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# AMBLoRa: a Wireless Tracking and Sensor System Using Long Range Communication to Monitor Animal Behavior

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**Abstract**—The University of Corsica decided to create in 2010 the platform STELLA MARE (Sustainable TEchnologies for Littoral Aquaculture and Marine Research) and its platform CNRS-Università di Corsica leads a project called AMB.I.EN.T.E (AMBient Intelligence for Environment using Technical Efficiency) to develop some tools to follow the terrestrial and underwater activities of animal. Global Positioning System (GPS) is considered as an essential key in the monitoring of animal activity. Indeed, the knowledge of the movement, the reproduction and spawning areas are important for the researchers. We were able to study some research on GPS tracking system however the energy consumption, a quick deployment and real-time data visualization are not clearly expressed in a same project. In this paper, we introduce a prototype of GPS tracker system using LoRa (for Long Rang) technology according to these three previous needs.

**Keywords:** GPS; LoRa; Tracking System; IoT

## I. INTRODUCTION

The continuous tracking devices can be fine in several applications in the literature. Indeed, in several experiments (patients, vehicles, objects, etc.), the researchers try to optimize the devices to allow a complete monitoring and long life time of the system. Monitoring animal behavior is an important research topic to understand the relations between the animals and their environment. To know the position of the animal, we can distinguish two types of action:

- Active tracking where the animal is equipped by a tag (sonar, RFID, etc.) and the researcher try to detect, to find a signal in a determined area
- Passive tracking where the signal is send towards the research.

The second method is often based on Global Positioning System inserted in a collar.

In [1], the authors have collected more information about GSP tracking works in Australia to explain the relative success of GPS Collars. Indeed, it appears a clear benefit of these solutions however the main used tools are not consumption optimized, real-time configured and long range

developed. The two mains solutions [2] [3] cited in this study demonstrate clearly their benefits however we note some lack in our research approach: a real time data visualization, a long life battery and wireless network system manageable. The University of Corsica leads a project called AMB.I.EN.T.E (AMBient Intelligence for Environment using Technical Efficiency) to develop some tools to follow the terrestrial and underwater activities of animal financed by an European Regional Development Fund (ERDF) and the Regional council of Corsica.

In [2], the authors try to evaluate the state of art in the using of LoRa based technologies. The first conclusions of this contribution show the capacity of long range communication and low power consumption of this technology in this research area. Numbers of application are developed [3, 4, 5, 6] using that confirm the potential of this communication technology in the tracking system.

We propose in Section II a survey of animal monitoring tool in research area. We introduce in Section III the AMBLoRa system and we present in Section IV the main result. We conclude in Section V with the future evolution of our system.

## II. RELATED WORKS IN COLLAR TRACKING SYSTEM

In this section, we propose to discuss on different major works on wildlife monitoring system using a collar approach.

LynxNet (described in Figure 1) is a wild animal monitoring system using sensor networks [9] with an animal-centric paradigm. This system is based on Tmote Mini sensor, with a 433 MHz transceiver, is mobile sensing and uses sparse radio connectivity network. The LinxNet collar device produces two types of data:

1. GPS location with temperature, humidity and ambient light
2. 3D accelometer and 2D gyroscope to calculate motion vector.



Figure 1 : LynxNet collar device [4]

This prototype is interesting but we don't have precisions on the components consumption and battery life.

ZebraNet [10] illustrated by the Figure 2 uses a wireless system to monitor the Zebra migration in Kenya. Based on energy consumption approach, the authors try to conciliate accuracy and energy efficiency. An important step in their research and development activities is to use two separate microcontrollers, one for the sensors software and another for GPS, to reduce energy budget. However, the energy consumption appears like a dark point. We can note also the incapacity to communicate on more than one kilometer.



Figure 2 : ZebraNet module [5]

The wildCENSE illustrated by the Figure 3 is considered by the authors [11] as a new approach of wildlife monitoring based on a wireless sensor system different of ZebraNet. It is a WSN system to monitor the behavior and migration patterns of Swamp Deer. Based on GPS and different sensors (temperature, humidity, accelerometer and light), the wildCENSE node manages the energy consumption by active or sleeping states.



Figure 3 : wildCENSE node

The data are collected every 3 minutes and a data transmission towards the base station is allowed every 30 minutes. The system proposes a range of more than a kilometer.

In [12] on Figure 4, the authors introduce a system using Long-Range Wireless Sensor Network for Geo-location for

livestock animals tracking. The system illustrated by Figure 4 shows the capacity of dynamic tracking and LoRa capacity however there is no approach on energy consumption and real-time

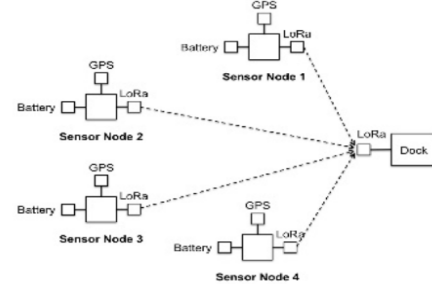


Figure 4 : WSN tracking system using Dragino node

A Wildlife Monitoring System [12] was developed using a special IoT Infrastructure. Based on a hybrid communication system, using LoRaWan standard and Bluetooth Low Energy (BLE), WMS. The capacity to communicate with a low power consumption on several kilometers is an important point in this system showed in Figure 5.

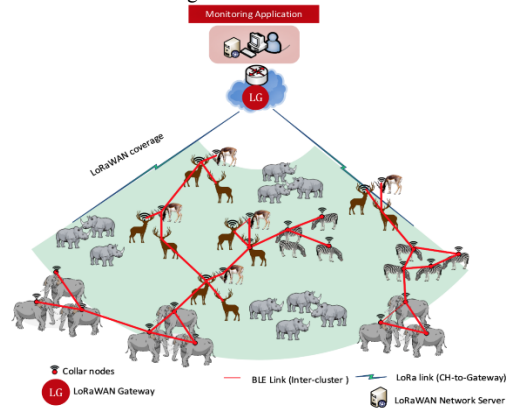


Figure 5 : WMS system using LoRaWan and BLE

WMS simulation results seem clearly an efficient architecture using two kinds of communication support however the information of battery life and the real-time monitoring system are not presented. The collar approach and Lora technology are clearly an important benefit points.

After this survey of major works on animal tracking system using a collar, we decided to develop our collar quickly deployable, energy efficient with relative real-time data visualization system associated.

### III. AMBLORA : GPS TRACKING SYSTEM AND RELATIVE REAL-TIME DATA VISUALIZATION

We describe in this part the method implemented for the GPS tracking of Corsican deer (*Cervus elaphus corsicanus*) [13]. We made a tracking collar consisting of a waterproof

case containing the AMBLoRa card and the battery and a strap on which we fixed the antennas.

#### A. Experimental area

The monitoring experiment described took place on the east coast of Corsica Island (red point on Figure 6) in an enclosure of the regional natural park of Corsica [14].

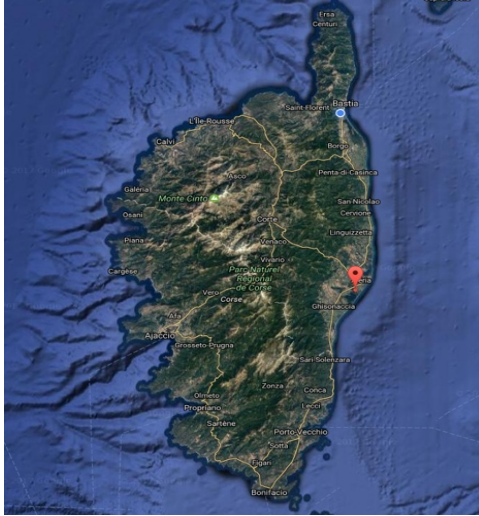


Figure 6: Casabianda in Corsica Island

Deers coming from Sardinia, pass by an enclosure before being released in Corsica. This is the case for the Casabianda enclosure (Figure 7). This enclosure of approximately 20.5 ha is used to keep the deer in semi-freedom and to prevent any health risks. The plant tissue is mainly composed of small bush and some trees. The ground is relatively flat. There is no electrical source on site but GSM coverage in the area is good for our operators. About 40 individuals were identified in the enclosure in 2015. We can see in this Casabianda closed space (Figure 7 red lines) the area where the staff feed the deers (yellow circle) and clearing areas (green circles). After a time of quarantine, they are released in the Corsican Mountains.



Figure 7: Closed space of Casabianda

We tested our GPS tracking system on a young male deer present in this enclosure to validate its proof of concept (autonomy, communication, design).

#### B. LoRa Tracker

We designed a GPS tracking collar [15] using a classic hardware architecture of GPS tracking devices (Figure 8): a microcontroller, a battery, a network transmitter and a GPS [16]. The system architecture interconnection uses an LPWAN to transport data from sensor nodes to the final communication end-point hosted on ours servers. Specifically, in this system, the LoRa communication protocol has been used. LoRa technology is used as wide area network wireless technology. We can use different frequency bands defined (US 928 MHz, EU 863 MHz, China 787 MHz) ; it is a low power, long range and low data rate based technology developed with initiative by Semtech.

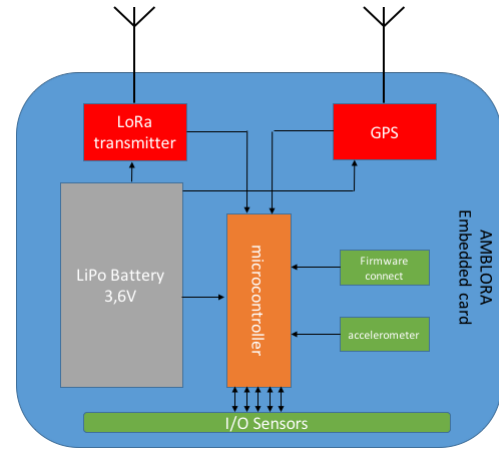


Figure 8: block diagram of the proposed wireless embedded card

The main part of the embedded card is the microcontroller, a Microchip PIC24FJ128GA310. This block receives the location data from the GPS, codifies and transmits this information to the data base by using the LoRa transmitter. This gateway module is based on a high-performance, low-current Microchip RN2483. With a power supply of 3.6 V, the transceiver offers a sensitivity of -148 dBm and a maximum output power of +14 dBm, which allows for achieving long-distance communication at 868 MHz frequency. Our GPS receiver is an Origin GPS ORG1208. This block is the most energy-consuming with 100mA when it is working. But the fast position fix ( $\pm 5s$ ) and the high sensitivity of -162dBm allow us to have low power consumption. We have also integrated an accelerometer into the AMBLoRa embedded card (an Analog Devices Inc ADXL345) measuring the tagged animal activity. It allows to know if the tracking collar falls to the ground: loose collar or dead animal. The GPS and GSM antennas of the AMBLoRa card were attached to the outside of the waterproof case using the collar as illustrated on





Figure 9 : AMBLoRa Collar on a young deer

### C. Autonomous LoRa Network

All the messages of the AMBLoRa card (ID, GPS position, accelerometer data, and time stamp) are transmitted to our servers via the LoRa network. We have deployed an antenna that covers the entire monitoring area. This antenna is autonomous in energy and communication network (Figure 10).



Figure 10: autonomous LoRa antenna system

The autonomous antenna system consists of a EPsolar LandStar LS1024B PWM Solar Battery Charge Controller 10A 12/24V, a 25W solar panel, a lead acid battery 105Ah 12V and a Kerlink LoRa IoT Station. The Kerlink gateway uses the cellular network (2G/3G) to communicate with our servers [17]. Figure 11 shows that the charge level of the battery used to power the LoRa gateway increases throughout the tracking, even if the sunshine is low for several days.

The components we have used allow us to have a LoRa network gateway that we can deploy in a natural environment without the need for a power supply or communication network.

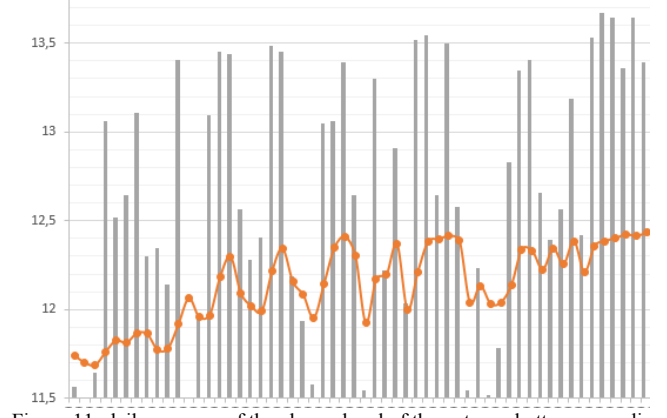


Figure 11: daily average of the charge level of the antenna battery according to the sunshine (gray)

### D. The relative real-time data visualisation

The supervision software is available as a web application enabling users and administrators, among other things, to visualize the position of their devices. We made the choice to build a web application because we needed to access our data at any time and on the largest number of devices. It offers four different services called real time, alerts, history and administration interface. Because it's the easiest way to display positions data on a screen, all data displaying is based on interactive maps. We also provide tables whose data can be exported.

The main purpose of the real time section is to display the latest position on the map of each individuals we follow, the positions of the fixed devices such as LoRa gateways are also available. Every target is represented by an interactive marker. The course shows the fifty latest positions as markers linked by lines that are dotted with arrows to indicate the direction. The Web application is able to compute received data to extract useful information. By analyzing the positions of the target we are able to determine if it is in trouble or not, for example a deer which is not moving during twenty-four hours. With these computed data the web application can emit alerts. Once an alert is emitted the corresponding marker on the real time section turns to red and it is visible into the alert section with more details available. Users can check alerts via a table which lists all current alerts and can acknowledge it. At the moment the system is able to issue alerts regarding the targets, the devices equipping these targets and the LoRa antennas. The web application enables us to be aware of the state of our facilities. We have created the history section to store data and extract old courses.

### E. Web interface for a supervision system

The data produced by the devices must be stored to be accessible by the end users. We provide a very simple network architecture using two separate servers called respectively application server and database server. We used Laravel [18],

a powerful and well documented PHP framework possessing a large community, to create both the web application and the API.

The supervision software illustrated by Figure 12 is available as a web application enabling users and administrators, among other things, to visualize the position of their devices.

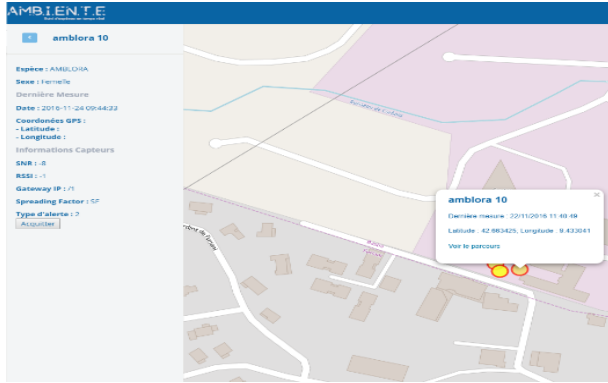


Figure 12: Real-time section with a target selected. Specific target information is displayed into the sidebar. Popup gives restricted information and offers the possibilities to display the recent course of the target

We made the choice to build a web application because we needed to access our data at any time and on the largest number of mobile devices (samrtphone). It offers four different services called real time, alerts, history and administration interface.

## IV. RESULTS

### A. Data visualization

The interpretation of the results is the last part of our work. We mainly worked with the historical section; indeed given that the deer was in a closed modest sized enclosure, it was not able to travel long distances. Its position belonging to a known interval, the real-time section was therefore useless. Hence we focused on studying its travels over short periods, ranging from 1 to 2 days, as well as on determining the places he frequented the most. Choosing a maximum gap of 2 days ensues from an obvious constraint. Considering the selected data sending frequency, it was not possible using the map to study the movement of the animal on a larger period of time, on such a small area, as this resulted in a mass of points and lines that could not be interpreted. We will see afterward that another technique has been favored.

Nevertheless, as shown in the previous Figure 13, it is possible to study the behavior of the animal over the short term via our web application. For the longest periods of time, we have carried out a data export, still via our interface, in order to integrate them into software fitted with tools adapted to this amount of data. The following figure clearly shows that it is not possible to extract a behavioral analysis from the raw data.

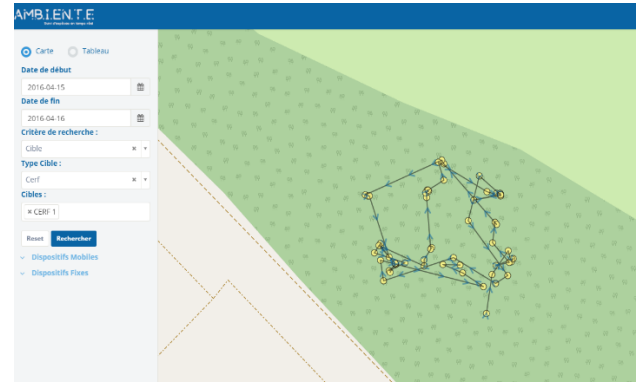


Figure 13: History section. The course of the deer between the 15th and the 16th March

Here, it was requested to display all the geolocation data collected for the deer. It didn't give us any useful information, besides it overloaded the web application making it slower to run, degrading the user's experience. We have found here one of the limitations of using such a solution for animals tracking.

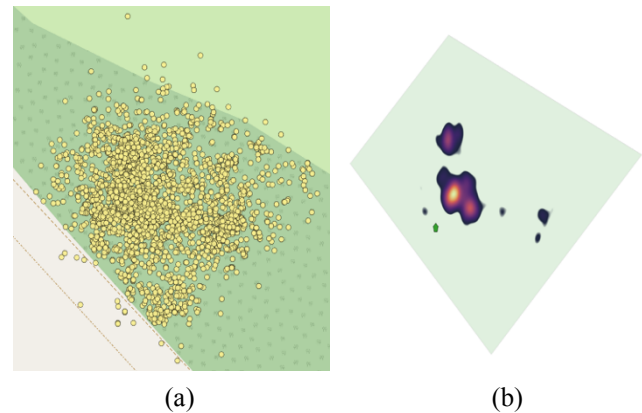


Figure 4: Data visualisation (a) massive point representation (b) QGIS GIS analysis

On the Figure 14, (a) shows a massive amount of points which are the whole positions that we collected during our experimentations. (b) shows the corresponding heat map generated via QGIS highlighting the most frequency location. In order to overcome these limitations we imported the data into the QGIS GIS software. This enabled to generate heat maps from the data. Thanks to this map we would highlight two areas: the first that is the closest to the hut, symbolized in green, is the area where the animal was fed and the second a cleared glade.

There are several advantages to having a real-time visualization of tracking data:

- No need to be on site to acquire positions (as, for example, for VHF tracking),
- Detection of abnormal behavior: short distance traveled, death of the animal, animal isolated from the livestock, etc.
- Be alerted if an animal get out of a virtual enclosure (rambling, flight, etc.)

## B. Energy consumption of AMBLoRa

The energy consumption of the AMBLORA card is an important issue for us. All our developments have been done to make it as low as possible. Our goal was to have a one year tracking time with one GPS location per hour.

We measured the energy consumption of each component of the card when they are on and in standby. The GPS is the block that consumes the most during its fixed time with 90 to 100 mA. The LoRa transmitter consumes 12.8 mA during sending and all other components (microcontroller, accelerometer, etc.) not more than 1.4 mA. In standby, the GPS consumes less than 40 $\mu$ A, the LoRa module between 30 and 40 $\mu$ A, the microcontroller less than 10 $\mu$ A in "sleep-deep" mode and the accelerometer less than 1 $\mu$ A.

These performances allow us to consider up to 5 GPS position transmissions per hour for a tracking period of one year, or 1 GPS position transmission per hour and a follow-up period of more than 2 years. But also a tracking time of 30 days with a transmission per minute (for example: for the monitoring of sportsmen, hikers or workers, etc.).

## V. CONCLUSION

AMBLoRa is a complete system that allows the researchers to visualize the relative real-time data from GPS tracking collar using LoRa communication, a designed low consumption support of communication. According this first experiment, we conclude that we consider that AMBLoRa has achieved the desired objectives. However we must enhance certain parameter:

The real-time visualization: we only get a position after a certain amount of time, it is impossible to have the real position anytimes. Even if we reduce the send period to minimum there will always be a delay due to all the processes involved in the sending and displaying chain.

We use only one collar and it is essential to develop a massive experiment with more GPS tracker.

The size of AMBLoRa is still too big and we have to reduce its size.

We must to continue to reduce energy consumption, key of efficient animal tracking system

We need to switch towards a LoRaWAN to integrate a Medium Access Control optimized secured protocol of communication.

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