Satellite Role in Emergency Services

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***Abstract*— This paper describes the SALICE (Satellite-Assisted LocalIzation and Communication systems for Emergency services) project, an Italian National Research Project which has been recently funded by the Italian Ministry of Research; the SALICE project aims at identifying the solutions which can be adopted in an integrated reconfigurable NAV/COM device and studying its feasibility in realistic scenarios. The first goal of the SALICE project is the definition of the baseline scenarios and system architecture which will allow the design of new and effective solutions for what concerns integrated communications and localization techniques, Software Defined Radio (SDR) NAV/COM devices, satellite and HAPS integration in the rescue services, heterogeneous solutions in the area of intervention (IAN, Incident Area Network). Particular attention will be devoted to the optimization of the resources management strategies and to the cooperative localization of rescue entities (persons and means) that intervene in emergency situations.**

I. Introduction

Recently communications and networking technologies for public safety and security represent one of the most important research topic of the scientific communities; this trend has been enforced by two specific facts:

- the rising of a new global menace, the terrorist actions against countries which are the most developed ones or have more heterogeneous population in terms of religions and ethnic and cultural identity;
- the big attention which has been given, also by the media, to catastrophic events such tsunamis, huge fires, floods which sometimes are deemed to be partially due to the climatic changes.

As a result, a big research and standardization activity has been accomplished at international level in order to define modern, interoperable communications and networking standards for emergency response and public safety [1]. Particularly, in Europe, the ETSI Recommendation TS 102 181 recognizes the importance of the Location Services in the EMTEL framework (Emergency Telecommunications [2]), which must provide real-time information regarding the position of personnel or vehicles to a command point [3]. The trends identified in those activities seem to propose two hot topics for further investigation, these are:

- the integration of navigation and communication systems in a unique terminal which can be used by the rescue teams;
- the integration between self-organizing space segments, such as satellite networks and HAPs (High Altitude Platforms) and terrestrial systems, such as UMTS or TETRA.

Generally speaking, during emergency situations, satellite communications present many advantages in supporting or replacing a terrestrial infrastructure (if any) subject to destruction or saturation. However, devising the right deployment model deserves close scrutiny in order to fit the responders needs and sustain financial viability. To this aim it is worth describing emergency telecommunications in a more detailed way. Assuming a focus on emergency response, we define emergency telecommunications as the telecommunication facilities used during the emergency response in order to support emergency operations and mitigate the humanitarian and economical impacts of the disaster.

Satellite systems display several properties crucial in the framework of emergency telecommunications. The satellites are more resilient to disasters and damages. Their weakest point as far as Earth disaster are concerned being the gateways and network control centres. Nonetheless, for large disasters, only satellites are actually able to cover the whole scene and provide broadband services. The use of spot beams support efficient management of the satellite capacity. For fixed and transportable systems, data rates of hundreds of kb/s are possible, serving a variety of services. Mobile systems display on the other hand reduced data rate (several tens of kb/s) with the advantage of improved versatility in deployment. Finally, the regulation of the satellite related bands is already handled at an international level as opposed to analogue PMR for example.

There are also drawbacks. Some of them are tightly bound to the physics of satellite transmissions, others relate to the business models of the various satellite industry actors. First of all, satellite transmissions often require line of sight. Indoor operations must then rely on gap filling. The data rates achievable through a satellite system is tightly linked to the size and directivity of the antenna. The higher the data rate, the

larger the antenna and the more accuracy required for pointing. Finally, satellite capacity and equipment may be perceived as costly especially when the competition is harsh with other terrestrial telecommunication technologies.

Satellite communications have an important role to play in emergency telecommunications provided a correct coupling is found between terrestrial and satellite technologies. This vision is supported by the belief that the following areas are especially tailored for deployment of satellite based solutions: Providing terminals with mobile and long haul capabilities for the first minutes/hours of the catastrophe.

- Trunking and backhauling mb/s of data over large ($\geq$ 100 km) distances using satellite terminals deployed "on the spot".
- Providing temporary links for "repairing" disconnected networks (either through pre-deployed satellite terminals or not) in order to convey critical traffic.
- Broadcasting of (possibly real time) data to large areas.
- Providing location data.
- Providing observation data.

In this framework, SALICE project aims at identifying the solutions which can be adopted in an integrated reconfigurable NAV/COM device and studying its feasibility in realistic baseline emergency scenarios, where several rescuers organized in Teams, or Clusters intervene to the emergency area from different locations, using different ways and possibly different transportation means. Particularly the main research topics of the projects are focused on: Localisation techniques, Software Defined Radio (SDR) and Cognitive Radio (CR) [4] NAV/COM devices, satellite and HAPS integration in the rescue services, heterogeneous solutions in the area of intervention (IAN, Incident Area Network).

The first goal of the SALICE project is the definition of the baseline scenarios and the system architecture which will allow the design of new and effective solutions to guarantee communication/navigation services in the area of intervention (IAN, Incident Area Network) by effectively integrating heterogeneous technologies. Integrated platform, in fact, intrinsically fits the requirements of emergency scenarios characterized by network resources scarcity, partially absence of active communications infrastructures due to an unpredictable emergency event.

In the following the organization of the paper is described: in Section II the SALICE baseline scenario definition and system architecture are analysed with the aim to introduce the SALICE project research topics. In Section III, after giving an overview of the network characteristics and requirements, the main research areas of the project are discussed, pointing out the specific objectives of each area.

II. SALICE BASELINE SCENARIO DEFINITION AND SYSTEM ARCHITECTURE

The investigation of the technologies, candidate to support the forecast system functionalities in emergency situation requires the definition of a baseline scenario. One of the early project activities, in fact, is devoted at defining the application scenario, considering also feedbacks coming from potential end-users. Such an activity is still on-going, but a preliminary issue of scenario definition, system requirements and architectural specification is already available.

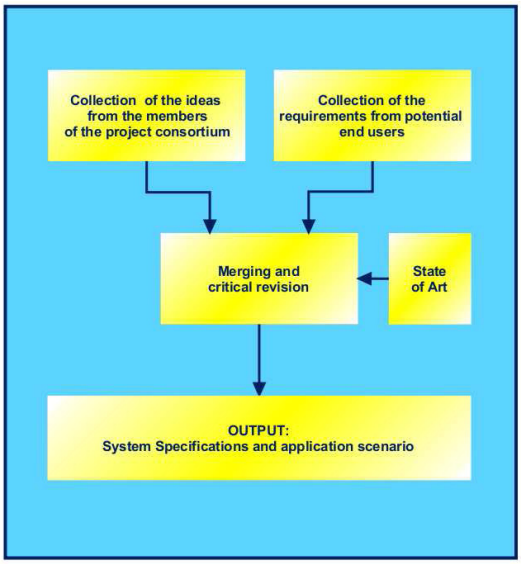

Fig. 1. SALICE Specification System and application scenario process

In particular the final definition of the SALICE specifications system and of the application scenario is the result of a well-constructed specification process, which consist in three phases (as depicted in Fig.1): first there is a collection of ideas coming from the members of the project consortium; such ideas will be merged with some requirements coming from potential end users belonging to the communities interested to the technology developed during SALICE project and finally ideas and requirements will be critically revised considering the state-of-the-art picture. The output of the processing phase will be the system specification, together with the application scenario.

Although the scenarios which can be considered in the SALICE project are multiple and differentiated, it is possible to describe the vision embedded in this project by discussing a fundamental environment with the related problems. In Fig.2, the SALICE baseline scenario is shown.

In order to describe the baseline scenario in the following the definitions of the main actors involved in the Incident Area Network [2] are listed:

Emergency Control Centre (ECC): facility used by emergency organizations to coordinate the intervention of the Authorized representatives. It is a permanent site, placed generally far from the disaster area.

Mobile Master Node (MMN): communication facility employed to guarantee the connection (possibly through a satellite/HAP radio link or possibly through a transportable UMTS Base Station) between the ECC and the FRs personnel operating in the emergency area; it is a temporary, mobile station placed at the perimeter of the emergency area.

Emergency Vehicle (EV) : any kind of terrestrial or marine,

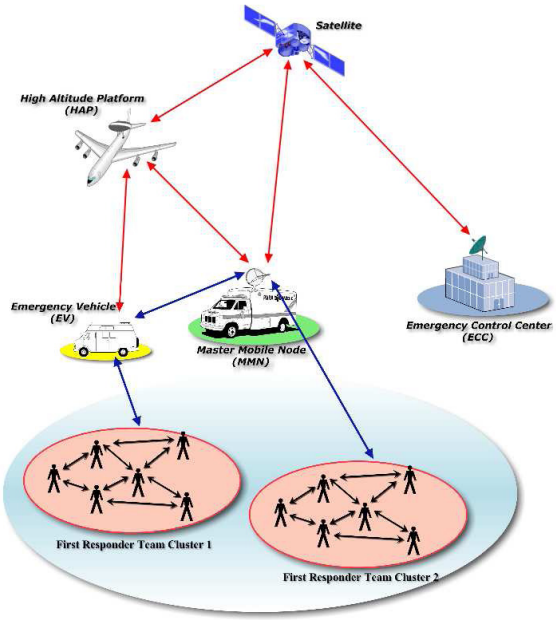

Fig. 2. SALICE baseline scenario

generally but not necessarily manned, vehicle that intervenes directly in the emergency area to transport persons (rescuers and rescued people) and tools for the intervention (e.g., water, stretchers, etc).

First Responder (FR): person belonging to an Authorized Representatives institution that directly intervenes on the emergency area as soon as the emergency has occurred or has been declared. First Responders may be organized in Teams, that intervene to the emergency area from different locations, using different ways and possibly different transportation means (e.g., Emergency Vehicles).

Emergency Service (ES): service, recognized as such by the Member State, that provides immediate and rapid assistance in situations where there is a direct risk to life or limb, individual or public health or safety, to private or public property, or the environment but not necessarily limited to these situations .

At the present specification phase, we can describe the application scenario with a satisfactory degree of reliability. With reference to Fig.2, we can consider a typical emergency rescue application scenario. As soon as the rescue team goes into the place of the emergency event (e.g.: a natural disaster like flood or earthquake or a bombing attack), namely the emergency picocell, the members of the team have in charge the task of restoring the radio connectivity in a very short time. This actually involves an ad-hoc network deployment, which should be very fast and should not involve any kind of complex installation or difficult plug-in; the main tasks of the deployed networks are:

- to draw a scene description;
- to assist navigation and localization functionalities;
- to gather messages coming from residually-active radio networking infrastructures.

Inside the emergency picocell the MMN works as local access-point. The MMN can be regarded as a small portable BTS. Such a device should be able to reconfigure itself on the basis of the picocell situation. This means that MMN should be a *smart terminal*.

The collection of data acquired by the rescue team is actually the scene description related to the emergency picocell. Such a *picture* of the scene can be augmented by text and voice messages transmitted by other kind of terminals (e.g. palmtops, laptops) owned by the operators of the rescue team. The MMN gathers the information sent in uplink by the ad-hoc WSN (Wireless Sensors Network) and by operators' terminals and forwards it to the EV. Inside the picocell, it is crucial to guarantee real-time access to sensors and terminals characterized by different data-rates. Due to the safety-critical nature of the considered application, QoS constraints are quite severe.

Moreover the MMN should coordinate the functionality of assisted localization, assisting GPS (or GNSS) in the localization tasks inside the picocell, even though the satellite localization is severely hindered.

The last functionality of MMN is to gather messages coming from terminals still active and hold by people asking for rescue in real dangerous situations (e.g. people buried in the debris). In such kind of occurrences, it is know that people try to call someone by cellphone or to launch textual messages by using WLAN connections. It is clear that such kind of information may be vital to save people that are in life danger. In order to implement this functionality, MMN should be able to reconfigure itself in order to recognize the presence of such kind of existing standard communication modes and to correctly detect them.

Considering all these requirements, the architecture of the MMN should provide noticeable tradeoffs in terms of computational power, reconfiguration capability, small size and electric power consumption. A multi-processor architecture capable of dynamically loading different baseband reception procedures (corresponding to the different wireless networking standards present in the picocell) should be forecast.

To conclude, as highlighted in Fig.3, SALICE baseline scenario definition and system architecture represents the input of the other main research topics, which are investigated in the project.

III. SALICE PROJECT RESEARCH AREAS

Network characteristics and requirements

In order to give a general view of the SALICE project its main objectives are described . As we have already mentioned in the previous sections, the first goal of the project consists in defining an application framework which can be useful for the definition of the scenarios of actual interest for real-world commercial providers and users. The definition of the application scenarios will drive the successive definition of the system architecture that will constitute the basis for the specification of algorithms and techniques developed in the project.

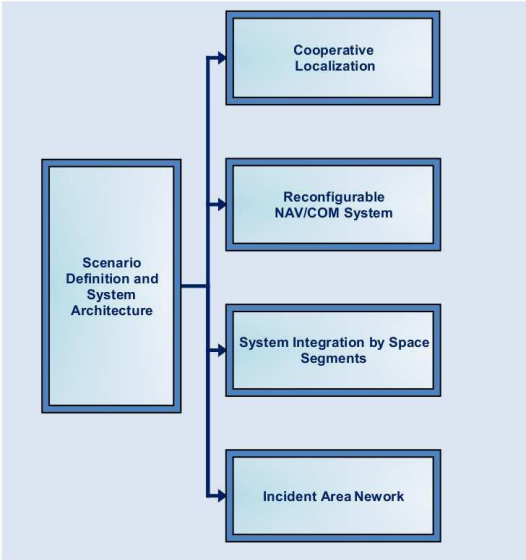

Fig. 3. SALICE project research areas

With respect to the baseline scenario depicted in the previous section a careful design of a very robust, reliable and flexible NAV/COM network among the FRs, the EVs and the ECC, which not (necessarily) relies on the presence in-loco of pre-existing public or commercial services (e.g,. GSM, UMTS networks) is required. Furthermore, direct radio communication with a far-away ECC could be impossible in several situations, or too expensive in terms of battery for the portable terminals. Therefore, the MMN (identified as a temporary, mobile station placed at the perimeter of the emergency area and acting as a master node for the local network), HAP and the satellite must be integrated in the SALICE NAV/COM network, respectively with the aim of:

- guaranteeing the connection (possibly through a satellite/HAP radio link or through a transportable UMTS Base Station) between the ECC and the personnel operating in the emergency area;
- providing ad-hoc and temporary communications capabilities, connecting the MMN with the ECC and possibly the EVs (which have higher available power than the FR terminals) with the MMN;
- guaranteeing very long distance communications between the MMN and the ECC and the ECC and the EV.

In such heterogeneous network, it is possible and necessary to identify some different radio links, or communication modes:

a) *Short-range*, intra-cluster, radio link, limited to the FRs belonging to the same Cluster, used to transmit voice, data and localization messages. Note that if a network-based localization system is implemented, the timely automatic transmission of localization messages is of the utmost importance for the system and some kind of message priority should be envisaged. A multi-hop networking structure will rely on the availability of this short-range link.
b) *Medium-range*, inter-cluster, radio link, used to communicate voice and data with the EVs and the FRs belonging to different clusters. Position information and localization messages also use this link.
c) *Long-range* radio link EV/MMN to HAP, used to communicate voice and data from the area of intervention to the ECC in the case that EV/MMN cannot communicate with this system.
d) *Very-long-range* radio link MMN-SAT, possibly used in the case that no HAP is available. Position information and localization messages also use this link.

In order to outline the objectives and the activities of the SALICE project, the main resaerch areas are defined in the following subsections.

Cooperative Localization

Timely and precise localization of the rescuers is essential for the coordination and planning of search, rescue and disaster relief operations, in terms of efficacy and safety for both rescuers and injured people. Therefore Cooperative Localization of rescue entities (persons and means) that intervene in emergency situations represents one of the main specific and important research topic of the project [5] [6] [7] [8] [9]. In particular two families of operational conditions in which the emergency localization network will be deployed are identified:

- some FRs are in LOS visibility with four or more GPS satellites while the others are in Non-LOS, with severely impaired personal GPS receivers;
- the FRs are requested to make an indoor intervention, so that most of their GPS receivers has a nearly blocked link with the GPS satellites. Instead, terrestrial radio communications are still reliably maintained through the FRs/EVs' ad hoc communication networks.

A Core Localization Framework (CLF) able to seamlessly cope and self-adapt with a heterogeneous and time-varying operational condition will be designed and hybrid scenarios will be considered together with it. Therefore interoperability or algorithmic-level cooperation among different localization algorithms is necessary and a possible approach will be investigated.

Reconfigurable NAV/COM System

Localization information should be communicated not only to the terminal holder, but also to the Emergency Control Centre (ECC), in order to coordinate the intervention, in fact, in some cases, the FRs of the same Team or of other Teams may need to know their reciprocal positions, for safety reasons. In this context the integration of communication systems and localization/navigation services represents a very important requirement; the localization information should be automatically transmit to the suitable entities as soon as it is available without human intervention. Therefore every FR, as well as the EVs, is supposed to be equipped with

a portable radio transceiver (ideally, the SALICE Terminal), with advanced and integrated NAV/COM capabilities.

In order to define of a reconfigurable and flexible user terminal able to modify itself to cope with any NAV/COM requirements, a SDR (Software Defined Radio) approach is needed [10] [11]. Therefore a feasibility study for a fully software handset will be performed, based on a futuristic (but realistic) SDR scenario. In particular the project is focused on:

- *SDR fully-software* implementation of a FR's terminal architecture;
- *SDR fully-software* implementation of a Master Mobile Node (MMN) architecture.

System Integration by Space Segments

The design of an efficient and flexible NAV/COM network among the FRs, the EVs and the ECC requires, in the long-range radio link, the system integration by space segments (satellite and HAPs) [12] [13]. This integration offers: the possibility of implementation of an emergency network, which can substitute the damaged one, a global coverage of the emergency area and a mean to connect the incident area with external areas [14].

Therefore, in the SALICE context the main research areas will concern:

- the design and test of Radio Resources Management strategies in order to effectively manage the available resources within the emergency areas, guaranteeing the connectivity to the integrated system;
- the implementation of mechanisms to deliver Multicast information to different groups of first responders through the integration of space and cellular terrestrial networks;
- the integration of TETRA [15] and Satellite Systems, considering both short-term and long-term scenarios.

Incident Area Network

The fundamental building block of the next generation network for emergency services is represented by the design and definition of the scenario for the Incident Area Network together with protocol solutions for location/environment data and information delivery through heterogeneous wireless networks. The IAN will enable the aggregation of context, location and environmental information concerning the user, the surrounding area and the heterogeneous networks with the aim of improving the availability, the accuracy and the exploitation of such information.

In this framework, a study of the most suitable PHY technologies as well as the study of the interference, coexistence and collaboration between them are required in order to design an efficient coexistence mechanism for bridge devices. In particular some of the project research area are:

- the design of a Middleware for the operation management communications between entities locally and widely distributed;
- the study of coexistence techniques for the design of multimode integrated communication/sensing devices [16] [17];
- coexistence and integration of standard networking architectures for local area and short-range communications with non-standard reconfigurable SDR-based transceiver solutions: analysis of problems and proposals for solutions.

IV. Conclusions

The aim of this paper is to give a general overview of the SALICE project. Special focus is on the first objective of the project: SALICE baseline scenario definition and system architecture, which represents the input of the other SALICE activities. Cooperative Localization, Reconfigurable NAV/COM System, System Integration by Space Segments and Incident Area Network are discussed, in order to highlight the main interests and investigations which will be carried out in the SALICE project.

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