Work in Progress: A low cost geographical localization system for a more secure coastal artisanal fishery in Senegal

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***Abstract*—Fisheries sector hold a prominent role in Senegalese economy according to foreign exchange earnings (exports) and vital needs of population. Fishery remains artisanal and involve more than $19,000$ dugout canoes with different sizes. Nowadays, according to climate changes and fishes that are far away from coastal a lot of crashes occurs with roughly 100 deaths per year. Nevertheless, there is no rescue communication system for these dugout canoes. Indeed, Senegalese GSM cellular networks do not cover distance upper than 7 km from coasts.**

Leveraging $LPWANs$, especially Long Range ($LoRa$) technology, firstly enable a communication system for fishermen in order to inform in case of damages other dugout canoes within their vicinity as well a given control center. Secondly, $LoRa$ communication empowers fishermen to collaborate at sea either by sharing information or to pull mesh. We performed several performance evaluation at sea where more than 90% of packets are received according to a maximum range of 22 km and a $RSSI$ of -95 dBm.

***Index Terms*—Localization, Artisanal fisheries, LoRa, Communication, Rescue management**

I. Introduction

In Senegal, fishing is an activity of economic, social and cultural importance. Agricultural sector faces several difficulties such as climatic adversities and deterioration of raw materials prices. This leads the country to rely heavily on the fishing to improve a deficit trade balance. Artisanal fishery, with $19,000$ active vessels ($6,000$ more than in 2009), including $4,350$ dugout canoes, is very active, contributing to 11 % of primary GDP and 2.5% of total GDP (According to the National Agency of Statistics) [1]. Landings in artisanal fisheries at the end of April 2016 amounted to $144,872$ tonnes ($8,793$ tonnes more than in the same period of 2015). Among the $600,000$ Senegalese that work within this sector, artisanal fishery involve $400,000$ fishermen [1].

However, the social and human conditions are difficult, including safety problems at sea [2] (nearly 100 deaths per year). Artisanal fishing boats are usually made of a wooden shell of local design, on which is fitted an outboard engine that can go up to at 60 horses. Dugout canoes are emblematic in Senegal, therefore their integration into modern fishing landscape of tomorrow will rely on their capacity for modernization. Indeed, at present, the embedded electronics is at best made up of the cell phones of the crew and a GPS "hand" of the captain [3]. Similarly, conventional centralized marine positioning systems (VMS or AIS) are not shipped for financial reasons. As results, the distribution of dugout canoes remains unknown to the institutions in charge of fisheries monitoring. Although Senegalese government is trying to equip some dugout canoe with geolocation system, they still have issues to equip everyone because of the equipment price. Proposing a low cost solution is on of their critical objectives.

Furthermore, fishermen who go beyond $7km$ of the coast are in white areas and have no way to communicate with each other or the land. This makes the potential consequences of engine damage or capsizing even more dangerous, as it is no longer possible to call for help. In case of no return of a dugout canoe, the committee of fisherman alerts the aviation which can carry out researches at sea, but with weak indication on the sector of research, and sometimes too late. Besides, the currents in the Senegal area tend to drive off any drifting objects offshore, especially during the up welling season (cold season), which is also the time when the fisherman ventures the most and the further away from the coasts. It's worth noticing this project is designed in collaborative manner with the union of fishermen of Ouakam (Dakar, Senegal)

The contributions of this paper are:

- Determine the geographical coverage range of cellular network operators at sea
- A LoRa-based communication that enables a given fisherman to send maydays in case of crash to a control center or other fishermen that are located within its vicinity.
- A geographical localization system that sends to neighborhood the actual position of each dugout canoe.

A couple of works have shown the possibility to use $LoRa$ technology as communication system. Indeed, the physical and data link layer performance of LoRa (*LoRa*) [5], [6] have been evaluated by field tests and simulations in [7] [9] [8]. Furthermore, *LoRa* outdoor performance within Dakar peninsula which covers a ground area of $83Km^2$ is evaluated in [10], [11].

The remainder of the paper is organized as follow. Section II describes. The limits of Geograpical coverage of cellular network. Section III depicts our experimental test-bed. We also

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illustrate the obtained results from extensive measurements. Finally, Section IV concludes our work.

II. Geographical coverage limits of cellular network operators

In telecommunications, Received Signal Strength Indication or $RSSI$ is a measure of the power in reception of a signal received from an antenna (conventionally a radio signal). Its purpose is to provide an indication on received signal intensity.

RSSI is used in mobile networks to select a relay antenna among several possible; it is also one of the criteria used to prepare and decide the handover (change of radio cell for a mobile terminal) by comparing received signal levels from old and new radio cell. RSSI measurement makes it possible to improve geolocation within a mobile network and can also be used within Wi-Fi networks, for indoor geolocation [12].

In this work, we want first to identify where the operator coverage stops or where its signal is no longer a reliable one. This information is important because it will help us to see where our service can be interesting for fisherman and what additional distance we can bring.

Table I from [14] shows the meaning of a given RSSI in $2g$ context. It's worth noticing that $2G$ (GSM) Signal strength is defined by only one value: RSSI – Received Signal Strength Indicator; RSSI is a negative value, and the closer to 0, the stronger the signal.

So we went in the sea and criss-crossed in order to see at what distance the RSSI is no longer reliable. We used two mobile applications ($inViu\ OpencellID$ and $network\ cell\ info\ lite$) and made some screenshots of the signal quality in different positions like in Fig. 1 and Fig. 2. Diferent positions we had are maped in Fig. 3.

Fig. 1 shows two important information: geographical coordinates of where screenshots was taken and RSSI. It also shows Cell-ID, Mobile Network Code (MNC), Mobile Country Code (MCC) and Location Area Code (LAC). With these information, we can find geographical coordinates of the Base station to which the cell phone was connected thanks to [15] and then know the distance between cell phone and Base Station . We notice that based on Table I received signal is fair until 3km but is poor after that and we have no signal starting from $7km$. RSSI was respectively $-95dBm$, $-107dBm$, $-113dBm$. It's worth noticing that we only considered Orange coverage which is the first telecomunication operator in Senegal and we have it's overall coverage in Senegal in [16]. We then assume that the coverage stops being reliable from 7km of the coast.

III. Experimental test-bed and Results

A. Test-bed

To make the tests, we had a scenario in which our device was on the top of a hill called "Phare des mamelles" that ranges up to 126 m.It was sending data every 5 secondes to an other which was on an artisanal dugout canoe as illustrated in Fig. 5. In [17] and [18] we describe in detail the device and the proposed architecture to make it work. For test purpose we had this configuration in our $LoRa$ device:

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

B. Results

During the real-life measurements, communication with respect to an acceptable RSSI and a good PER worked up to $22km$ from the coast. According to [14], a signal between $-86dBm$ and $-100dBm$ is a fair signal. In a previous work [10] we showed that a signal with that RSSI have less than 20% of loss packets. So we decided to take that metric to have a minimum RSSI to consider. It's the reason why the results we present stops at $22km$. It is the maximum distance where we have a decent RSSI.

We sent 4146 packets and received 3935. The packet Error rate was nearly 5% in total. Table II and Fig. 6 shows test performance with packet loss ratio as a function of covered

Fig. 1. $2G$ RSSI with "inViu OpenCellID" application

TABLE I
$2G$ EXPECTED PERFORMANCE ACCORDING TO THE RSSI AT THE MOBILE SIDE

RSSI	Signal Strength	Description
$>= -70$dBm	Excellent	Good signal and maximum data speeds
-70dBm to -85dBm	Good	Good signal and good data speeds
-86dBm to -100dBm	Fair	Fair but usefull, fast and reliable data speeds may be attained, marginal data with drop outs
< -100dBm	Poor	Performance will drops drastically
-110 dBm	No signal	Disconnection

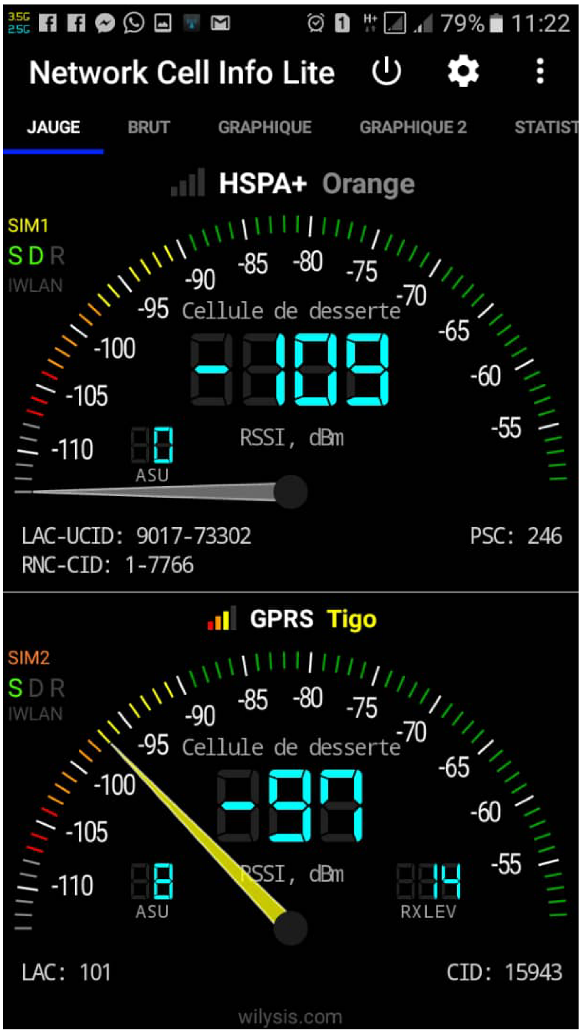

Fig. 2. $2G$ RSSI with Network Cell Info Lite application

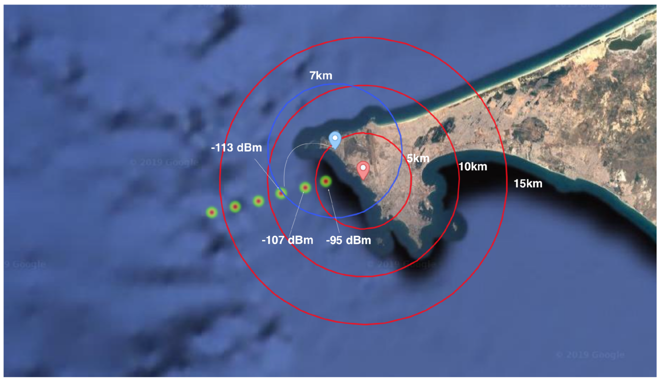

Fig. 3. 2G RSSI during test

Fig. 4. Received Signal with RSSI higher than $-95dBm$

distance. This table shows that the packet loss ratio increases a bit when the range goes up. Fig. 4 shows received signal with RSSI higher than -95dBm.

IV. CONCLUSION

Provide a low cost and reliable communication system with a geolocation system to fisherman in Senegal was the major objective of our work. This system could help them in their every day work which is their main source of income. It helps also in preventing from disaster since they can send maydays and let people know their exact geolocation

TABLE II
PERFORMANCE EVALUATION

Range (Km)	Number of transmitted packets	Number of received packets	Packet Loss Ratio
0-5Km	1057	1037	2%
5-15Km	1727	1685	3%
15-20Km	903	862	5%
20-22Km	459	351	13%
Total	4146	3935	5%

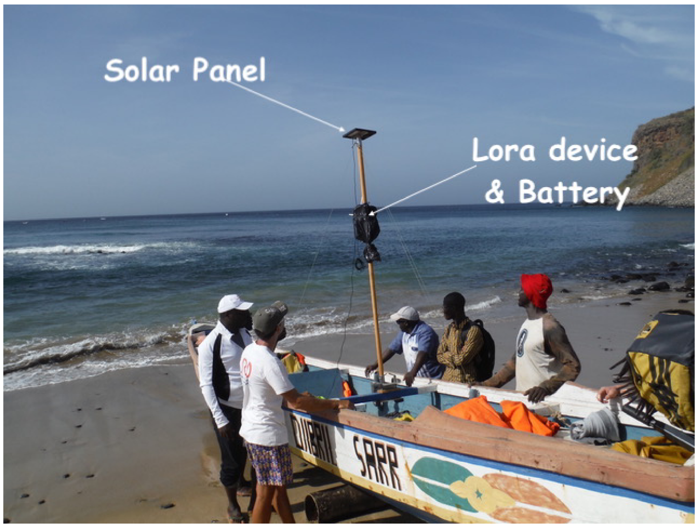

Fig. 5. Mobile Relay in the Canoe

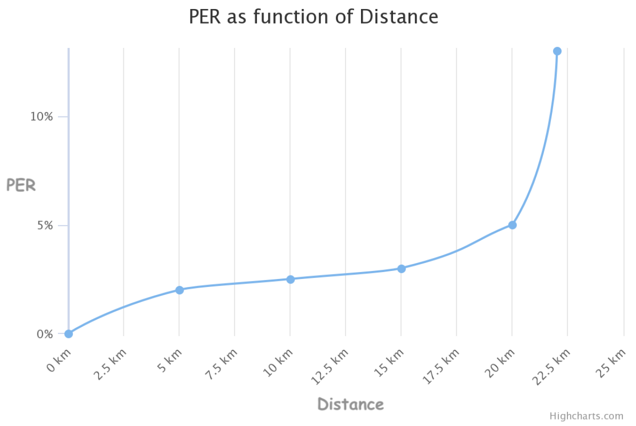

Fig. 6. Packet Error Rate (PER) as function of distance

In this paper we showed that the telecommunication operators have some coverage limits and don't go further than 7km in the sea. We then presented a solution based on LoRa than can serve the fisherman beyond those $7km$. 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, add some services related to the fishing activities and build a communication model in order to add routing algorithms in case we don't have a direct connection to the ground. It could help in the search of users and good fishing areas but also to find country borders as well as protected areas etc.

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REFERENCES

[1] La pêche et les ressources halieutiques au Sénégal *https://www.senegal-export.com/les-ressources-halieutiques.html*
[2] http://yveslebelge.skynetblogs.be/archive/2014/12/24/89-victimes-de-la-mer-8352358.html
[3] *(http://www.osiris.sn/La-geolocalisation-des-pirogues.html)*
[4] http://www.senjob.com/news/entry/394/24/Sécurité-des-pêcheurs-Des-balises-de-géolocalisation-pour-26-embarcations
[5] U. Raza, P. Kulkarni, and M. Sooriyabandara, "Low Power Wide Area Networks: A Survey," arXiv preprint arXiv:1606.07360, 2016.
[6] Usman Raza, Parag Kulkarni, Mahesh Sooriyabandara, "Low Power Wide Area Networks: An Overview", *IEEE Communications Surveys and Tutorials*, vol. 19, no. 2, January, 2017.
[7] by Aloÿs Augustin 1, Jiazi Yi 1,*, Thomas Clausen 1 and William Mark Townsley 2 "A Study of LoRa: Long Range and Low Power Networks for the Internet of Things", https://doi.org/10.3390/s16091466 *IEEE SENSORS*, 2016.
[8] NGOM, Bassirou, SEYE, Madoune Robert, DIALLO, Moussa, et al. A Hybrid Measurement Kit for Real-time Air Quality Monitoring Across Senegal Cities. In: *IEEE ICSCC*, July 2018, Ouagadougou, Burkina Faso.
[9] Tara Petrić ; Mathieu Goessens ; Loutfi Nuaymi ; Laurent Toutain ; Alexander Pelov "Measurements, performance and analysis of LoRa FABIAN, a real-world implementation of LPWAN", *2016 IEEE 27th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC).*
[10] Madoune R. Seye, Bassirou Ngom, Bamba Gueye, Moussa Diallo. "A Study of LoRa Coverage : Range Evaluation and Channel Attenuation Model". *IEEE ICSCC*, July 2018, Ouagadougou, Burkina Faso.
[11] Robert M. Seye, Bamba Gueye, Moussa Diallo. "An Evaluation of LoRa Coverage in Dakar Peninsula". In: *IEEE IEMCON 2017*, Vancouver, Canada.
[12] P. Marichamy Dept. of Electron. and Electr. Commun. Eng., Indian Inst. of Technol., Kharagpur, India ; S. Chakrabarti ; S.L. Maskara "Overview of handoff schemes in cellular mobile networks and their comparative performance evaluation", *Gateway to 21st Century Communications Village. VTC 1999-Fall. IEEE VTS 50th Vehicular Technology Conference (Cat. No.99CH36324).*
[13] Dragino Technology, http://www.dragino.com/products/module/item/102-LoRa-shield.html.
[14] *https://wiki.teltonika.lt/view/*
[15] Profone GSM Tracker https://cellphonetrackers.org/gsm/gsm-tracker.php
[16] ORANGE, *https://www.orange.sn/2/particuliers/1/429/404-10806.html*, September 2018.
[17] Madoune R. Seye, Moussa Diallo, Bamba Gueye, Christophe Cambier. COWShED: Communication Within White Spots for Breeder. In: IEEE ICIN, February 2019, Paris, France. (Best Demo Award)
[18] Madoune R. Seye, Moussa Diallo, Bamba Gueye, Christophe Cambier. An Ad Hoc communication system for an Efficient Milk collection within White Areas. In: IEEE IWCMC, June 2019, Tangier, Morocco.