LoRaWAN Network Server Demonstration: Gateway to Server Interface Definition

1 History

Revision	Modification / Remarks / Motive	Author
1.0	Document created	DRo

2 Introduction

This document defines the protocol by which the Semtech LoRa gateway communicates with the Semtech LoRa network server.

The protocol authenticates neither the gateway nor the server.

Neither participant retransmits unacknowledged messages.

3 Protocol stack

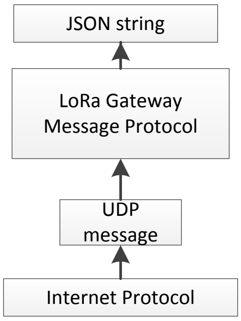

Figure 1: Semtech LoRa gateway to Semtech LoRa network server protocol stack

4 UDP

All communication between a gateway and a network server is over UDP [1]. The UDP source and destination port numbers shall be as listed in Table 1.

The GWMP message occupies the entire user data area of the UDP packet. The gateway shall periodically transmit a PULL_DATA message to the network server, in order to keep any intervening firewall open.

GWMP message type	Direction	Gateway UDP source port	Network server UDP port	Gateway UDP destination port
PUSH_DATA	To server	Arbitrary	Server GWMP port (default 1700)	
PUSH_ACK	To gateway			The source port of the PUSH_DATA message to which this message is an acknowledgement
PULL_DATA	To server	Arbitrary		
PULL_ACK	To gateway			The source port of the PULL_DATA message to which this message is an acknowledgement
PULL_RESP	To gateway			The source port of the most recent PULL_DATA message received by the network server from the destination gateway

Table 1: UDP port used to send and receive GWMP messages

5 Gateway message protocol

5.1 Sequence diagrams

5.1.1 Gateway PULL_DATA

The gateway sends a PULL_DATA message in order to keep open any firewall protecting the network server.

The period between the transmissions of PULL_DATA messages is configured in the gateway.

The gateway does not react to a missing PULL_ACK message.

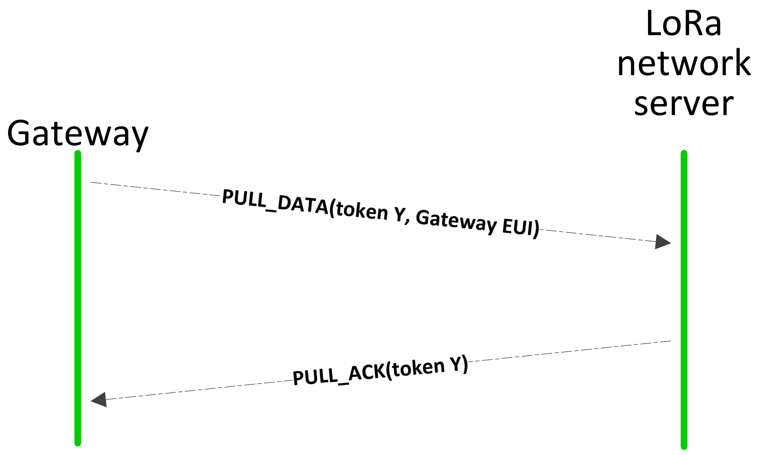

Figure 2: Gateway PULL_DATA

5.1.2 Upstream message flow

The gateway sends a PUSH_DATA message, containing the data being transferred to the network server. The network server responds with a PUSH_ACK message, containing the sequence number contained in the PUSH_DATA message.

The gateway does not react to a missing PUSH_ACK message.

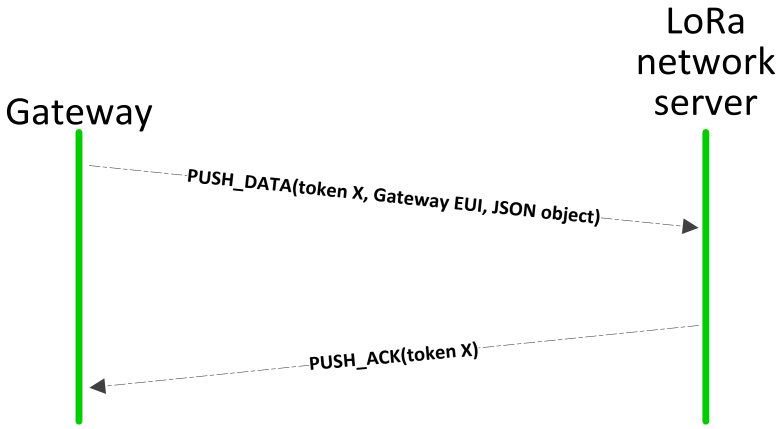

Figure 3: Upstream GWMP sequence diagram

5.1.3 Downstream message flow

The network server sends a PULL_RESP message, containing the data being transferred to the gateway.

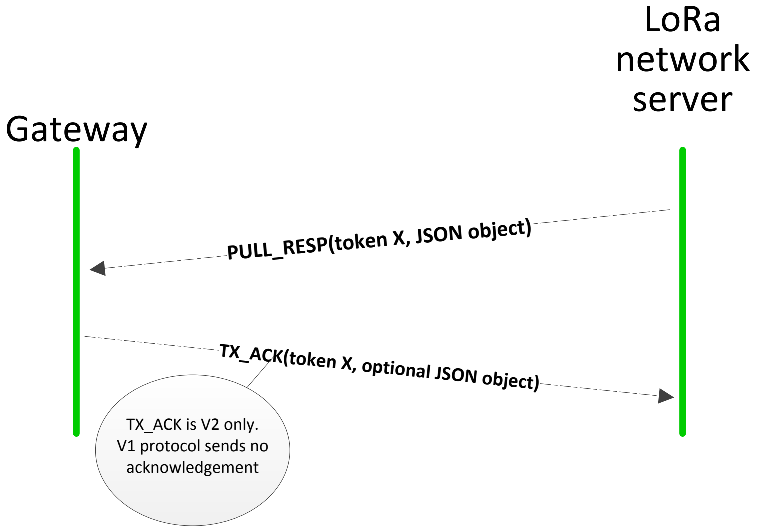
Gateway
LoRa network server
PULL_RESP(token X, JSON object)
TX_ACK(token X, optional JSON object)
TX_ACK is V2 only. V1 protocol sends no acknowledgement

Figure 4: Downstream GWMP sequence diagram

5.2 Message formats

5.2.1 PUSH_DATA message

The PUSH_DATA message transports its payload, a JSON object, from the LoRa gateway to the LoRa network server.

The length of a PUSH_DATA message shall not exceed 2408 octets.

Offset (from start)	Number of octets	Function	Value or description
0	1	Protocol version	0x01 or 0x02
1	2	Token	Arbitrary value set by Gateway
3	1	PUSH_DATA identifier	0x00
4	8	Gateway EUI	
12		JSON object	

Table 2: PUSH_DATA message format

5.2.2 PUSH_ACK message

The PUSH_ACK message is transmitted by the network server to acknowledge receipt of a PUSH_DATA message.

The server shall transmit a PUSH_ACK message immediately on receipt of a PUSH_DATA message.

Offset (from start)	Number of octets	Function	Value or description
0	1	Protocol version	0x01 or 0x02
1	2	Token	The value of the token of the PUSH_DATA message that is being acknowledged
3	1	PUSH_ACK identifier	0x01

Table 3: PUSH_ACK message format

5.2.3 PULL_DATA message

The PULL_DATA messages are periodically transmitted to the LoRa network server in order to inform the server of the UDP port number to which the network server should send any PULL_RESP message.

The PULL_DATA message also keeps open any firewall that protects the LoRa gateway.

Offset (from start)	Number of octets	Function	Value or description
0	1	Protocol version	0x01 or 0x02
1	2	Token	Arbitrary value set by Gateway
3	1	PULL_DATA identifier	0x02
4	8	Gateway EUI	

Table 4: PULL_DATA message format

5.2.4 PULL_ACK message

The PULL_ACK message is used by the network server to acknowledge receipt of a PULL_DATA message.

The server shall transmit a PULL_ACK message immediately on receipt of a PULL_DATA message.

Offset (from start)	Number of octets	Function	Value or description
0	1	Protocol version	0x01 or 0x02
1	2	Token	The value of the token of the PULL_DATA message that is being acknowledged
3	1	PULL_ACK identifier	0x04
4	8	Gateway EUI	

Table 5: PULL_ACK message format

5.2.5 PULL_RESP message

The PUSH_DATA message transports its payload, a JSON object, from the LoRa network server to the LoRa gateway.

The length of a PUSH_RESP message shall not exceed 1000 octets.

Offset (from start)	Number of octets	Function	Value or description
0	1	Protocol version	0x01 or 0x02
1	2	Unused (V1)/ Token (V2)	If protocol version is 1, transmit as zero, ignore on receipt. If protocol version is 2, the
3	1	PULL_RESP identifier	0x03
4		Payload	

Table 6: PULL_RESP message format

5.2.6 TX_ACK message (Version 2 only)

The TX_ACK message is sent by a gateway to the network server as an acknowledgement to a received PULL_RESP message.

Offset (from start)	Number of octets	Function	Value or description
0	1	Protocol version	0x02
1	2	Token	If protocol version is 1, transmit as zero, ignore on receipt. If protocol version is 2, the
3	1	TX_ACK identifier	0x05
4		Payload	If no error is reported, the 'Payload' field comprises one octet of value '\0'. If an error is reported, the field contains a JSON "error" object.

Table 7: TX_ACK message format

The JSON "error" object is described in Section 6.1.2

6 JSON protocol

The JSON protocol is defined by [2]. Within the LoRa system, JSON objects shall comprise only ASCII characters.

No JSON object shall contain white-space that is outside quoted text (i.e. names and text values). The examples given in this section are, however, printed with white-space to aid the reader.

The top level JSON objects contain many lower level JSON objects, of which many are not required. Some of the descriptions of these object rely on this. For example, the description of optional Boolean object as 'not true' means either its value is 'false' or the object is not present.

6.1 Top level

6.1.1 Upstream

The root JSON object shall contain zero or more “rxpk” objects, zero or one "stat" object and zero or more other, unknown, JSON objects. The "rxpk" objects may or may not be the elements of an array.

```
{
    "rxpk":[ {...}, ...],
    "rxpk":{...},
    "stat":{…},
    "other":{…},
    "other1":value
}
```

6.1.2 Upstream TX_ACK messages only

A TX_ACK message may contain a root JSON object. The object, if present, shall contain a single "error" object.

6.1.3 Downstream

The root JSON object shall contain zero or more “txpk” objects.

```
{
    "txpk":{...}
}
```

6.2 Components

6.2.1 stat (upstream)

Name	Required	Type	Function
time	No	string	UTC system time of the gateway. The precision is one second. The format is ISO 8601 [3] 'expanded' format
lati	No	float, containing up to 5 decimal places	The latitude of the gateway's position in units of degrees North of the equator.
long	No	float, containing up to 5 decimal places	The longitude of the gateway's position in units of degrees East of the prime meridian.
alti	No	signed integer	The altitude of the gateway's position in units of metres above sea level (as defined by the United States' GPS system).
rxnb	No	unsigned integer	The number of radio frames received since gateway start
rxok	No	unsigned integer	The number of radio frames received with correct CRC since gateway start
rwfw	No	unsigned integer	The number of radio frames forwarded to the gateway's network server since gateway start
ackr	No	unsigned integer	The proportion of radio frames that were forwarded to the gateway's network server and acknowledged by the server since gateway start. The proportion is expressed as a percentage.
dwnb	No	unsigned integer	The number of radio frames received (from the network server) for transmission since gateway start
txnb	No	unsigned integer	The number of radio frames transmitted since gateway start

Table 8: "stat" elements

6.2.1.1 Example

White-spaces, indentation and newlines are added to aid comprehension

```
"stat":
{
    "time":"2014-01-12 08:59:28 GMT",
    "lati":46.24000,
    "long":3.25230,
    "alti":145,
    "rxnb":2,
    "rxok":2,
    "rxfw":2,
    "ackr":100.0,
    "dwnb":2,
    "txnb":2
}
```

6.2.2 rxpk (upstream)

Name	Required	Type	Function
time	No	string	UTC time of receipt of the LoRa frame. The precision is one microsecond. The format is ISO 8601 ‘compact’ format ([3]). The object is present only when the receiving gateway has a source of accurate time.
tmst	Yes	unsigned integer < 2^{32}	The value of the gateway internal time counter at the instant the LoRa frame was received, with microsecond granularity. The value will rollover approximately every 72 minutes. The timestamp values generated by different gateways are unrelated.
freq	Yes	unsigned float, Hz precision	The centre frequency of the received signal in units of MHz.
chan	Yes	unsigned integer	Concentrator “IF” channel on which the frame was received
rfch	Yes	unsigned integer	Concentrator radio frequency chain on which the frame was received
stat	Yes	signed integer	The result of the gateway's CRC test on the frame. • 1 = correct • -1 = incorrect • 0 = no CRC test was performed
modu	Yes	string	The modulation technique used: • “LORA”, representing LoRa modulation • “FSK”, representing FSK modulation
datr	Yes	string	Datarate identifier. When "modu" equals "LORA", "datr" comprises "SFnBWm", where 'n' is an integer representing the frame's 'spreading factor' and 'm' is an integer representing the frame's bandwidth in units of kHz. When "modu" equals "FSK" "datr" comprises an integer representing the frame's bit rate in Hz
codr	Yes, if "modu" equals "LoRa"	string	ECC code rate. "codr" comprises the string "k/n", where 'k' represents the carried bits and 'n' the total number of bits received, including those used by the error checking/correction algorithm.
rssi	Yes	signed integer	The measured received signal strength in units of dBm.
lsnr	Yes	signed float, containing a maximum of 1 decimal place	The measured received signal to noise ratio in units of dB.
size	No	unsigned integer	The number of octets in the received frame.
data	Yes	string	The frame payload, encoded into Base64, [4]. The Base64 padding characters shall not be added.

Table 9: "rxpk" elements

6.2.2.1 Example

White-spaces, indentation and newlines are added to aid comprehension

```
"rxpk":
[
    {
        "time":"2013-03-31T16:21:17.528002Z",
        "tmst":3512348611,
        "chan":2,
        "rfch":0,
        "freq":866.349812,
        "stat":1,
        "modu":"LORA",
        "datr":"SF7BW125",
        "codr":"4/6",
        "rssi":-35,
        "lsnr":5.1,
        "size":32,
        "data":"-DS4CGaDCdG+48eJNM3Vai-zDpsR71Pn9CPA9uCON84"
    },
    {
        "time":"2013-03-31T16:21:17.532038Z",
        "tmst":3316387610,
        "chan":0,
        "rfch":0,
        "freq":863.00981,
        "stat":1,
        "modu":"LORA",
        "datr":"SF10BW125",
        "codr":"4/7",
        "rssi":-38,
        "lsnr":5.5,
        "size":32,
        "data":"ysgRl452xNLep9S1NTIg2lomKDxUgn3DJ7DE+b00Ass"
    }
]
```

6.2.3 error (upstream)

The value of the object is a description of the cause of the error. Expected values include:

Text	Description
TOO_LATE	Rejected because it was already too late to program this packet for downlink
TOO_EARLY	Rejected because downlink packet timestamp was received by the gateway too long before the scheduled transmission time
COLLISION_PACKET	Rejected because there was already a packet programmed in requested timeframe
COLLISION_BEACON	Rejected because there was already a beacon planned in requested timeframe
TX_FREQ	Rejected because requested frequency is not supported by TX RF chain
TX_POWER	Rejected because requested power is not supported by gateway
GPS_UNLOCKED	Rejected because GPS is unlocked, so GPS timestamp cannot be used

Table 10: Description of TX_ACK error values

6.2.3.1 Example

"error":"TOO_LATE"

6.2.4 txpk (downstream)

Name	Required	Type	Function
imme	No	Boolean	If true, the gateway is commanded to transmit the frame immediately
tmst	No	unsigned integer < 2^{32}	If "imme" is not true and "tmst" is present, the gateway is commanded to transmit the frame when its internal timestamp counter equals the value of "tmst". Section 6.2.2 contains a description of the gateway timestamp counter.
time	Y	string	UTC time. The precision is one microsecond. The format is ISO 8601 ([3]) 'compact' format. If "imme" is false or not present and "tmst" is not present, the gateway is commanded to transmit the frame at this time.
freq	N	unsigned float, Hz precision	The centre frequency on when the frame is to be transmitted in units of MHz.
rfch	Y	unsigned integer	The antenna on which the gateway is commanded to transmit the frame.
powe	N	signed integer	The output power which what the gateway is commanded to transmit the frame
modu	N	string	The modulation technique to be used: • "LORA", representing LoRa modulation • "FSK", representing FSK modulation
datr	N	string	Datarate identifier. When "modu" equals "LORA", "datr" comprises "SFnBWm", where 'n' is an integer representing the frame's 'spreading factor' and 'm' is an integer representing the frame's bandwidth in units of kHz. When "modu" equals "FSK" "datr" comprises an integer representing the frame's bit rate in units of Hz
codr	Yes, if "modu" equals "LoRa"	string	ECC code rate. "codr" comprises the string "k/n", where 'k' represents the carried bits and 'n' the total number of bits transmitted, including those added by the error checking/correction algorithm. Transmitted only when "modu" equals "LORA"
ipol	Y	bool	If true, commands gateway to invert the polarity of the transmitted bits. LoRa Server sets value to true when "modu" equals "LORA", otherwise the value is omitted.
size	N	unsigned integer	The number of octets in the received frame.
data	N	string	The frame payload, encoded into Base64, [4]. Base64 padding characters shall not be not added.
ncrc	N	bool	If not false, disable physical layer CRC generation by the transmitter.

Table 11: "txpk" elements

6.2.4.1 Example

```
"txpk":
{
    "imme":true,
    "freq":864.123456,
    "rfch":0,
    "powe":14,
    "modu":"LORA",
    "datr":"SF11BW125",
    "codr":"4/6",
    "ipol":false,
    "size":32,
    "data":"H3P3N2i9qc4yt7rK7ldqoeCVJGBybzPY5h1Dd7P7p8v"
}

"txpk":
{
    "imme":true,
    "freq":861.3,
    "rfch":0,
    "powe":12,
    "modu":"FSK",
    "datr":50000,
    "fdev":3000,
    "size":32,
    "data":"H3P3N2i9qc4yt7rK7ldqoeCVJGBybzPY5h1Dd7P7p8v"
}
```

7 Glossary

ASCII: American Standard Code for Information Interchange. A widely used standard for representing Latin text, Arabic numerals and punctuation as binary values.

Base64: A method of encoding binary data into ASCII text. The LoRa system uses Base64 to transport LoRa frames in JSON objects. Base64 is defined by IETF RFC 4648 [4].

CRC: Cyclic Redundancy Check

Cyclic Redundancy Check: A method of detecting transmission errors. CRC is particularly easy to implement and is robust to corruption from inversion of many nearby bits.

dB: decibel; a logarithmic ratio of power. Defined by Bell Laboratories

dBm A logarithmic measure of power, decibel, relative to 1mW

Downstream: Toward the mote

End-device: Synonymous with 'mote'

EUI: Extended Unique Identifier. In this document 'EUI' refers to a value from the 'EUI-64' number space managed by the IEEE.

Firewall: A firewall is a network security system that controls the incoming and outgoing network traffic based on an applied rule set. A firewall establishes a barrier between a trusted, secure, internal network and another network (e.g., the Internet) that is assumed not to be secure and trusted.

FSK: Frequency shift keying. FSK is a modulation technique that encodes each frame bit value using a shift of the carrier frequency.

Gateway: A LoRa gateway transmits LoRa frames to, and receives LoRa frames from, LoRa motes

GWMP: Gateway message protocol. The protocol used to transport JSON objects between the network server and the gateways. GWMP is defined by this document.

IEEE: Institution of Electrical and Electronic Engineers (www.ieee.org).

IETF: Internet Engineering Task Force (www.ietf.org).

IP: Internet Protocol

IP port address An IP address or host name and either a UDP or a TCP port number. This document represents a port address in the form <IP address>:<port number> or <host name>:<port number>. E.g. 1.2.3.4:4500 or a.com:4500.

JSON: JavaScript Object Notation. JSON is a textual based method of representing name, value pairs. The value of an object may itself be a JSON object. Within LoRa, JSON objects contain only ASCII characters.

JSON object A JSON name, value pair.

LoRa: Long Range. Defined by the LoRa Alliance

LoRa Alliance: The industry body that defines the LoRaWAN protocol.

LoRaWAN: The protocol by which a LoRa mote communicates with a LoRa gateway. LoRaWAN is defined by the LoRa Alliance [5]

Metadata: LoRa Metadata refers to information about the transmission or reception of a LoRa frame.

Mote: A LoRa end device. A LoRa mote communicates with a LoRa Gateway using the LoRa MAC or LoRa WAN protocol.

NS: The LoRa network Server

RSSI: Received Signal Strength Indication. The power of the received signal, normally measured in dBm.

Rx: Receive

Signal quality: The signal quality is normally measured in dBm and is the sum of the SNR (measured in dB) and the RSSI (measured in dBm).

SNR: Ratio of signal power to noise power, normally measured in dB.

Spreading factor: A parameter of a LoRa transmission. Two to the power of 'spreading factor' 'on the air' bits are transmitted to represent each frame bit.

Thread: An independent path of execution within a process. The threads of a process share access to memory within the process.

Tx: Transmit

UDP: User Datagram protocol: a simple protocol for transporting data messages. Delivery is not guaranteed. In addition the order of receipt is not necessarily the same as the order of transmission.

upstream: Away from the mote

UTC Co-ordinated Universal Time; also known as Greenwich Mean Time and Zulu

8 References

Each trademark is the property of its owner.

[1] J. Postel, “User Datagram Protocol RFC 768,” 28 August 1980. [Online]. Available: https://www.ietf.org/rfc/rfc768.txt.

[2] ECMA International, The JSON Data Interchange Format, 2013.

[3] ISO, *ISO 8601:2004 Data elements and interchange formats -- Information interchange -- Representation of dates and times,* 2004.

[4] IETF, “The Base16, Base32, and Base64 Data Encodings,” October 2006. [Online]. Available: https://www.ietf.org/rfc/rfc4648.txt.

[5] LoRa Alliance, “LoRaWAN Specification,” LoRa Alliance, 2015.

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Contact Information

Semtech Corporation
Wireless Sensing and Timing Products Division
200 Flynn Road, Camarillo, CA 93012
Phone: (805) 498-2111 Fax: (805) 498-3804
E-mail: support_rf_na@semtech.com
Internet: http://www.semtech.com