RESEARCH ON BUILDING AN ENVIRONMENTAL QUALITY MONITORING MANAGEMENT DEVICE USING THE INTERNET OF THINGS

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ARTICLE INFORMATION

Journal: *Vinh University Journal of Science Natural Science, Engineering and Technology*
p-ISSN*: 3030-4563*
e-ISSN: *3030-4180*

Volume: 53
Issue: 4A
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Received: *09 July 2024*
Accepted: *10 September 2024*
Published: *20 December 2024*

Citation:
Ho Thi Tuyen (2024). Research on building an environmental quality monitoring management device using the Internet of Things ***Vinh Uni. J. Sci.*** *Vol. 53 (4A), pp. 47-58*
doi: 10.56824/vujs.2024a077a

ABSTRACT

The paper proposes an innovative solution with a new air monitoring system that utilizes IoT technology, featuring compact, flexible, and automated nodes. This system operates without human intervention and can perform real-time measurements, reducing errors and consuming less energy. The product is developed and designed based on WiFi communication technology, NodeMCU Module, and the application of various sensors such as rain sensors, temperature-humidity sensors, soil moisture sensors, UV (Ultraviolet) sensors, dust sensors, fire sensors, and GAS sensors. The final product is a feasible hardware system for use in WiFi-covered areas, serving not only environmental monitoring but also households, farms, and agricultural areas.

Keywords: Measurement; monitoring; control; environment; Internet of Things (IoT).

1. Introduction

Monitoring environmental quality has become more urgent than ever in the context of increasing climate change and environmental pollution. The Internet of Things (IoT) technology has opened new opportunities for the efficient and accurate collection, analysis, and management of environmental data [1], [2], [3], [4], [5]. This paper focuses on the research and development of an environmental monitoring device based on IoT technology.

Overview of studies to date. Several studies have been published on environmental pollution monitoring systems, including: In [6], the authors propose an IoT-based environmental pollution monitoring system. This system only monitors pollution caused by vehicles, using sensors to collect real-time data on air pollutants such as SO_2, CO, CO_2, and NO, and calculates the percentage of these substances. The pollutants addressed include Ammonia, Oxygen, and Carbon Monoxide. In [7], the authors present a model to assess the complexity of air pollution in a workplace monitoring and forecasting system. The system uses multiple sensors and Neural

Networks to track and predict temperature, humidity, wind direction, and wind speed. In [8], the authors propose a framework for a monitoring system based on wireless sensor networks (WSN), using mobile communication networks (GSM) and LabView to build an interface for displaying monitoring information. This system only monitors Carbon concentration in the air. In [9], the authors present an intelligent monitoring system using IoT and Petri Nets (PN) to track temperature and predict reference temperature, which can be used for temperature control units. This study also emphasizes energy consumption and model efficiency. In [10], the authors discuss using Zigbee networks to monitor indoor air quality, tracking PM2.5, CO2, temperature, and humidity. Data is collected through IoT devices and shared via GPRS/4G networks. This system also focuses on energy consumption and the efficiency of the monitoring model. Other studies have built IoT-based monitoring systems to track hazardous pollutants in air, water, and soil by various authors [11], [12], [13], [14], [15]. These models use different controllers and sensors to collect and monitor data on air pollutants, pH values in industrial wastewater, and other factors. Surveys of related devices, products, and publications indicate that these solutions are complex and expensive. Moreover, these technologies are proprietary (require licensing) and are only suitable for specific subjects or areas proposed by the authors.

This paper presents the development of a new air quality monitoring system intended for use in several areas in Vietnam to address the shortcomings of previous systems by using compact, flexible, and fully automated network nodes. This system minimizes errors, consumes less energy, and operates independently of human intervention. The system is expected to have a simple operation, requiring no high-level user knowledge, and be easy to maintain, repair, and install at a much lower cost. The research aims to design an environmental monitoring system capable of collecting data from various sensors, transmitting data in real-time, and providing detailed information on environmental parameters such as air quality, temperature, humidity, and noise levels. This system will use sensor modules connected to microcontrollers like Arduino and ESP8266 to collect and transmit data wirelessly to a central server. The study also addresses the development of environmental data management software (website), allowing scientists and authorities to access, monitor, and analyze the data quickly. This software will provide data visualization tools, detect trends, and offer early warnings about environmental changes.

2. System design diagram

The overall block diagram of the system is described in Figure 1.

Description of Functional Blocks [2-10]:

• Node MCU Block: Receives data from the control block and sends it to the server while receiving control signals from the server to control the sensors.

• Actuator Block: Receives signals from the control block to switch electrical devices on and off.

• Control Block: The central control unit is responsible for collecting and processing data from the sensor block through the Node MCU block and receiving control signals from the Node MCU to manage the sensor block. The system's smooth operation and efficiency depend heavily on the control block, which uses the Arduino UNO R3 board.

• Sensor Block: Collects data from the environment and sends it to the control block for processing.

• Display Block: Informs the observer of the current system status.

• Power Block: Provides power to the other blocks in the system.

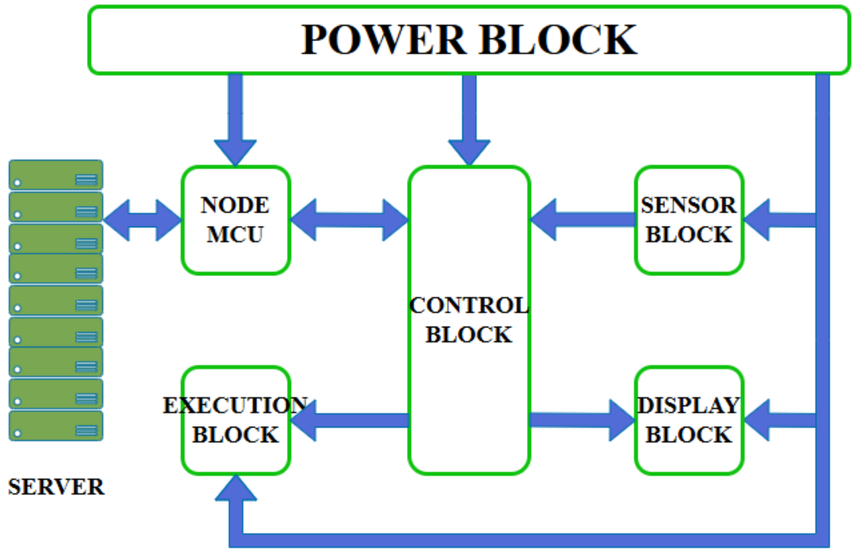

Figure 1: *Block diagram of the overall system*

System Operation Principle: Sensors (temperature-humidity sensor, dust sensor, UV sensor, rain sensor, soil moisture sensor, gas sensor, fire sensor) collect environmental data and send the values to the Arduino. The Arduino receives and processes these values and then sends them through the NodeMCU module while displaying them on an LCD screen. The NodeMCU receives data from the Arduino, transmits it to the server (website) via a Wi-Fi connection, and waits for control signals from the server to control electrical devices. The web server visually displays the parameters received from the sensors in real-time (with a delay due to upload time). It controls the electrical devices through on/off buttons on the system website.

Component Selection:

• Data Transmission Block: The system uses the Node MCU module to send and receive data via Wi-Fi.

• Actuator Block: Uses the BMC water booster pump.

• Control Block: The system uses the Arduino UNO R3 board as the main microcontroller.

• Sensor Block: Includes Temperature and Humidity Sensor (DHT11); Soil Moisture Sensor (YL-69); Rain Sensor: Detects rain or conductive liquids contacting the sensor surface, useful for automatic applications such as rain detection and automatic water level alerts; Dust Sensor (Sharp Optical Dust Sensor PM2.5 GP2Y1010AU0F); UV Sensor (ML8511); Gas Sensor (MQ-2 for LPG/CO/CH_4); Fire Sensor.

• Display Block: Uses the LCD 12864 screen to display status and sensor readings. The system uses a green LCD12864 screen for display.

• Power Block: The system uses three different power supplies: 12V 5A Powers the pump, motor, motor control circuit L298, and cooling fan. 9V Powers the Arduino, Node MCU module, and sensors. The 9V supply to the Arduino goes through a 5V regulator IC for Arduino operation, and the 5V supply for the sensors is taken from the Arduino's 5V pin. 5V Powers ensures sufficient current for the relay circuit, preventing voltage drops.

3. Hardware design

The hardware circuit design of the system is illustrated in Figure 2.

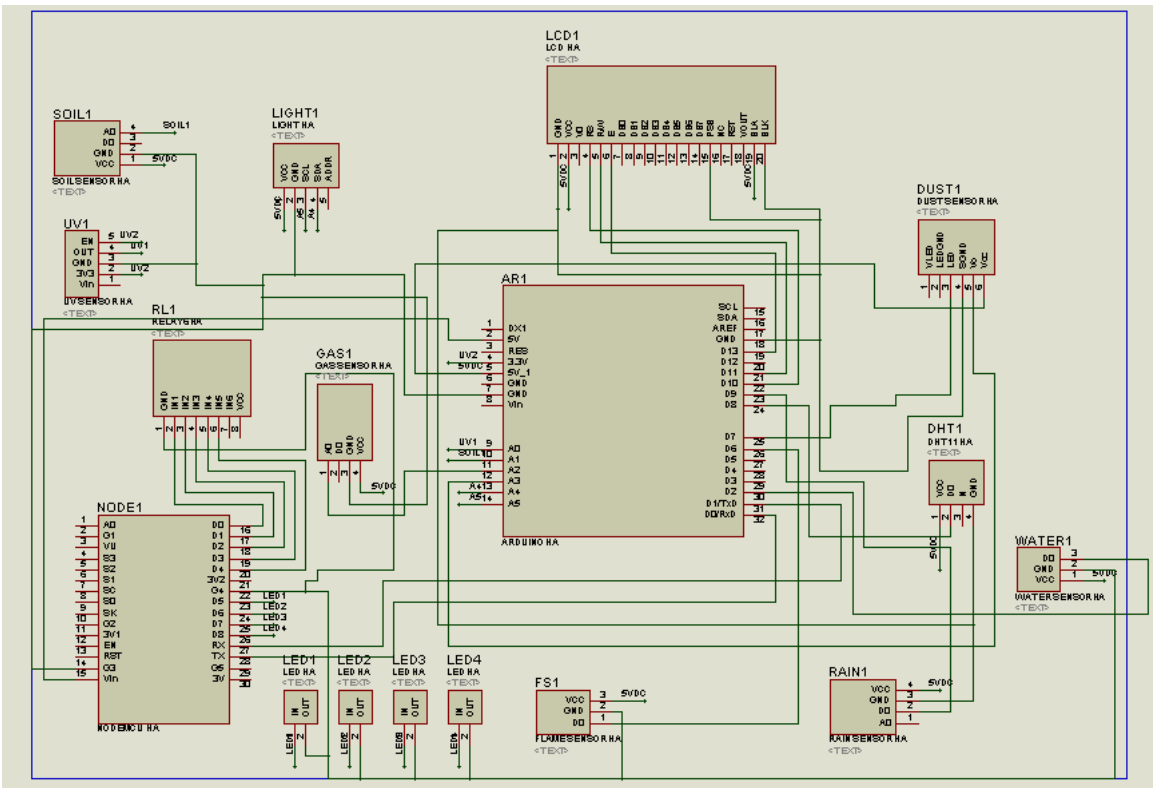

Figure 2: *Schematic diagram of the system circuit*

In Figure 2, the sensors and modules are connected to the Arduino UNO R3 board according to the pin connection tables provided below (Tables 1, 2, 3, and 4). The system uses a 5V relay that is activated at a high level, allowing it to control the power for the water pump, cooling fan, and the L298 motor control module, which operates the curtain motor. To display the operating status, an LCD 12864 screen is connected to pins D10 through D13 of the Arduino. The NodeMCU ESP8266 module is used to send and receive data from the server.

All sensors and relays are powered by a 5V DC supply, the water pump uses a 12V DC supply, and the Arduino operates on a 9V DC power source. Sensor data is continuously updated automatically and sends value information or warning signals to both the LCD screen and the web interface in real time. Additionally, users can control actuators (fan, water pump, curtain, etc.) remotely via the internet or perform other tasks as needed.

Table 1: *Pin connection table for sensor block*

Arduino	GND	5V	3.3V	A0	A1	A2	A3	D6	D7	D8	D9
Dust Sensor	GND	VCC	-	-	-	-	V0	-	LED	-	-
Temperature Sensor	GND	VCC	-	-	-	-	-	-	-	D0	-
Rain Sensor	GND	VCC	-	-	-	-	-	-	-	-	D0
Gas Sensor	GND	VCC	-	-	-	A0	-	-	-	-	-
Soil Moisture Sensor	GND	VCC	-	-	A0	-	-	-	-	-	-
UV Sensor	GND	-	VCC	OUT	-	-	-	-	-	-	-
Fire Sensor	GND	VCC	-	-	-	-	-	D0	-	-	-

Table 2: *Pin connection table for data transmission block*

Arduino	**D0**	**D1**	**5V**	**GND**
Node MCU	**TX**	**RX**	**Vin**	**GND**

Table 3: *Pin connection table for display block*

Arduino	**5V**	**GND**	**D10**	**D11**	**D12**
LCD12864	**VCC, BLA**	**GND, BLK, RST**	**RS**	**RW**	**E**

Table 4: *Pin connection table between node mcu and relay module*

Node MCU	**D0**	**D1**	**D2**	**D3**	**D4**	**GND**
Module Relay	**IN1**	**IN2**	**IN3**	**IN4**	**IN5**	**GND**

4. Software design

To ensure the system operates effectively, an algorithm flowchart that meets the problem requirements is essential. Based on the functions of the system components described in Figure 1, this study proposes the development of algorithm flowcharts for the system, divided into two separate flowcharts: one describing the functions of the controller, and the other describing the functions of the server [6], [7], [8], [9], [10], [11], [12], [13], [14], [15]. Additionally, to develop the software interface that supports connection to the hardware system, an Integrated Development Environment (IDE) is used to program the Arduino boards.

a. Controller algorithm flowchart

The algorithm flowchart for the system node controller is shown in Figure 3. Upon initialization, the system starts by setting up libraries, sensors, and modules, followed by checking the Wi-Fi connection status. If Wi-Fi is connected, the system will await commands from the server to control the devices, read and process sensor data, and subsequently send this data to the server. This process repeats in an infinite loop. If Wi-Fi is not connected, the system will continue checking until a connection is established, after which the subsequent processes are executed. The <ESP8266WiFi.h> library enables the NodeMCU DEVKIT to perform Wi-Fi connection functions in various modes.

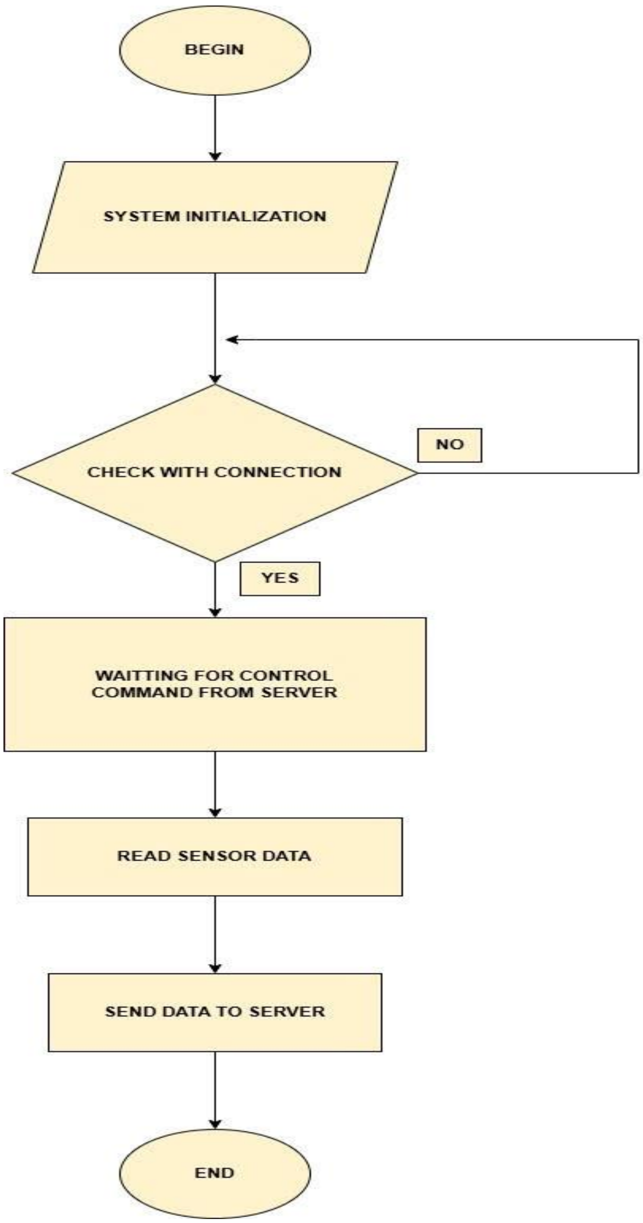

Figure 3: *Algorithm flowchart for controlling system nodes*

b. Server algorithm flowchart

The algorithm flowchart describing the server operation of the system is constructed as shown in Figure 4. Upon successful initialization, the server immediately receives data sent from the Node. During this process, the server listens for control commands from the user. If the user wishes to operate a device (such as a pump, fan, or curtain), the server promptly sends an ON/OFF control signal to the Node.

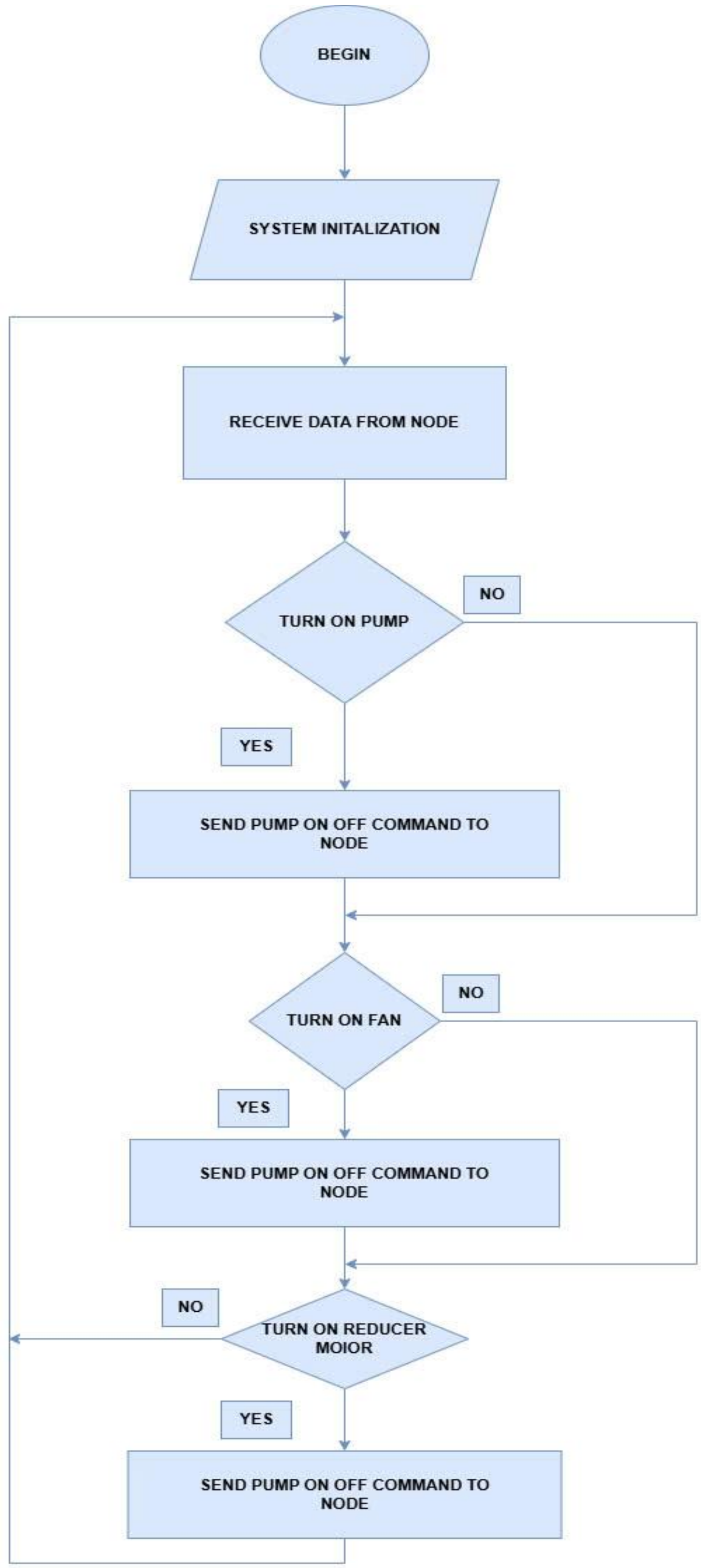

Figure 4: *Algorithm flowchart for server operation*

5. Results and discussion

The design product in practice is illustrated in Figures 5, 6, 7, 8, 9, 10, 11, and 12:

Figure 5: *Image of the completed product*

Figure 6: *Front view of the product*

Figure 7: *Top view of the product*

Figure 8: *Side view of the product*

And images of the results when operating the product in practice:

Figure 9: *LCD screen displaying measured environmental parameters*

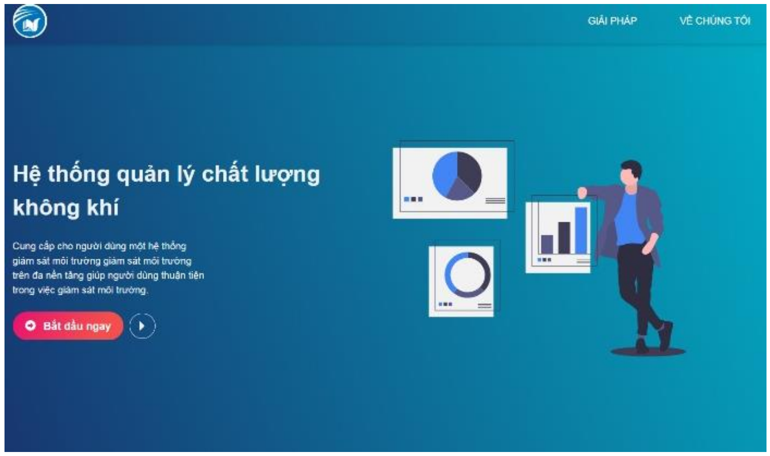

Figure 10: *Homepage of the system website*

Figure 11: *System introduction website image*

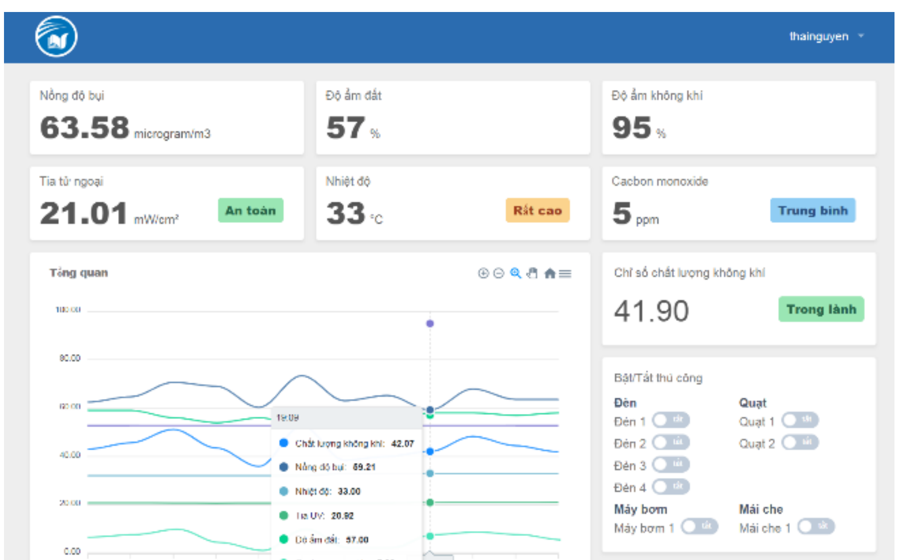

Figure 12: *Main operating website image of the system*

The development of an environmental quality management and monitoring device based on IoT represents a significant advancement in environmental science and technology. By leveraging IoT technology, this device addresses core issues of traditional monitoring systems, such as bulkiness, high energy consumption, and the need for manual intervention. The integration of diverse sensors, along with real-time data collection and analysis, ensures greater accuracy and efficiency. Its compact and flexible design also facilitates deployment across various environments, including households, agricultural settings, and urban areas.

6. Conclusion

This paper presents the research results on developing an environmental quality monitoring and management device based on IoT technology. The device has demonstrated high stability and accuracy in measuring environmental parameters as required. Users can remotely monitor and configure the device, making it suitable for specific operational environments. Future developments could include additional features such as scheduled on/off controls, power cut-off in case of faults, and audio alerts for operational status. Furthermore, additional sensors could be integrated to enhance monitoring capabilities. Upcoming enhancements may also incorporate control and monitoring methods such as voice control, touchscreens, or mobile phone integration. The research aims to create products that are practical for daily life, ensuring quality, affordability, and suitability for Vietnamese consumers.

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TÓM TẮT

NGHIÊN CỨU XÂY DỰNG THIẾT BỊ QUẢN LÝ GIÁM SÁT CHẤT LƯỢNG MÔI TRƯỜNG SỬ DỤNG MẠNG KẾT NỐI VẠN VẬT

Hồ Thị Tuyến
Trường Đại học Công nghệ thông tin và Truyền thông, Đại học Thái Nguyên, Việt Nam
Ngày nhận bài 09/7/2024, ngày nhận đăng 10/9/2024

Bài báo đề xuất một giải pháp cải tiến cho hệ thống giám sát không khí mới, sử dụng công nghệ IoT, với các node nhỏ gọn, linh hoạt và tự động. Hệ thống này không cần sự can thiệp của con người và có thể đo đạc theo thời gian thực, giảm sai số và tiêu thụ năng lượng ít hơn. Sản phẩm được xây dựng và thiết kế dựa trên công nghệ truyền thông WiFi, Module NodeMCU, và ứng dụng các cảm biến đa dạng như cảm biến mưa, nhiệt độ - độ ẩm, độ ẩm đất, tia UV (Ultraviolet), bụi, lửa và GAS. Sản phẩm cuối cùng là một hệ thống phần cứng khả thi để sử dụng tại các nơi có phủ sóng WiFi, phục vụ không chỉ cho quan trắc môi trường mà còn cho các hộ gia đình, trang trại và khu vực nông nghiệp.

Từ khóa: Đo đạc; giám sát; điều khiển; môi trường; mạng kết nối vạn vật.