International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14, Number 2, 2019 (Special Issue)

Performance Evaluation of LoRaWAN with Decreasing RSSI Values

Ms. Shivi Mangal
B.Tech Final Year, Department of Electronics,
Banasthali University, Niwai - Jodhpuriya Road,
Vanasthali, Rajasthan, India.
[Affiliation -University Grants Commission]

Dr. Ketan Rajawat
Assistant Professor, Department of Electrical Engineering,
Indian Institute of Technology, Kalyanpur,
Kanpur, Uttar Pradesh, India.

Abstract
The vision of a world with the Internet of Things (IoT) requires a large number of sensor nodes connected to each other and a network that can handle them accordingly. Techniques to save energy have gained popularity as a research trend because wireless sensor networks use energy limited devices. Considering a large number of nodes connected to the Internet, issues like bandwidth latency and range coverage are important features of IoT. Thus, a low power, long range and low bit-rate protocol for the data link layer known as LoRaWAN seems to be an apt solution for IoT. Here the nodes use LoRa to communicate with gateways. LoRaWAN protocol can solve the problems of connectivity by connecting tens of billions of devices to the internet. Although a large number of other LPWAN technologies are becoming popular, this paper focuses on the performance evaluation of LoRaWAN protocol. LoRa has a lot of scope of research in the current scenario. Some use cases have been considered and open issues have been discussed in the paper. The main objective is to make LoRa a viable communication technology for long-range applications.

Keywords: LoRaWAN, LoRa, Internet of Things, performance evaluation, energy, LPWAN

Introduction

Low–Power, Wide-Area Networks (LPWAN) are projected to solve a major connectivity issue of the billions of devices connected for the Internet of Things (IoT). LoRaWAN is designed to optimize LPWANs for larger battery life, capacity, coverage, and low-cost [1]. A single technology cannot fit for all applications of IoT. Wi-Fi and Bluetooth are a great fit for applications related to communication between personal devices. Cellular technology is a widely adopted standard for applications that need high data rate and have a power source. LPWAN is ideal for applications that need to send low bit rate data over a long range. Thus, it offers a multi-year battery lifetime [2]. LoRa is the first low-cost implementation of this modulation for commercial usage.

LoRaWAN is a MAC protocol which is built on LoRa, a physical layer which is utilized to create a long-range communication link. It is ideal for applications that need to send low bit rate data over a long range at relatively long intervals of time (one transmission per hour or even days). LoRaWAN has a link budget which is greater than any other communication technology. But the range greatly depends upon the construction and environment in the area [2]. The link budget is the primary factor which determines the range in a given region.

LoRaWAN Overview

LoRa is the physical layer which is utilized to create a long-range communication link while the system architecture and communication protocol for the network is defined by LoRaWAN [3]. The network architecture and protocol used have the most influence in determining the battery life of the end device, the capacity of the network, the QoS (quality of service), the security, and applications served by the network [4].

This section describes the LoRaWAN V1.0 specification [5], as released in January 2015.

Network Architecture

Mesh network architecture is utilized by many of the existing deployed networks. In a mesh network, the information of the individual nodes is forwarded by the other nodes in order to increase the cell size and the communication range of the network. In addition to increasing the range, it also adds complexity, reduces network capacity, and reduces battery lifetime of the nodes as fording data of other nodes is irreverent for them. Thus, long range star architecture is preferred for networks which need large battery lifetime and long-range connectivity [6].

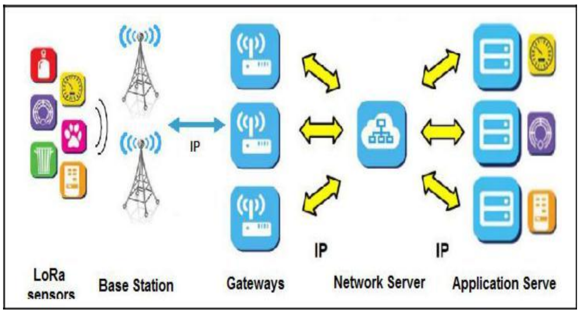

Figure 1: LoRaWAN network architecture

In a LoRaWAN network, the end devices are not connected to any particular gateway. Instead, data transmitted by an end device is received by a number of gateways. Each gateway then forwards the received packet from the end-node to the network server via some backhaul (either cellular, Ethernet, satellite, or Wi-Fi). The network server manages the complexity and filters the redundant received packets, performs security checks, schedules acknowledgments through the optimal gateway, and performs adaptive data rate [7].

LoRaWAN Message Format

The physical frame format used by LoRaWAN is shown in Fig. 2 and is detailed in Fig. 3. Downlink messages have the header, but may or may not have the CRC. While both the header and CRC are mandatory for uplink messages. The code rate and the low rate optimization used by the end-devices are not specified [8].

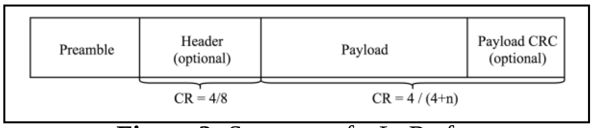

Figure 2: Structure of a LoRa frame.

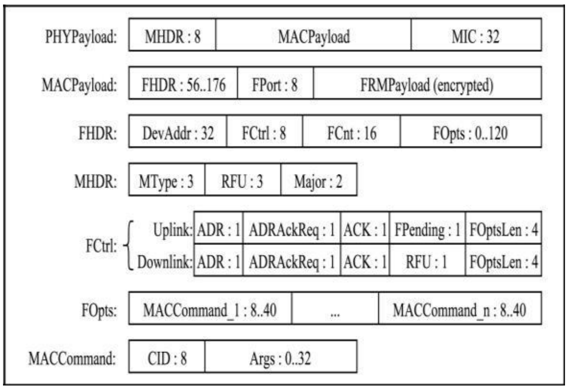

Figure 3: LoRaWAN frame format. The size of the fields is in bits.

Security

To ensure that the end devices operate without any external interruption, the security plays an extremely important role for the future IoT networks. LoRaWAN considers two layers of security, one at the application level and another at the network level [1]. The LoRaWAN network has an authentication framework and a security framework based on the AES-128 (Advanced Encryption Standard) encryption scheme. The AES-128 encrypts the frame for confidentiality and generates a MIC (Message Integrity Code) for integrity. The application owners or device manufacturers assign keys to each end device. Other LPWAN technologies use a single key for encryption as well as authentication, compared to LoRaWAN. Authentication of packets and integrity protection is ensured by LoRaWAN since it uses different keys for authentication and encryption [2].

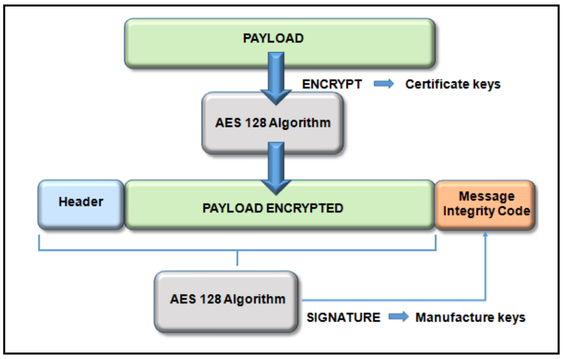

Figure 4: AES-128 encryption schemes

Methodology and Experimental Setup

Components of a LoRaWAN Network

The following components are required to form a LoRaWAN network as defined in the LoRaWAN specification: end-nodes, base stations (i.e. gateways) and the network server.

- End-Nodes: The end-nodes are the low-power end devices that communicate to the gateway via LoRaWAN.
- Gateway: The gateways are the non-intelligent devices that forward the packets received from the end-devices to the network server via some IP backhaul interface such as cellular data, Wi-Fi or Ethernet. A LoRa deployment can have a number of gateways and a single can be can be received and forwarded by more than one gateway
- Network server: The network server manages the complexity and filters the redundant received packets, performs security checks, schedules acknowledgments through the optimal gateway, and performs adaptive data rate.

End Device Setup

Every end device communicating in LoRaWAN network must be activated. It can be done in the following two ways: Over-The-Air Activation (OTAA) and Activation by Personalization (ABP).

Before the activation process starts, an end-device must have the following information:

- DevAddr (End-device address): It is a unique 32-bit identifier of the end-device. The network identifier is defined by the first seven bits and the other 25 bits define the network address of the end-device.

- AppEUI (Application Identifier): The owner of the end device is uniquely identified by a global application ID in the IEEE EUI64 address space.

- NwkSKey (Network session key): To ensure the data integrity of all the messages transmitted between the end device and the network server, this key is used.

- AppSKey (Application session key): To encrypt and decrypt the payload field of data messages, this key used by the network server and end-device.

Experimental Architecture

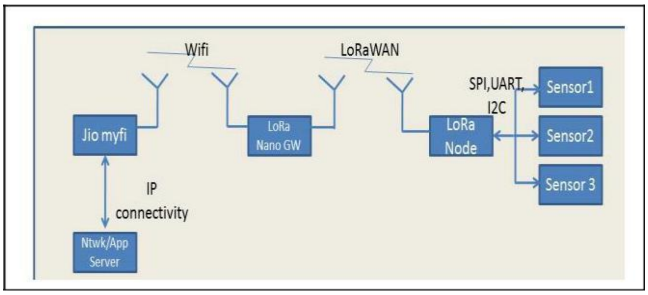

Figure 5: LoRaWAN Experimental Architecture

The setup uses two LoPy modules, one programmed as the nano gateway and the other programmed as the node. The gateway is connected to the internet through a Wi-Fi device which in turn connects it to a LoRa server which acts as the network server. This connection uses IP connectivity on the backend. On the other end, the node may be connected to a number of sensors. The communication between the sensors and the node is wired. The sensors transfer the information to the node via the UART protocol. The communication between the node and the gateway uses the LoRaWAN protocol checks, schedules acknowledgments through the optimal gateway, and performs adaptive data rate [9].

Experimental Setup

In order to evaluate the performance of LoRaWAN with decreasing RSSI, the setup is modified using two attenuators and a metal foil. The two attenuators were placed in series on the transmitter end and the metal foil was used on the receiver end. The modified setup is shown in Figure 6.

The attenuators used are variable attenuators. Both are capable of working within a range of 9 kHz to 3 GHz. The attenuator 1 has values that can vary between 0dB to 70dB and attenuator 2 has values that can vary between 0dB to 120dB.

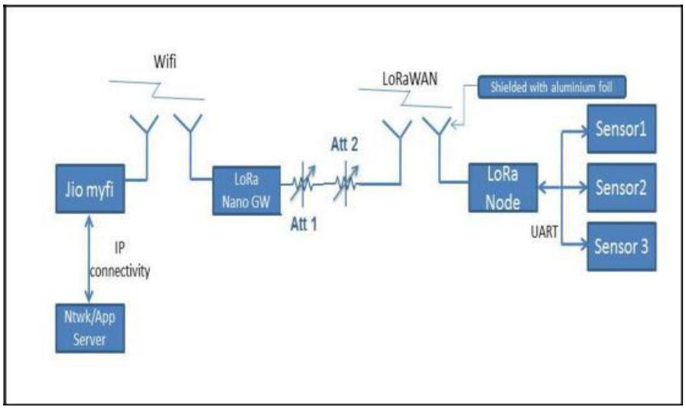

Figure 6: Experimental setup for the evaluation of performance with decreasing RSSI values

Experimental Observations

The following values were observed by reducing the RSSI values and packet loss is seen.

The parameters are as follows:

- Data rate=5
- Spreading factor= 7
- Packet size=51 bytes
- No of packets=60
- Periodicity=2 sec
- Frequency= 866100000
- The distance between antennas= 2.5m to 3m

Table 1: Observation Table When Antenna Is Open

S.No.	Avg RSSI	Min RSSI	Max RSSI	Packets Lost	No. of Packets Lost
1	-68.01	-70	-66	-	-
2	-69.24	-70	-68	1f,22,27	3
3	-69.02	-71	-68	-	-
4	-69.7	-70	-68	09,16	2
5	-68.18	-68	-67	-	-
6	-69.78	-71	-68	34	1
7	-70.94	-72	-69	1f,38	2
8	-70.80	-72	-70	-	-
9	-70.76	-72	-70	13	1
10	-68.62	-72	-67	-	-
11	-70.84	-72	-70	-	-
12	-72.22	-74	-70	-	-
13	-69.46	-71	-68	-	-
14	-68.52	-70	-67	-	-
15	-68.68	-71	-67	36	1

Table 2: Observation Table When Antenna Is Covered

S.No.	Avg RSSI	Min RSSI	Max RSSI	Packets Lost	No of Packets Lost
1	-97.44	-103	-95	07	1
2	-97.26	-99	-96	-	-
3	-99.46	-102	-96	-	-
4	-100.96	-102	-100	-	-
5	-100.02	-101	-98	-	-
6	-99.28	-102	-98	-	-
7	-99.24	-100	-98	-	-
8	-96.74	-98	-96	-	-
9	-99.36	-101	-97	-	-
10	-98.54	-106	-95	2A,2B	2
11	-100.16	-103	-98	05	1
12	-99.64	-102	-96	14,2C	2
13	-97.9	-100	-96	2D	1
14	-96.16	-99	-95	0D,31,33	3
15	-98.04	-99	-97	04,07	2

Table 3: Observation Table When Both Antennas are covered

S.No.	Avg Rssi	Min RSSI	Max RSSI	Min SNR	Max SNR	Packets Lost	No. of Packets lost
1	-114.38	-119	-110	-4.0	3.0	21,24,25,32,35	5
2	-113.5	-122	-109	-5.0	4.0	03,04,05,07,0C,0D,0E, 12	8
3	-115.18	-121	-111	-5.0	3.0	2D,2E,2F,30,31,32,34,35,36,37,38,39	12
4	-113.94	-120	-109	-4.0	4.0	07,0A,0C,1D,1E,21,28, 29,2E,31,32,33,38,39,3B	15
5	-113.88	-120	-111	-4.0	3.0	01,02,03,05,14,15,20, 21,22,23,24,25,2F,30,3538,3B	17
6	-115.3	-122	-108	-6.0	5.0	05,13,15,18,19,1C,1E,1F,20,26,34,39	12
7	-112.28	-121	-106	-5.0	5.0	04,05,06,08,09,10,11, 13,18	9
8	-108.1	-111	-106	3.0	5.0	-	-
9	-110.68	-113	-109	1.0	4.0	2F	1
10	-113.06	-116	-111	-1.0	3.0	29	1

Results And Discussions

With decreasing RSSI values, the performance of LoRaWAN is seen to decrease. The SNR is lowered and the packet loss frequency is increased. The attenuation was introduced to physically realize the large distance between the node and the gateway, this shows that increasing the distance between the end device and the gateway beyond a specific value can result in loss of data and poor performance.

Future Scope

Since LoRaWAN is a new protocol, its security level is not fully studied and thus cannot be guaranteed in practice. There is ample room for improvements in LoRaWAN security study. For vulnerability of LoRaWAN, it is possible that there are still different kinds of attacks towards the protocol. This is because LoRa device development is still at a very early stage, and mass production for LoRaWAN devices is not launched yet. With the development of LoRaWAN and LoRa devices, the protocol flaws in class B and class C communications should also be analyzed. Besides LoRa security, another possible advancement is to consider the influence of large scale LoRaWAN deployment. In a large scale LoRaWAN deployment, the number of end devices and gateways will increase, and different scenarios, like overlapping, collisions and gateway capacity will need to be taken under consideration.

Conclusion

LoRa is a long-range, low-power and low bit-rate telecommunication protocol for the Internet of Things. The physical layer uses the LoRa modulation, proprietary technology with a LoRaWAN MAC protocol. An experimental setup has been built, to experimentally study the network performance, documented in this paper. The results show that LoRa modulation offers good resistance to interference. Experiments show that LoRa can offer satisfactory network coverage. The spreading factor has a significant impact on network coverage and so does the data rate. LoRa is thus well suited for low-power, low-throughput, long-range and low bit-rate networks.

References

[1] LoRa Alliance. White Paper: A Technical Overview of Lora and Lorawan; The LoRa Alliance: San Ramon, CA, USA, 2015.

[2] J. de Carvalho Silva, J. J. P. C. Rodrigues, A. M. Alberti, P. Solic and A. L. L. Aquino, "LoRaWAN — A low power WAN protocol for an Internet of Things: A review and opportunities," 2017 2nd International Multidisciplinary Conference on Computer and Energy Science (SciTech), Split, 2017.

[3] Rathod N., Jain P., Subramanian R., Yawalkar S., Sunkenapally M., Amrutur B., Sundaresan R. "Performance analysis of wireless devices for a campus-wide iot network;" Proceedings of the 2015 13th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt); Mumbai, India. 25–29 May 2015

[4] Centenaro M., Vangelista L., Zanella A., Zorzi M. "Long-Range Communications in Unlicensed Bands: The Rising Stars in the IoT and Smart City Scenarios," 2015.

[5] LoRaWAN Specification V1.1. LoRa Alliance, 2017

[6] Bor, M.; Vidler, J.E.; Roedig, U. "Lora for the Internet of Things." In Proceedings of the 2016 International Conference on Embedded Wireless Systems and Networks (EWSN '16), TU Graz, Austria, 15–17 February 2016

[7] Lavric, Alexandru and Valentin Popa. "Internet of Things and LoRa™ Low-Power Wide-Area Networks: A survey." 2017 International Symposium on Signals, Circuits, and Systems (ISSCS) 2017.

[8] Kim D.H., Jo JS, Lee EK. (2019) "Performance Evaluation of LoRaWAN on Campus Environment." In: Hwang S., Tan S., Bien F. (eds) Proceedings of the Sixth International Conference on Green and Human Information Technology. ICGHIT 2018. Lecture Notes in Electrical Engineering, vol 502. Springer, Singapore

[9] U. Noreen, A. Bounceur and L. Clavier, "A study of LoRa low power and wide area network technology," 2017 International Conference on Advanced Technologies for Signal and Image Processing (ATSIP), Fez, 2017.