Improving SAR ops using Wi-Fi and LoRa on UAV

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***Abstract*—Solutions for improving Search and Rescue operations (SAR) operations are receiving increasing attention. Transponder is one of the an open-source, lightweight and low-cost solution. It installed on top of a drone, conceived for the analysis of Wi-Fi beacons or probe requests in areas without network infrastructure. It relies on LoRa communications and uses a Complex Event Processor for the enhancing and enriching data analysis and for providing first-aid information. The use of Transponder in a realistic scenario is also presented.**

***Index Terms*—SAR, UAV, LoRa, Wi-Fi, CEP, Monitoring**

I. Introduction

Nowadays, Search and Rescue operations (SAR) are becoming performed also through the usage of Unmanned Aerial Vehicles (UAVs), using cameras [1] and in some cases thermo-cameras installed on it. However, in several scenarios, with adverse weather conditions, such as in case of low visibility or dense bush, cameras cannot provide the expected outcomes for helping in SAR operations [2]. Thanks to the direct interactions with rescuers and through the analysis of the documentation related to the SAR procedures, some important key points for solving the issues related to SAR operation have been identified. Among them on of the most critical are: i) the lack GSM or generic mobile signals: many times people that get lost in very vast area not covered by GSM or mobile signal so they are hardly or not localizable; ii) Critical time constraints: SAR operations have strong and critical time constraints for different reasons: people can be injured, they can be lost during night on areas with very low temperatures, or they can be lost in area with the concrete risks of encountering wild animals or land-deep ravines or mountainsides; iii) limited resources: usually a limited, well equipped number of UAVs,are available within short time. In order to solve the above mentioned issues, in this demo paper, the Transponder (*supporT foR locAliziNg diStress People thrOugh a flyiNg Drone nEtwoRk*) solution is presented. Transponder is an open-source, lightweight and low-cost solution, to be installed on top of an UAV, conceived for the analysis of Wi-Fi *beacons* or *probe requests* [3] in areas without network any other infrastructure. It relies on LoRa communications and uses a Complex Event Processor (CEP) for enhancing and enriching data analysis and providing first-aid information in scenarios where the user under distress has installed a specific mobile application. The paper is organized as in the following: Sections II and III describe the solution and its use respectively, Sections IV and V provide the system validation, discussion and future work respectively.

II. Transponder description

Transponder relies on the detection of Wi-Fi signals with the optional support of a specific mobile application. The hardware used for the system has been selected taking in account the weight, in order to be able to deploy Transponder on a commercial drone and the costs, to let the system scale without a significant economic impact. The main component is a Raspberry-PI (R-Pi)[1] on which Raspios AARCH 64bit is running. The R-Pi has been enhanced with: 1) a Wi-Fi 2.4/5 Ghz High-Gain antenna that supports monitor mode for capturing network traffic over the air through tcpdump[2]; 2) a GPS module for providing the detected Wi-Fi packet position; 3) a LoRa SX1275 ESP32 device with a dedicated antenna for notifying detection to the rescuers. The system, with an overall weight of 188 gmm is shown in Figure: 2, and is powered by a battery pack placed under the R-Pi board that provides an autonomy of approximately 30 minutes.

As depicted in Figure: 1 Transponder consists in the following components and devices:

OnBoard node is the component on which different devices are deployed. Among them the *CEP* is in charge of analyzing events generated by GPS probe and Wi-Fi probe and inferring more complex pattern [4] specified through a rules language, in this case: Drools [3]. The event contains information about drone position and Wi-Fi beacons captured by the High-Gain antenna. Once a *Beacon* or a *Probe request* packet is captured, a message event is generated and sent to the CEP. The CEP will check if the position value is valid and if there are rules that match any adverse condition before sending a message to the LoRa device connected to the R-Pi for notifying the detection to the rescuers. The *JMS/MQTT Server*, realized by means of Apache Artemis [4] is the backbone of the system collecting the JMS and MQTT messages generated by probes. The *JMS/MQTT Mediator* allows the interaction between the protocols JMS used by probes and MQTT used by the Mobile application converting MQTT messages generated by the mobile application to JMS messages managed by the CEP and viceversa. The *Sender Module*, deployed on the *LoRa transmitter* device, transmits the CEP detection results (i.e.

[1]https://www.raspberrypi.com/products/raspberry-pi-4-model-b/
[2]https://www.tcpdump.org/manpages/tcpdump.1.htm
[3]https://www.drools.org/
[4]https://activemq.apache.org/components/artemis/

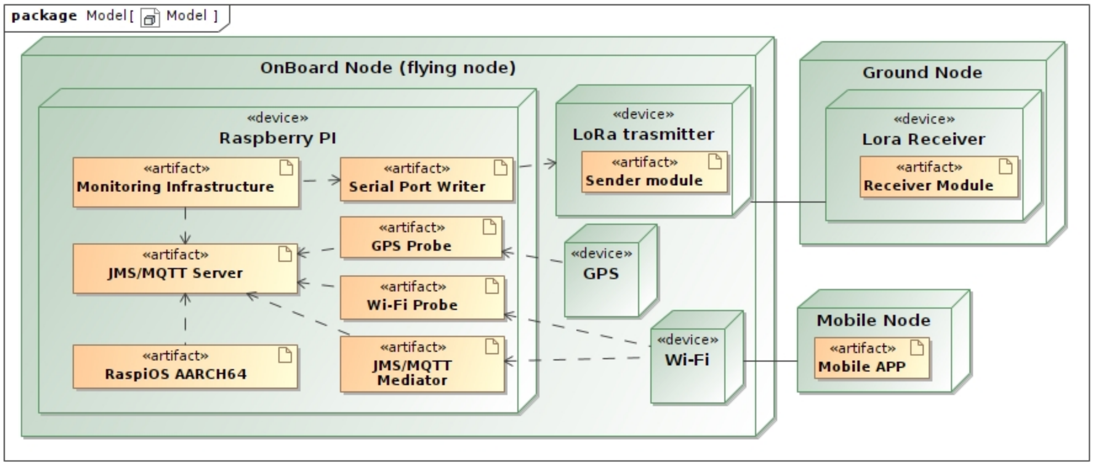


Fig. 1. Nodes, devices and artifacts of the proposed system

location coordinates, MAC address and dB of the detected beacons) by means of LoRa technologies to the *Ground node*.

Ground node receive the CEP detection results by means of the *Receiver Module* which is running on the *Lora Receiver* device. The *Receiver Module* is continuously listening for incoming LoRa messages. As shown in Figure: 3(b), the *Receiver Module* also exposes the web server used by rescuer device for connecting and reading the CEP detection results.

Mobile Node In order to enhance rescue experience and to provide an immediate medical and psychological support to the subject under distress, a optional prototype of Android application has been also developed. As shown in Figure: 3(a) the application allows the user in distress to specify the type of emergency (such as *Loss of blood, Inability to move, etc.*.) and the number of persons involved in it. In this case, the application tries to continuously connect to an additional Wi-Fi network generated by the R-Pi device, for sending the emergency data to the *JMS/MQTT Server*. As shown in Figure: 3(a), the application is also in charge of visualizing the first-aid suggestions computed by the CEP device to the person in distress.

In this solution the detection mechanisms relies on the detection of two types of messages generated by any Wi-Fi interface turned on, the *Probe Request* or the *Beacon*. Both messages are broadcasted without any cryptography mechanism, so they are detectable by any other Wi-Fi device in monitor mode. The detection of one of those messages in a area where is supposed to do not have devices, may means the presence of a person.

In the best of the authors' knowledge, Transponder advances the state of the art in the SAR solutions [2] by considering the following aspects: i) it is the only one that relies on Wi-Fi beacons detection; ii) it uses a CEP mechanism to enhance analysis; iii) it manages emerging scenarios thorough rules-based pattern detection mechanism; iv) it does rely on the person in distress specific hw device.

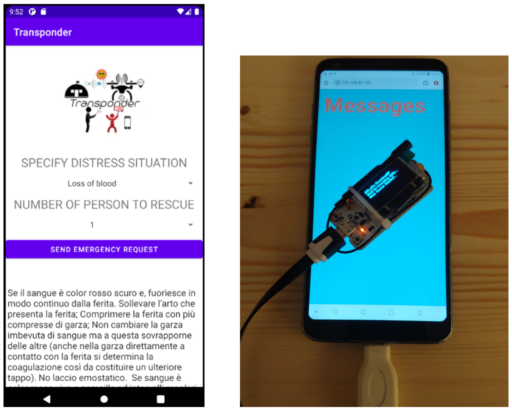
Additionally, the majority of the analyzed solutions either relies on images scan, and therefore requires the use of artificial intelligence or high computation power or rely on GSM, ARVA or LoRa devices, and therefore cannot provide valid data in case of adverse weather or environment conditions such as dense bush or fog. On the contrary, Transponder relies on pervasive technology, such as Wi-Fi mobile network, does not need high computational power, and can scale and adopted in critical environments and situation.

Fig. 2. The OnBoard node installed on a commercial drone

III. Usage scenarios

To be used in an emergency situation Transponder needs to startup the *OnBoard node*, this can be done through a shell script that: sets the high-gain Wi-Fi device in monitor mode; enables the additional Wi-Fi network with a specific SSID and password; starts the JMS/MQTT Server; starts the CEP and loads the rules related to first-aid responses; starts the Wi-Fi and GPS probes.

After that, considering the case in which a drone is flying over a research area, two different not exclusive situations can be experienced:



(a) *(b)*

Fig. 3. *(a)* Mobile app prototype; *(b)* Rx module connected on smartphone.

a) Non-Cooperative Scenario (NCS): in which there is not a mobile application installed on the person in distress mobile device. In this case the drone looks for Wi-Fi beacons generated by user's in distress device.

b) Cooperative Scenario (CS): where the *OnBoard Node* generates a dedicated Wi-Fi network which the mobile application can connect to. In this case, as soon as the connection is established, the emergency data are sent and first-aid information are received through the mobile app as shown in Figure 3(a). Both in NCS and CS, the nodes involved are: (i) the *OnBoard Node* on top of the drone (see Fig. 2); (ii) the *Mobile Node* with Wi-Fi interface turned on; (iii) *Ground Node* represented by the rescuer device as shown in Figure: 3(b). In particular, it is a smartphone configured for generating a Wi-Fi hot-spot. This is used by the LoRa device for exposing a web-server with a dedicated web-page used for visualizing the detection messages received by the *OnBoard Node*. A detection message contains the MAC address of the user in distress device, the dB signal level measured by the High-Gain antenna and the *OnBoard Node* detected GPS position. Those data are used by rescuer for localizing user in distress.

IV. System Demonstration

A demonstration of Transponder executed in the NCS scenario has been performed in a woods with no flight restrictions and not GSM coverage. In this case, as shown in Figure IV(a), a smartphone has been left in an unknown position of the wood by a person not involved in the experiment. The drone pilot performed the startup phase and let the drone took off reaching an altitude of 35 meters. After that, it starts sift the area at a speed of 5.4 km per hour (1.5m/s) receiving the first detection message after 8 minutes. Executing a post analysis of the data sent to the rescuer device and collected by the CEP, the following analysis has been performed. The take off was done at a distance of 150mt from the abandoned mobile device. The first detection occurred at a ground distance of 79 meters that, considering the flight height, indicates a LOS of about 86.5 meters. These results were extremely positive for heavily reducing the research area in a short time and letting a sudden rescue operation. As in Figure: IV(b), while the drone was approaching the lost device, the density of the beacons received over a period of time increased letting a more precise localization. The obtained results provides also the opportunity to improve the system. Indeed, the post-analysis evidenced an high number of packet loss due to LoRa transmission timing [5]. This has been solved by buffering messages on *OnBoard Node* and scheduling the sending so as to avoid burst of collisions in data transmission.

(a) *(b)*

Fig. 4. *(a)* Smartphone left under a tree; *(b)* Beacons frequency.

V. Discussion and Future Works

In this demo paper the Transponder solution has been described. It is an open-source, lightweight and low-cost solution for improving SAR operation. Its use in a realistic scenario has been presented in order to confirm its feasibility and effectiveness. As a future work, Transponder will be improved letting the CEP to analyze the dB level of the beacon detected so as to generate piloting commands to the drone. The aim is to improve scrambling of the area by using the message detection itself. Additionally, the mobile app will be improved from the usability point of view as well as to manage data retrieved from possible available BAN devices.

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