An Ad Hoc communication system for an Efficient Milk collection within White Areas

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***Abstract*—The dairy industry holds an important part of the food sector of Senegal. Nevertheless, milk collection is a difficult logistical problem that has long been of interest to researchers. In addition, some dairies notably those in Senegal's sylvo-pastoral zone (Ferlo), encounter many problems related to the impossibility of communicating with their surroundings because they are in white areas (i.e areas where the services of telecommunications operators are not available). This affects their efficiency in the daily collection of milk from the production unit to the milk processing unit. In this paper, thanks to the ramp-up of LPWANs, especially Long Range($LoRa$) technology, we build a communication system that facilitates the collection, manipulation and presentation of data related to milk collection in these areas. The system enables the creation of a system that helps in the decision making to support logistical management in the milk collection sector.**

***Index Terms*—Ad Hoc, Network, Milk collection, LoRa, communication**

I. INTRODUCTION

After the failure of milk industrialization in West Africa, many little dairies have developed with more or less success and allowed a better valuation of local production. But they need to improve their collection and distribution devices to be more performing[1]. Since the 1990s, dairy sectors have been among the priorities of livestock development programs in West Africa. Several collection systems have been developed to supply small artisanal dairies created in several countries (Senegal, Mali, Burkina Faso, etc.). The collection can be grouped or individual, provided by collectors equipped with more or less rudimentary containers (plastic can) and who use bicycles, mopeds or carts to transport milk from the production areas to the processing units . These units collect 50 to 700 liters per day. They manufacture mainly fermented milk and pasteurized milk, marketed in heat-sealed bags of 200 to 500 ml [2].

These activities are therefore generating significant income and many families live through the collection and sale of milk. However, in the Ferlo, there are areas like the village of Namarel which is the headquarter of the Association for the Development of Namarel and its surroundings (ADENA) [3] where the main source of income for women is based on the milk collection. There is a collection system based on the milk collection with pick-up cars (milk is contained in plastic buckets or aluminum cans) or at the collection centers equipped with refrigerated milk cars Fig. 2. The product of the collection is then transferred to a dairy where the milk is processed and bagged. The inhabitants of the nearby villages make the route on foot to bring their stocks. For the most distant villages, the use of the cart is more common. In case of high demand, the pick up moves to collect the milk but that has a cost. Indeed the fuel and the material resources necessary for the collection and the safeguarding of the milk are loads to be taken into account, these are not the only constraint that must be taken into account because in these areas, telecommunications operators are not present at all and large areas are not covered in terms of mobile networks (2G, 3G or 4G)[4]. For instance Fig. 1 illustrates *SONATEL* operator network coverage according to $2G$ in Senegal. The inhabitants of these villages can not communicate, which makes the task of the collection even more complicated because it is necessary to ensure an optimal management of the resources for the collection in order to avoid making journeys for in the end not to have milk . In this paper, we propose a communication system with a Low Power Wide Area Networks(LPWANs) based technology LOng RAnge (*LoRa*)[5], [6] allowing the inhabitants of Namarel to be able to communicate by text messages or the sending of vocal notes in order to regularly inform the collection center on the quantity of milk in stock but also, a system of geolocation is added and allows to know the position of the suppliers. This would allow better management of resources and decision making in relation to collection. In order to enable an efficient communication between users of our system, it is mandatory to have a good link quality between users. Previous work have shown that LoRa can be a reliable link for low cost remote sensing applications[7][8] but also it has been tested in Oulu (Finland)[9] and Rennes (France) [10] to evaluate its coverage performance according to the Received Signal Strength Indicator (RSSI). Furthermore, we evaluated *LoRa* outdoor performance within Dakar peninsula [11], [12], which covers a ground area of $83Km^2$. Dakar is an urban area and is the Capital of Senegal. We observed a maximum communication range up to $10km$ with a good Received Signal Strength Indication (RSSI).

The remainder of the paper is organized as follow. Section II describes our LoRa-based communication architecture. Section III depicts our experimental test-bed and illustrates obtained results from extensive measurements. Finally, Section IV concludes our work.

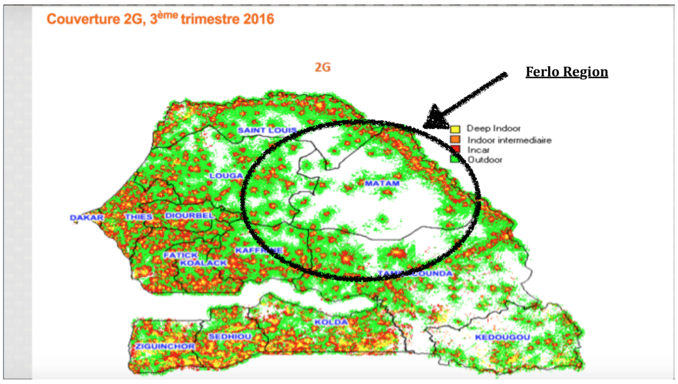

Fig. 1. 2G “ORANGE” cellular network coverage within Senegal in 2016

Fig. 2. A refrigerated milk car in Namarel village

II. LoRa-BASED COMMUNICATION ARCHITECTURE

A. *LoRa-based Communication Architecture*

Since in undeserved areas, satellite communications are very expensive for rural population, in order to choose the best communication system, we have to take into account some critical metrics to make a comparison between the existing Long Range solutions. Coverage, power consumption and cost are one of the most important metrics. In fact, villages in Ferlo are very far one from another and there isn't constant electrification. The device shouldn't consume a lot of energy and should be low-cost. We assume that a LPWA device is the best solution. We chose LoRa which is one of the most used and reliable technology for large coverage with respect to $LPWAN$ [6]. Therefore, we built an end-to-end communication system between smart phones via relay boxes that exchange information through $LoRa$ transmission protocol. Fig. 3 shows the communication architecture between users in our context.

B. *Communication Architecture components*

A communication between a given mobile box (smart phone) and a relay box (based on $Dragino\ LG01-P$) is

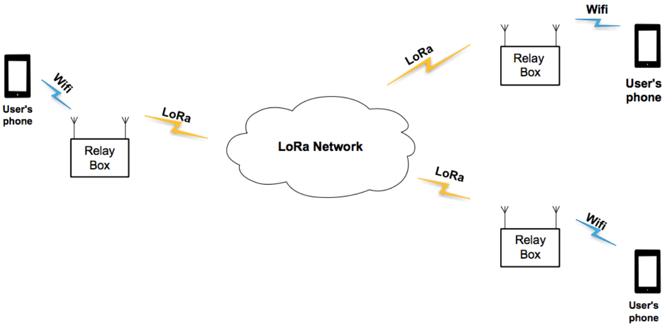

Fig. 3. LoRa-based Communication Architecture

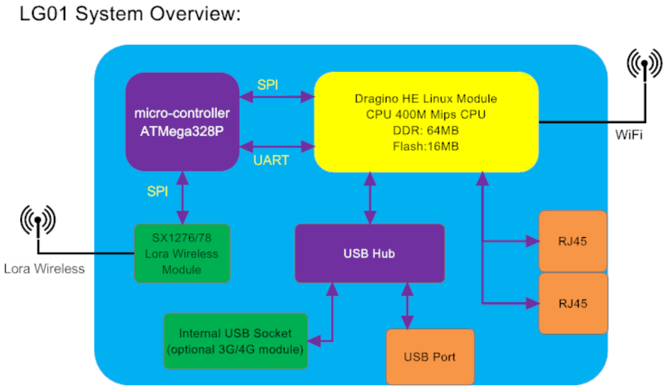

Fig. 4. Relay Box components

done by $Wi-Fi$ based on $IEEE802.11n$[13]. We consider a $LG01-P$ box which contains a $400MHz$ CPU that hosts $openwrt$ with $16MB$ flash and $8MB$ of storage memory, a LoRa chip ($SX1276$) transmitter, and an *arduino Yun* card. We build a mobile application in which we can connect to a web server installed in the relay box and send/receive data through $Wifi$. A MySQL server is installed in the box to save both data sent from the mobile application and data coming from the network. Then we made a *Shell* script that takes data from the database and send it to an arduino Yun card. The arduino Card reads the data by running Linux process with the *Bridge library's Process class*. Once the data is in the arduino card, we send it through LoRa to the destination node. For LoRa configuration, we had :

- spreading factor: 12 (4096 chips)
- channel size: $125khz$
- Power transmission: $14dBm$
- coding rate: $4/5$

It's worth noticing that LoRa uses the 868MHz ISM Band which is a free band. Communications are then free of charge for the users. Fig. 4 shows the components of the relay box. Furthermore, in the mobile application configuration, a registration is done for each village representative and information like their name, village name are stored. Every time they send a message, a label goes with it to identify the sender. They can also choose the recipient of their message in the application.

In order to enable a geographical information system, we considered an offline map which is deployed in the mobile application. Therefore, geolocation service can be used in order to locate message sender. According to our application, user's geographic location are retrieved from a GPS, and thus, we are able to send geographic location. These coordinates can be displayed by considering an offline map like $maps.me$.

Furthermore, $Ferlo$ is an area in Senegal where solar irradiation is very important. Sunshine duration ranges from 7 to 12 hours by day overall the year. Therefore, to ensure power supply, we use solar power systems with replaceable batteries of $7.4V$ and $5200mA$ which have 8 hours of autonomy. The battery is recharged by a $4W$ solar panel. In Fig. 5 we show the device placed in Namarel village equipped with the solar panel and Fig. 6 shows the relay box in a car for test purpose.

It's worth noticing that people who live in the Ferlo area are not often literate. Although we met representatives in the villages with a sufficient level of education to exchange text messages, we thought it would be useful to add to our system the possibility to send voice messages limited to 5 seconds to give information on their village and the amount of milk stored. we have added an option in the mobile application to send a voice message that stops automatically after 5 seconds, this voice message is sent by the same method as when sending text messages to the Web server and is stored in a database. A shell script that runs like a daemon comes to retrieve it and send it to the arduino card thanks to the process and the message is sent to the LoRa network by the arduino card. LoRa bit rate is very low so sending voice notes takes a bit of time (approximately 5 minutes). In fact, we send 4000 bytes for a 5 seconds voice note with payloads of 60 bytes sent every 4 seconds. All the relay boxes receive the first payload of a voice note and are paused for the duration of the transmission in order to avoid possible collisions. It is important to remember that the recipient of the message is added during the sending process in the mobile application as for the text message.

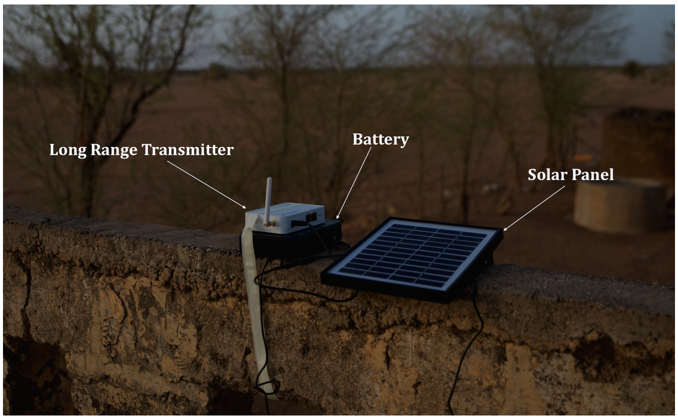

Fig. 5. Communication prototype kit used in Namarel Village

Fig. 6. Relay box embedded in a mobile car

III. EXPERIMENTAL TEST-BED AND RESULTS

Namarel is in a semi desert zone, the environment is almost the same for kilometers as shown in Fig. 7. There are large

Fig. 7. Namarel overview with a Drone

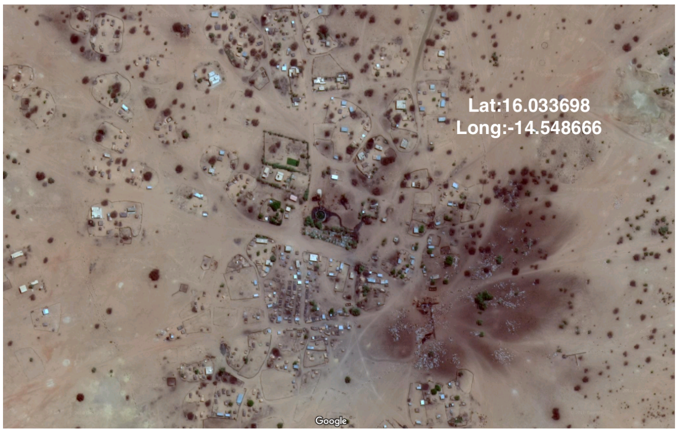

Fig. 8. Village in Ferlo at 12km from Namarel

areas of land with some trees and villages around. On Fig. 9 and Fig. 8 we can see images of two villages in this area. We tested the device around Namarel trying to cover a large part of the villages involved in milk collection and the economical development of the ADENA area. During these tests we put a base station on the roof of the Namarel headquarters as shown in Fig. 5, we placed another device on a pick up Fig. 6 and we criss-crossed around the village. We stored the Reception Signal Strength Indicator (RSSI) every time a packet was received and we also stored the number of packets sent and received. During the real-life measurements, communication with respect to an acceptable RSSI and a good PER worked up to 16km from Namarel Village.

Fig. 9. Village in Ferlo at 7km from Namarel

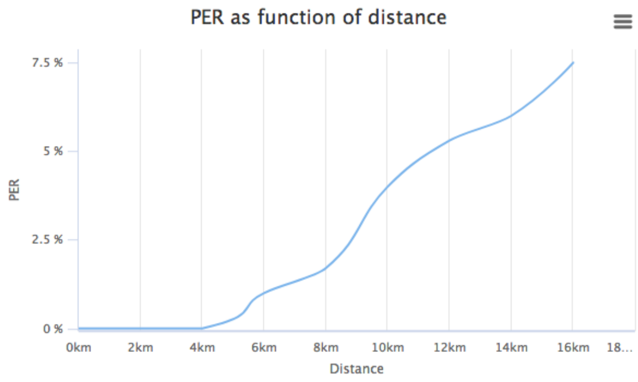

Fig. 10. PER as function of distance

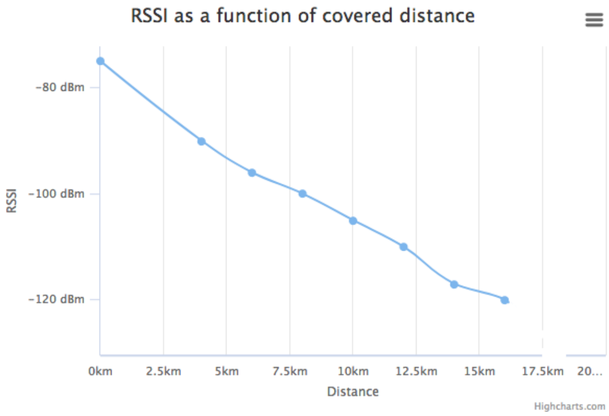

Fig. 11. RSSI as function of Distance

TABLE I
PERFORMANCE EVALUATION

Range (Km)	Number of transmitted packets	Number of received packets	Packet Loss Ratio
0-4Km	757	757	0%
4-8Km	807	793	1.7%
8-12Km	803	760	5.3%
12-16Km	650	601	7.5%
Total	3017	2911	4%

We sent 3017 packets and received 2911. The packet Error rate was 4% in total. Table I and Fig. 10 shows the test performance with the packet loss ratio as a function of covered distance This table shows that the packet loss ratio increases a bit when the range goes up. Fig. 11 shows the RSSi as function of the distance.

We can therefore say that villages around Namarel within $16km$ of distance can use the system to inform about milk storage. A mesh system could also permit the extension of the area so that villages at the extremities can forward messages of farthest villages.

IV. CONCLUSION

Providing a low cost and reliable communication system for people living in white areas in order to help them communicating with their surroundings for the milk collection was the major objective of our work.

In this paper we described the conception of the system and the communication architecture. We also made connectivity tests and showed the reliability of our system.

In the Future we plan to work on how to increase the range of our system and also see how to implement this system in the fishing environment where there are real problems with the safety of seamen at sea because there is no network coverage in this environment beyond a certain distance from the ground.

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