IoT Based PJUTS Performance Monitoring System Using Extended Star Topology

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Abstract. Monitoring the performance of solar street lighting (PJUTS) has several obstacles, namely the total number of PJUTS and cases of component theft. Internet security system based on Things (IoT) is a solution to overcome these obstacles. The system enables the improvement of all infrastructure in real time, thereby increasing efficiency, accuracy, and providing economic benefits that include low system construction and maintenance. In this paper I propose an IoT-based PJUTS search system using an extended star network topology that is carried out through a web interface. The system also provides economic benefits consisting of minimizing costs incurred for transportation in the form of manuals to the location. The extended star topology used is also able to reduce system development costs because only the gateway node requires a sending module (WiFi / GSM) to send data to the database. Additionally, the system does not stop one of the wrong gateway nodes.

Keywords: PJUTS, Solar Panels, Internet of Things, Monitoring, Extended Star

INTRODUCTION

Photovoltaic (PV) technology can be used for various applications that require electrical energy. Several uses of PV technology such as solar home systems, solar street lighting, and solar-powered water pumping [1]. Solar street lighting (PJUTS) is an alternative in providing electrical energy, especially in locations that are not covered by the PLN electricity network [2] - [4]. The location of PJUs that are scattered in remote areas and the many cases of theft of PJU equipment are the main obstacles in monitoring PJUTS performance. the development of PJUTS provides benefits to the community in the form of improving economic, social, and cultural conditions [7]. The obstacles to the operation of PJUTS in remote areas need more attention. Internet of Things (IoT) based security systems are a solution to overcome these obstacles. The system allows real-time monitoring of the entire infrastructure, thereby increasing efficiency, accuracy, and providing economic benefits in monitoring [3]. Data transmission using IoT wireless also intends to replace the data transmission media in the form of cables [4]. IoT has been implemented to monitor the condition of solar panels. Parikh [21] developed a solar panel monitoring system based on a wireless sensor network (WSN). Each node is equipped with a light sensor (photo-resistor), temperature (LM35), and a dust sensor (GP2Y1010AU0F). Data transmission is carried out using the Xbee S2 (as a transmitter) which has an outdoor transmission distance of up to 90 M. Data is sent to the Xbee S2 (as a receiver) which is connected to a computer via a USB to RS232 converter. The monitoring results are displayed in a graphical user interface (GUI) created using the Python programming language. Monitoring result data is also stored in the form of an excel log file.

Wahyuni and Wijaya [22] also use the Xbee module for data transmission in a solar panel performance monitoring system. In this research, each node is equipped with a real-time clock (RTC) module and an SD card module so that it can store data independently. The system still uses the Xbee module which is connected to the computer for monitoring. Gusa and Dinata [23] increased the flexibility of the solar panel monitoring system by sending data to a database so that it did not require the Xbee module to be connected to a computer. The system uses the Arduino Mega2560 as the main processor and uses a WiFi module to send data. The system utilizes the Blynk server and application to display monitoring results via a smartphone.

In this paper, a solar panel monitoring system for PJUTS that has a more effective architecture is proposed using the extended star topology computer network interconnection. Each node has a longer data transmission distance (up to 1 KM) because it uses the NRF24L01L module which is equipped with a signal booster antenna. The long-distance for sending data also minimizes the number of gateway nodes.

System administrators get effectiveness and efficiency to manage networks, especially computer network connections that use wireless [13] [14] [17]. The proposed monitoring system is equipped with voltage, current and radiofrequency sensors as data transmission media. Data containing the power value is sent by the PJUTS transmitter (node) to the nearest gateway node in the form of a microcontroller equipped with a receiver and the ability to send data to the database. A web-based interface is provided to manage and monitor the performance of each PJUTS node.

METHODS

PJUTS consists of solar panels, solar charger controllers, sensors, microcontrollers, batteries and lights. Voltage and current sensors are installed at the output of the solar panel and the load input. The measured value is sent via the NRF24L01L radio frequency module equipped with a signal booster antenna to the nearest gateway node. The block diagram of the proposed PJUTS node is shown in **FIGURE 2**.

A. System Block Diagram

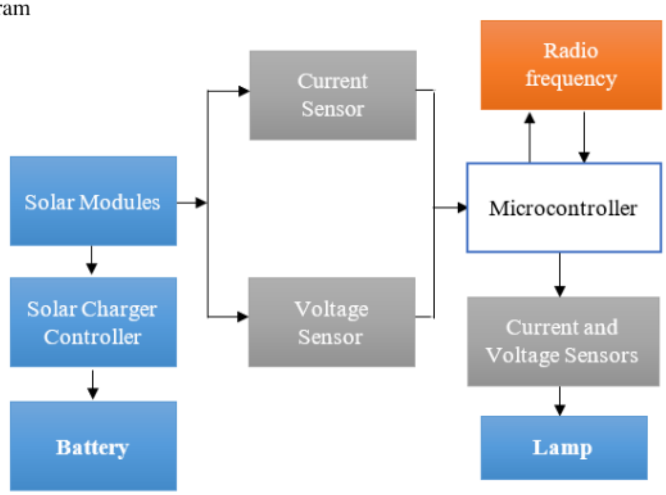

FIGURE 2. PJUTS Node Block Diagram System

The gateway node is equipped with a radio frequency module and the ability to send data to the database. The data can be accessed by administrators using a computer via a web interface. Data administrators can also download data in excel format. Figure 3 shows a block diagram of the proposed gateway node.

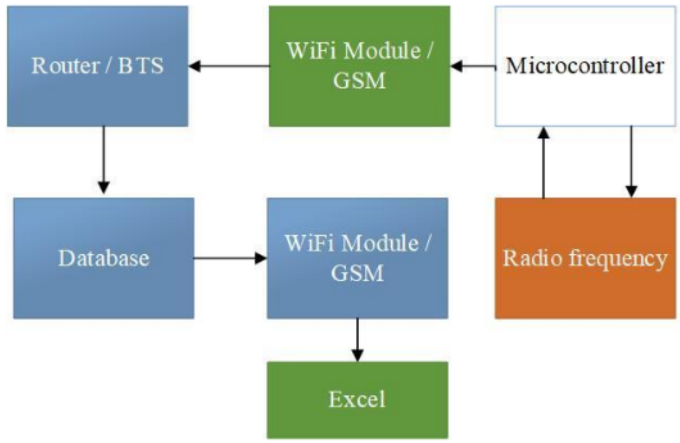

FIGURE 3. PJUTS Node Block Diagram System

The proposed system uses extended star topology interconnection which is the development of a star topology by combining several star topologies into one topology consisting of several clients [13] [14]. The client is a PJUTS node that sends data in the form of solar panel power and lights to the nearest gateway node. The gateway node sends every data received from the PJUTS node to the database. Figure 4 shows the overall system design.

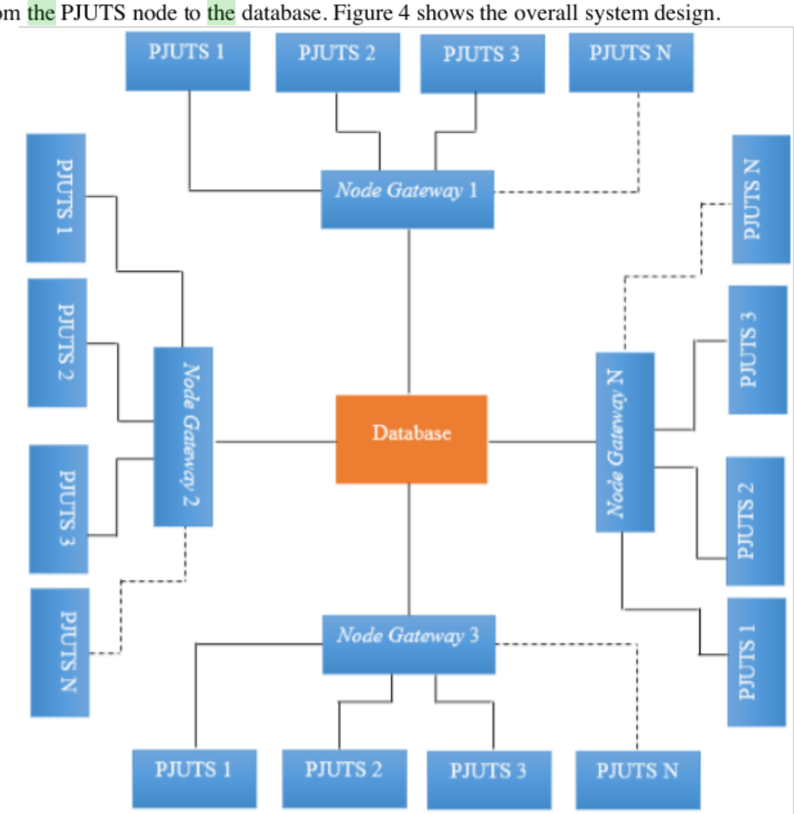

FIGURE 4. Overall System Design

Administrators can monitor the data of all PJTUS nodes. Solar panel data and lights are recorded in real-time, so that administrators can find out when there is a PJUTS node that has a problem. Figure 5 shows the interface for accessing data per gateway node.

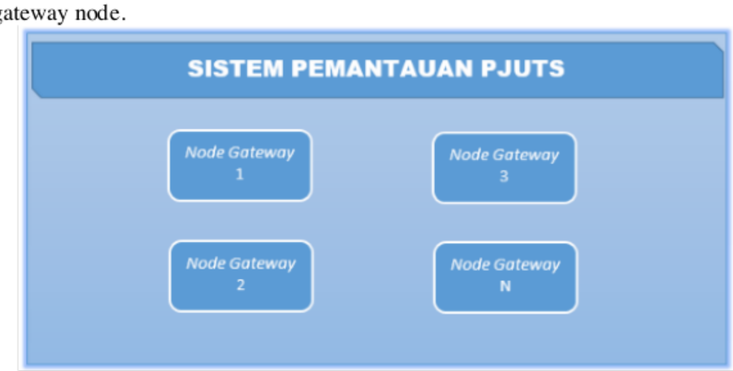

FIGURE 5. Data Selection Per-Node Gateway

The web-based system interface can display the voltage and current values of solar panels and lights for each PJUTS node. The PJUTS node which is operating properly is marked with the ON status. If the PJUTS node does not operate or the displayed power is 0 watts, the status will automatically become OFF. The power rating of the solar module and lamps can be viewed within the previous 7 days with the Log Data button. The monitoring display per PJUTS node can be shown in Figure 6.

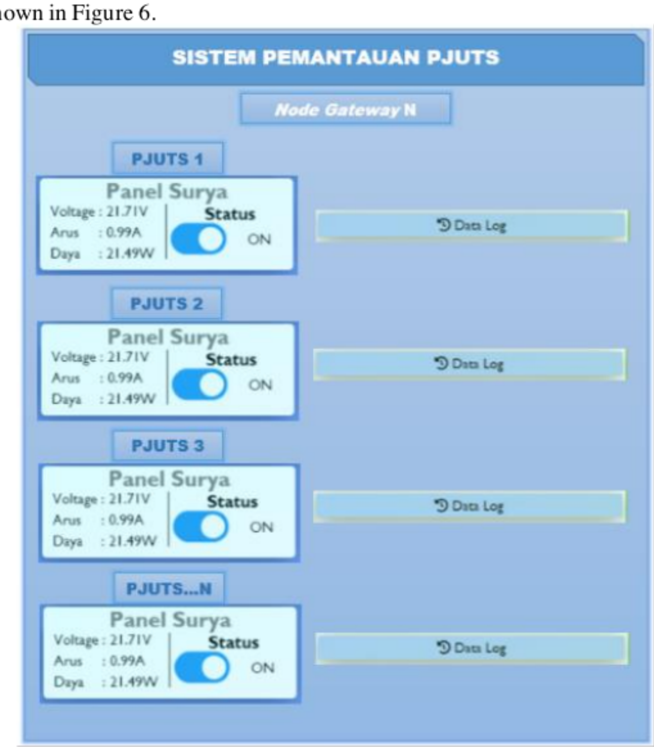

FIGURE 6. Monitoring of each PJUTS node

Each PJUTS node collects voltage and current data generated by solar panels. Data of the voltages and currents used by the lamps were also collected. The data is sent by the PJUTS node to the nearest gateway node. The gateway node sends data received from the PJUTS node to the database.

RESULTS AND DISCUSSION

In testing the IoT-Based PJUTS Performance Monitoring System Using the Extended Star Topology, it includes testing the NRF 2401 radio frequency device which is carried out as a sender and an NRF checker in the form of a prototype as a receiver. Testing is based on the distance in the process of sending and receiving data. In the distance tester, data retrieval is also carried out for the response time required for the process of sending and receiving data. Following are the results of tests conducted by NRF 2401 based on distance and time.

TABLE I. Experiment 1

Testing to	Receiver and Sender Distance (Meters)	Data on Module NRF 2401		Response Time (s)	Data Status
		NRF Sender	Recipient's NRF		
1	0-10	16.44 V	16.44 V	1.60	Sent
2		16.43 V	16.43 V	1.62	Sent
3		16.43 V	16.43 V	1.64	Sent
4		16.43 V	16.43 V	1.74	Sent
5		16.43 V	16.43 V	1.75	Sent
6		16.43 V	16.43 V	1.80	Sent
7		16.43 V	16.43 V	1.85	Sent
8		16.43 V	16.43 V	1.98	Sent
9		16.43 V	16.43 V	2.89	Sent
10		16.43 V	16.43 V	3.27	Sent

TABLE II. Experiment 2

Testing to	Receiver and Sender Distance (Meters)	Data on Module NRF 2401		Response Time (s)	Data Status
		NRF Sender	Recipient's NRF		
1	0-10	16.44 V	16.44 V	1.38	Sent
2		16.43 V	16.43 V	1.40	Sent
3		16.44 V	16.43 V	1.41	Sent
4		16.43 V	16.43 V	1.41	Sent
5		16.43 V	16.43 V	1.45	Sent
6		16.43 V	16.43 V	1.48	Sent
7		16.43 V	16.43 V	1.55	Sent
8		16.43 V	16.43 V	1.55	Sent
9		16.43 V	16.43 V	1.58	Sent
10		16.43 V	16.43 V	1.60	Sent

TABLE III. Experiment 3

Testing to	Receiver and Sender Distance (Meters)	Data on Module NRF 2401		Response Time (s)	Data Status
		NRF Sender	Recipient's NRF		
1	0-10	18.37 V	18.34 V	1.24	Sent
2		18.37 V	18.34 V	1.26	Sent
3		18.37 V	18.37 V	1.26	Sent
4		18.37 V	18.37 V	1.30	Sent
5		18.37 V	18.34 V	1.30	Sent
6		18.37 V	18.34 V	1.31	Sent

7		18.37 V	18.34 V	1.34	Sent
8		18.37 V	18.34 V	1.34	Sent
9		18.37 V	18.37 V	1.35	Sent
10		18.37 V	18.37 V	1.35	Sent

TABLE IV. Experiment 4

Testing to	**Receiver and Sender Distance (Meters)**	**Data on Module NRF 2401**		**Response Time (s)**	**Data Status**
		NRF Sender	**Recipient's NRF**		
1	0-10	20.04 V	20.04 V	1.05	Sent
2		20.04 V	20.03 V	1.07	Sent
3		20.04 V	20.04 V	1.09	Sent
4		20.04 V	20.03 V	1.10	Sent
5		20.04 V	20.04 V	1.15	Sent
6		20.04 V	20.04 V	1.15	Sent
7		20.04 V	20.04 V	1.19	Sent
8		20.04 V	20.04 V	1.22	Sent
9		20.04 V	20.03 V	1.24	Sent
10		20.04 V	20.04 V	1.24	Sent

In the monitoring system log data menu, voltage, current and power data of the PJUTS node are displayed. Current, voltage and power data stored in the database are the data for the last seven days where data recording is done every 1 second. Monitoring data can also be downloaded in excel format. Figure 7 shows a display of the system log data feature.

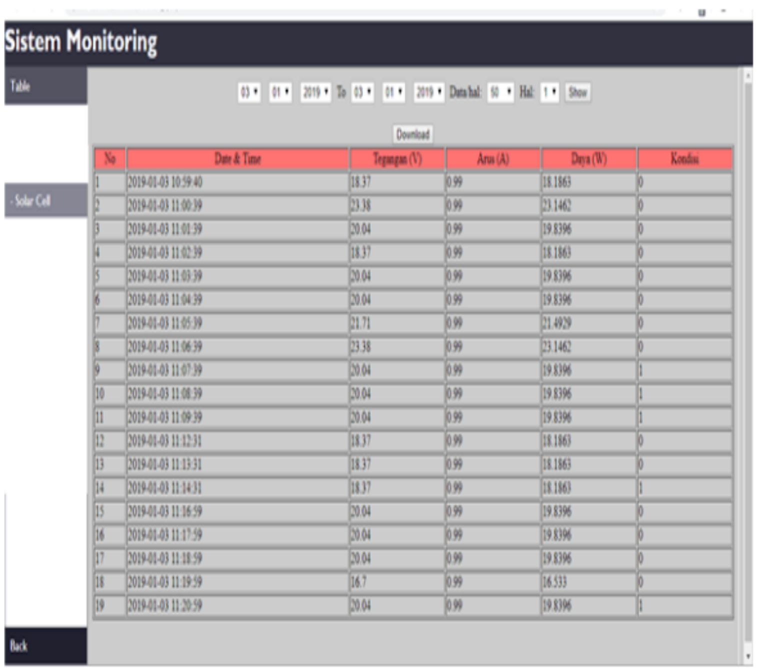

FIGURE 7. Monitoring web for each PJUTS node

TABLE V. Data on Monitoring Results of PJUTS Per-Node Monitoring

No.	Time	Voltage	Current	Power
1	1/3/2019 10:59	18,37	0,99	18,1863
2	1/3/2019 11:00	23,38	0,99	23,1462
3	1/3/2019 11:01	20,04	0,99	19,8396
4	1/3/2019 11:02	18,37	0,99	18,1863
5	1/3/2019 11:03	20,04	0,99	19,8396
6	1/3/2019 11:04	20,04	0,99	19,8396
7	1/3/2019 11:05	21,71	0,99	21,4929
8	1/3/2019 11:06	23,38	0,99	23,1462
9	1/3/2019 11:07	20.04	0,99	19,8396
10	1/3/2019 11:08	20,04	0,99	19,8396
11	1/3/2019 11:09	20,04	0,99	19,8396
12	1/3/2019 11:10	18,37	0,99	18,1863
13	1/3/2019 11:11	18,37	0,99	18,1863
14	1/3/2019 11:12	18,37	0,99	18,1863
15	1/3/2019 11:13	20,04	0,99	19,8396
16	1/3/2019 11:14	20,04	0,99	19,8396
17	1/3/2019 11:15	20,04	0,99	19,8396
18	1/3/2019 11:16	16,70	0,99	16,5330
19	1/3/2019 11:17	20,04	0,99	19,8396

The proposed system is able to provide effectiveness and efficiency in monitoring PJUTS performance. PJUTS node damage detection is made easier because it is marked with an OFF status in the web interface. If all PJUTS nodes in one gateway node do not transmit data, it can be analyzed that the damage occurred at the gateway node. The extended star topology that is used makes the system not completely stopped when one of the gateway nodes has a problem.

The system being developed also provides economic benefits in the form of minimizing system development costs and system maintenance. System development costs are reduced because not all PJUTS nodes are equipped with modules to send data to the database. The long distance for sending data nodes (up to 1 KM) also minimizes the number of gateway nodes needed. Data is collected at the nearest gateway node to be sent to the database. Transferring data without cables also reduces the cost of building the system. In terms of maintenance, maintenance costs can be minimized because there is no need to visit every PJUTS to monitor their condition and performance.

CONCLUSIONS

The proposed system has been tested and can transmit data properly. This system can increase the effectiveness and efficiency of monitoring the performance of PJUTS. PJUTS damage can also be detected more easily. The damaged PJUTS node is marked with OFF status on the web interface. The system also provides economic benefits in the form of minimizing costs incurred for transportation in manual monitoring to the location. The extended star topology used is also able to reduce system development costs because only gateway nodes require a transmission module (WiFi / GSM) to send data to the database. In addition, the system does not come to a complete stop when one of the gateway nodes has a problem.

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