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Invention Number DMSR009

SafeZone

The objective of the SafeZone project is to simplify disaster recovery situations and to create a decentralized peer-to-peer (P2P) communication system to be used in situations of natural disasters, when phone towers and traditional communication systems are unavailable. In particular, an app was developed for the creation and connection of users to a network used to request help, communicate their conditions and position to rescuers, send essential messages to other network users, and remotely activate the flashlight and sound signals on the users' device to facilitate rescue operations. The app also allows first responders access to real time vitals data (Heart Rate, Blood Oxygen levels...) through wearable devices such as the Apple Watch.

The app uses cross-platform technologies that make it usable on both Android and iOS. The system is based on Wi-Fi and Bluetooth technologies to create a peer-to-peer network of phones and directly connects rescuers to survivors. The geolocation of the survivors is made possible through GPS and triangulation based on the surrounding devices. Among the functions of the app are also the messaging system, optimized for the P2P network, and additional features such as turning on the flashlight and generating sound. Remote access of rescue teams to survivors' phones is also made possible.

Each registered user on the network is assigned a unique identifier created by the framework and a user friendly name represented by the telephone number. The main messaging function has two types: broadcast and direct. The broadcast system allows to send a distress notification on the network that is sent to all the rescuers connected to the network itself or to the rescue operations base camp. The distress call also automatically sends the user positioning information, the person's name and other useful data. The direct communication system, on the other hand, allows to send short messages, with a maximum length of 120 characters, to a selected.

The additional features allow rescue teams access to the remote management of the devices connected to the network through an authentication protocol. Note that the remote system does not allow access to the total control of the phone, but only to functions programmed in the application. Among these functions I highlight the "flashlight" function, which can help locate a person, even unconscious, in the darkness and the "sound" function that can be used not only to signal the presence of a person but also to generate ultrasound facilitating search with rescue dogs.

Another function available in remote access is also the geolocation, which sends the GPS position of the device, and the barometer, that can detect the altitude of the survivor. All this data can be sent automatically through the P2P network to the rescue teams. SafeZone can also fetch real time health data from wearable devices, such as the Apple Watch or Fitbits, and send it to the emergency responders' systems.

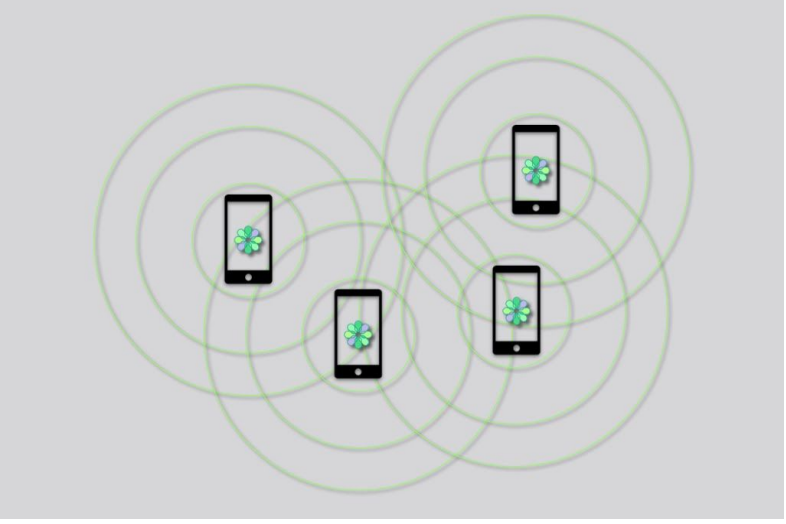
The app can not only work in case of unavailable telecommunication systems, but also when connected to normal WiFi routers and cell towers using a hybrid mode. In this case, the app becomes a tool to connect people requesting help with rescuers, keep track of the disaster, and analyse the situation through computational tools. Additionally, the app can allow phones with no internet or phone connectivity to still contact rescuers and send their data (general information, real time wearable device data, GPS...) to the first aid team through nearby devices.

Further future development of the app could include the connection of SafeZone to automatic unmanned aerial or terrestrial vehicles equipped with antennas to extend the network and to elaborate data collected by these devices through thermal camera and other tools that can be used to three dimensionally compute maps of the disaster zone and support rescue plans. Drones with beamforming capable antennas can also be used to better locate where the devices are in a large area and concentrate an RF signal to the device for better geolocation and connection.

P2P Network

Introduction

Peer-to-peer (P2P) networking is a distributed application architecture that partitions tasks and communication between peers. In this application, each device on the network is considered as a peer, and is interconnected directly to reachable nearby devices. Through the SafeZone app, phones can reach each other using the integrated WiFI and Bluetooth.



Peer-to-Peer Wireless Network

Encryption

As messages are broadcasted on the network and passed along device by device, encryption is needed to protect the users of the network. Based on the framework used, encryption types can change. The two main frameworks taken in consideration are the

Multipeer Connectivity Framework by Apple, and the *Google Nearby* framework by Google. The one from Apple relies on DTLS with Anonymous TLS cipher suites. No certificate is exchanged and the system internally relies on AES 128 and 256, with SHA1 and SHA 256. Google's framework also uses encryption, but they only disclosed that it is AES based.

Compression

A decentralized P2P network is a good solution for this case scenario, but there are some limits. The most relevant are the relatively high broadcasting time of a message and the low bandwidth. As a system for emergency telecommunication, however, this solution is appropriate, as the messages transmitted on the network are short, and multimedia files are not allowed to be sent on the network. Although short messages are already lightweight, they can be compressed further, through an appropriate compression methodology. Consequently, this design allows for faster broadcasting times (in terms of seconds) and less bandwidth usage, improving performance for the other network users as well.

The compression methodology I employed compresses the messages based on limiting the dictionary of characters. In this way, the only characters sendable are uppercase letters, numbers, and 4 symbols (“,” - ”.” - ”!” - ”?”). This system allows to use 6 bits to encode all the characters, so that 2^6 characters can be represented (read table below). Compared to normal 8 bit per char messages, the weight of a 120 char message can decrease from 960 bits, to 720 bits, with an improvement of 25.0% per message.

Character	Decimal	6 bit
A	0	000000
B	1	000001
C	2	000010
...		
Z	25	011001
0	26	011010
...		
9	35	100011
.	36	100100
,	37	100101
?	38	100110
!	39	100111

The conversion table between characters and 6 bits

Triangulation and Additional Features

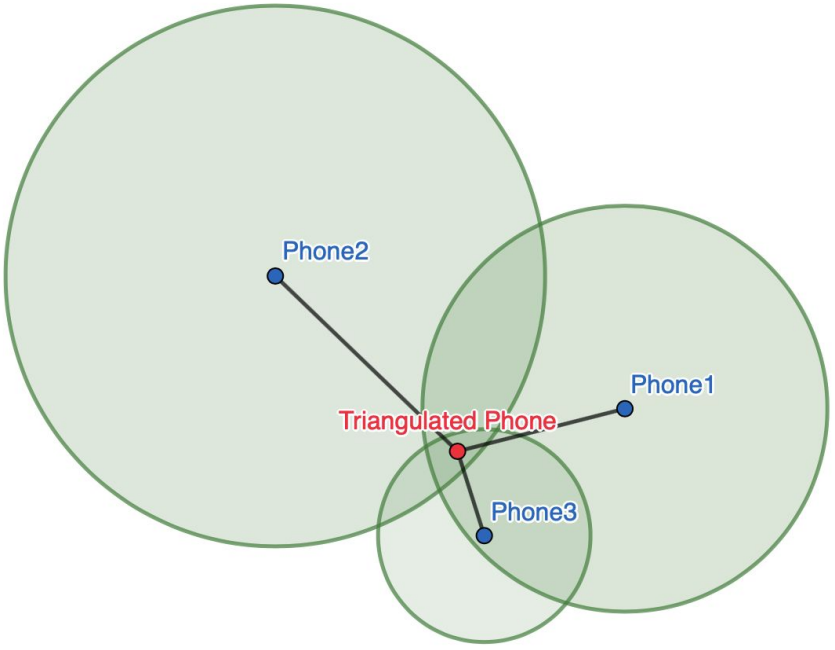
Global Positioning System (GPS)

Basically any phone nowadays has a GPS antenna, that allows geolocating the device anywhere in the world. GPS is a technology that can have a great accuracy of even a couple meters, especially in open fields and without obstacles to the satellite signal (roofs,

skyscrapers in proximity...). Once connected to the network, devices can send their GPS position and altitude to emergency personnel, when requested. When first responders trigger the specific action, the target phone will run the code to request its current GPS position (coordinates) and altitude. This will then be encrypted and sent directly to the first responders that requested the position.

Device Based Triangulation

In some situations, devices don't have a GPS connection. In these cases, the only way to triangulate the phone could be using the position of nearby devices. Being each phone connected to other devices over wireless, the connection details can be computed. This information includes the distance between the two devices and, if available, the GPS position of the receiving connected device. Using this data, it is possible to triangulate the device without a GPS connection and send its connection details to first responders.



Locating an unknown phone based on three nearby devices

Remote Rescue Triggers

While designing SafeZone, I implemented functions that I called *Remote Rescue Triggers*. These functions can be activated remotely by the first responders and can help locating a person. While the app is running, it listens for special incoming messages that are the triggers. Once a trigger is received, the corresponding code is executed.
The three functions pre integrated in the app are:

- Light On / Off: Turns Brightness to 100% and makes the flashlight blink.
- Play Audio: Plays a sound that can help first responders locate the phone.

- Play High Frequency Audio: Plays a 23/24 kHz tone that can be only heard by rescue dogs. Being this an uncommon sound for dogs, it can be easier for them to locate the person.

Real Time Vitals Detection

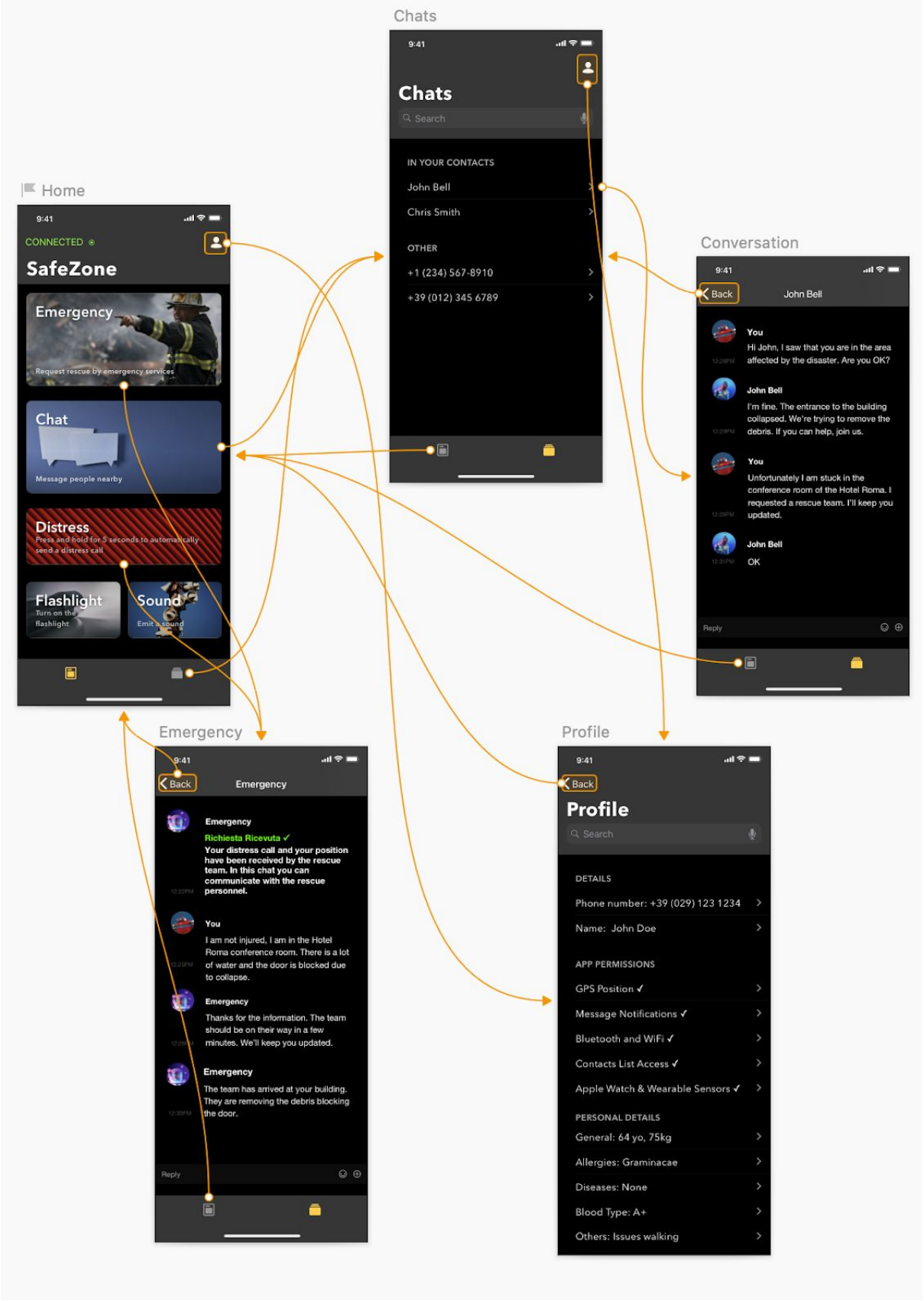
Wearable devices that integrate vitals monitoring sensors are often connected via bluetooth or other similar technologies, including the Apple Watch and Fitbit. As such, wearable devices can be a great source of data to help first responders better monitor and understand emergencies. SafeZone is compatible with the HealthKit and can fetch real time health data from wearable devices and send it to the emergency responders' systems. Data is requested from the first responders, retrieved by the phone, encrypted, and then sent through the P2P network.

UI and UX

Overview

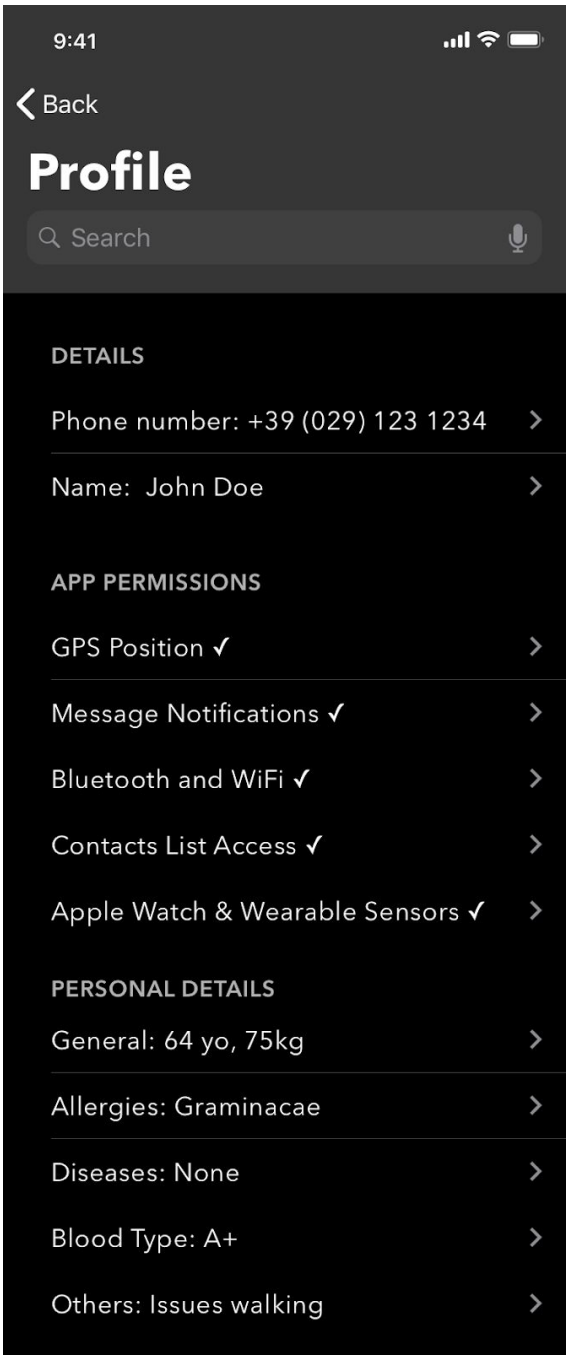
The primary objective of the User Experience is to achieve simple interactions that allow straightforward access to the app's functions. A force touch shortcut was implemented to allow sending "distress" requests directly from the Home screen of the iPhone.

Prototype of the App Scenes

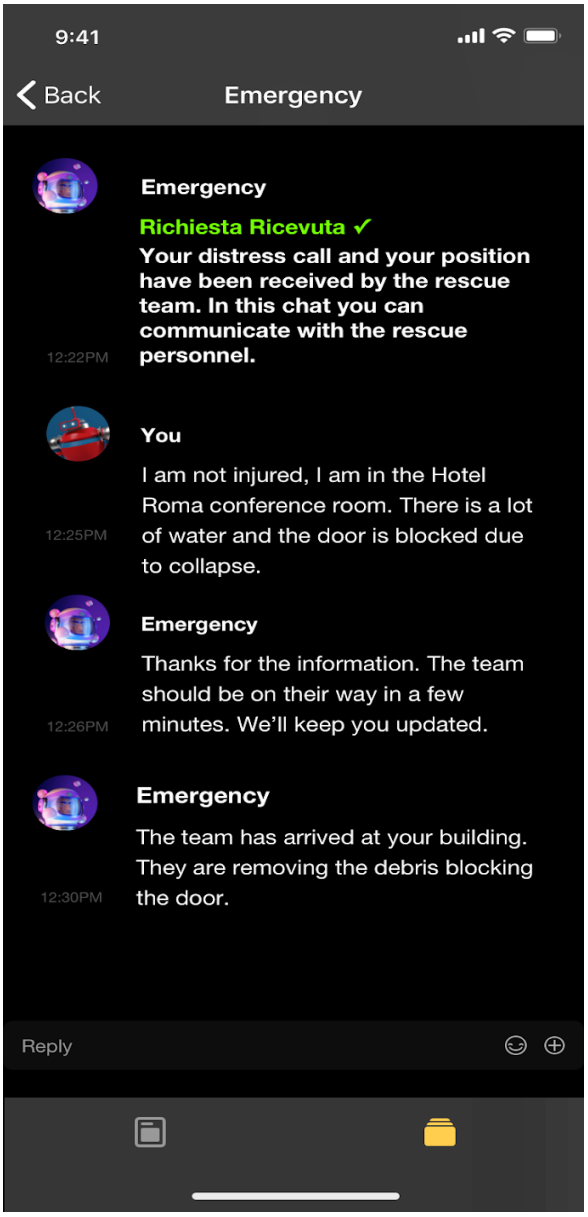


Screenshots

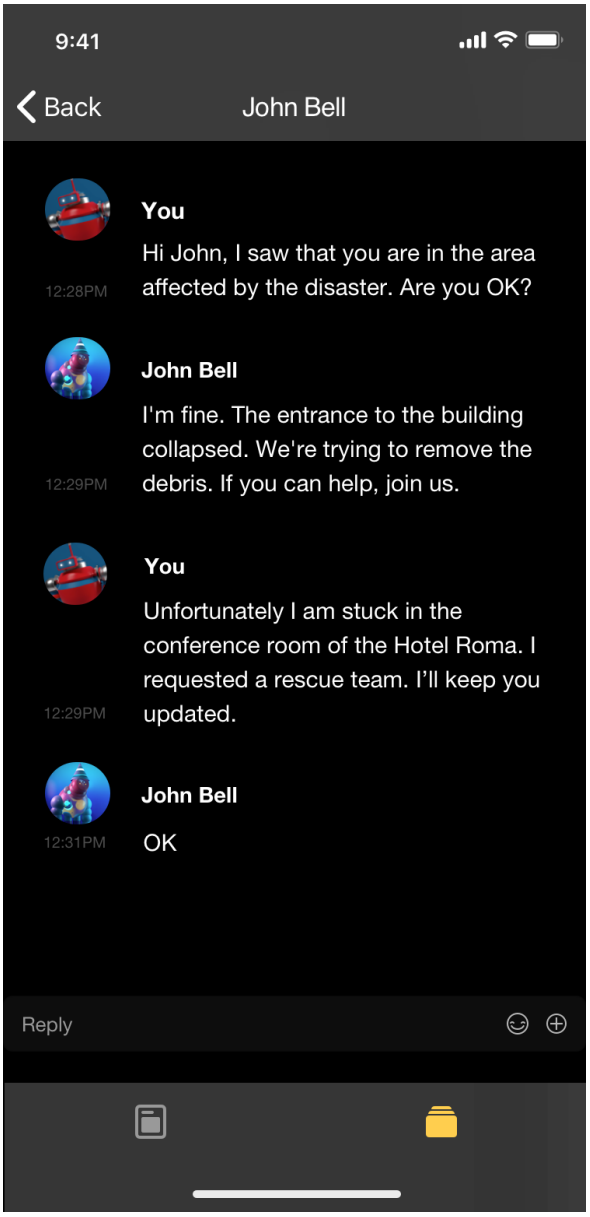
Home of the App. Buttons to communicate with first responders, chat, distress, and utilities



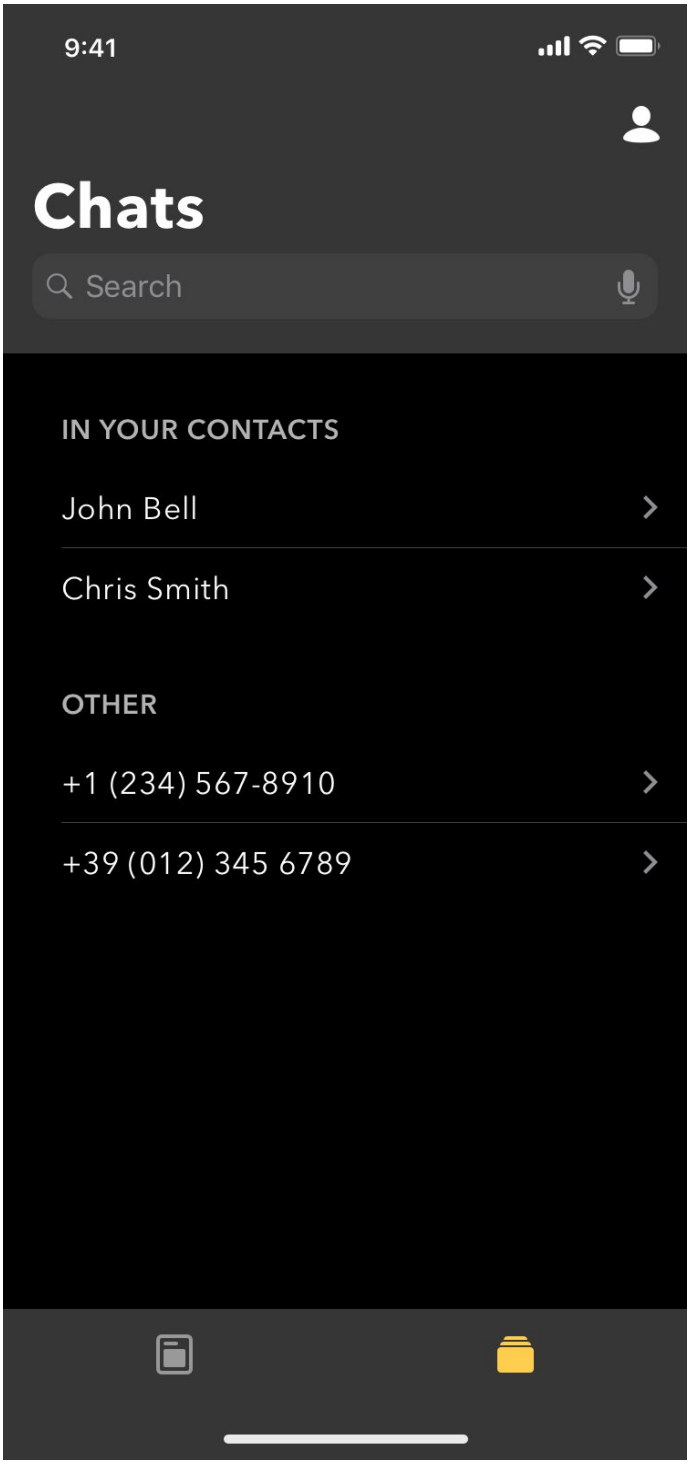
User profile



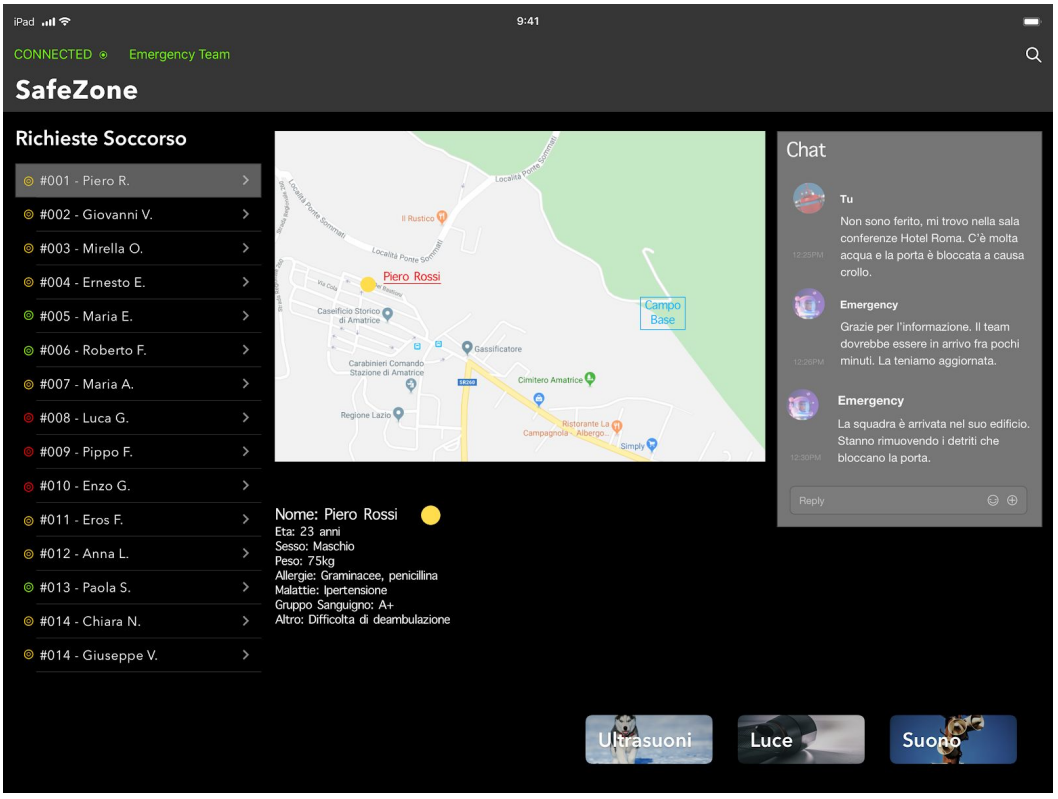
"Emergency" page
Example of communication
User with First Responders



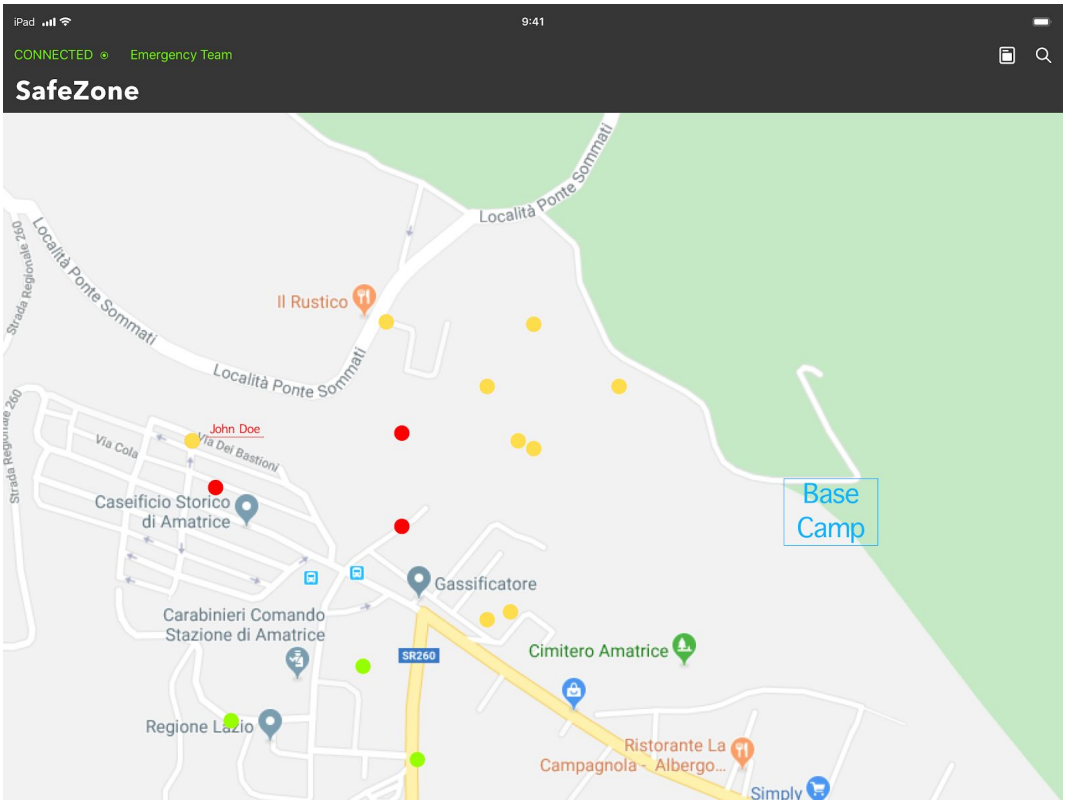
Example of Chat between users



List of open chats. Communications
sorted based on the presence in the contacts.



SafeZone screen on iPad for the rescue team



Map with the ongoing emergency requests received by the operator

Further Developments of the project

The incoming data from devices connected to the SafeZone network can be used to analyse three-dimensionally the disaster site using multiple drones (equipped with thermal cameras, antennas…), through AGVs with antennas mounted to extend the network, or other vehicles appropriate for the situation (such as small floating devices with sensors and repeaters).
Three-dimensional data based on wireless antennas, cameras, drones, and other autonomous vehicles, can be used to compute maps of the disaster zone, accurately identify the locations of people, and compute faster and safer rescue plans, based on more reliable real time data.