Dual-Channel LoRa Gateway using Channel Assignment on Raspberry Pi

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Abstract: This research is about designing and implementing dual channel at LoRa gateway by using channel assignment method. The result of this experiment is distance of 1.15 km. LoRa gateway is able to connect well with sensor node. With the success of this distance, it can be analyzed at a glance about the value of RSSI, datarate and other metadata as well as how to select channels based on the queue which at this time focuses on single channel first.

1. Introduction
LoRa gateway is a long-distance telecommunications system that utilizes radio frequency (RF). LoRa gateway low power with a low bitrate as well [1]. Currently, the use of LoRa gateway itself is already widely used for its ability in transmitting data from end-node to the server to reach very far, with this capability, LoRa gateway can be applied in terms of civic infrastructure, health monitoring, and monitoring of environmental quality in real time or data needed to come right then and there [2][3].

In the case of retrieval of data from sensors that only use WiFi signals, such as for example the use of wifi in a campus environment [4] to forward the data to the sensor must only have a limited distance to the user, the distance that can only be achieved by wifi approximately 30 meters with a data rate higher, with a LoRa gateway to the problem of distance is not a problem anymore, by utilizing the signal of Radio Frequency (RF) LoRa gateway to a distance of approximately 2.5 km in Line of Sight (LOS) and there is the obstacle though.

With the ability to LoRa in terms of distance despite having the bit rate is low, then came the idea to implement Dual-channel at LoRa gateway, which aims to be both a gateway to connect properly and forwards data packets from end-node to the server by harnessing radio frequency (RF) owned [5].

In experiments conducted The Things Network (TTN) [3] have been implemented on a single channel that serves as a gateway LoRa. The results of these experiments are the obtainment of results or metadata that contains information to then be analyzed, but LoRa gateway used to forward data packets to the end nodes only one and if likened to the network topology is simply the gateway merely like a switch, which weakness is at least the sensor module can be used.

In this paper, LoRa implements Dual Channel Gateway uses the Raspberry Pi with Channel Assignment method. Picture channel assignment method using either fixed or dynamic in order to optimize the available channels, and also provides a schematic representation of data sent in a single channel or dual channel via LoRa.

2. LoRa Gateway
LoRa which stands for "Long Range", is a long-distance communication system, promoted by LoRa alliance, this system aims can be used in battery-powered device that has a long life, where battery consumption is very important [6]. Therefore, in LoRa gateway requires only low power despite the shortcomings that have a low bitrate anyway.
LoRa usually refers to two layers different: (i) physical layer using radio modulation technique Chirp Spread Spectrum (CSS) [2], and (ii) a MAC layer protocol (LoRaWAN), although Lora communication system also implies a specific access network architecture.

LoRa physical layer, developed by Semtect, enabling remote communication, low power and low throughput. LoRa himself was in the ISM bands 433, 868, and 915 MHz, depending on the area where he used. The charge of each transmission can range from 2-255 octet, and the data rate can reach up to 50 Kbps when an aggregation of channels used. LoRa, a typical network "star topology", which covers three types of different devices, as shown in the figure below architecture.

![LoRa Architecture](image)

**Figure 1. LoRa Architecture**

LoRaWAN basic architecture of the network is as follows: end-devices to communicate with the gateway. Gateways crude LoRaWAN forward frames from the device to the network server via a backhaul interface with a higher throughput, typically Ethernet or 3G. As a result, the only gateway relay two-way, or protocol converter, with a network server that is responsible for decoding the packets sent by the device and produce packages that should be sent back to the device. There are three classes LoRa end devices, which only differ in terms of scheduling downlink.

3. Research Methodology

a. Channel Assignment

Channel assignment itself is the method used in this research that involves the selection of channels is right as the path queue, if the single channel has only one lane, it causes the queue builds up which led to the end-node which requires a lot of time to send the data to the server, another as if the queue is made of two lines in this case a dual-channel, with two lines through which the flow of data from end-node can be smoothly in a faster time than single-channel.

In WMN (Wireless Mesh Network), the number of radio interface is much higher than the number of channels available. Thus, many of the transmissions between mesh nodes will use the same channel, which will lead to mutual interference and dramatically reduce its use [7]. The key factor to reduce interference is the use of non-overlapping channels (standard IEEE 802.11b / g provides 3 and the standard IEEE 802.11a up to 12 non-overlapping channels). Channel assignment to the interface must ensure that the many available paths between nodes (nodes must share the same channel between neighbouring transmission to maintain connectivity).
Assignment channel algorithms can be divided into three main categories: fixed, dynamic and hybrid, depending on the frequency modified by the channel assignment scheme [8].

The research will focus on two methods: Fixed and Dynamic Channel Allocation. The difference between the two is:

- **Fixed Channel Allocation (FCA)**
  Fixed channel allocation is a technique in which the channel allocation in each cell is allocated a permanent basis. Since each cell is allocated remain so in this system required a fixed channel management. If all the channels filled, then the cells are blocked and sometimes used the strategy of borrowing channels from neighbouring cells [7].

- **Dynamic Channel Allocation (DCA)**
  Dynamic channel allocation is a technique that no channel allocated permanently in the cell. The basic concept of the DCA strategy is not evenly distributed when the traffic load in each cell then the provision of frequency channels in each cell will often unused in the cell is less dense, and blocking occurs in cells with dense traffic load. DCA techniques can allocate a frequency channel when only the traffic load increases and releases the frequency channel when the traffic load decreases [7].

### b. Design Tools

The tools used in this experiment, among others, on the side of the node using LoRa Mini Dev combined with temperature and humidity sensors DHT 11, while on the GPS LoRa HAT use gateway combined with a Raspberry Pi models B.

![Gateway Image](image2.png)

*Figure 2. Gateway*

![Node Image](image3.png)

*Figure 3. Node*

On the side of the node to upload a sketch to LoRa mini using the program Arduino IDE that has been equipped with several libraries needed, while on the gateway requires a forwarder that will be used to forward the packet to the server, forwarder used already available on github to alter the settings there is adapted to the tool being used.
So that the device can be detected by the server TTN will require activation method, activation method itself is divided into two: ABP (Activation By Personality) and OTAA (Over The Air Activation).

a. OTAA (Over the Air Activation)

This activation method is a method of air, more precisely through a handshake scheme, the activation method requires information sharing among others:

- **AppEUI**: Usefully for unique application identifier classifying the data, the address consists of 64 bits, and is useful to classify the peripheral devices, applications, and settings can be adjusted.
- **DevEUI**: The application identifier is set at the factory and can not be changed
- **APPKey**: This is a secret key shared between the device and network peripherals. This is used to determine the session key. These settings can be adjusted.

The advantage of using an activation method OTAA has a strong security system, because the network generates and sends the encryption key.

b. ABP (Activation By Personalization)

In this activation method is easier because only enter the required information and the device will be connected, but in regards to the security of this method is very weak, as to the necessary information, among others:

- **DevAddr**: Logical Address is used to identify the network.
- **NetSKey**: The encryption key between the object and the carrier used for transmission and to validate the integrity of the message.
- **AppSKey**: The encryption key between the object and the user (via applications) used for the transmission and to validate the integrity of the message.

This study used the method of activation ABP easier though to have shortcomings in terms of security, the method of activation is done on both sides of both the node and the server, after the activation method on both sides of the tasks of the gateway that forwards the data transmitted by the sensor nodes to the server, using the same radio frequency signals both located at 868 Mhz.

![Figure 4. Forwarder successfully receive data packets](image)

On the side of the raspberry pi with the LoRa GPS / Hat module functions to forward data packets from the mini LoRa to the server, with the same frequency between LoRa Hat and LoRa mini, it will be connected properly. For how long the packet is successfully forwarded will depend on the distance and obstacles between the two.
pseudocode: Node / Sensor program

Input: Data from the sensors
Output: The value of temperature and humidity values

Begin
Global declarations:
   NWKSKEY <- 0xD0, 0x9F, 0xDB, 0x55, 0x95, 0xF6, 0x69, 0xA7, 0x6D, 0x06, 0x5F, 0x50,
   0xEC, 0x82, 0xBB, 0x1D -> constant character
   APPSKEY <- 0x84, 0xD0, 0x2F, 0xD1, 0x08, 0xAD, 0xB8, 0xBE, 0x5E, 0xCD, 0xC7, 0x97,
   0x48, 0xAE, 0x67, 0x37 -> constant character
   DEVADDR <- 0x26011C47 -> constant character

setup procedure (): {procedures to activate the functions that exist in LoRa mini}
   Set output D0 pinmode
   Start serial ()
   Start activation (nwkskey, appskey, devaddr)
   While activation not connected then
      Set delay 1000 ms
      Print "connecting" to serial
   end while
end setup

procedure loop (): {arduino to repeat the procedure in continuous operation conducted}
   humidity <- readhumidity () -> float
   temperature <- readtemperature () -> float
   Print humidity to serial
   Print temperature to serial
      <- temperature, humidity -> character

   If the activation of connected then
      http -> HttpClient
      Start http
      httpCode <- GET () -> integer
      If httpCode large than 0 then
         payload <- GetString () -> string
         Print payload to serial
      end if
      stop http
   end if
   Set delay 1000 ms
end loop
4. Results & Discussion
In this intensive search conducted an experiment with a range of ± 1.15 km with obstacles and 700 m in LoS (Line of Sight). Actually LoRa itself has the communication distance more than that but limited space so obtained maximum limit is ± 1.15 km. Here is a screenshot taken from a distance google map:

![Figure 5. Testing the distance of 1.13 km](image)

![Figure 6. Testing the distance of 750 m](image)

On LoRa there is something called SF (spreading factor), In LoRa spread spectrum modulation is achieved by generating a signal chirp that continuously varies in frequency. The advantage of this
method is the timing and frequency offset between the transmitter and receiver are equivalent, greatly reducing the complexity of the receiver design. The Spreading Factor is a set of parameters that specify transmit power, sub frequency and air time. LoRa define spreading factors numbered from 6 to 12, where LoRaWAN is used from 7 to 12. The lower is the spreading factor, the higher is the throughput, and the lower is the distance covered. Also, lower spreading factor means lower power consumption.

Table 1. Data rate and spreading factor

| DataRate | Configuration | Indicative physical bit rate [bit/s] |
|----------|---------------|-------------------------------------|
| 0        | LoRa: SF12 / 125 kHz | 250                                 |
| 1        | LoRa: SF11 / 125 kHz | 440                                 |
| 2        | LoRa: SF10 / 125 kHz | 960                                 |
| 3        | LoRa: SF9 / 125 kHz  | 1760                                |
| 4        | LoRa: SF8 / 125 kHz  | 3120                                |
| 5        | LoRa: SF7 / 125 kHz  | 5470                                |
| 6        | LoRa: SF6 / 250 kHz  | 11000                               |
| 7        | FSK 50 kbps        | 50000                               |

From the experiment output data obtained apart from the temperature and humidity are also other data as shown in the figure below this:

![Figure 7. Metadata obtained on the server side](image)

In Figure 4 there is information in the metadata column that has its own value, while the mean of the values that appear in Figure 4 are:

1. **Frequency: "868.1"** is the frequency used is at a frequency of 868.
2. **LoRa Spreading Factor:** In the LoRa spread spectrum modulation is achieved by generating a signal chirp that continuously varies in frequency. The advantage of this method is the timing and frequency offset between the transmitter and receiver are equivalent, greatly reducing the complexity of the receiver design.
3. **Modulation:** "LORA" is a module that is used in research that is LORA.
4. **Data_rate**: "SF7BW125" is the number of bits sent per second, how to find the data rate by using the formula:

\[ R_b = SF \times \frac{BW}{2^{sf}} \times CR \]

Where:
- \( R_b \) = data rate
- \( sf \) = spreading Factor
- \( BW \) = Bandwidth
- \( CR \) = code rate

Then will be generated Data Rate

\[ R_b = 7 \times \frac{125}{128} \times 4/5 \]

\[ R_b = 5.46875 \text{ bps} \]

5. **Gateways**: In this section there RSSI and SNR values, which are strongly influenced by distance and obstacles that exist, figure 4 show the value of RSSI = -71 and SNR = 9, to determine the quality of the signal obtained the required formula:

\[ \text{Quality} = 2 \times (\text{dBm} + 100) \]

where dBm: [-100 to -50]

\[ \text{Quality} = 2 \times (-71 + 100) \]

\[ \text{Quality} = 2 \times 29 \]

\[ \text{Quality} = 58\% \]

So for the reception of data in Figure 4, the quality of the signal is at Normal limits, then there SNR indicates a value of 9, which means noise at the level of the fair (enough) but susceptible to changes in the network variations.

On the Quality has a value of 58\%, which means that the signal quality is at a good level, with the RSSI increasing on the vulnerable value of -100 to -50, the signal quality is more perfect, the value of RSSI varies depending on the distance and obstacles that hinder the reception process, from the transmitter to the receiver.

5. **Conclusions**

In the testing that was done, then get concluded as follows:

1. LoRa was able to get the data sent by the node / sensor well with a great distance ± 1.15 km in LoS (Line of Sight) but if the distance barriers / obstacles will require time and have a lot of obstacles before the data is sent.

2. RSSI is strongly influenced by distance and obstructions, the greater the distance and number of obstacles make smaller RSSI value, which could potentially be hindered data packet received by the gateway. This is evidenced by the connection between nodes and gateways, and obtained results in the form of data shown in Figure 7, in this case a distance of 1.15 km will remain connected even though it takes a long time to communicate, because of the distance and obstacles between nodes and the gateway.

3. Activation method ABP nodes will get accurate results and connect quickly, but must be registered manually and the activation method is a low security level because the id of the device is not encrypted automatically as in the method OTAA.

4. LoRa Spreading Factor greatly affects the connectivity between nodes and gateways, the SF was on the 7th then, although there were a lot of noise when communication takes place, but the data will still be available for the repeated ping of the second device (chirp).
5. For the use of Channel Assignment in this case fixed channel allocation method of sending data is still relying on the queue at the track, resulting in the accumulation of data to be transmitted and cause a fairly long waiting time before further data will be sent.

6. From the calculation of the value data rate is done, obtained a value of 5.46875 bps which means the true LoRa used is in SF7, which makes the connection between the transmitter and receiver occurs more quickly and easily send data from the sensor to the server.

6. References

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