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LoRa-Based System for Tracking Runners in Cross Country Races †

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† Presented at the 6th International Electronic Conference on Sensors and Applications, 15–30 November 2019; Available online: https://ecsa-6.sciforum.net/

Published: 14 November 2019

Abstract: In recent years, there is an important trend in the organization of cross country races and popular races where hundred people usually participate. In these events, runners usually subject the body to extreme situations that can lead to various types of indisposition and they can also suffer falls. Currently, the electronic systems used in this type of racing refer only to whether a runner has passed through a checkpoint. However, it is necessary to implement systems that allow controlling the population of runners knowing their status all the time. For this reason, this paper proposes the design of a low-cost system for monitoring and controlling runners in this type of event. The system is formed by a network architecture in infrastructure mode based on Low-Power Wide-Area Network (LPWAN) technology. Each runner will carry an electronic device that will give their position and vital signs to be monitored. Likewise, it will incorporate an S.O.S. button that will allow sending a warning to the organization in order to help the person. All these data will be sent through the network to a database that will allow the organization and the public attending the race to check where the runner is and the history of their vital signs. This paper shows the proposed design to our system. Therefore, the paper will show the different practical experiments we have been carried out with the devices that have allowed proposing this design.

Keywords: Wireless Sensor Nerworks (WSNs); Low-Power Wide-Area Network (LPWAN); runners; Long Range (LoRa); Monitoring.

1. Introduction

Nowadays, it is more often the organization of cross country races and popular races where hundred people usually participate. These races are organized both in the city and in natural environments. In these events, amateurs and professional runners usually subject the body to extreme situations. People can suffer falls, injuries and can lead to various types of indisposition.

It is a known fact that regular physical activity is a key to the prevention of physical injuries and diseases [1], but both very sportive people and not so much sportive people can suffer some injury or disease during a race. Falls, bumps, muscle and bone injuries, fainting, etc. are possible incidents that can occur to runners when participating in races.

Currently, when races take place there some methods based on RFID or Bluetooth to control when a runner pass through any checkpoint and to control how much time he spent to get there [2]. Neither runners are tracked, nor injuries of runners are controlled. Some investigations show that wireless technologies such as LoRa or GPS can be used for tracking people in real time, obtaining information about localization and information about runner health [3][4].

In regard to cross country races and popular races where it is wanted to track runners continually to know where they are and how they are in wide areas, LoRa is a reliable wireless communication option to be used. LoRa is a wireless technology that operates on the 433, 868 or 915 MHz ISM band, and provides long-range coverage. LoRa is also resistant against interferences and, regarding energy cost, LoRa could be considered energy-efficient technology [5].

Taking into account these issues, this paper proposes the design of a low-cost system for monitoring and controlling runners in these races events. The system is formed by a network architecture based on Low-Power Wide-Area Network (LPWAN) technology. Each runner will carry an electronic device that will give their position and vital signs to be monitored. It will incorporate an S.O.S. button to send a warning to the organization. All these data will be sent through the network to a database to be stored and analyzed.

The remainder of this paper is organized as follows. Section 2 presents some related work. The proposed system and hardware used are explained in Section 3. Section 4 describes the test bench and the results obtained. Finally, Section 5 draws the main conclusions and future work.

2. Related Work

This section presents some works related to the topic of this paper. Works discuss on tracking localization, movement and health status of people in different situation and using different technologies. It is common to find proposals focused on tracking people disabled and elderly people [6] but in most cases, these proposals are based on mobile networks. So, we have to pay for using this infrastructure. There are other recent proposals that authors are tending to use free technologies. For example, Dondrup et al. [7] present components that have already been proposed for human detection, tracking, the generation of qualitative representations of HRSI, and trajectory stitching. And also, they implement all these components in a concise and easy way to deploy systems based on ROS the Robot Operating System, for the first time. Their study shows the possibility of tracking people movements.

Linder et al. [8] propose a fully integrated real-time multi-modal laser/RGB-D people tracking framework for moving platforms in environments like a busy airport terminal. Authors say that they want to go one step further and examine how well other publicly available tracking methods performed in challenging, highly crowded and dynamic scenarios.

The two works exposed before showed the possibility of tracking people movements using video technologies. In regards to the different technologies such as wireless technologies, we are going to expose some different investigations.

Hadwen et al. [9] discussed building an energy-efficient LoRa GPS wristband tracker for dementia patients. They inspected energy consumption of the components in a GPS tracker and proposed a novel energy efficient. Their prototype shows that the GPS wristband can support up to 40 hours continuous GPS tracking with a frequent 60 seconds location update rate, and a ranger coverage of 3 Km. LoRaWAN stands out for its low power usages and long-range data transmission.

Kim et al. [10] suggest object tracking and managing system based on LoRaWAN technology. They design and perform bicycle location management system and shows its efficiency. Firstly, they explain the required service of the tracking and managing system. Using IoT and LPWAN technology, they designed the system, identified necessary services, and constructed the system. Their study shows that IoT technology enables to real-time monitor the status of object when Internet is not connected.

Hoffman et al. [3] demonstrate how the requirement to carry a GPS tracking unit during a wilderness ultramarathon enabled a successful rescue of a lost runner that likely would have had an adverse outcome if the runner had not been carrying the GPS tracking unit. They showed how a GPS tracking system can enable the rescue of lost athletes in the wilderness. Authors suggest that wilderness endurance event organizers consider requiring their participants wear a GPS tracking device, especially when the event extends over multiple days, and that they assure a system is in place to monitor for athletes who are off course.

These technologies have been also used to monitor health and to improve exercise performance. In [4] Pandey et al. explore how recreational athletes use tracking technologies to assess and improve their performance. They study 25 recreational athletes that are runners, soccer, tennis, and basketball players. They used wearable devices and mobile applications to track general physical activity data.

In contrast of the existing systems, our proposal wants to collect data from the runners and create a platform to monitor them and to be sure they have no problem by using LoRa Networks.

3. Proposal Description

This section presents the design description of our LoRa-based system for tracking runners in cross country races. Additionally, the devices used to develop our system are described.

3.1. Overview

As mentioned before, in popular races and cross country races it is important to have runners located and to be able to monitor their status. To do this, our LoRa-based system for tracking runners proposes the deployment of a LoRa network composed of mobile nodes, which will be worn by the runners and a fixed node that will act as a gateway.

The gateway will be the node responsible for collecting all the desired information from the mobile nodes and sending them to the application server and the database.

The storage and data collection can be performed by using the own servers developed to this purpose or the use of existing platforms such as The Thing Networks (TTN), using an existing Internet connection or mobile connections through 3G/4G networks [11]. TTN is a community that offers open-source software projects to its users to make possible the connectivity between different elements in a LoRaWAN network. One of its main strengths is the capability of connecting any LoRaWAN gateway to its network servers, so no extra infrastructure is required.

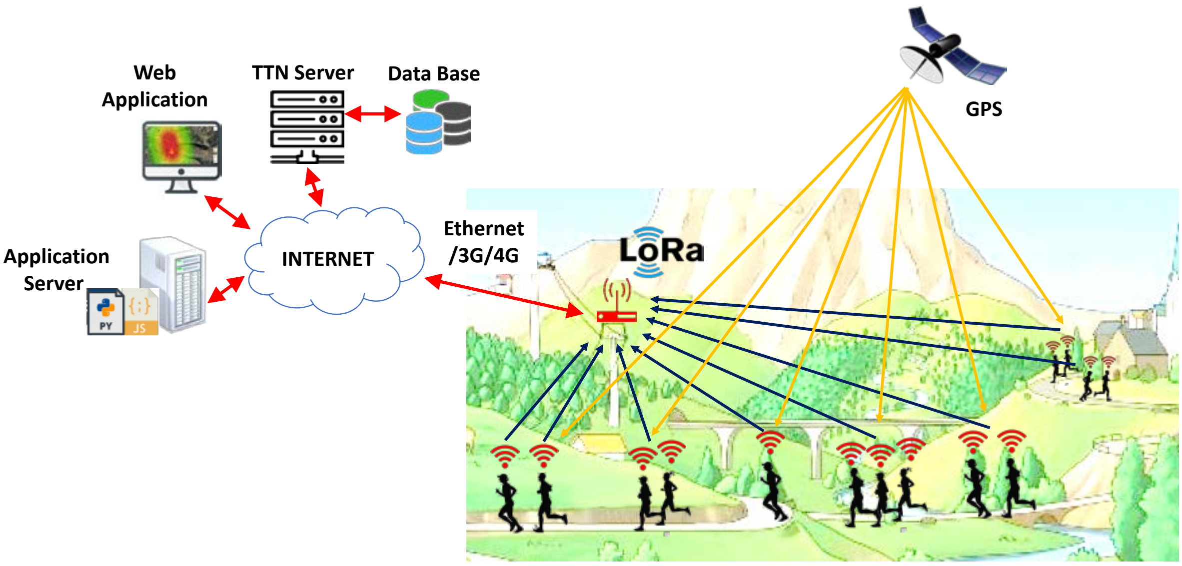

Figure 1. Network architecture for our LoRa-based system for tracking runners in cross country races

The race information and runner's location will be available in the Data Base (DB). Any user and relatives can access to the web application to see it, identifying the runner by its dorsal. Finally, if a runner suffers an incident can launch a warning message by using the SOS button. This message will contain the runner ID and the GPS position. However, if the runner status makes impossible he/she activates this warning, but the system has detected this runner is static for a long time, the SOS button will send an automatic message informing the runner does not reply and his/her position and ID in order to offer him/her the necessary medical attention as quickly as possible.

3.2. Hardware used

In order to implement our LoRa gateway, we have used a RAK2245 module [12] coupled with a Raspberry Pi board (see Figure 2). RAK2245 Pi HAT is fully compatible with the Raspberry Pi 40pin header to be used as a gateway of a low cost LoRaWAN network. The RAK2245 Pi HAT is based on the Semtech 1301 and dual SX1257/58 front-end chips. This concentrator is able to manage up to 8 channel LoRa with a Tx Power up to 27dBm and a RX sensitivity down to -139dBm. It has been improved to support the noise resistance due to improved RF chain filtering and presents a redesigned heat sing for better thermal dissipation and reduced thermal noise. Finally, the RAK2245 Pi HAT supports the frequency bands of EU433, CN470, IN865, EU868, AU915, US915, KR920, AS920 and AS923.

On the other hand, the mobile nodes are implemented by using a Dragino LoRaWAN GPS Tracker LGT-92 [13]. It is an open-source GPS tracker based on the STM32L072 MCU and SX1276/1278 LoRa Module. The LGT-92 includes a low power GPS module L70 with a 9-axis accelerometer to detect motion and attitude. The LGT-92 uses LoRa wireless technology to send data measured by sensors that can be added to the module. It is able to reach long distances at low data-rates. Finally, it is important to highlight that this device can be used for a long time due to its very low power consumption (77uA for Sleeping Mode, 38mA for Tracking mode and 24 to 150mA for LoRa Transmission). Figure 3 shows the Dragino LoRaWAN GPS Tracker LGT-92 module.

Figure 2. RAK2245 module with a RaspBerry Pi board

Figure 3. Dragino LoRaWAN GPS Tracker LGT-92

To add more functionalities to our system which is our final goal, the Dragino LoRaWAN GPS Tracker LGT-92 could be replaced by similar modules that allow connecting sensors to measure heart rate, body temperature, etc. but in this paper, we focus the study on the maximum coverage these devices can offer.

4. Results

This section shows the results of network performance in terms of Received Signal Strength Indicator (RSSI) and signal-to-noise ratio (SNR). To carry out the test, we have placed a gateway in a building where the gateway is powered by electricity and can be connected to the wired network of the same building. This fact is necessary to be able to record the data captured by the LoRa network and be seen by the users. The cable internet connection can be replaced by a 3G or 4G mobile connection, and even 5G when this technology is fully implemented and available to users. On the other hand, we have used a node to follow the path and collecting the GPS node position, the RSSI and the SNR values registered by the node in each position.

The measures have been taken in the city of Medicina located in the Province of Bologna, in Emilia-Romagna (Italy). Figure 4 shows the path followed by the node. The gateway has been placed on the red circle while the mobile node (represented by a blue circle) has followed the blue line. According to the results, the maximum distance reached by our node is 11.46 km.

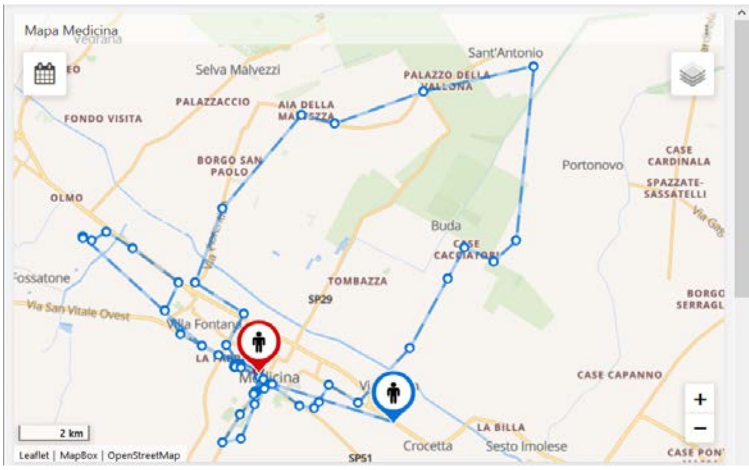

Figure 4. Path followed by the node during the test.

Regarding to the network performance, we analyze the parameters of RSSI and the SNR which are indicative of the quality of our signal and our service. Figure 5 shows the value of RSSI as a function of the distance to the gateway registered during the test. The results are compared to the free propagation model. As we can see, the results show a behavior away from the ideal model. This behavior is the expected one, if we consider that the ideal models are obtained under optimal conditions without considering the presence of obstacles or meteorological factors. In our case, the measurements have been made in urban and rural areas where many objects come out that can make the received signal worse. However, considering the specifications of the standard (which say that you can work with Lora up to -120dBm) we can find these results useful, for the type of application we want to implement. Figure 6 shows the value of SNR as a function of the distance to the gateway registered during the test. As we can see, there is a great scattering. This is due to the distance and the presence of objects that generate reflections and refraction of the transmitted signal.

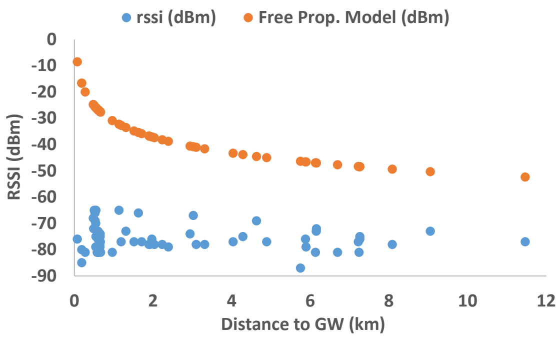

Figure 5. RSSI as a function of the distance to the gateway registered during the test.

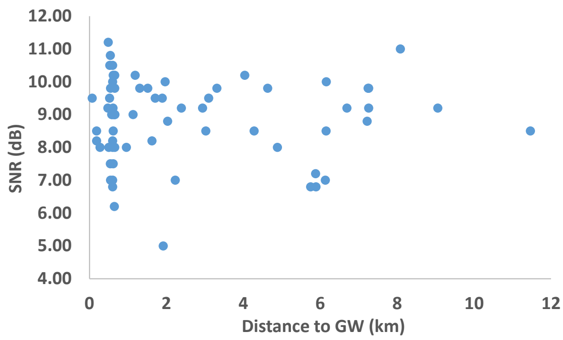

Figure 6. SNR as a function of the distance to the gateway registered during the test.

4. Conclusion and Future Works

In this paper, we have presented the design of a system for tracking runners in cross country races. The system is based on the use of a LoRa network composed by a fixed node that works as a gateway and a set of mobile nodes that the runners wear. These mobile nodes are in charge of collecting data from runners (such as vital signs) and the GPS position. In case of a runner has a problem the developed platform will help the runner and the races organization to provide the required help. In this first step of our design, we have tested the maximum coverage that an infrastructure as the one describes could offer. Our results have shown that with an only gateway we could give coverage up to 11km far from the gateway with an acceptable network performance.

As future works, we want to include the sensors for collecting the vital signs of runners and test the system simultaneously in several runners, just to see the scalability of our LoRa-based system for tracking runners in cross country races.

Author Contributions: Conceptualization, S.S., J.L. and P.R.; methodology, S.S.; validation, J.L.G.; formal analysis, J.L.; writing—review and editing, S.S. and J.L. G.

Funding: This work has been partially supported by the "Ministerio de Ciencia, Innovación y Universidades" through the "Ayudas para la adquisición de equipamiento científico-técnico, Subprograma estatal de infraestructuras de investigación y equipamiento científico-técnico (plan Estatal I+D+i 2017-2020)" (project EQC2018-004988-P).

Acknowledgments: This work has been partially supported by the "Ministerio de Ciencia, Innovación y Universidades" through the "Ayudas para la adquisición de equipamiento científico-técnico, Subprograma estatal de infraestructuras de investigación y equipamiento científico-técnico (plan Estatal I+D+i 2017-2020)" (project EQC2018-004988-P).

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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