Informatics, Electrical and Electronics Engineering (Infotron)
Volume 5, Number 2, (2025) pp. 88-95
ISSN 2798-0197
Sinta 4 Accreditation – No SK. 177/ E/ KPT/ 2024
http://riset.unisma.ac.id/index.php/infotron/article/view/24553
DOI: 10.33474/infotron.v3i2.24553

Design and Prototyping of WNS (Wireless Sensor Node) System Based on Lora Ebyte E220-400t22d for Monitoring Oscillations on Palur Bridge Structures

Fajar Budi Setiawan[1]*, *Royka Na'im*[2], *Khampaserth Xaphakdy*[3]
[1,2] *Electrical Department, Universitas Surakarta, Surakarta, Indonesia*
[3] *Electrical Department, National University of Laos, Laos*
[1]*fajar.budi.st@gmail.com**, [2]*roykanaim229@gmail.com*, [3]*k.xaphakdy@nuol.edu.la*

**corresponding author*

Article History:

Received 16 October 2025
Reviewed 16 November 2025
Revised 25 November 2025
Accepted 30 November 2025

A B S T R A CT

Recent advances in the Internet of Things (IoT) have enabled the development of Wireless Sensor Network (WSN) architectures for long-range data transmission in infrastructure monitoring applications. This study focuses on the design and performance evaluation of an IoT-based WSN communication system for bridge monitoring, with particular emphasis on reliable data transmission from sensor nodes to a cloud-based gateway. The sensor data acquisition process is handled by a previously established system, while this research concentrates on the communication layer and data delivery mechanism. System performance was evaluated under various environmental and transmission channel conditions, including Line of Sight (LOS) scenarios. Experimental results demonstrate that the proposed WSN system achieves a maximum communication range of up to 2.5 km with a 0% transmission error rate under LOS conditions. Furthermore, the average packet loss rate remained below 30% across different channel conditions, indicating stable and reliable data delivery. These results confirm that the LoRa E220-400T22D module is well-suited for IoT-based WSN applications requiring long-range and low-power communication, particularly for infrastructure monitoring systems where continuous and dependable data transmission to a central gateway is essential.

Keywords: LoRa Ebyte E220-400T22D, WSN, IoT Gateway, LORAWAN, Smart Monitoring.

1. Introduction

Modern technological developments have influenced various aspects of life, from business competition and job demands to people's lifestyles. These changes have led to the emergence of technologies that can improve efficiency and effectiveness in completing tasks. One of the rapidly developing technologies is the Internet of Things (IoT), which integrates sensors with online control systems, enabling real-time monitoring and control [1].

The application of IoT in large-scale infrastructure is gaining increasing attention as it can support continuous monitoring of structural conditions. Several studies have highlighted the importance of using sensors to detect infrastructure health. With sensors, structural conditions can be monitored directly, enabling potential damage to be identified earlier [2], [3], [4]. One vital infrastructure is bridges, which serve as connectors between regions. Bridges are susceptible to dynamic loads from traffic and environmental factors that can trigger oscillations or vibrations. If left uncontrolled, these

Informatics, Electrical and Electronics Engineering (Infotron)
Volume 5, Number 2, (2025) pp. 88-95
ISSN 2798-0197

conditions can cause serious damage and reduce the service life of bridges. Therefore, regular bridge monitoring is essential to ensure user safety and support a longer service life.

Previous studies have focused on IoT-based and LoRa-based data transmission systems [5]. Successfully designed a wireless data transmission system using a localizer receiver with an LoRa SX-1278 connected to a Google Spreadsheet. The performance of an IoT-based wireless data transmission system at a solar energy station has also been demonstrated, along with recommendations for a suitable monitoring system for solar energy applications [6]. In addition, an IoT-based vehicle health data transmission system utilizing DHT222 sensors has been developed to provide real-time information aimed at reducing the risk of traffic accidents [7].

In the context of infrastructure, an IoT-based bridge health monitoring system has been successfully implemented to analyze water levels, vehicle counts, vibrations, and structural deformations on bridges [8]. In addition, a LoRa–MQTT gateway enabling two-way communication between sensor nodes and cloud servers has been designed, with experimental results indicating that transmission distance affects the data delivery success rate [9]. A LoRa-based ECG data transmission mechanism has also been successfully implemented; however, it still experiences an end-to-end delay of 25.5 seconds [10].

In addition, various studies further reinforce the role of Wireless Sensor Networks (WSNs) in data transmission. A WSN-based water–fertilizer control system for precision agriculture and a real-time gas detection system with low power consumption have been developed in previous works [11],[12],[13]. The performance of IoT data transmission at a solar energy station has also been evaluated using parameters such as delay, jitter, throughput, and packet loss [14]. Moreover, a distributed WSN-based smart lighting system aimed at improving energy efficiency has been implemented, and the performance of the LoRa E22-900T30D module has been tested in an urban area of Surakarta, demonstrating effective transmission up to 2.08 km with a success rate of 75% [15].

These studies indicate that IoT and LoRa-based data transmission systems continue to be developed across various fields, including agriculture, transportation, energy, healthcare, and infrastructure. However, specific research on bridge oscillation monitoring using the LoRa EBYTE E220-400T22D is still rare. Therefore, this study designs and builds a LoRa EBYTE E220-400T22D-based data transmission system for bridge oscillation monitoring. This system utilizes vibration sensors connected wirelessly to a monitoring center via a LoRa network. The E220-400T22D module was selected due to its good signal stability, low power consumption, and support for long-range data transmission. The main objective of this research is to improve bridge safety and reliability through real-time monitoring, support early detection of damage, and extend the service life of infrastructure.

2. Method

2.1. Research methodology

This study uses the Research and Development (R&D) method, which includes the stages of problem identification, system design, device implementation, and testing and evaluation. This method was chosen to design and test the effectiveness of an oscillation monitoring system on bridge structures based on Internet of Things (IoT) technology. The developed system consists of a transmitter node using an Arduino Nano as a microcontroller and vibration sensor, and a receiver node (gateway) based on ESP8266 connected to the internet. Data communication is carried out through the LoRa EBYTE E220-400T22D module, which enables long-distance transmission with low power consumption. To maintain signal stability, the device is also equipped with an external antenna. The communication mechanism is set up using a request–response system, so that nodes only send data when requested by the receiver to minimize transmission interference.

2.2. Wireless sensor node system diagram

The system diagram is implemented using the method shown in Figure 1. This wireless sensor node system diagram consists of two data transmitter nodes and one receiver gateway connected to the internet. Each transmitter node obtains sensor data, then processes it using Arduino Nano before sending it through the LoRa module. The communication mechanism is designed based on request–response, where the transmitter only sends data when it receives a request from the gateway. Requests

DOI: 10.33474/infotron.v3i2.24553

Informatics, Electrical and Electronics Engineering (Infotron)
Volume 5, Number 2, (2025) pp. 88-95
ISSN 2798-0197

are sent alternately to each node, and if there is no response after two requests, the node is considered offline, and the system continues the request to the next node.

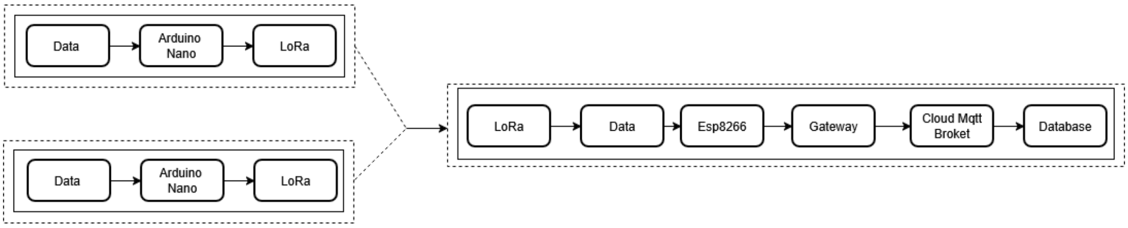

Fig. 1. Wireless sensor node system diagram

On the receiving side, the gateway is equipped with a LoRa module that receives data from the nodes and forwards it to the ESP8266. The ESP8266 device functions as a communication bridge between the LoRa system and the internet network. The received data is processed and then sent to the server for remote monitoring purposes. With this architecture, the system is able to manage the transmission of sensor data from remote locations efficiently, in a controlled manner, and in real time through a combination of LoRa technology and ESP8266-based internet connectivity.

2.3. System Flowchart

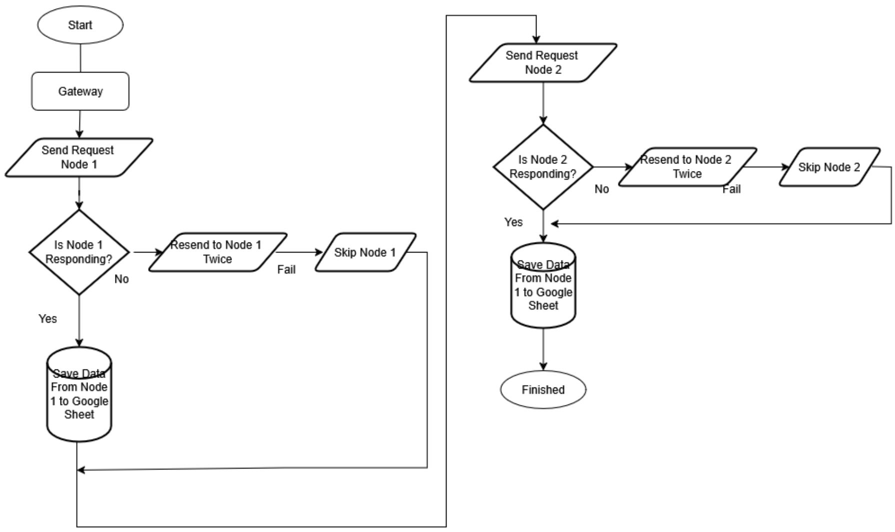

Fig. 2. System Flowchart

When the system is turned on, the gateway first sends a data request to node 1. The gateway then waits for a response from that node. If there is no response, the request is resent a maximum of two times. If there is still no response after two retries, the system considers node 1 to be inactive and continues the process to the next node. Next, the gateway sends a data request to node 2 using the same mechanism, i.e., waiting for a response and retrying the request up to two times if there is no response. After data from both nodes is successfully received, or after exceeding the retry limit, the collected data is processed and stored with an incrementing index (N++). This mechanism ensures that each node has the opportunity to respond and keeps the system tolerant to potential communication failures.

DOI: 10.33474/infotron.v3i2.24553

Informatics, Electrical and Electronics Engineering (Infotron)
Volume 5, Number 2, (2025) pp. 88-95
ISSN 2798-0197

2.4. Flowchart Sender Flow

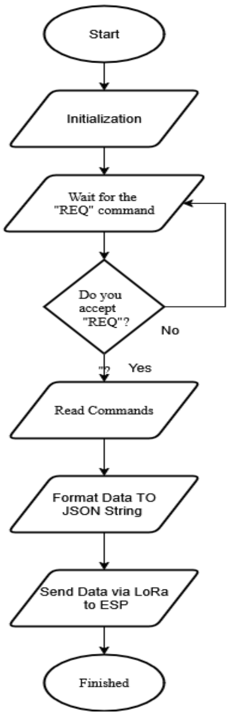

Fig. 3. Sender Flowchart

When the device is turned on, node 1 will wait for a request from the receiver. If a request is received, node 1 will read and parse the message content. Next, the system will check whether the received message is indeed in the form of "REQ". If so, node 1 will create a response in the text format "Node 1,x", where x is the counter value that increases each time there is a request. After the response is created, the data is immediately sent back to the receiver via the LoRa module. If no request is received, the system will return to the waiting state and the process will repeat (looping).

2.5. Recipient Flowchart

When the device is turned on, two sensor nodes are connected to the Arduino Nano. The Arduino Nano reads and processes the data, but only sends it when there is a request from the receiver. The receiver then sends a request to the sender, and if there is no response after two requests, the node is considered offline and the process continues to the next node. Data is transmitted wirelessly via LoRa to the receiver, then forwarded to the Esp8266. The Esp8266 stores the data on a micro SD card as a local log and sends it to the gateway via the internet. This program flowchart illustrates the sequential, controlled, and queued data transmission process.

2.6. Wiring Design

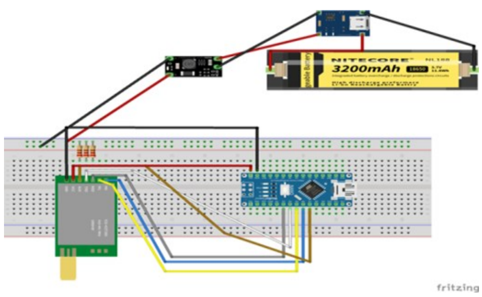

Fig. 4. Sender Schematic Diagram

DOI: 10.33474/infotron.v3i2.24553

Informatics, Electrical and Electronics Engineering (Infotron)
Volume 5, Number 2, (2025) pp. 88-95
ISSN 2798-0197

This device is assembled according to the circuit diagram, by connecting the Arduino Nano, Lora Ebyte E220-400, Step-Up Converter Module, and TP-4056 Power Bank Charger Module using jumper cables. The design is based on the schematic in Fig. 4., As shown in the schematic diagram, the Arduino Nano is connected to the Lora E220-400 with the following pinout: Arduino Nano pin D6 to Lora M0, Arduino Nano pin D5 to Lora M1, Arduino Nano pin D3 to Lora RX, Arduino Nano pin D4 to Lora TX, Arduino Nano pin D7 to Lora AUX, with power supply from the battery and step-up to increase the output voltage from the battery power source, as well as for charging using the power bank charger module. In general, the wiring diagram of the base station and sensor node is shown in Fig. 4.

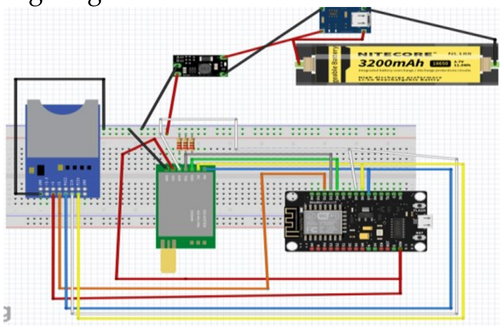

Fig. 5. Receiver Schematic Diagram

Fig. 5., has a similar configuration. The only difference is in the use of Esp8266, MicroSD Card Adapter Lora ebyte E220-400, Step Up Converter Module, and Power Bank Charger Module TP-4056 using jumper cables. The design was carried out according to the schematic in Fig. 4. As shown in the schematic diagram, the esp8266 is connected to the lora e220-400 and microSD card adapter with its pinout, pin D7 of the ESP8266 to M0 of the LoRa, pin D6 of the ESP8266 to M1 of the LoRa, pin D4 of the ESP8266 to RX of the LoRa, pin D3 of the ESP8266 to TX of the LoRa, pin D5 of the ESP8266 to AUX of the LoRa, and for the microSD card connected to the ESP8266 with pin D8 of the ESP8266 to CS of the microSD, pin D5 of the ESP8266 to the SCK of the microSD, pin D7 of the ESP8266 to the MOSI of the microSD, pin D6 of the ESP8266 to the MISO of the microSD, with power supply from the battery and a step-up converter to increase the output voltage from the battery power source, as well as for charging using a power bank charger module.

3. Test Results and Discussion

System testing was conducted using two main scenarios, namely Line of Sight (LOS) and Non-Line of Sight (NLOS). The testing methods applied included LOS Outdoor, NLOS Indoor, and NLOS Outdoor. These three methods were chosen to evaluate the performance of data transmission under different environmental conditions, and were used as the basis for gap research or hypothesis testing. The comparison of the results from each method was analyzed based on the distance between the transmitter location at the University of Surakarta and the receiver location at the Jurug Bridge, which served as the main reference in the system performance analysis.

Testing was conducted at distances ranging from 500 m to 4 km under LOS (line of sight) conditions (without obstruction) as shown in Table 1. A total of 200 packets were sent at each distance using the request method.

DOI: 10.33474/infotron.v3i2.24553

Informatics, Electrical and Electronics Engineering (Infotron)
Volume 5, Number 2, (2025) pp. 88-95
ISSN 2798-0197

Table 1. The Test Results Under Line Of Sight (LOS) Outdoor Condition

No	Distance	Loss/No Loss	Data Amount		Packet Loss	Indeks
			Send	Accepted		
1	500 m	Loss	200 Data	200 Data	0%	4
2	1 Km	Loss	200 Data	200 Data	0%	4
3	1,5 Km	Loss	200 Data	200 Data	0%	4
4	2 Km	Loss	200 Data	200 Data	0%	4
5	2,5 Km	Loss	200 Data	200 Data	0%	4
6	3 Km	Loss	200 Data	100 Data	50%	1
7	3,5 Km	Loss	200 Data	50 Data	75%	1
8	4 Km	Loss	200 Data	0 Data	100%	0
Average Packet Loss					28,13%	2

Average packet loss for this condition is 28.13%. From the table 1, it can be seen that the system performs very well up to a distance of 2.5 km with a success rate of 100%. However, at distances greater than 3 km, there is a significant drop, and at 4 km, no packets are received. This indicates the limitations of the LoRa E220-400T22D module in outdoor LOS conditions, with a maximum stable transmission range of approximately 2.5 km.

The testing was conducted at distances ranging from 100 m to 500 m under NLOS conditions (obstructed by buildings/urban environment). The number of data packets sent at each distance was 100 packets.

Table 2. The Test Results Under None-Line Of Sight (NLOS) Outdoor Condition

No	Distance	Loss/No Loss	Data Amount		Packet Loss	Indeks
			Send	Accepted		
1	100 m	No Loss	100 Data	100 Data	0%	4
2	200 m	No Loss	100 Data	100 Data	0%	4
3	300 m	No Loss	100 Data	65 Data	35%	1
4	400 m	No Loss	100 Data	50 Data	50%	1
5	500 m	No Loss	100 Data	0 Data	100%	1
Average Packet Loss					16.82%	2

Average packet loss for this condition is 16.82%. The results show that the system works optimally at a distance of 100–200 m, but performance declines at 300–400 m. At 500 m, no data is received. This is normal because urban conditions with concrete and building obstacles worsen signal quality.

Testing modul LoRa Ebyte E220-400T22D (Non-Line of Sight (NLOS) Indoor) is explained in Table 3. The testing was conducted between floors (floor 1 to floor 2, and floor 1 to floor 3) with a vertical distance of ±9 meters. The amount of data sent was 100 packets per position.

Average packet loss for this condition is 3.17%, as explained in Table 3. These results indicate that data transmission in indoor NLOS conditions is relatively stable. Concrete barriers between floors reduce signal quality, but still within reasonable limits (<5% average). The test was conducted at a distance of 270 m under NLOS conditions (obstructed by buildings), as shown in Table 4. The amount of data transmitted was 500 packets.

DOI: 10.33474/infotron.v3i2.24553

Informatics, Electrical and Electronics Engineering (Infotron)
Volume 5, Number 2, (2025) pp. 88-95
ISSN 2798-0197

Table 3. The Test Results Under Non-Line Of Sight (NLOS) Indoor Condition

No	Distance		Loss/No Loss	Floor 2 Data Count		Packet Loss Floor 2	Indeks
	Floor 1	Floor 2		Send	Accepted		
1	Room A	Room A	No Loss	100 Data	100 Data	0%	4
2	Room A	Room B	No Loss	100 Data	100 Data	0%	4
3	Room A	Room C	No Loss	100 Data	100 Data	0%	4
No	Distance		Loss/No Loss	Floor 3 Data Count		Packet Loss Floor 3	Indeks
	Floor 1	Floor 3		Sent	Accepted		
1	Room A	Room A	No Loss	100 Data	98 Data	2%	3
2	Room A	Room B	No Loss	100 Data	95 Data	5%	3
3	Room A	Room C	No Loss	100 Data	88 Data	12%	3
Average Packet Loss						3.17%	3

Table 4. The Test Results Jurug Bridge - Universitas Surakarta Gateway

No	Distance	Loss/No Loss	Data Amount		Packet Loss	Indeks
			Send	Accepted		
1	270 m	No Loss	500 Data	486 Data	2,8%	3
Average Packet Loss					2.8%	3

The results show that despite building obstructions, the system is still able to operate with a success rate of 96%, making it suitable for real-time monitoring of bridge oscillations.
Based on all tests, it can be concluded that:

1. LOS Outdoor → maximum performance up to 2.5 km with a success rate of 100%. Above 3 km, signal quality decreases drastically.
2. NLOS Outdoor → optimal at 100–200 m, begins to decline above 300 m, and fails completely at 500 m.
3. NLOS Indoor → performance remains good between floors with an average packet loss of only 3.17%.
4. Field Implementation (Jurug–UNS) → successful, with low packet loss of 2.8% at a distance of 270 m.

In general, the LoRa E220-400T22D module has proven capable of transmitting sensor data effectively under various transmission channel conditions. The average packet loss rate remains low (<30%) and is suitable for bridge infrastructure monitoring applications.

4. Conclusion

Based on the design and testing of the LoRa-based data transmission system, it can be concluded that this system has been successfully designed and implemented to transmit vibration or oscillation data in real-time using Wireless Sensor Network (WSN) technology based on the LoRa EBYTE E220-400T22D module. The system operates effectively in transmitting data from sensors installed on bridge structures to receiving devices with low power consumption and a wide range, consistent with LoRa characteristics.

Testing shows that the system functions well under both Line of Sight (LOS) and Non-Line of Sight (NLOS) conditions. The data transmission success rate is high, with an average error rate of 28.13% for

DOI: 10.33474/infotron.v3i2.24553

Informatics, Electrical and Electronics Engineering (Infotron)
Volume 5, Number 2, (2025) pp. 88-95
ISSN 2798-0197

LOS and 16.82% for NLOS. In field implementation, the system demonstrates better performance with an error rate of only 2.8%, making it suitable for remote infrastructure monitoring.

Additionally, the developed system is integrated with a gateway and cloud-based storage (Google Sheets), enabling continuous and real-time access and analysis of monitoring data from a distance. This demonstrates that the LoRa E220-400T22D-based data transmission system has the potential to be applied in structural health monitoring, particularly for bridges, in remote locations requiring long-range wireless communication with high reliability.

5. Reference

[1] Ju, Jaehyeon, Mi-Seon Kim, and Jae-Heon Ahn. "Prototyping Business Models for IoT Service." Information Technology and Quantitative Management 882-890. 2016.

[2] Jang, W., W. Healy, and M. Skibniewski. Wireless sensor networks as part of a webbased building environmental monitoring system, Automation in Construction, 17(6), 729736. 2008

[3] Kim, J., J. Park, and B. Lee. Vibration-based damage monitoring in model plate-girder bridges under uncertain temperature conditions, Engineering Structures, 29(7), 13541365. 2007.

[4] Masri, S. F., L.-H. Sheng, J. P. Caffrey, R. L. Nigbor, M. Wahbeh, and A. M. Abdel-Ghaffar Application of a Web-enabled real-time structural health monitoring system for civil infrastructure systems, Smart Materials and Structures, 13(6), 1269–1283. 2004.

[5] Muh Ridho R, Muh Wildan, Tohazen., "Rancangan Sistem Transmisi Data Wireless Pada Receiver Localizer Dengan Lora Sx-1278 Berbasis Google Spreadsheet". Proceding SNVP (2022) Vol 1 113-118. 2022

[6] Abdirandra, K. D. Perancangan Sistem Transmisi Data Pada Solar Energy Station Berbasis Iot (Internet Of Things) Dengan Menggunakan Jaringan Wireless. 2020.

[7] Wiko, B., Muayyadi, A. A., & Armi, N. (t.t.). Perancangan Sistem Transmisi Data Kesehatan Mobil Menggunakan Dht22. eProceeding of Engineering. Telkom University. 2024

[8] Prajwal .C, Goutham. C, Kiran. N, Shiva Prasad. D R, Dr. K V Padmaja. IOT Based Bridge Health Monitoring System. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering. Vol 9, 1586-1592. 2020

[9] Firmansyah, D. W., Ichsan, M. H. H., & Bhawiyuga, A. (t.t.). Pengembangan Gateway LoRa-MQTT untuk Transmisi Data Dua Arah antara Wireless Sensor Network dan Cloud Server. JPTIIK Vol 4, 397-405. Brawijaya University. 2020

[10] Alifiandi, F. R., Pramukantoro, E. S., & Primananda, R. (t.t.). Penerapan Mekanisme Transmisi Data ECG Berbasis Teknologi LoRa (Long Range). . JPTIIK Vol 4, 90-99. Brawijaya University. 2020

[11] Du, C., Zhang, L., Ma, X., Lou, X., Shan, Y., Li, H., & Zhou, R. A. Cotton High-Efficiency Water-Fertilizer Control System Using Wireless Sensor Network for Precision Agriculture. Processes, 9(10), 2021

[12] Yadav, S. A., Sharma, S., Das, L., Gupta, S., & Vashisht, S. An Effective IoT Empowered Real-time Gas Detection System for Wireless Sensor Networks. 2021 International Conference on Innovative Practices in Technology and Management (ICIPTM), 44–49. 2021.

[13] Abdirandra, K. D. Perancangan Sistem Transmisi Data Pada Solar Energy Station Berbasis Iot (Internet Of Things) Dengan Menggunakan Jaringan Wireless. 2020.

[14] Cheng, Y., Fang, C., Yuan, J., & Zhu, L. Design and Application of a Smart Lighting System Based on Distributed Wireless Sensor Networks. Applied Sciences, 10(23), 8545. 2020

[15] Setiawan, F. B. Rancang Bangun WSN Menggunakan Ebyte E22-900T30D sebagai Media Komunikasi Jarak Jauh di Daerah Urban Area (Palur, Surakarta). Informatics, Electrical and Electronics Engineering (Infotron), 3(2), 65–75. 2023.

DOI: 10.33474/infotron.v3i2.24553