# SATELLITE BACKHAULING OF WIRELESS TECHNOLOGIES FOR EMERGENCY COMMUNICATIONS

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Emergency Communications, Satellite, backhauling, GSM, UMTS, WLAN, WiMAX, TETRA.

## 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. The core element of the architecture, the WISECOM Access Terminal, is then described in details. The targeted infrastructure covers bi-directional communication needs for voice and data and will be scalable, covering the needs for a few persons to larger groups. It comprises equipment that is easy to carry by a person, ideally as a carry-on cargo on planes. The infrastructure covers the immediate needs in the first hours and days following an emergency. Furthermore, the system integrates location-based services assisting Search and Rescue (S&R) operations for emergency scenarios. A secondary objective is to provide an easily deployable infrastructure meant for medium to longer term needs, useful during the recovery and rebuilding phase following an emergency. The infrastructures allow the integration of alert systems, communication to and from the citizens or rescue teams, and rapidly deployable emergency telecommunication systems.

## Introduction

Several recent global disasters have resulted in high losses of lives and massive damage. Both early warning systems and rescue operations would have benefited from improved communications systems providing global disaster proof coverage. Katrina wiped out 3

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million telephone lines, took out 38 emergency 911-call centres, and impaired more than 1,000 cellular transceiver towers. There were major gaps in communication between different entities operating in the disaster recovery, which resulted in a series of logistical errors and led to a chaotic situation that required massive aid to control. The EU Commission states: "Recent large catastrophes and crises like Tsunami the Katrina hurricane dramatically showed the importance of communication to prevent the deaths of thousands of people." And the UN Office for Coordination of Humanitarian Affairs says "A Global Disaster Relief System is desperately needed". Satellite communications offer a required robustness, global coverage and enables infrastructures to be in place in shorter time then any other technology. Awareness of communication needs in times of disasters is now at a high level worldwide, and satellites can play a key role in creating temporary ad-hoc infrastructures suitable for both rescue workers and victims during disasters. In order to address this issues, the European Commission is supporting a project called WISECOM [1]; an acronym for Wireless Infrastructure over Satellite for Emergency Communications.

This paper presents the WISECOM project, and discusses the potential impact WISECOM may have by use of satellites in disaster recovery, outlining global requirements for emergency communications in light of initiatives by the UN, EU, ETSI and others.

WISECOM studies, develops, and validates by live trials the candidate rapidly deployable lightweight communications infrastructures for emergency conditions. The infrastructures will integrate several terrestrial mobile radio networks - GSM, UMTS, WiFi, and optionally WIMAX and TETRA - with satellite systems. The hardware shall be both lightweight and rapidly deployable, and thus suitable for public safety communication. Satellite systems, due to their very wide area coverage and the possibility of readily transportable terminals, intrinsically allow for a rapid deployment of a telecommunication infrastructure when and where a terrestrial infrastructure is not available (e.g. after a natural or industrial hazard). The connection to the public networks (PSTN, ISDN, Internet) is directly provided at the satellite gateway, depending on the offered service. The satellite segment of the WISECOM project will be based on both Inmarsat BGAN and DVB-RCS, the former for worldwide basic services and the latter providing larger bandwidth support. The hardware will be tested in real trials at the end of 2007 with emergency simulations under stress.

The paper is organized as follows. In the next section the overall concept of the WISECOM system architecture is presented together with the business model which maps to it, and which describes which role is played by the different and many actors involved. The following section describes in details the key element of this architecture, which is the WISECOM Access Terminals, WAT. The final discussion is given in the "Conclusion" section.

## WISECOM Architecture

The WISECOM system represents the technical answer to telecommunication needs for people involved in a post-disaster emergency situation. The reference architecture of this WISECOM system, illustrated in Fig. 1, is based on a modular approach. A WISECOM Client guarantees the interworking between the various access and satellite solutions, providing additional functionalities. Despite the multitude of technical solutions that could be used to realise the WISECOM system, several distinct logical blocks can be distinguished. It is the aim of this section to define these logical blocks, 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 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.

Two main segments are defined in WISECOM:

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

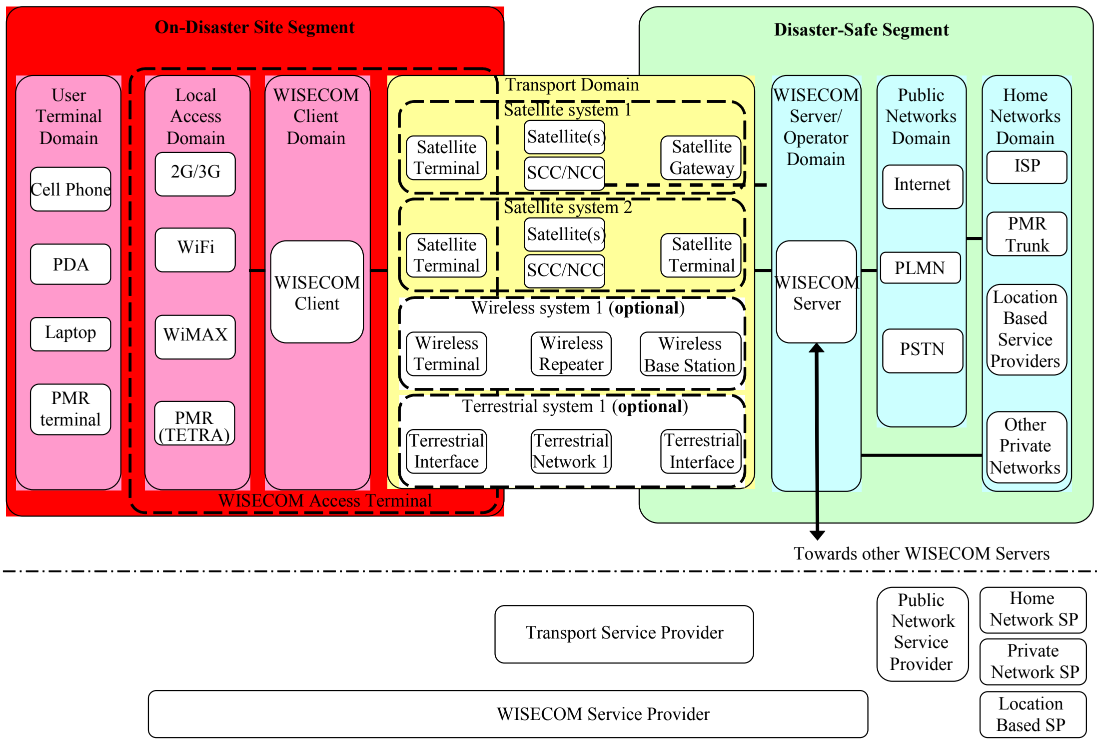
The former consists of the User-terminal Domain, the Local Access Domain, the WISECOM Client Domain and the group of network elements responsible for the access to the transport domain from the disaster area (satellite terminals, terrestrial wireless terminals, etc…).

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; where one part is located in the On-Disaster Site Segment and the other in the Disaster-Safe Segment.

In Fig. 1, the full lines between the WISECOM Server / Operator Domain and the Home Networks Domain are used to represent possible direct high security connections between a WISECOM server and some special networks or servers dedicated to emergency situations. Of course, these connections can also be achieved via public networks.

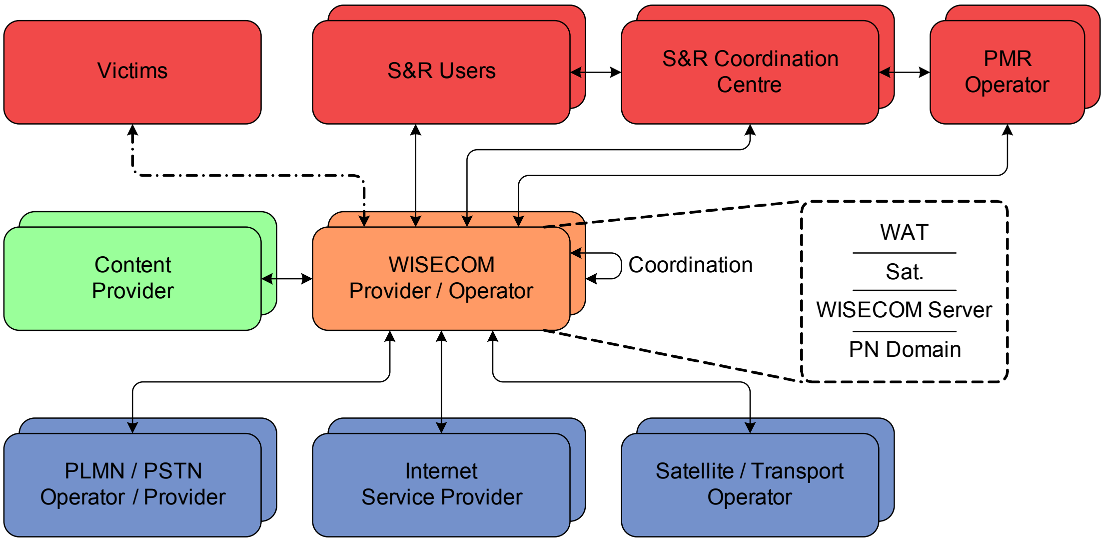
Figure 1 – WISECOM Functional Architecture.




The technical architecture shown in Fig. 1 is part of a more or less complex set of relations among different operators and service providers involved in the provision of services for the WISECOM system(s). In any case beyond the various business relations among the different players involved, the solution is technically simple and for this reason reliable.

These relationships are clarified in the role model presented in the following Fig. 2. 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.

Figure 2 – WISECOM Role Model.




The following roles can be identified: WISECOM operator or service provider, victims, S&R (Search and Rescue) users, S&R coordination centres, PMR (Professional Mobile Radio) operators, content providers, satellite transport service operator/provider, Internet Service Provider, PLMN/PSTN (Public Land Mobile Network / Public Switched Telephone Network) operator/provider, Mobile Network Operator (MNO).

The WISECOM operator or service provider plays the central role in the considered system, interfacing all of the following roles, as illustrated in Fig. 2; 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.

The victims come in as passive or active end users from a communications system point of view 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).

S&R users include both early phase (immediate search & rescue) and response phase (rescue, transport and medical treatment etc.) forces; here the main relation is provisioning of services (communications, LBS, and content) via WISECOM Access Terminals available to the rescue organisations. S&R coordination centres mainly coordinate and command the field rescue forces throughout all disaster phases.

PMR operators, like national/regional TETRA operators, 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 can for instance be providers of Geographic Information Systems (GIS), of maps, image services or of other kind of data. 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.

The satellite transport service operator/provider 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.

The last three players take care of the connections to the core terrestrial public networks: 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; an MNO, for the local access domain. An 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.

When one looks at the various levels of size (geographical extent) of disasters (local, national, regional, large-area [2]) 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.

In any case the WISECOM architecture is general and flexible enough and to accommodate both an organized and hierarchical solution and the fully distributed-cooperative model. This is one of the most important benefits of the WISECOM technical approach.

## WAT and WISECOM Client

The WISECOM Access Terminal (WAT) is the key equipment of the WISECOM system, it is the physical device which is brought to the place of the disaster by the i.e. rescue teams, it includes all logical and physical modules which enable the connection of standard mobile phones (GSM, UMTS, TETRA) and wireless data transmitters (WiFi, WiMAX) to the public networks (Internet, PSTN/PLMN).

As it was already explained, the WAT spans over three domains: the Local Access Domain (LAD), the WISECOM Client Domain (WCD), and the Transport Domain (TD). For this reason it can be thought as a combination of three modules: one interacting with the LAD technologies, one providing the operations needed for the satellite transmission and reception, and one module in the middle interfacing these two worlds with more or less intelligence. The functionalities located in the two external modules are specified by the characteristics of the related technologies (terrestrial or satellite), and thus they are well defined.

The core interfacing functionalities of the WAT lay in the middle module, the WISECOM client, for this reason it represents the main subject of the present section.

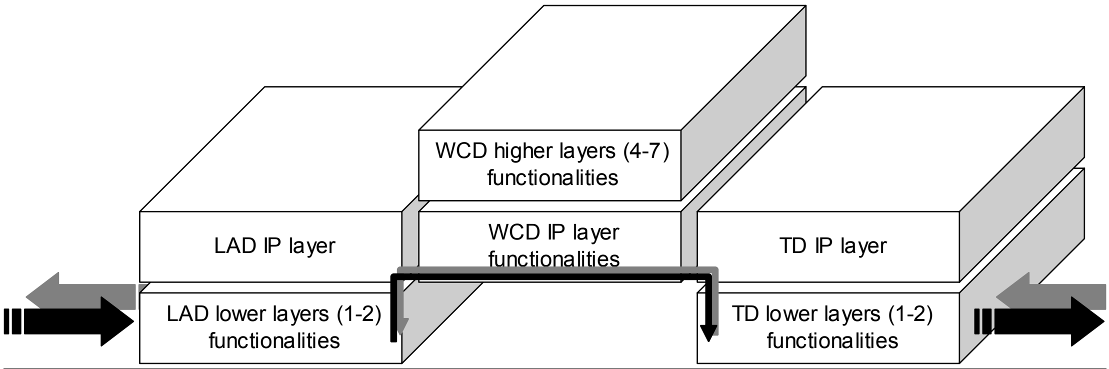
The functionalities to be found in the WAT can be classified according to the three domains (LAD, WCD, TD) and to the layers of the ISO/OSI (International Standard Organization's Open System Interconnect) protocol stack. For this analysis we can divide the seven layers of the ISO/OSI into the three following groups:

- Lower layers (physical and link layer, layers 1 and 2);
- IP layer (network layer, layer 3);
- Higher layers (transport layer and above, layer 4-7).

This is done, as we will see that the IP layer plays a fundamental role, and all transitions and interfacing operations can be performed going through the IP layer; this makes the operations easier, on one hand, and, on the other hand, it allows the system to be handled in a unique way independently of the technologies which are used on the two sides of the LAD and of the TD.

The resulting WAT functional block architecture is shown in the following figure.

Figure 3 - WISECOM Access Terminal (WAT) functional block architecture.




In real implementations the three domains of the WAT, and the six logical modules, may be located on the same physical device or on physically different devices. In the former case the WAT will look like one single “box” which integrates the satellite modem and the base station(s) for the LAD (e.g. a GSM base station, or a WiFi access point). Nevertheless satellite modems and wireless base stations (GSM picocells or WiFi access points) are commercial off-the-shelf and standalone equipments, so the latter case seems to be more likely. In this latter case the WAT will be composed of several physical elements: at least one element for every LAD (one GSM picocell, one WiFi access point, etc…), one (or more) element(s) for the WCD (e.g. a LINUX computer), and one element (and only one for each WAT) for the satellite TD. It is assumed that the connections among the elements (across the three domains) will be performed over IP by means of Ethernet cables, for this reason the IP layer remains a core one. In this case the WCD will also have modules implementing Ethernet functionalities at layer 1 and 2, but this is not considered relevant and can be neglected for the present analysis, and thus it is not depicted in Fig. 3.

The LAD modules in the WAT contain all functionalities characteristics of the particular wireless technology used in the local terrestrial loop: GSM, UMTS, WiFi, WiMAX, and TETRA. The modules should allow the operation of standard user terminals (mobile phones, PDAs or laptops, etc…), this implies that the air interface provided on the LAD should comply the given standards. On the other side a transition to IP should be already performed in this domain for all standards which natively do not run over IP, i.e. GSM, UMTS, and TETRA. So the two LAD modules take care respectively of these two tasks, the needed functionalities are summarized in the following:

- LAD lower layers (1-2):
  - Physical and link layer functionalities (e.g. modulation, power control, MAC, etc…).
- LAD IP layer:
  - Data format conversion to IP: e.g. encapsulation of GSM signalling (e.g. the A-bis interface between the BTS and the BSC) into IP, codec conversion, encapsulation of TETRA signalling into IP, etc… It should be noted that in this module only simple operations of signalling adaptation to IP should be performed, more complex functionalities, such as protocol or signalling conversion, should be performed in the WISECOM client (WCD).

The WISECOM client logically operates only at IP layer and above. It is a transition module for all the traffic in the middle of the WAT, it may be the destination of some higher layer signalling, such as authentication or LBS. The WCD may also intercept (or spoof) some signalling which is destined to higher layers counterparts beyond the TD. For both these two reasons the WCD contains functionalities at layers higher than IP. The needed functionalities are summarized in the following:

- WCD IP layer:
  - All IP QoS functionalities (it is foreseen to adopt DiffServ approach): data flow classification, packet marking, traffic policing (filtering), traffic shaping, queuing and scheduling (priority aware scheduling should be used together with smart buffer management and dropping policies, e.g. RED, Random Early Detection), connection admission control and congestion control (optional in DiffServ).
  - All conventional IP functionalities, such as IP routing and addressing, if NAT (Network Address Translation) is needed, it should not be used here but in the TD module.
  - IP add-on functionalities: e.g. IP sec may be implemented here, if needed; it is not foreseen to use Mobile IP.
- WCD higher layers (4-7) terminated at the WCD:
  - LBS functionalities.
  - Authentication, authorization: specific GSM/UMTS functionalities may be implemented in this module, in order to save signalling over the satellite (e.g. Visitor Location Register, VLR), a RADIUS (or DIAMETER) authentication server may be also implemented in this module, acting as an authentication proxy.
  - Billing.
- WCD higher layers (4-7) "intercepted" at the WCD:
  - Caching: e.g. Performance Enhancement Proxy for TCP.
  - IP signalling adaptation to satellite: this kind of operations are particularly important for non-native IP traffic, such as GSM/UMTS, protocol conversion/adaptation may deserve an own software unit and may run on dedicated computers: e.g. GSM connection control may be translated into SIP, timers may be adapted to the longer satellite delays.

The TD is the last stage of the WAT processing the outgoing traffic before it is sent over the satellite and it is the first stage for the incoming traffic. This module performs the very final operations needed for the satellite transmission (or the very preliminary ones for incoming traffic); all operations requiring more complex processing should be located in the WCD.

- TD IP layer:
  - IP queue management: taking into account that most of the QoS IP management is performed in the WCD, and that packets are already marked with the appropriate DSCP (DiffServ Code Point) according to their (DiffServ) service class, the IP management in the TD results to be very easy; nevertheless a set of DiffServ queues has to be foreseen, packets are classified according to their DSCP and mapped to the related queue. All other operations (traffic policing, traffic shaping, buffer management and dropping policies, admission control and congestion control) can be neglected as they are already performed in the WCD module.
  - IP encapsulation and segmentation
- TD lower layers (1-2):
  - Satellite L2 management: address resolution, L2 security, L2 scheduling and resource management: This latter operation is very important, as it is responsible of gathering the needed physical resources (satellite capacity) to transmit the traffic, and of mapping the IP queues to appropriate L2 classes. The operations performed in the real systems (BGAN and DVB-RCS) may differ, but this is normally transparent to IP layers and to the other modules (WCD), so it can be neglected in the present analysis.
  - Satellite physical layer operations.

As it was already explained the connection of the WCD and of the LAD modules should occur at IP layer. The following technologies should be considered for the interfacing of the WCD with the LAD: GSM, UMTS, TETRA, Wi-Fi, WiMAX..

The latter two can be considered native IP bearers, so they do not pose particular problems when they have to be interfaced with IP. The former three technologies are voice-based and in conventional architectures they do not run originally over IP, at least at this stage, i.e. immediately behind the base station. In any case since the LAD-to-WCD interfacing should occur over IP, it is recommended to make a simple encapsulation of these conventional signalling (GSM, UMTS and TETRA) over IP. This type of traffic should be then forwarded to the WCD. More complex protocol translations or conversions deserve particular attention and for this reason they should be left to dedicated processing units, i.e. to the WCD.

The technologies foreseen for the transport domain are: Inmarsat BGAN, and DVB-RCS. The equipment needed to implement the WCD-to-TD interface is a commercial off-the-shelf satellite terminal. These types of terminals normally include the lower layers implementation (the TD lower layer module) and the related IP layer one (the TD IP layer module). Normally it is possible to connect a computer to this type of terminals over Ethernet, so the interfacing occurs over IP, as already anticipated and shown in Fig. 3. The operations performed in the TD IP module are just the ones strictly needed by the satellite transmission, they are normally in any case performed by conventional satellite terminals; all more advanced operations and all WISECOM-specific functionalities have to be performed in the WCD module, as already explained in this section.

It is worth mentioning that the interface between the TD IP module and the TD lower layer one, may optionally comply with the ETSI Broadband Satellite Multimedia Working Group (BSM) model [3]. This model separates the protocol and procedures in a satellite system into two parts: The upper part provides IP-based interworking using a set of common satellite independent (SI) functions that are applicable to many satellite systems. The lower part provides the satellite dependent (SD) functions. ETSI/BSM air Interface specifications define a mapping of the SD functions to the mechanisms used by specific types of satellite system. This framework allows protocols at the SI layer can develop without impacting the design of satellite technology, enabling satellite systems at the SD layer to evolve in parallel. The BSM reference model has a logical interface between the SI and SD layers provided by the Satellite-Independent Service Access Point (SI-SAP). This suggests the existence of the SI-SAP as an internal standard interface within a satellite terminal. If this is the case the TD IP module may be able to interoperate with different underlying TD lower-layer modules, and this is considered highly advantageous for the WISECOM system.

## Conclusion

Disasters are often combined with the destruction of the local telecommunication infrastructure, causing severe problems to the rescue operations. 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. 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 [4,5] 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.

This paper has presented the approach proposed by the WISECOM project [1], which 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 paper also presented technical details of the key system modules.

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.

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## Author Biography

Dr. Matteo Berioli (M.Sc. ’01, Ph.D. ‘04) is with the German Aerospace Center (DLR) since 2002. His expertise covers many fields in the area of Internet communications over satellite. His project experience includes several national and international projects at European level, in the framework of ESA, EU-IST and COST, experiments and trials over satellite, development of prototypes and demonstrators, measurement campaigns, where he has often covered leading roles (e.g. he coordinated all demonstration and trials activities of the WirelessCabin project). He has also experience in running industrially funded projects, as well as more theoretical works: He is author/co-author of several papers, which appeared in international journals and conference proceedings. He has been reviewer for technical international journals and for many international conferences (IEEE and non-IEEE). He has worked as an ETSI (European Telecommunications Standards Institute) expert in broadband multimedia satellite communications. He is currently coordinating the WISECOM project, and the satellite working group in the PSC Forum (Public Safety Communication Forum).

Dr. Harald Skinnemoen (M.Sc. ‘85, Ph.D. ’94), managing director of AnsuR, joined Nera in 1987, and has been working with aeronautical, mobile and broadband satellite systems, covering most technical aspects from the physical layers to the system concept. He has participated in a number of international studies and published a number of conference papers. He also worked as Nera SatCom R&D Product Manager. Since 1998 he has served as an expert to ETSI in broadband multimedia satellite communications, and as the first and founding Chairman of the corresponding ETSI SES BSM workgroup. He has been deeply involved in global satellite standardization and regulatory work in cooperation with ESA, ITU, TIA, the DVB Project, IETF and others. He also serves as an expert reviewer to the EU Commission and as a lecturer to TopTech’s international Master of Space Engineering program in Holland.  Dr. Skinnemoen is a Senior IEEE Member.

Sindre Kopland-Hansen (M.Sc. ’93) technical director of AnsuR, hired by Nera Satcom 00-06 for DVB-RCS terminal work and later the Nera World Pro 1010 Inmarsat BGAN terminal development project working from pre studies to responsible for the non access stratum - access stratum interworking protocol stack. Ericsson ’93-00 working with IN services for 2 years , GSM data interworking for 2 years and H.323 IP telephony Gatekeeper development for 2 years. These total 13 years has all been in heavy research and development projects incorporating pre studies, standardization work, modeling, implementation and testing. Before this Mr. Kopland did his main Thesis on Tracking of Remote Sensing LEO Satellites at the Norwegian Defence Research Establishment/University of Oslo. Mr. Kopland is hired by the University of Oslo as external examiner for final M.Sc. level exams.

Dr. Markus Werner (M.Sc. ’91, Ph.D. ‘02) has been with the Institute of Communications and Navigation of the German Aerospace Center (DLR), Oberpfaffenhofen, Germany, between 1991 and 2005, where he worked as a research scientist, project manager and group leader. He has been a managing partner of TriaGnoSys GmbH since 2002. His project experience includes several national and ESA studies and various projects in the framework of European ACTS, IST, COST 227, and COST 252 and COST 272 programs. He has been the project manager of the EC FP6 Network of Excellence in Satellite Communications (SatNEx). He lectured on mobile satellite communications at Ilmenau Technical University from 1995-96. He is also a Lecturer at the Carl-Cranz-Gesellschaft (CCG), Oberpfaffenhofen, Germany, teaching satellite communications courses for telecommunications professionals. He is co-author of more than 80 scientific publications and of the textbook ‘Satellite Systems for Personal and Broadband Communications’ (Berlin, Germany: Springer-Verlag, 2000). Dr. Werner is a Senior Member of IEEE, and a member of VDE/ITG.