Emergency Communications over Satellite: the WISECOM Approach

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Abstract — **This paper presents the overall architecture of the WISECOM system, which can quickly re-establish and provide telecommunication services after a disaster. The architecture is explained and it is described together with a role model, which adapts to the system. The work tries to map the existing complex interactions taking place nowadays in an emergency situation to a sensible architecture, which can accommodate all needed actors and roles, and which can exploit, at the same time, the newest wireless technologies.**

Index Terms — **Emergency Communications, satellite, GSM, UMTS, WLAN.**

I. Introduction

DISASTERS are often combined with the destruction of the local telecommunication infrastructure, causing severe problems to the rescue operations. Disasters may also happen where such infrastructures did not exist beforehand. In an emergency situation first line telecommunication services are of paramount importance. Telecommunications offer a way for victims of a disaster to connect to others, and for rescue workers to co-ordinate their efforts.

In these cases the only possible way to guarantee communication services is to use satellites to provide a backhaul connection to the intact network infrastructure. Such a system could be set up anywhere in the world where there is satellite coverage.

In fact the existing solution today to overcome the communication problems is to use satellite phones in the first hours after the disaster. With the help of more complex and bulky technologies [1,2] it is also possible to rebuild and deploy a wireless telecommunication infrastructure to transmit both voice and data over the satellite, e.g. providing connection for standard GSM/UMTS, WLAN, WiMAX, TETRA, etc. to the public networks. So in addition to supporting search and rescue operations, these solutions restore local 3G/4G infrastructures allowing normal mobile phones and terminals (e.g. laptops) to be used by the victims of the disaster. Anyway the latter solutions require many hours to several days to be brought to the place of the disaster.

The WISECOM project [3] aims at developing a complete telecommunication solution that can be rapidly deployed immediately after the disaster, within the first 24 hours, replacing the traditional use of satellite phones or heavy and cumbersome devices. WISECOM restores local GSM or 3G infrastructures, allowing normal mobile phones to be used, and enables wireless standard data access (e.g. WiFi or WiMAX). The system uses lightweight and rapidly deployable technologies, which can be carried by one person on board a flight and be deployed within minutes. WISECOM also incorporates location-based services for the purposes of location of victims and rescue teams, logistic and disaster management support and targeted disaster messages sending.

This solution for the very first hours and days after an emergency should be easily upgradeable: during the response phase, the capacity and coverage of the WISECOM system could be improved and telecommunication services provided at lower costs, whereas the WISECOM system could be used to re-establish a permanent wireless telecommunication infrastructure in the recovery phase.

The aim of this work is also to put the basis for a standardized system architecture, which could enable a proper interworking of the many and heterogeneous actors, and of the different equipments operating in the area of emergency communications.

The document is structured as follows. In the next section we describe the disaster scenario; we then present the system architecture, and in section IV we show how this can be mapped to a sensible role model. We drive the conclusions of the work in section V.

II. Disaster Scenarios

A. Post-Disaster Phases

Short, medium and long terms can be defined to reflect consecutive and different phases of a disaster. As a first assumption, short, medium and long terms can be thought to last typically in the order of one day, one week and one month respectively.

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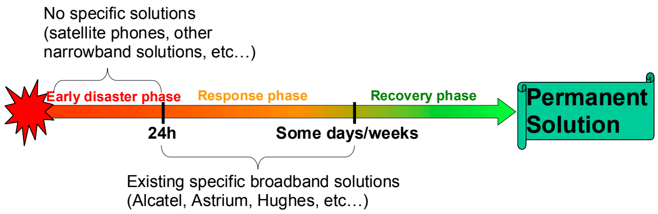

Fig. 1. Telecommunication solutions and their relation to a disaster timeline (Early disaster, response and recovery Phases).

The short term corresponds to a phase right after the disaster, during which rescue teams are not yet well organized, post-disaster area has not been secured, and a high amount of casualties should be quickly rescued.

The medium term was defined as a phase during which rescue teams are better organized, rescue materials are brought on the post-disaster phase and post-disaster area has been cleaned up. In this phase, casualties have all been transferred in field hospitals were they can be nursed.

Finally, the long term was defined as a phase during which all the casualties have likely been transferred to a hospital, and during which infrastructures are re-built.

However the time duration of a post-disaster phase is not strictly linked to time (one day, one week, one month), but rather to the evolution of the rescue operation, which may last differently depending on the type and size of the disaster. For this reason in order to adopt a terminology suiting better to emergency situations, the early disaster phase, the response phase and the recovery phase will be used in this document in place of the short, medium and long terms respectively (see Fig. 1). This new adopted terminology for the disaster phases is more sensible than the previous one, not only considering the pure time scale but really the state of the emergency site, the time scale varying significantly from disaster to disaster.

B. *Classification of Disaster Scenarios*

Disasters can be classified into 3 categories with respect to the geographical expanse of the disaster and the amount of damage done: small, medium and large disasters. In addition, several consecutive post-disaster phases can be distinguished, characterized by different emergency levels and the clearing, relief and rescue work already performed on-site. In the immediate or early disaster phase, it is likely that cars and trucks cannot move and that rescue teams are exposed to a dangerous environment with fire, smoke, water, and risk of resulting consecutive disasters. This amounts altogether in the definition of 9 disaster categories, from large disaster with large amount of casualties and dangerous environment to small disasters in their recovery phase. These categories are summarized in Table I.

According to the selected disaster scenario, the envisaged emergency telecommunication system undergoes different constraints. Therefore, the requirements expressed in this document are applicable to the different selected disaster categories and phases at different levels.

For instance in case of the recovery phase in a small disaster, heavy telecommunication equipment can be carried on-site with cars and trucks, and the stress situation of the rescue team using the device has fallen away, whereas in case of the early phase of a large disaster, only light, portable equipments able to resist severe environmental conditions (e.g. shocks, heat and humidity) should be used by highly stressed rescue teams.

TABLE I
CLASSIFICATION OF DISASTER SCENARIOS
ACCORDING TO THE TYPE AND PHASE OF THE DISASTER

Disaster Size / Disaster Phase	Small Disaster	Medium Disaster	Large Disaster
Early Disaster Phase	SD1	MD1	LD1
Response Phase	SD2	MD2	LD2
Recovery Phase	SD3	MD3	LD3

The WISECOM system and the solution proposed in this paper focus on emergency situations where the telecommunication infrastructure is destroyed and the recovery of telecommunication services is not trivial. For this reason, scenarios SD2, SD3 and MD3 (bottom left scenarios in Table I) are not really targeted in this work.

C. *System Requirements for Emergency Communications*

From a general point of view, in case of emergency or disaster situations, portable wireless telecommunication equipments should be carried on-site and should be rapidly deployed by the rescue team. The target emergency telecommunication device (WISECOM Access Terminal) is not used in normal conditions (everyday life) and should be accordingly designed.

The WISECOM Access Terminal (WAT) should be as light and small as possible so that it can be easily carried by a single person. This device should be resistant to shock, water, humidity, dust, heating and chemicals. It should have its own independent and redundant set of power supplies, and should be user friendly and easy to use by stressed staffs with different origins, languages, knowledge and background and who do not have time to get a deep insight of the system. Additionally, the WAT should enable the use of standard telecommunication devices and should be integrated into future restored telecommunication systems. Finally, the costs resulting from the production of the WAT and from the supported telecommunication services should be as reduced as possible.

Of course, the WISECOM system should enable the use in emergency situations of a wide set of telecommunication applications, ranging from classical voice services to the transfer of data and the location-based broadcasting of information to on-site spread rescue teams or to the population. This last service could be especially useful to warn people about dangers (poisoned water, further risks of collapse in case of earthquake, etc…) related to emergency situations.

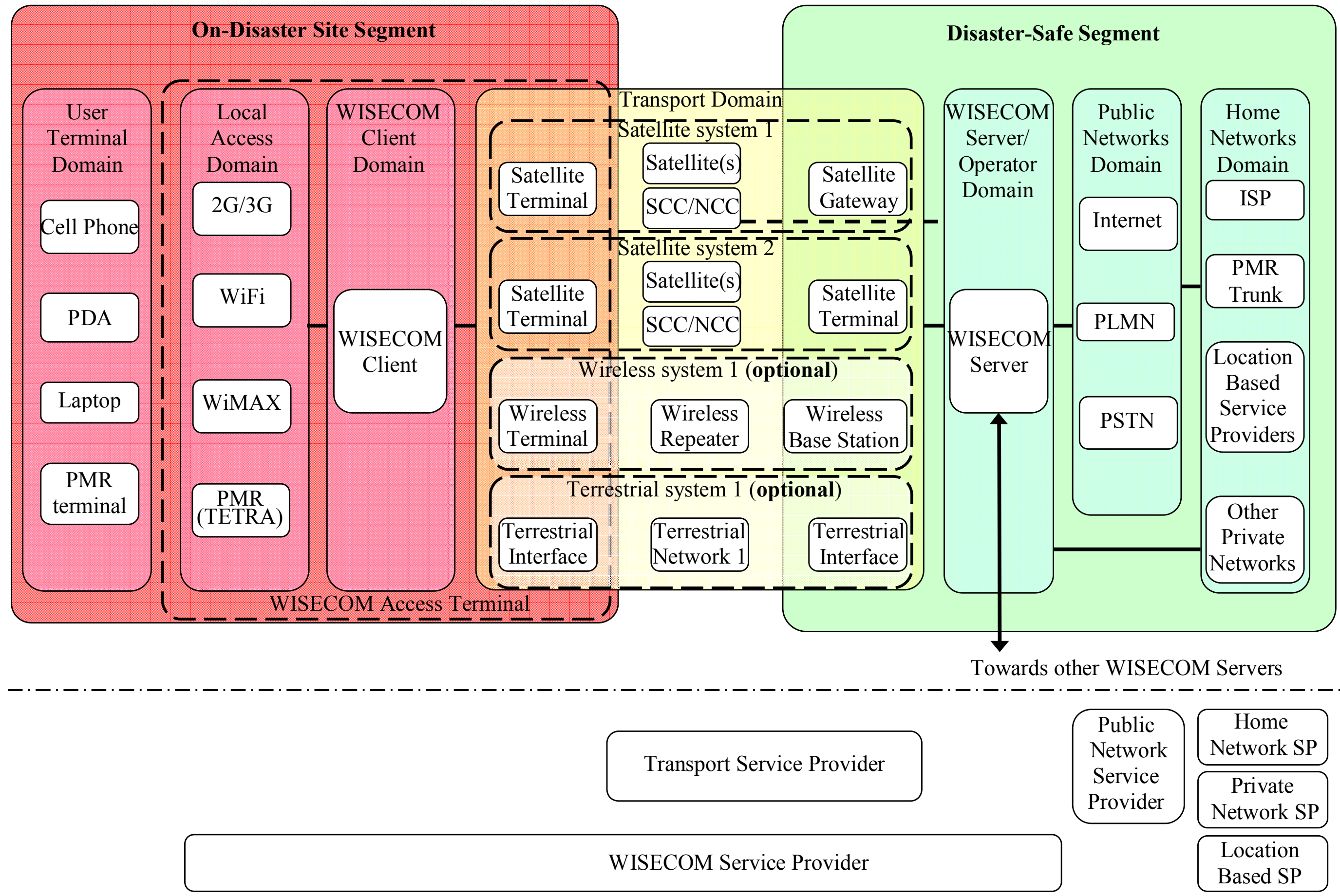

Fig. 2. WISECOM Functional Architecture.

III. Reference Architecture

The WISECOM system represents the technical answer to telecommunication needs of people involved in a post-disaster emergency situation. The reference architecture of this WISECOM system, illustrated in Fig. 2, is based on a modular approach where several access and transport solutions can be supported without a need to have more than at least one of each. A WISECOM Client, able to interwork between the various access and transport solutions, as well as providing additional functionality, binds the two domains together in the WAT.

The WISECOM system is also upgradeable in order to meet the different user and services requirements of the post-disaster scenarios, and to benefit from the next development. As a consequence, the WISECOM system is not unique and may benefit in its first step of realisation from a number of current off-the-self technical systems and ad-hoc solutions using both terrestrial- and satellite-based telecommunication technologies. The variety of needs coming from the various defined disaster phases may be addressed thanks to very different combinations of telecommunication solutions.

Despite the multitude of technical solutions that could be used to realise the WISECOM system, several distinct logical blocs can be distinguished. It is the aim of this section to define these logical blocs, so that a common high-level WISECOM reference architecture and terminology can be adopted.

The WISECOM system enables the communication between the disaster end-users (victims, rescue teams or any other kind of involved people) located inside or outside the disaster area using different kinds of communication devices; the transmission occurs across a number of network elements, which compose the WISECOM communication chain.

The segments represent sections of the WISECOM communication chain involving network elements physically located in the same geographical area with respect to the disaster. All network elements in the same segment undergo very similar usage constraints.

The network elements involved in the WISECOM communication chain and playing logically neighbouring functionalities in this chain (e.g. a wireless LAN access point or an UMTS Node B) or jointly enabling the provision of a given functionality (e.g. local access) belong to the same domain.

The white boxes in each different domain represent possible groups of network elements with complementary or close characteristics, or supporting the same type of technology. Inside a network element group there might be several network elements involved in the communication. The physical implementation of the domain in the WISECOM system may include at the same time technologies belonging to one or several network element groups, but the communication chain will always flow across one of group of network entities per domain at a time.

Functional architectures describing the organisation of the different network elements in different groups of network elements, domains, and segments are provided for the early disaster, response and recovery phases in Fig. 2.

Two main segments are defined in WISECOM:

- the On-Disaster Site Segment,
- the Disaster-Safe Segment.

The former consists of the User-terminal Domain, the Local Access Domain, the WISECOM Client Domain and the group of network elements responsible for the access to the transport domain from the disaster area (satellite terminals, wireless terminals, etc…).

The latter comprises the group of network elements responsible for the access and control of the transport domain, the WISECOM Server / Operator Domain, the Public Networks Domain and the Home Networks Domain.

The interface between the two segments is provided by the Transport Domain. Nevertheless, part of the network elements of the Transport Domain is located in the On-Disaster Site Segment whereas another part is located in the Disaster-Safe Segment.

In Fig. 2, the full lines between the WISECOM Server / Operator Domain and the Home Networks Domain are used to represent a possible direct connection between a WISECOM server and some special networks or services dedicated to emergency situations. Of course, this connection can also be achieved via public networks.

In this figure, it is assumed that Location-based Services are logically provided in the Home Network Domain. Actually, Location-based Services are supported thanks to the LBS local and global servers, co-located in the WISECOM client and Server / Operator domains respectively.

The different providers shown in this figure are only presented as an illustrative example. For more information about the different operators and service providers involved in the provision of services for the WISECOM systems, the relationship and the network entities they are responsible for please refer to the next section.

IV. WISECOM Role Model

The definition of roles in the WISECOM communication system has to closely follow the typical organisational structures in handling of global, regional or national disasters, whereby current practice but also ongoing efforts and future plans for an improved (re)organisation of disaster relief operations must be taken into account. It is still to be studied and evaluated in the framework of this project, in how far the role model and system architecture of the WISECOM communication system can in turn have an active influence on these future organisational structures.

The role models and the interfacing also go hand in hand with the WISECOM architectural and functional description as displayed in Fig. 2.

The following roles can be identified:

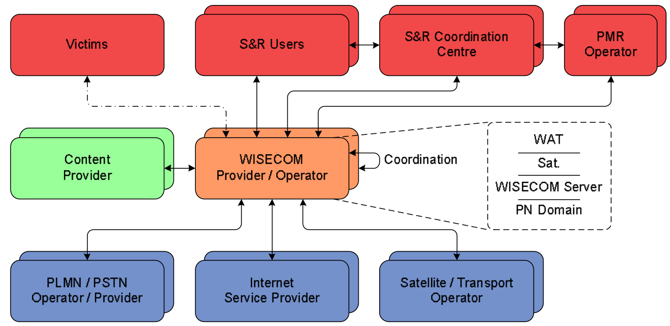

Fig. 3. Schematic Representation of the Role Model and of the Relationship between the Different Players involved in the WISECOM System.

- *WISECOM operator or service provider*, being the central role in the considered system and interfacing to all of the following roles, as illustrated in Fig. 3; usually, each WISECOM operator owns one WISECOM server to which one or several WISECOM clients (or WISECOM Access Terminals, WAT) are connected; the WISECOM operator acts as a kind of "concentrator" for a complete and tailored service provisioning – in terms of communications services, content, and infrastructure – to the system users, and is their main/single direct interface;
- *victims*, which come in as passive or active end users from a communications system viewpoint via their standard equipment (mainly mobile phones), which may be used both in active and passive modes (active calling or sending SMS or being located within a certain cell);
- *search and rescue (S&R) users*, including both early phase (immediate search & rescue) and response phase (rescue, transport and medical treatment etc.) forces; here the main relation is provisioning of services (comms, LBS, and content) via WISECOM Access Terminals available to the rescue organisations;
- *S&R coordination centres*, which mainly coordinate and command the field rescue forces throughout all disaster phases;
- *PMR operators*, like national/regional TETRA operators, which have an established operator/provider relationship with the users and obviously must be interfaced also in the more general WISECOM role model and architecture;
- *content providers*, like GIS/map data providers; in general, the WISECOM service provider should be the central entity responsible for the integrity of all content provided to end-users; for instance the WISECOM service provider would buy and regularly update static reliable GIS map information from various respective content providers and take care of central provisioning to all end-users; for dynamic real-time data, on the other hand, he would preferably secure via agreements reliable and permanent on-line access to content hosted by those providers, for the sake of efficiency and timeliness;
- *satellite transport service operator/provider*, which provides the key backhauling link from the disaster areas to the disaster-safe segment; here the relation between the WISECOM operator and the satellite operator should be

preferably simple and direct, i.e., the WISECOM service provider would ideally be or become a service provider of the satellite backhauling capacity at the same time; in the case of one global satellite system like Inmarsat, one could think of one truly global WISECOM provider which could be a key advantage in support of streamlining global coordination of disaster management;

- *Internet Service Provider*, providing access to the Internet;
- *PLMN/PSTN operator/provider*, providing voice/data communication and connection to the fixed and mobile legacy networks, mobile positioning and messaging;
- for the local access domain, a *mobile network operator (MNO)* – potentially the same as the previously mentioned PLMN operator/provider – may come in as a specific player if the WISECOM operator/provider does not act at the same time as a (virtual) MNO itself; here the main relation would be a tailored contract for provisioning of vendor-specific SIM cards, specific roaming agreements and use of its licensed frequencies; note that in such a case one unique provider per considered WISECOM service area would be preferable, to keep the number of involved partners low and thus the complexity of contractual, technical, and service level frameworks.

Finally, a general and long-term (maybe only indirect or implicit) relation exists between WISECOM operators /providers and regulatory and licensing bodies; the related issues are the whole licensing process for dedicated reserved emergency frequency bands (both terrestrial wireless and satellite) or potential pre-emption usage of general frequencies only in emergency situations etc; this role and relationship has its own complexity and is thus not addressed in this paper.

The schematic representation of the role model and of the relationship between the different operators involved in the WISECOM system is presented in Fig. 3.

When one looks at the various levels of size (geographical extent) of disasters (local, national, regional, large-area [4]) and of the organisational structures in performing disaster relief operations (local, single or multi-rescue-organisations, national extent, international extent), apparently the WISECOM communication system should be generic in a sense that it could be used in all cases.

A multi-national or global approach can only be met by properly adapted structures in cooperation and command, and some level of hierarchy can be expected, but in any cases a distributed-cooperative approach will be required. Consequently a respective WISECOM system would certainly mirror such structures to some degree. However, looking at the current reality, global harmonization and setting up such structures seem to have just started with still quite visionary goals. In many cases, national structures dominate the scenario, and also many of the smaller to medium disasters are typically of regional or national extent.

For further studies in the framework of this project it is therefore certainly a pragmatic approach to assume typically national command/coordination centres that would typically have a national WISECOM operator/service provider as counterpart. In addition, to ensure a harmonized development of a WISECOM infrastructure over both national borders and over time, also some technical coordination between such national operators/providers will be required. To have the multi-national component reflected in a simplified way in the WISECOM communication system studies, one could imagine one regional (e.g. European) WISECOM "master centre"/operator/provider which serves all the national command centres and rescue organisations, potentially with slightly tailored content and communications services, rather than setting up a complicated distributed or hierarchical system infrastructure from the beginning. At the same time, it would provide the single infrastructure for the communication between central cooperation/command centre and all national counterparts; in this latter case, as long as only sites in the disaster-safe segment are involved, corresponding parts of the infrastructure would certainly not involve satellite transport links.

In any case the WISECOM architecture would be able to accommodate both the hierarchical and the fully distributed-cooperative models.

V. Conclusion

Looking at the current reality of emergency communications it is easy to conclude that satellites are a fundamental element which has to be considered in this area, but their integration with terrestrial technologies is needed. Unfortunately it seems that there is no global harmonization and no widely accepted way of organizing the re-establishment of a telecommunication infrastructure in a post-disaster situation. For this reason the WISECOM project proposes a model which includes the existing state of the art, which is easily to be upgraded with new upcoming technologies, and which, at the same time, is general enough to accommodate the complex interactions between rescue teams and different service providers, in both a hierarchical and distributed fashion. This should be considered in future standardization activities.

Acknowledgment

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