LoRa Gateway as Internet of Things (IoT) Infrastructure Components on Undip Vocational School

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Abstract. Internet of Things (IoT) is a concept that aims to broaden the benefits of continuously connected internet connectivity. The IoT concept infrastructure can be built using existing digital communication standard protocols such as Wifi, Zigbee, Bluetooth, but these three standards have limitations in terms of distance and power consumption. The LoRa communication protocol is a special communication standard that emphasises the aspects of long-distance, low power, low data transfer at relatively low prices. It utilises a gateway to forward messages from nodes. This research focuses on the implementation of open and low-cost LoRa gateway, which will be installed in the area of the Diponegoro University Vocational School Semarang. Communication functionality is tested using The Things Network server. The coverage range of gateway was tested by recording RSSI and SNR values received by the gateway. Test results show RSSI readings above -100 dBm at a radius below 100 m from the gateway. RSSI and SNR values appear to drop dramatically in low elevation conditions, especially if the position of the node-gateway is almost obstructed by the ground surface. The surface obstacle in the form of dense trees and thick buildings also contribute to reducing the quality of signal reception.

1. Introduction

Indonesia government has launched Roadmap Making Indonesia 4.0 for readiness to enter the 4th industrial revolution era. Internet of Things (IoT) is one of the mainstays of the road map that was initiated by the Ministry of Industry. The big aspiration in Making Indonesia 4.0 is to promise Indonesia to be among the ten countries that have the strongest economy in the world by 2030. IoT refers to a network of physical devices, vehicles, household appliances, and other items planted with electronic devices, software, sensors, actuators, and connectivity that make it possible to connect to the internet and collect and exchange data.

There are standard wireless network-based protocols such as Wifi, Bluetooth, Zigbee can be utilised as IoT infrastructure, but all of them have limitations in terms of low range coverage and relatively high power consumption and are not suitable when applied to distributed applications with limited resources. LoRa can be the main solution for this problem because it provides long-distance wireless connectivity capability, low power consumption, relatively low price, the limitation is the low data transfer capacity [1]. Technically, it’s modulation performance has been evaluated, discussed and considered to be a good candidate in addressing the IoT challenges and low-cost remote sensing applications [2]–[4]. Figure 1 shows typical LoRa network. It is designed to allow low-powered devices to communicate with Internet-connected wide area networks applications over long-range wireless connections [4]. The LoRa hardware component consists of nodes and gateway, both a type of radio wave transceiver with the ability to communicate over long distances with low energy.
Performance and capability analysis of a currently available LoRa transceiver has been conducted, achieving reliability of 80%, through experimental demonstration covering 1.5 ha in a built-up environment [5]. The LoRa application for IoT based tactical troop tracking system in Thailand uses a Raspberry Pi-based gateway and a node containing Global Positioning Position (GPS), temperature, humidity and water sensors for tracking geological and physical conditions of troops in areas with a radius of 0.5 km [6]. LoRa is also used in the implementation of the concept of precision agriculture as a wireless and integrated data collector utilising node and gateway on farmland and tested on small scale melon farming [7]. Technical experiments have been carried out on LoRa's transceiver capability in scheduling transmission frames with less than 3 microseconds for smart metering, smart building, and process industry applications [8]. Furthermore, LoRa was also applied to a water level monitoring system where the LoRa node was placed as a medium between the sensor hub and the gateway and successfully tested its functionality using 50 node simulations [9].

Those examples describe LoRa with its gateway and nodes has been widely applied in various fields and applications, making it very potential to support the development of IoT. The existence of LoRa gateway is mandatory, so this research focuses on building open and low-cost LoRa gateway to emphasise its “low price” feature as the initiation of IoT infrastructure components in the area of Diponegoro University Vocational School, which in its current condition does not available. The gateway hardware is built using ESP8266 microcontroller and HopeRF RFM96 LoRa transceiver module. It has a task to forward messages or data payload from nodes to LoRa network server, The Things Network (TTN) via internet access. The availability of the proposed gateway will open the continues development of LoRa-based IoT applications on campus, specifically on Undip Vocational School.

2. Research Method
LoRa uses license-free sub-gigahertz radio frequency bands like 433 MHz, 868 MHz (Europe) and 915 MHz (North America). Indonesia adopts the US902-928MHz ISM Band as specified on LoRaWAN 1.1 Regional Parameters Document [10]. The Lora gateway hardware section consists of the NodeMCU ESP8266 controller module, HopeRF RFM96 915 MHz Lora transceiver module with a spiral antenna, and the power supply module. The HopeRF RFM9x families are LoRa long range modem that provides ultra-long range spread spectrum communication and high interference immunity while minimising current consumption. It has several key features [11] such as:

- 100 mW constant RF output
- +14 dBm high-efficiency PA
- High sensitivity: down to -148 dBm
- FSK, GFSK, MSK, GMSK, LoRa and OOK modulation
- 127 dB Dynamic Range RSSI
- Small form factor, 16*16mm

The controller is connected to the transceiver via the Serial Peripheral Interface (SPI) communication protocol. Figure 2 shows the Lora gateway block diagram.
The Lora gateway software section is built using an open-source library Arduino-lmic by Matthijs Kooijman [12] that is ported to the Lua programming environment by Jaap Braam [13]. This library is intended for constructing single-channel Lora gateway listening to all spreading factors on one specific channel. It has features that allow online setting for gateway parameter configurations via the preset command list as shown by Table 1.

With the help of Java-based software, ESPplorer, source code from the library can be opened, edited, compiled and downloaded to the controller. It is needed to set SSID and password of the internet-connected Wifi access point to the library source code so the connection between gateway and Lora network server can be established. This process is done by sending the following sequence command [9] in the ESPplorer command input terminal.

```plaintext
wifi.setmode(wifi.STATION)
station_cfg={}
station_cfg.ssid="SSID name"
station_cfg.pwd="password"
station_cfg.save=true
wifi.sta.config(station_cfg)
wifi.sta.autoconnect(1)
```

Gateway will remember it and automatically attempt to connect to Wifi access point. If it fail on the first attempt, the gateway will try again until it is successfully connected to the network marked by the appearance of a notification in the shell window of ESPplorer.

The frequency parameter configuration of the gateway needs to be matched with the frequency of LoRa transceiver module. So, GW_FREQ parameter is set to 902300000. This is the first channel of the US902-928MHz ISM Band specified by LoRa Alliance.

After the gateway is up and running, parameter configurations can be changed online (no need redownloading) by sending the preset command from Table. in the ESPplorer command input terminal with this format: CONFIG.PARAMETER=VALUE. Figure 5 shows the example of changing gateway hostname with these commands: CONFIG.GW_HO

```
CONFIG.GW_HOSTNAME="LoRa 1Ch Gateway SV Undip",
```

followed by CONFIG.save()to saves the current configuration and CONFIG.print()will show the current configuration as shown by figure 3.

The Things Network (TTN) is one of the Lora network servers that offers open-source, decentralised infrastructure for the Internet of Things, and supported by the large community around the globe. The next step is to register the gateway on TTN server so the gateway can be recognised and forward data payload from nodes to TTN server. This stage is the main indicator of success/failure on the gateway-Lora network server communication. After registration, it will receive gateway ID number from the server.

After the gateway registration process is complete and successfully connected, it is necessary to create an application on the TTN containing the node devices. The server will issue several identification numbers: Device EUI, Application EUI, Device Address, Network Session Key, and App Session Key specifically for each node that is registered.
Table 1. Default preset command for gateway parameter configurations.

| Parameter   | Description                                      | Default                  |
|-------------|--------------------------------------------------|--------------------------|
| GW_HOSTNAME | A hostname for telnet server                     | "lorawangw"              |
| GW_NTP_SERVER | DNS name of the NTP server to connect            | "nl.pool.ntp.org"        |
| GW_ROUTER   | DNS name of the router to connect                | "router.eu.thethings.network" |
| GW_PORT     | Port number of the router to connect             | 1700                     |
| GW_FREQ     | Frequency (in Hz) to listen to                   | 868100000                |
| GW_BW       | BW to listen to                                  | "BW125"                  |
| GW_SF       | SF to listen to ("SF7".."SF12"|"ALL")                   | "ALL" (listen to all SF's) |
| GW_ALT      | The altitude of your gateway location            | 0                        |
| GW_LAT      | Latitude of your gateway location                | "0.0"                    |
| GW_LON      | Longitude of your gateway location               | "0.0"                    |
| GW_NSS      | NSS pin number                                  | 0                        |
| GW_DIO0     | DIO0 pin number                                 | 1                        |
| GW_DIO1     | DIO1 pin number                                 | 2                        |

3. Result and Discussion

In the Gateway Overview menu on TTN console, the connection status of the gateway can be seen as shown in figure 4. According to its location, the up and running gateway will appear on Lora world map provided by TTN. It also displays information related to hardware of the gateway, especially the controller model.

The coverage area of the gateway is tested by placing nodes in several locations around the Undip Vocational School with a radius of approximately 100 m from the gateway. On each point, the RSSI and SNR value of the signal are recorded as seen from TTN’s server. Google Map application is used for distance measurements of node-gateway. The position of the gateway is inside building D with elevation 2.5 m from the floor.

Figure 3. Example of changing gateway hostname parameter.

Location no.2 shows the test location in front of the microcontroller lab, with elevation of the node approximately 2 m above the floor of building D, there are obstacles in the form of buildings and trees, the distance of the node to the gateway is approximately 103.33 m, resulting in a reading of RSSI = -106 dBm, SNR = 9. Location no.3 shows the test location in the motorcycle parking lot, with elevation node about 7 m above the floor of building D, there are obstacles in the form of buildings and trees, the distance of the node to the gateway is approximately 49.62 m, resulting in a reading of RSSI = -104 dBm, SNR = 9.
Figure 4. Gateway connection status on TTN server.

Table 2. Test results from several point locations

| No | Location                | RSSI (dBm) | SNR | Distance (m) |
|----|-------------------------|------------|-----|--------------|
| 1  | in front of the hall    | -114       | 5   | 87.82        |
| 2  | in front of the microcontroller lab | -106 | 9   | 103.33       |
| 3  | motorcycle parking lot  | -104       | 9   | 49.62        |
| 4  | behind the mechanical technology lab | -117 | -2  | 100.07       |
| 5  | next to the Law Faculty | -119       | -4  | 137.58       |
| 6  | in front of the Law Faculty | -113 | 4   | 92.86        |

Location no. 4 shows the test location behind the mechanical technology lab, with the elevation of the node approximately 6 m above the floor of building D, at this point the ground surface almost obstructs the position of the node-gateway. There are obstacles in the form of buildings and trees, the distance of the node to the gateway is approximately 100.07 m, resulting in a reading of RSSI = -117 dBm, SNR = -2. Location no. 5 shows the test location next to the Law Faculty, with elevation of the node about 5 m below the floor of building D, there are obstacles in the form of buildings and trees, the distance of the node to the gateway is approximately 137.58 m, resulting in a reading of RSSI = -119 dBm, SNR = -4. Location no. 6 shows the test location in front of the Law Faculty, with node elevation of approximately 4 m below the floor of building D, there are obstacles in the form of buildings and trees, the distance of the node to the gateway is approximately 92.86 m, resulting in a reading of RSSI = -113 dBm, SNR = 4.

Test results show RSSI readings above -100 dBm at a radius below 100 m. RSSI and SNR values appear to drop dramatically in low elevation conditions, especially if the position of the node-gateway is almost obstructed by the ground surface. The surface obstacle in the form of dense trees and thick buildings contribute to reducing the quality of signal reception. The SNR even drops below the noise floor (negative value) at the location next to the law faculty and behind the mechanical technology laboratory. With this unique topographical land surface, the coverage service of LoRa gateway on Undip Vocational School may not be effective if the radius of nodes is more than 100 m.

4. Conclusion
The LoRa gateway has been successfully implemented on Undip Vocational School. Test results show the effective coverage range of gateway is approximately 100 meters, that is enough to cover LoRa based IoT applications on Undip Vocational School. The test result also proves the ability of LoRa to receive signal below the noise floor (negative values of SNR). Thick buildings, dense vegetations and trees, are major contributors limiting the range of LoRa communication. To extend its coverage service, the position of the gateway is recommended to be placed in a high location such as mounted on a dedicated tower or installing more gateway on another location. The success of test demonstrations also proved that LoRa can be realised using open and low-cost components. The up and running gateway is a part of the infrastructure for unlimited multidiscipline LoRa based IoT applications.

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