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Research Report RR-08-216

Security scenario definition report

March 20th, 2008

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1 Institut Eurecom research is partially supported by its industrial members: BMW Group Research & Technology – BMW Group Company, Bouygues Telecom, Cisco Systems, France Telecom , Hitachi, SFR, Sharp, STMicroelectronics, Swisscom, Thales

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1 INTRODUCTION

1.1 Scope of the Document

This document aims at identifying and describing the preliminary system architecture of a rapidly deployable and interoperable mobile broadband emergency communications system that best meet mobile communications requirements for security applications. The overall architecture is IPv6-based and the important role of Vehicle Communication Gateways (VCGs) in the system is highlighted. Thanks to the satellite and wireless interfaces, VCGs are able to connect via satellite the disaster area with the headquarter, to create an inter-vehicular mobile ad-hoc mesh network in the emergency field and to provide connectivity to isolated IPv6 wireless cells. Two types of VCGs are envisaged, S-UMTS vehicles operating in L or S band and nomadic Digital Video Broadcasting, Return Channel via Satellite (DVB-RCS) vehicles operating in Ku or Ka band.
The major characteristics of the proposed system architecture for emergency mobile communications are presented and the results of preliminary satellite link budgets are provided.

1.2 Structure of the Document

The document starts, in section 2, with a general description of emergency phases that characterize a disaster and important requirements for communication networks in emergency situations.

Section 3 presents an overview on terrestrial and satellite systems currently used for emergency communications together with a state of the art description of hybrid terrestrial/satellite solutions.

Section 4 defines the overall scenario for the proposed hybrid satellite and terrestrial system. A detailed description of S-UMTS vehicles and DVB-RCS vehicles is presented together with link budget results in S and Ka bands.

Finally main conclusions from the proposed system architecture and obtained results are presented.

2 SATELLITE ROLE IN EMERGENCY COMMUNICATIONS

Improving the security of human beings is one of the most important contributions which space technologies and services can offer. Space, a strategic and multiple-use technology by nature, is a key instrument for a comprehensive approach to security scenarios. Effective telecommunications capabilities are imperative to facilitate immediate recovery operations. The crisis scenarios are quite complex as frequently terrestrial infrastructure is disrupted, civil protection agencies involved in the recovery operations use different systems, and services supporting emergency preparedness missions must be provided priority treatment over other traffic. In these scenarios, satellite communications networks can play an important role as they provide ubiquitous coverage, instant and flexible hot spot capacity, including broadband services, and a backup for terrestrial networks. Therefore, the satellite community needs to consider how it can best support emergency management and recovery operations in all their phases.

2.1 Emergency phases for disaster management

Disaster can be defined as the onset of an extreme event causing profound damage or loss as perceived by the afflicted people. Disasters can be of different types: natural disasters, as hurricanes, floods, drought, earthquakes and epidemics, or man-made disasters, as industrial and nuclear accidents, maritime accidents, terrorist attacks. In both cases, human lives are in danger and the terrestrial telecommunication infrastructures are no longer operational.

Disaster management involves three main phases [1]:

1. <u>Preparedness</u> must be to some extent envisaged:
   - Satellite networks must be operational when some disaster occurs.
   - To observe the Earth, to detect hazards at an early stage.
2. <u>Crisis</u> from break-out (decision to respond) to immediate disaster aftermath, when lives can still be saved. Crisis is understood as the society's response to an imminent disaster; it must be distinguished from the disaster itself.
3. <u>Return to normal situation</u> must be envisaged with provisory networks based on satellite links.

Figure 1 represents the three main phases of a disaster management in a temporal scale underlining each different state.

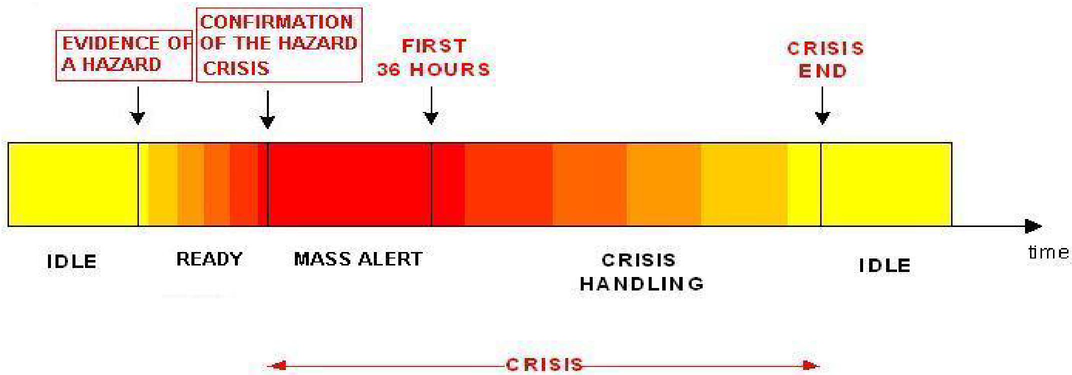

Figure 1: Successive phases of an emergency situation

In this way it is possible to represent all the phases in a state diagram as shown in Figure 2.

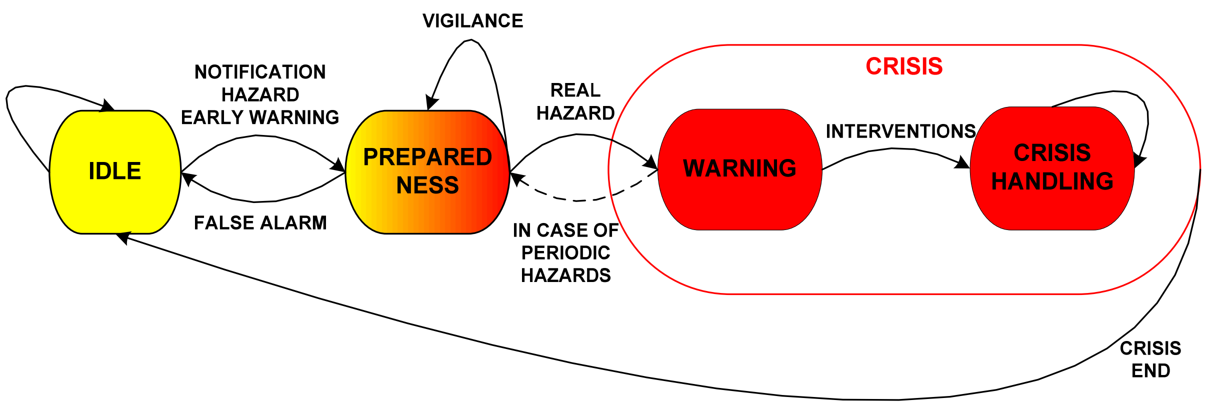

Figure 2: Emergency state diagram

2.1.1 PREPAREDNESS

The first phase called preparedness involves missions accomplished in normal situation. They are basically of three kinds:

1. Observation. The observation system has two main functions:
   - Detection of hazards. Satellite can play a role to that respect by means of observation and scientific satellites. A typical case when satellites can detect hazards prior to any other means is meteorological hazards.
   - Location of the source of hazards. Satellite is nowadays the best means to provide the geographical coordinates of any object thanks to GPS/Galileo/Glonass constellations. The idea is to have terrestrial sensors coupled with a GPS/Galileo/Glonass sensor.
2. Maintenance of the system. An emergency system must be ready to start at any time. To that end, it must be tested at regular time intervals in quiet times from end to end.
3. Education of professionals and citizens.

2.1.1.1 *Detection of a hazard*

In terms of networks, detection may be considered as the essential function of a *feeder link* or *uplink*. Detection of a hazard may be done by several means:

- Emergency call: this is the case where a Citizen is calling a dedicated emergency call centre e.g. dialing 112 in Europe to witness of the break out of a hazard.
- Systematic watch by professionals e.g. helicopters flying over forests in summertime to detect fires.
- Sensors involved in a complex network with machine-to-machine connections. Sensors are useful in places where human being can not go (nuclear reactor) or actually rarely goes (water level sensor upward a river to detect inundations). Satellite is then a relevant solution to connect the sensors to an expertise centre.

2.1.2 CRISIS

In a situation of crisis the involved parties can be classified in the following way, taking also into account the degree of mobility they need:

- <u>Local Authority (ies) (LA)</u>; *fixed*: the person (or group of persons) in the administrative hierarchy competent to launch a warning to the population and to the Intervention Teams ;
- <u>Citizens (Cs)</u>; *either mobile or fixed*: non professional people involved in the crisis.
- <u>Intervention Teams (ITs)</u>; *mobile*: professionals (civil servants or militaries) in charge of rescuing Citizens in danger, preventing hazard extension or any time critical mission just after the break out of the crisis; in charge of caring injured people once the crisis is over.
- <u>Risk Management Centre (RMC)</u>; *fixed*: group of experts and managers in charge of supervising operations. The Risk Management Centre works in close cooperation with Local Authorities.
- <u>Health Centres (HC)</u>; *fixed*: infrastructure (e.g. hospital) dedicated to caring injured citizen and backing intervention teams as for this aspect of their mission.

2.1.2.1 *Warning*

It is important to manage properly this critical phase as it is the moment where a quick response is the most efficient in terms of lives and goods saved. This means advertising professionals of the incoming hazard.

Warning makes sense if and only if there is a delay between the very break out of the hazard and the damages it could cause which leaves time to people to escape. Warning to the population is always Local Authorities' responsibility since they are the only one who can clearly appreciate the danger depending on local circumstances. Deciding that the situation is critical may be taken at governmental, national level. This is the case for examples for earthquakes in all European countries.
In every stage, satellite could be an efficient way to propagate alert. Alert could be a typical mission of a satellite based emergency system.

2.1.2.2 Crisis handling

Coordination of Intervention Teams begins when the crisis breaks out. The Local Authorities alert them just before the population and then hand over supervision to the Risk Management Centre.
Later on, Intervention Teams still receive instructions from their Local Authorities, from the Risk Management Centre and from the Health Centre. In general, instructions are transmitted through a back-up network made up by a satellite terminal which links the disaster area to terrestrial backbones.

It is worth to create a "cell" surrounding the satellite terminal within which Intervention Teams communicate by terrestrial mobile radio means. It is called an EDECC (Easily Deployable Emergency Communications Cell). It is a very flexible solution based on a lot of radio mobile communication devices that could be packed in a container and transported to the field of operations by helicopter or any other means. In an EDECC, it is possible for example recreate a GSM communication cell by means of a mini Base Transceiver Station linked to a Mobile Switch Centre of any operator. Other technologies are possible too (e.g. Wi-Fi).
Intervention Teams return information to Local authorities, to the Risk Management Centre, to Health Centres about the situation and request for help. They use one and the same network for receiving instructions and returning feedback.

2.1.3 RETURN TO NORMAL SITUATION

At that point, the crisis is over and the situation has come back to a stable point. The ordinary networks are down and it is necessary to set up a network able to work on a regular basis.
The main functions of the network are the following:

- Coordinating intervention teams and returning feedback from the field which is still necessary at that point.
- As far as possible enabling the same services as before the crisis and offering public access.

The architecture may be the same as the one outlined above with a satellite link but the network should be more stable and powerful.

2.2 Important factors for communication networks in emergency situations

A flexible communication infrastructure has some specific requirements that need to be considered within the context of emergency response scenarios [2]. They are summarized in the following.

Disaster categories:

Disasters differ from each other depending on their scale, which is crucial to consider in designing an appropriate response/recovery system. This can be defined by the degree of urbanization or the geographic spread. Degree of urbanization is usually determined by the number of people in the affected area, which is very important in disaster handling as the impact of the event changes based on the number of people involved and the breadth of spatial dispersion, both of which impact response and recovery from disasters.

Another key factor, which makes a big difference in the response and recovery stage, is whether the disasters have been predicted or not. Clearly, sudden natural or man-made disasters do not give sufficient warning time. Other disasters may give a longer time window to warn people and take appropriate actions. Thus, if there is advance notification, it is potentially possible to set up a better communication infrastructure and possibly even have a backup technology in place before the disaster occurs.

Specific technology requirements:

Sometimes depending on the nature of disaster, there are more specific communication needs. For example, telemedicine communication may require interactive real-time communication. Transferring data, audio and video require special bandwidth requirements and high network security. The service needs to be reliable and continuous and work with other different first responder organizations' devices if necessary. Users may have different devices such as laptops, palms, or cell phones which may work with different network technologies such as WLAN, Wi-Max, WWAN, Satellite, or wired networks. Additionally a communication network needs to be easily configurable and quickly deployable at low cost.

Mobility, reliability and scalability:

In order to help emergency personnel to concentrate on the tasks, emergency network should be mobile, deployed easily and fast with little human maintenance. Therefore devices must be capable of automatically organizing into a network. Procedures involved in self-organization include device discovery, connection establishment, scheduling, address allocation, routing, and topology management.

The reason for reliability is twofold. First, in emergency situations each rescue worker must neither be isolated from the command center nor from other team members. Second, mobility is likely to occur frequently in an emergency network. Thus, ability to adapt to network dynamics and harsh situations plays a major role in the design.

Scalability refers to the ability of a system to support large number of parameters without impacting the performance. These parameters include number of nodes, traffic load and mobility aspects. Limited processing and storage capacities of some of the radio devices are also a concern.

Interoperability and interdependency:

Communication technology provides the tool to send data; however when information is sent over different channels or systems, interoperability may not necessarily have been provided. First responder should be equipped with devices capable of using different technology by choosing the appropriate interface card and still working together to form a mesh network and communicate data. Therefore, regardless of what technology each individual might use, they are uniformly connected to the relaying mesh nodes and able to exchange data.
Another factor which needs to be considered in the design of future communication technology is minimizing possible interdependencies in a system. This helps to design a more robust system which is resilient to failures in sub-components of the system.

Multimedia broadband services:

Communications for the benefit of local rescuers, national authorities or international assistance are mainly to coordinate efforts of field teams and connect teams to remote decision-making centers. In particular, to retrieve monitoring data from the disaster site and to distribute data to local teams or remote expertise centers are important requirements for an emergency communication system. Thus, providing broadband communication capacity during emergency or crisis times is becoming more and more necessary. Concerning services, users' basic requirements are voice and data communications with short and long range capabilities, but users require also multimedia communications with large volume of data able to provide the logistics of the situation, medical data, digital map, blueprints or intelligence data.

Knowledge and training:

An important factor to be considered as addressed is the lack of knowledge on exact capabilities of the new technology being deployed and lack of training. The new technology needs to be installed and fully tested in drills and preparation exercises well before it is used in an actual disaster. It is also very important to consider who will be the users of this technology and what level of knowledge and technical background they have. We would like to design future emergency communication tools and public awareness systems to be user friendly with minimal training requirements, yet also secure.

Information sharing and data dissemination:

In some disaster scenarios when people have important information, there needs to be a motivation for them to share it across first responder organizations. When the information is provided, there needs to be some mechanism to verify the accuracy of the information provided. Privacy is a factor that needs to be considered in determining who should have access to this information.

Warnings and alerts:

Warning messages should be provided with the consideration that some people may disregard the warnings, therefore even the well-designed warning system must consider human error or resistance.

People may not evacuate to safe areas even if asked or ordered to do so for different reasons such as family, belongings, and pets, or they may not trust the accuracy or source of the warning. They may not take the warning serious if they hear different messages from different sources, or if the source of the warning has not proven to be accurate or reliable in the past. The warning should provide a clear explanation of the nature of the disaster and appropriate actions to be taken.

3 TERRESTRIAL AND SATELLITE SYSTEMS FOR EMERGENCY COMMUNICATIONS: STATE OF THE ART

3.1 Terrestrial-based solutions

Even though modern telecommunication technology is readily available with modern satellite communication, when faced with a situation of a disaster, rescue forces often rely on very simple communication systems as analogue and digital radio systems described hereafter.

3.1.1 HF, VHF, UHF EQUIPMENTS

In times of crisis and natural disasters, Amateur radio is often used as a means of emergency communication when wired communication networks, cellular wireless networks and other conventional means of communications fail.
High Frequency (HF) designates a range of electromagnetic waves whose frequency is between 3 MHz and 30 MHz.
Very High Frequency (VHF) designates a range of electromagnetic waves whose frequency is between 30 MHz and 300 MHz.
Ultra high frequency (UHF) designates a range of electromagnetic waves whose frequency is between 300 MHz and 3.0 GHz (Figure 3).

It is the actual most common tool used for communications by rescue teams because it is very easy to use and widely deployed in most of countries. Different rescue organizations can use the same frequency and so can communicate with each other (firemen, police officers). This solution is quite limited because the basic services provided by HF, VHF and UHF communication devices are voice.

Figure 3: UHF terminal

3.1.2 PMR

The Professional Mobile Radio (PMR) is a communication system, which is composed of portable, mobile, base stations and some console radios [3]. The antenna must be mounted in height. The coverage can vary a lot (between 3 and 7 km for point to point, up to 50 km for an extend networks). The PMR system is actually used by a lot of police centers and fire brigades. It is easy to use and to deploy. Many rescue teams are now familiar with these equipments in all the kinds of crises.
Some standards have been developed for specific usage and the Trans European Trunked Radio (TETRA) [4] is the most developed. Several manufacturers propose different terminals for the communications, but all these equipments offer interoperability. The user can choose the manufacturer and the product he prefers.

3.1.2.1 TETRA

It is an open digital standard defined by the European Telecommunications Standard Institute (ETSI). The purpose of TETRA is to cover the different needs of traditional user organizations such as public safety, transportation, military and government.
TETRA is based on a suite of standards that are constantly evolving. It can support the transportation of voice and data in different ways. It is able to operate in direct mode (DMO) by building local radio nets and in standard mode (TMO). TETRA can thus be used as walkie-talkie (DMO) or as cell phones (TMO). Another mode, called “Gateway” allows a TETRA terminal to use a gateway in order to extend the coverage zone.

The different network elements of a typical TETRA architecture makes TETRA fully operational with other infrastructures (PSTN, ISDN and/or PABX, GSM, etc.). TETRA provides excellent voice quality through individual calls (one-to-one) but also through group communication. This technology can be utilized for emergency calls and ensure secure encrypted communications (Figure 4). The Release 2 of TETRA improves the range of the TMO (up to 83 km), introduces new voice codecs and speeds up the transmission of data up to 500 kbps.
Thus, the high coverage provided by TETRA, the fast call set-up (less than 1 s), both direct and gateway modes make of TETRA an interesting communication technology.

Figure 4: TETRA terminals

3.2 *Satellite-based solutions*

International rescue forces have nowadays started more and more to use satellite communications. After a disaster, even if the terrestrial network is completely out of order, it remains always possible to communicate using the satellite network.
Satellite communications are highly *survivable*, *independent* of terrestrial infrastructure, able to provide the load sharing and *surge capacity solution* for larger sites, best for redundancy: they add a layer of *path diversity* and *link availability*.

Satellites are the best and most reliable platform for communications in emergency scenarios and perform effectively when:

- Terrestrial infrastructure is damaged, destroyed or overloaded;
- Interconnecting widely distributed networks;
- Providing interoperability between disparate systems and networks;
- Providing broadcasting services over very wide area such as a country, region or entire hemisphere;
- Providing connectivity for the "last mile" in cases where fiber networks are simply not available;
- Providing mobile/transportable wideband and narrow-band communications;
- Natural disaster or terrorist attacks occur.

Thus, the benefits of using satellite in emergency communications are:

- <u>Ubiquitous Coverage</u>: a group of satellites can cover virtually all of the Earth's surface;
- <u>Instant Infrastructure</u>: satellite services can be offered in area where there is no terrestrial infrastructure and the costs of deploying a fiber or microwave network are prohibitive. It can also support services in areas where exiting infrastructure is outdated, insufficient or damaged.
- <u>Independent of Terrestrial Infrastructure</u>: satellite service can provide additional bandwidth to divert traffic from congested areas, provide overflow during peak usage periods, and provide redundancy in the case of terrestrial network outages.
- <u>Temporary Network Solutions</u>: for applications such as news gathering, homeland security, or military activities, satellite can often provide the only practical, short-term solution for getting necessary information in and out.
- <u>Rapid Provisioning of Services</u>: since satellite solutions can be set up quickly, communications networks and new services can be quickly recovered and reconfigured. In addition, it is possible to expand services electronically without traditional terrestrial networks, achieving a high level of communications rapidly without high budget expenditures.

In times of disaster recovery, solutions provided via satellite are more reliable than communications utilizing land-based connections.
Satellite can provide different connection scenarios and different services as showed in Figure 5 and Figure 6.

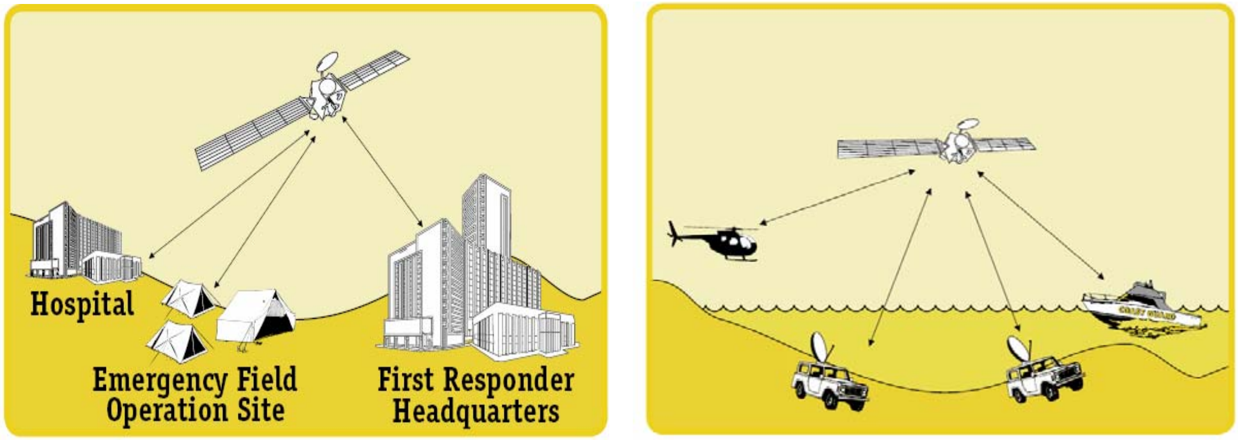

Figure 5: Fixed-to-fixed communications and transportable-to-mobile communications

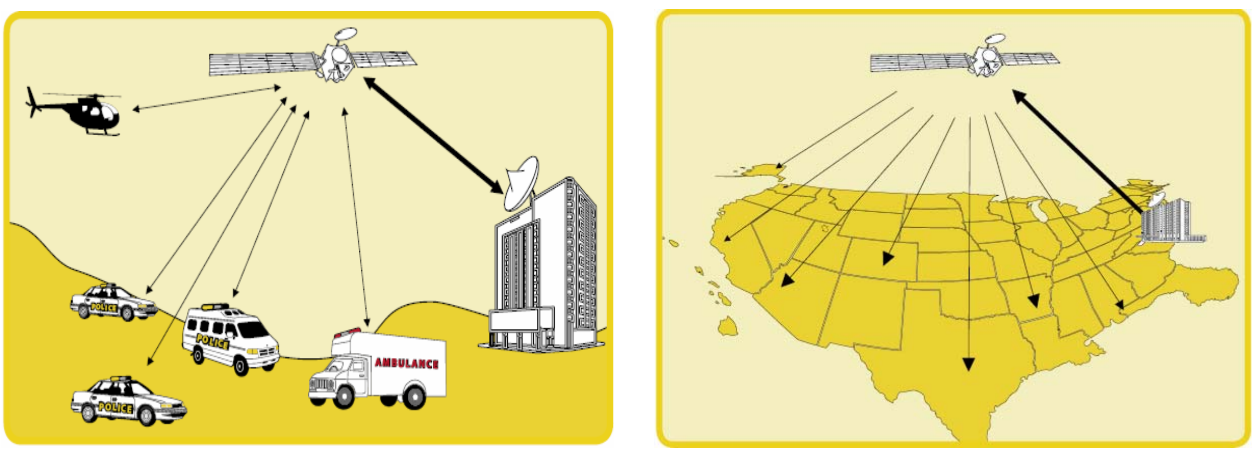

Figure 6: Fixed-to-mobile communications and point-to-multipoint communications

3.2.1 FIXED SATELLITE SERVICES

Fixed Satellite Service (FSS) has traditionally referred to a satellite service that uses terrestrial terminals communicating with satellites in geosynchronous orbit (Figure 7). New technologies allow FSS to communicate with mobile platforms.

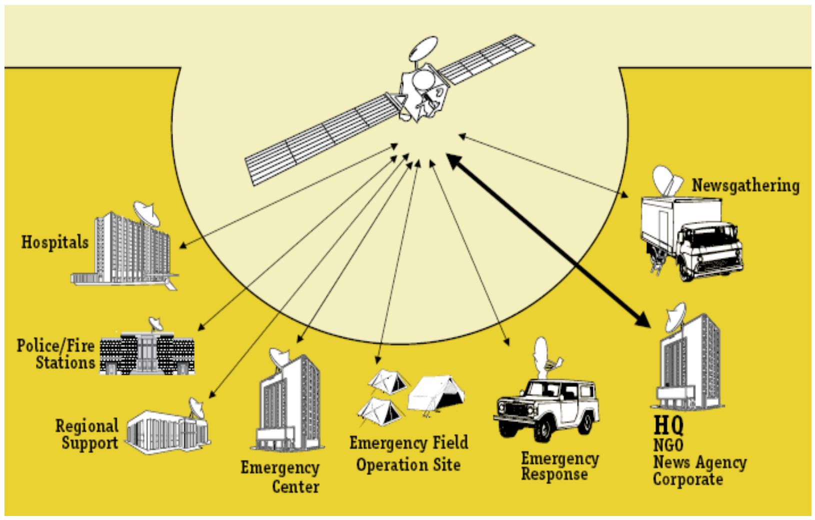

Figure 7: Fixed Satellite Services

3.2.1.1 Satellite VSAT network

A satellite Very Small Aperture Terminal (VSAT) network consists of a pre-positioned, fixed, or transportable (Figure 8) VSAT that connects to a hub station to provide broadband communications to hospitals, command posts, emergency field operations and other sites. Very small aperture terminal refers to small earth stations, with antennas usually in the 1.2 to 2.4 m range. Small aperture terminals under 0.5 m are referred to Ultra Small Aperture Terminals (USATs). There are also variants of VSATs that are transportable which can be on-the-air within 30 minutes and require no special tools or test equipment for installation. Remote FSS VSAT equipment requires standard AC power for operation, but comes equipped with lightweight, 1 and 2KW, highly efficient and self-contained power generator equipment for continuous operation, regardless of local power availability.

Internet access and Internet applications (i.e. VoIP) are supported through the remote VSAT back through the FSS provider teleport location which is connected to the PSTN and/or the Internet. A typical VSAT used by a first responder may have full two-way connectivity up to several Mbps for any desired combination of voice, data, video, and Internet service capability. VSATs are also capable of supporting higher bandwidth requirements of up to 4 Mbps outbound and up to 10 Mbps inbound.

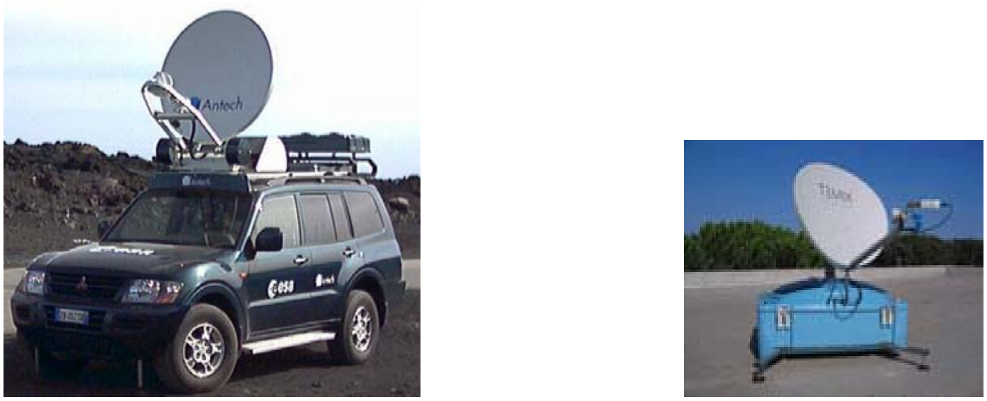

Figure 8: ESA Pajero and Temix EasyFlySat terminal

3.2.2 MOBILE SATELLITE SERVICES

Mobile Satellite Service (MSS) uses portable satellite phones and terminals. As shown in Figure 9, MSS terminals may be mounted on a ship, an airplane, truck, or an automobile. MSS terminals may even be carried by an individual. The most promising applications are portable satellite telephones and broadband terminals that enable global service.

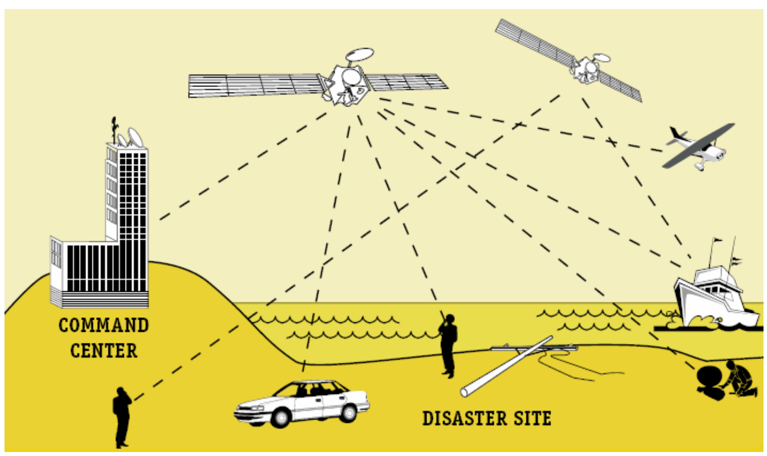

Figure 9: Mobile Satellite Services

3.2.2.1 Satellite phones

Several manufacturers offer mobile phones providing different coverage of the earth [5]-[7]. In general, satellite phone is very user friendly; it looks like GSM mobile phone with one telephone number and one mini personal subscriber identity module (SIM) (Figure 10). Satellite phones are water, shock and dust resistant for rugged environment and offer voice and data services with additional capabilities as call forwarding, two-way SMS, one touch dialling, headset/hands-free capability.

Figure 10: Satellite phone

The major advantage of this solution is the possibility to phone anywhere, any time, using a satellite link and then the normal public terrestrial phone network.

3.2.2.2 BGAN system

Broadband Global Area Network (BGAN) from Inmarsat [8] operates in L-band and offers a number of innovative services (3G like) in the arena of mobile multimedia, video and audio multicasting and advanced broadcasting, with three land portable terminal types. Target users are professional mobile users (on-ground, maritime, aeronautical) in any service area worldwide, except Polar Regions. The service is IP-based and allows data transfer speeds up to 492 kbps, streaming up to 256 kbps. The high levels of portability of BGAN terminals (Figure 11), as well as the easiness of use, make BGAN attractive for emergency services. It is also the first mobile communications service to offer guaranteed data rates on demand.

Figure 11: BGAN terminal

This way, it is relatively easy to plug a laptop on this equipment and to have an Internet access. It is so possible to use IP facilities like Visio conference or other real time applications, with a correct quality thanks to the guaranteed data rate.
Currently the solution yet is not very exploited but tends to be developed. Its major advantage is the quasi-total cover of planet thus same that the polar zones and oceans.

3.2.3 COTM SOLUTION

Communications On The Move (COTM) is the most promising solution for emergency communications. FSS and MSS COTM solutions can provide fully mobile IP data and voice services to vehicles on the move up to 100 km/h (Figure 12). The comprehensive FSS COTM offering includes the terminal, teleport, and satellite capacity to provide high performance COTM IP connectivity.

Typical applications supported:

- Any vehicle can also serve as a mobile command post while in-route and as a fixed command access point for personnel upon arrival at the designated location when local Telco terrestrial and wireless infrastructures are not available.
- A full 10 Mbps downlink channel is delivered via FSS to the vehicle and 512 Kbps uplink channel transmitted from the vehicle to the Internet using IP support for voice, video and data simultaneously.
- Support for 802.11x wireless access allows vehicle to function as wireless hot spot access point for a First Responder convoy while in-route or a fixed hot spot for personnel upon arrival.

Figure 12: COTM equipments

3.3 Hybrid satellite/terrestrial solutions

Two European projects, Tracks and Emergesat, have developed hybrid satellite-terrestrial solutions for emergency communications, but both solutions cannot be hand-carried to the disaster site and require either a van or a helicopter respectively.

3.3.1 TRACKS

In the frame of the ESA-Industry Telecommunications Partnership Program, the project ARTES 4 "TRACKS" [9] deals with the development of the prototype of a van transportable communication station (VSAT terminal, GSM Micro Switch, BSC and BTS, internet access) dedicated to support pre-operational applications (Figure 13). It represents a good candidate telecom solution in case of crisis, when terrestrial communication are damaged or destroyed after a disaster.

TRACKS is first of all a van, which can be driven with a normal driving license. The principal characteristics of the system are the following:

- Quick move on site;
- Link with Internet Network;
- Link with the Public Switched Telephone Network;
- Provide GSM services and Internet access Services.

TRACKS is deployed on the disaster area by local rescue teams. A local command centre can be deployed using the services provided by the van. Thanks to the satellite link, the teams are directly connected to a global command centre, which collect all the information (weather forecast, satellite images) and coordinate the local actions.

TRACKS is composed of several equipments:

- Power generating unit: the van can be autonomous during a period of one or two days. An external 220 VAC power supply can be used too;
- VSAT Terminal;
- On the roof of the VAN, a 1.2 m antenna is used for communications with satellite. Several air interface access schemes have been tested and used in Ku-band, including the SCPC and DVB-RCS. An automatic pointing permits to deploy quickly the antenna;
- a telescopic mast (12 m);
- GSM Equipments (coverage : 1 km);
- Wi-Fi Equipments.

Thanks to the Wi-Fi Equipments, the rescue team on site can use the network developed by TRACKS with the office tools: PC, PDA and laptop. The services are not limited. Some applications like videoconference, telemedicine, cartography can be used thanks the internet access provided by the van.

Figure 13: Tracks

Different configurations with these equipments have been tested in demonstration or crisis simulation. Compared with handheld solutions or easily portable solution like BGAN, TRACKS has limits inherent to this type of transportable solutions: when the roads are damaged, the van cannot reach immediately the site. A second point is the need to train rescue teams or some specialized people to use this material. Improvements are necessary to make it user-friendlier to be used as "GSM-like" solutions.

3.3.2 EMERGESAT

Emergesat [10] is a system developed by Thales Alenia Space as an initiative funded by the French government in response to needs of responding to humanitarian crises.
Flown in locally to a disaster site, Emergesat provides all emergency aid teams, irrespective of nationality, with global information on the crisis situation and assistance with coordination of aid work, and other decision-making aid services. The Emergesat humanitarian aid tool applies the space-based technologies of telecommunications, earth observation and location/navigation satellites. Emergesat is a federating tool, proposed by France and open to partnerships and cooperation arrangements, designed to be at the service of all worldwide.

Figure 14: Emergesat container before and after installation

Emergesat is basically a container as shown in Figure 14, specially designed in its dimensions, weight and the composite materials used in its construction, for transport in the luggage hold of any passenger line aircraft. It has rings for slinging under a helicopter, and is seal-tight under the most extreme weather conditions and totally autonomous in terms of power supply. The basic container incorporates its own communication equipment, and can also be used to transport a complete, autonomous water purification plant or small medical centre.

The container has the following characteristics:

- transportable, adaptable and easy to use;
- rapidly deployable and operational as soon as the relief teams arrive;
- easy to bring in by line aircraft, helicopter and truck, ship, etc.;
- configurable according to the nature of the disaster;
- simple to use, user friendly and multi-lingual;
- all-weather, strong, lightweight, air-conditioned and autonomous;
- weight: 400 kg;
- dimensions: 2 m x 1.5 m x 1.6 m ;
- volume: 4,8 m^3;

The core of the Emergesat communication system is a satellite transceiver unit, providing for high-rate communication from any point on the globe. Its automatic dish antenna ensures that the system can be placed in service immediately. A GSM transmission BTS connected to the satellite system makes it possible to set up a complete GSM network. A long-range Wi-Fi network system provides for connection with a large action perimeter.
A remote server collects all information required by the rear support bases. A software suite enables the operational teams to keep themselves fully informed about the evolution of the crisis, treatment of victims, civil engineering problems, etc. in real time. This system is fully open to all users. The teams in the field can hook up using a conventional tool (PC, PDA, etc.), and obtain information and decision-making aid services, including cartography, meteorology, languages and dialects, and also access collaborative working tools such as videoconference, messaging, application sharing.

4 PROPOSED SYSTEM ARCHITECTURE FOR EMERGENCY MOBILE COMMUNICATIONS

Emergency situations require reliable communication broadband systems able to transmit relevant information from the disaster site to the decision makers and to send feedback from first responders regarding potential dangers or decision. Key factor in designing a robust communication system with applications to emergency response is the development of a quickly, easily deployable and mobile infrastructure providing voice and data communications, available within the first 24 hours.

As highlighted in the previous chapter, no existing terrestrial and/or satellite system for emergency communications is able to cover all those requirements at the same time. Hence, we propose a hybrid satellite and terrestrial system that provides, at once, full mobility in the disaster site to rescue teams and broadband connectivity inside the disaster network and with the headquarter. The proposed architecture is quickly deployable and dynamically adaptable to disaster of any nature and location. It is IPv6-based and able to support IP interoperability with terminals belonging to different administrators and technologies.

4.1 Scenario description

Figure 15 presents a general overview of the proposed system architecture for emergency mobile communications. It consists of:

- A space segment which includes two GEO satellites, one MSS and one FSS;
- A terrestrial infrastructure segment which includes two Earth stations connected through the Internet to the headquarter (or operation centers in case of international support), providing the link between the satellite system and satellite terminal segment deployed in the disaster site;
- A terminal segment which includes:
  - A satellite terminal segment composed of:
    - User terminals such as satellite phones that provide direct satellite access to end-users;
    - VCGs that provide satellite access to terrestrial user terminals and mobile routers;
  - A terrestrial terminal segment that includes:
    - End-user terminals such as handhelds, PDAs, PCs;
    - Vehicular terminals that provide access to the terrestrial end-user terminals and are enabled with routing capabilities, they form a mobile ad-hoc mesh network over the crisis area.

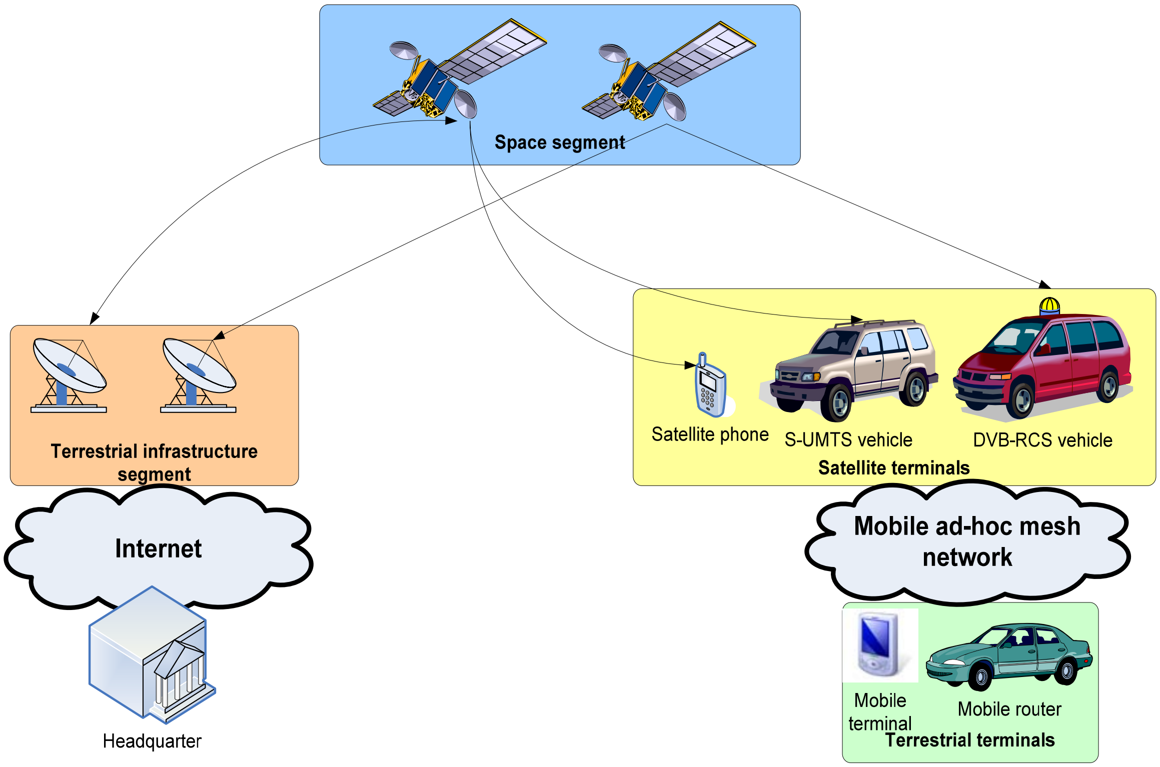

Figure 15: General overview of the proposed system architecture

Generally, the deployment of Public Safety units makes use of two entities, vehicles and Public Safety users equipped with satellite and radio terminals. The present scenario allows Public Safety units to move on the crisis site and to communicate urgent information among devices in the field and from devices to Internet and headquarter. This is achieved by having the different entities organize themselves into a decentralized and distributed network, thus forming a mobile ad-hoc mesh network at the disaster site, a structure which enables any entity to easily reach the headquarter.

The mobile ad hoc mesh network is characterized by two types of vehicles, one with routing capabilities and an other type, the VCGs, performing IP routing and gateway functionalities. In this architecture, only gateways are connected through satellite links to the headquarter, whereas all relaying nodes are able to find each other and form the mobile ad hoc mesh network. The packets are forwarded in a multi-hop fashion throughout the network to reach their destination. Even if the mobile ad hoc mesh network is addressed in more details in the "IPv6 mobility and ad hoc network mobility overview" report [11] and this report is focusing more on the definition of the satellite infrastructure, a first definition of the network deployment on the crisis area is provided.

Since the disaster occurs, two different and consecutive phases can be identified for the network deployment of rescue teams in the disaster area.

During this first phase, as soon as a hazard is detected, Public Safety units use vehicles to move in the crisis site and to reach the most critical areas of the disaster. As shown in Figure 16, S-UMTS vehicles provide connectivity through S/L band between the two main networks: the mobile ad hoc mesh network at the disaster field and the Internet backbone where a fixed decision center is situated. At the same time, in a scenario of high mobility in the crisis area, all the vehicles can exchange multimedia data inside the ad hoc mesh network and coordinate the first rescue operations.

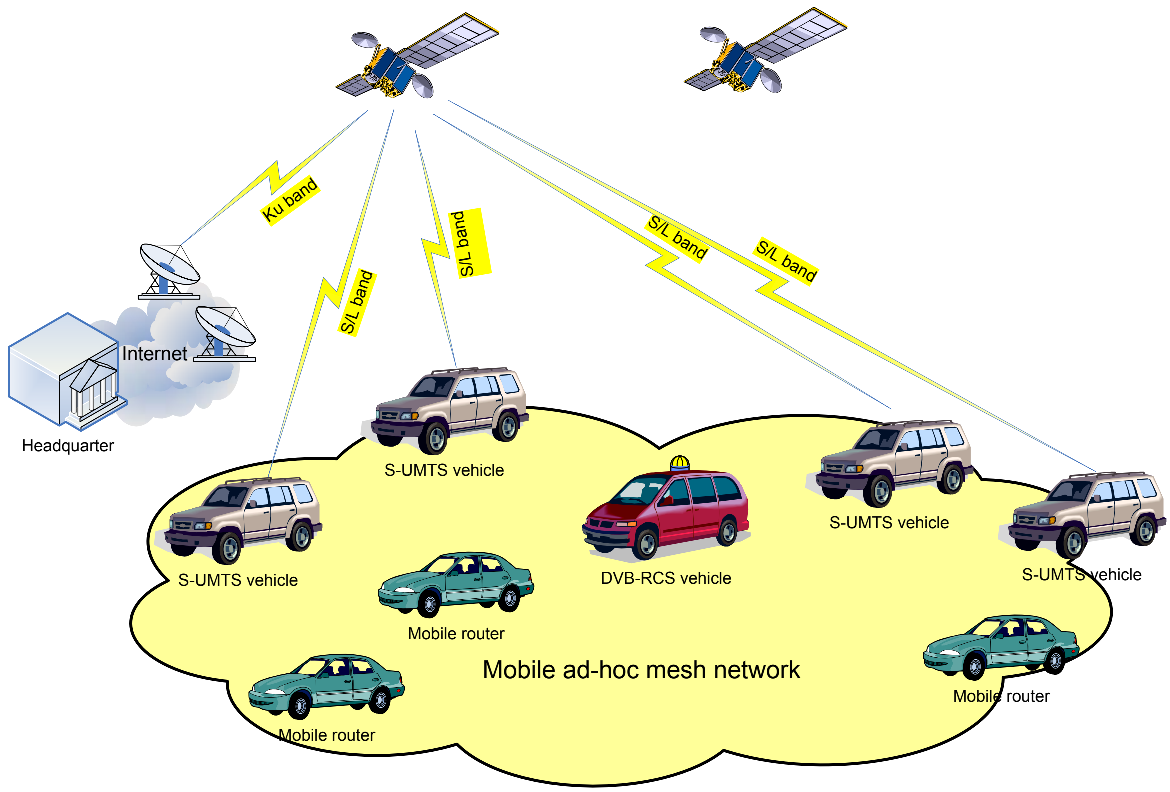

Figure 16: Hybrid satellite-terrestrial system architecture - Network deployment phase 1

In the second phase, once vehicles have reached critical areas, pedestrian Public Safety units start the rescue operations. As shown in Figure 17, Wi-Fi and ad hoc networks are created by mobile terminals and attached to the ad hoc mesh network through the closest vehicles. The proposed IPv6-based architecture allows Public safety units to use different types of technologies as required (e.g. TETRA or GSM pico cells), making the architecture very flexible and providing interoperability in the disaster area. The mobility in the crisis field decreases in this phase, as vehicles mainly work on-the-pause or at very low speed. Broadband connectivity is possible not only in the disaster area, but also for external communications with the headquarter. It is provided by DVB-RCS vehicle, making use of Ku/Ka band, or by several S-UMTS vehicles that share the external connectivity and create a distributed gateway, providing the aggregate MSS capacity. In addition, S-UMTS vehicles can be used to give external connectivity to groups not reached by the terrestrial mobile ad-hoc mesh network.

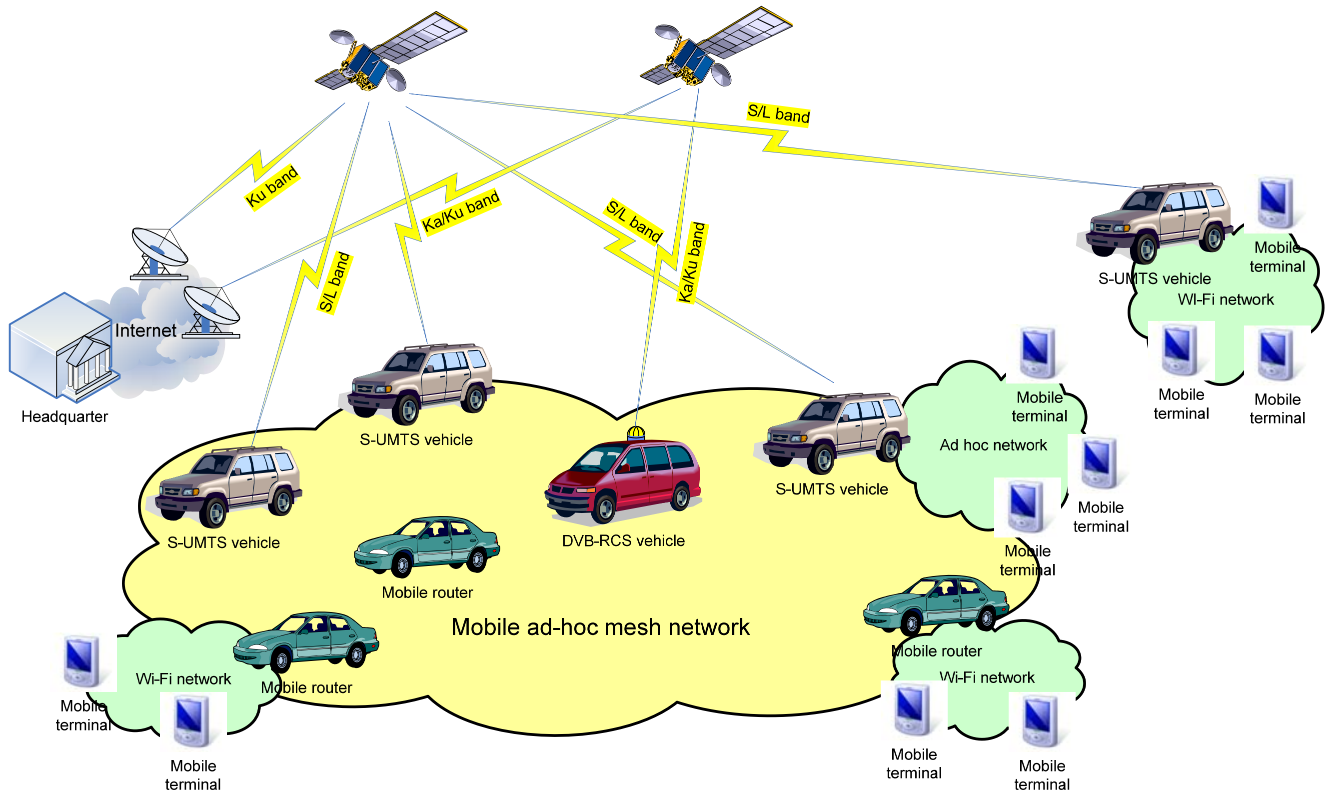

Figure 17: Hybrid satellite-terrestrial system architecture - Network deployment phase 2

4.2 Vehicle Communication Gateways

During the first critical days of a disaster, when no infrastructure is available, Vehicle Communications Gateways play the most important role. As shown in Figure 18, they are equipped with multiple network interfaces in order to use different available technologies while they are moving in the disaster site. Satellite antennas provide access to the backhaul where headquarter is located, while terrestrial wireless interfaces give ad hoc connectivity in the terrestrial domain. This combination allows creating a mesh architecture much more robust than a hub-spoken based architecture as it permits local communications when the satellite link fails and gives connectivity to the hub when a satellite terminal fails via an other ground terminal (multi-hop communication).

In particular, the mobile ad hoc mesh network, created by VCGs and mobile routers, allows deploying a broadband network on site in a very simple way. Each vehicle in the disaster area is a Mesh Point (MP), establishes peer links with MP neighbors and is fully participant to the mobile ad-hoc mesh network. According to the topology configuration of the network, a MP can assume the functionality of Mesh Access Point (MAP), providing access to the mesh network to mobile terminals. VCGs are also Mesh Portal Points (MPPs), as they represent MPs through which is possible to enter and exit the ad-hoc mesh network.

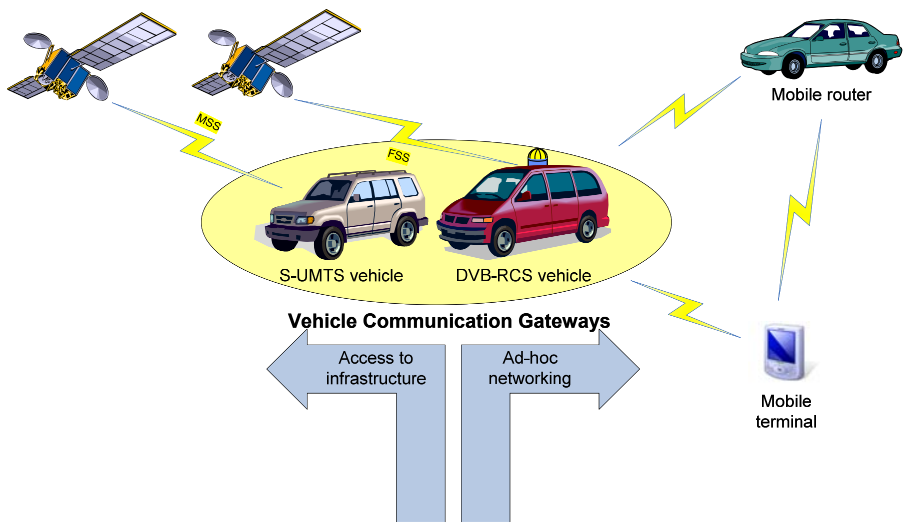

Figure 18: Vehicle Communication Gateways

4.2.1 S-UMTS VEHICLES

The use of narrowband, such as L or S band, has encountered such a success in emergency mobile communications that it cannot be ignored in a disaster system scenario definition as it permits mobility and low cost antennas and terminals. Narrow band allows developing mobile terminals which serve as interface between the satellite and any type of terrestrial network access point (e.g. UMTS, Wi-Fi, 2G).

Considering the limited bit rate that can be reached at those frequencies, the leading idea is to dynamically create a distributed gateway between S-UMTS vehicles that are in LOS for the external communications, so the effective bit rate can be higher depending on the number of vehicles used.

As regards the type of L or S band vehicular antenna installed on it, two candidate solutions are presented in this work: active antenna and omnidirectional antenna. Terminal mobility is around 50 Km/h. Technical specifications for the S-band link, described in Table 1, have been chosen as baseline to characterize S-UMTS vehicles.

Category	Parameters	Active antenna	Omnidirectional antenna
RF Section Characteristics	Frequency Band	2.1-2.2 GHz	
	Antenna Diameter	0.16 m	0.09 m
	Rx G/T	- 16 dB/K	- 21 dB/K
	Tx EIRP	18.5 dBW	10.5 dBW
	Total Bandwidth	Tx: 5 MHz Rx: 5 MHz	
Downlink	Proposed Air Interface	DVB-S2	
	Modulation and Coding	QPSK 1/2	
	Waveform	TDM	
	Max data rate	4Mbit/s	
Uplink	Proposed Air Interface	S-UMTS	
	Modulation and Coding	QPSK 1/3	
	Waveform	CDMA	
	Spreading factor	32	64
	Max data rate per user	80 Kbit/s	40 Kbit/s

Table 1: Specifications of S-UMTS vehicle

Based on the technical specifications outlined before, an analysis and assessment of system performance in S band has been carried out. The proposed S-UMTS specifications shall be considered as a study case to show capabilities and performance of the system design. The DVB-S2 standard [12] has been assumed as baseline for the Forward link, while the S-UMTS has been assumed for the Return link. A ground station antenna diameter of 8m, channelization of 5MHz and satellite effective EIRP/beam of 68 dBW have been taken into account.
Moreover, the following assumptions have been considered:

- C/(N+I) uplink in FL is at least 20 dB
- C/(N+I) downlink in RL is at least 20 dB
-

End-to-end link budget results for S-UMTS vehicle in S band are summarized in Table 2 and Table 3.

Category	Parameters	Active antenna	Omnidirectional antenna
Up-link result	C/(N+I)	20 dB	
Satellite Transmission Characteristics	Transmission frequency	2.2 GHz	
	Effective EIRP/beam	68 dBW	
Satellite to S-UMTS vehicle Propagation	Total attenuation	191.2 dB	
S-UMTS vehicle	G/T	- 16 dB/K	- 21 dB/K
Down-link results	C/N	22.5 dB	17.5 dB
	C/I	94 dB	
	C/(N+I)	22.5 dB	17.5 dB
Forward link results	Total C/(N+I)	18.5 dB	16 dB
TDM	Required C/N at physical layer at BER 10^5 in AWGN	1dB	
	Implementation Losses	0.5 dB	
LOS Margin at Physical Layer wrt AWGN		17 dB	14.5 dB

Table 2: Forward link in S band

Category	Parameters	Active antenna	Omnidirectional antenna
S-UMTS vehicle Transmission Characteristics	Transmission frequency	2.1 GHz	
	Effective EIRP/beam	18.5 dBW	10.5 dBW
S-UMTS vehicle to Satellite Propagation	Total attenuation	190.4 dB	
Satellite	G/T	12 dB/K	12 dB/K
Up-link results	C/N	3 dB	-5 dB
	C/I	12 dB	
	C/(N+I)	2.5 dB	-5.1 dB
Down-link result	C/(N+I)	20 dB	
Return link results	Total C/(N+I)	2.4 dB	-5.1 dB

CDMA	Required C/(N+I) at physical layer at BER 10^5 in AWGN	-12.1 dB	-15.1 dB
	Implementation Losses	0.5 dB	
LOS Margin at Physical Layer wrt AWGN		13.9 dB	9.4 dB

Table 3: Return link in S band

Preliminary results show that S-UMTS vehicles with active antenna can reach data rate up to 4 Mbit/s in the forward link, and up to 80 Kbit/s in the return link. Thanks to CDMA and Spread Aloha access method in the return link, the data rate can reach 800 Kbit/s if at least 10 vehicles are in LOS, transmitting simultaneously as a distributed gateway.

4.2.2 DVB-RCS VEHICLES

S or L band provides services as voice and data for emergency communications, but only broadband, as Ku or Ka band, can offer large capacity and high date rate necessary to exchange multimedia data such as medical data, digital map or intelligence data. This frequency band has several advantages. Transportable terminals can benefit of broadband communications, efficient bandwidth utilization and cheap capacity. The terminal mobility spans from fixed to a target speed of 10 Km/h. The available bandwidth is very large and not much occupied and it is possible to use small antennas for terminals as the Ultra-Small Aperture Terminal (USAT) in Figure 19 [14][15].

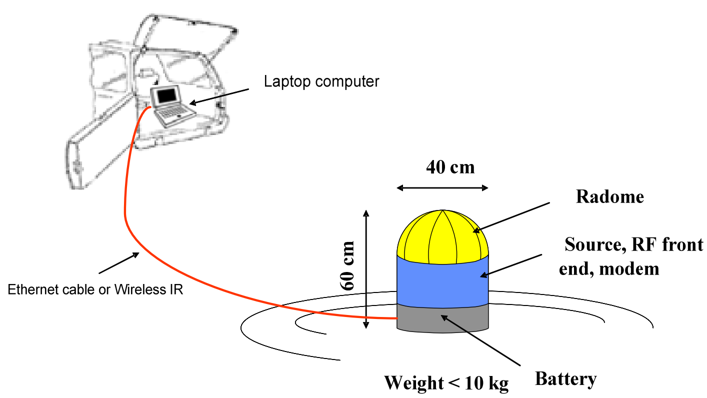

Figure 19: Nomadic Terminal in Ka band

Technical specifications for the Ka band link of DVB-RCS vehicle are provided in Table 4.

Category	Parameters	Rain conditions	Clear sky conditions
RF Section Characteristics	Frequency Band	20.2-30 GHz	
	Antenna Diameter	0.3 m	
	Rx G/T	8 dB/K	
	Tx EIRP	38 dBW	
	Total Bandwidth	Tx: 56 MHz Rx: 56 MHz	
Downlink	Proposed Air Interface	DVB-S2	
	Modulation and Coding	QPSK 1/4	QPSK 1/2
	Waveform	BH-TDM	
	Max data rate	8 Mbit/s	25 Mbit/s
Uplink	Proposed Air Interface	DVB-RCS	
	Modulation and Coding	QPSK 1/2	
	Waveform	MF-SDMA	
	Max data rate	128 Kbit/s	512 Kbit/s

Table 4: Specifications of DVB-RCS vehicle

Once again, the proposed DVB-RCS specifications shall be considered as a study case to show capabilities and performance of the system design. The Digital Video Broadcasting via satellite version 2 (DVB-S2) standard has been assumed as baseline for the Forward link, while the DVB-RCS standard [13] has been assumed for the Return link. The idea is to use, in the future, DVB-RCS mobile for the Return Link. Based on the same feeder link assumptions of S-UMTS vehicle, end-to-end link budget calculations have been done for the DVB-RCS vehicle in Ka band. Results are summarized in Table 5 and Table 6.

Category	Parameters	Rain conditions	Clear sky conditions
Up-link result	C/(N+I)	20 dB	
Satellite Transmission Characteristics	Transmission frequency	20.2 GHz	
	EIRP on overall bandwidth	58 dBW	
Satellite to DVB-RCS vehicle Propagation	Total attenuation	218.6 dB	213.6 dB

DVB-RCS vehicle	G/T	7 dB/K	8 dB/K
Down-link results	C/N	0.15 dB	5.8 dB
	C/I	23.8 dB	
	C/(N+I)	0.13 dB	5.8 dB
Forward link results	Total C/(N+I)	0.1 dB	5.7 dB
TDM	Required C/N at physical layer at BER 10^5 in AWGN	-2.35 dB	1dB
	Implementation Losses	0.5 dB	
LOS Margin at Physical Layer wrt AWGN		1.95 dB	4.2 dB

Table 5: Forward link in Ka band

Category	Parameters	Rain conditions	Clear sky conditions
DVB-RCS vehicle Transmission Characteristics	Transmission frequency	30 GHz	
	EIRP per carrier	38 dBW	
DVB-RCS vehicle to Satellite Propagation	Total attenuation	225.5 dB	214.5 dB
Satellite	G/T	19 dB/K	
Up-link results	C/N	9 dB	14 dB
	C/I	20 dB	
	C/(N+I)	8.6 dB	13 dB
Down-link result	C/(N+I)	20 dB	
Return link results	Total C/(N+I)	8.3 dB	12.2 dB
SDMA	Required C/(N+I) at physical layer at BER 10^5 in AWGN	5.7 dB	5.7 dB
	Implementation Losses	0.5 dB	
LOS Margin at Physical Layer wrt AWGN		2.1 dB	6 dB

Table 6: Return link in Ka band

As shown in Table 5 and Table 6, with a diameter of 30 cm and a satellite EIRP of 58 dBW, the presented DVB-RCS vehicle can receive, on the satellite downlink, data rates up to 25 Mbit/sec in temperate and desert zones and a data rate of 8 Mbit/sec in tropical zone. With a satellite G/T of 19dB/K thanks to the Space Division Multiple Access (SDMA), it can provide uplink with a data rate up to 512kbit/sec in temperate and desert zones and a data rate of 128 kbit/sec in tropical zone.

CONCLUSIONS

Disasters are often combined with the destruction of the local telecommunication infrastructure, causing severe problems to the rescue operations. In this cases the only possible way to guarantee communications services, is to use satellite to provide a backhaul connection to the decision center.
A new system architecture, which supports IPv6 and can integrate hybrid satellite and wireless terrestrial networks to provide mobile emergency communications, has been presented. The key objectives of the targeted heterogeneous infrastructure are the full mobility of rescue teams and the covering of bi-directional communication needs for voice and data in the first critical hours following an emergency. Two types of VCGs have been envisaged as mobile and transportable backhaul to headquarter via satellite, S-UMTS vehicles operating in S or L band and DVB-RCS vehicles operating in Ku or Ka band.

Results presented in this document show that a combined solution composed of S-UMTS vehicles and DVB-RCS vehicles permits to create a universal scenario suitable for all emergency mobile communications. S-UMTS vehicles allow higher mobility in the disaster site so they can be used to extend the coverage of DVB-RCS vehicles in more critical area and to exchange critical data with headquarter taking advantages of a more robust link. On the other side, DVB-RCS vehicles, working on-the-pause or at very low speed, offer high throughput, important aspect as it allows receiving and sending multimedia data to headquarter.
Future work will focus on the definition of the mobile ad hoc mesh network deployed in the crisis site.

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ACRONYMS

BGAN	Broadband Global Area Network
COTM	Communication On The Move
DVB-RCS	Digital Video Broadcasting with Return Channel via Satellite
DVB-S2	Digital Video Broadcasting via satellite version 2
EDECC	Easily Deployable Emergency Communications Center
ETSI	European Telecommunications Standard Institute
FSS	Fixed Satellite Service
HC	Health Center
HF	High Frequency
IT	Intervention Team
LA	Local Authority
MSS	Mobile Satellite Service
PMR	Professional Mobile Radio
RMC	Risk Management Center
SDMA	Space Division Multiple Access
TETRA	Trans European Trunked Radio
UHF	Ultra High Frequency
USAT	Ultra Small Aperture Terminal
VCG	Vehicle Communication Gateway
VHF	Very High Frequency
VSAT	Very Small Aperture Terminal