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Rapidly Deployable Satellite Communications for Emergency Situations: the WISECOM Trials

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Abstract: This paper presents a general overview of the WISECOM (Wireless Infrastructure over Satellite for Emergency Communications) system, focusing on the trials performed on a specifically developed demonstrator during a live simulation of a disaster event. The WISECOM system is intended to rapidly deploy a complete communications infrastructure in the early hours after a disaster occurs through the integration of several terrestrial networks, such as GSM, WiFi, WiMAX and TETRA, with satellite systems, such as Inmarsat BGAN and DVB-RCS. In order to test the fulfilment of the different capabilities that are required by the system, a demonstrator has been designed, implemented and finally used in a simulation scenario. The architecture of the developed demonstrator is described introducing two versions of the system intended to be used in the different phases after the disaster event. The work details the different capabilities tested on the WISECOM demonstrator, before and during the live simulation, taking into account the drawbacks of already existing solutions for communication in emergency scenarios and analysing the achieved improvements. The main aim of the system is to provide victims and members of rescue forces with voice and data services, such as transmission of images and Location Based Services, in order to improve the coordination of rescue operations and reduce the necessary time until victims receive a proper treatment.

Keywords: Emergency communications, satellite backhauling, GSM, TETRA, WiFi, WiMAX, Location Based Services, VoIP.

1. Introduction

Global disasters, either natural or man-made, represent a permanent threat to humanity that must be tackled by states and international organizations with urgency. Recent examples like the earthquakes in Turkey in 1999, the devastating tsunami in Indonesia in 2004 and the destruction brought by the Katrina hurricane in the United States in 2005 can give an image of the high losses caused by them, both in terms of lives and material damages. A common problem in this kind of situations, as stated in the European Space and Human Security working group report [1], is the partial or total destruction of the existing communication networks, which on the one hand, makes it impossible for the victims to contact any emergency service, and on the other hand, leads to a lack of coordination among the members of the different rescue forces deployed in the disaster area. In order to approach this problem, the WISECOM [2] (Wireless Infrastructure over Satellite for Emergency Communications) project, supported by the European Commission, presents a lightweight, easy-to-deploy system in order to provide the disaster area with communication infrastructures integrating several terrestrial mobile radio networks (GSM, WiFi, WiMAX and TETRA) with satellite communication systems. The integration of the different wireless technologies using a satellite backhaul offers a robust and reliable solution providing global and seamless coverage that benefits both the victims and the rescue teams.

The main objective of the WISECOM project is the design, development and test of a lightweight and easily deployable communication infrastructure for providing services in disaster areas after an emergency situation. In order to reach this aim, two different versions of the system have been developed in order to satisfy the communication needs of the different phases after a disaster situation. The first version of the system integrates GSM and WiFi networks using Inmarsat BGAN satellite system and is intended to be deployed in the early disaster phase after the event occurs in order to cover the basic services that victims and rescue teams' members need, such as voice communication, Internet access and Location Based Services (LBS). The second version of the system, which integrates GSM, WiFi/WiMAX and TETRA over DVB-RCS, is intended to be deployed in a later phase after the disaster event in order to provide services that require a higher bandwidth, such as transferring pictures of the affected area and establishing video conferences. In order to test and validate the developed system, a live simulation of a disaster event was performed in Oberpfaffenhofen, Germany, in May 2008, with the participation of local fire brigades and rescue forces. This paper provides a description of the already mentioned demonstrator together with an account of the different capabilities provided by the system and tested both in a laboratory environment and during the live trials.

The document is structured as follows. The next section describes the main objectives of the system in comparison with the currently existing solutions, together with the considered business case. The following section presents a detailed description of the demonstrator architecture for the different configurations of the system. Thereafter, the different tested capabilities as well as their results are stated. Finally, the conclusions extracted from the tests and the live simulation are presented, leading to the identification of the different gaps to be filled and the improvements to be performed in order to achieve the intended objectives.

2. WISECOM Objectives and Business Approach

The final objective of the WISECOM project is to reduce the time until patients receive the final treatment and minimize the risk undergone by the involved rescue forces. Unlike currently used systems, mainly satellite telephones and Public Mobile Radios (PMR) to be used in the first hours after a disaster event and more bulky technologies [3, 4] to be deployed in a later phase, WISECOM presents a extremely small, lightweight, flexible and rapidly deployable system which allows the transmission of voice and data already within the early disaster relief phase, as can be observed in Figure 1. The utilization of the different communication means together with LBS, leads to an improved coordination of the rescue teams and a reduction of the necessary time for localizing and treating victims.

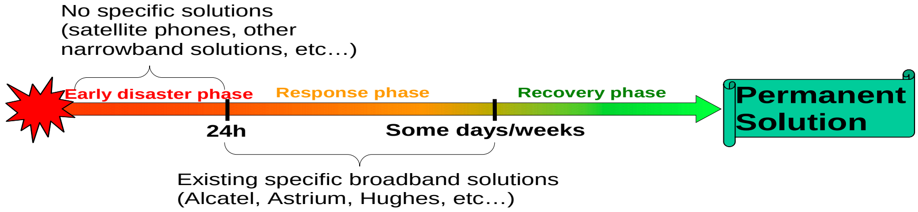

Figure 1: Disaster Situation Timeline

According to the final objective of the system, several requirements must be fulfilled taking into account that, on the one hand, the system has to allow victims to communicate with the rescue services, and on the other hand, it has to provide the rescue forces with a reliable information and communication platform in order to perform an efficient management of the rescue teams. Regarding communication with the victims, a WiFi network will be available for any user able to connect through a PDA or laptop. When trying to use this network, users are redirected to a web site where a limited amount of services are provided, such as information regarding the disaster situation, a map of the area with the relief camps that victims can find and an interface to communicate via text message with the rescue teams. Regarding the use of the system by the rescue forces, it must allow voice communication, either GSM or VoIP, and also data transmission, such as maps displaying dangerous areas, video and images to be used by telemedicine applications, text messages, and victims' data obtained by using LBS. In addition to these requirements, the system must be rapid and easy to deploy, even by non-experienced operators, and support multi-user access with heterogeneous devices, such as GSM terminals, WiFi PDAs, WiFi laptops and TETRA handhelds.

Regarding the business approach, it must be remarked that final end users are the operational first responders deployed on the field. Therefore, the potential buyers of the system would be mainly public entities in charge of public safety, both national and international, such as the United Nations, the Red Cross Organization, fire brigades and Civil Protection Authorities. Regarding costs, although the performance of a cost/benefit analysis of a life-saving solution turns out to be difficult, it can be stated that the associated OPEX should be unimportant and hence, affordable, due to the non-permanent use of the system, while an efficient policy of use of the satellite capacity should be devised. Due to the complexity of emergency relief scenarios, involving different players such as end users, network and satellite operators and service providers, several business cases must be taken into account in order to bring a product to market, involving hardware purchase, infrastructure, service delivery, support and training. Nevertheless, this business approach is likely to be a long process that must be carried out after further proof of concept in order to fully adapt the solution to the standard emergency procedures performed by rescue forces.

3. Technology Description: the WISECOM Demonstrator

As can be observed in Figure 2, the high-level architecture of the WISECOM system presents three different domains: the On-Disaster Site Segment, the Disaster-Safe Segment and the Transport Domain.

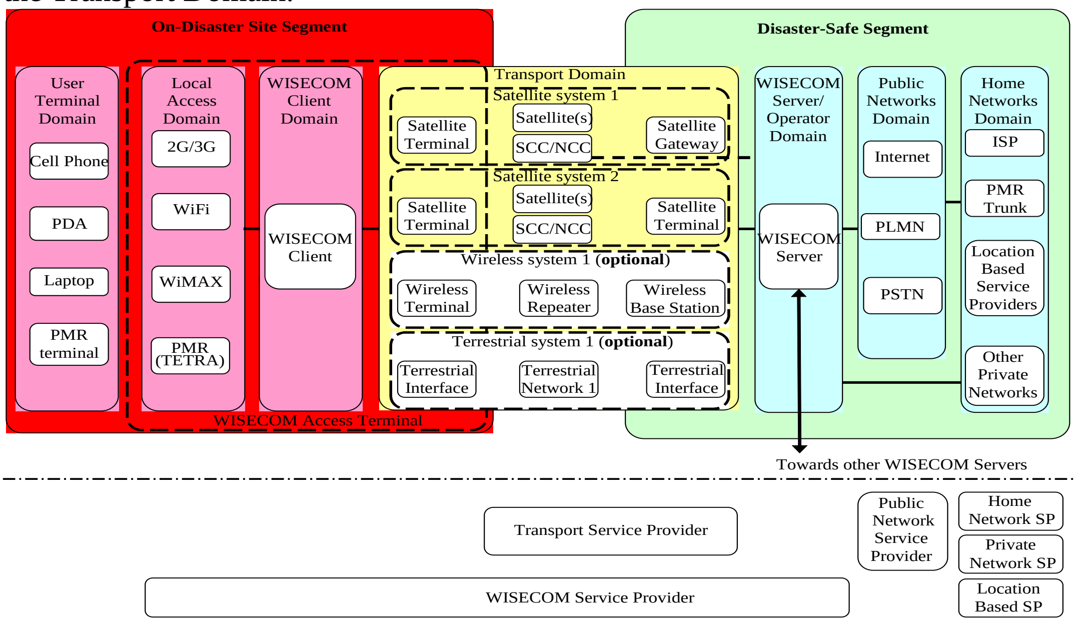

Figure 2: High-Level WISECOM Functional Architecture

Taking into account the presented architecture, two different versions of the system have been defined and deployed in order to satisfy the requirements of the different phases after the disaster occurs. The main differences between both configurations lie in the satellite backhaul that is used, and the wireless terrestrial networks that are integrated. In the first configuration, Inmarsat BGAN provides the satellite link in order to offer GSM and WiFi connectivity while in the second case, GSM, WiFi/WiMAX and TETRA networks are integrated using DVB-RCS as satellite backhauling.

In order to perform both configurations of the system, the WISECOM Access Terminal (WAT) acts as a gateway between the different networks, in order to provide smooth integration, providing also additional features such as security and traffic management. The modularity of the WAT allows it to be easily configured according to the wireless networks that must be integrated, and to upgrade it with new-coming technologies. Taking the WAT as a central integration element, the different architectures of the On-Disaster Segment for both versions of the system can be observed in Figure 3 and Figure 4.

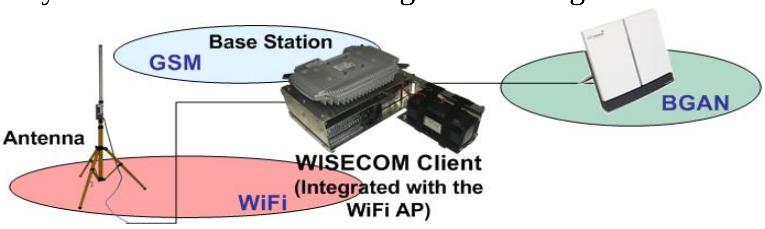

Figure 3: GSM and WiFi over BGAN architecture

Figure 4: GSM and WiFi/WiMAX over DVB-RCS architecture

It is also necessary to remark that the practical integration of the TETRA network over the satellite link was not performed during the final demonstration, but at a laboratory level, and for this reason, TETRA architecture is not included in the demonstrator diagrams.

4. Trials Results

The present section describes the tests performed either at a laboratory level or during the live simulation, together with their results. They are presented taking into account, for each system configuration, the easiness in the deployment and the services provided by the different integrated networks. Finally, a section describing the global performance of the integrated capabilities of the system during the live simulation is presented, focusing on the added value provided by the use of Location Based Services.

4.1 BGAN Configuration

- Deployment: The necessary equipment is intended to be transported using a ruggedized box with the exception of two WiFi antennas that must be transported apart. Due to the reduced size and weight of the components (see Table 1), it can be easily transported by a single person in a robust and secure way, protecting the equipment against any environmental adversity. The installation and starting procedure can be quickly carried out in a simple and easy way by non-technicians, as demonstrated during the trials.

Table 1: Characteristics of the BGAN configuration

Power consumption	-Li-Ion batteries: 25.9 V (4 hours) -External AC power supply: 24 V
Weight of the ruggedized box	Approx. 6.5 kg
Size (height, width, depth) of the ruggedized box	24 x 49 x 38 cm
Time for installation and deployment	5 minutes (including initialization)

- GSM over BGAN: The main services provided by this hybrid configuration are the establishment of voice calls, and the reception and transmission of SMS. Regarding voice calls, they could be successfully established between members of the rescue teams in the local access domain and also from the local access domain into the PSTN/ISDN and PLMNs. Regarding the transmission and reception of SMS, the possibility to send SMS from a user terminal in the local domain to any other number was confirmed, specifically to another terminal located in the local access domain and to a terminal located in the ground network (control centre). The possibility of receiving SMS from terminals located in the already mentioned domains was successfully tested.
- WiFi over BGAN: The tests performed over this configuration were mainly addressed to check the availability and quality of the different provided services, such as HTTP and FTP connections and to estimate the coverage area provided by the WiFi antennas.

  Regarding the provided services, it was confirmed that it was possible to establish HTTP and FTP connections, as well as VoIP communications. Regarding voice calls, several communications involving up to 3 participants were held, testing the case with 2 participants in the local domain and one in the remote and vice versa. Calls from the local domain to the PSTN network were in the same way successfully tested. The proper operation of LBS services was also tested together with the possibility of using several services, such as VoIP, HTTP and FTP, simultaneously.

  With reference to the WiFi coverage provided by the system, it was noticed that, even when the simulation area was provided with enough coverage by the WiFi antennas, the different user terminals, such as laptops or PDAs, lost the connection in case of losing the line of sight with the antenna. According to this, any obstacle in the way between the terminal and the antennas, such as the person holding the terminal, could lead to a loose of connection. Moreover, reflections of the signal on the different urban elements can have an effect on the signal strength. For these reasons, the use of several repeaters in order to assure coverage in the different areas is suggested together with the use of alternative wireless technologies, like for example, WiMAX.

4.2 DVB-RCS Configuration

- Deployment: The necessary equipment to be used in the DVB-RCS configuration, consisting of a power generator, a DVB-RCS antenna, a WiMAX subscriber station and a rack containing the GSM and WiMAX equipment, is intended to be transported with the use of a vehicle, such as a 4-wheel drive or a helicopter. The characteristics of the system are summarized in Table 2.

  In order to provide the equipment with the necessary robustness to be transported in the vehicle in a safe way, the different parts are fixed to the plates of the rack to avoid any movement during the transportation. It was also tested that it could be easily loaded and unloaded from the vehicle with the help of two people, who should be taught about the way of pointing the antenna.

Table 2: Characteristics of the DVB-RCS configuration

Power consumption	1 kW supplied by a power generator with an autonomy of 2.5 hours
Size (height, width, depth) of the rack	78 x 51 x 45 cm
Weight of the rack	40 kg
Size (height, width) of the WiMAX subscriber station	51 x 45 cm
Diameter of the antenna	1.2 m
Weight of the antenna	35 kg
Time for installation and deployment	13 minutes

- GSM over DVB-RCS: The main features to be tested on this hybrid configuration are the establishment of voice calls and the transmission and reception of SMS. Furthermore, the use of GPRS is also tested.

  Regarding voice calls, communications between user terminals located in the local access domain were successfully performed, as well as communications between a user located in the local access domain and a user connected to the ground network. In addition to this, the performance of several calls simultaneously was tested, being able to perform up to 7 simultaneous calls.

  Regarding the transmission and reception of SMS, it was possible to send and receive SMS from user terminals in the local access domain, and also from terminals connected to the ground network, including the control centres.

  Finally, the use of simple GPRS applications, such as web browsing, was successfully tested.
- WiFi/WiMAX over DVB-RCS: The tests performed over this configuration were addressed to check the availability of the different provided services, such as HTTP and FTP connections and the performance of voice and video calls.

  Regarding the provided services, it was confirmed that it was possible to establish HTTP and FTP connections, as well as VoIP communications and video conferences. In order to test voice and video communications, a voice/video conference was successfully established among 4 different participants during the live demonstration in order to simulate a real rescue operation. One participant was located on the disaster area, connected to the WiMAX subscriber station, the second one was connected to the WAT using a WiFi access point, the third one was located in a remote control centre, and the fourth one was connected in a remote location using a normal Internet connection.
- TETRA over DVB-RCS: Although the trials of the TETRA configuration were not performed during the live demonstration, different tests have been carried out in a laboratory environment in order to check the availability of voice communication services and also the transmission and reception of SMS.

  Regarding voice communications, the possibility of performing a call between two handhelds located in the local TETRA network was successfully tested, as well as the possibility of establishing a communication between a TETRA handheld and any other phone connected to public phone networks (PSTN and PLMN) and also to a cell phone. In addition, the transmission and reception of SMS was successfully tested between two TETRA handhelds in the local area network.

4.3 Integrated Telecommunication and LBS Services

This section aims to present a global view of the capabilities provided by the system in the context of a live simulation of a disaster event, focusing on the use of LBS.

According to the trials results, LBS could be properly run using both system configurations. In the case of the live demonstration, the rescue forces were provided with the BGAN version in order to realistically simulate the early disaster phase. The demonstration emulated an explosion at a construction area with a diameter of more than 400 m, where 20 simulated victims, presenting injuries with different levels of severity, were randomly placed. A panoramic view of the disaster area can be observed in Figure 5. Rescue forces members were divided into different groups according to their usual mode of operation and each group was provided with a PDA able to connect to the WAT and access the different WISECOM services, including LBS.

Figure 5: Overview of the Disaster Area

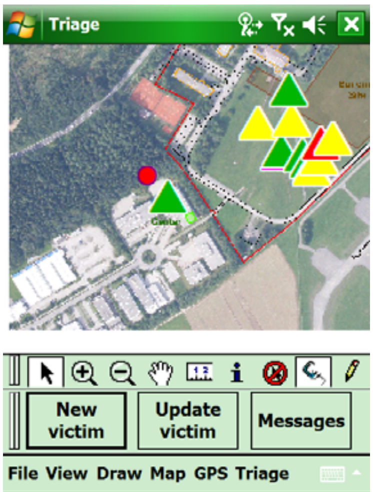

Figure 6: PDA with LBS Data

Thereafter, the rescue operation was started according to the following guidelines:

- When a victim is found, a message containing the GPS location and status of the victim is sent to the control centre.
- PDAs of all rescue members are periodically updated with the location of the already found victims and their status, which is shown on a map on the PDA (see Figure 6).
- Personnel in the control centre use the gathered information and communicate with the rescue teams on the field, via VoIP or the text message functionality included in the LBS software, in order to coordinate the process of evacuating victims according to the severity of their injuries.
- When a victim is picked up, the location and status is updated in the server again.
- When the victim is placed in a relief area or hospital, the status is updated by the rescue teams and the position of the victim disappears from the maps on the PDAs and the control centre.

This mode of operation, using the different communication features and LBS provided by the WISECOM system, allows an improved coordination of the rescue teams, providing all the time a complete overview of the disaster situation and therefore, reducing the time needed to evacuate and treat the victims.

In order to provide an image of the effectiveness of the system, Figure 7 shows the evolution of the triage process during the live simulation, taking into account the amount of victims that have been localized by the rescue teams and are waiting to be transported to a relief area or hospital and classifying them according to the severity of their injuries. The initial time considered in the graph is the moment when the system is deployed. According to it, within the first half of the simulation, the rescue forces had already localized most of the victims, communicating their position and severity of their injuries to the control centre. Simultaneously, the control centre gathers all the information, which is displayed on every PDA, and coordinates the different teams in order to transport the victims to the relief areas or hospitals in an efficient way, giving priority to victims with more critical injuries and taking into account the location of the victims and the rescue forces.

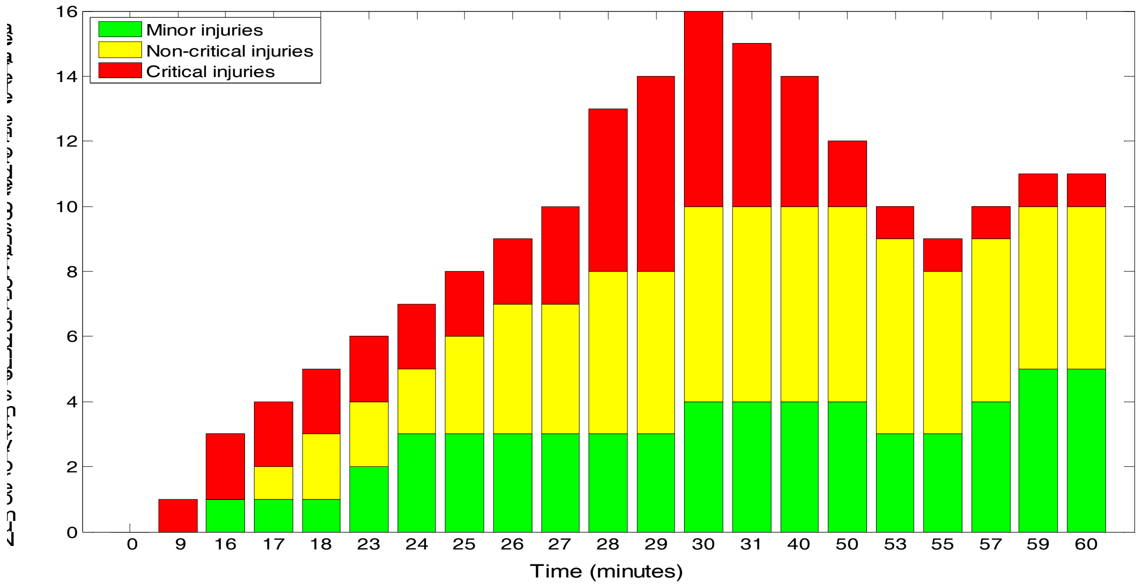

Figure 7: Evolution of the triage process during the live simulation

5. Conclusions

Disaster events frequently cause the destruction of the local communication infrastructures. This situation affects both the victims and rescue forces, who suffer from a lack of coordination due to the late deployment of communication systems or the use of different terrestrial networks among the different rescue teams. In this case, satellite backhauling becomes a robust and reliable communication solution.

This paper has presented the WISECOM [2] system, which is intended to provide a complete communication infrastructure integrating several terrestrial mobile radio networks, such as GSM, WiFi, WiMAX and TETRA using Inmarsat BGAN and DVB-RCS as satellite backhauling. The paper presents the structure of the demonstrator developed for testing the system and focuses on the capabilities tested during the several trials, including a live simulation of a disaster event.

As extracted from the results of the trials, the WISECOM system is able to provide victims and rescue forces with a series of services, such as voice communication, HTTP, FTP, transmission of images and LBS, which result in an improvement of the time needed to offer treatment to the victims and a reduction of the risks taken by the rescue forces. Due to the advantages that these systems can provide in situations of global disasters, integration with evolving wireless technologies should be taken into account as a further step, together with the harmonization of the provided services with the standard procedures of rescue forces in order to enhance the system performance.

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