ABSTRACT: The RESCUECELL project aims at developing a new kit to search avalanche (and earthquake) victims by means of their mobile phones signal. This new system will complement Search and Rescue techniques available for professional rescuers and ski patrollers teams to support operations in case of unequipped (transceivers, Recco®) buried victims and assuming that they probably carry a cell phone. The system is mainly composed of a Control Center and portable nodes that are installed around the affected zone, even if there is no GSM network available: roughly, the system generates an autonomous mobile phone network in the search zone and making possible the interaction with mobile phones in the area to allow a proper positioning (the expected accuracy is few meters). The emergency network starts sending messages to which connected phones respond with a series of bursts. The signals sent by a phone are caught by the nodes. Using the output of the nodes, the Control Center is capable of estimating a position for the mobile phone. A mobile node carried by a rescuer will display the position of the victims and it allows increasing the accuracy. In parallel to the software developments and tests, keypoints consist also in global ergonomics (weight of each component, autonomy…), deployment requirements and operation time: at this stage, first mobile phones would be located in less than 80 seconds after the system deployment.

KEYWORDS: SAR, mobile phone, location, GSM, emergency.

1. INTRODUCTION

In mountainous terrain, avalanches are among the most serious objective natural hazards to life and property, with their destructive capability resulting from their potential to carry enormous masses of snow at high speeds. Table 1 presents a list of some notable avalanches in Europe and confirms that largest catastrophes occurred in "urban" or "high mountain" contexts.

Assuming that nowadays a majority of citizens own a cell phone, the opportunity to use this way to find people trapped in an accident is a civil safety challenge. However, such services cannot be offered by cellular operators since they do not provide the location with enough precision to be useful. This situation led to the RESCUECELL project supported by EU within the Research for SMEs program. This project started at the beginning of 2013 and this paper presents the main principles of the development of this new tool, initially dedicated to earthquakes ruins and snow avalanches.

<table>
<thead>
<tr>
<th>Death toll estimate</th>
<th>Event</th>
<th>Location</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Mount Blanc avalanche</td>
<td>France</td>
<td>2012</td>
</tr>
<tr>
<td>6</td>
<td>Redamuz</td>
<td>France</td>
<td>2009</td>
</tr>
<tr>
<td>3</td>
<td>2019 Buceghiolu Mitre avalanche</td>
<td>Romania</td>
<td>2009</td>
</tr>
<tr>
<td>11</td>
<td>Ševčík snow avalanche</td>
<td>Austria</td>
<td>2009</td>
</tr>
<tr>
<td>12</td>
<td>Marmolada avalanche</td>
<td>Italy</td>
<td>1906</td>
</tr>
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<td>10</td>
<td>Follin</td>
<td>Italy</td>
<td>1906</td>
</tr>
<tr>
<td>14</td>
<td>Ševčík snow avalanche</td>
<td>Austria</td>
<td>1906</td>
</tr>
<tr>
<td>15</td>
<td>Vrsic</td>
<td>Slovenia</td>
<td>1906</td>
</tr>
<tr>
<td>12</td>
<td>Ševčík snow avalanche</td>
<td>Austria</td>
<td>1904</td>
</tr>
<tr>
<td>20</td>
<td>Vršič</td>
<td>Slovenia</td>
<td>1904</td>
</tr>
<tr>
<td>19</td>
<td>Tatra</td>
<td>Slovakia</td>
<td>1904</td>
</tr>
<tr>
<td>18</td>
<td>1994 Buceghiolu avalanches</td>
<td>Romania</td>
<td>1994</td>
</tr>
<tr>
<td>260</td>
<td>Winter of Terror series of 654 avalanches</td>
<td>Austria</td>
<td>1991</td>
</tr>
<tr>
<td>31</td>
<td>Ševčík snow avalanche</td>
<td>Austria</td>
<td>1994</td>
</tr>
<tr>
<td>19</td>
<td>1994 Ševčík snow avalanche</td>
<td>Austria</td>
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<td>18</td>
<td>Ševčík snow avalanche</td>
<td>Austria</td>
<td>1994</td>
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<tr>
<td>20</td>
<td>1994 Ševčík snow avalanche</td>
<td>Austria</td>
<td>1994</td>
</tr>
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</table>

2. GENERAL PRINCIPLES

Mobile phones have become a personal device and it is difficult to find somebody without a mobile phone. This fact allows a connected life, where anybody, if desired can be accessed and can be located with the only condition of having the mo-
bile on. The capability to locate a terminal, and by
distribution its owner is seen mostly as a potential
privacy concern, but it can offer advantages that
can save lives (Atkins 2008). The first usage of
this potential has been implemented by United
States in case of an emergency call (911 in the
United States) and uses the infrastructure of the
mobile operator, the mobile terminals, and it can
use also a satellite positioning system such the
GPS. The precision in the location is very poor
and only allows achieving a precision of tens of
meters in the best case and requires having mo-
 bile coverage and the interaction of the victim.
The lack of precision is a serious issue in any emer-
gency, but particularly in cases where people are
trapped in debris due to a building collapse or in-
side the snow after an avalanche. Survivors are in
risk to die in a very short period of time if they are
not located and rescued. It is also part of the limit
of smartphones apps (Floyer 2013).

Having every human being associated with a mo-
bile device that can be located opens the oppor-
tunity to develop a system with the aim to save
lives. This system should provide the best possible
location precision and coverage in the affected
area. The RESCUECELL project has been con-
ceived with the aim to build such system achieving
a compromise between cost, quick deployment
and location precision. The unique purpose of the
system is to help to save lives and in the worst
case to find corpses with the minimum delay, try-
ing also to safeguard the rescuers’ lives which is
also a key-parameter (Brundl and Etter 2012).

To locate a terminal several approaches can be
considered. The first classification can be between
legacy and non-legacy. The first type consists on
using the infrastructure of the different operators to
contact the mobile terminals in the area and make
them to transmit. The operator location platform
can point if the mobile is in the affected area. It is
clear that the network of the operator is not able to
achieve the needed precision since base stations
are far away between them and they cannot as-
sure the coverage of all mobile terminals, in par-
ticular the ones buried. Consequently the system
should be non-legacy in the sense that new ele-
ments should be added. Non legacy systems can
also be classified as passive and active. The new
elements can be just receivers that collect the in-
formation transmitted by the mobile terminals
(MTs) and allow to point towards its location or
they can be transmitters and receivers. In the last
mode, the active mode, a node of the system has
to transmit in order to force the mobile terminals to
generate signals without any user intervention.

The response from the MTs is going to be used by
the receivers in the area to estimate the location of
the mobile terminal.

The passive method can be based on the periodic
transmissions from the mobile terminals when im-
plementing a mandatory procedure called periodic
location update. According to this procedure, and
depending on the configuration of the mobile op-
erator, MTs have to update their registration regu-
larly, with the maximum period setting being two
hours. This means, if the time between updates is
bounded to two hours, some of them are going to
transmit immediately after the deployment of the
system and others are going to take two hours.
This is not the best timing to save lives, but it is an
alternative very simple to implement and use, and
it can be seen as an example of the potential of
the system. In the active system, as one node is
going to poll the terminals, they have to reply im-
mEDIATELY. This means a terminal can be polled
several times, very rapidly and with different fre-
quencies if desired.

It is clear that the active mode has lots of benefits
in front of the passive one in terms of time to lo-
cate the terminals. The problem with the active
mode is the fact that the RESCUECELL system
has to transmit to the terminals which means using
a frequency band that is licensed to a mobile op-
erator. Also it is needed all mobile terminals to
leave its legacy operators and to attach to the
RESCUECELL network. To achieve this in all cir-
cumstances certain bands may have to be
jammed within a limited power and duration.

Transmitting in a band that belongs by license to
another operator is by default forbidden according
to most of the national authorities but there are
exceptions that even have been agreed at Euro-
pean level (see EU regulation EU166/2010). For
example cruise ships are behaving as mobile op-
erators and use frequencies granted to mobile op-
erators. They are offered as roaming operators
and the terminals should select them automatically
when enough quality is not obtained from the ter-
restrial operator. It is suggested that the boat cov-
erage should not be used if the distance to the
cost is less than 2 nautical miles, but even in this
case this implies interference to the terrestrial op-
erators. A similar case can be encountered with
some airplane companies offering mobile tele-
phone coverage onboard. The plane has a mobile
operator onboard that is offered to mobile termi-
nals of the passengers for roaming. In this case
the situation is closer to the RESCUECELL sys-
tem since the system in the plane jams certain
bands to assure all communications are done using the onboard coverage avoiding high power transmissions required to reach the terrestrial system.

Jamming the mobile band is also illegal for a couple of reasons. The first one is already mentioned, using a band that is already licensed to an operator and the other is for avoiding, while jamming, the possibility to support emergency calls. In some countries jamming has been allowed originally in public places such theaters and hospitals, but banned later since they avoid the setup of emergency calls. For the RESCUECELL system the second argument, avoiding the setup of emergency call, is not an issue since the RESCUECELL system is able to attend any call, in particular emergency call and with a clear advantage from conventional services offered by national authorities since the responder of the call is in place, close to the people making the call.

At this point the only aspect that remains an issue for the usage of a full functional system is the transmission in a band that is licensed to operators and the interference that can be produced. All national authorities have exceptions that allows in certain circumstances to use the operator band resulting in a significant degree of interference that brings the mobile terminal completely useless. Some examples of the legal usage of jammers are:

- To avoid remotely command the explosion of a bomb
- To avoid coordination or communication of wrongdoers in a police operation
- To avoid communication of prison inmates with the exterior
- To leave useless hearing devices in secret meetings

In all these cases with the argument of having lives in danger or with intention to avoid a crime, the national authority grants permission to certain bodies to jam mobile communications totally. The RESCUECELL system is going to be used when it is positively known that people are trapped and it has to be rescued in a very short period of time to save their lives. This seems a stronger argument than the ones used to justify the usage of jamming. In addition the mobile telephone service is not going to become useless and it is going to be the only radio communication service partially affected.

Apart from the uses that are allowed to police and the military, there are some countries that allow the usage of jammers in public places like music halls, theatres, cinemas or hospitals. Again jamming is allowed with the sole excuse to not disturb other people attending the event or having side effects with the health care equipment.

Also it is good to note that in the license agreement between the national authority and the mobile operator, the national authority keeps the right of using the licensed band in case of an emergency. An earthquake, a snow avalanche or even the collapse of a single building can be considered an emergency situation, so justify the national body to grant permission to the RESCUECELL user during a limited period of time and within a limited area for the rescue operations. The power transmitted by the RESCUECELL system will be 3.5 W, which is much lower than the one of a legacy base station since the transmitter is very close to terminals (few hundred of meters in the worst case) and the location of antennas (less than two meters high) make difficult to have a wide propagation. This is a guarantee that the interference of the system will be confined to the area where the incident takes place, not affecting other users.

3. SYSTEM USERS’ SPECIFICATIONS

In order to obtain the system specifications, a questionnaire was formulated at the beginning of the project. The questionnaire was translated into eight languages and was circulated to a list of SAR teams. The total number of answers came from 48 SAR organizations/teams. The questionnaire was divided into three sections. The first one contained general questions concerning the participant’s organization and general system requirements, while the other two sections contained specific questions about the collapsed buildings scenario and the avalanche scenario respectively. This questionnaire and additional meetings with French SAR services highlighted the necessity to consider this new approach as complementary to current technics: new procedures will have to be developed to include it in the overall SAR operations management. At the same time, if saving large group of people is hopefully not the main situation, the interest is confirmed by the percentage of victims carrying a cell phone (Fig. 1).

This questionnaire gave also valuable information about different parameters such as ideal surface coverage, transportation and deployment methods, power sources, operational time before recharging, ergonomics (size, weight...). This led to the system specifications shown in table 2.
4. SYSTEM ARCHITECTURE

The RESCUECELL system is basically composed of one control center, in charge of creating a GSM network to establish connections with the mobile terminal buried in the affected zone, a number of static nodes, as well as a reduced number of mobile nodes used by the rescue operators. The nodes will collaborate with the control center to localize the mobile terminal in the affected zone. The control center and the nodes will be installed in the affected zone to ensure that their position does not change and to avoid creating further problems in unstable areas. On the other hand, the mobile nodes will be of reduced size and will be able to move freely around and over the affected zone while being carried by the rescuers. A simplified scheme showing the overall architecture of the system is included in next figure (Fig.2).

![Image](image_url)

**Fig. 2: System architecture**

The control center is intended to provide a plug-and-play portable backup mobile network, offering coverage and re-establishing communications with victims involved in emergencies. The control center will establish a network, to communicate with the mobile terminal as well as to communicate with both the static and mobile nodes. For the mobile terminal, the control center will act as a standard GSM Base Transceiver Station so that the mobile terminal will receive information on the downlink channel only from the control center. On the other hand, the static nodes will communicate with the control center only and will act as sniffers, listening to the transmissions in the uplink GSM channel and using the detected signal for mobile

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**Tbl. 2: system specifications for avalanches**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coverage</td>
<td>More than 1000m²</td>
</tr>
<tr>
<td>Weight</td>
<td>2 to 4 kg per node</td>
</tr>
<tr>
<td>Price</td>
<td>5-10 k€</td>
</tr>
<tr>
<td>Extreme conditions</td>
<td>Cold, moisture</td>
</tr>
<tr>
<td>Power</td>
<td>Batteries</td>
</tr>
<tr>
<td>Operational time</td>
<td>4-6 hours</td>
</tr>
<tr>
<td>Not influenced by</td>
<td>Rock, wood</td>
</tr>
<tr>
<td>Extra functionalities</td>
<td>Audio/visual indications</td>
</tr>
</tbody>
</table>
terminal positioning purposes. The information gathered at the static nodes and forwarded to the control center will allow the control center to estimate the mobile terminal position. Finally, the mobile node will receive the mobile terminal position estimate so that the rescuers can localize the buried people. As a further improvement, it is also expected that the mobile nodes will have the sniffing capability to actively collaborate with control center for improved mobile terminal purposes.

The accuracy of the mobile terminal position estimate will depend not only on the algorithms to be implemented on the nodes and on the control center, but also on the technical aspects of the system. Indeed, a variety of error sources of the mobile terminal position estimate have been identified, and have to be minimized and quantified in order to evaluate beforehand the accuracy of the mobile terminal position estimate provided by the system.

Firstly any error in the position of the nodes will negatively impact on the mobile terminal position estimate, so that the higher the position error of the nodes the worse the accuracy of the estimate of mobile terminal’s position. Therefore, the system will include a high precision Global Navigation Satellite System (GNSS).

Another important source of error in the MT position estimate is the time synchronization error between nodes. Therefore, the nodes and control center will include a synchronization module that synchronizes the clocks of the nodes each second with a maximum error of 5ns. Additionally, the clock jitter will eventually degrade the synchronization error at a maximum rate of 200 ns per second (in the worst case scenario).

Although the minimum number of nodes required to estimate the positions of the MTs is four, the number of nodes to be deployed in the system and their geometrical arrangement among themselves and with respect to the mobile terminal will also impact the final accuracy of the mobile terminal position estimate. Broadly speaking, the higher the number of deployed nodes the more accurate the mobile terminal position estimate will be which opens new possibilities in comparison to other systems (Morgand 2004). Moreover, the nodes should be placed surrounding the affected zone while avoiding being aligned.

Finally the RESCUECELL system will be able to identify in minutes all the mobiles in the research area, initiate a call to any of these mobiles (making the terminal ring) and at the same time locate the terminals to know if a terminal is buried in snow, and locate them with a precision of meters that make the rescue operation very fast and easy.

5. PRELIMINARY SNOW TESTS

Different developments and tests are conducted in parallel to optimize location algorithms, graphic interfaces and ergonomics. Among them and regarding snow properties, tests were conducted with the aim of quantifying the advantages and disadvantages of using the different equipment, to gather an idea of how the GSM signal is affected by the surrounding environment, and even more important, to help defining the hardware needed to fulfil the system specifications of the RESCUECELL system.

Both for the indoor and outdoor test, the use of a power amplifier and a directive antenna improves the performance of the system providing better performance on a bigger range. In addition, the results of the snow test corroborate that the use of a directional antenna improves the system performance a larger range of coverage.

![Image](image_url)

**Fig. 3:** Downlink measurements during snow tests
From the graphs of the tests we can conclude that the coverage of the system is limited by the output power. Since the mobile terminal can be forced to work at 2W on the GSM900 band, a similar (even higher) output power has to be achieved to improve the system performance. At the same time, obtained results are consistent with results of Bataller et al. 2011.

6. CONCLUSIONS
The RESCUECELL system aims at providing a new solution for the research of victims through their mobile phone. It will be solely dedicated to SAR services with an adapted communication not to let recreationists think that their mobile phone is the only keypoint. Further steps will consist in new fullscale tests during the next winter to validate the overall process based on prototypes before to start with final products developments. Preliminary contacts with the Icar (Etter et al. 2004) avalanche branch and French SAR services are promising.

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REFERENCES
Bataller V, Ayuso N, Muñoz A., Tardioli D., Cuchí J.A., Lera F. and Villarroel J. L. 2011: Modeling of through-the-snow electric field propagation for rescue systems, COMSOL Conference, Stuttgart (Germany)