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Development Of A Realtime IoT Smart Home Monitoring System Using ESP8266, ThingsBoard, And Telegram Bot

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Abstract

The rapid advancement of Internet of Things (IoT) technology has significantly contributed to the development of intelligent automation systems for residential environments. This study aims to design and implement an IoT-based Smart Home system using the NodeMCU ESP8266 microcontroller for realtime monitoring and control applications. The proposed system integrates several hardware components, including the YF-S201 water flow sensor for monitoring water flow rate and total water consumption, the MQ2 gas sensor for gas leakage detection, a 3-channel relay module for household lighting control, and a buzzer alarm as an early warning mechanism. Furthermore, the system is integrated with ThingsBoard Cloud and Telegram Bot to support realtime monitoring, remote control, and automatic notification services through internet communication using the MQTT protocol. This research employed an experimental method with a prototype-based development approach involving system requirement analysis, hardware and software design, system integration, implementation, and performance testing. The system was implemented and tested at a residential environment located in North Lampung Regency, Indonesia. The testing process evaluated the performance of water monitoring, gas detection, notification delivery, and lighting control functionalities. The results demonstrated that the developed Smart Home system successfully performed realtime monitoring of water flow rate, total water usage, gas leakage conditions, and remote lighting control through cloud-based communication. The water flow sensor achieved an average reading of 8.82 liters per minute with cumulative water usage reaching 50 liters during testing. In addition, the MQ2 gas sensor successfully detected dangerous gas conditions and automatically activated the buzzer alarm while simultaneously sending warning notifications through Telegram Bot with a testing success rate of 100%. The relay module also successfully controlled all household lighting devices remotely through the ThingsBoard dashboard with stable MQTT communication and low delay response. Overall, the developed IoT-based Smart Home system demonstrated strong capability in improving household monitoring efficiency, environmental safety, and user convenience through intelligent realtime automation technology.

Keywords: ***Internet of Things, Smart Home, ESP8266, ThingsBoard, MQTT, Water Flow Sensor, MQ2 Gas Sensor, Telegram Bot.***

INTRODUCTION

The rapid advancement of information and communication technology has significantly accelerated the development of various automation systems based on the Internet of Things (IoT) . IoT technology enables electronic devices, sensors, and embedded systems to communicate and exchange data through internet networks, thereby supporting realtime monitoring, automation, and remote control capabilities. The integration of IoT into everyday life has transformed conventional systems into intelligent and interconnected environments capable of improving operational efficiency, data accessibility, and user convenience.

One of the most widely implemented applications of IoT technology is the Smart Home system. Smart Home technology has attracted considerable attention due to its ability to enhance residential comfort, energy efficiency, security, and automation processes. Through IoT-based communication, users can remotely monitor and control household devices such as lighting systems, environmental sensors, security alarms, water usage systems, and electrical appliances using smartphones, web dashboards, or cloud-based platforms. The implementation of Smart Home systems not only improves user convenience but also contributes to more efficient resource utilization and improved safety management within residential environments.

Despite the increasing adoption of Smart Home technology, several common problems are still frequently encountered in household environments. These problems include excessive water consumption, the absence of realtime monitoring for daily water usage, potential gas leakage hazards, and lighting systems that are still manually operated. In many conventional residential systems, users often experience difficulties in obtaining realtime information regarding environmental conditions within the house. Furthermore, traditional monitoring systems generally lack automatic warning mechanisms capable of providing immediate notifications when dangerous situations occur, such as gas leaks or abnormal environmental conditions. These limitations may increase the risk of accidents, energy waste, and inefficient household management.

To address these challenges, this study proposes and implements a Smart Home system based on Internet of Things technology using the NodeMCU ESP8266 microcontroller as the primary control unit. The developed system integrates several hardware and software components to support realtime monitoring and automation functions. A YF-S201 water flow sensor is utilized to measure water flow rate and total water consumption, while an MQ2 gas sensor is implemented to detect gas leakage conditions within the residential environment. In addition, a 3-channel relay module is employed to control household lighting systems remotely, and a buzzer is used as an alarm mechanism to provide immediate warning notifications when hazardous gas levels are detected.

The proposed Smart Home system also integrates ThingsBoard Cloud as a cloud-based monitoring dashboard and Telegram Bot as a realtime notification service. Through the MQTT communication protocol, sensor data can be transmitted continuously from the ESP8266 microcontroller to the cloud platform, allowing users to monitor system conditions remotely via smartphones or internet-connected devices. The integration of Telegram Bot further enhances the responsiveness of the system by automatically sending warning notifications whenever abnormal conditions are detected, particularly during gas leakage events.

The implementation of the proposed system was conducted at Mrs. Murni Saraswati's residence located in Kebun Empat, Tanjung Harapan Village, South Kotabumi District, North Lampung Regency, Indonesia. The developed Smart Home system is expected to improve household water usage efficiency, enhance residential safety, and simplify the monitoring and control of household devices through realtime internet-based communication. Furthermore, the proposed IoT-based Smart Home system is expected to contribute to the advancement of intelligent residential technologies that support safer, smarter, more efficient, and environmentally sustainable living environments.

RESEARCH METHODS

This study employed an experimental research method using a prototype-based Internet of Things (IoT) approach. The experimental method was selected because the research focused on the design, implementation, integration, and evaluation processes of a Smart Home system based on the ESP8266 microcontroller integrated with ThingsBoard Cloud and Telegram Bot platforms . The prototype approach was considered appropriate because it allows the system to be developed incrementally, starting from requirement analysis, hardware and software design, system integration, and realtime testing according to user requirements and environmental conditions.

The research stages began with the identification of household-related problems, including inefficient water usage monitoring, manual lighting control systems, and the lack of an automatic warning mechanism for gas leakage detection. After identifying the problems, a system requirements analysis was conducted to determine the necessary hardware and software components required for the Smart Home system. The next stage involved designing the Smart Home architecture using the NodeMCU ESP8266 microcontroller as the primary processing unit. Subsequently, the system was implemented and integrated with the ThingsBoard Cloud platform and Telegram Bot service to support realtime monitoring and notification capabilities. The final stage involved system testing and performance analysis to evaluate the effectiveness, reliability, and overall functionality of the developed Smart Home system.

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The research flowchart presented in Figure 1 illustrates the systematic stages of the Smart Home development process, starting from problem identification to the analysis of system testing results. During the implementation phase, the system integrated several IoT components, including the ESP8266 microcontroller, YF-S201 water flow sensor, MQ2 gas sensor, relay module, buzzer, and cloud-based monitoring dashboard. Comprehensive testing was then conducted to evaluate all system functionalities, including water usage monitoring, realtime lighting control, gas leakage detection, and Telegram notification delivery. The testing results were further analyzed to assess MQTT communication stability, sensor performance accuracy, and the overall effectiveness of the Smart Home system.

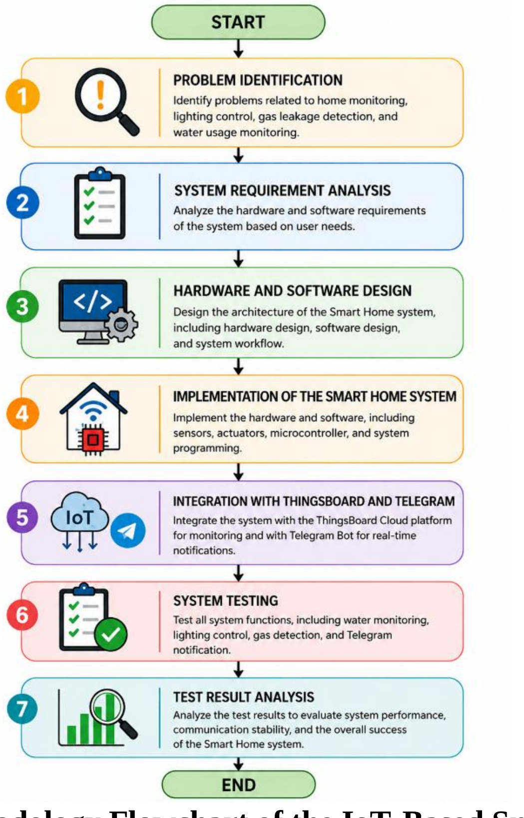

Figure 1. Research Methodology Flowchart of the IoT-Based Smart Home System

Source: Prepared by the Author, 2026

Research Location and Object

The implementation and testing of the proposed Smart Home system were conducted at Mr. Budi's residence located in Kebun Empat, Tanjung Harapan Village, South Kotabumi District, North Lampung Regency, Indonesia. The research object focused on the development of an IoT-based Smart Home monitoring and control system capable of operating in realtime through internet communication.

The developed Smart Home system consisted of several main hardware and software components, including:

NodeMCU ESP8266 microcontroller, YF-S201 water flow sensor, MQ2 gas sensor, 3-channel relay module, Buzzer alarm, ThingsBoard Cloud dashboard, Telegram Bot notification system

These components were integrated into a unified IoT ecosystem to support realtime monitoring, automation, and remote device control through internet-based communication.

System Architecture

The Smart Home architecture proposed in this study was designed using the Internet of Things (IoT) concept, which integrates sensors, microcontrollers, actuators, cloud platforms, and notification systems into a single interconnected system. The architecture was specifically designed to support realtime monitoring and remote control of household devices using internet communication and MQTT protocols.

In the developed system, the YF-S201 water flow sensor was utilized to measure water flow rate and total water consumption in realtime, while the MQ2 gas sensor was employed to detect gas leakage conditions within the household environment. All sensor data were processed by the NodeMCU ESP8266 microcontroller before being transmitted to the ThingsBoard Cloud platform via WiFi connectivity. In addition to environmental monitoring, the system was also capable of controlling household lighting through a 3-channel relay module connected to the cloud dashboard interface.

Whenever the MQ2 sensor detected dangerous gas levels exceeding the predefined threshold value, the system automatically activated the buzzer alarm and sent warning notifications through Telegram Bot to inform users about the hazardous condition. The overall architecture of the IoT-based Smart Home system is illustrated in Figure 2.

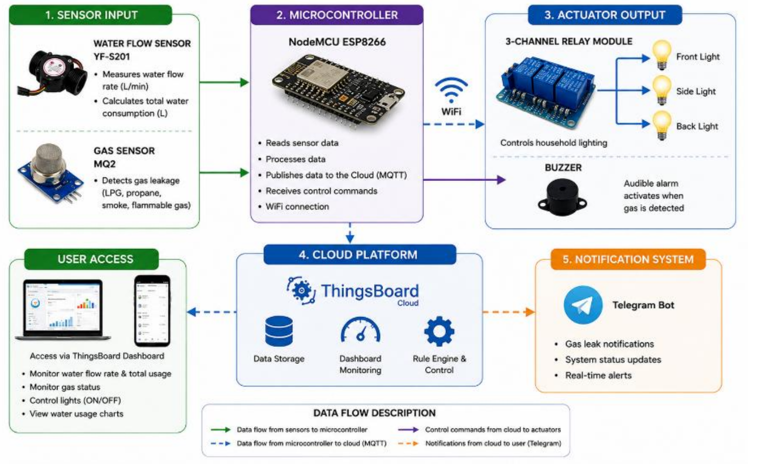

Figure 2. IoT Smart Home Monitoring and Control Architecture

Source: Prepared by the Author, 2026

Figure 2 demonstrates that the Smart Home architecture consists of five primary subsystems: sensor input, ESP8266 microcontroller, actuator output, cloud platform, and notification system. The water flow and gas sensors functioned as input devices responsible for collecting environmental data in realtime. The collected data were then processed by the ESP8266 microcontroller and transmitted to ThingsBoard Cloud using the MQTT communication protocol via wireless internet connectivity.

The ThingsBoard dashboard served as the main interface for monitoring sensor data and controlling household lighting devices remotely. Meanwhile, the relay module functioned as an actuator responsible for controlling the lighting system, while the buzzer acted as an audible warning device during gas leakage conditions. Telegram Bot was integrated as an automatic notification service to ensure users could receive realtime information directly on their smartphones regardless of location.

System Wiring Diagram

The wiring diagram was designed to illustrate the interconnection among all hardware components used in the IoT-based Smart Home system. In this study, the NodeMCU ESP8266 functioned as the central control unit connected to the YF-S201 water flow sensor, MQ2 gas sensor, 3-channel relay module, buzzer, and household lighting system. The system utilized a 5V power adapter as the primary power supply source to provide stable electrical power to all hardware components.

The YF-S201 sensor was used to monitor water flow rate and cumulative water usage in realtime, while the MQ2 sensor was responsible for detecting gas leakage conditions within the residential environment. The 3-channel relay module acted as an electronic switching mechanism to control three household lamps consisting of the front lamp, side lamp, and back lamp through the ThingsBoard dashboard interface. Furthermore, the buzzer functioned as an alarm system activated whenever dangerous gas conditions were detected.

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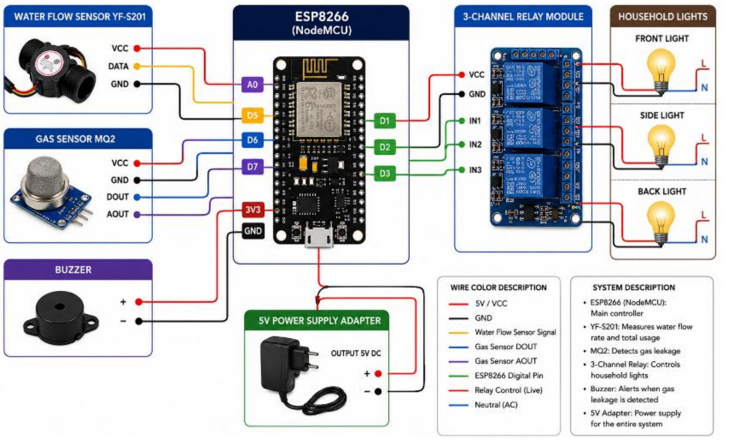

Figure 3. Wiring Diagram of the IoT-Based Smart Home System
Source: Prepared by the Author, 2026

Figure 3 illustrates the complete wiring configuration among all Smart Home hardware components. Each component was connected to the ESP8266 microcontroller according to its specific function using digital and analog pins. The water flow sensor was connected to digital input pins for pulse-based water flow measurement, whereas the MQ2 sensor was connected to analog pins to monitor gas concentration levels.

The relay module was connected to ESP8266 digital output pins and functioned as an electronic switch for controlling household lighting devices in realtime. When the MQ2 sensor detected gas concentrations exceeding the predetermined threshold value, the buzzer was automatically activated and the system transmitted warning notifications through Telegram Bot. This integrated wiring configuration enabled the system to perform realtime monitoring and remote control operations effectively within an Internet of Things environment.

Hardware Components

The hardware components used in this research are presented in Table 1.

Table 1. Hardware Components

No	Component	Function
1	NodeMCU ESP8266	Main microcontroller
2	YF-S201 Flow Sensor	Water flow monitoring
3	MQ2 Gas Sensor	Gas leakage detection
4	3-Channel Relay	Lighting control
5	Buzzer	Warning alarm
6	AC Lamps	System output
7	Smartphone	Dashboard monitoring
8	5V Adapter	Power supply

The NodeMCU ESP8266 was selected because it provides integrated WiFi connectivity, low power consumption, and compatibility with various IoT communication protocols. The combination of sensors, relay modules, and cloud-based platforms enabled the developed Smart Home system to operate efficiently in realtime monitoring and automation scenarios.

Software Components

The software components used in this research are presented in Table 2.

Table 2. Software Components

No	Software	Function
1	Arduino IDE	ESP8266 programming
2	ThingsBoard Cloud	Realtime monitoring
3	Telegram Bot API	Realtime notification
4	MQTT Protocol	Data communication

The system was programmed using Arduino-based C++ programming language. Several libraries were utilized to support communication, cloud integration, and notification functionalities, including:

ESP8266WiFi.h, PubSubClient.h, UniversalTelegramBot.h

The ESP8266WiFi library was used to establish wireless internet connectivity, while the PubSubClient library supported MQTT-based communication between the ESP8266 and ThingsBoard Cloud platform. Additionally, the UniversalTelegramBot library enabled automatic message transmission and realtime notification services through Telegram Bot integration.

RESULTS AND DISCUSSION

Implementation Results of the IoT-Based Smart Home System

The implementation of the Internet of Things (IoT)-based Smart Home system was successfully carried out using the NodeMCU ESP8266 as the primary control unit integrated with the YF-S201 water flow sensor, MQ2 gas sensor, 3-channel relay module, buzzer alarm, ThingsBoard Cloud platform, and Telegram Bot notification service. The developed system was designed to support realtime monitoring of water flow rate, total water consumption, gas leakage detection, and remote lighting control through internet-based communication using the MQTT protocol.

The hardware implementation process was conducted by connecting all sensors and actuators to the ESP8266 microcontroller according to the wiring diagram designed in the previous stage. The relay module functioned as an actuator to control three household lamps consisting of the front lamp, side lamp, and back lamp remotely through the ThingsBoard dashboard interface. Meanwhile, the buzzer was configured as an audible warning device to notify users whenever dangerous gas conditions were detected.

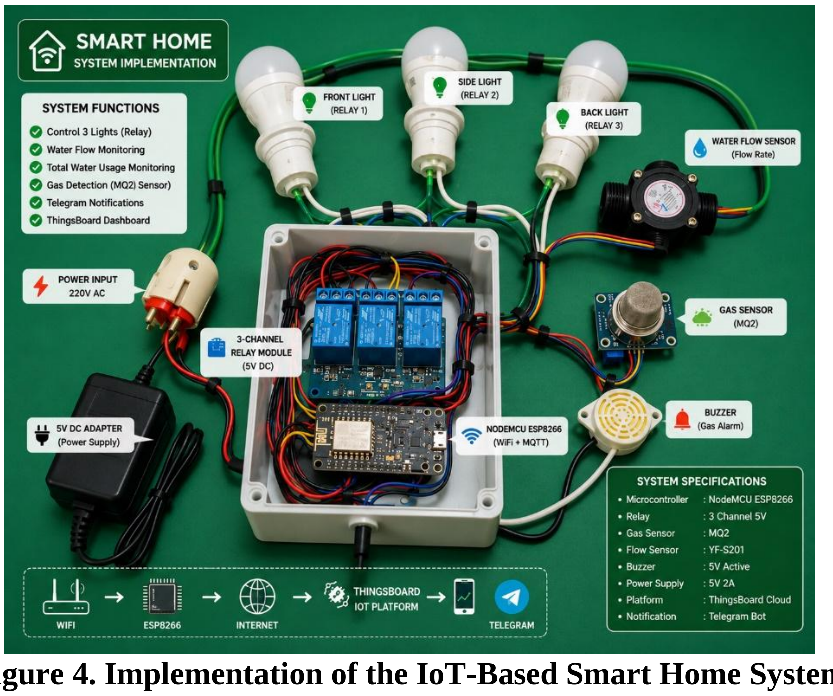

Figure 4. Implementation of the IoT-Based Smart Home System

Figure 4 illustrates the implementation of the developed IoT-based Smart Home system. Based on the implementation results, the Smart Home system consists of several primary components, including:

1. NodeMCU ESP8266 as the main processing and communication controller.
2. A 3-channel relay module for controlling household lighting devices.
3. A YF-S201 water flow sensor for monitoring water flow rate and total water usage.
4. An MQ2 gas sensor for detecting gas leakage conditions.
5. A buzzer as an alarm and warning mechanism.

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6. A 5V adapter as the primary power supply source.
7. Household lighting devices as system output components.

All hardware components were successfully integrated and capable of communicating with each other through WiFi connectivity and cloud-based platforms in realtime. The integration process demonstrated that the proposed Smart Home architecture could effectively support automation, environmental monitoring, and remote device control within residential environments.

Dashboard Monitoring Results

The ThingsBoard dashboard was successfully implemented as the main interface for monitoring and controlling the Smart Home system in realtime. The dashboard displayed several important parameters, including gas conditions, water flow rate, total water consumption, and lighting control status. Through cloud-based communication, users were able to access the monitoring dashboard remotely using smartphones, laptops, or other internet-connected devices.

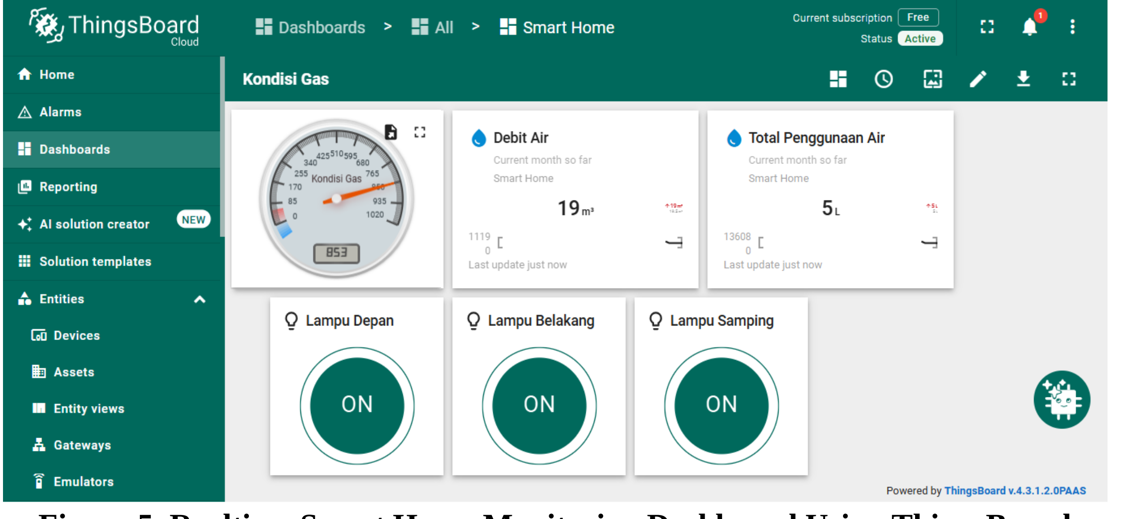

Figure 5. Realtime Smart Home Monitoring Dashboard Using ThingsBoard

Figure 5 presents the monitoring dashboard interface developed using ThingsBoard Cloud. Based on the dashboard implementation results, several main monitoring features were successfully displayed, including:

Realtime gas condition monitoring, Realtime water flow monitoring, Total water consumption monitoring, Front lamp control, Side lamp control, Back lamp control

The testing results showed that the dashboard successfully received telemetry data transmitted from the ESP8266 microcontroller using the MQTT communication protocol. In addition, the relay control system integrated with the ThingsBoard switch widget successfully controlled household lighting devices with an average communication delay of less than two seconds. This result indicates that the developed Smart Home system achieved stable realtime communication performance suitable for practical household automation applications.

Furthermore, the cloud-based dashboard significantly improved user accessibility and monitoring efficiency because all sensor data and actuator statuses could be observed remotely without requiring direct interaction with the hardware system. The integration of MQTT communication with ThingsBoard also provided lightweight and efficient data transmission suitable for IoT-based applications.

Water Flow Rate and Total Water Usage Testing Results

The YF-S201 water flow sensor was tested to evaluate the system's capability in measuring realtime water flow rate and cumulative water consumption accurately. The testing process was conducted five times under normal household water usage conditions.

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Table 3. Water Flow Rate and Total Water Usage Testing Results

No	Testing Time	Water Flow Rate (L/min)	Total Water Usage (Liter)	Status
1	08:00 WIB	5.2	10.5	Normal
2	09:00 WIB	7.8	18.6	Normal
3	10:00 WIB	8.5	25.4	Normal
4	11:00 WIB	10.2	37.8	Normal
5	12:00 WIB	12.4	50.0	Normal

Based on the testing results presented in Table 3, the developed system successfully measured water flow rate with an average value of 8.82 liters per minute. The measured values were still categorized as normal household water consumption levels. In addition, the cumulative daily water usage reached 50 liters according to the predefined testing scenario. The results indicate that the YF-S201 sensor was capable of providing stable and consistent water flow measurements in realtime. The sensor also demonstrated the capability to continuously calculate cumulative water usage data, enabling users to monitor household water consumption patterns more effectively. Such functionality can contribute to water conservation awareness and support more efficient resource management in residential environments.

Water Flow Monitoring Graph

The water flow monitoring graph was used to visualize changes in water flow rate during the testing process. Figure 6 illustrates the graphical representation of water flow measurements obtained during the experiment.

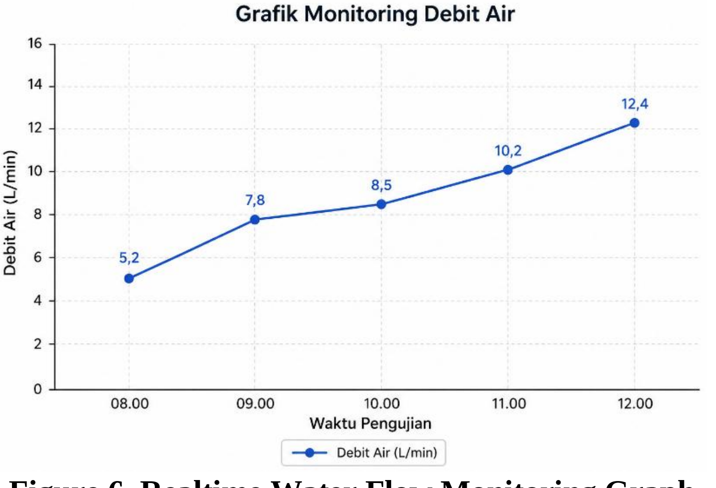

Figure 6. Realtime Water Flow Monitoring Graph

Based on Figure 6, the water flow rate increased gradually from 5.2 liters per minute to 12.4 liters per minute according to household water usage activities during the testing period. The measured values remained within the ideal range of normal household water consumption, which is approximately 5–15 liters per minute. The graphical representation clearly demonstrates that the developed monitoring system was capable of capturing realtime changes in water usage conditions accurately. Furthermore, the graphical dashboard visualization improved data readability and enabled users to identify water consumption trends more efficiently.

Total Water Usage Monitoring Graph

The total water usage graph was utilized to analyze cumulative water consumption during the testing period. Figure 7 illustrates the increase in total water usage values obtained from the YF-S201 sensor measurements.

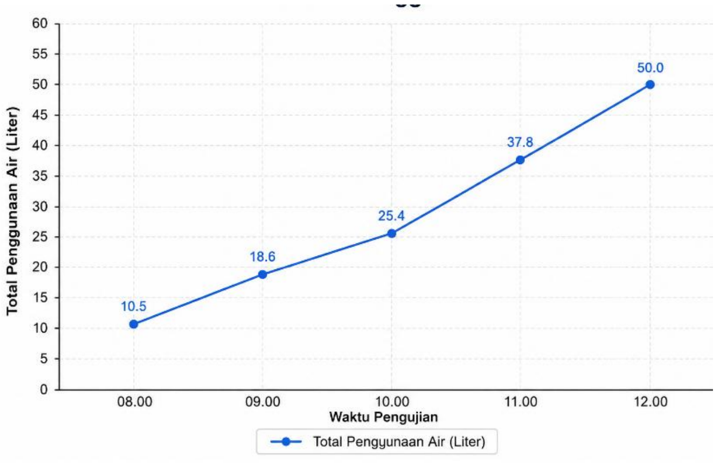

Figure 7. Total Water Consumption Monitoring Graph

Based on Figure 7, the total water usage increased gradually and consistently until reaching 50 liters at the end of the testing session. These results indicate that the developed Smart Home system successfully performed cumulative water usage monitoring in realtime.

The ability to monitor total water consumption continuously provides important advantages for household resource management. Users can evaluate daily water consumption behavior, detect abnormal usage patterns, and improve water efficiency through realtime monitoring information provided by the IoT system.

Gas Detection and Telegram Notification Results

The MQ2 gas sensor was tested to evaluate the system's capability in detecting gas leakage conditions and delivering realtime warning notifications through Telegram Bot integration. The MQ2 sensor was connected to the NodeMCU ESP8266 microcontroller and buzzer alarm to function as an early warning system whenever dangerous gas concentrations were detected.

When the gas sensor reading remained below the predefined threshold value of 500 PPM, the system operated under normal conditions, causing the buzzer to remain inactive and no Telegram notifications to be transmitted. However, when the gas concentration exceeded the threshold value, the system automatically activated the buzzer alarm and sent warning messages to users through Telegram Bot.

Figure 8. Telegram Notification Interface for Gas Leakage Detection

Figure 8 shows the Telegram notification interface generated by the Smart Home system. The results demonstrated that the ESP8266 microcontroller successfully connected to both the internet network and Telegram Bot server, indicated by the notification message "Smart Home ESP8266 ONLINE." This result confirms that communication between the ESP8266 microcontroller and Telegram server operated properly through internet connectivity.

Furthermore, the system successfully detected dangerous gas conditions when the MQ2 sensor value reached 1024 PPM. Under this condition, Telegram Bot automatically transmitted a warning message stating: “WARNING GAS, Gas detected! Sensor Value: 1024” as an early warning mechanism for users. After gas conditions returned to normal, the system automatically sent an additional notification stating that the environment was safe again.

Table 4. MQ2 Sensor Testing Results

No	MQ2 Sensor Value	System Condition	Buzzer Status	Telegram Status
1	95	Safe	OFF	Not Sent
2	120	Safe	OFF	Not Sent
3	250	Normal	OFF	Not Sent
4	507	Warning	ON	Sent
5	1024	Dangerous	ON	Sent

Based on the testing results shown in Table 4, the MQ2 sensor successfully detected changes in gas conditions in realtime with a testing success rate of 100%. When the gas concentration exceeded the threshold value of 500 PPM, the buzzer alarm was automatically activated and Telegram Bot successfully transmitted warning notifications to users. These results indicate that the developed IoT-based gas monitoring system can function effectively as an early warning mechanism for household gas leakage prevention.

Lighting Control Testing Results

Lighting control testing was performed using the ThingsBoard dashboard through MQTT communication. The testing results demonstrated that the relay module successfully controlled all three household lighting devices in realtime.

Table 5. Lighting Control Testing Results

No	Lamp	Dashboard Status	Relay Condition	Result
1	Front Lamp	ON	Active	Successful
2	Front Lamp	OFF	Inactive	Successful
3	Side Lamp	ON	Active	Successful
4	Side Lamp	OFF	Inactive	Successful
5	Back Lamp	ON	Active	Successful
6	Back Lamp	OFF	Inactive	Successful

The testing results showed that all relay modules successfully controlled household lighting devices in realtime with a success rate of 100%. The MQTT communication protocol enabled fast and reliable command transmission between the ThingsBoard dashboard and the ESP8266 microcontroller, ensuring stable remote lighting control functionality.

System Analysis

Based on the implementation and testing results, the IoT-based Smart Home system using ESP8266 successfully operated according to the proposed design. The integration among the water flow sensor, MQ2 gas sensor, relay module, ThingsBoard Cloud platform, and Telegram Bot produced an effective realtime monitoring and control system for household environments.

The developed system offers several advantages, including:

1. Realtime household device monitoring
2. Automatic water usage monitoring
3. Automatic gas leakage detection
4. Internet-based lighting control
5. Realtime Telegram notifications
6. Cloud-based monitoring dashboard

Despite its advantages, the system still has several limitations, particularly its dependency on stable internet connectivity and WiFi network reliability. In addition, the accuracy of the water flow sensor measurements can still be influenced by water pressure fluctuations and sensor quality variations.

Overall, the developed Smart Home system successfully improved household monitoring efficiency, environmental safety, and the convenience of remotely controlling household devices through Internet of Things technology.

CONCLUSION

Based on the research results, the Internet of Things (IoT)-based Smart Home system using the NodeMCU ESP8266 microcontroller was successfully designed, implemented, and tested. The developed system successfully integrated several important components, including the YF-S201 water flow sensor, MQ2 gas sensor, 3-channel relay module, buzzer alarm, ThingsBoard Cloud platform, and Telegram Bot notification service into a unified realtime monitoring and control system.

The implementation results demonstrated that the system was capable of performing realtime monitoring of water flow rate, total water consumption, gas leakage conditions, and household lighting control through internet-based communication using the MQTT protocol. The ThingsBoard Cloud platform successfully displayed telemetry data in realtime and enabled users to remotely control household lighting devices with stable communication performance and low delay response.

The water flow monitoring system successfully measured water usage with an average flow rate of 8.82 liters per minute and a cumulative water consumption value of 50 liters during the testing process. In addition, the MQ2 gas sensor successfully detected dangerous gas conditions and automatically activated the buzzer alarm while simultaneously sending warning notifications through Telegram Bot. The gas detection system achieved a testing success rate of 100%, indicating that the developed system can effectively function as an early warning mechanism for household gas leakage prevention.

The lighting control subsystem also operated successfully, where all relay channels were capable of controlling household lamps remotely through the ThingsBoard dashboard with a success rate of 100%. These results indicate that the integration of IoT communication technology, cloud computing, and realtime notification systems can significantly improve household monitoring efficiency, environmental safety, and user convenience.

Despite the successful implementation, the developed system still has several limitations, particularly its dependency on internet connectivity and WiFi network stability. Furthermore, the accuracy of water flow measurements may still be influenced by water pressure fluctuations and sensor quality conditions. Therefore, future research can focus on improving sensor calibration accuracy, enhancing communication reliability, integrating artificial intelligence for predictive monitoring, and developing mobile-based applications for a more advanced Smart Home ecosystem.

Overall, the proposed IoT-based Smart Home system demonstrates strong potential for supporting intelligent, efficient, secure, and realtime residential automation systems in modern smart living environments.

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