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Public Street Lighting Monitoring System Uses Telegram-Based Application Wireless Sensor Network

Sistem Monitoring Penerangan Jalan Umum Menggunakan Aplikasi Telegram Berbasis Jaringan Sensor Nirkabel

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Abstract

Public Street Lighting (PJU) usually operates all night until early morning without a remote device to adjust the conditions. In monitoring the PJU lights, the officers are still carrying out their duties manually by visiting the place. This study aims to build a PJU monitoring system tool by utilizing the NodeMCU ESP32 as a microcontroller and a wifi module, which will later send notifications via the Telegram Bot. This system uses the ACS712 current sensor to detect the value of the current flowing in public street lighting installations, the VDC voltage sensor to detect the voltage value, and the LDR sensor to detect light. The read data will be processed by ESP32, which will then be sent to the Telegram Bot. The result of this study is a PJU monitoring tool. With this tool, officers can remotely monitor the PJU lights' condition. The Telegram bot will send notification messages to officers at 07.00 and 19.00. In addition, officers can ask about the state of the lights by instructing "cek pju" to the Telegram Bot. The system has been successfully implemented and operates normally and optimally, demonstrating its efficacy in practical testing.

Keywords: PJU monitoring, NodeMCU ESP32, Telegram Bot, wireless sensor network.

***SDGs*:**

Abstrak

Penerangan Jalan Umum (PJU) biasanya beroperasi sepanjang malam hingga dini hari tanpa dilengkapi perangkat yang dapat memantau kondisinya dari jarak jauh. Dalam pemantauan lampu PJU, petugas masih melakukan tugasnya secara manual dengan mendatangi tempat tersebut. Penelitian ini bertujuan untuk membangun alat sistem monitoring PJU dengan memanfaatkan NodeMCU ESP32 sebagai mikrokontroler dan modul wifi yang nantinya akan mengirimkan notifikasi melalui Bot Telegram. Sistem ini menggunakan sensor arus ACS712 untuk mengukur nilai arus pada instalasi PJU, sensor tegangan VDC untuk mendeteksi nilai tegangan, dan sensor LDR untuk mendeteksi cahaya. Data yang dibaca akan diproses oleh ESP32, yang kemudian akan dikirim ke Bot Telegram. Hasil dari penelitian ini berupa alat monitoring PJU. Dengan alat ini, petugas dapat memantau kondisi lampu PJU dari jarak jauh. Bot Telegram akan mengirimkan pesan notifikasi kepada petugas pada pukul 07.00 dan 19.00. Selain itu, petugas dapat menanyakan keadaan lampu dengan menginstruksikan "cek pju" ke Bot Telegram.

Kata Kunci: PJU monitoring, NodeMCU ESP32, Telegram Bot, jaringan sensor nirkabel.

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1. INTRODUCTION

Government provide Public Street Lighting (PJU) through the Department of Transportation (DISHUB) for increase facility equipment road like tool lighting road highway, which is stated in Regulation of the Minister of Transportation Republic of Indonesia PM Number 27 of 2018. Purpose main PJU is for increase safety, security, order, and smoothness Then cross at a time ensure comfort user road (Purnama, Desriyanti and Kurniawan, 2020).

PJU is facility society used for activity evening day, managed by the Department of Housing and Settlements (DISPERKIM). However, DISPERKIM officers experienced lateness in repair and organize PJU. Information damage PJU lamps are obtained from user roads and officials in a manner periodically visit every PJU location for check conditions, especially If the location far (Tansri *et al.*, 2020). Because of it, a system that allows monitoring condition lighting road distance remote and real-time required for increase efficiency management and repair is highly required. PJU monitoring systems have been developed in several studies by integrating IoT (Adriansyah *et al.*, 2020) and WSN systems (Burtsev *et al.*, 2020). By applying these two technologies, the monitoring process can be carried out in real-time.

In this study, ESP32 is selected as platforms development because own excess in matter connection strong wireless capabilities for transmit data in time real. Study this utilizes the LDR sensor (Light Dependent Resistor) as the input to be processed by the ESP32 microcontroller (Fitriyani and Susandi, 2022). LDR sensors work as indicator for know circumstances day and night. Then, the voltage sensor used for show failure source voltage. Besides Therefore, the ACS712 current sensor is used for identifying current electricity that passes through it (Rohman, Lomi and Muljanto, 2022). Working LCD For displays the value that the sensor reads and has processed by ESP32. Next, system monitoring has associated with system Telegram Bot notifications. Telegram Bot is used because it is open source and can be integrated with a microcontroller system.

This possible PJU officer for ask PJU condition with send message to tool monitor via Telegram Bot. Monitoring tool this aim for make it easy work officer with tell PJU condition and reduce time required for identify root reason PJU damage (Putra, Amrita and Suyadnya, 2018).

The research conducted was almost the same as previous research (Adriansyah *et al.*, 2020; Burtsev *et al.*, 2020). Difference the lies in the use of sensors used in study this, namely the voltage sensor, the ACS712 current sensor and the LDR sensor. Then LCD and the Telegram application are also used as media for display and monitor the value sent by the ESP32 it received the data from voltage sensor readings, current sensors, and LDR sensors. Besides it, that becomes differentiator main in study this that is utilise progress technology with using the NodeMCU Module more series great compared ESP8266's predecessor, the ESP32. Difference mainly, this ESP32 consists of dual-core whereas ESP8266 only single-core. On ESP32, one dedicated core for connectivity WiFi+Bluetooth. Cores other dedicated for user application. So ESP32 is more qualified to handle intensive applications. Besides it, ESP32 have feature WiFi and Bluetooth at once. The most important thing is that the ESP32 has 6 analog pins where most of its predecessors only had 1 analog pin.

2. METHODOLOGY

2.1. Wireless Sensor Network

Wireless sensor network, also known as Wireless Sensor Networks (WSN) is something system characteristic network wireless and consists of many sensor nodes are placed in different positions for observe and monitor condition a certain area (Hanisadewa, Viananta and Primawan, 2019). In WSN there are sensor nodes. Component in a node can seen in Figure 1. The node component includes:

1) Communication device
   Device communication on each WSN node role in receive and send data to the node or other devices use IEEE 802.15.4-2003 or IEEE 802.11b/g protocols.

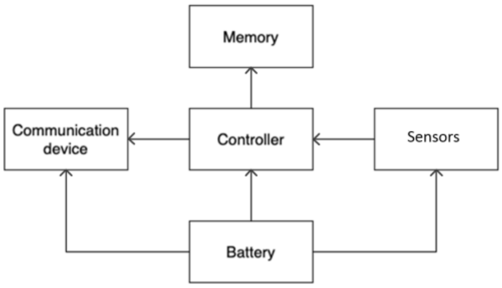


Figure 1. Node components.

2) Microcontroller
Microcontroller used for carry out calculating, controlling, and processing connected device with nodes.
3) Sensors
The sensors on the WSN node are working for detect magnitude physical want measured. Internal sensors matter This change magnitude measurable become Power electricity, which by Analog-to-Digital Converter (ADC) changed become Suite credit quantized. Credit This Then can read by the microcontroller (Istiana and Firdaus, 2022).
4) Memory
Function from memory on the WSN node is as addition memory for WSN system, even though it 's a microcontroller unit basically Already be equipped with memory internal alone.
5) Battery
Source power on the WSN node is used as source energy for whole running WSN system.

2.2. Topology WSN network

In coordinating WSN, there is several topology networks used including:
1) Bus topology
The bus topology is something type architecture network where all nodes or device connected to One channel so called communication by bus. In other words, the bus topology uses track communication single.
2) Star topology
In star topology, every device own connection alone with switches, so if one device experience problem or separated connection, only device those affected (Rahadjeng and Ritapuspitasari, 2018). Other devices in network still can communicate without disturbed.
3) Mesh topology
Mesh topology is typing network possible communication each node for communicate with other nodes. In network in this case, every node is connected to another node via track different communication for reach the gateways. This design ensures that data package available diverted through track alternative if one node fails or experience disturbance (Alvionita and Nurwarsito, 2019).
4) Tree topology
Every node in tree topology still maintains one track connected communications to the gateway, but the node also uses other nodes in the send data through same path.

2.3. WSN Performance Parameters

The following describes the parameters of WSN:
1) Packet loss
Packet loss is phenomenon where several packages in communication No succeed reach intended destination. Incident this happen when one or several packages sent through network no succeed reach intended destination (Rofii, Hunaini and Sholawati, 2018). The equation (1) to calculate packet loss:

$$PL = P_s - P_r \quad (1)$$

where:
PL = Packet loss (package)
P_s = Many packets sent (packet)
P_r = Many packets received (packet)

2) Throughput
Capacity connectivity network can be measured with throughput, which refers to the average speed of successful data packets transmitted through channel communication. Besides that, amount data packets received per second can also be used for measure throughput (Fahmi, 2018). The equation (2) to calculate throughput:

$$Throughput = \frac{Pr}{t} \quad (2)$$

where:
Pr = Many packets received (packet)
T = Retrieval time sample (ms)

3) Delays
Delay, or as it is also known as delay time, refers to the time required by a data plan for do journey traverse network from point origin until reach purpose. delays This includes transmission delay, propagation delay, and process delay (Budiman, Duskarnaen and Ajie, 2020). The equation (3) to calculate delay:

$$Delay = t_r - t_s \quad (3)$$

Where:
t r = Receiving time package (ms)
t s = Delivery time package (ms)

2.4. Modelling General System

Initial step in designing device is modeling general system. This involves installation three-point sensor placement. First sensors connected direct to the battery output and parallelized with voltage sensor input for know is There is supply voltage. The second sensor, the LDR sensor, is mounted on the lamp for monitor condition. Finally, the current sensor installed at the output light for determine flowing current through system.

Mechanism operation tool this with send notification Telegram messages every day to officers at 07.00 and 19.00 for ensure voltage, current, and PJU lights inside normal conditions. Besides that, the user can also with easy send message to the Telegram Bot using the format that has been programmed in the PJU monitoring tool every time the user performs checking. After accept message, monitoring tool will verify format and send announcement message to the user / officer if valid, indicates the status of the PJU.

2.5. Design System

Monitoring system consists from a number of components, namely; ESP32, ACS712 current sensor, voltage sensor, LDR sensor, battery for ESP32, LCD I2C, and RTC. block diagrams system shared become two block diagrams ie slave node block diagram and master node block diagram can be seen in Figure 2 and Figure 3.

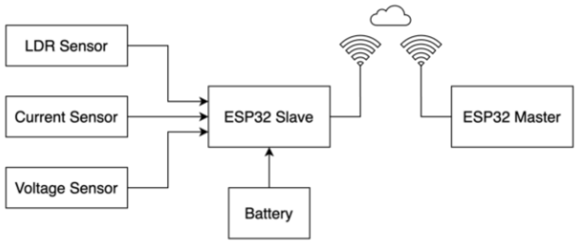


Figure 2. Slave block diagram.

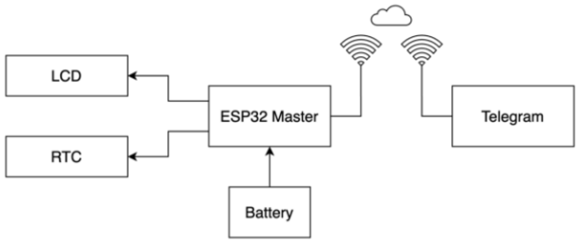


Figure 3. Master block diagram.

2.6. Flowchart System

Flowchart system or work processes tool can see in Figure 4.

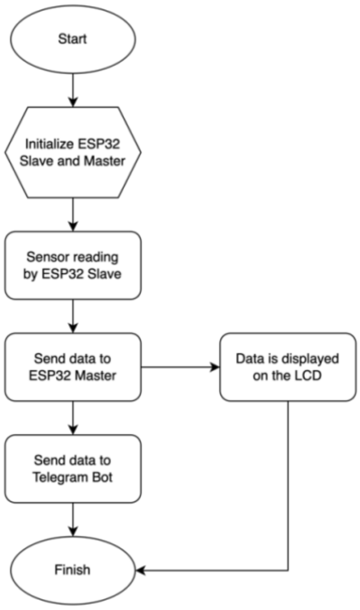


Figure 4. Tool work process flow chart.

The following is an explanation of the flow chart in Figure 4:

1) The tool starts
2) ESP32 Slave and ESP32 Master initialization process or ESP32 initialization process turned on.

3) Reading tool the value given and read by the ACS712 current sensor, voltage sensor, and LDR sensor for processed by ESP32 Slaves.
4) After the ESP32 Slave processes reading data, then will shipped to ESP32 Master.
5) When ESP32 Master receives data from ESP32 Slave1, ESP32 Slave2, and ESP32 Slave3, then stage furthermore divided into 2 namely:
    a. Data that has been accepted by ESP32 Master which has shipped previously of ESP32 Slave1, ESP32 Slave2, and ESP32 Slave3, will displayed on a 20x4 I2C LCD.
    b. Data that has been accepted by ESP32 Master which has shipped previously from ESP32 Slave will sent by ESP32 Master to Telegram Bot.

Flowchart at the moment do PJU check shown in Figure 5.

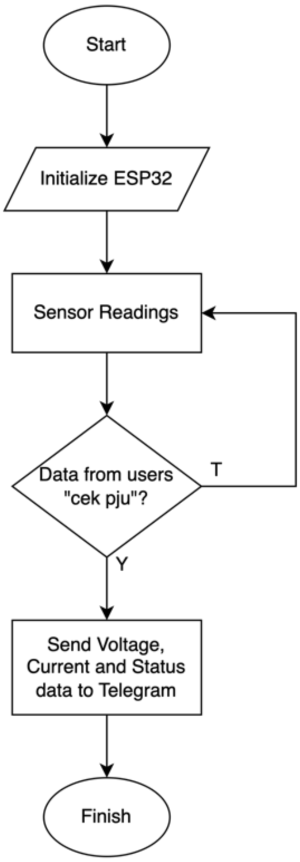


Figure 5. PJU checking flowchart.

From Figure 5 can seen PJU checking program flow, namely the user provides order Telegram Bot messages with code "cek pju" to ESP32 module. For ensure that ESP32 module can process the values read on each sensor, then message sent must in accordance with programmed code in module the. After it, ESP32 will send data to the user via Telegram Bot messages.

Flow chart from delivery notification telegram messages to officer as shown in Figure 6. The second program flow that is tool give notification in a manner automatic to users via telegram bot with provision as following:

1) The ESP32 module will send voltage sensor reading direct to Telegram, accompanied with notification showing value obtained from sensors.
2) The ESP32 module will send current sensor reading direct to Telegram, accompanied with notification showing value obtained from sensors.
3) The ESP32 module will send notification to Telegram with the message "Lampu PJU Normal" which means the PJU lights are normal if the voltage sensor read value > 5 V, LDR sensor < 500, and current sensor > 0.04 A.
4) The ESP32 module will send notification to Telegram with the message "Lampu PJU Redup" which means the PJU lights are dim if the voltage sensor read value > 5 V, LDR sensor 1000 <= LDR <= 3000, and current sensor > 0.04 A.
5) The ESP32 module will send notification to Telegram with the message "Lampu PJU Putus" which means the PJU lights are disconnected if the voltage sensor read value > 5 V, LDR sensor > 3000, and current sensor < 0.04 A.
6) The ESP32 module will send notification to Telegram with the message "*Supply* PJU Putus" which means the supply PJU are disconnected if the voltage sensor read value < 5 V.
7) On the ESP32 microcontroller, the RTC connected to the ESP32 will send notification to Telegram Bot every day at the hour that has been specified, ie every at 07.00 and 19.00.

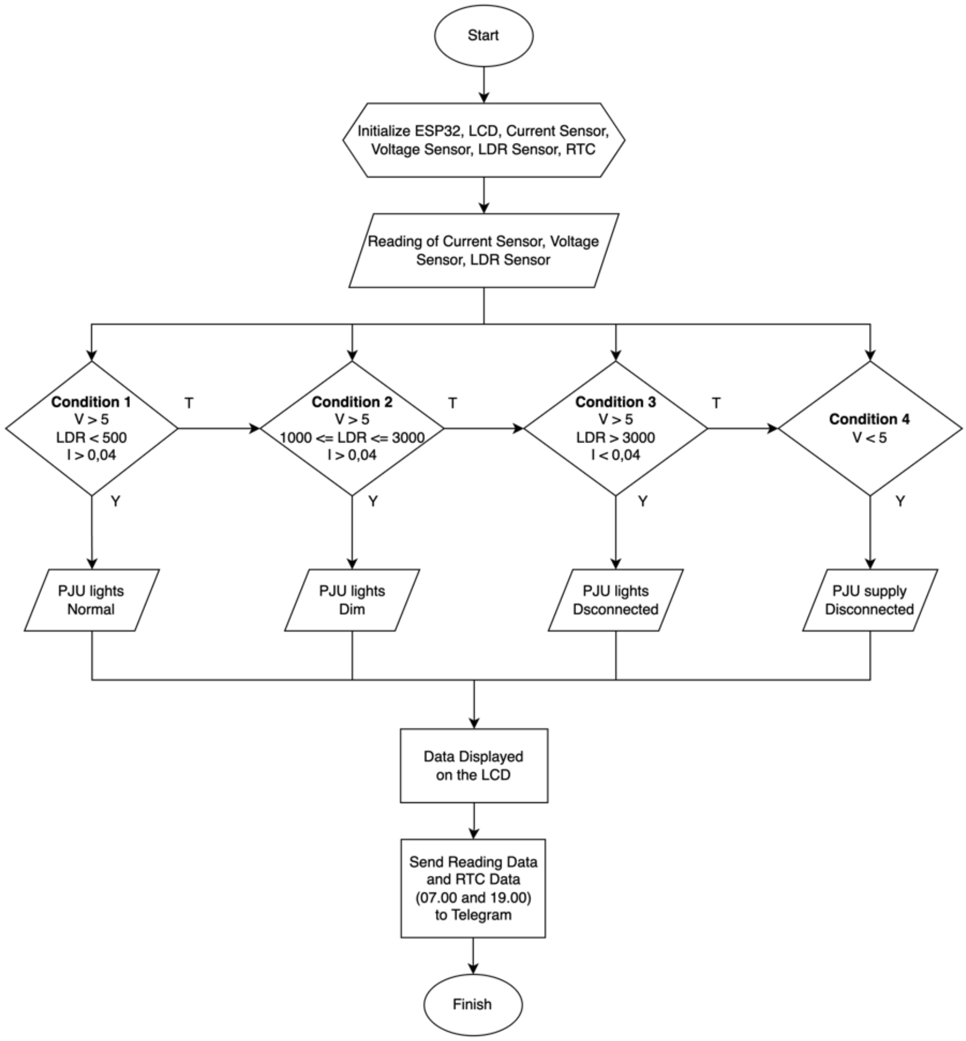


Figure 6. Flow diagram of sending telegram message notifications to users.

3. RESULTS AND DISCUSSION

3.1. Design Results System

PJU monitoring system is tool useful help you can help officer in operate duties, incl detect interrupt and judge PJU condition fast. Automated tool this scheduled for operating at the specified time determined, so more comfortable for user. Officer will get notification Telegram messages every day at 07.00 and 19.00 for ensure that voltage, current, as well indoor PJU lights normal state. The PJU model is shown in Figure 7.

This monitoring system possible inspection lighting road in accordance request with send code / message "cek pju" via Telegram Bot to device. After accept message such, tool will send order to the PJU master for get PJU slave reads and sends it return to monitoring tool. Received message will verify the format, and if valid, the message containing PJU conditions will ship to the user / officer through equipment installed at the PJU point in question. This tool designed and installed in each PJU point for make it easy monitoring.

3.2. ACS712 Current Sensor Testing

Objective current sensor test is for test performance. Test This compare the data obtained from sensor readings with ammeter reading. With do testing this can is known capacity indoor PJU lights produce current electricity. Testing This done using a 47 Ω/2 A rheostat as burden replacement lamp so that the load Can set. Suite ACS712 current sensor testing is shown in Figure 8.

Figure 7. PJU models.

Figure 8. Suite ACS712 current sensor testing.

For do current sensor testing, using the ACS712 sensor. Test done with connect current sensor ACS712 with load (rheostat) automatically series, and then connect it to the ammeter for get reading. Ammeter works as tool measuring second and used as comparison. Results data current sensor test can seen in Table 1.

The data presented in Table 1 is results testing performed to comparison measured current with ACS712 current sensor and ammeter. Percentage error measurement counted with share difference readings obtained from second device with mark ammeter reading, then multiply result with 100%.

$$Error = \frac{\text{difference in reading values}}{\text{ammeter value}} \text{ x } 100\% \qquad (4)$$

From the equation (4) can done calculation as following:

$$Error = \frac{0{,}040}{1{,}2} \text{ x } 100\% = 0.03\%$$

From the Table 1 results test, created chart comparison the current measured by the sensor with that measured on the ammeter. Figure 9 is chart from results comparison. Colored line blue shows reading data from the current sensor and the colored line orange shows the data from the ammeter. From the results testing concluded that the average error reading from the current sensor is 0.016%.

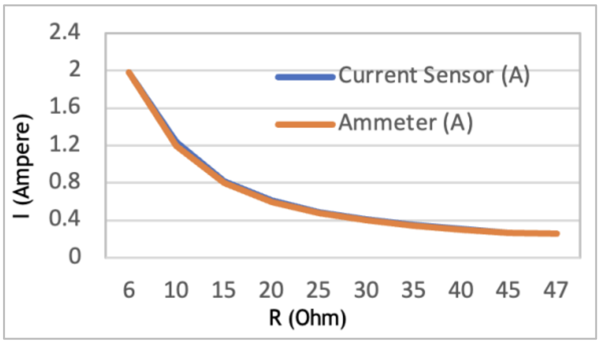


Figure 9. Chart current sensor comparison with an ammeter.

3.3. Voltage Sensor Testing

Voltage sensor testing aim for test sensor efficiency. This test done with compare the voltage generated by the supply on a multimeter with a voltage sensor. Suite voltage sensor test can seen in Figure 10.

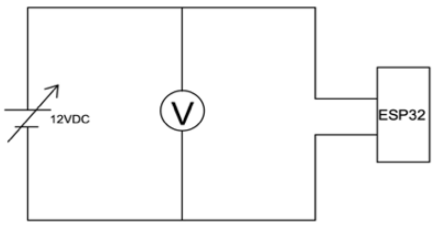


Figure 10. Suite voltage sensor test.

After do measurement with suite experiment in Figure 10, then taken voltage sensor measurement data. Results data voltage sensor test can seen in Table 2.

Figure 11 is chart from results comparison. Colored line blue shows reading data from the voltage sensor and the colored line orange shows data from multimeter. From Table 2 and Figure 11 can seen that voltage read by the voltage sensor and multimeter is linear ie mark voltage will increase when mark resistance increase with error a reading of 0.016%.

Table 1. Results data ACS712 current sensor testing.

No.	R=47Ω/2A (Ω)	Reading Current by Sensor (A)	Reading Current by Ammeter (A)	Difference	Errors (%)
1	6	1.98	1.98	0.000	0.000
2	10	1.24	1.2	0.040	0.033
3	15	0.82	0.8	0.020	0.025
4	20	0.61	0.6	0.010	0.017
5	25	0.484	0.48	0.004	0.008
6	30	0.408	0.4	0.008	0.020
7	35	0.35	0.34	0.007	0.021
8	40	0.307	0.3	0.007	0.023
9	45	0.268	0.27	0.001	0.005
10	47	0.257	0.26	0.002	0.008
Average error (%)					0.016

Table 2. Results data voltage sensor test.

No.	Vs (Volts)	Reading Voltage by Multimeter (Volts)	Reading Voltage by Sensor (Volts)	Difference	Errors (%)
1	1	1	0.89	0.110	0.124
2	2	2	1.98	0.020	0.010
3	3	3	2.99	0.010	0.003
4	4	4	3.99	0.010	0.003
5	5	5	4.97	0.030	0.006
6	6	6	5.88	0.120	0.020
7	7	7	6.97	0.030	0.004
8	8	8	7.98	0.020	0.003
9	9	9	8,92	0.080	0.009
10	10	10	9.99	0.010	0.001
11	11	11	10.96	0.04	0.004
12	12	12	11.88	0.12	0.010
Average error (%)					0.016

Table 3. Results data LDR sensor testing.

No.	Condition	Voltage (V)
1	Dark (LDR sensor closed whole)	3,8
2	Dim (LDR sensor covered by plastic black)	0.96
3	Bright (LDR sensor supplied light from light flashlight *cellphone*)	0.26

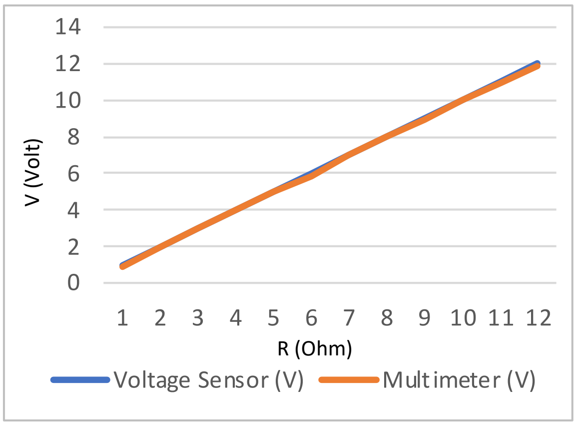


Figure 11. Chart voltage sensor comparison with multimeter.

3.4. LDR Sensor Testing

For test the LDR sensor, voltage the output be measured in condition different lighting, moment room truly dark, moment light dim, and moment bright. Test results the output voltage of the LDR sensor can be seen in Table 3.

From the Table 3 results test, created chart results LDR sensor testing in Figure 12. After analyzing the data from the LDR sensor test results in Table 3 and Figure 12, it can be concluded that the sensor is working well. ESP32 operates at the TTL level, with range voltage 0 to 1 volt for logic 0 (low) and 2 to 5 volts for logic 1 (high). LDR sensors are used in this monitoring application for detect condition dark and light, gives description of the status of PJU lights used during the day and night day.

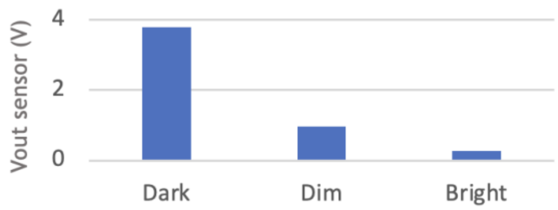


Figure 12. Chart results LDR sensor testing.

3.5. Testing Wireless Sensor Network

Wireless sensor network testing is carried out to ensure the wireless sensor network is functioning properly. In task end this, is used topology mesh as topology wireless sensor network. Following This is results calculation of performance parameters topology mesh contained in Table 4.

Based on results testing in Table 4, shown in the simulation try 1 i.e. slave1 to master, many packets sent by slave1 as many as 85 packets. Meanwhile, a lot of packets received by the master as many as 82 packets. So, from that, there is lost / no packets up to (packet loss) as many as 3 packets. The resulting throughput is 0.82 kbps with mark delay 4.69 ms.

On simulation experiment 2 looks that many packets sent by slave2 as many as 85 packets, meanwhile many the packet received by the master is 83 packets. because that 's big lost / no packets until (packet loss) is 2 packets. The resulting throughput is 0.83 kbps with mark 4.46 ms delay.

On simulation experiment 3 looks that many packets sent by slave3 as many as 85 packets, meanwhile many packets received by the master is 84 packets. because that's big lost / no packets until (packet loss) is 1 packet. The resulting throughput is 0.84 kbps with mark 4.34 ms delay. Compared to with trials 1 and 2, trials 3 more Good although only there is 1 pack difference. this is because distance slave3 with master more near compared to distance between slave1 and slave2 with master.

Then, in experiments 4, 5, and 6, it appears that mark packet loss Far more Lots compared to experiments 1, 2, and 3. The resulting throughput is 0.51 kbps with delay value of 0.16 ms in experiment 4, great throughput with 0.5 kbps mark delay 0.16 ms on trial 5, and large throughput with 0.49 kbps mark delay 0.12 ms in experiment 6. The large sign of packet loss caused in experiment 4, experiment 5, and experiment 6 was caused by sending data / packets on only one network / communication route. So, a lot lost and crashed packets.

3.6. Show Working Tool Monitoring to the LCD

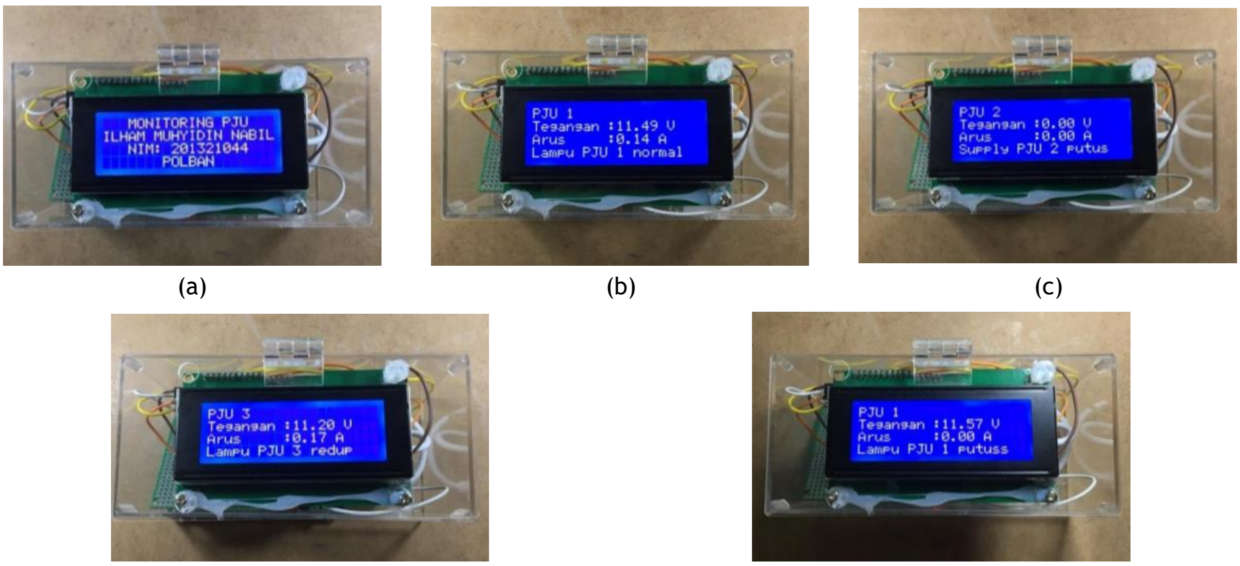
Testing monitoring system is carried out for know performance monitoring tool on implementation PJU system whole. In this case, the monitoring results from PJU slave 1, PJU slave 2, and PJU slave 3, will be sent to the master and will be displayed on the LCD. Appearance results testing shown Figure 13.

3.7. Telegram Testing

Telegram testing was carried out to determine the performance of sending data from ESP32 (master) to Telegram. In this case the Telegram message delivery notification to users / officers in accordance schedule that has regulated and / or accept order from the user / officer with send message "cek pju" to Telegram for accept outside notification timetable delivery notification. Test results shown in Figure 14 and Figure 15.

Table 4. Results data testing wireless sensor network.

No.	Simulation	Many Packages Sent (Packages)	Many Packages Received (Packages)	Sampling Time (ms)	Package Receiving Time (ms)	Package Delivery Time (ms)	Parameter	Mark
1	slave1 - master	85	82	100	215060.86	215056,17	Packet loss	3 (3.52%)
							Throughput	0.82 kbps
							delays	4.69 ms
2	slave2 - master	85	83	100	215535.76	215531.29	Packet loss	2 (2.35%)
							Throughput	0.83 kbps
							delays	4.46 ms
3	slave3 - master	85	84	100	215935,46	215931,11	Packet loss	1 (1.17%)
							Throughput	0.84 kbps
							delays	4.34 ms
4	slave1 - slave2 - master,slave3 - master	85	51	100	220449.54	220449,38	Packet loss	34 (40%)
							Throughput	0.51 kbps
							delays	0.16ms
5	slave1 - slave3, slave2 - slave3,slave 3 - master	85	50	100	220447,34	220447,18	Packet loss	35 (41.17%)
							Throughput	0.5 kbps
							delays	0.16 ms
6	slave1 - slave2 - slave3 - master	85	49	100	220449,34	220449,22	Packet loss	36 (42.35%)
							Throughput	0.49 kbps
							delays	0.12 ms



(a) (b) (c)

(d) (e)

Figure 13. Appearance results testing, (a) Initial LCD; (b) Condition normal PJU light; (c) PJU supply cut off; (d) Condition dim PJU lights; (e) Condition PJU lights are broken.

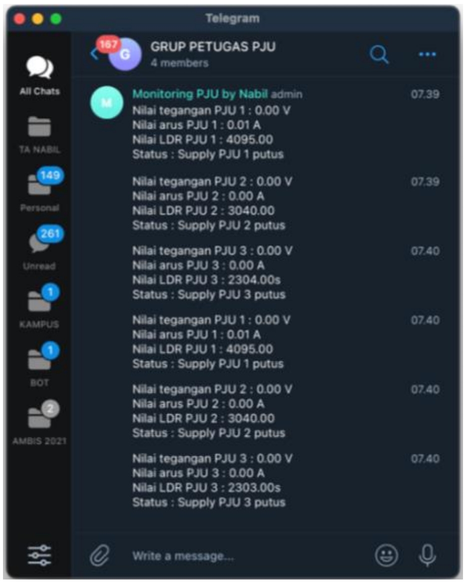


Figure 14. Appearance notification Telegram messages to users.

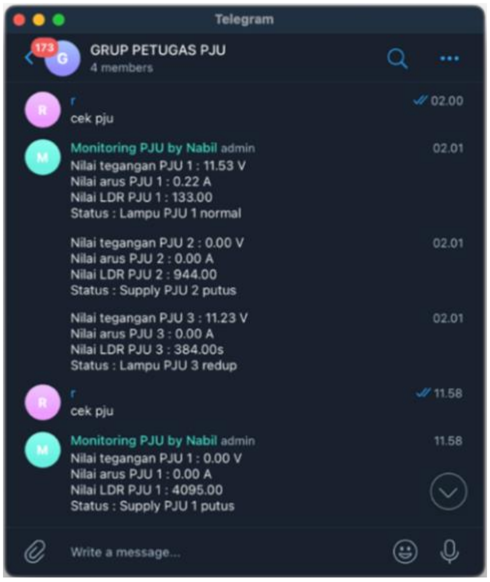


Figure 15. Appearance checking PJU on Telegram.

4. CONCLUSION

PJU monitoring system designed has can operate in accordance function. However, still there is error on the current sensor measurement and on the voltage sensor. Average error on both current sensor and voltage sensor measurements is 0.016 %. This error is due to instability of the internal sensor during the measurement process, as well as poor cable or jumper connectivity.

Mesh topology used can increase reliability communication. With exists route communication alternative through neighboring nodes, The network can still function if one or more nodes experience failure or disruption. From the results testing seen that test simulations 1, 2, and 3 with the process of sending data from the slave directly to the masters, only there are 1 to 3 missing packets in trip.

With the program that has made, the PJU monitoring system uses Telegram based application wireless sensor network Already can operate in accordance function. Although in data transmission exists data packets are lost and there is also some delay milliseconds in the delivery process. The PJU monitoring tool has can display result data readings on LCD and Telegram ie voltage, current, and status of PJU lights such as the PJU lights are normal, the PJU lights are dim, the PJU lights are disconnected, and the PJU supply is broken or disconnected.

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