URSI GASS 2021, Rome, Italy, 28 August - 4 September 2021

LoRaWAN Networks: a More Precise Assessment of the Energy Consumption

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Abstract

In this paper, we evaluate the network energy consumption (NEC) of a LoRaWAN network based on the pure ALOHA protocol. First, we define a reference scenario, which limits the energy consumption to the energy consumed by the radio transceiver. Then, we consider a second scenario in which we add to the energy consumption the energy consumed by the different operation modes of the end-devices after transmission of a packet. Finally, we simulate and compare the energy consumption of both scenarios. Our simulations results show that the energy consumption increases significantly when considering the different operation modes of the end-device.

1 Introduction

With the digitalization of everyday life and the proliferation of Internet of Things (IoT), new radio technologies called Low Power Wide Area Networks (LPWAN) have been emerged to meet connectivity requirements for a massive number of devices [1]. One of the most promising LPWAN technologies is Long Range (LoRa) [2] which is the physical layer of LoRaWAN networks [3]. Although LPWAN technologies are being adopted, their actual capabilities and performances are yet to be investigated and analyzed. As a result, several works have been carried out in the past few years, focusing on MAC protocols in order to improve the performance of the LoRaWAN network in terms of scalability and energy consumption. For example, authors in [4] showed how a simple enhancement of LoRaWAN based on a MAC Carrier Sense Multiple Access (CSMA) protocol can reduce the number of collisions and the energy consumption for high-capacity networks compared to the pure ALOHA protocol used by default. Further, in [5] and [6] authors studied the performances of LoRa based IoT applications regarding network throughput and power consumption. Finally, the authors in [7] show that using several sinks and dynamic configurations of communication parameters can leverage scalability issues and reduce network energy consumption. In this context, this paper focuses on the aspect of energy consumption of a LoRaWAN network which is by default based on pure ALOHA channel access method. More specifically, this paper analyzes the energy consumption related to the data traffic and the states of LoRa end-devices. We show by simulation that the energy consumption depends on the states of the end-devices. Indeed, a more precise evaluation of the energy consumption is achieved when considering the different states of the end-device. The rest of this paper is organized as follows. Section 2 gives an overview of the system model. Section 3 presents the simulation results obtained by using LoRasim simulator. Finally, section 4 draws the conclusion.

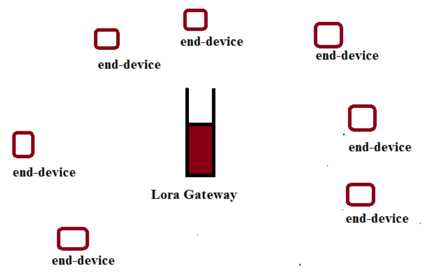

Figure 1. LoRaWAN Network Architecture.

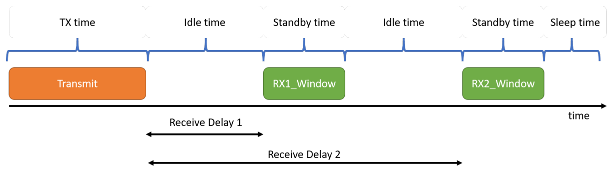

Figure 2. Channel Access for LoRaWAN Class A End-devices.

2 System Model

As shown in Fig. 1, LoRaWAN networks are deployed using access gateways to connect a very large number of LoRa end-devices to a remote and centralized Network Server (NS). End-devices are battery powered, randomly distributed in the region of interest and utilize LoRa modulation for data transmission. LoRaWAN channel access method is based on ALOHA protocol. The specification defines three modes of operation corresponding to three end-device classes, namely class A, class B and class C. However, for the sake of simplicity we only consider class A type of devices which is the default mode of operation. As shown in Fig. 2, for class A devices each uplink transmission is followed by two short receive windows for downlink data transmission.

2.1 Energy Consumption Metric

Many IoT deployment scenarios involve battery powered end-devices. To assess the performances of end-devices, it is necessary to evaluate the energy consumption of the network. Therefore, we define the Network Energy Consumption (NEC) as the energy consumed by the network to successfully retrieve the messages sent by all end-devices in the region of interest. This leads to :

$$NEC = \sum_{i=1}^{N} \sum_{p=1}^{N_p^i} Ec_p^i. \tag{1}$$

where N is the number of end-devices, N_p^i refers to the number of transmitted packets by an end-device i and Ec_p^i is the energy consumption related to the packet p sent by end-device i. This NEC metric is then used to study the performances of the network. For instance, a low value of the NEC metric leads to an efficient network deployment since end-devices autonomy will be longer.

2.2 Energy Consumption Scenarios

The evaluation of the energy consumption of the packet is generally limited to the energy consumed by radio transceivers [7]. However as shown in Fig. 2, each packet transmission is followed by two receive windows which leads to an additional energy consumption. Therefore we define two simulation scenarios to study the impact of the end-device operation modes on the energy consumption.

First, we define a reference scenario (*scenario 0*) in which the energy consumption of a packet in (1) is only given by the energy consumed by the transceiver :

$$Ec_p^i = E_{Tx}{}_p^i \tag{2}$$

Where E_{Tx} is the energy consumption of the transceiver related to a transmitted packet.

Based on this reference scenario, we define a second scenario (*scenario 1*) in which the energy consumption of a packet is calculated based on the different operation mode of the end-devices. As shown on Fig 2, these modes are idle, sleep and standby mode. This leads to :

$$Ec_p^i = E_{Tx}{}_p^i + E_{idle}{}_p^i + E_{stb}{}_p^i + E_{sleep}{}_p^i \tag{3}$$

where E_{idle}, E_{stb}, E_{sleep} are the energies consumed in idle, standby and sleep operation mode respectively.

3 Simulation and Results

Simulations are performed with the LoRaSim simulator tool [7] with the following settings. End-devices transmit a 20 byte packet (SF12, BW125, CR4=8) every 106 ms and are placed at a random distance from a single gateway in an area of 3.8 ha. The number of end-devices varies from 100 to 1600 by a step of 100. The simulation time is set to a period of 58 days.

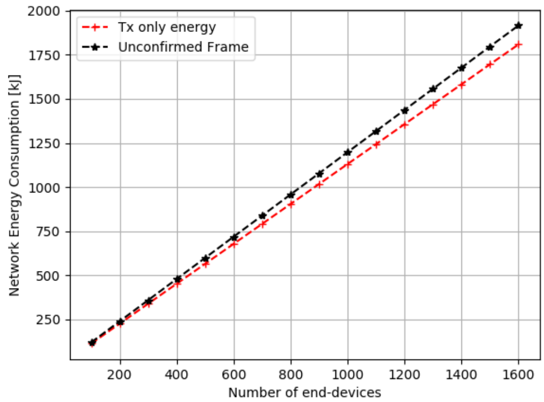

Figure 3. Evolution of NEC as a function of the number of nodes for scenario 0 and scenario 1.

Fig. 3 shows the evolution of the NEC as a function of the number of nodes in the region of interest. Results are presented for *scenario 0* (Tx energy only) and for *scenario 1* (Unconfirmed Frame). It can be seen that as the number of nodes increases, the NEC metrics increases as well. However, it can be observed that *scenario 1* leads to a higher energy consumption when the number of nodes increases. For example, with 1600 end-devices, the NEC is approximately 1917 kJ for *scenario 1* and 1809 kJ for *scenario 0*, i.e. a difference of 108 kJ. Actually, this additional energy consumption is related to the energy consumed by the end-devices in the different operation modes. Consequently, it is obvious that a more precise evaluation of the energy consumption should include the energy consumption generated by the different operation mode of end-devices. Finally, note that these operation modes also depend on the LoRaWAN end-device classes.

4 Conclusion

In this paper we evaluated the network energy consumption (NEC) of a LoRaWAN network based on the pure ALOHA radio channel access protocol. Our goal was to highlight the impact of the operation modes of the LoRa end-devices on the energy consumption metric. We then defined two simulation scenarios that allow us to show the impact on the NEC. Simulation results showed that the NEC increases when the different end-devices operation modes are considered. As a result, it is crucial to consider the different end-devices operation modes for a more precise evaluation of the energy consumption. This should allow a better prediction of the end-devices battery life.

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