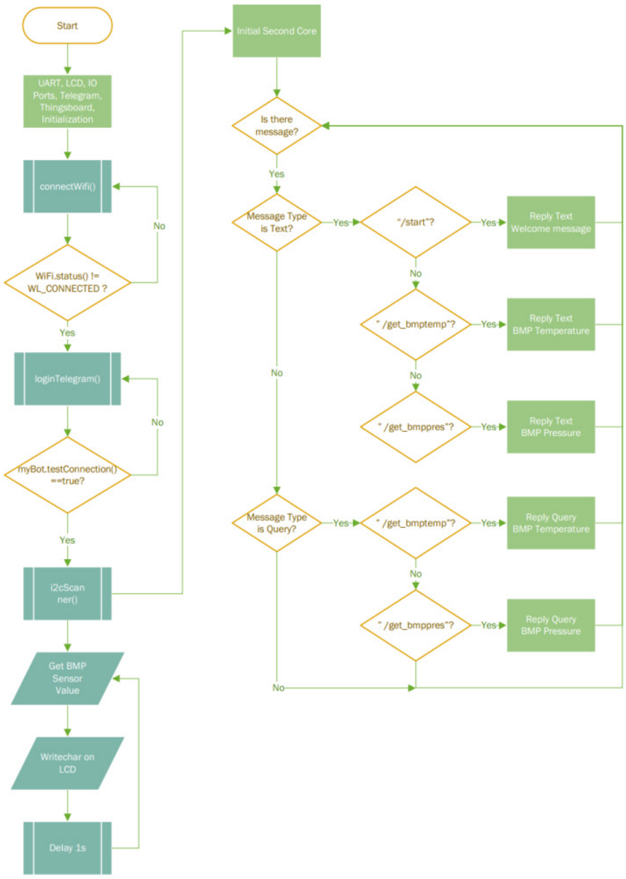

Fig. 6. Decision Flowchart

3.3 Thingsboard configuration

ThingsBoard offers a cloud-based PaaS edition, an open-source community edition, and a premium professional edition. It is also excellent in visualizing data. Through Kafka Streams, ThingsBoard transmits device data to external analytics systems. Trendz Analytics provides excellent analytical skills to professionals. ThingsBoard provides security via HTTPS and OAuth 2.0 access tokens across all accessible communication routes. ThingsBoard supports many installation and deployment methods. The platform may be deployed using Docker containers or installation packages for all desktop operating systems.

It is necessary to have a device configuration on the Thingsboard platform. Before starting to program on ESP32, we must do a few setups to support ESP32's ability to perform data transfer to ThingsBoard as can be seen in Figure 7. Data transmission is carried by ESP32 (slave), sending data through the surrounding wifi network. In addition to sending data to the ThingsBoard web server with the MQTT method, we must first enter topics before sending them to the web server. In this study, ESP32 acts as a publisher that will fetch data from sensors, which it will forward to the MQTT broker, which serves as MQTT. The broker is the ThingsBoard. If somehow the hardware subscribes, it will then transmit the data to the hardware. It is an efficient messaging protocol that publishes and subscribes to users. In MQTT, a client is any device that has subscribed to the protocol. Every subscriber can spread the information further. It is the broker that is responsible for sending the message. To communicate using the MQTT protocol, publishers (such as data, sensors, and embedded systems) must define two elements that will enter the MQTT Broker. The two elements are messages and topics. The news is a string of data that the publisher (publisher) wants to share with subscribers (customers) via MQTT Broker.

On the other hand, a topic is string brokers use to filter and select which subscribers should be sent which messages [8]. The MQTT protocol is a platform for transmitting data based on TCP/IP. It uses a small power supply because it only sends data of about 2 bytes [9].

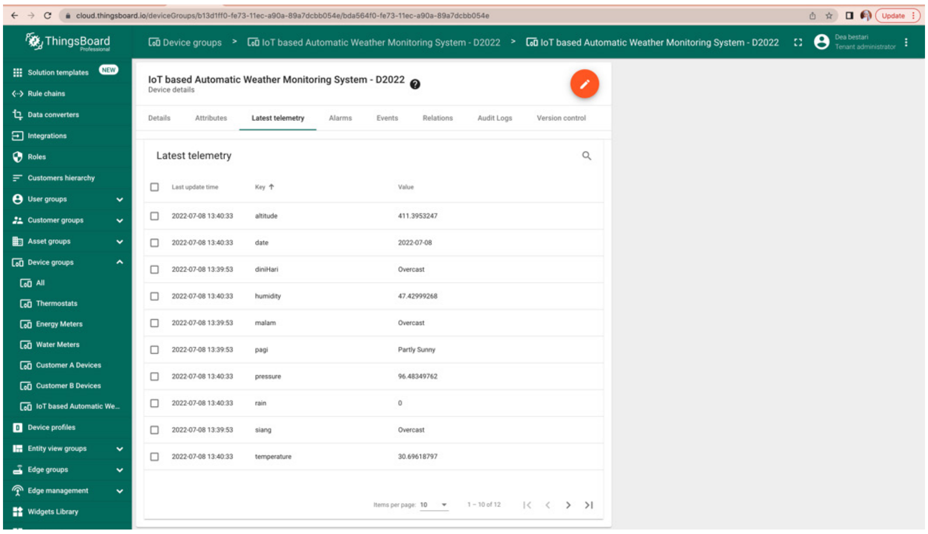

Fig. 7. Thingsboard Telemetry Configuration

Both the sensor device and the ESP32 microcontroller are able to successfully connect to the platform provided by the things board. As can be seen in Figure 8, the dashboard is able to successfully display the data that was collected from the sensor.

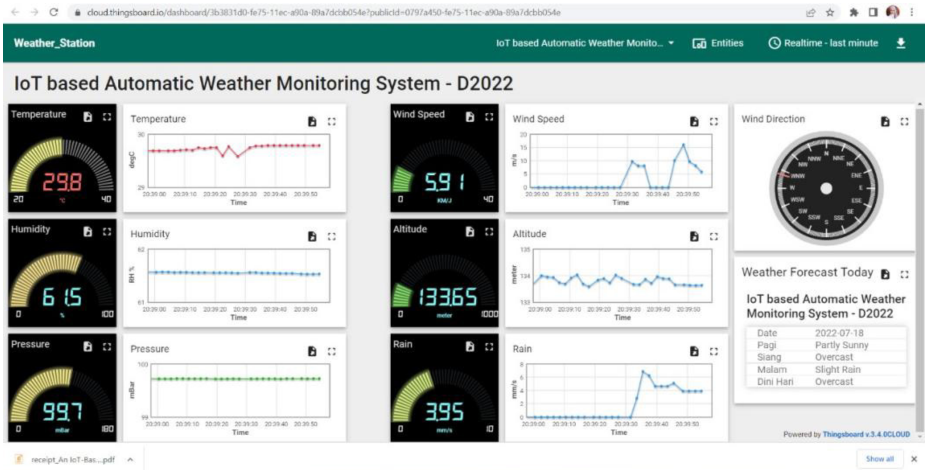

Fig. 8. Thingsboard Dashboard Result

3.4 Telegram Bot configuration

Telegram Bot is an abbreviation of a robot, which in other words, means a machine that can respond to a user's message automatically for the desired job. Telegram bots can create as needed in their use [10]. Telegram is a messaging application available on mobile, desktop, and web platforms. Telegram bots have automatic functions that can respond to user commands or requests. End-to-end encrypted chats have become an optional feature of Telegram. To be able to configure and set up the Telegram bot, the first step is to get a token code from the Botfather. After that, we can configure the token into the code. Telegram bots can create as needed in their use. These are the definition of the command for telegram data request:

```
#define TEMP_CALLBACK "/get_temp"
#define HUM_CALLBACK "/get_hum"
#define PRES_CALLBACK "/get_pres"
#define ALTITUDE_CALLBACK "/get_altitude"
#define WINDSPEED_CALLBACK "/get_windspeed"
#define WINDDIR_CALLBACK "/get_winddirection"
#define RAIN_CALLBACK "/get_rain"
#define ALL_CALLBACK "/get_all"
#define FORECAST_CALLBACK "/get_forecast_today"
```

Figure 9 depicts how users can successfully access data via telegram by clicking the command button that corresponds with the data that they want to access. This can be seen in the illustration. Table 1 contains information regarding data units and orders, which can be found there.

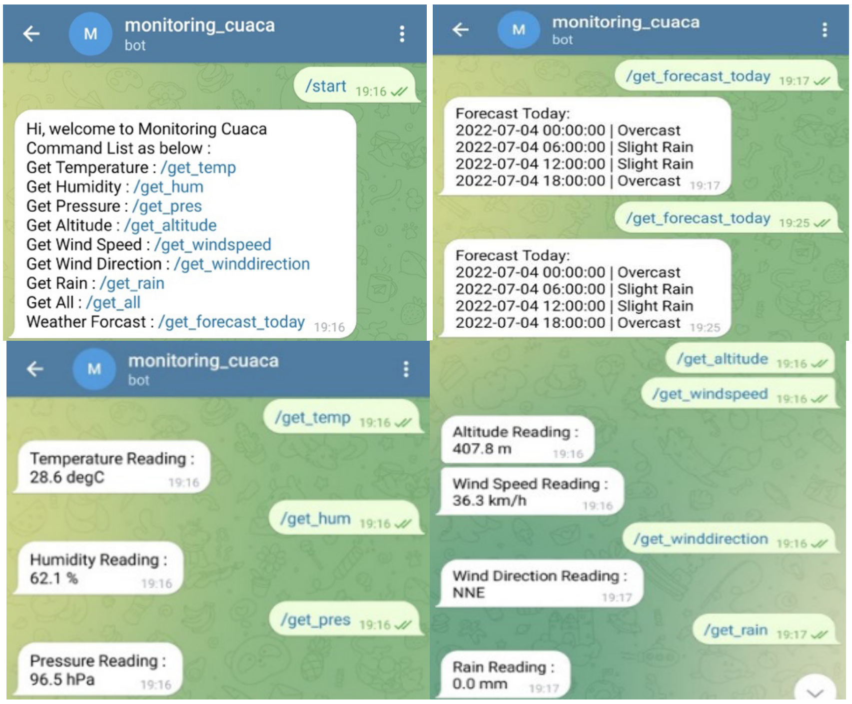

Fig. 9. Telegram Bot Result

Table 1. Telegram Bot Command for Data Request

Command	Function	Unit
/start	To start the bot	-
/get_temp	Retrieve temperature data	Degree Celsius
/get_hum	Retrieve humidity data	Percentage
/get_pres	Retrieve pressure data	hPa
/get_altitude	Retrieve altitude data	Meter
/get_windspeed	Retrieve windspeed data	Km/h
/get_winddirection	Retrieve wind direction data	Wind Direction
/get_rain	Retrieve precipitation data	Millimetre
/get_all	Retrieve all parameter data	All
/get_forecast_today	Retrieve today's forecast data	Weather prediction

This research made it simpler for users to obtain real-time local weather information and daily forecasts using only their mobile phone's response to the growing utilization of instant messaging apps within people's daily activities. Real-time applications can use these features to report the system's current status, and managers and developers can freely call these APIs without physically accessing the devices [11]. In this research, chatbots are more efficient and time-saving than thingsboard because users can instantly get real-time data on their mobile phone and the bot system responds instantaneously. Thingsboard displays all data by default, but the chatbot lets users access both complete or selected data only.

4 Discussion

The ESP8266 wifi serial transceiver module is one of the most popular devices for the Internet of Things (IoT) applications. In the design of syifaul fuad's IoT-based smart street lighting system, ESP8266 is configured as a Mesh network. The ESP8266 was programmed to control the light level by generating a PWM signal, which sends a dimmer value and reads the sensor data [12].

Kusrianto and Putra [13] researched weather monitoring stations based on an IoT platform. Weather monitoring stations create to collect and monitor weather data at a specific location. The ESP8266, Arduino Mega, DHT-11 sensor, BMP180 sensor, and FC-37 sensor were used. In this study, the MPL115A system algorithm was also used to predict weather conditions by calculating changes in air pressure values. The weather parameters measured by this tool are temperature, humidity, and air pressure. As technology continues to improve, the ESP32 microcontroller, the most recent generation of the ESP8266, was used to conduct this study. The ESP32 is more suitable for developing IoT devices with multiple sensors because it has more GPIOs with more functions, a CPU core, faster wifi than the ESP8266, and Bluetooth 4.2 support with less power consumption. In order to reach the required power levels, one must pay close attention to the design of the hardware, the design of the software, and the application algorithms [14]. One of the issues with IoT devices is their energy consumption. As a result, research on the development of energy-saving devices continues to be conducted by Jamal Mabrouki et al. [15]. They devised a method for monitoring environmental parameters that rely on the Internet of Things (IoT) test to validate parameters relating to the atmosphere and the weather using Arduino Uno as a microcontroller. The system offers a solution for establishing a station weather system with low overall energy consumption. This finding was consistent with the advantages of developing the internet of things, specifically the ability to monitor real-time data and reduce energy consumption [16].

A real-time application can be developed using the WebSocket protocol, which offers a two-way communication channel between clients and servers via a single Transmission Control Protocol (TCP) connection. People's daily routines are moving to the virtual world, where people can work, buy, and communicate while living in reality, as communication and internet technology advance quickly. Ogundeyi and Banjo [17] developed the water level and precipitation system observation. The device can detect rain and water levels in functional testing and has relatively high accuracy because it follows the design. Andriy Holovatyy is also involved in creating the hardware and software that comprise the Internet of Things weather monitoring system that measures pressure, temperature, and humidity [18]. Farmers are also one group that benefits from IoT devices. Farmers must be able to use various devices to improve their decision-making in numerous agricultural operations, such as the placement of irrigated agriculture, the placement of pesticides, and the use of fertilizers as required by the crops, in the right amounts, and at the appropriate times [19]. An advanced farming system based on the internet of things could also be suggested for low-income farmers to monitor environmental conditions and protect livestock. Not only does market farming lead to an improvement in the farm's overall physical management, but it also assists policymakers in the decision-making process [20].

Bahaswan and Manicam [21] compare several IoT communication protocols in their research. Data transmission protocols such as CAOP, MQTT, AMQP, and WebSocketthat used in different IoT applications. Although almost all of them support a wide variety of applications, they have distinct performance and security capabilities that may enhance IoT operations because the user can choose which protocol to employ based on primary network conditions. As IoT incorporates advanced telemetry capabilities, the remote temperature is monitored remotely. Users can access the data collected by remote temperature monitoring sensors via web or mobile applications. Multiple IoT devices are interconnected to transmit messages using Internet protocols. IoT platforms serve as a connection between the data network and sensor devices [22].

The hardware of weather observation instruments has been developed in those research, and IoT communication protocols have also been implemented. In this study, however, multiple sensors are integrated into a single device to detect changes in a broader range of meteorological parameters, including temperature, humidity, pressure, altitude, wind speed and direction, and precipitation. With the support of National Digital Forecast verified weather forecast data from BMKG, this research was conducted even more beneficial, accompanied by weather forecast information from the day of observation.

Several previous research has previously achieved real-time data display through a web dashboard, but real-time data display through a chatbot application is innovative. This research greatly simplifies the monitoring procedure. By selecting a chat button and executing a prepared command, users may access the information anywhere at a time and from any location.

5 Conclusion and future works

This research developed an IoT-based real-time weather monitoring system that works well in devices and data transfer systems. Sensors work to capture changing conditions in each weather parameter. The data transfer system via MQTT, WebSocket, and HTTP request protocols has been successfully implemented through the Thingsboard platform and the Telegram bot for real-time and forecast data. Data can be monitored via the web dashboard and also called via Telegram chatbot queries at any time via mobile phone. This research can be further developed by adding database data for processing. In terms of functionality, this research can be applied and integrated with smart farming, smart homes, or weather monitoring in very local areas, such as farms, mining areas and plantations. The Internet of Things (IoT) device can enhancing with artificial intelligence or machine learning algorithms to provide prediction data or by incorporating artificial intelligence for warnings or alerts for specific alarms, such as an excessive temperature rise.

6 Acknowledgement

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