Assessing the Impact of Mobility on LoRa Communications

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Abstract. The use of LPWAN (Low Powered Wide Area Network) technologies in the scope of the Internet of Things have become the best alternative to send data between devices and cloud systems. Among these technologies, LoRa stands out as a novel and promising system that could be used in areas with a high device density, and in locations where other technologies do not provide enough communications range. In the past, most research works have made experiments in static scenarios, without taking the mobility of the things into account.

Our research is focused in analyzing the impact that mobility will have in LoRa communications performance, with the objective to determine the adequacy of this technology for vehicular scenarios oriented to data sensing, or in applications where small pieces of data are transmitted over long distances.

Experimental results show that both the mobility and the message size affect LoRa communications, despite still allowing to reach an acceptable coverage range.

Keywords: LoRa · Long range communications · Internet of Things
Sensors

1 Introduction

The Internet of Things (IoT)[1] is a novel paradigm where massive data collection and analysis has become a hot topic, especially when we are selecting the data transmission system to be adopted. Among the most widely used technologies, a few stand out, including WiFi, Bluetooth, NB-IoT, CAT-M1, and cellular communication. It is hard to choose the best option because one solution can achieve a good performance in a specific case, but perform poorly in other situations.

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[1] www.internet-of-things-research.eu.

G. Fortino et al. (Eds.): InterIoT 2017/SaSeIoT 2017, LNICST 242, pp. 75–81, 2018.
https://doi.org/10.1007/978-3-319-93797-7_10

In most of the cases, the short data messages generated by IoT devices derive from sensors mounted on such devices, and must meet different requirements in terms of communications performance, including long range, low power consumption, and low cost. As an example of solutions where sensor data is remotely retrieved, authors in [1] selected vehicles that, combined with fixed nodes located at strategic places, allow the data acquisition range to be extended. More recently, Alvear et al. [2] proposed a more sophisticated implementation where flying drones are used for sensing tasks. The above alternatives aim at addressing the sensor location problem, especially when the distances involved are high. There is a set of implementations and protocols named LPWAN (Low Powered Wide Area Network) [3,4] that accomplish and offer these requirements. In this group of technologies we can find SigFox, Random Phase Multiple Access (RPMA), Weightless, and the new technology LoRa (Long Range). Notice that only some of these are proprietary, while others are open source. LPWAN systems are currently the best alternative for sensing applications in dense locations where long term monitoring is necessary, sending small data packets in a wide area, and preserving battery life for a long period of time; these features are the differentiating factor between LPWAN and any other kind of wireless network.

In this paper we focus on the LoRa technology [5], which has been designed to transmit small data packets at large distances. In fact, according to the authors in [6], the transmission range can reach up until 50 km in rural areas if line of sight conditions are met, and up to 2 km in urban areas. In this work, we analyze the LoRa transmission range in both stationary and mobile environments. The rest of this paper is organized as follows: in Sect. 2 we refer to related works. An overview of LoRa is provided in Sect. 3. The testbed used in this work is presented in Sect. 4, and the obtained results are then discussed in Sect. 5. Finally, Sect. 6 presents the conclusions and refers to future work.

2 Related Work

Since LPWAN solutions emerged as an enabling technology allowing "things" to communicate, several researchers have focused their efforts on studying and improving these technologies. In [7] authors provide a detailed description of LPWAN, highlighting the advantages and disadvantages of this new model for IoT, and characterizing it in terms of efficiency, effectiveness, and architectural design for typical smart city applications.

In [8] the authors refer to it merely as LPWA (avoiding the network concept associated to the "n"). They offer a comparison between this type of protocols from a machine-to-machine (M2M) communications perspective, finding that this type of data transmission solutions is a potential candidate in ubiquitous computing contexts. Furthermore, they provide examples about specific scenarios where LPWA could be applied.

In the scope of LPWAN protocols, LoRa is a novel promising member, and many authors have analyzed this IoT-related solution from different points of view. For instance, in [9], authors evaluate the physical and data link layers of the LoRa technology through both field tests and simulations, proposing some improvements.

In [10], LoRa is adopted for sensing applications where the researchers tested the LoRa and LoRaWAN communications in urban areas with a high building density and irregular topography conditions. Using devices mounted in Raspberry and Arduino boards, the results show that, by using multiples gateways, the signal can span over certain areas that other radio technologies are unable to reach. A similar experiment is made in [11,12], where the authors analyze the LoRa properties in both indoor and outdoor scenarios, exploring how the environment affects its core communication properties. The result obtained is better than other alternatives that offer data transmission for alerts or sensing.

Overall, we find that there are many exciting research studies about LoRa, and in all of them the authors highlight both the benefits and the limitations of this novel technology. It is also worth pointing out that most of these articles have focused on data transmission under stationary conditions. In our research instead we present the results achieved when LoRa transmissions are performed under mobility conditions, and taking into account both the transmitter-receiver distance and the actual speed. Our ultimate goal is to determine the feasibility of adopting LoRa as a vehicular communications technology.

3 LoRa Technology Feature

LoRa is a LPWAN (Low–Power Wide-Area Networks) designed to optimize different aspects such as communication range, battery lifetime, and costs, supporting thousands of devices headed for the Internet of Things in several domains such as sensing, metering, and machine-to-machine (M2M) communications.

Theoretically, LoRa achieves a transmission range of more than 15 km in rural environments, and more than 2 km in dense urban zones. Its bandwidth ranges between 250 bps and 50 Kbps in different frequencies: 169 MHz, 433 MHz, and 868 MHz in Europe, and 915 MHz in North America.

LoRa Technolgy significantly increases the communications range thanks to the chirp spread spectrum modulation technique adopted. This communication system has been used in military activities for several years due to the long transmission distances that can be achieved, and also due to their robustness to interference.

The LoRa Spreading Factor is the "duration of the chirp" operating at various levels, from SF7 to SF12, where each level doubles the "duration" to the previous one, causing the bitrate to vary from 250 bps to 5.47 Kbps for a bandwidth of 125 kHz.

In this work, we are interested in long-range communications in vehicular networks. Low power is a bonus, but it is not a substantial requirement for our target application since in vehicular scenarios energy is not a critical factor.

4 Experimental Setup

In this section we detail the experiments undertaken using a LoRa-based data communications system under diverse mobility conditions. Our purpose is to determine to which degree do speed and distance affect data transmission. To achieve it, we analyze the transmission between a gateway and a mobile node using LoRa.

Fig. 1. Test architecture.

Figure 1 provides an overview of the testbed we have used. As shown, we have acquired Pycom modules[2] for our experiments. Both devices have nearly the same features. As a static gateway we configured a Pysense expansion board including a LoPy module and SD memory. Since we are interested in determining the impact of mobility on communications performance, the second device works as a mobile node that is equipped with a GPS receiver (Pytrack expansion board).

In our tests, we locate a gateway (Pysense equipped with a LoPy module) in a fixed position (39.480590 −0.346855, next to Universitat Politecnica de Valencia). To analyze how the speed affects the packet delivery ratio, we install the mobile node in a vehicle moving along the Tarongers Avenue (Valencia, Spain) under medium-high traffic levels, and at speeds up to 60 km/h, as shown Fig. 2.

In the gateway, we store all the data received from the mobile node, and in the mobile node we send and store two message types: (i) a large message - 30 bytes -, with an identifier and the GPS position, and (ii) a short message - 3 bytes -, carrying the identifier alone.

The LoRa radio configuration depends on the application scenario to be implemented. The most relevant configuration parameters are the Spreading Factor, the power, and the bandwidth. In our experiments, the power was set to the maximum value, the bandwidth to 125 MHz, and the Spreading Factor was changed from the minimum value 7 (recommended for short distance line-of-sight propagation), up to the maximum value 12 (for large distances and non-line-of-sight scenarios). In our experiments, we vary these parameters to determine what is the most optimal setting when operating under mobility. In the next section we describe the experiments made, and discuss the achieved results.

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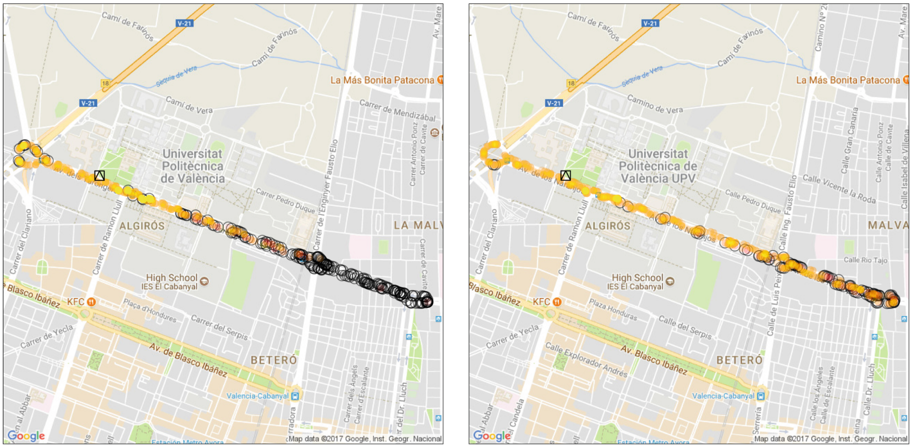
[2] www.pycom.io.



(a) Spreading Factor 7.

(b) Spreading Factor 12.

Fig. 2. Delivered (colored points) and lost (black circles) packets for different values of the Spreading Factor. (Color figur online)

5 Mobility Test and Results

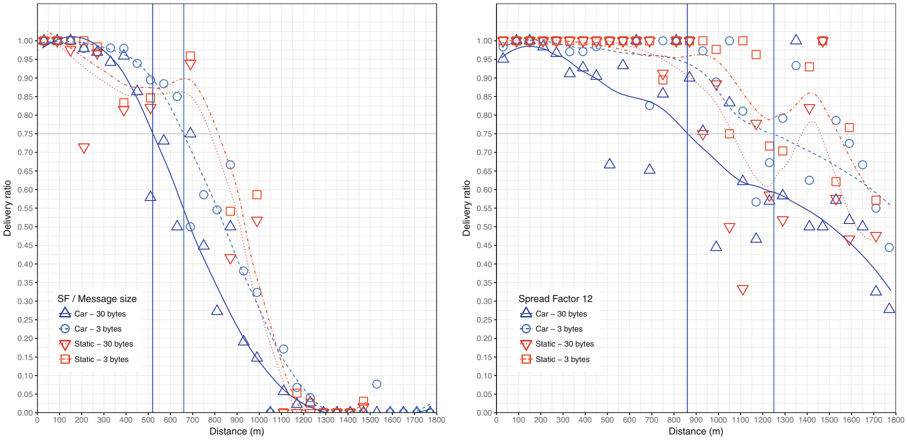
In this section we present the LoRa performance results achieved under different conditions.

Figure 2 shows two maps that illustrate packet loss (black circles) and packet reception (colored points) when using a Spreading Factor of 7 (see Fig. 2a), or when using a Spreading Factor of 12 (see Fig. 2b). It becomes clear that a high Spreading Factor increases robustness when distances are high, as expected according to theory.

Figure 3 presents the analysis of the delivery ratio versus distance between Gateway and Node. Figure 3a shows the delivery ratio behaviour of the node installed in the vehicle (moving up to 60 km/h) when a Spread Factor of 7 is used. To analyze the impact of mobility on the packet delivery ratio, the figure also shows the delivery ratio with a static node at different distances, and for both message sizes (large -30 bytes-, and short -3 bytes-). We can observe that higher degrees of mobility cause the delivery ratio to be degraded. Moreover, the message size affects the maximum coverage area. The maximum range at which the delivery ratio remains higher than 75% is 520 m and 660 m for message sizes of 30 bytes and 3 bytes, respectively.

In Fig. 3b we make a similar results analysis when adopting a Spreading Factor of 12. We find that the results are similar: both message size and mobility have an impact on the LoRa range, achieving up to 860 m and 1250 m for message sizes of 30 bytes and 3 bytes, respectively.

In general we find that, as expected, using a Spreading Factor equal to 12 allows achieving better results than a Spreading Factor of 7, but its bit rate is much smaller: 250 bits/s against 5470 bits/s. Also, when using the Spreading



(a) Spreading Factor 7. (b) Spreading Factor 12.

Fig. 3. Delivery ratio vs. range comparing: (i) Car (60 Km/h) and large messages, (ii) Car (60 Km/h) and short messages, (iii) Static and large messages, and (iv) Static and short messages for different values of the spreading factor.

Factor of 12, the loss variability is much higher than when using a Spreading Factor of 7.

It is worth pointing out that our objective was to analyze the performance of LoRa in a real urban scenario, and so the tests were made in an avenue with medium-high traffic levels, including an abundant number of cars, buses and trains moving along the avenue, which cause the loss rate levels and the variability to increase. Under ideal conditions, without line-of-sight obstructions, much better results are expected.

6 Conclusions and Future Work

In this paper we evaluated the combined use of LoRa communications with mobility to determine its applicability to vehicular networks in urban scenarios. Specifically, we wanted to determine the impact of the data size, the covered distance and the receiver speed on the packet delivery ratio. We found that both mobility and message size deteriorate the Lora performance. In addition, we changed the Spreading Factor in the LoRa devices, and found that the Spreading Factor provides a trade-off between transmission rate and packet loss.

Based on the obtained results, we conclude that the applicability of the LoRa technology in vehicular sensing scenarios is feasible as long as suitable parameters are set in the LoRa radio configuration. Our future work is focused in analyzing the performance of LoRa in different scenarios, and to perform exhaustive vehicular network simulations.

Acknowledgments. This work was supported by the *Ministerio de Economía y Competitividad, Programa Estatal de Investigación, Desarrollo e Innovación Orientada a los Retos de la Sociedad, Proyectos I+D+I 2014*, Spain, under Grant TEC2014-52690-R, the *Generalitat Valenciana*, Spain, the Secretaría Nacional de Educación Superior, Ciencia, Tecnología e Innovación del Ecuador (SENESCYT), the Universidad de Cuenca, and the Universidad Laica Eloy Alfaro de Manabí, Ecuador.

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