# 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 technical solution. In this paper, we introduce a prototype of GPS tracker system using LoRa (for Long Range) 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 but 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 animals ; it was 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 area of research. Numbers of application [3]-[6] use this LoRa technology showing the potential of this communication media in the tracking system.

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

## II. A SURVEY IN THIS AREA OF RESEARCH

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

LynxNet is a wild animal monitoring system using sensor network [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.

This LynxNet prototype is interesting but we do not have precisions on the components consumption and battery life time.

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ZebraNet [10] 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. We can note the incapacity to communicate on more than one kilometer.

The wildCENSE illustrated 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 Swam Deer. Based on GPS and different sensors (temperature, humidity, accelerometer and light), the wildCENSE node manages the energy consumption by active or sleeping states. 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], the authors introduce a system using Long-Range Wireless Sensor Network for Geo-location for livestock animals tracking. The system illustrated shows the capacity of dynamic tracking and LoRa capacity however there is no approach on energy consumption and real-time. 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.

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 important benefit points. However we can note some needs in our vision on the new design of wildlife tracking system comparison as showed on Table 1.

TABLE I. COMPARISON OF COLLAR SYSTEM FOR ANIMAL TRACKING

| Important Contributions | **Energy** | **RT Data** | **Long range** | **quick deployme nt** |
|---|---|---|---|---|
| LynxNet[9] | + | + | - | - |
| ZebraNet [10] | - | - | + | - |
| Wildcense [11] | | | + | + |
| WMS [12] | - | - | ++ | - |

After this survey of major works on animal tracking system using a collar, we decided to develop our collar according to four needs for our experiment : quickly deployable, energy efficient with relative real-time data visualization system associated. We propose in previous part a presentation of our solution and the first results in this work.

## 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 integrated in a Lora system architecture.

The monitoring experiment described took place on the east coast of Corsica Island (red point on Figure 1) in an enclosure of the regional natural park of Corsica [14].

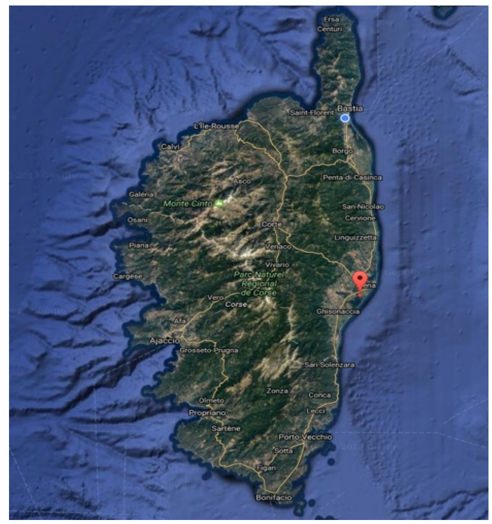


Figure 1: Casabianda in Corsica Island

Deers coming from Sardinia, pass by an enclosure before being released in Corsica. This is the case for the Casabianda enclosure (Figure 2). 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 bushes 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 2: Closed space of Casabianda

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We tested our GPS tracking system on a young male deer in this enclosure to validate its proof of concept (autonomy, real time visualization, long range communication and quick deployment ).

## A. The Network architecture

We propose to develop a basic architecture developed in two parts as showed on the Figure 3 :

1. Lora Antenna towards the monitored area : a LoRa tracker is integrated in a collar AMBLoRa. A LoRa network is deployed trough a KerlinK antenna ;
2. Lora Antenna towards the server database : a GSM connection allows a data transmission towards our data server.

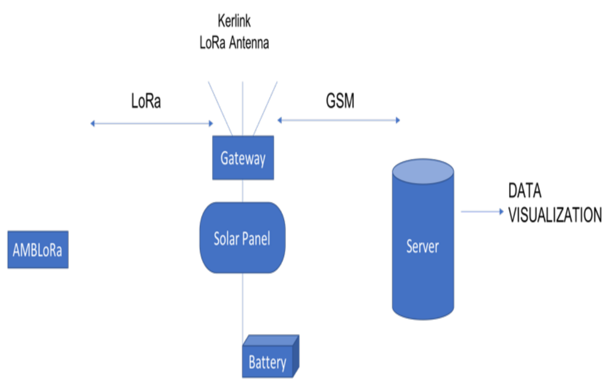



Figure 3 : Sytem architecture

## B. The Lora Tracker

We designed a GPS tracking collar (Figure 4) using a classic hardware architecture of GPS tracking devices : a microcontroller, a battery, a network transmitter and a GPS. The embedded card is based on a microcontroller, a Microchip PIC24FJ128GA310.

This block, showed on Figure 5, receives the GPS location data, codifies and transmits this information to the data base with a LoRa transmitter. This module uses 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, allowing 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 (± 5s) and the high sensitivity of -162dBm allows us to have low power consumption. We have also integrated an accelerometer into the 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. 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 4 : GPS Collar on a young deer using LoRa communication

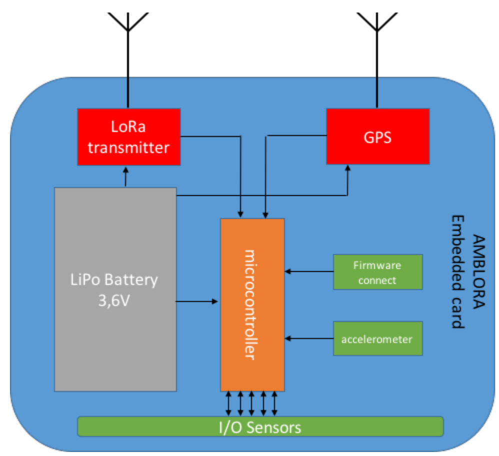



Figure 5 : block diagram of the proposed wireless embedded card

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.

## C. Autonomous LoRa Network

All 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 6).

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 long-distance communication at 868 MHz frequency.

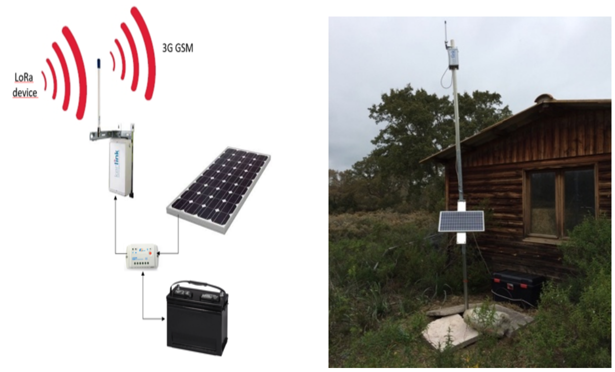



Figure 6 : autonomous LoRa antenna system

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].

The components we have used allows 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.

### *D. The relative real-time data vizualisation*

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 on the largest number of devices. It offers four different services called real time, alerts, history and administration interface. Because it is 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 target positions, 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 created the history section to store data and extract old courses.

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 (Figure 7) is available as a web application enabling users and administrators, among other things, to visualize the position of their devices.

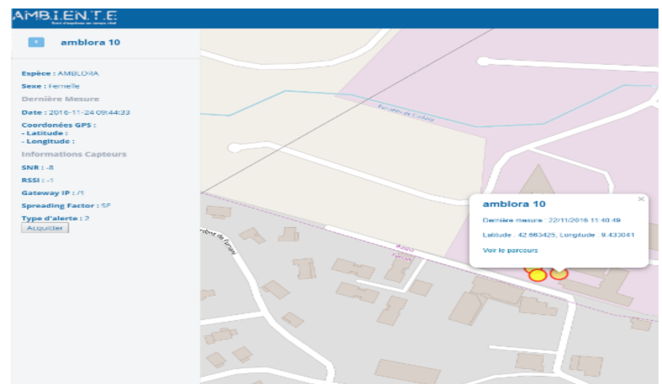



Figure 7 : Real-time section with a selected target. Specific target information is displayed into the sidebar. Popup gives restricted information and offers the possibilities to display the recent course of the target

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 (smartphone). It offers four different services called real time, alerts, history and administration interface.

## IV. First Results

In this part we present the first results of our experimentation according to two parts : data visualization and energy consumption.

### *A. Data visualization*

The interpretation of the results is the last part of our work. We mainly worked with the historical section ; 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 most frequented places. 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 afterwards that another technique has been favored.

Nevertheless, as shown in the Figure 8, it is possible to study the animal behavior over the short term via our web application.

We can have a yellow point for each position of the dear after 10 minutes, determine a trajectory, and we can extract the history of a course for a post treatment of the data. For the longest periods of time, we have carried out a data export, still via our interface, in order to integrate them into a tools fitted software adapted to this amount of data. The following figure shows that it is not possible to extract a behavioral analysis from the raw data.

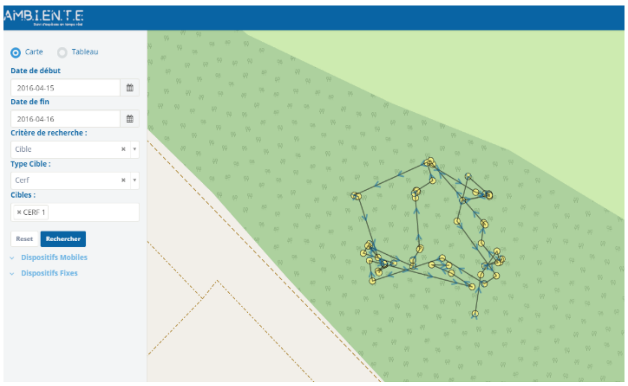
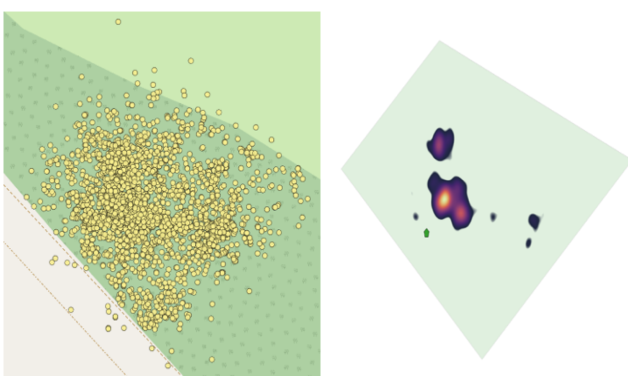



Figure 8 : History section. The course of the deer between the 15th and the 16th March

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



(a) (b)

Figure 9 : Data visualization (a) massive point representation (b) QGIS GIS analysis

On the Figure 9, (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 frequented 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 closest to the hut, symbolized in green, is the area where the animal was fed and the cleared glade.

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

- Possibility to acquire remote positions (as, for example, for VHF tracking),
- Detection of abnormal behavior : short distance traveled, death of the animal, animal isolated from livestock, etc.
- Be alerted if an animal get out of a virtual enclosure (rambling, flight, etc.)

### *B. Energy consumption of AMBLoRa*

In this part we introduce the first elements of energy consumption approach.

The Figure 10 shows the battery lifetime on the gateway and the charge level according to the sunshine. We can observe the robustness of the system. Figure 10 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.

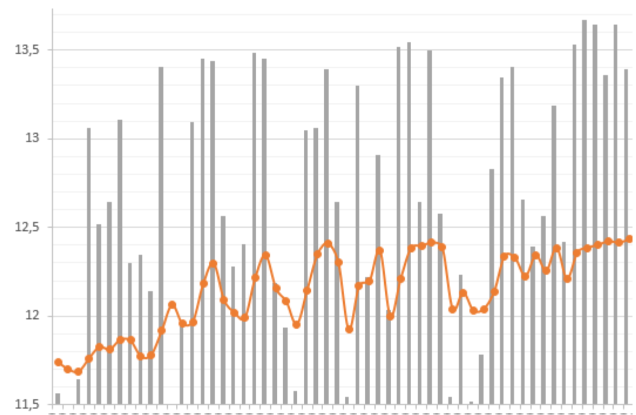



Figure 10 : daily average of the charge level of the antenna battery according to the sunshine (gray)

The energy consumption of the AMBLoRa card is an important issue for us. Our goal was to have a one year tracking time with one GPS location per hour. We can see on the Figure 11 the AMBLoRa battery life according to the number of GPS messages/hour.

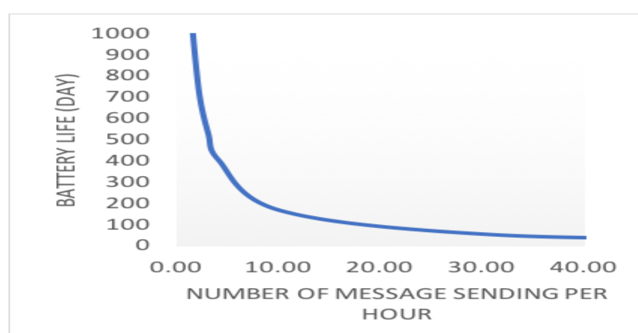



Figure 11 : Battery Lifetime of AMBLora

We measured the energy consumption of each component of the card when they are on, and also 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 40µA, the LoRa module between 30 and 40µA, the microcontroller less than 10µA in "sleep-deep" mode and the accelerometer less than 1µA.

These performances allow us to consider up to 5 GPS position transmissions per hour for a tracking period of one year. For 1 GPS position transmission per hour, we can reach a follow-up period of 2 years.

## 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 to this first experiment, we conclude that AMBLoRa has achieved the four desired objectives : long range communication, low power consumption of the system, quick deployment and relative real time visualization. However we must enhance some parameters.

We get a position after a certain amount of time ; we can consider that it is a relative real time ; we must reduce the send period to minimum. But, there will always be a delay due to all the processes involved in the sending and displaying chain.

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

The size of AMBLoRa is still too large and we must reduce its size.

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

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

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