A focus on communication solution in agricultural telemetry systems

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Abstract. Digital agriculture emphasizes the need for the development of telemetry systems that enabling the monitoring of the crops and the agricultural machinery. The key of digital agriculture is connectivity. Unfortunately, long-range connectivity is a limited resource in rural areas. To fill this gap, in this work, a communication solution based on LoRaWAN for telemetry systems is proposed. As proof of concept, an end-to-end telemetry system is implemented. The telemetry system collects data of seeding from ISOBUS agricultural machinery and sends them to a cloud-based service through a LoRaWAN gateway and LoRaWAN network server securely. The telemetry system is implemented considering low-cost and open-source hardware and software technologies available on the national market. The results obtained agree with those expected, showing the viability and scalability of the proposed solution.

Keywords: LoRaWAN · Agriculture 4.0 · ISOBUS · cloud-based services

1 Introduction

Agriculture has experienced several revolutions throughout its history. The last revolution is the digitization of every part of the agro-industry value chain [1] [2]. In this context, the development of the digital infrastructure [3] such as agricultural telemetry systems is relevant. The telemetry systems enable more sustainable and optimal agricultural practices by means of collect, transfer, and processing of data that help to the intelligent decision-making of the agronomist and farmer [4]. An important challenge in the implementation of digital agriculture is the interoperability of systems. Consequently, the development of systematic tools for the interoperability of agricultural systems through the use of standardized communication protocols is necessary. In the context of the agricultural machinery industry, this has been achieved through of the creation of the communication standard ISO 11783 [5], better known as ISOBUS, which specifies a serial data network for control and communication in agricultural machinery. And in the context of the whole agro-industry value chain, it is recently addressed by the ATLAS project funded by the European Union H2020 research program [6]. *Another important challenge in the implementation of digital agriculture is the deployment of communications infrastructure that allows the transparent data exchange between the systems of the agro-industrial value chain.* According to this, the use of cellular technology such as LTE is attractive [7]. However, this type of connectivity technology is scarce or null outside of the large urban centers in Argentina. Similar situations occur in countries such as South-Africa or Bolivia, where the Argentine agricultural machinery is exported. In this way, the deployment of communications infrastructure is the main obstacle to the implementation of digital agriculture. Fortunately, new wireless connectivity technologies under the concept of IoT have been developed such as LoRa technology and the LoRaWAN protocol [8]. For this reason, in this work, we address the development of a communication solution for telemetry systems based on LoRaWAN. In order to connect to the Internet, those agricultural systems that are not connected due to the limited coverage of telecommunications in rural areas. LoRaWAN protocol based on LoRa technology [9] operates in unlicensed radio bands (915 MHz for America), and it offers a long distance of radio data propagation, low consumption of energy, low data rate, and secure transmission based on data encryption.

In particular, in this work, we address the communication issue from agricultural machinery to the cloud [10]. To achieve this, an end-to-end telemetry system is implemented. The telemetry system collects data of seeding from ISOBUS agricultural machinery and sends them to a cloud-based service [11] through a gateway and network server using LoRaWAN protocol. This work is carried out under the hypothesis that the platforms for the interconnection and interoperability of agricultural systems through the use of standardized communication protocols facilitate the development of Agriculture 4.0 applications. Added to the premise that the high cost of commercial equipment puts the development of digital agriculture at risk. So it is necessary to develop solutions considering the low-cost and open-source hardware and software technologies available on the national market.

2 Methods and Materials

The agricultural telemetry systems are based on the collection, transfer, store and processing of data. In this work, we focus on data transfer from the agricultural machinery to the cloud-based micro-services. In particular, we are addressing the communication issue in rural areas with limited coverage of telecommunication infrastructure through an approach based on LoRaWAN protocol. LoRaWAN is an open network technology at the Media Access Control layer that complements LoRa a physical layer technology. Typical LoRaWAN network architecture is composed of five elements, *the End-Device, the Gateway, Network and Application Servers and Applications*. In this context, the proposed system for a communication solution approach to agricultural systems in areas with limited coverage of telecommunication is shown in Fig. 1.

In this proposed solution proof of concept (Fig. 2), the End-Device in the agricultural machinery is designed to collect data and transmit them (Fig. 3) to Network Server through Gateway. The wireless connection between End-Device and Gateway is based on LoRa radio. The End-Device was implemented on Arduino Mega board with Adafruit RFM95W LoRa radio module. The LMIC library for Arduino was used to the LoRaWAN stack implementation. The implemented End-Device is suitable for different kinds of applications. Regarding the Gateway, it is constantly listening and retransmitting messages from End-Device to Network Server and vice-versa. To this,

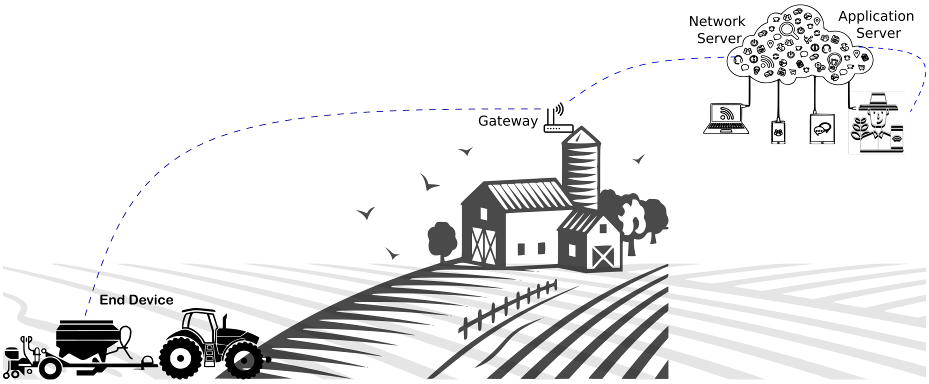

Fig. 1. A High-level view of agricultural telemetry system architecture based on LoRaWAN. The system is composed of five essential elements: *End-Device, Gateway, Network Server, Application Server and Applications.*

the Gateway requires a LoRa connectivity to connect with End-Device, and an Ethernet, WiFi, or Cellular connectivity to connect with the Network Server. The Gateway was implemented using a RAK831 concentrator module that acts as an 8 channel LoRaWAN gateway on top of a Raspberry Pi 3B+ board running the Semtech UDP Packet Forwarder. We should note that LoRaWAN elements require different features according to applications. In [12], without loss generality, a good review of different hardware options to implementation of End-Device and Gateways in a Smart City context can be found. Regarding the Network Server and Application Server, it carries out the management of communication through the authorization and secured interchange of data between the End-Devices and the applications by means of the use of end-to-end encryption methods, and a register of associations between network elements. In this work, we implemented a private network using ChirpStack as an open-source Network Server stack on a Raspberry Pi 3B+ board. The communication, proof of concept, with the Gateway was implemented using UDP messages on a WiFi connection and the communication with the Application was implemented using MQTT protocol. Regarding the Application (Fig. 4), it was implemented using the Node-Red programming tool.

3 Results and Discussion

To evaluate the operation of the proposed system, an end-to-end agricultural telemetry system was implemented. The End-Device acts as a data-logger located at the seeder attach to the Tractor. The End-Device collects data from a GPS receptor, the Tractor, and seed metering devices. For simulated this, collected data by a CAS-4500 seeding monitor [13] were used. The dataset was processed and adequate to the ISOBUS data format. Every 10 seconds, the End-Device sends messages with each one collected data to Application on the cloud. The messages are first received by Gateway, which retransmits it to Network Server. Finally, the Application requests these messages to Application

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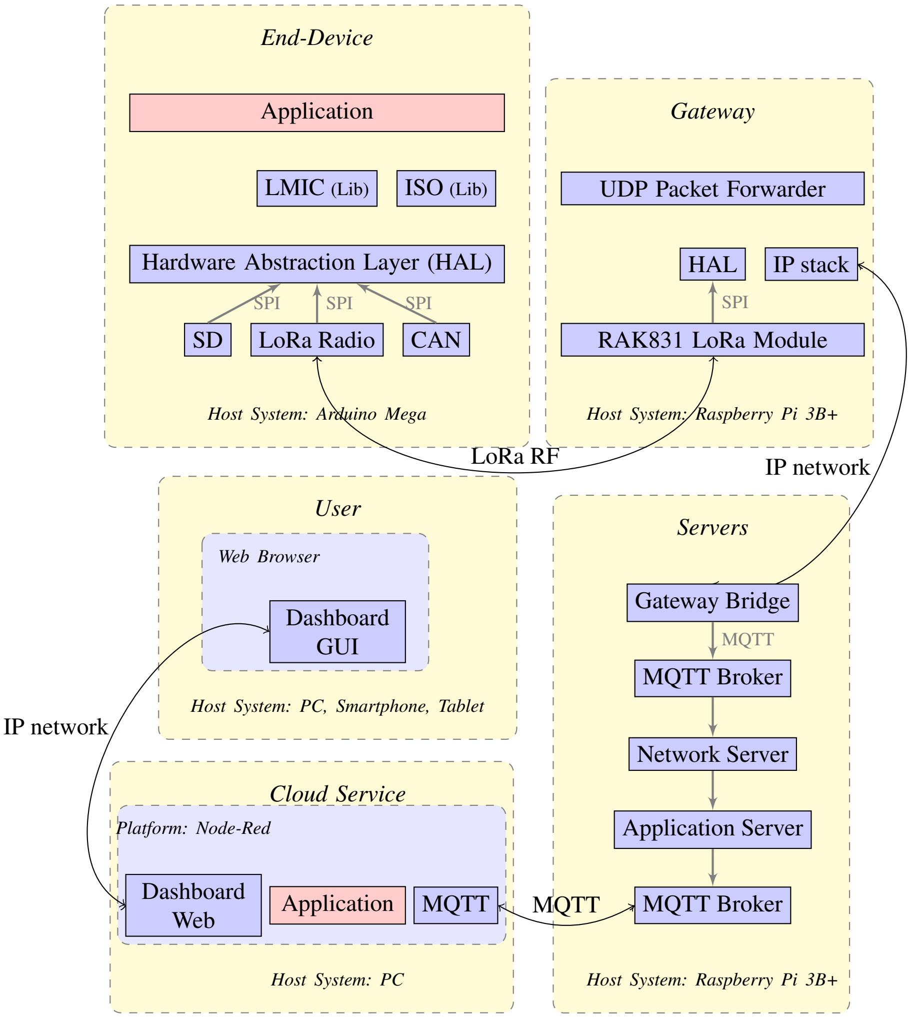


Fig. 2. Blocks diagram of the architecture of the system.

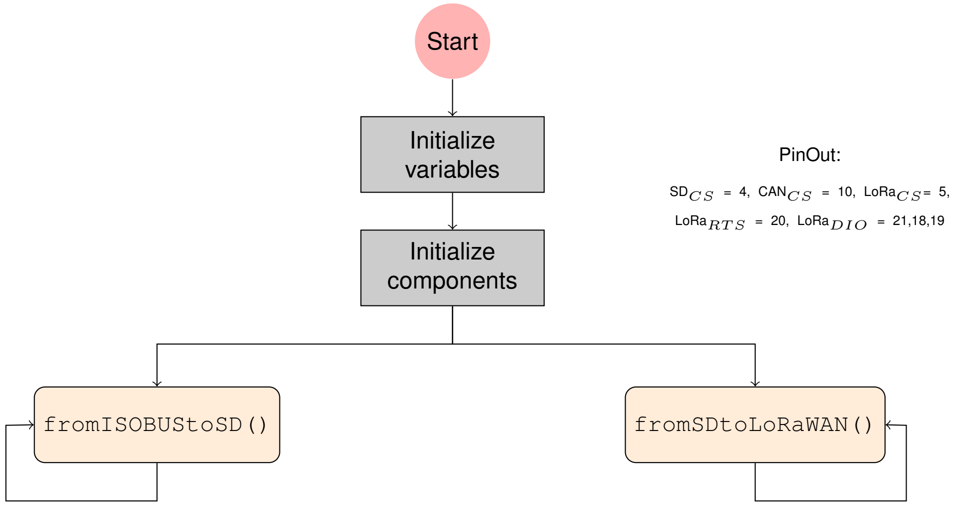


Fig. 3. Flowchart of the Application in End-Device. The FromISOBUStoSD() function is described in Algorithm 1 and the fromSDtoLoRaWAN() function is described in Algorithm 2.

Algorithm 1 FromISOBUStoSD(): Receive data from the ISOBUS and store the data in SD memory.

```
procedure FromISOBUStoSD()
    Variables Initialization
    if $ISOBUSReceive(lPGN, nPrio, nSA, nDA, nData, nDataLen) == 0$ then
        if $lPGN == PGN1 || lPGN == PGN2 || lPGN == PGN3$ then
            datatoSD[] = $(PGN, SA, DA, DataLen, Data)$
            if $SDflag == 0$ then
                SDflag = 1                                        ▷ Semaphore: lock SD
                Open file ISOData.txt
                Seek position pos to write
                Write datatoSD[] to ISOData.txt
                pos = Get the current position within the file
                Close file ISOData.txt
                SDflag = 0                                        ▷ Semaphore: unlock SD
```

Algorithm 2 FromSDtoLoRaWAN(): Read data from the SD memory and transmit the data over LoRaWAN.

```
procedure FROMSDTOLORAWAN()
    Variables Initialization
    STATE = Read                                        ▷ STATE = Read or Send
    procedure STATE()
        if $STATE == Read$ then
            ReadData()
        else
            SendData()
    procedure READDATA()
        if ISOData.txt then
            if $SDflag == 0$ then
                SDflag = 1                              ▷ Semaphore: lock SD
                Open file ISOData.txt
                Seek position posl to read
                Read ISOData.txt
                Write datatoLo[]
                posl = Get the current position within the file
                Close file ISOData.txt
                SDflag = 0                              ▷ Semaphore: unlock SD
                STATE = Send
                Scheduler State()
    procedure SENDDATA()
        if $TXRXPend$ then
            Nothing
        else
            Transmit datatoLo[] over LoRa
    procedure ONEVENT()
        if $TXCOMPLETE$ then
            TXRXPend = 0
            STATE = Read
            Scheduler State()
```

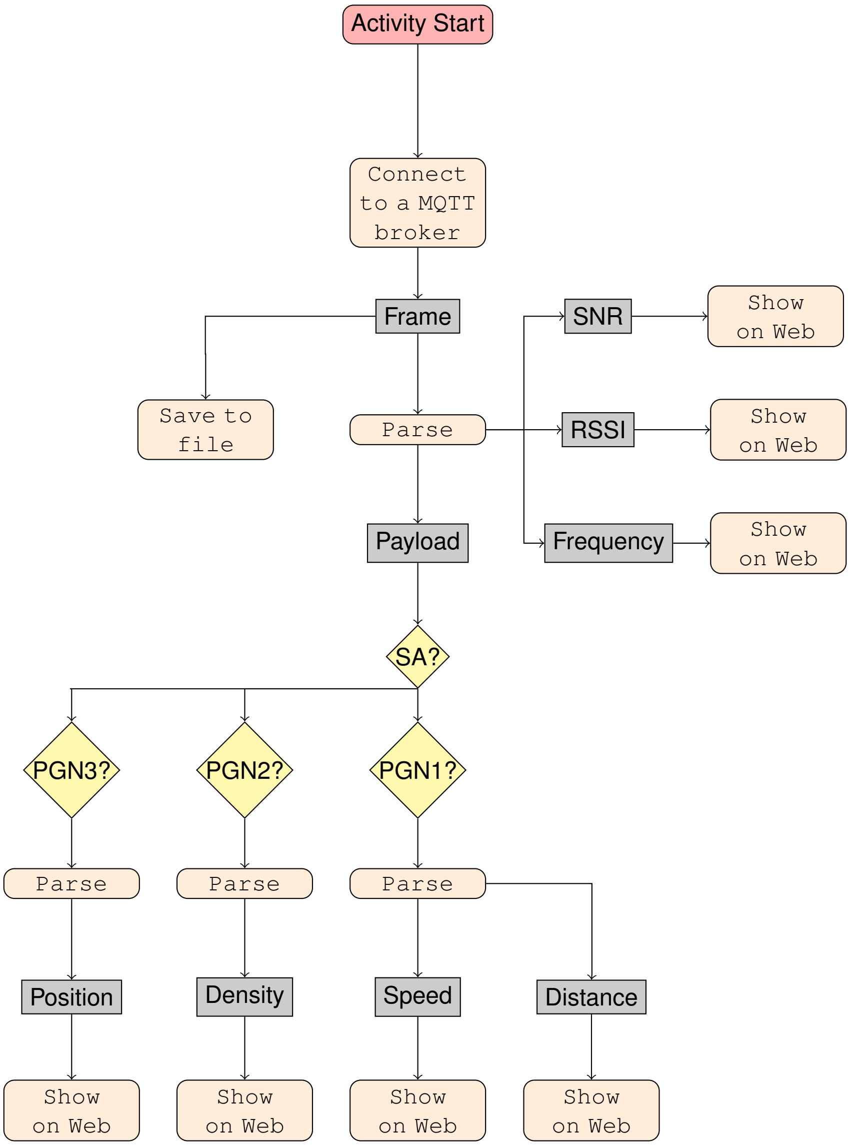
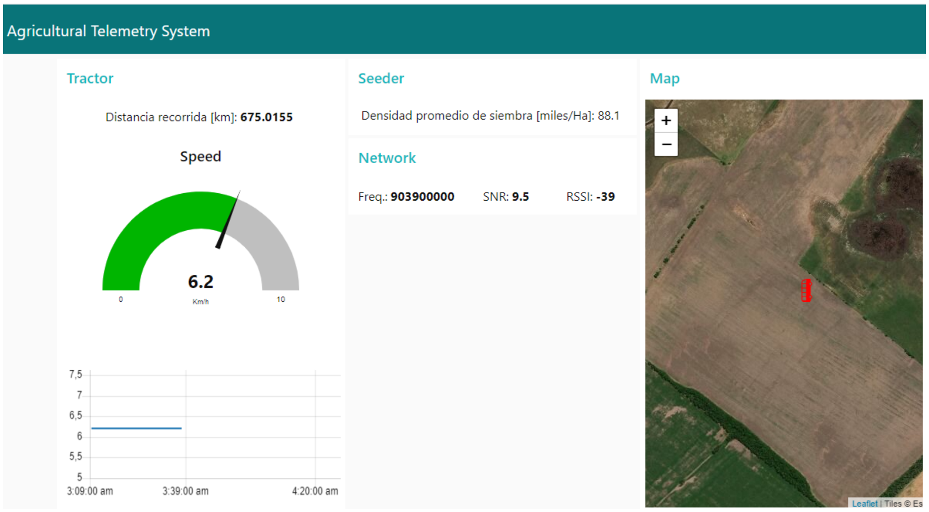


Fig. 4. Activity diagram of the Cloud Service Application.

Server and processing these. Fig. 5 shown the graphical user interface (GUI) of the developed application where information about the tasks on the farm are visualized. Users can access to the information, both locally and remotely through the internet connection from a PC or mobile devices.



Distancia recorrida [km]: **675.0155**

Densidad promedio de siembra [miles/Ha]: 88.1

Freq.: **903900000** SNR: **9.5** RSSI: **-39**

Fig. 5. The graphical user interface of the developed application. The application shows collected data from i) Tractor such as speed, and distance traveled by the machine; ii) Seeder implement such as average planting density; iii) LoRaWAN network such as SNR and RSSI.

With the purpose of the evaluate of the performance of the LoRa connectivity, the system was tested in a laboratory context. The LoRaWAN parameters were set as follows: SF 7, BW 125kHz, CR $4 \setminus 5$, and Payload 13 Bytes. In outdoor measurement, the Gateway was located at 2.5 m, and the End-Device at 0.7 m over the ground level, respectively. Both separated by 3m and 7m. The results of the RSSI and SNR measures are shown in Fig. 6 . We can see that the RSSI parameter is a poor indicator of the quality link, whereas that SNR parameter is an accurate indicator. A $SNR > 10dBm$ represents a strong signal. Note that the LoRa technology can work below the noise floor up to a value of SNR = -7.5 dBm when it is configured with SF = 7.

Performance measurements were also made on a moving scenario. For this, the End-Device was mounted inside a vehicle, moving at an average speed of $6km/h$, simulating the speed of a tractor. In this scenario, the distance between the End-Device and the Gateway was in the range of 10 m to 600 m according to the calculus of the Egli propagation model [17]. Measurements were made in a semi-urban area. The obtained results (Fig. 7) show that the RSSI value, inside and outside of the vehicle, changes in approx. 10 dBm whereas the SNR value is stable. The Rx Sensitivity of the Gateway calculated from the parameters of the device used [14] was about -123.5 dBm, but the result of the measurement shows that the minimum RSSI value register was about -101

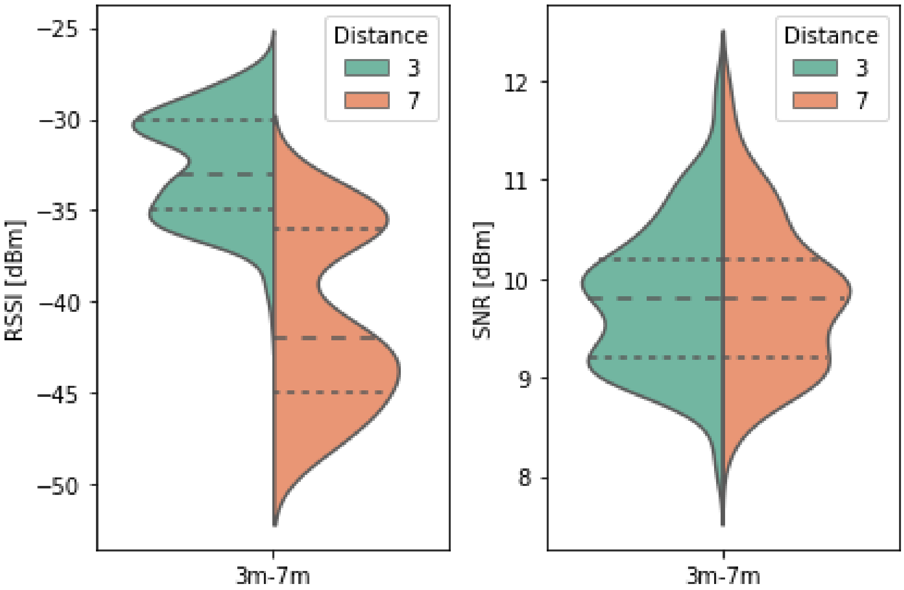


Fig. 6. Distribution of SNR and RSSI values measured at 3 meters and 7 meters. The dash lines indicate the quartiles of the distribution.

dBm, so we can say that the Rx sensitivity can be approx. 20dBm worse due to the impact of the environment. The shadow area in Fig. 7 indicates the missed observations. The observations were made each 5 sec. The communication performance is highly dependent on the environment.

It remains to carry out more measurements in the field by varying the LoRaWAN configuration parameters. However, it is known from the LoRaWAN specification that increasing the SF parameter increases the signal coverage range at the expense of a decrease in the data rate. Note that for Latin-America the value of SF cannot be greater than 10. Regarding this, [16] presents an interesting work that provides an evaluation of LoRaWAN technology at 868 MHZ frequency in terms of SF, BW, and CR, with respect to immunity to the EM interference and the multipath propagation. This shows that LoRaWAN setting with an SF10-12 is characterized by immunity to both the EM interference and the multipath propagation while with an SF7-9 is strongly influenced by both the EM interference and the multipath propagation.

4 Conclusions

In this paper, we present a first approximation to an agricultural telemetry system with a focus on long-range communication issues in rural areas with limited coverage of telecommunications. The proposed system enables the *development of digital infrastructure* for agriculture contemplating the use of *standardized communication interfaces* such as ISOBUS and LoRaWAN. In this context, the proposed system complies

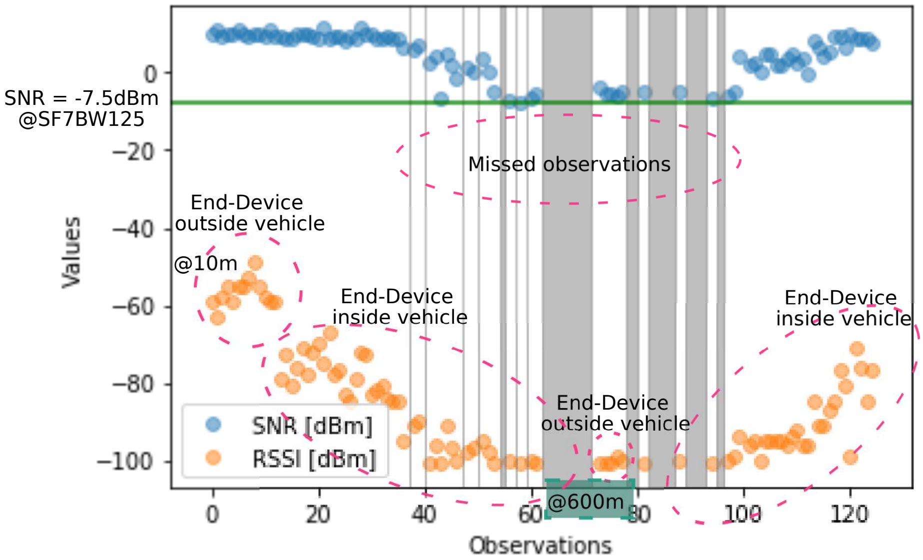


Fig. 7. Link performance on a moving scenario. The End-Device inside a vehicle travels in a round trip up to 600 meters away from the Gateway at an average speed of $6km/h$

with the requirements of: i) the *cybersecurity* through of the use of data encryption, ii) *data privacy* using the implementation of a private network and iii) *attractive and user-friendly applications* development for farmers through of software tools that allow the integration of hardware devices, and cloud-based micro-services. Although it remains to perform many more experiments the results obtained agree with those expected, showing the viability and scalability of the proposed solution.

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