

## A Design of Multi-hop Network Protocol based on LoRaWAN Gateway

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### Abstract

Currently, LPWA(Low Power Wide Area) communication technology is widely used due to the development of IoT(Internet of Things) technology. Among the LPWA technologies, LoRaWAN(Long Range Wide Area Network) is widely used in many fields due to its wide coverage, stable communication speed, and low-cost modem module prices. In particular, LoRa(Long Range) can easily construct LoRaWAN with a dedicated gateway. So many organizations are building their own LoRaWAN-based networks. The LoRaWAN Gateway receives the LoRa packet transmitted from an End-device installed in the adjacent location, converts it into the Internet protocol, and sends the packet to the final destination server. Current LoRa Gateway uses a single-hop method, and each gateway must include a communication network capable of the Internet. If it is the mobile communication(i.e., WCDMA, LTE, etc.) network, it is required to pay the internet usage fee which is installed in each gateway. If the LoRa communication is frequent, the user has to spend a lot of money. We propose an idea on how to design a multi-hop protocol which enables packet routing between gateways by analyzing the LoRaWAN communication method implemented in its existing single-hop way in this paper. For this purpose, this paper provides an analysis of the standard specification of LoRaWAN and explains what was considered when such protocol was designed. In this paper, two gateways have been placed based on the functional role so as to make the multi-hop protocol realized: (i) hopping gateway which receives packets from the end-device and forwards them to another gateway; and (ii) main gateway which finally transmits packets forwarded from the hopping gateway to the server via internet. Moreover, taking into account that LoRaWAN is wireless mobile communication, a level-based routing method is also included. If the protocol proposed by this paper is applied to the LoRaWAN network, the monthly internet fee incurred for the gateway will be reduced and the reliability of data transmission will be increased.

**Key words:** IoT, LPWA, LoRaWAN, Multi-hop, Routing.

## 1. INTRODUCTION

The development of wireless data communications and the decrease in the hardware price have currently resulted in release of various types of IoT(Internet of Things) products which are used by many users. Today's IoT products basically have a wireless data communication function to be connected with internet. The home IoT products with a wireless data communication function use the Wi-Fi(IEEE 802.11) technology

and most of the outdoor IoT products use the cellular modem(i.e., WCDMA, LTE, etc.), in each case they send and receive data and servers by connecting with internet through the cellular network built by mobile carriers. For the IoT products using the cellular modem, they are expensive compared to other IoT products since the price of the modem module is high, and expensive monthly fees should be paid since data transmission is made in the cellular network of the relevant mobile carrier. Moreover, their battery efficiency is not high since the power consumption of the cellular modem is high compared to the other modules[1-3].

Currently, wireless communications for the IoT devices which send and receive small data are released. In particular, the LPWA(Low Power Wide Area) communication technology which enables low-power wide area communications is used for IoT devices and LoRaWAN(Long Range Wide Area Network) communication represents a typical communication thereof. For the data communications of LoRaWAN, the end-device connects the single-hop between more than one gateways[1,3-4]. In Korea, SK Telecom Co., Ltd.("SKT") operates the nationwide LoRa network service and if using such network, the user should pay SKT the monthly fee based on the data size to use[1,5]. The monthly fee for the nationwide LoRa network is low in comparison with the existing cellular communication network but if operating many IoT devices, the regular payment of such monthly fee is also burdensome. In this case, therefore, a number of gateway devices are installed autonomously to build and operate a private LoRaWAN network. If building a private LoRaWAN network, internet needs to be connected for each gateway, for which the internet communication network of a communication service provider is used and the monthly fee therefor also needs to be paid for the relevant communication service provider. Such monthly fee should be paid based on the amount of internet packets used for each LoRaWAN gateway device. If the existing single-hop communication method of LoRaWAN is configured as a multi-hop network which finally transmits data to the internet by way of data routing between gateways, the aforementioned monthly fees for each gateway device in the private LoRaWAN may be reduced and the communication coverage will become wider to handle more end-devices.

This paper deals with what should be necessarily considered to design the multi-hop network in LoRaWAN: analysis carried out based on the communication method and protocol set out in the standard specification of LoRaWAN, and how to implement the multi-hop network which enables communications between gateways of LoRaWAN.

## 2. LORAWAN COMMUNICATION

When LoRaWAN transmits packets generated by the end-device to the neighboring gateway via LoRa communication method(wireless), the gateway which received the packets transfers them to the network service based on the internet protocol by using the connected back-haul(e.g., cellular(3G/4G/5G), Ethernet, satellite, Wi-Fi, etc.). At this time, due to the nature of the wireless mobile communications, all the end-devices in the LoRaWAN("Node") transfer packets to the neighboring gateway, not a specific gateway. Therefore, the data transferred by Node are received by the gateway which is near to Node. For the overlapped packets, the network server conducts filtering and security inspections and transfers the relevant packets to the application server which is the final destination(Figure 1 and Figure 2). After then, the application server sends Node an acknowledgment message("ACK") through the network server that it received the packets sent from Node. At this time, the network server sends ACK to the optimal gateway(one that Node sent for the first time). Then, the gateway which receives ACK transfers the ACK to the Node of the destination[1,3,6,7].

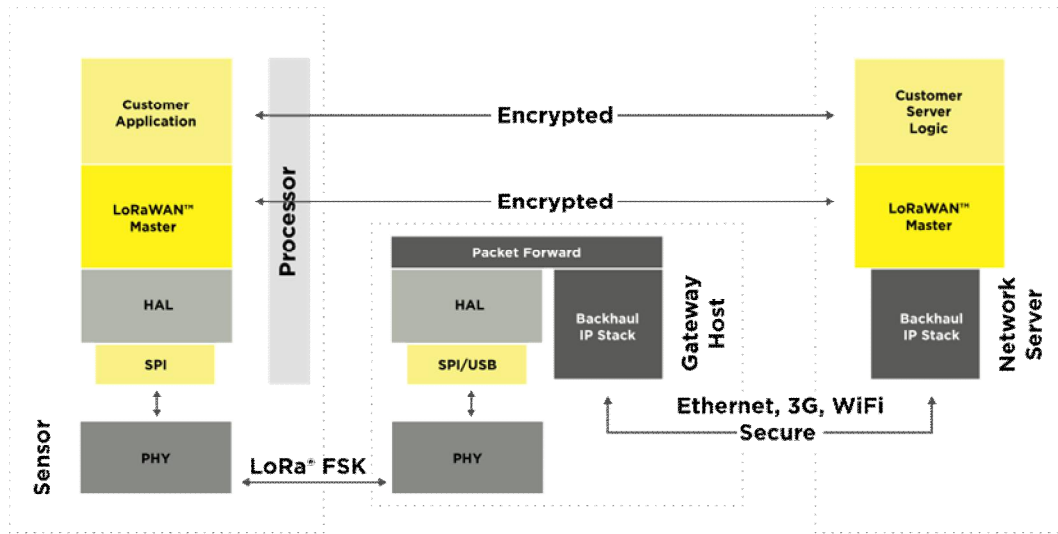


Figure 1. Flowchart of LoRaWAN Communication Method [4]

In order for an end-device to make communications with an application server in LoRaWAN, activation process should be taken. The activation process refers to joining to LoRaWAN communications and there are two methods in LoRaWAN: OTAA(Over-The-Air Activation) and ABP(Activation By Personalization). In LoRaWAN, the communication process is encrypted and the method of generating the keys to be used therefor is different for each joining method. Therefore, the end-device should make communications according to the joining method for the LoRaWAN to be used for data communications [1,3,7,8].

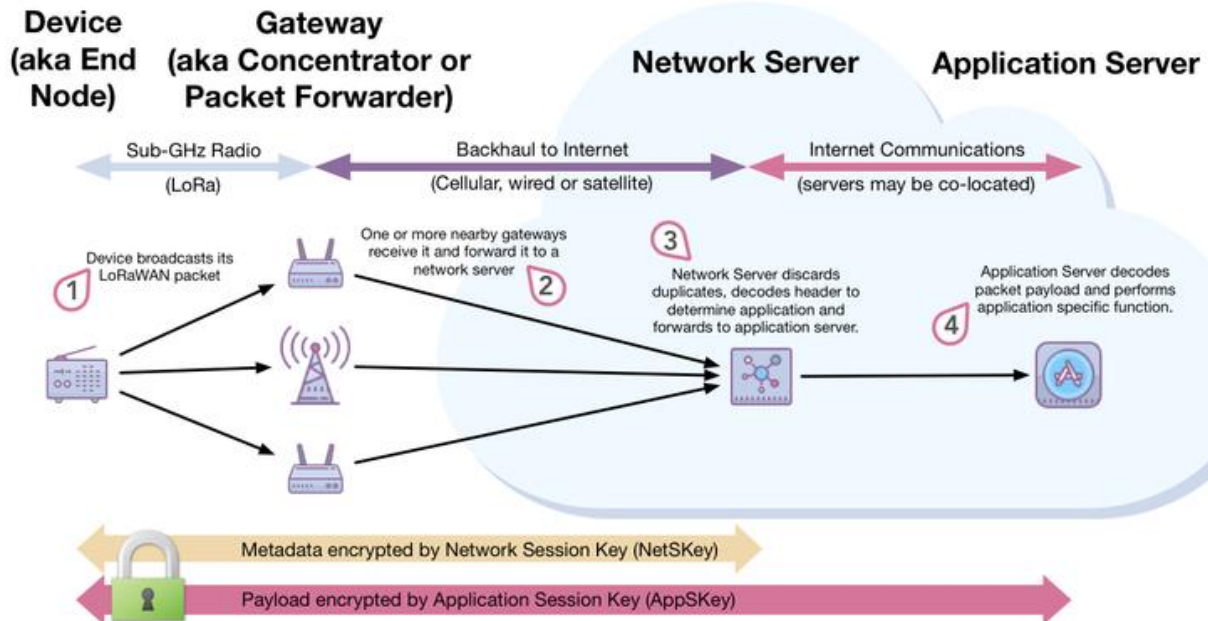


Figure 2. Flowchart of LoRaWAN Communication Method [8]

### 3. DESIGN OF THE MULTI-HOP NETWORK PROTOCOL

Figure 3 shows a diagram of multi-hop network for LoRaWAN to be implemented by this paper. In the

multi-hop network for LoRaWAN that this paper intends to propose, the end-device communicates with gateways as the existing method but the gateways are classified into two types based on the function when their routing is made to forward the packets received from the end-device. Both of them receive the packets from the end-device but the hopping gateway(“HGW”) forwards the relevant packets to another HGW and finally transfers them to the main gateway(“MGW”). At this time, MGW converts the packets received from HGW(or its neighboring end-device) to the standard protocol of the network server for LoRaWAN(based on JSON) and transmits them to the relevant server via the internet by connecting with back-haul[1,9,10].

The HGW of the network in this paper should be designed and implemented so as to have its own level, the addresses of end-devices and the address of MGW in the final destination of the packets. This is due to the non-directional nature of mobile communications. If an end-device sends a packet, it will be sent to the neighboring gateway. The existing single-hop way results in a few of overlapped packets but the multi-hop way results in a number of overlapped packets since there are many gateways, which may cause the network speed to decrease. Therefore, this paper proposes to design a network where each gateway has the relevant information in advance so that when checking the packet that the end-device or another gateway receives if the packet is not for itself, the packet is automatically deleted so as to minimize the overlapped transmitted packets.

The network routing method proposed by this paper is to place levels between gateways so that transmission is made from HGW with low level to MGW with high level. If a signal is received by an end-device from HGW with ‘Level 1’(H4 of Figure 3), it is sent to HGW with the next level ‘Level 2’(H6 and H7 of Figure 3) which transmits the signal to MGW with the final level ‘Level 3’. When sending ACK received from the server to the end-device, the transmission direction from MGW with Level 3 to HGW with the lower level is reverse to the previous direction.

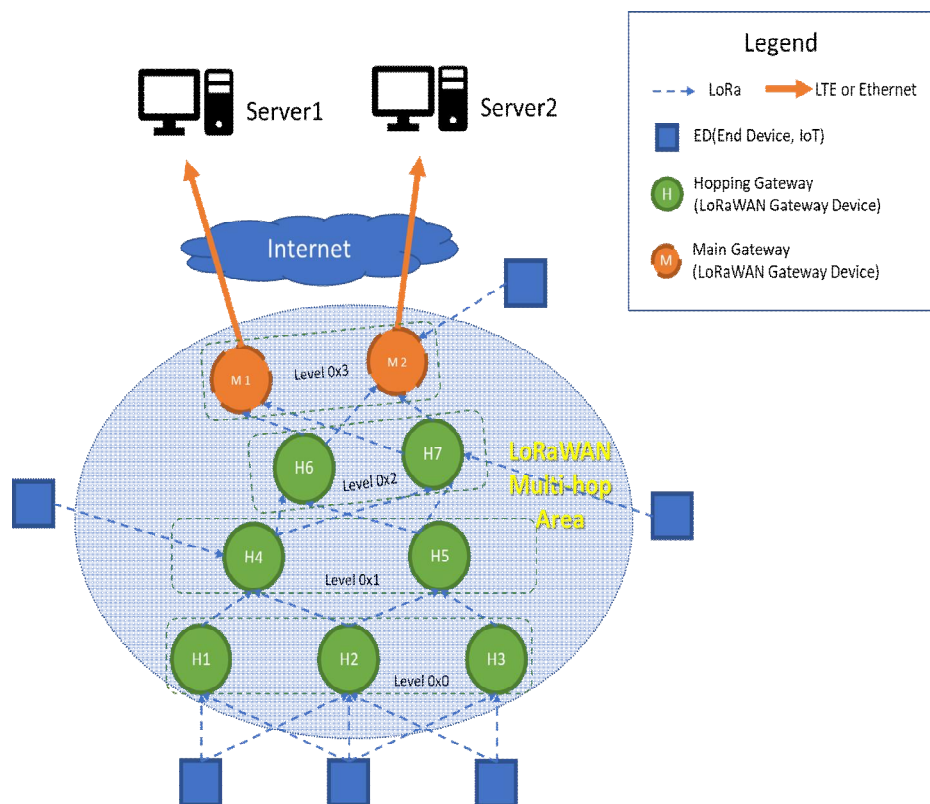
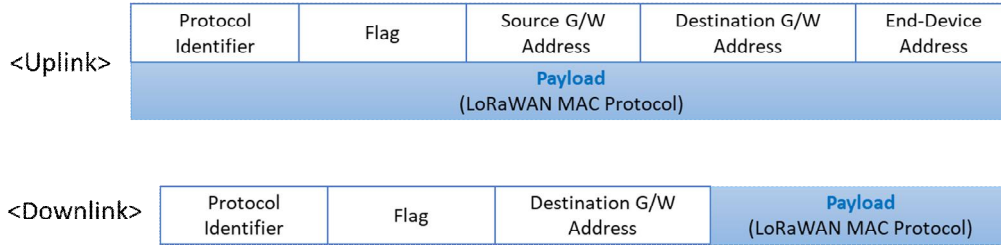


Figure 3. Diagram of Multi-hop Network for LoRaWAN Proposed by This Paper

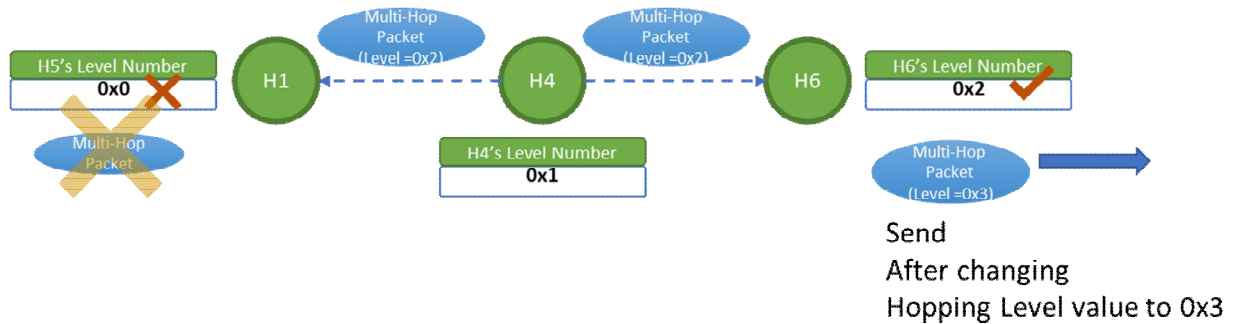
**Protocol Identifier (1byte)** : Multi-Hop Protocol Primitive Identity Character  
**Flag(1byte)** : Details of the corresponding packet  
 (Link mode, Next Group Number, etc.)  
**Source G/W Address (1byte)** : Address of sending GW (Only used when Uplink)  
**Destination G/W Address (1byte)** : Address of destination GW  
**End-Device Address (4byte)** : End-Device address of the packet sent  
 (Only used when Uplink)  
**Payload(*n* Byte)** : Existing LoRaWAN Packet Data



**Figure 4. Exclusive Protocol Structure for the Network in this Paper**

In order to solve the foregoing issues, an exclusive protocol for this paper should be designed. Figure 4 shows the design of the protocol proposed by this paper. Communications between gateways are made by putting headers containing various information before the existing payload (LoRaWAN MAC Protocol). For the gateway which earlier receives the packet transmitted by the end-device, when checking the MGW of the destination from the original packet of the end-device, if it is the packet that it should process, it converts the packet into the packet proposed by this paper to transmit to HGW with the next Level.

*< When H4 Hopping GW transmits multi-hop packet to next level hopping GW >*



**Figure 5. Non-directional Packet Process Method**

Various matters should be considered since the network of this paper handles routing in the wireless communication environment. First of all, whether to receive wireless signals sent by itself should be considered due to the matter of reflected waves. In this case, the level of the gateway and the level of destination among other data included in the wireless signals are confirmed. There is a need to design and implement a method by which a message is deleted automatically when the message has the level equivalent to its own level. Next, for the wireless communications, non-directional process should be considered for gateways to handle the method of processing the received messages. As can be seen in Figure 5, there is a need to design and implement a

method by which a message is automatically deleted as mentioned above if the message is not the relevant message for itself, but the relevant process should be taken if it is for itself.

In addition, time synchronization is difficult since HGW is not connected to back-haul. In response to this, HGW should receive time information through GPS (Global Positioning System) sensor for time synchronization. Communications should be always enabled in the network of this paper and thus, all the gateways in the network of this paper should be implemented as LoRa Class 3[1,6,7].

#### 4. CONCLUSION

In this paper, we have dealt with the design of multi-hop network and protocol for LoRaWAN. For this purpose, the existing communication method of LoRaWAN has been analyzed based on the matters referred to in the relevant standard specification. In this paper, the matters to be considered at the time of actual implementation have been taken into account and the solution therefor has been proposed. We need to study for an additional design of dynamic routing functions in this paper. The network protocol proposed in this paper has a structure in which a packet passes simply by giving a level value to a layer of a LoRa gateway. However, when many LoRa gateways are installed and operated, the non-directional transmission in the wireless communication environment may cause unnecessary LoRa packets to be received and processed, and the processing speed of the corresponding gateways may be delayed. Current we are considering an algorithm that determines whether to process the received packet based on the pre-registered device table which is similar to Ethernet. When implementing this paper in the future, MGW will have more things to deal with than HGW. In addition to the functions to be implemented in HGW, MGW has to implement the function to send data to and receive from the server. While HGW is implemented with an embedded device, MGW should be implemented with a general PC in order to improve the performance of MGW.

#### ACKNOWLEDGEMENT

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