Autonomous Safety Tracking System: The AIOSAT Approach to Indoor & Outdoor Security

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Keywords: *GNSS, Galileo, tracking, firefighting, multisensor, integration, communication optimization*

The European population experiences about two million fires yearly with around five thousand deaths and fifty thousand reported injuries [1]. Countries in the Mediterranean region are by far the most affected by forest fires. Even though satellite-based positioning increases rescue workers' safety and efficiency, signal availability, reliability, and accuracy are often poor during fire operations, due to smoke, terrain formation or natural and structural obstacles. In central Europe, the stakeholders report a strong necessity to complement the location for indoor and GNSS blocked scenarios. As such, location information often needs to be augmented. For that, European Global Navigation Satellite System (GNSS) Galileo could help by improving the availability of the satellites with different features. Moreover, a multi-sensored collaborative system could also take advantage of the rescue personnel who are already involved in firefighting and complement the input data for positioning.

The Autonomous Indoor & Outdoor Safety Tracking System (AIOSAT) [2] is a multinational project founded through the Horizon 2020 program, with seven partners from Spain, Netherlands and Belgium. The overarching objective of AIOSAT system is to advance beyond the state of the art in tracking rescue workers by creating a high availability and high integrity team positioning and tracking system. On the system level approach, this goal is achieved by fusing the GNSS, EGNOS, pedestrian dead reckoning (PDR) and ultra-wide band (UWB) ranging information, possibly augmented with map data. The system should be able to work both inside buildings and rural areas, which are the test cases defined by the final users involved in the consortium and the advisory board panel of the project.

System architecture

The key innovation target of AIOSAT is the integration of:

a) Augmented GNSS positioning module
b) PDR based on inertial movement sensors
c) Distance measurements between the members of a team with UWB technology
d) High availability communication system;
e) An application backend that enables the brigades and mission commanders to track the location of the rescue workers during a mission, based on map and status information from every First Responder node.

In Figure 1, the overall architecture and the data flows between the actors in the AIOSAT system are shown. Each rescue worker is equipped with a sensor pack consisting of GNSS, PDR and UWB sensor modules and an embedded platform that collects and process the sensors' data and exchanges the estimated location with other actors in a rescue team. The locations of the rescue workers are communicated through a radio link to the sub-officer, who in turn forwards it to the COmmand Post at Incident (COPI). Both the sub-officer and the COPI have the ability to observe the locations of the rescue workers in real-time through a visualization application. The data links are realized by means of Bluetooth Low Energy (BLE), Long Range Wide Area Network (LoRaWAN) and Narrow-Band IoT (NB-IoT). Not all communication channels are utilized at the same time and some are meant as fall-backs only.

One import point is that the voice communication channel is neither considered nor disturbed by the AIOSAT location and tracking module.

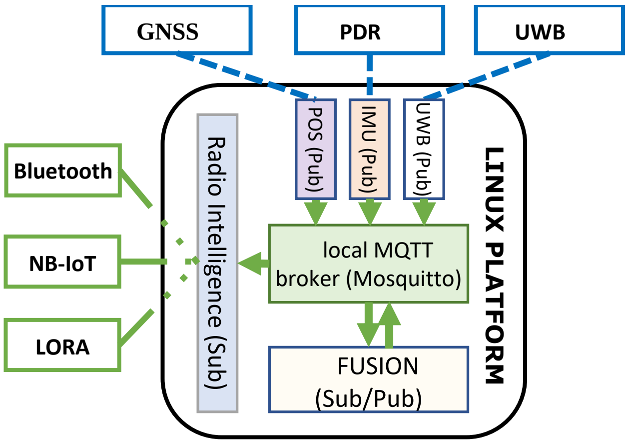


Figure 2 – **Sensor system functional architecture blocks.**

Embedded system and sensor fusion platform

The AIOSAT locator device, worn by each first responder, is based on the Raspberry Pi Zero W (RPi) embedded platform running Linux. It contains a rechargeable battery pack, and consist of the sensors and the communication sub-modules. Internally, all the data is routed using the message queuing telemetry transport (MQTT) protocol through a MQTT broker (Mosquitto) running on the RPi. The sensors report their measurements by publishing messages to the broker. In turn, the sensor fusion component subscribes to the sensors' topics to collect data and publishes an estimated location and its uncertainty. The exchange of information to and from the radio intelligence module is organized in a similar way. The different functional blocks of the locator device are shown in Figure 2. Information exchange between the components based on message passing through a

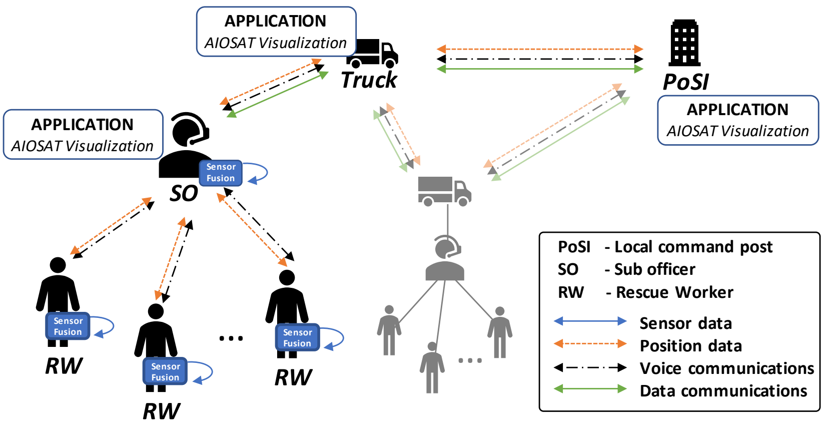
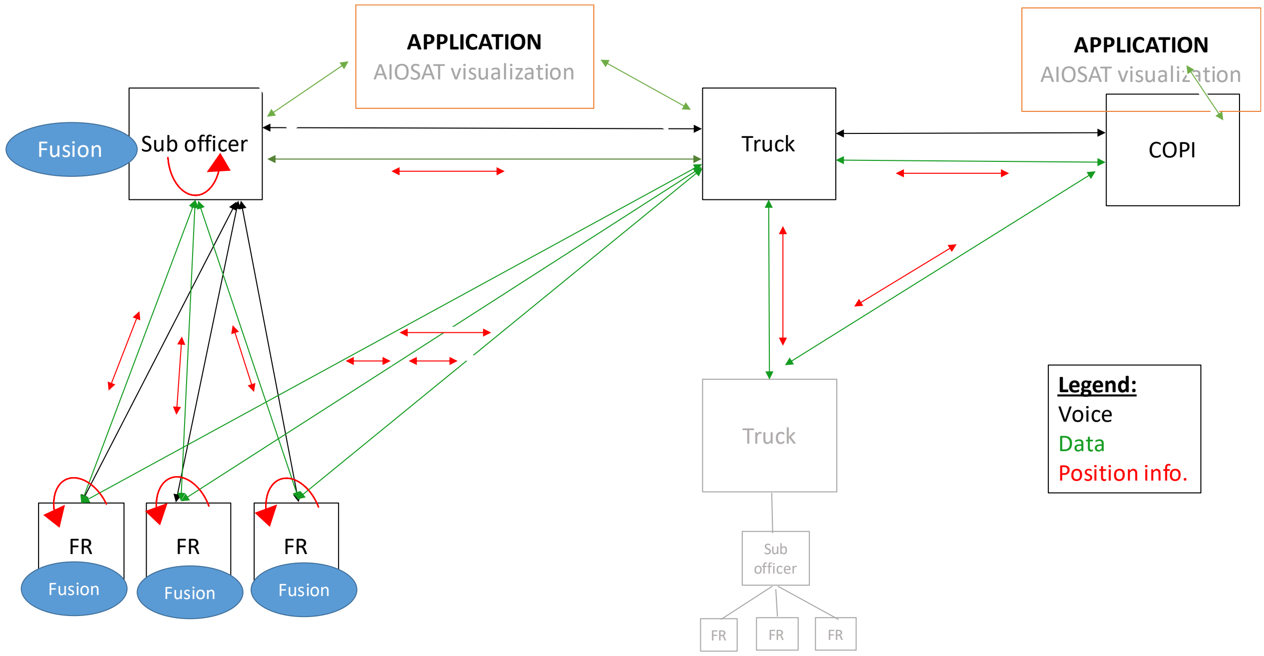


Figure 1 - Architecture of the AIOSAT system and data flows between the actors.

broker enables strong decoupling of the software modules and allows for independent development and testing.



The sensor fusion component will run as a separate process on the RPi. It implements a particle filter that combines GNSS, PDR [3] and UWB data with a 1 Hz frequency and publishes the position estimates. The fusion component is developed as a cross-platform application in C++17 and utilizes data-oriented design [4] to enable fast processing.

RTCM3 data compression

The embedded platform transfers position corrections in RTCM3 message format via Bluetooth Low Energy (BLE), Long Range Wide Area Network (LoRaWAN), Narrow-Band IoT (NB-IoT) and Long-Term Evolution (LTE). This information exchange requires a high flow of real-time message transmission, which may result into bandwidth issues. In order to avoid those issues, the system will apply a filter on the given positioning corrections, thus reducing the amount of data transferred at each message. This way, only the non-repeated chunks of positioning data will be sent through the communication channels.

RTCM transmission optimization has been already done in previous researches by implementing compression protocols, such as PECOG protocol [5], which performs data compression based on differential entropy coding. As the goal of our filtering process is to reduce the amount of data forwarded on the communication channels while keeping the real-time flow, our compression method will not apply any prediction model or coding system. Every RTCM3 message will be processed on the go, just the non-repetitive data will be kept and the filtered message will be sent to the output as explained in Figure 3.

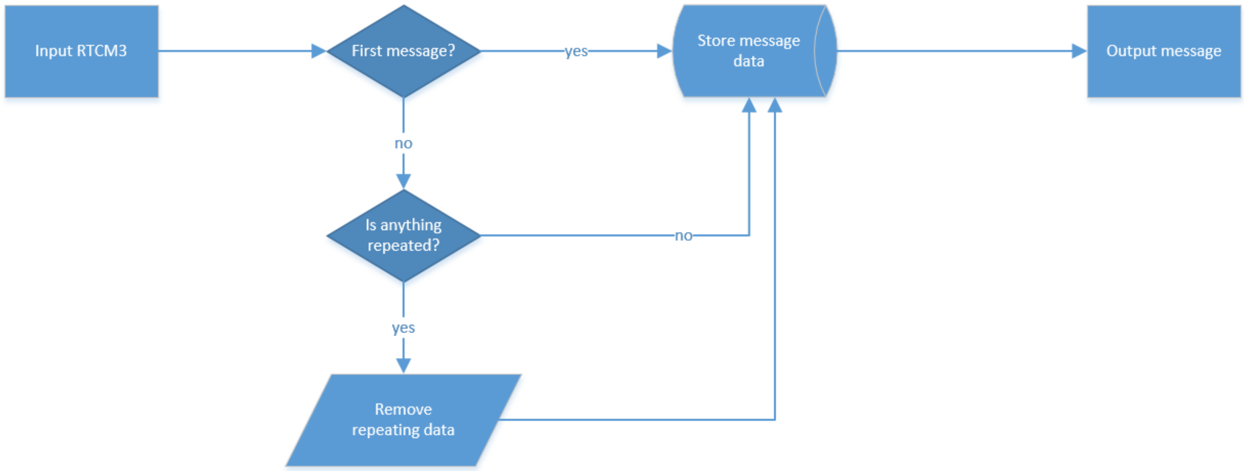


Figure 3 – RTCM3 message filtering process

At the same time, the receiving end will need to reconstruct the message in the same way as it was filtered. This means that the program will keep track of the received message chunks and fill the missing parts with the ones previously gathered. The output will be a full RTCM3 message with its corresponding fields as it was first received before the filter. The flow of the reconstruction part of this mechanism is shown in Figure 4.

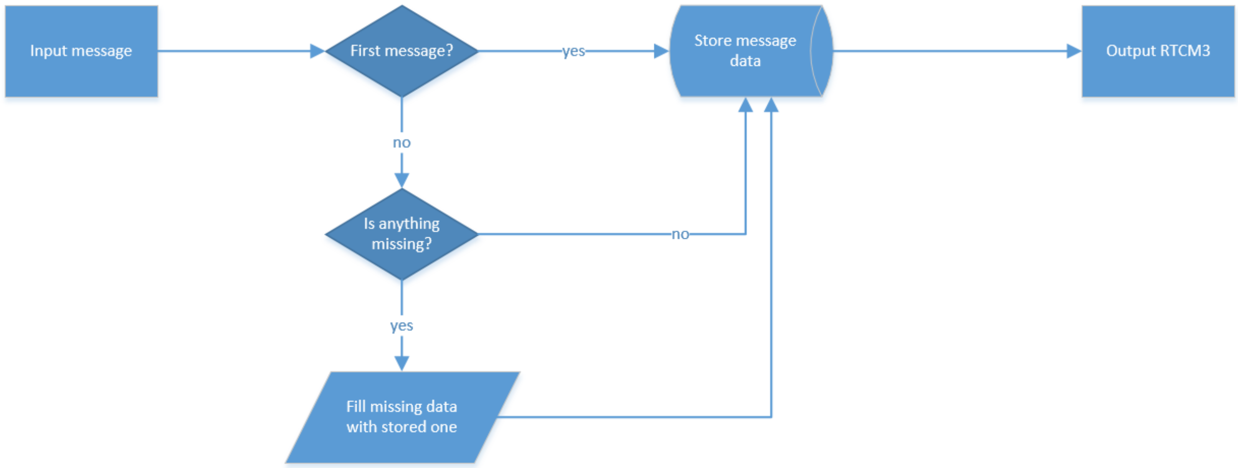


Figure 4 – RTCM3 message recovering process

The above filtering process has been implemented using Python 2.7 scripting language as a cross-platform application that can be further on easily integrated with other languages such as C, C++ or Java.

Conclusions and Future Steps

The AIOSAT project aims at providing high-reliability location information during rescue operations. Its design focuses on modularity and ensuring data availability by integrating multiple sensors such as GNSS, IMU and UWB ranging subsystem, from which information, a fusing algorithm obtains the localization data. The communication technologies are various, starting with BLE and LORA but extendable to others such as NB-IoT or LTE. In the coming months, the partners will work towards the integration of all the sub-components. Moreover, the field tests, simulating real-life scenarios will be carried out to help collecting sensor data and evaluate the fusion algorithm.

Results incorporated in this paper received funding from the European GNSS Agency under the European Union's Horizon 2020 research and innovation program under grant agreement No 776425.

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