Journal of Computer Networks, Architecture and High Performance Computing
Volume 7, Number 1, January 2025
https://doi.org/10.47709/cnahpc.v7i1.5165

Submitted : Dec 23, 2024
Accepted : Jan 3, 2025
Published : Jan 12, 2025

Implementation of WSN and IoT to Monitor and Control Villa Electronic Equipment in Blankspot Areas

Muhammad Saifulloh[1)], Banu Santoso[2)*], Dony Ariyus[3)]
[1,2,3)] Computer Engineering, Faculty of Computer Science, Amikom University Yogyakarta.
[1)] saifl@students.amikom.ac.id, [2)]banu@amikom.ac.id, [3)] dony.a@amikom.ac.id

ABSTRACT

Maintaining a remote villa in a blank spot area presents challenges in ensuring optimal environmental conditions without the direct presence of the owner. This study aims to develop an Internet of Things (IoT)-based Wireless Sensor Network (WSN) system using the XBee S2C module with the Zigbee remote monitoring and control protocol. This system utilizes temperature, humidity, lighting, and water level sensors connected to electronic device controls such as lights, fans, and water pumps. Sensor Nodes are placed in the villa to collect data, while Coordinator Nodes are located in areas with internet access to upload data to the Thingspeak platform. Data is visualized through an interactive web interface that allows for remote control up to 1.03 km. The test results show a data transmission success rate of 100% with an average control response time of 6.5 and 9 seconds. This system offers the best solution for managing a villa in a blank spot area, making it easy for owners to monitor and control electronic equipment in real-time. This research contributes to developing WSN and IoT technologies, especially for applications in remote areas with website platform.

Keywords: Wireless Sensor Networks (WSN), Internet of Things (IoT), Isolated Vila, Website Platform, Thingspeak.

INTRODUCTION

Remote villa maintenance in blank spot areas often presents various challenges (Andreadis et al., 2023). Due to difficult terrain and inaccessible distances, routine monitoring becomes a significant inconvenience. Many tasks require consistent attention and time, such as controlling indoor humidity to prolong the lifespan of furniture and equipment, ensuring water availability, and managing lighting by turning lights on during low lighting conditions or evening and off at dawn. This creates difficulties for villa owners who want to maintain their villas in a livable and well-maintained state. On the other hand, villa owners are often preoccupied with affairs outside the area, leaving them unable to provide immediate attention. To address these issues, the Xbee Pro S2C module (Hapsari et al., 2020) and a Wireless Sensor Network (WSN) system have been developed to meet the villa owners' needs for periodic monitoring. This system enables real-time environmental monitoring through energy-efficient wireless communication, easy installation, and scalability, making it ideal for areas inaccessible by wired networks (Harianja & Santoso, 2022).

The system utilizes the Zigbee communication protocol, known for its low power consumption, low latency, adequate range, and cost-effectiveness, making it suitable for IoT (Internet of Things) applications (Calvo et al., 2021). IoT refers to the concept of connecting physical devices to the internet for data exchange, enabling automated remote monitoring and control (Ouni & Saleem, 2022). The system integrates various sensors, such as temperature, humidity, motion, and water level sensors, to monitor environmental conditions and actuators like relays and IR transmitters to control water pumps, fans, lights, and MP3 players. Automated control is based on the collected data, enhancing the efficiency and reliability of the system(Pérez & Salvachúa, 2021). Furthermore, platforms like Thingspeak and web-based interfaces

* Corresponding author

Journal of Computer Networks, Architecture and High Performance Computing
Volume 7, Number 1, January 2025
https://doi.org/10.47709/cnahpc.v7i1.5165

Submitted : Jun 11, 2024
Accepted : Jan 6, 2025
Published : Jan 11, 2025

are considered for data storage and visualization, supporting real-time analytics and remote control for effective management and decision-making(Ali et al., 2020). This paper focuses on developing a system that facilitates wireless monitoring and control, even in areas without internet (blank spots), providing a practical solution for remote villa maintenance.

LITERATURE REVIEW

Wireless Sensor Networks (WSN) have been widely acknowledged as an effective technology for real-time environmental monitoring due to their low power consumption, easy installation, and scalability(Harianja & Santoso, 2022). The Zigbee communication protocol, built upon the IEEE 802.15.4 standard, is specifically designed for wireless personal area networks (WPAN) and offers a range of 10 to 100 meters, depending on conditions. It also supports mesh networking, enabling extended signal coverage and scalability by accommodating thousands of nodes in a single network(Alfarabi et al., 2024). These characteristics make Zigbee an ideal choice for IoT applications such as smart homes and industrial automation.

IoT integrates various components to monitor environments through internet-connected devices, allowing data storage on web servers for remote access(Sarah et al., 2020). Sensors like temperature, humidity, light, and water level sensors are commonly used to collect environmental data, which is analyzed by controllers to automate actions and improve energy efficiency in applications like smart buildings and environmental automation(Pérez & Salvachúa, 2021). However, IoT systems face security challenges due to vulnerability to cyberattacks, although ongoing development of security protocols aims to protect data integrity (Jayetileke et al., 2023). For data storage and visualization, cloud technologies like Thingspeak enable real-time data collection with interactive dashboards and analytics support through MATLAB. This capability helps detect patterns and anomalies while providing threshold-based notifications, which are particularly useful for applications such as smart agriculture, environmental control, and early detection systems(Suryana, 2021). WSN's low latency (around 10 milliseconds) and minimal jitter (less than 1 millisecond) make it ideal for applications requiring quick responses and consistent data reliability. The protocol's ability to form mesh networks further enhances its usability in remote and challenging terrains, addressing the connectivity issues commonly faced in blank spot areas(Rivaldo & Calvinus, 2019).This study builds on previous research by incorporating Zigbee-based WSNs with IoT platforms to create a comprehensive system for remote villa maintenance. The system employs sensors to monitor parameters such as temperature, humidity, lighting, and water availability, with data transmitted to a central hub connected to the internet. The data is then uploaded to Thingspeak and displayed on a web platform, enabling remote monitoring and control of electronic devices in the villa(Suryana, 2021). Despite its advantages, limitations of this research include the focus on specific environmental factors and the constraints of operating in remote, internet-inaccessible locations. Future developments aim to address these challenges by optimizing the system's functionality and scalability.

METHOD

This research uses an experimental method to design, develop, and test a wireless sensor network (WSN) system based on Xbee S2C with Zigbee protocol integrated with IoT technology. A literature review and needs analysis were conducted to determine the required equipment such as temperature, humidity, light, and water level sensors, as well as to design the system and network architecture, which includes the placement of sensor nodes and coordinators in blank spot areas. The system is also integrated with the Thingspeak platform for data visualization and reliable processing with MATLAB support to facilitate remote monitoring and control via a web interface. The overall research flow is shown in Figure 1.

* Corresponding author

Journal of Computer Networks, Architecture and High Performance Computing
Volume 7, Number 1, January 2025
https://doi.org/10.47709/cnahpc.v7i1.5165

Submitted : Jun 11, 2024
Accepted : Jan 6, 2025
Published : Jan 11, 2025

System testing includes testing network connectivity, sensor readings, and system response to changes in environmental conditions and user commands.

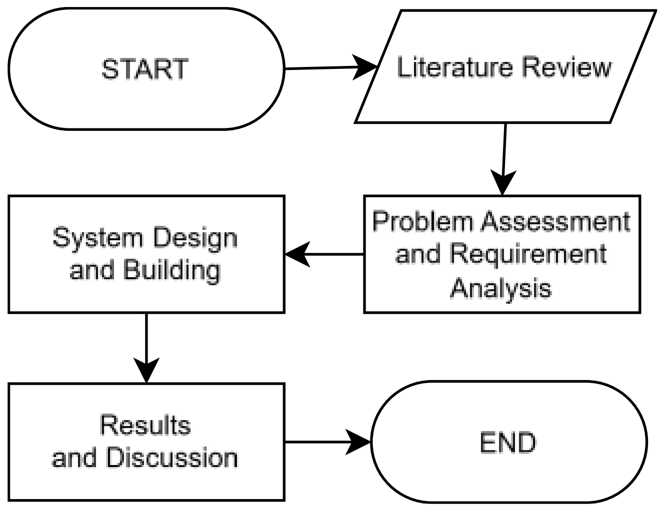

Figure 1. Research Flow

Problem Assessment and Requirement Analysis

To identify the villa owner's requirements, interviews were conducted. Key needs included remote monitoring of temperature, humidity, lighting, and water availability, accessible at any time and from any location. The system also needed to control electronic devices such as water pumps, fans, lights, and audio systems. A literature review guided the selection of appropriate sensors. The analysis highlighted the need for a flexible system capable of remote monitoring and control.Choosed Microcontroller is Node use Arduino Uno, Selected for its multiple pins, enabling direct integration of sensors and actuators (Sarah et al., 2020).Coor uses ESP32, Chosen as the coordinator due to its built-in WiFi, eliminating the need for additional modules (Megantoro et al., 2022).for Sensors this choose DHT11: Measures temperature and humidity (Yulizar et al., 2023). LDR LM393: Detects ambient light levels (Al Ghifari et al., 2022). HC-SR04: Measures water levels (Anantajaya et al., 2022). IR Receiver KY-022: Reads and converts IR signals into digital data (Anantajaya et al., 2022).and the Devices for Control is Relay Modules: Enable control of electrical circuits (Basri et al., 2021) And IR Transmitter KY-005: Transmits IR signals based on digital inputs (Anantajaya et al., 2022).The research was conducted in a villa located in an open, isolated area with specific geographic challenges. A layout map (Figure 2) illustrates sensor node placements, coordinator locations, and areas of limited coverage, providing a contextual framework for system design.

* Corresponding author

Journal of Computer Networks, Architecture and High Performance Computing
Volume 7, Number 1, January 2025
https://doi.org/10.47709/cnahpc.v7i1.5165

Submitted : Jun 11, 2024
Accepted : Jan 6, 2025
Published : Jan 11, 2025

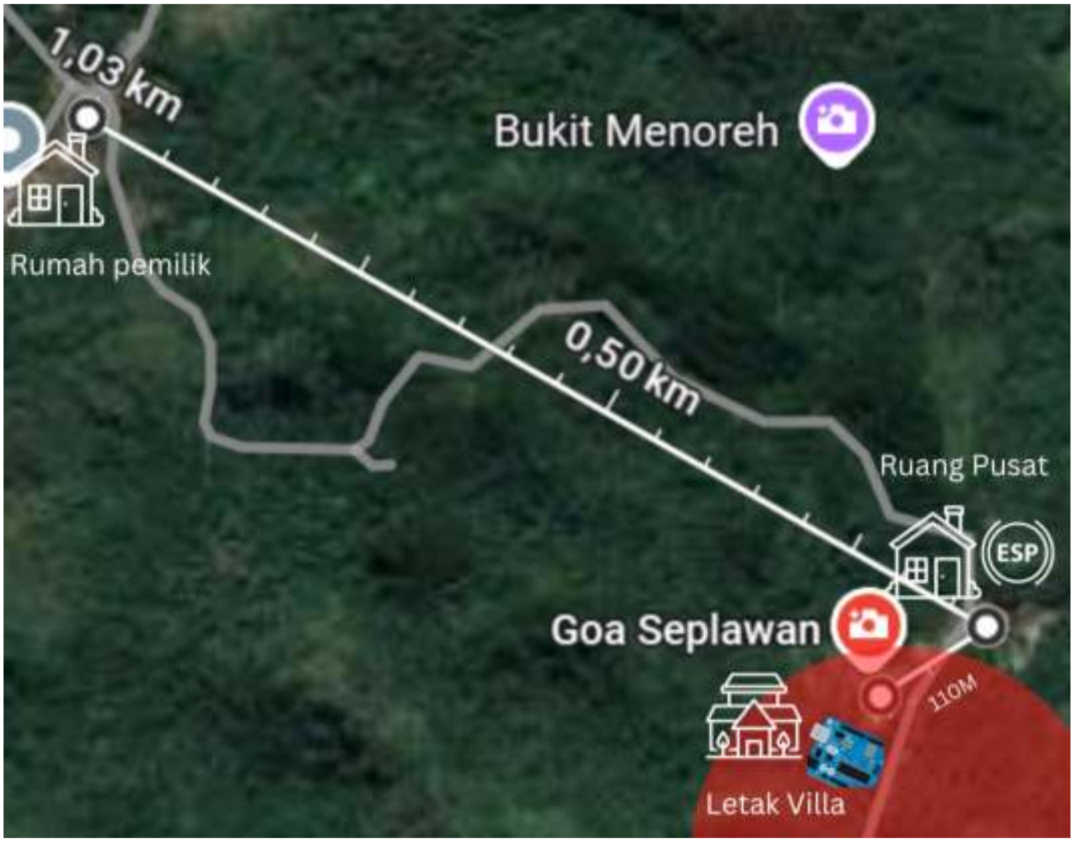

Figure 2. Location

System Design and Building

The system was designed to fulfill the villa owner's need for remote environmental monitoring and control. It integrates sensors, Xbee modules, and electronic devices, with the ESP32 serving as a central hub to connect to Thingspeak using its built-in WiFi (Sabo et al., 2024). Figures 3–5 illustrate the system's logic, manual controls, and monitoring workflows. The jobdesk and fungstions is Node in Villa (Blank Spot): Equipped with sensors to measure environmental parameters such as temperature, humidity, lighting, and water levels. Includes actuators for operating lights, fans, water pumps, and audio systems. Operates autonomously based on sensor data. Coordinator in Control Room (With Internet Access): Serves as a bridge between sensor nodes and the Thingspeak platform. Receives data from nodes via WSN (Komilov, 2023), parses it, and uploads it to Thingspeak (Setiawan et al., 2023).And Web Platform: Displays real-time data for monitoring and device control.provides a user-friendly interface for remote management (Mabrouki et al., 2021).

* Corresponding author

Journal of Computer Networks, Architecture and High Performance Computing
Volume 7, Number 1, January 2025
https://doi.org/10.47709/cnahpc.v7i1.5165

Submitted : Jun 11, 2024
Accepted : Jan 6, 2025
Published : Jan 11, 2025

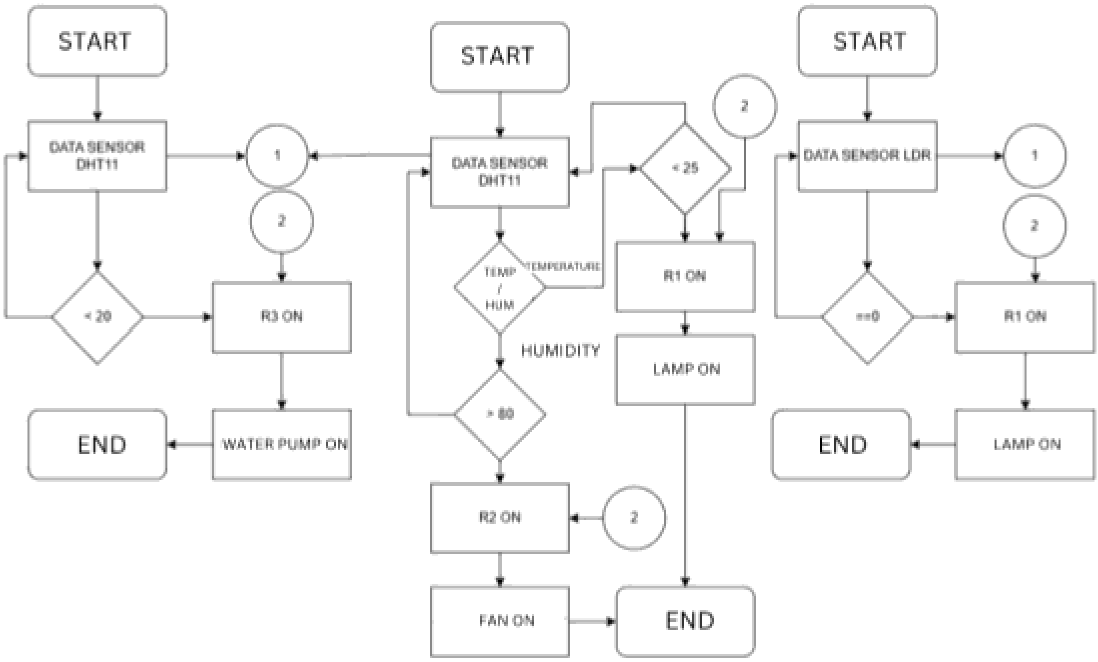

Figure 3. System Control Based on Sensor Input Values

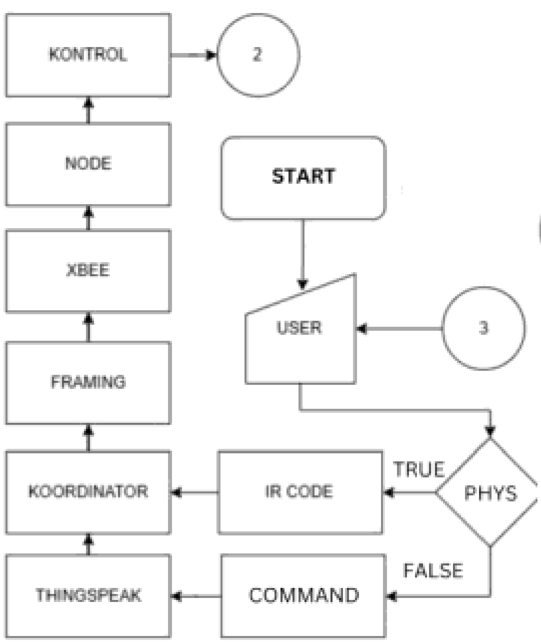

Figure 4 . Control Manual System

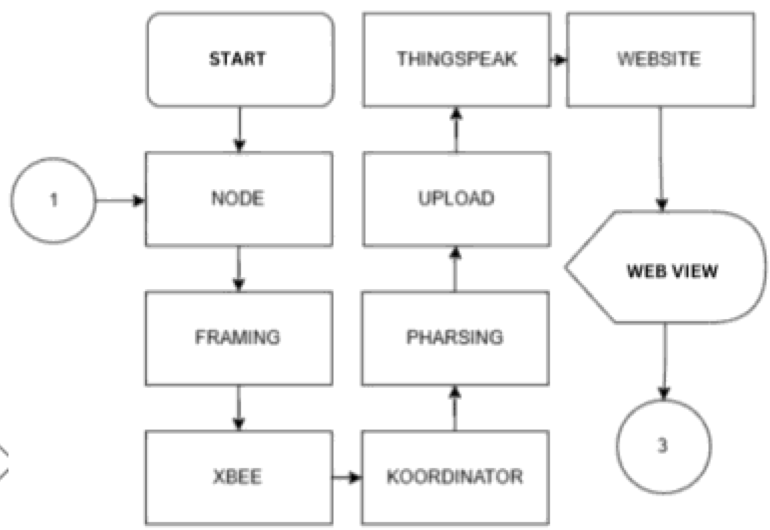

Figure 5 . Monitoring System Flow

* Corresponding author

Journal of Computer Networks, Architecture and High Performance Computing
Volume 7, Number 1, January 2025
https://doi.org/10.47709/cnahpc.v7i1.5165

Submitted : Jun 11, 2024
Accepted : Jan 6, 2025
Published : Jan 11, 2025

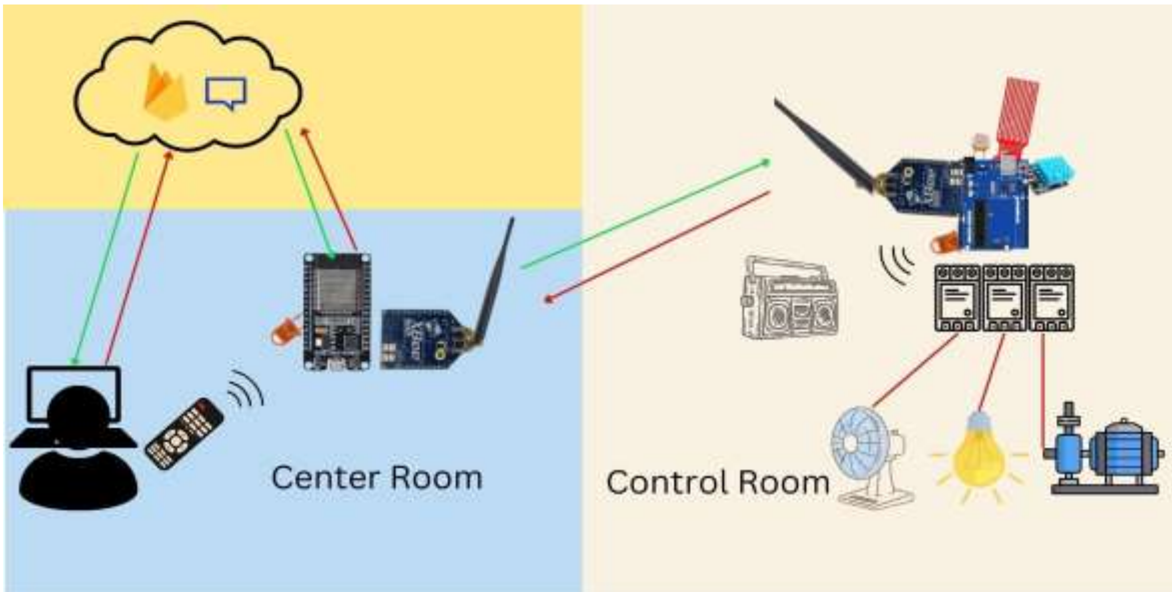

Figure 6 . System Architecture Schematic

Figure 7 . Website Interface

The system's hardware architecture (Figure 6) consists of three main components:

a) Sensor Nodes: Monitor environmental parameters and provide automatic device control.
b) Coordinator: Connects sensor nodes to Thingspeak, handling data transfer and formatting.
c) Web Platform: Offers real-time data visualization and analytics, enabling users to monitor and control devices remotely.

* Corresponding author

Journal of Computer Networks, Architecture and High Performance Computing
Volume 7, Number 1, January 2025
https://doi.org/10.47709/cnahpc.v7i1.5165

Submitted : Jun 11, 2024
Accepted : Jan 6, 2025
Published : Jan 11, 2025

Data flows from Xbee-equipped sensor nodes to the coordinator, which processes and uploads it to Thingspeak. The web platform then presents the data, facilitating monitoring and control. Figure 7 shows the developed web interface.

Testing

The system underwent rigorous testing to ensure functionality and reliability:

1. Data transmission via Xbee modules was tested 50 times per module to validate consistency.
2. System responsiveness to control commands was evaluated for accuracy and speed.
3. Data uploads to Thingspeak were examined to confirm seamless integration.

Connectivity between Xbee modules and overall device coordination were prioritized during testing. Functional tests demonstrated that the system operated as intended under varying conditions.

RESULT

Testing results reveal a 100% success rate in data transmission during connectivity assessments, involving the transfer of 50 data packets from the coordinator to the node and vice versa. This evaluation ensured reliable communication between devices utilizing Xbee modules, with all packets transmitted and received without data loss. Figures 8 and 9 illustrate the connectivity test outcomes, demonstrating minimal latency and stable system performance under varying conditions.

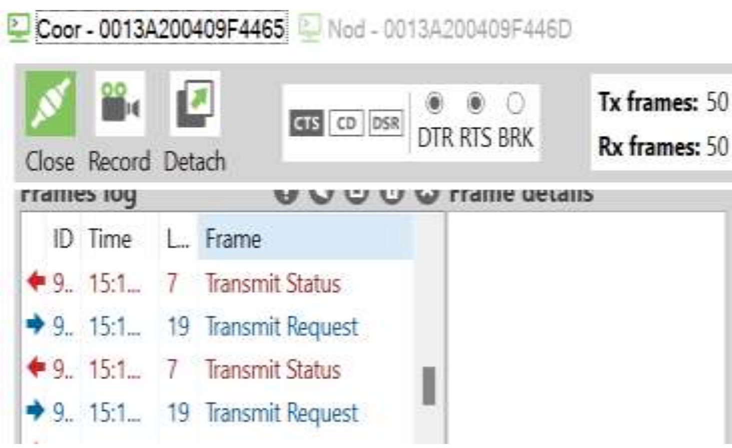

Figure 8 . Traffic in Coor

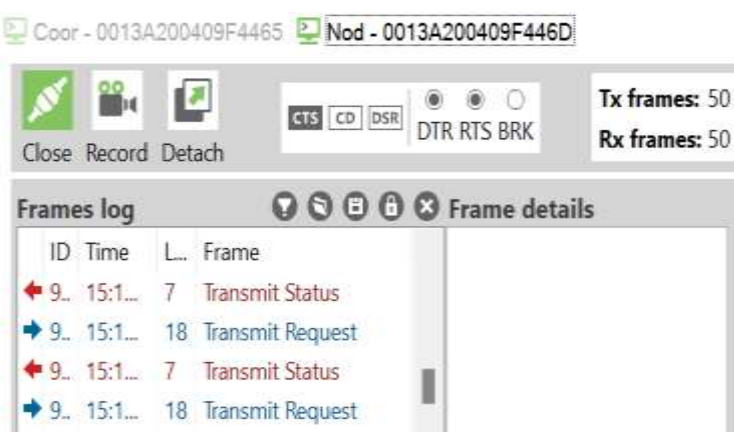

Figure 9 . Traffic in Node

* Corresponding author

Journal of Computer Networks, Architecture and High Performance Computing
Volume 7, Number 1, January 2025
https://doi.org/10.47709/cnahpc.v7i1.5165

Submitted : Jun 11, 2024
Accepted : Jan 6, 2025
Published : Jan 11, 2025

Additionally, the system underwent data upload testing to the Thingspeak platform, as depicted in Figure 10, showing consistent and uninterrupted sensor data uploads. Node responsiveness to commands was evaluated (Figure 11), while Table 1 summarizes functional tests of controlling devices like lights, fans, and water pumps via remote commands. Results indicate rapid and accurate responses to user instructions. This study successfully developed an IoT-based Wireless Sensor Network (WSN) using Xbee S2C modules and the Zigbee protocol, specifically designed for remote monitoring and control of villas located in blank spot areas. The system demonstrated its capability to monitor environmental parameters such as temperature, humidity, lighting, and water levels accurately through a web interface, providing an effective solution for regions with limited internet access. Users can control electronic devices like lights, fans, and water pumps from up to 1.03 kilometers away, with average response times ranging between 6.5 to 9 seconds. This significantly enhances ease and comfort in villa management.

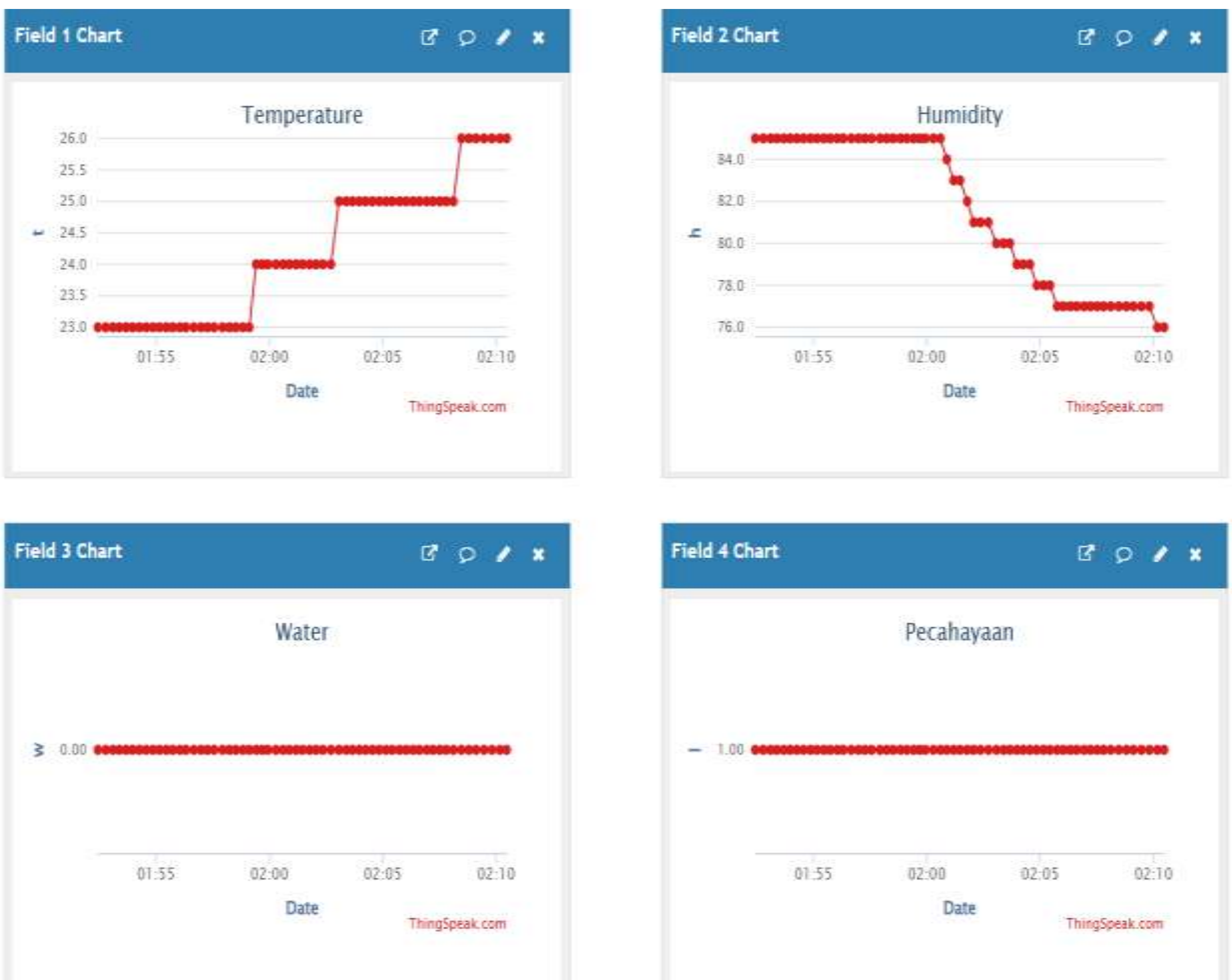

Figure 10 . Result Data Uploading to Thingspeak

* Corresponding author

Journal of Computer Networks, Architecture and High Performance Computing
Volume 7, Number 1, January 2025
https://doi.org/10.47709/cnahpc.v7i1.5165

Submitted : Jun 11, 2024
Accepted : Jan 6, 2025
Published : Jan 11, 2025

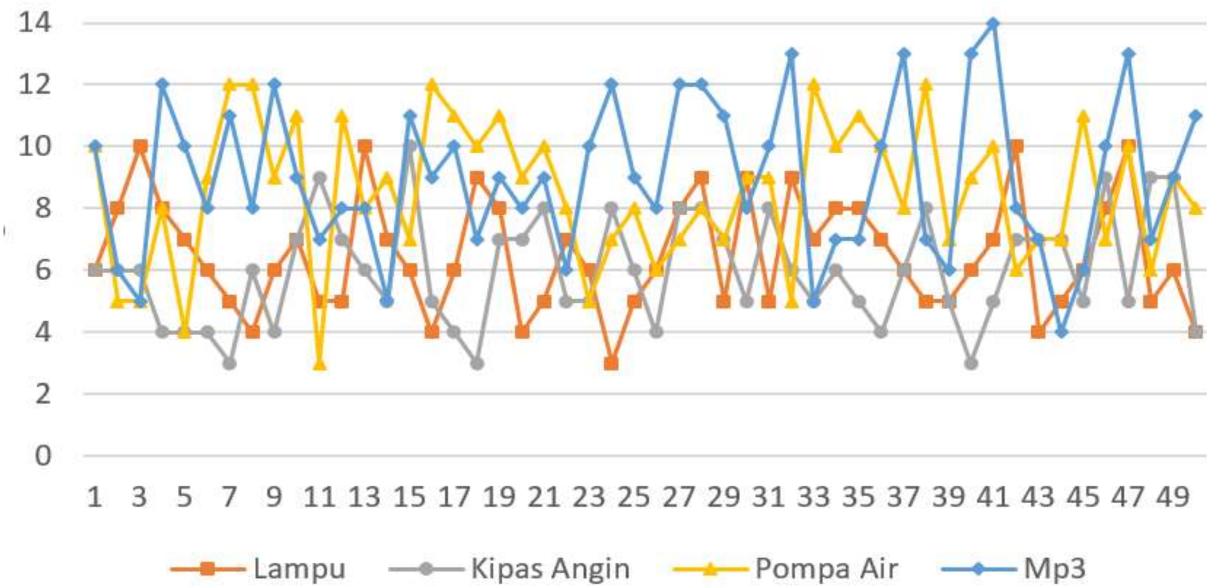

Figure 11 . Response Test Graph

System testing showed that the Zigbee-based network achieved a 100% data transmission success rate for 50 transmissions, confirming its stability and reliability in wireless communication. Figures 8 and 9 illustrate the connectivity test results, which highlight the system's stable performance with minimal latency under various conditions. Additionally, consistent and uninterrupted sensor data uploads to the Thingspeak platform were observed, as shown in Figure 10.

DISCUSSIONS

The implementation of an IoT-based Wireless Sensor Networks (WSN) system has shown its effectiveness in monitoring and controlling villas located in blank spot areas. Findings show that the system offers significant flexibility for villa owners to monitor environmental conditions and control various electronic devices from a distance of 1.03 km via a web-based interface. This capability allows users to manage devices such as fans, lights and water pumps, ensuring optimal temperature, lighting and humidity levels in the villa according to their needs. Node responsiveness to remote commands was also evaluated, with the results summarized in Table 1, demonstrating rapid and accurate device control.

Table 1.Response Testing Summary

	Lamp	Fan	Water Pump	Mp3
Sum Data	325	300	425	450
Average	6,5 second	6 second	8,5 second	9 second
Min	3 second	3 second	3 second	4 second
Max	10 second	10 second	12 second	14 second

This functionality ensures that villa owners can maintain optimal environmental conditions with minimal manual intervention. The system's ability to provide smooth data transmission and reliable device control even under challenging conditions strengthens its potential for broader applications in similar environments. This research confirms that IoT-based WSN systems not only increase comfort, but also significantly simplify the monitoring and management of villas in areas with limited internet connectivity.

* Corresponding author

Journal of Computer Networks, Architecture and High Performance Computing
Volume 7, Number 1, January 2025
https://doi.org/10.47709/cnahpc.v7i1.5165

Submitted : Jun 11, 2024
Accepted : Jan 6, 2025
Published : Jan 11, 2025

CONCLUSION

This research succeeded in developing a Wireless Sensor Networks (WSN) system based on the Internet of Things (IoT) using the Xbee S2C module and Zigbee protocol, which is designed for remote monitoring and control in villas in blankspot areas. This system enables accurate monitoring of environmental parameters such as temperature, humidity, lighting and water level via a web interface, providing an effective solution for areas with limited internet access. In addition, users can control electronic devices such as lights, fans and water pumps from a distance of 1.03 KM with a fast response averaging between 6.5 to 9 seconds, which increases the ease and comfort in managing the villa. Tests also show that the Zigbee network based on the Xbee S2C module has a data transmission success rate of 100% for 50 transmissions, indicating high stability and reliability in wireless communications. This system opens up great opportunities for application in remote areas or blank spots, allowing property owners to stay connected and manage assets remotely via an IoT platform. This research not only contributes to the advancement of WSN and IoT technology in the field of environmental monitoring, but also opens up opportunities for further development, such as the integration of artificial intelligence for data analysis and exploration of the use of other communication protocols that can expand network coverage.

REFERENCES

Al Ghifari, F., Anjalni, A., Lestari, D., & Al Faruq, U. (2022). Perancangan Dan Pengujian Sensor Ldr Untuk Kendali Lampu Rumah. *Jurnal Kumparan Fisika*, *5*(2), 85–90. https://doi.org/10.33369/jkf.5.2.85-90

Alfarabi, M., Fauziah, A., Teknologi, P., Jaringan, R., Teknik, J., Politeknik, E., & Lhokseumawe, N. (2024). *ANALISIS QUALITY OF SERVICE (QOS) ALAT MONITORING SUHU RUANGAN MENGGUNAKAN XBEE DAN ESP32*. *8*(1).

Ali, M., Nazim, Z., Azeem, W., Javed, K., Tariq, M., Haroon, M., & Hussain, A. (2020). An IoT based approach for efficient home automation with Thingspeak. *International Journal of Advanced Computer Science and Applications*, *11*(6), 118–124. https://doi.org/10.14569/IJACSA.2020.0110615

Anantajaya, I. M. R. A., Kumara, I. N. S., & Divayana, Y. (2022). Review Aplikasi Sensor Pada Sistem Monitoring Dan Kontrol Berbasis Mikrokontroler Arduino. *Jurnal SPEKTRUM*, *8*(4), 171. https://doi.org/10.24843/spektrum.2021.v08.i04.p20

Andreadis, A., Giambene, G., & Zambon, R. (2023). Low-Power IoT for Monitoring Unconnected Remote Areas. *Sensors*, *23*(9). https://doi.org/10.3390/s23094481

Basri, B., Akhmad Qashlim, & Suryadi. (2021). Relay Kontrol Menggunakan Google Firebase dan Node MCU pada Sistem Smart Home. *Technomedia Journal*, *6*(1 Agustus), 15–29. https://doi.org/10.33050/tmj.v6i1.1432

Calvo, I., Gil-García, J. M., Villar, E., Fernández, A., Velasco, J., Barambones, O., Napole, C., & Fernández-Bustamante, P. (2021). Design and performance of a xbee 900 mhz acquisition system aimed at industrial applications. *Applied Sciences (Switzerland)*, *11*(17). https://doi.org/10.3390/app11178174

* Corresponding author

Journal of Computer Networks, Architecture and High Performance Computing
Volume 7, Number 1, January 2025
https://doi.org/10.47709/cnahpc.v7i1.5165

Submitted : Jun 11, 2024
Accepted : Jan 6, 2025
Published : Jan 11, 2025

Hapsari, G. I., Mutiara, G. A., Rohendi, L., & Mulia, A. (2020). Wireless sensor network for monitoring irrigation using XBee pro S2C. *Bulletin of Electrical Engineering and Informatics*, *9*(4), 1345–1356. https://doi.org/10.11591/eei.v9i4.1994

Harianja, N. S., & Santoso, I. (2022). *OPTIMASI ENERGI PADA JARINGAN SENSOR NIRKABEL*. *11*(1), 9–16.

Jayetileke, H. R., De Mel, W. R., & Mukhopadhyay, S. C. (2023). A Reconfigurable SensorNet for Industry 5.0 Applications using Arduino Due/ESP32 and Xbee S2C Based on IEEE 802.15.4 Protocol with Programmable Sensor Array. *Proceedings of the International Conference on Sensing Technology, ICST*. https://doi.org/10.1109/ICST59744.2023.10460797

Komilov, D. R. (2023). *54_343_349_Ijasr__a__Application+of+Zigbee+Technology+in+Iot*. *03*(09), 343–349.

Mabrouki, J., Azrour, M., Dhiba, D., Farhaoui, Y., & Hajjaji, S. El. (2021). IoT-based data logger for weather monitoring using arduino-based wireless sensor networks with remote graphical application and alerts. *Big Data Mining and Analytics*, *4*(1), 25–32. https://doi.org/10.26599/BDMA.2020.9020018

Megantoro, P., Prastio, R. P., Kusuma, H. F. A., Abror, A., Vigneshwaran, P., Priambodo, D. F., & Alif, D. S. (2022). Instrumentation system for data acquisition and monitoring of hydroponic farming using ESP32 via Google Firebase. *Indonesian Journal of Electrical Engineering and Computer Science*, *27*(1), 52–61. https://doi.org/10.11591/ijeecs.v27.i1.pp52-61

Ouni, R., & Saleem, K. (2022). Framework for Sustainable Wireless Sensor Network Based Environmental Monitoring. *Sustainability (Switzerland)*, *14*(14). https://doi.org/10.3390/su14148356

Pérez, L. J., & Salvachúa, J. (2021). Simulation of scalability in cloud-based iot reactive systems leveraged on a wsan simulator and cloud computing technologies. *Applied Sciences (Switzerland)*, *11*(4), 1–38. https://doi.org/10.3390/app11041804

Rivaldo, A. M., & Calvinus, Y. (2019). Studi Pengukuran Jarak Antara Tiga Xbee Dengan Arduino Sebagai Data Counter. *Program Studi Teknik Elektro, Universitas Tarumanegara, Jakarta.*, 31–45.

Sabo, A., Suleiman, H. O., Dahiru, Y., Jatau, N. D., Yusuf, A., & Chikodi, A. T. (2024). Development and Implementation of an ESP32 IOT-Based Smart Grid for Enhanced Energy Efficiency and Management. *European Journal of Theoretical and Applied Sciences*, *2*(3), 565–576. https://doi.org/10.59324/ejtas.2024.2(3).43

Sarah, A., Ghozali, T., Giano, G., Mulyadi, M., Octaviani, S., & Hikmaturokhman, A. (2020). Learning IoT: Basic Experiments of Home Automation using ESP8266, Arduino and XBee. *Proceedings - 2020 IEEE International Conference on Smart Internet of Things, SmartIoT 2020*, *August 2020*, 290–294. https://doi.org/10.1109/SmartIoT49966.2020.00051

Setiawan, Z., Hiswara, A., & Muthmainah, H. N. (2023). Mengoptimalkan Jaringan Sensor Nirkabel dalam Aplikasi Monitor Lingkungan dengan Teknologi IoT di Indonesia. *Jurnal Multidisiplin West Science*, *2*(10), 858–867. https://doi.org/10.58812/jmws.v2i10.704

* Corresponding author

Journal of Computer Networks, Architecture and High Performance Computing
Volume 7, Number 1, January 2025
https://doi.org/10.47709/cnahpc.v7i1.5165

Submitted : Jun 11, 2024
Accepted : Jan 6, 2025
Published : Jan 11, 2025

Suryana, T. (2021). Implementasi Web Server NODEMCU ESP8266 Untuk Kontrol Peralatan Elektronik Jarak Jauh Via Internet. *Jurnal Komputa Unikom*, 29. https://repository.unikom.ac.id/68707/1/Kontrol Peralatan Via Web dengan Mengunakan NODEMCU ESP8266 taryana.pdf

Yulizar, D., Soekirno, S., Ananda, N., Prabowo, M. A., Perdana, I. F. P., & Aofany, D. (2023). *Performance Analysis Comparison of DHT11, DHT22 and DS18B20 as Temperature Measurement* (Vol. 1). Atlantis Press International BV. https://doi.org/10.2991/978-94-6463-232-3_5

* Corresponding author