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Performance evaluation of LoRaWAN technology in campus of Thies University

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Abstract With the growth of the Internet of Things (IoT), LPWAN technology becomes more and more popular. LPWAN networks are well designed for large-scale IoT deployment due to low power consumption and long-range wireless communications especially in urban and metropolitan areas. A large number of devices typically communicate directly to a sink node which forwards packets to a remote server for specific treatments. In the context of large-scale deployment, LoRaWAN is one of the preferred technologies due to its simplicity and flexibility. LoRaWAN has generated a lot of interest by the scientific community these recent years. Thus, this paper presents performance evaluation of LoRaWAN technology in campus of University of Thies (Senegal). Lo-Ra is used to create a local network where parameters such as Spreading Factor, delivery ratio and packet loss are analyzed. Results show that LoRa is adapted for communications in a wide area such as a campus over certain conditions.

Keywords Internet of things, LoRa, WSN, ADR, Performance evaluation

1. Introduction

Internet of things has allowed the development of a set of services and applications such as Smart Cities. Short range wireless technologies like IEEE 802.11 consume much energy while long range technologies like GSM (Global System for Mobile Communications) are too expensive and not suitable for IoT applications. Therefore, Low-Power Wide Area Networks (LPWAN) defines a category of wireless communication technologies that have recently gained significant improvement for realistic deployment. These LPWAN networks provide low power consumption and long range transmission that are adapted for applications in Internet of things. LoRa is an emerging LPWAN technology that is widely deployed and is considered by many industries as a base for their IoT applications. LoRa provides a wide choice of options such as center frequency, spreading factor, bandwidth, coding rates from which a transmitter can choose to improve transmission quality. It also uses unlicensed bands Industrial, Scientific and Medical (ISM) and enables power efficient wireless communication over very long distances. However, given the fact that a large area is covered, and all devices and should communicate directly to a sink node, the question of performance evaluation of LoRa arises. This paper presents a field study concerning the performance evaluation of LoRaWan technology for data communication which is conducted at the Campus of the University of Thies in Senegal. The campus covers an area of 64 hectares. The remaining of the paper is organized as follows: Section II gives an overview of LoRa technology. Section III presents the related work. Section IV depicts implementation. Section V details the simulations and analyses the performances. Finally, section VI presents the conclusion and future works.

2. Related works

Several recent related works have sought to evaluate the performance of LoRa net-works using analytical modeling [5], and real measurements [6], [7]. According [8] to propose an analytical model that takes into account the Rayleigh attenuation and makes it possible to balance the probabilities of coverage of the nodes of a network by considering two probabilities of failure: the disconnection and the collision.

The study by [5] Shows that the coverage probability decreases exponentially as the number of end devices increases due to interference signals using the same spreading sequence.

The study by [9], shows that simulations prove the variability (5,6,7,8,9,10,11) of the channels and the number of gateways significantly affect the performance of LoRa applications. Increasing the number of gateways improves network performance but the improvement is not unlimited. This study also shows that using the smallest SF reduces energy consumption and extends the SF network lifetime equal to 10 gives the best results with an average DER of 92% and 69% in variability channels respectively moderate and high.

As far as we know, this study of LoRa deployment at the University of Thies in Senegal is the first one. In fact, before deploying new LoRa services, it's obvious that we should understand performance evaluation of LoRa deployment in this context.

3. LoRa technology

This section provides an overview of both physical (LoRa) and medium access control MAC (LoRAWAN) layer protocol. The basic architecture of a LoRaWAN network con-sists of nodes equipped with sensors that communicate with servers through gateways. The main purpose of these sensors is to collect a set of parameters of the immediate environment, such as temperature, atmospheric pressure, light intensity and to route them to treatment points. LoRa is a physical layer radio modulation based on Chirp Spread Spectrum (CSS) [1-2]. It allows long range communication up to several kilometers while using low power consumption. The advertised communication range of LoRa is more than 15 km for suburban environments. Free unlicensed ISM bands are used and particularly the 868 MHz [3-4] frequency in Senegal. LoRa provides several physical parameters that can be customized. These parameters include Spreading Factor (SF), Bandwith (BW) and Coding Rate (CR) that affect the quality of the transmission. Table 1 explicits the influence of these three parameters on binary throughput, sensibility and energy consumption.

Table 1: Influence of LoRa physical parameters[1]

Parameters	Binary throughput	Sensibility	Energy consumption
Increasing BW	+	-	-
Increasing SF	-	+	+
Increasing CR	-	≈	+

LoRaWAN is a MAC layer organized in a star of star topology composed of three elements: end-devices represented by sensor nodes, gateways and network server (figure 1).

[1] + →increasing, - →reducing, ≈ →substantially equal

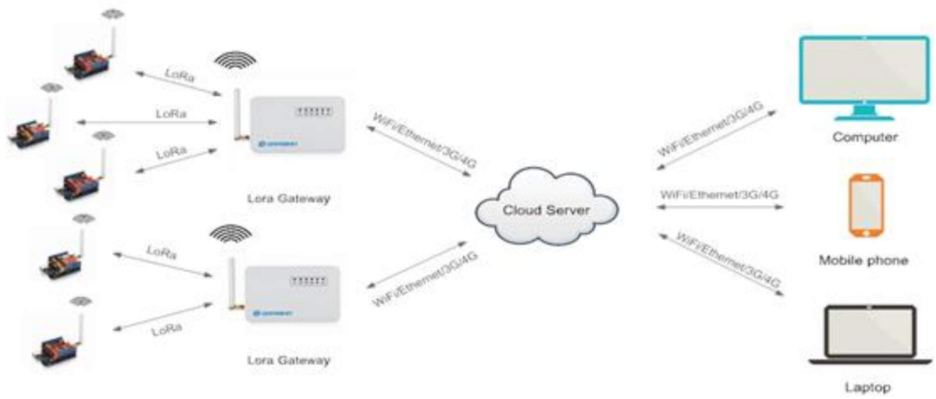

Figure 1: LoRawan architecture

The LoRaWAN specification defines three device types:

a) Class A is the basic LoRaWAN and must be implemented by all end-devices. It allows bidirectional communication and use pure ALOHA access for the up-link.
b) Class B is conceived to guarantee uplink and downlink separation. Nodes are synchronized using a beacon transmitted by the gateway. Thus, they can re-ceive information from Internet without sending requests.
c) Class C, the node has a continuously opened receive windows that are closed only while transmitting. Compared to A and B classes, C class consumes much energy to operate but it offers the lowest latency.

4. Performance evaluation of LoRa deployment

This section describes the detailed implementation of LoRa deployment and results obtained through simulations at the campus of University of Thies in Senegal (Figure 3) which covers an area of almost 64 hectares. The main objective is to show that LoRa performance is strongly dependent on the choice of different parameters. LoRA presents some customizable settings that provide the system with a valuable flexibility to adapt it to different use cases. Five different configurable parameters can be customizing namely, Spreading Factor (SF), Coding Rate (CR), Bandwidth (BW), Transmission Power (TP) and Carrier Frequency (CF).

For the purpose of this study, we use Flora (Framework for LoRa), a simulation framework based on the OMNeT++. Flora is designed to make LoRa network simulations and is a custom-build discrete event simulator [10]. Flora allows us to place Lo-Ra nodes in a 2-dimensional space using deterministic or random distribution. LoRa sinks (the data collection points) acting as gateways can also be placed within the space.

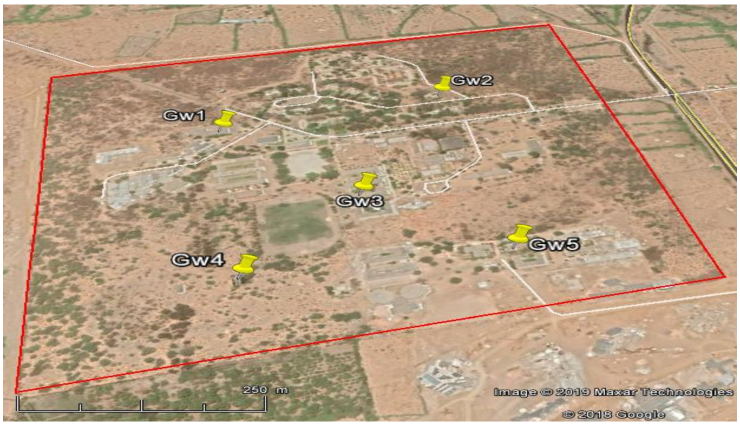

Figure 2: Map of campus of University of Thies in Senegal

Each LoRa node has a specific communication characteristic defined by the transmission parameters TP, CF, SF, BW and CR. Each LoRa gateway is able to receive for a given CF multiple signals with different SF and BW combinations. To evaluate performance of LoRa deployment, the DER (Data Extraction Rate) which represents ratio of received messages to transmitted messages over a period of time, is used.

Table 2: Simulations parameters

Parameters	Value
Number of nodes	400
Power transmission	14 dBm
Frequency	868 Mhz
Spreading factor	7 to 12
Bandwidth	125 Khz
Coding rate	4/5
Packet size	20 bytes
Simulation duration	7 days

The topology implemented is composed of 400 nodes randomly distributed in the campus. The number of gateways is varying from 1 to 5. All these gateways are connected to a specific network server. The parameters used for all simulations are presented on Table 2.

Figure 3 presents the Data Extraction Rate for each SF (from 7 to 12) when the number of gateways is varying from 1 to 5.

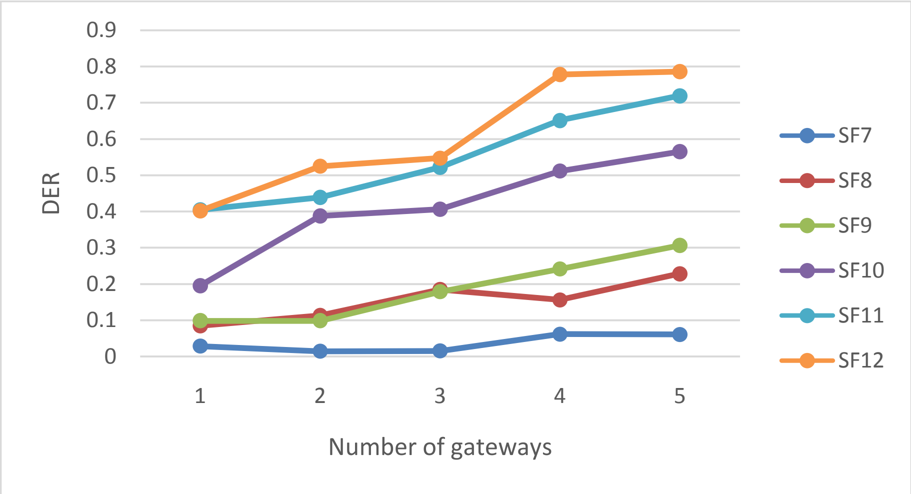

Figure 3: DER in function of SF and number of gateways

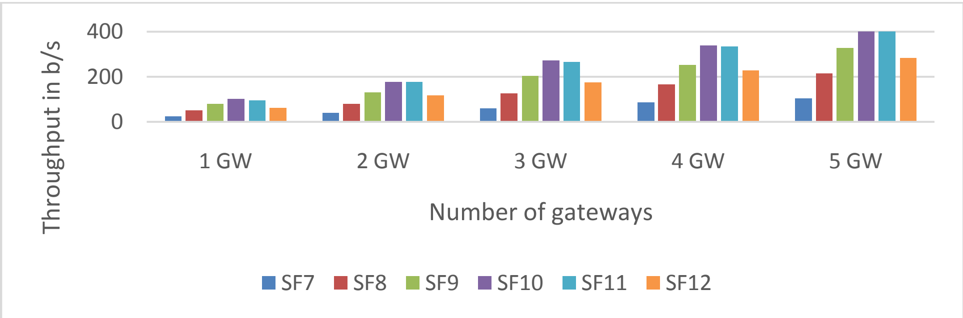

Figure 4: Throughput in function of SF and number of gateways

For a fixed number of gateways, we notice that DER increases significantly when the SF increases. For example, if four gateways are used, the DER is respectively 8%, 18%, 23%, 49%, 62% and 78% for SF equals to 7, 8, 9, 10, 11 and 12. In fact, increasing the SF implies that the transmission range becomes higher and then more packets can reach gateways.

It is also important to notice that for a fixed SF, increasing the number of gateways also provides better DER because packet not received at one gateway (due to packet loss or collision) can be recovered at another one. On Figure 3, for SF = 12, DER increases from 40% to almost 80% when varying the number of gateways from 1 to 5. If the number of gateways is weak, more collisions appear. These collisions lead to an important throughput decrease as shown in Figure 4 and packet loss on the gateway, consequently, DER also decreases.

For this simulation, let us now considers that ADR (Adaptive Data Rate) is enabled. In LoRa, ADR is a mechanism the server can use to let devices transmit on as low power as possible. If the device is close to the gateway the device can transmit at lower power and at a higher data rate until it uses as little power as possible. Lora physical layer present many customable parameters. ADR is designed to dynamically set the data rate and transmission power of nodes to optimize battery life's and to increase the overall network performances [11].

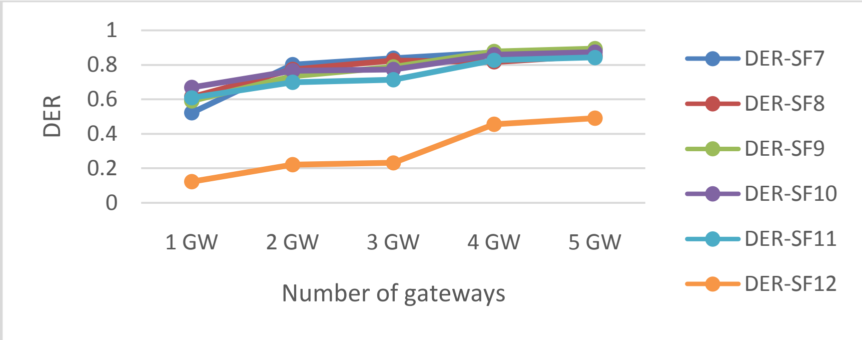

Figure 5: DER in function of SF and number of gateways when ADR is activated

In Figure 5, same remarks as previously could be done: when the number of gateways increases, DER also augments. However, we notice that when ADR is triggered, the nodes tend to use SF = 7, 8, 9, 10 and 11 while SF=12 provides poor performance. In fact, most of the nodes don't use SF12 because it consumes too much energy, has a longer transmission and therefore involves more collision.

We see also that DER improvement is less important from 3 gateways and sometimes inexistent for more than 4 gateways. Therefore using ADR, leads to better performances.

In conclusion, simulations prove that increasing the number of gateways substantially affects the performance of the LoRa applications through DER and throughput metrics. Multiple gateways help balance the load among the different gateways and reduce noise and collision. When ADR mechanism is activated, LoRa gives better performance by adapting the best SF in function of the context.

5. Conclusion and future works

Various LPWAN technologies are currently contending to gain an edge over the competition and provide a massive connectivity. Nowadays, objects are connected through wireless network in order to communicate with each other. This paper focuses on performance evaluation of LoRa deployment at the campus of University of Thies in Senegal. We study delivery ratio, and throughput in function of the number of gateways and spreading factor. Simulation results show that multiple gateways can significantly improve network performances by reducing packet loss rate and collision up to 30%. When ADR mechanism is activated, the overall performance on the network is substantially improved. In the future we plan to investigate some mechanism on MAC layer to avoid collisions (poor performance of LoRa networks are principally due to collision when the number of sensors nodes is important).

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