Comparison of three LoRa devices and its application on street light monitoring system

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Abstract. This paper discusses implementation of Long Range (LoRa) networks as an Internet of Things (IoT) objects especially on street light monitoring. Low Powered Wide Area Network (LPWAN) is used as a communication network. LoRa devices are configured with a frequency of 470 MHz, spread factor 9, bandwidth of 31.25 KHz, and code rate of 4/5. The study found that the UM402 LoRa module has the farthest network range, up to 1 Km. By focusing on a range of up to 250 m, the LoRa Dragino shield has the fastest data packet delivery time at 0.77 s. UM402 LoRa module has the largest Received Signal Strength Indication (RSSI) value at 50m, it is -34. All LoRa devices used in this research can operate well at the ideal distance of street lights (35 m).

Keywords: Long Range, Internet of Things, dan Low Powered Wide Area Network.

1. Introduction

Internet of Things (IoT) is present and it is a trending topic, almost all objects can be connected and controlled via the internet [1][8]. There are many ways to allow an object communicates with each other, one is by using wireless communication technology. Low-power wide-area network (LPWAN) is a new wireless communication technology. LPWAN uses low-rate long-range transmission technology and works on a rarely used frequency spectrum in general [2][6].

LPWAN is a new representation of the evolution of telecommunication technology that can be applied to IoT based projects, especially on outdoor projects [3][7]. By using this method the overall cost of communication between IoT devices can be reduced.

The main objective in this study is to solve the implementation of LoRa network to street light system to allow each light to communicate with each other. The ability of Lamp nodes to communicate with each other at an ideal distance of street lights. LoRa network can be used in densely populated city such as DKI Jakarta, and LoRa gateway can be used to receive data from LoRa nodes and then upload the data to ThingSpeak cloud. The expected benefit is a system which capable to monitor lights condition and able to upload data to cloud so that can be monitored online and can be used to provide information about the temperature and humidity of the surroundings.

Scope of this study includes: 2 LoRa devices used as LoRa nodes; Dragino LoRa shield as the chosen LoRa device; The Dragino LoRa shield configuration is spread factor 9, bandwidth 31.25 KHz, code rate 4/5; Arduino as the chosen microcontroller; Sensors used in the system are LDR, PIR, IR/photodiodes, and DHT11; Gateway uploads data to ThingSpeak cloud one at a time with 20 seconds interval; The data transaction between LoRa devices is done interchangeably. The coverage of

the LoRa network is determined by the LoRa configuration and the number of physical objects that lie between LoRa nodes; Using PVC board to build a miniature for the sake of street lights simulation.

2. LoRa

LoRa network topology is generally a star-of-stars where the gateway acts as a bridge to connect LoRa nodes to the central network. Gateway connects to the internet by using IP connections, while LoRa nodes communicate with each other by using single-hop wireless communication method. Generally, LoRa nodes communicate in two directions, but if necessary, LoRa node can also broadcast to all nodes around. Communication between LoRa nodes and the gateway can be configured according to the used frequency and used data rate. The value of the data rate determines the distance and the length of time of a packet data transaction. Communication using different data rates will not interfere with each other, so the gateway can receive packets of data from multiple LoRa nodes simultaneously [4].

The quality of a wireless communication technology is determined by 3 things, distance, speed and power consumption. Only 2 of the 3 spesifications can applied at a same time. The comparison of some wireless communication technology is shown in **Figure 1**.
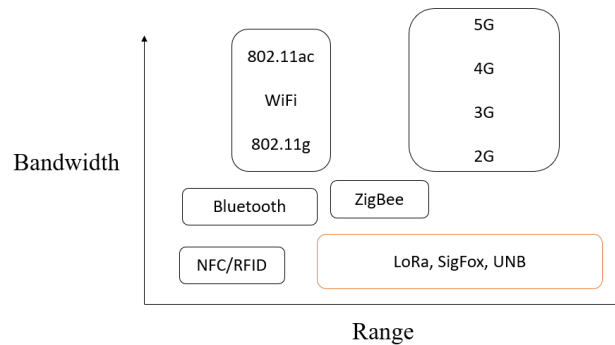

Fig 1. Bandwidth vs Range of wireless technology [4].

2.1 LoRa Link Budget

Link budget is the result of calculating all the gains and losses that occur when a data packet is sent by the transmitter, via a medium consisting of various physical objects, to the receiver. Gains and losses are caused by several factors, such as antenna gain, transmission power, connector loss, and physical objects that are between transmitter and receiver. **Figure 2** depicted graph of change of link budget value.
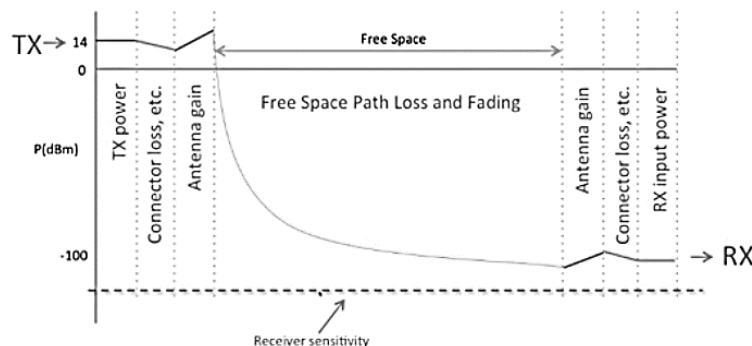

Fig. 2 Graph of link budget value [5]

The sensitivity value of the LoRa can be calculated using expression (1). The value of the LoRa sensitivity depends on the bandwidth (BW) and signal to noise ratio (SNR) used in the LoRa configuration. In addition, the noise figure (NF) also has a value based on the spreading factor that is

also used in the LoRa configuration. Both of these configurations affect the value of the LoRa receiver sensitivity.

$$Sensitivity(dBm) = -174 + 10\log_{10}(BW) + NF + SNR \tag{1}$$

The value of link budget can be calculated by using expression (2). In the equation, the sensitivity value is only taken as its absolute value and added with TX power value which is used when data packet is transmitted by transceiver.

$$Link\ Budget(dB) = TXPower + |Sensitivity| \tag{2}$$

The value of the Link Budget can be used to calculate the ideal distance of packet data transmission or so-called free-space path loss (FSPL) in expression 3.

$$FSPL(dB) = 20 \times \log(d) + 20 \times \log(f) - 147.55 \tag{3}$$

2.2 LoRa modulation and demodulation

Figure 3 below illustrates the difference between on-off keying (OOK) modulation, frequency-shift keying (FSK), and LoRa modulation. LoRa modulation consists of chirp data that changes from low frequency (left) to high (right) with constant velocity.
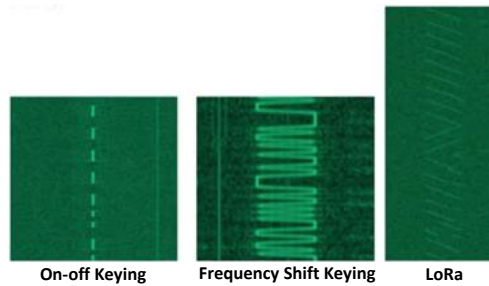

On-off Keying   Frequency Shift Keying   LoRa

Fig. 3 OOK, FSK, dan LoRa modulations [5]

LoRa demodulation process itself, done by multiplying modulated data packets with inverse chirps on the receiver. LoRa demodulation process is depicted by **Figure 4**. At the end of the process, horizontal lines are formed which are the real data packets.
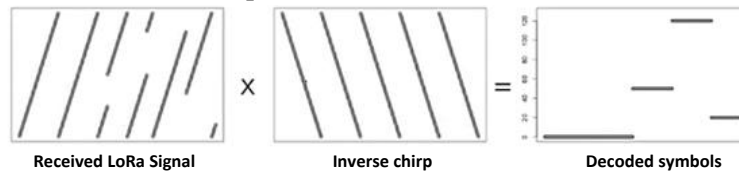

Received LoRa Signal   Inverse chirp   Decoded symbols

Fig.4 LoRa demodulation [5]

LoRa demodulation is resistant to noise in the data packets received by the receiver. If there is noise in the data packet, then the real data packet from LoRa demodulation process is not too damaged by noise in the package. The slope of the LoRa modulation depends on the spread factor used in the LoRa configuration. The higher the spread factor used in the LoRa configuration, the more oblique the LoRa modulation occurs. This slope will determine the speed of sending a data packet, the more oblique the modulation then it means the longer it takes to send the data packet.
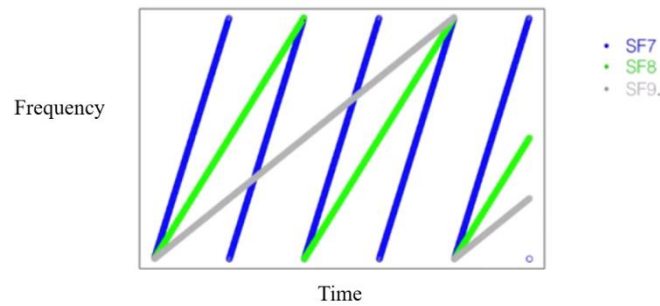
Fig.5 Relation between spreading factor value and the slope of LoRa modulation [5]

Figure 5 shows the different modes of LoRa modulation based on the used speading factor. SF8 takes 2 times longer to deliver a data packet than the time needed by SF7, as well as SF9 than SF8 and so on [4].

2.3LoRa Configuration

Some LoRa configurations that should generally be set for the LoRa device to work properly are frequency, badwidth, spreading factor, TX power and code rate. Frequencies range used by LoRa devices are by the manufacturer. LoRa devices based on their frequency are divided into 3 types, 915MHz, 868MHz and 433MHz. LoRa devices with 915MHz frequency will never operate at 433MHz frequency, thus the user must ensure the range of frequencies that will used when using LoRa devices. For a 433MHz LoRa device, the usable frequency range is 410MHz - 525MHz.

The combination of bandwidth, spreading factor, and TX power affect the performance of the LoRa device. Both bandwidth and spreading factor values affect the sensitivity value of the LoRa device, which is described by equation 1. While the TX power and sensitivity values affect the link budget value described by equation 2. The higher the value of the link budget, the greater the coverage of the LoRa network obtained and the resistance of data packets to the hindrances, diffraction and reflection will be better. Code Rate has a value of $4 / (4 + n)$, with $n \in \{1,2,3,4\}$. This value affects the packet data tolerance of interference when transmitted by the transceiver. The smaller the value of the code rate then Packet Error Rate (PER) will be smaller [5].
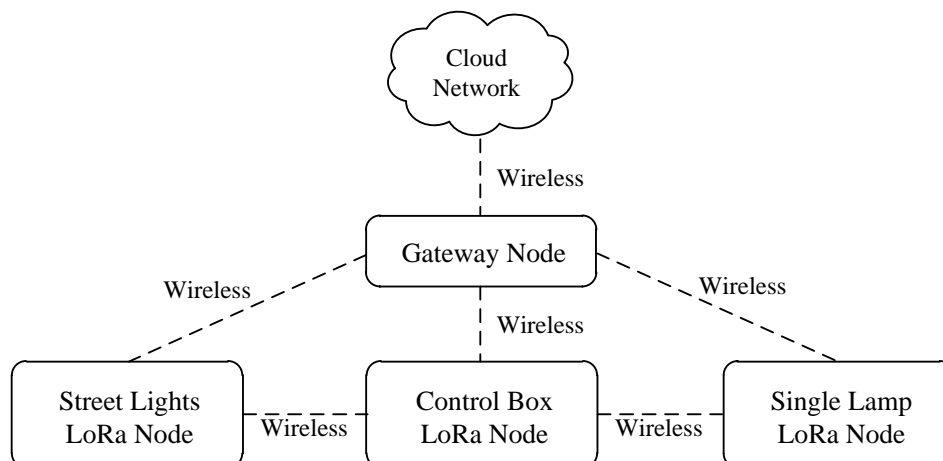
3. Methodology
3.1 Hardware

Fig.6 System Block diagram

The system will upload all data received from all LoRa nodes to the cloud. Communication with each LoRa node is done wirelessly using LoRa Dragino Module and the gateway node will upload the received data to ThingSpeak cloud.

Figure 6 shows block diagram in this study, where all nodes will be able to communicate with gateway node and Control node LoRa node can also communicate with street lights LoRa node and single lamp LoRa node. Single lamp LoRa node represents one lamp node that has 3 pieces of sensor and 2 pieces of actuator. Street lights LoRa node is a miniature of street lights in a real district and comes with 7 LEDs, 7 switches, 7 light sensors and 5 infrared photodiode sensor pairs. Control Box LoRa node has two buttons, 3 indicator LEDs and also has a 16x2 LCD that will display the state of another node when comman has been given or an error occurs on other node. Each of the hardware configuration is shown in **Figure 7 (a), (b), and (c).**
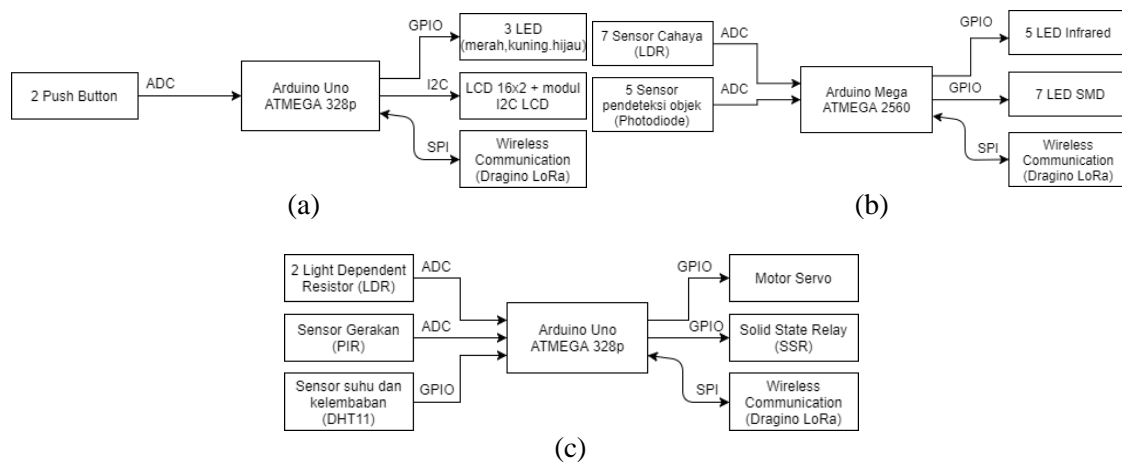

(a)

(b)

(c)

Fig.7. (a) Control Box of LoRa Node; (b) Street Lights LoRa Node; (c) Single Lamp LoRa Node
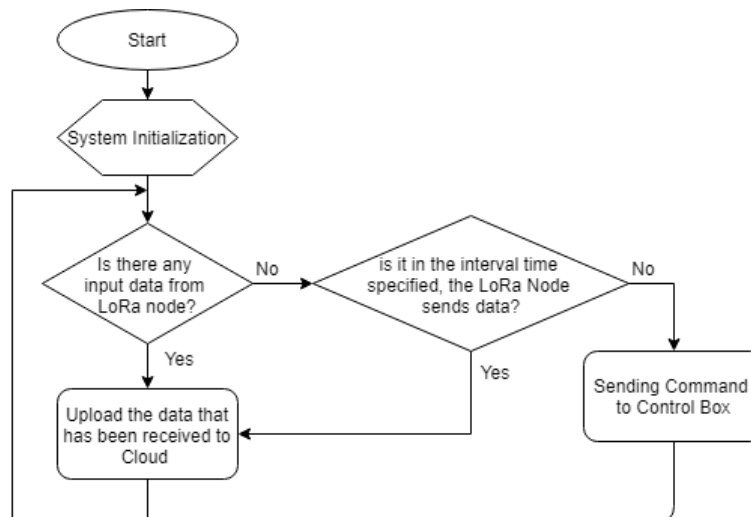
3.2 Software

Fig.8 Main flow diagram of software

Figure 8 shows these following steps, system will initialize the configuration of LoRa and connect to the internet through a configured SSID. The system will wait for an input from other nodes. After checking the address of the incoming input the input will be translated and will be uploaded to the cloud. If there is no data the system will check whether it is time for other nodes to transmit data (single lamp LoRa node has 3 minute time interval and for street lights LoRa node has interval of 5 minutes).If data is not sent by the LoRa node, then the control box will display "*Time Out*"on the LCD and will turn on the red LED.

3.3 LoRa UM402 Configuration
UM402 default configuration:
- Air baud rate 2604,17 bps
- TX power 20 dBm
- Frequency 470 MHz

The UM402 custom configuration, set by using RF Module Manager used in this study, is as follows:
- Air baud rate 244,14 bps
- TX power 20 dBm
- Frequency 470 MHz

3.4 LoRa Configuration for Dragino, RA-02 and LG01-P LoRa Gateway
This study uses RadioHead library. The default LoRa configuration used in this study is as follows:
Spreading factor 7 or 128 chips/symbol
- Bandwidth 125 KHz
- Code rate 4/5
- TX power 20dBm
- Frequency 470 MHz

Custom LoRa configuration used in this study is written as follows :
- Spreading factor 9 or 512 chips/symbol
- Bandwidth 31,25 KHz
- Code rate 4/5
- TX power 20 dBm
- Frequency 470 MHz

3.5 Measured Parameter
    There are several parameters that will be measured by using different modules. Modules used are LoRa UM402, LoRa Sheild Dragino, and AI-Thinker RA-02. The measured parameters are:
- Distance
- Time needed to transmit data packet
- RSSI

4. Results
4.1 System Spesification
LoRa network spesification:
- Consists of 3 LoRa nodes and 1 LoRa gateway, more LoRa node can be added if necessary.
- Maximum range between LoRa nodes is 250 m (line of sight)
- Time needed to send a data packet is 0,77 s @ 250 m (line of sight)
- The least RSSI is -110 @ 250 m (line of sight)
- Single Lamp LoRa node spesification:
  - Operating voltage 9 V for mikrokontroler and 220 V for light bulb
  - Operating current ≤ 606,60 mA
  - Equipped with PIR sensor, temperature & humidity sensor and light dependent resistor
  - Has a mechanism to automatically turn on the MCB after the MCB break the circuit
- Street Lights LoRa node spesification:
  - *Operating voltage* 9 V
  - *Operating current* ≤ 181,8 mA
  - Equipped with IR/*photodiode* and *light dependent resistor*
  - Has an ability to dim the lights of the LEDs when there is no object detected.
- Control Box LoRa node spesification:
  - *Operating voltage* 9 V

- *Operating current* $\leq$ 86 mA
- Equipped with *LCD* 16x2 and *indicator lights*
- Has an ability to give a command to other LoRa nodes and give a notification using indicator lights and LCD display to the user.
- LoRa gateway spesification:
  - *Operating voltage* 9-24 V
  - *Operating current* $\leq$ 10,3 mA
  - Connected to ThingSpeak *cloud*
  - Has an ability to recall when the last time LoRa nodes sent their data to gateway in a specified time.

4.2 Comparison between UM402, Dragino shield and RA-02

In this section, UM402 LoRa device, Dragino shield and RA-02 will be compared based on the range, delivery time of data packets, and RSSI. All tests are done by using the Arduino UNO board. In addition, the comparison of range, data packet delivery time and RSSI are done with 2 different configurations. Both default LoRa configuration and custom configuration are used in all tests. These configurations are already described previous section. The amount of data packets sent during the test is always the same, it is 10 bytes.

4.2.1 Range Comparison Between LoRa Module UM402, Shield Dragino and AI-Thinker RA-02

Figure 9 shows that the UM402 module has the furthest LoRa range compared to the Dragino shield and RA-02 module, which is up to 1 km. The radius of this range can be achieved by UM402 module either by default configuration or by custom configuration.
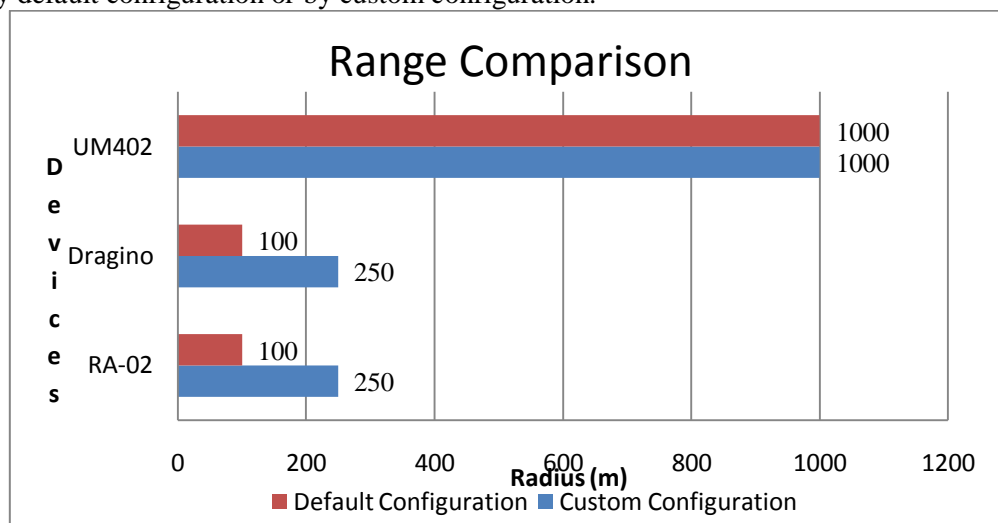

Fig.9 Range comparison graph between LoRa devices

4.2.2 Data Packet Delivery Time Comparison Between LoRa Module UM402, Shield Dragino and AI-Thinker RA-02
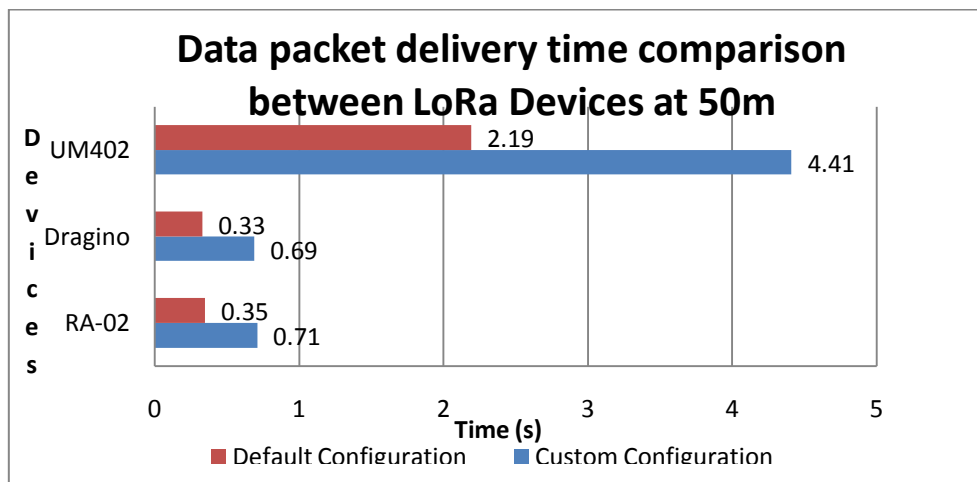
Fig.10 Data packet delivery time comparison between LoRa devices at 50 m

Based on **Figure 10**, the Dragino shield needs the shortest transmission time compared to the UM402 and RA-02 modules, it is up to 0.33 s. This value is obtained by using the default Dragino shield configuration.

4.2.3 RSSI Value Comparison Between LoRa UM402, Shield Dragino, dan AI-Thinker RA-02
Figure 11 shows that RA-02 has the greatest average RSSI value, which is up to -60.4 at 50 m. This value is obtained by using a custom RA-02 configuration.
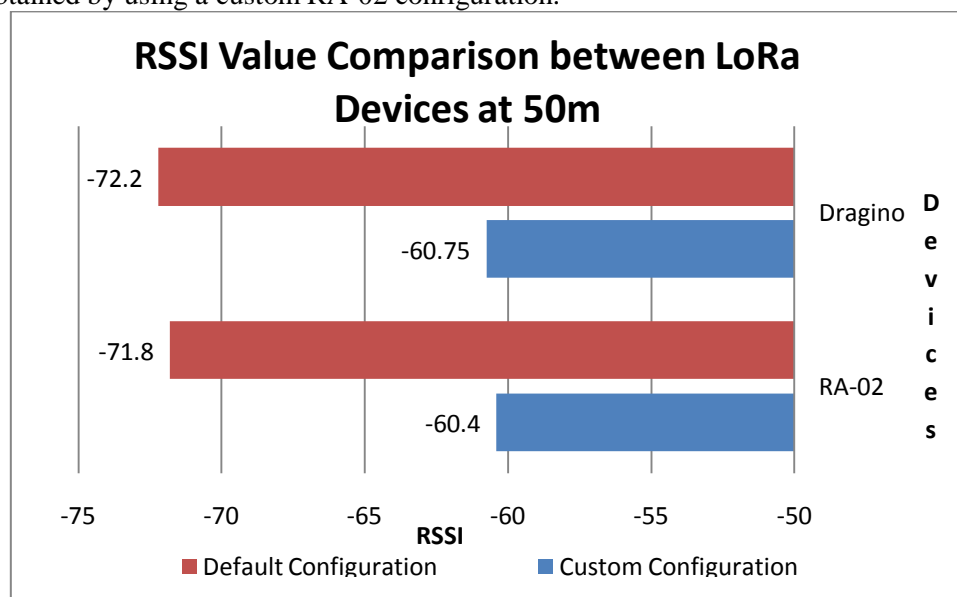

Fig.11 RSSI value comparison between LoRa devices at 50 m

The changes of average RSSI value caused by the changes of distance between LoRa nodes is shown in **Figure 12,** the changes of the RSSI value of the LoRa network affected by the distance between the LoRa nodes. The farther the distance between the LoRa nodes, the smaller the RSSI value.
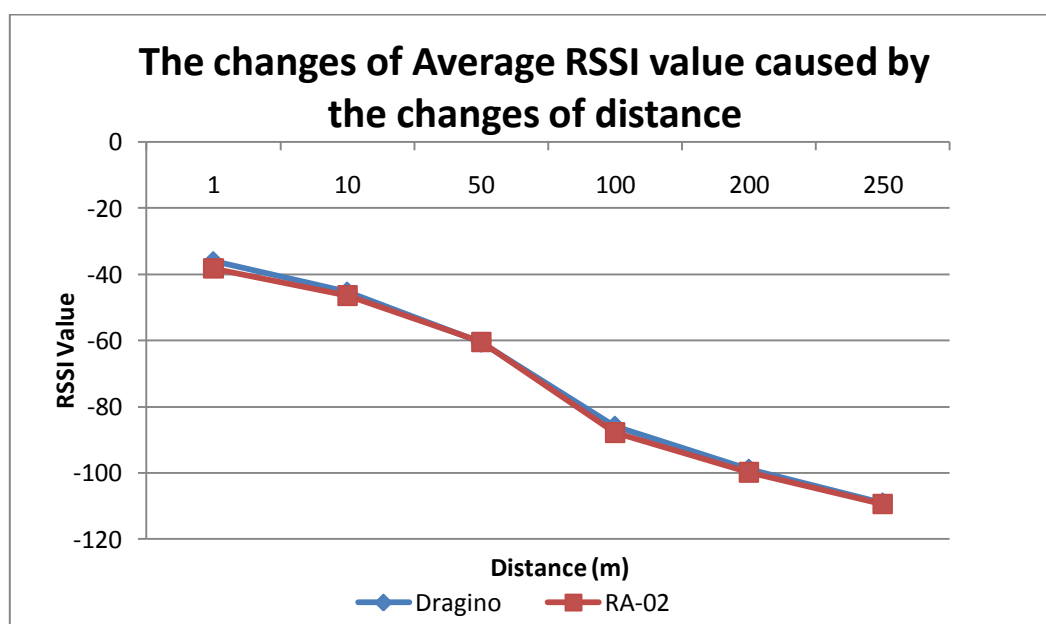
Fig.12 The changes of average RSSI value caused by the changes of distance between LoRa nodes

4.3 Testing the Dragino Shield as a Chosen LoRa Device
Based on the comparison result of the three different LoRa devices described in the previous section, LoRa shield Dragino is selected as the preferred LoRa device. The speed of packet data delivery and the flexibility of the LoRa configuration became the consideration of choosing a Dragino shield. The dragino shield test in this section is done by connecting the shield to the Arduino board powered on a 9 V battery. All tests are performed by using the custom configurations. The amount of data packets transmitted during this test remains the same, it is 10 bytes.

4.4 Testing LoRa Node with Ideal Distance of Street Lights
The LoRa node consists of a Dragino shield complete with its antenna and it is connected to the Arduino UNO via the SPI protocol. Both LoRa nodes are powered on 9V batteries. The configuration used for the Dragino shield is spread factor 9, bandwidth 31.25 KHz, code rate 4/5, 470 MHz frequency and TX Power 20 dBm. The test is performed on a 5 m wide road and the distance between the sender LoRa node and the recipient LoRa node is 35 m, the distance between the LoRa nodes corresponds to the distance between the street lights aranged by the Indonesia Badan Standarisasi Nasional.

Table 1. LoRa success test in sending and receiving data packet at the ideal distance of street lights

Number of data	Distance	Test									
		1	2	3	4	5	6	7	8	9	10
10 byte	35 m	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 2. Time needed by LoRa to send a data packet at the ideal distance of street lights

Number of data	Distance	Test (in seconds)									
		1	2	3	4	5	6	7	8	8	10
10 byte	35 m	0,67	0,67	0,67	0,67	0,67	0,67	0,67	0,67	0,67	0,67

Table 3. RSSI value at the ideal distance of street lights

Number of data	Distance	Test (in seconds)									
		1	2	3	4	5	6	7	8	9	10
10 byte	**35 m**	-45	-45	-45	-45	-45	-46	-45	-45	-45	-45

Based on the data, Dragino LoRa shield can send and receive data with a success rate of up to 100%, packet data transmission speeds up to 0.67 s, and has the greatest RSSI value of -45. The results of this test, indicate that the LoRa shield Dragino device can work with the ideal lamp distance.

5. Conclusion

This study addressed the capabilities of LoRa module in street light applications, the study revealed that UM402 has the farthest reach if the LoRa network range, up to 1 km. By focusing on a range of 250 m, the LoRa Dragino shield is the fastest with data packet delivery time at 0.77 s. UM402 LoRa module has the largest RSSI value at 50 m, it is -34. All LoRa devices used in this research can operate well at the ideal distance of street lights (35 m). Dragino is more flexible to be configured for specific purposes. This study of LoRa indeed may not represent the whole aspect of LoRa implementation in IoT Industry, further study could include using LoRa gateway that has 8 channels to allow LoRa gateway to receive data from multiple LoRa nodes at a same time and add an algorithm to solve the LoRa data packet collision.

6. References

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