

Integration of Modbus_Ethernet Communication for Monitoring Electrical Power Consumption, Temperature, And Humidity

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Abstract— Effective management of electrical energy requires monitoring, controlling, and storing parameters gathered from power measurement devices including voltage, current, and power factor. This assessment of the quality of electrical energy is essential for management organizations, power companies, and individual consumers to develop efficient electricity usage plans. In this paper, we propose a hardware implementation for data collection and online communication software integrated with a system for collecting data on consumption of electrical energy. The EM115-Mod CT multifunction industrial meters by FINECO, the KLEA 220P three-phase multifunction meter by KLEMSAN, and the ME96SS-ver.B by MITSUBISHI are utilized. The collected data of electrical consumption, temperature and humidity is stored on an SD card and transmitted to the cloud for real-time monitoring on mobile devices, facilitated by the ESP-WROOM-32 microcontroller from Espressif.

Keywords— Espressif system, ESP32, Supervision, Data collection, Microcontroller, Modbus protocol via RS485 ports

I. INTRODUCTION AND LITERATURE REVIEW

Nowadays, transmitting data from industrial meters manufactured by companies such as MITSUBISHI, KLEMSAN, and FINECO to the web has become an important issue. This capability is essential for operators who seek to monitor and propose optimal solutions for power utilization in manufacturing facilities. However, the traditional methods of data transmission to the internet for monitoring incur significant costs, limiting their suitability to large corporations and the needs of small and medium-sized enterprises. Recently, the ESP32 microcontroller is highlighted to develop applications for data measurement and processing [1-4]. The advancements in microcontroller technology, have coupled with the ability to connect to various devices such as sensors, amplifiers, electronic circuits, and memory cards (Micro SD), have played a important role in enhancing the overall capabilities of monitoring and data collection systems [5-8].

To describes the framework development process of ESP32 microcontroller, some articles [9-15] have introduced for the development of applications using an ESP32 development board and integrated sensors adapted to work on Microsoft's Azure platform to monitor temperature and critical electrical parameters. Broell et al. (2023) [16] proposed a foundation describing the connection diagram of

ESP-WROOM-32 communication with the Internet. In automation for building, network communication with protocol ESP32 and ESP8266 have been used in many applications such as weather monitoring, soil moisture and air pollution to warn of floods [17], tree growth and air pollution [18], measuring heart rate and body temperature in real time [19], monitoring fetal heart rate [20]. Also, ESP8266 is used to control the entire process of the system for collecting data to control the vehicle on the cloud platform [21], optimizing the lighting system in the yard fly ESP32 [22], protecting farms from the intrusion of wild animals [23], developing low-cost smart remote environmental temperature monitoring system [24,25], developing a real-time smart home monitoring system based on ESP32 and Android application [26-28].

The Espressif Systems developed using IEEE802.11 technology for the indoor environments have been designed and implemented for a smart door access system for continuous monitoring of solar PV system [29-32]. Users can monitor power parameters such as three-phase voltage, current, active, and reactive power, remotely via a web interface helping to control energy consumption and optimize usage [33]. Management of the power consumption of an electrical cabinet can be useful to manage and choose appropriate power devices with real-time monitoring to save electrical energy and reduce costs.

For a powerful ESP32 microcontroller with Internet of Things (IoT) connectivity, various sensors to collect environmental data. The humidity and temperature parameters of the electrical cabinet are also sent to the cloud for comprehensive monitoring purposes [34-37]. Data is transmitted in a wireless network and stored on a central server in the cloud with IoT approach for a system framework [38-40]. For the automating monitoring system using IoT for environmental conditions, the system, uses integrated sensors to provide an overall view of environmental conditions, has the ability to send real-time data to a remote monitoring computer via the ESP8266 platform protocol [41-49] and IoT and GSM Based Smart Grid Controlling and Monitoring System [50-58]. Recently, the integration of Modbus protocol communication with industrial meters has been reported in [59,60]. However, the temperature and humidity parameters have been monitored with Modbus protocol communication with industrial meters.



In this paper, a new design of Modbus_Ethernet communication system for collecting, storing data, and monitoring electrical power consumption, temperature, and humidity have been extended to communicating with industrial meters using the Modbus protocol via RS485 ports to read data from devices manufactured by companies such as KLEMSAN, MITSUBISHI, and FINECO. Then, the parameters such as voltage, current, power, and apparent power are recorded over time and transmitted directly to the cloud for monitoring. Finally, the electrical power consumption, humidity, and temperature parameters of the electrical cabinet are sent to the cloud for comprehensive monitoring purposes.

II. SYSTEM DESIGN

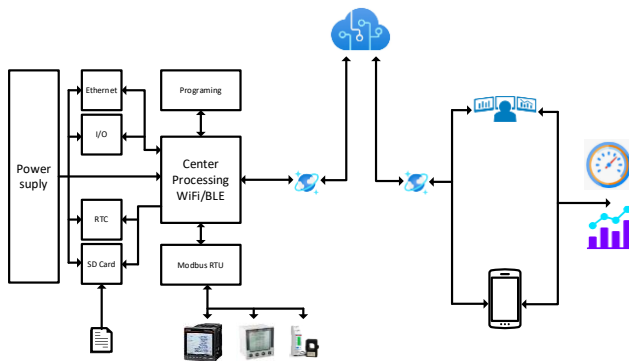


Fig 1. System Block Diagram Design

Figure 1 shows the system connection diagram. The Power Supply serves as the primary power source providing input 220V AC and output DC 3.3V to various components of the system. The central processing, connects with the RTC, SD card, I/O, Internet, Modbus RTU, Center Processing Wifi/BLE, and the meter, is powered by this block. Also, the Center Processing Wifi plays a crucial role in connecting measuring devices from different manufacturers through Modbus RTU communication. This connection allows for the monitoring of energy data from these devices. Then, the Center Processing Wifi unit collects temperature and humidity data using I2C communication with the RTC (real-time clock) temperature sensor. After connecting to the Internet via wireless (WiFi) or wired Ethernet, the Center Processing Wifi unit transmits data to the cloud. This data is then displayed through a smartphone application with the Android operating system. Simultaneously, the collected data is stored on the SD card and transmitted to the phone app for monitoring and controlling. The SD card receives data from the meter and the RTC through the Center Processing Wifi unit. Then, real-time data, which is stored based on predefined intervals on the SD card, is sent to the Center Processing Wifi unit.

III. SYSTEM TESTING AND RESULTS

The circuit for connecting and storing electrical energy data is divided into three parts:

A. The hardware circuit communicates with measuring devices



Fig 2. The circuit connects wires to the Module Master RTU

Figure 2 demonstrates the stable operation of the Module Master RTU connection circuit. The module establishes connections with devices utilizing the Modbus RTU. The sensor system is directly integrated into the main board to facilitate the collection of environmental data such as temperature and humidity. The real-time operating system is automatically updated. The data, gathered from connected devices to measure temperature and humidity values, is instantly stored on the Micro SD card. The structured data on the Micro SD card are compatible with Microsoft Excel are gone to real-time checking and data referencing. The data is efficiently transmitted through either the internal network or the Internet. The inclusion of a smartphone application significantly augments flexibility and efficiency in energy monitoring and management. This application further supports data monitoring of the system through Internet connectivity.



Fig 3. The cabinet with the Modbus_Ethernet Communication System for Collecting, Storing Data, and Monitoring Electrical Power Consumption, Temperature, and Humidity Parameters

To check the circuit's stability. Figure 3 illustrates the Modbus_Ethernet communication system for collecting, storing data, and monitoring electrical power consumption, temperature, and humidity installed in the cabinet. Then, it can operate very stably and yield experimental results.

B. The algorithm flowchart for the Board Master RTU program

Figure 4 illustrates the algorithm flowchart for controlling the entire system. Initially, the system retrieve data from the EEPROM to check the connection with the SD Card, and then verify the internet connection to establish a connection with the application on the phone. Then, the connection with the RTC sensor and temperature sensor is checked. When the connection process is completed, the system proceeds to read and store data in the Cloud and the SD Card. The algorithm flowchart are explained as follows

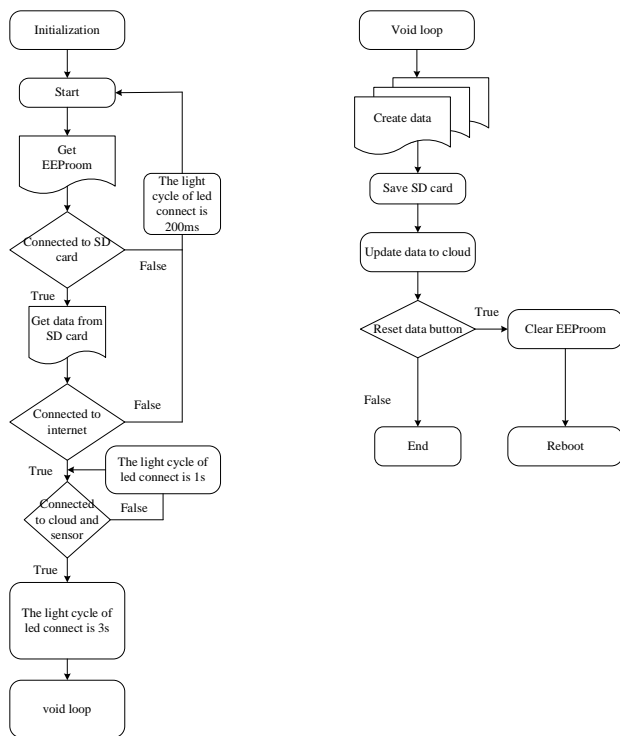


Fig 4. The algorithm flowchart

Block Start: The program initializes libraries, variables, constants, etc.

Block Get EEPROM: this process retrieves data stored in EEPROM memory, such as WiFi user, password, the path to cloud data, the secret code for the cloud, etc. These values will be empty for the first initialization.

Block Internet Connection: This block attempts to connect to the internet. If a connection cannot be established due to an unavailable WiFi network during the first initialization, the device will broadcast a WiFi hotspot (e.g., ESP32 Reading). Users connecting to this hotspot automatically open a Captive portal (an automatic web server with an embedded HTML interface and the main program). Then, users configure system parameters on this portal, save the settings, and proceed.

Block Save EEPROM: The program saves the data entered by users on the webserver into EEPROM memory and restarts the device.

Block Cloud Connection: The program attempts to connect to the Cloud database. If the connection fails due to

misconfigured information or a poor connection, the device will reset after a certain period of unsuccessful attempts.

Block Void Loop: This is an infinite loop after a successful device initialization.

Block Create Data: Data is compressed from two sources following a specific structure: data collected through Modbus RTU (e.g., power parameters like voltage, amperage, frequency) and real-time data obtained from RTC (date, hour, minute, second).

Block Save SD: Before uploading to the cloud, the program saves a copy on the SD card in a predefined data structure.

Block Update Data To Cloud: Sends data to the cloud.

Block Reset Data Button: This block checks if the user pressed the reset button. If so, the program deletes specific data (e.g., WiFi account) and restarts the device, allowing users to reconfigure the device. The reset button can be configured as an external switch.

C. The Android application monitors real-time electrical parameters from the device online

Figure 5 displays a user monitoring interface in which users can easily select the device to monitor directly. It provides convenient options for connecting to measuring devices for both single-phase and three-phase electrical devices. For single-phase devices, the circuit connects to the EM115 Mod CT measuring device from FINECO. For three-phase devices, users have the option to connect to two measuring devices of either KLEA 220P from KLEMSAN or ME96SS-ver.B from MITSUBISHI based on their specific electrical usage requirements.

Then, users can select the device to monitor and confirm the choice by pressing the ACCEPT button on the interface in Fig. 5.

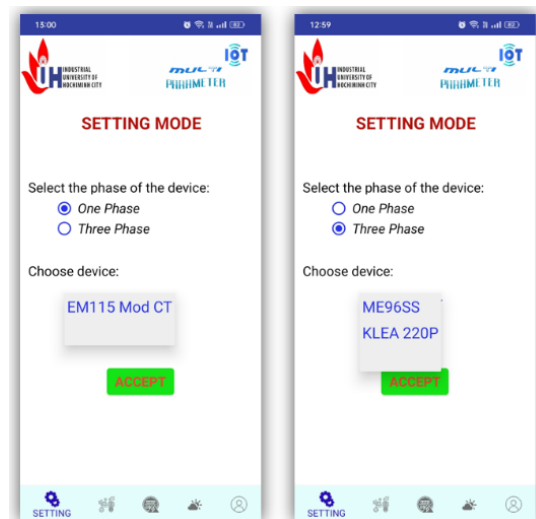


Fig 5. System connection interface in KODULAR software for smartphone application.

Figure 6 illustrates the monitoring interface for all electrical parameters from the selected device in the interface shown in Fig. 5.

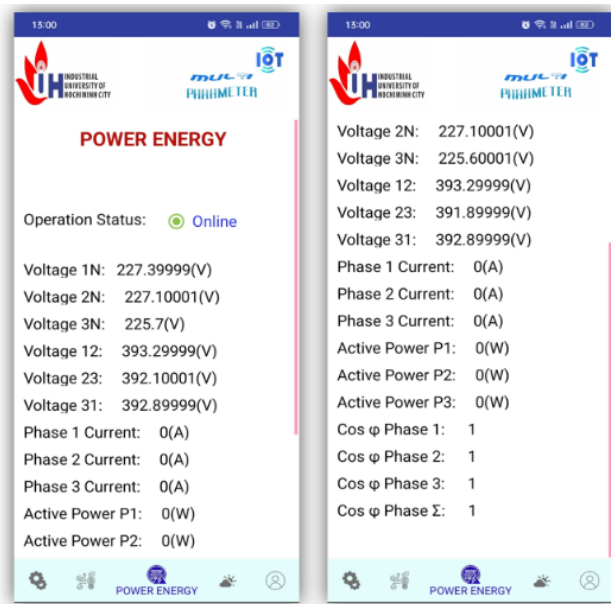


Fig 6. The monitoring interface for electrical energy of the three-phase meter while it is operational

After pressing ACCEPT button in Fig. 5, the device starts collecting all the measured parameters in real-time. It transmits this data to the Cloud and displays all the measured parameters, such as voltage, phase angle, current, and frequency on the interface as in Fig. 6.

D. Storing data on the SD Card and exporting it as an Excel file

After selection ACCEPT button of the interface in Fig. 6, the system proceeds to store the data on the SD Card. Figures 7,8,9,10 shows the extraction of data collected from the measuring device and stored on the SD Card. Users can utilize this data for storage, reporting, forecasting as a database for future artificial intelligence system integration as follows.

Step 1: Insert the micro SD card containing the electrical parameter data from the meter into the micro USB and plug it into the computer.

Step 2: Open Microsoft Excel and open the file with the name of the meter from which you want to export data to Excel.

Step 3: Set up the export of electrical power data from the meter to Microsoft Excel.

Final Step: Choose the data type as General and click Finish to complete the process

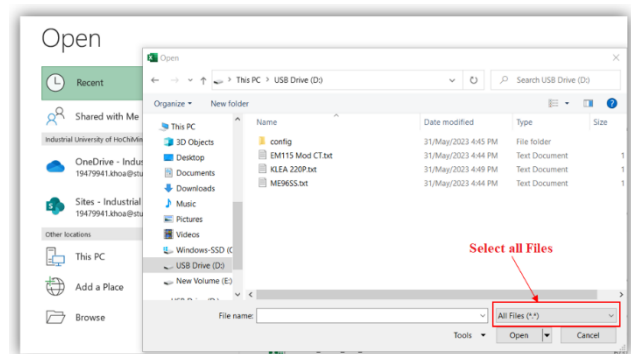


Fig 7. Step 1: Insert the micro SD card containing the electrical parameter data from the meter into the micro USB and plug it into the computer

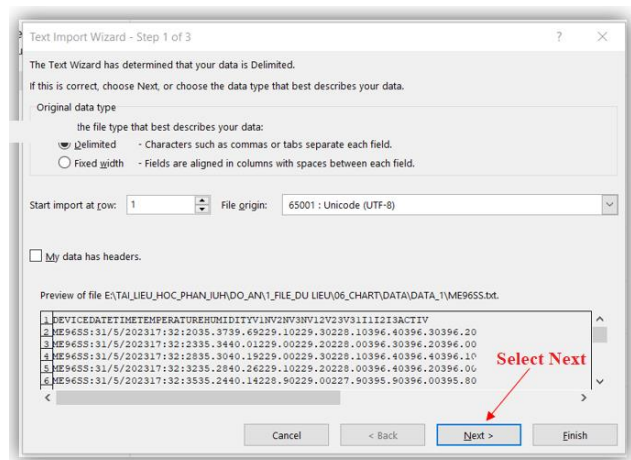


Fig 8. Step 2: Open Microsoft Excel and open the file with the name of the meter from which you want to export data to Excel

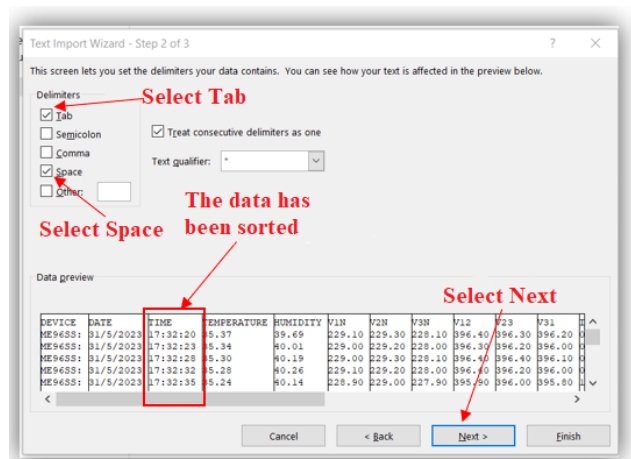


Fig 9. Step 3: Set up the export of electrical power data from the meter to Microsoft Excel

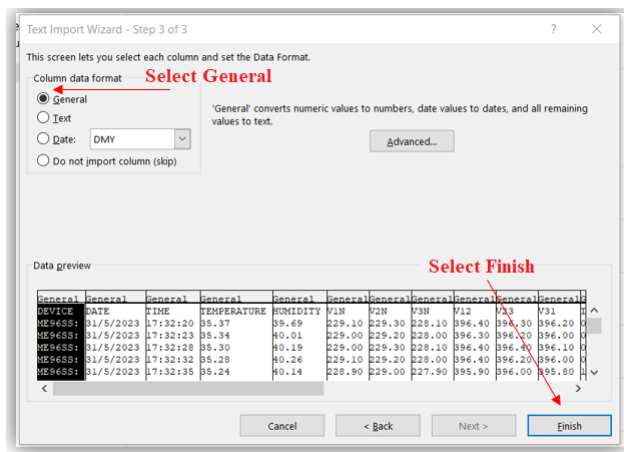


Fig 10. Final Step: Choose the data type as General and click Finish to complete the process

After performing the data extraction in Fig. 10, Table 1 illustrates that the system data has been exported into an Excel file for management and use.

TABLE I. ELECTRICAL POWER DATA FROM THE METER ON THE EXCEL SPREADSHEET

Device	Date	Time	Temperature	Humidity	V1N	V2N
ME96SS	31/5	17:32	35.7	39.69	229.1	229.3
ME96SS	31/5	17:32	35.34	40.01	229	229.2
ME96SS	31/5	17:32	35.1	40.07	228.9	229.1
ME96SS	31/5	17:33	34.98	40.09	228.9	229.12
ME96SS	31/5	17:33	35.16	39.96	229.2	229.3
ME96SS	31/5	17:33	35.29	39.79	229.1	229.3
ME96SS	31/5	17:34	35.3	39.84	229.1	229.4
ME96SS	31/5	17:34	35.29	39.98	229.5	229.4
ME96SS	31/5	17:34	35.32	39.98	229.5	229.4

Figure 11 represents the temperature data collected from Excel, presented in the form of a chart for reporting purposes.

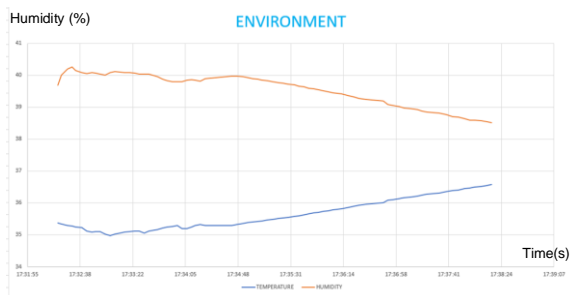


Fig 11. The graph displaying temperature and humidity values on Excel collected by the system

The obtained data in Table 1 and Fig. 11 show that the real-time monitoring on temperature, humidity, and electrical power of the electrical cabinet. The of temperature and humidity of the electrical cabinet are still inside the standard range of temperature ($-5^{\circ}\text{C} \leq T \leq 70^{\circ}\text{C}$) and relative humidity (RH) ($0\% \leq RH < 95\%$), respectively.

IV. CONCLUSION AND FUTURE WORK

This paper has successfully implemented both hardware and software components for data collection and online communication within a system designed to monitor electrical power consumption. This system effectively gathers data from the EM115-Mod CT single-phase multifunctional meter by FINECO and the KLEA 220P three-

phase multifunctional meter by KLEMSAN, along with the ME96SS-ver.B by MITSUBISHI. The collected data is then stored on an SD card and transmitted to the Cloud, allowing for convenient remote monitoring of power parameters using Android phones without the need for on-site inspections.

In future work, the paper will focus on developments for utilizing an outlet-connected display for meter selection, monitoring circuits, and communicating data with various devices such as PLCs to the RS485 communication standard. In addition, it can be extended monitoring capabilities for variable frequency drives with RS485 communication standards. Then, the overall goal is to integrate these advancements into an artificial intelligence system for further enhancing the efficiency and intelligence of the overall monitoring and control system.

REFERENCES

- [1] M. Sharma, and S. C. Gupta, "An Internet of Things Based Smart Surveillance and Monitoring System using Arduino," 2018 Int. Conf. Adv. Comput. Commun. Eng., no. June, 2018, pp. 428–433.
- [2] A. Jain, S. Basantwani, O. Kazi, and Y. Bang, "Smart surveillance monitoring system," 2017 Int. Conf. Data Manag. Anal. Innov. ICDMAI 2017, 2017, pp. 269–273.
- [3] M. Babiuch, P. Foltýnek, and P. Smutný, "Using the ESP32 microcontroller for data processing," 2019 20th International Carpathian Control Conference (ICCC). IEEE, 2019.
- [4] M. Alexander, A. Sharp, and Y. Vagapov, "Comparative analysis and practical implementation of the ESP32 microcontroller module for the internet of things," Internet Technologies and Applications (ITA). IEEE, pp. 143-148, 2017.
- [5] D. Srisuchinwong, S. Benyap, and C. Theerasak, "Acquiring unobtrusive sleep-related signals through an ESP32-based data logger," International Conference on Knowledge and Smart Technology (KST). IEEE, 2021.
- [6] P. Rai, and R. Murk, "ESP32 based smart surveillance system," International Conference on Computing, Mathematics and Engineering Technologies (iCoMET). IEEE, 2019.
- [7] P. Macheso, et al. "Design of standalone asynchronous ESP32 web-server for temperature and humidity monitoring," International Conference on Advanced Computing and Communication Systems (ICACCS). vol. 1. IEEE, 2021.
- [8] P. Foltýnek, B. Marek, and Š. Pavel, "Measurement and data processing from Internet of Things modules by dual-core application using ESP32 board." Measurement and Control 52.7-8, vol. 52, 2019, pp. 970-984.
- [9] M. Babiuch, and F. Petr, "Creating a Mobile Application with the ESP32 Azure IoT Development Board Using a Cloud Platform," International Carpathian Control Conference (ICCC). IEEE, 2021.
- [10] A. Koushal, et al. "Home Automation System Using ESP32 and Firebase," International Conference on Parallel, Distributed and Grid Computing (PDGC). IEEE, 2022.
- [11] C. G. C. Carducci, et al. "Enabling ESP32-based IoT applications in building automation systems." 2019 II Workshop on Metrology for Industry 4.0 and IoT (MetroInd4.0&IoT). IEEE, 2019.
- [12] J. Qi, et al. "Design and Application Analysis of Intelligent Low-voltage Switchgear Based on Internet of Things." Journal of Physics: Conference Series. vol. 1617. No. 1. IOP Publishing, 2020.
- [13] J. Vijayakumar, "Turmeric Farm Monitoring System using Wireless Sensor Network with ESP32 Module," Smart Technologies, Communication and Robotics (STCR). IEEE, 2021.
- [14] A. Zare, and M. T. Iqbal, "Low-cost esp32, raspberry pi, node-red, and mqtt protocol based scada system," IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS). IEEE, 2020.
- [15] H. Hieu, "Design and Implementation of a BLE Gateway Using ESP32 Chipset," Technology and Communication, p.65, 2023.
- [16] L. M. Broell, H. Christian, and K. Dominik, "IoT on an ESP32: Optimization Methods Regarding Battery Life and Write Speed to an SD-Card," Edge Computing - Technology, Management and Integration, 2023.
- [17] A. Joel, P. Cujilema, A. Gustavo, B. Hidalgo, L. Dixys, R. Hernandez, J. Joffre, C. Cartuche, "Secure home automation system

- based on EpSP-NOW mesh network, MQTT and Home Assistant platform". IEEE Latin America Transactions, vol.21, 2023.
- [18] K. M. Sankar, B. Booba, C. Rangaswamy, P. V. Pramila, S. R. Kar, A. Kumar, M. Sudhakar. "IoT based Weather, Soil, Earthquake, Air pollution Monitoring System", International Conference on Innovative Practices in Technology and Management, 2023.
 - [19] T. H. Y. Ling, L. J. Wong, R. Moore, "IoT Fitness Device with Real Time Health Assessment and Cloud Storage" International Conference on Smart Computing & Communications (ICSCC), 2019.
 - [20] A. G. Skrivanos, S. K. Chronopoulos, E. I. Kosma, I. Kouretas, K. P. Peppas, "Home Healthcare Technologies and Services: Heart-Rate Fetus Monitoring System Using an MCU ESP8266 Node", Panhellenic Conference on Electronics & Telecommunications, 2022.
 - [21] S. Thombare, S. Baral, A. Gangrade, R. Jaiswal, "Design & Development of Smart Electric Vehicle Safety Device by using IoT and AI", Fourth International Conference on Emerging Research in Electronics, Computer Science and Technology, 2022.
 - [22] L. M. Silalahi, S. Budiyo, F. A. Silaban, I. U. V. Simanjuntak, A. D. Rochendi, G. Osman, "Optimizing The Performance Of The Power Station Generator Space Lighting System Performance Based On Internet Of Things Using ESP32", International Conference on Research and Academic Community Services, 2021.
 - [23] P. Manikandan, G. Ramesh, P. Lokesh, P. Narasimha Raju, M. Durga Prasad, P. Madhu, "IOT Based Farm Protection System from Animals and Humans Theft using ESP32 with Camera Module", International Conference on Advance Computing and Innovative Technologies in Engineering, 2022.
 - [24] S. Das, S. Saxena, N. K. Rout, "Low Cost Smart-Glass using ESP-32", International Conference on Applied Electromagnetics, Signal Processing, & Communication, 2021.
 - [25] A. Bouraiou, A. Kouddad, K. Kjabbouri, A. Necaibia, S. Lachtar, M. Hamouda, A. Dahbi, A. Rouabhia, A. Slimani, "Remote Supervision of Ambient Temperature Using Wi-Fi ESP8266 Controller Via MIT Android Application", International Conference on Energy Transition and Security, 2023.
 - [26] M. S. Abdul, S. M. Sam, N. Mohamed, N. H. Hassan, A. Azizan, Y. M. Yusof, "Peer to Peer Communication for the Internet of Things Using ESP32 Microcontroller for Indoor Environments", International Conference on Information and Communication Technology Convergence, 2022.
 - [27] T. Ahmed, A. T. B. Nuruddin, A. B. Latif, S. S. Arnob, R. Rahman, "A Real-Time Controlled Closed Loop IoT Based Home Surveillance System for Android using Firebase", International Conference on Control, Automation and Robotics, 2020.
 - [28] C. Z. I. Arnob, N. S. Mitra, A. B. H. Saad, M. T. Alam, M. Islam, A. S. N. Huda, "Smart Load Monitoring and Controlling Approach Connected to Solar System Using ESP32 and Blynk", International Conference on Energy and Power Engineering, 2022.
 - [29] D. Urazayev, A. Eduard, M. Ahsan, D. Zorbas, "Indoor Performance Evaluation of ESP-NOW", International Conference on Smart Information Systems and Technologies, 2023.
 - [30] A. A. Zainuddin, R. M. Nor, A. A. Hussin, M. N. M. Sazali, "MQTT-Enabled Smart Door Access System: Design and Implementation Using NodeMCU ESP 8266 and HiveMQ", International Conference on Computing, Engineering and Design, 2023.
 - [31] N. Dharap, R. Porwal, S. Jindal, "Real-time Forest Fire Detection and Alert System Using Wireless Sensor Networks and Solar Energy", 2023 IEEE International Conference on Next Generation Electronics (NEleX 2023), 2023.
 - [32] P. R. B., P. Sridevi, R. Shamitha, A. Sneha, J. S. S. Maggi, D. Abirami, "Smart Solar Energy Monitor using ESP 32 Controller", International Conference on Electronics, 2023.
 - [33] A. S. Salunkhe, Y. K. Kanse, S. S. Patil, "Internet of Things based Smart Energy Meter with ESP 32 Real Time Data Monitoring", International Conference on Electronics and Renewable Systems, 2022.
 - [34] D. R. Bolla, JijeshJJ, S. S. Pale, M. Penna, K. Shivashankar, "An IoT Based Smart E-Fuel Stations Using ESP-32", International Conference on Recent Trends in Electronics, 2020.
 - [35] M. N. V. Thalatam, J. N. V. R. Pratibha, S. Kumar, "An IoT Based Smart Water Contamination Monitoring System", International Conference on Intelligent Systems for Communication, IoT and Security, 2023.
 - [36] R. Lal, B. Singh, M. A. Wassay, "IoT in Smart Irrigation and Node MCU ESP 8266 Wi-Fi Module", International Conference on Computational Modelling, Simulation and Optimization, 2022.
 - [37] R. P. R. Kumar, S. Polepaka, S. K. Numaan, M. Kumari, S. Pulikantham, M. Peddineni, "Determining the Optimal Parameter for Wheat and Paddy Crops using Smart Farming: An Investigation", International Conference on Computer Communication and Informatics, 2023.
 - [38] H. Liang, W. Zhang, "Stochastic-Stackelberg-Game-Based Edge Service Selection for Massive IoT Networks", Internet of Things Journal, vol. 10, pp. 22080-22095, 2023.
 - [39] D. Mohapatra, B. Subudhi, "Development of a Cost-Effective IoT-Based Weather Monitoring System", Consumer Electronics Magazine, vol. 08, pp. 008-016, 2022.
 - [40] J. P. Pawar, S. Amirthaganes, S. ArunKumar, K. B. Satiesh, "Real time energy measurement using smart meter", pp. 1-5, 2016.
 - [41] V. B. Niranjane, A. Bhagat, K. M. Punwatkar, K. Chaurey, P. Niranjane, "Sustainable Water Management using Internet of Things", International Conference on Smart Systems and Inventive Technology (ICSSIT), 2022.
 - [42] S. Saha, "Crash Recovery and Accident Prediction Using a IoT Based Blackbox System", North Karnataka Subsection Flagship International Conference, 2022.
 - [43] F. T. Z. Saima, M. N. I. Rimoni, T. I. Talukder, "IoT and GSM Based Smart Grid Controlling and Monitoring System", 2022 International Conference for Advancement in Technology (ICONAT) Goa, India. Jan 21-22, 2022.
 - [44] A. Paul, N. Rakhaine, N. J. Ohee, A. Ahammad, "A Comprehensive Android App Based Solution for Automated Attendance and Management in Institutions Using IoT and TinyML", International Conference on Information and Communication Technology for Sustainable Development, 2023.
 - [45] S. N. M. Al-Faydi, H. N. Y. Al-Talb, "IoT and Artificial Neural Network-Based Water Control for Farming Irrigation System", International Conference on Computing and Machine Intelligence, 2022.
 - [46] L. Syafa'ah, A. E. Minarno, F. D. S. Sumadi, D. A. P. Rahayu, "ESP 8266 For Control And Monitoring In Smart Home Application", International Conference on Computer Science, Information Technology, and Electrical Engineering, 2019.
 - [47] S. Thombare, S. Baral, A. Gangrade, R. Jaiswal, "Design & Development of Smart Electric Vehicle Safety Device by using IoT and AI", International Conference on Emerging Research in Electronics, Computer Science and Technology, 2022.
 - [48] Y. Saragih, J. Horas P. Silaban, H. A. Roostiani, S. A. Elisabet, "Design of Automatic Water Flood Control and Monitoring Systems in Reservoirs Based on Internet of Things (IoT)", International Conference on Mechanical, Electronics, Computer, and Industrial Technology, 2020.
 - [49] K. Singh, A. Jain, P. Thiyagarajan, "Design and implementation of integrated control system for IoT enabled home automation", International Conference on Advances in Computing, Communication Control and Networking, 2022.
 - [50] N. Fahmi, E. Prayitno, T. Musri, S. Supria, F. Ananda, "An Implementation Environmental Monitoring Real-time IoT Technology", International Conference on Electrical, Computer and Energy Technologies, 2022.
 - [51] R. H. Arif, H. N. Hilal, A. S. Novian, "Internet of Things (IoT) for Exhaust Emissions on Motor Vehicles Monitoring", International Conference on Intelligent Cybernetics Technology & Applications, 2023.
 - [52] A. Gulati, S. Thakur, "Smart Irrigation Using Internet of Things", International Conference on Cloud Computing, Data Science & Engineering, 2018.
 - [53] U. Aakesh, Y. Rajasekaran, S. T. Sudhakar, "Review on Healthcare Monitoring and Tracking Wristband for Elderly People using ESP-32", International Conference on Smart Systems and Inventive Technology, 2023.
 - [54] W. M. Samoda Ravishani, G. A. Sithmi Ganepola, E. D. M. Silva, G. H. G. Chamodi Jayanika, U. U. Samantha Rajapaksha, N. H. P. Ravi, S. Swarnakantha, "IoT Based Smart Pillow for Improved Sleep Experience", International Conference on Advancements in Computing, 2022.
 - [55] S. A. Devi, M. S. Ram, K. Ranganarayana, D. B. Rao, V. Rachapudi, "Smart Home System Using Voice Command With Integration Of

- ESP8266", International Conference on Applied Artificial Intelligence and Computing, 2022.
- [56] M. B. Sowmya , N. S. Sai , V. Ponkarthikeyan , P. Bowman , R. Archanaa , S. Jayasri , "IoT Driven High Pressure Pasteurisation", International Conference on Smart Structures and Systems, 2023.
- [57] U. Musa, S. M. Shah, H. A. Majid , I. A. Mahadi, M. K. A. Rahim, M. S. Yahya, Z. Z. Abidin, "Design and Implementation of Active Antennas for IoT-Based Healthcare Monitoring System", IEEE Access, vol. 12, pp. 48453-48471, 2024.
- [58] A. Panicker, D. Gupta, H. Deora, A. Jain, A. Kumar, N. Gupta, "Real Time Environmental Factors Monitoring System by Sensor Fusion on a NodeMCU ESP8266-Wemos-D1 R1 Board", Region 10 Humanitarian Technology Conference, 2023.
- [59] I. Mourishwar, M. D. Chandram, K. Selvakumar, Raja S. R., "Programmable Wireless Adapter for Commercial Electric Drives and Multifunction Meters", 2023 Innovations in Power and Advanced Computing Technologies (i-PACT), 2023.
- [60] A.Heri, S. Yohana, J. Vincent, I. Nanang, "Design of IoT-Based Electrical Energy Meter", 2023 IEEE 9th International Conference on Computing, Engineering and Design (ICCED), 2023.