

# Integrating Satellite and Terrestrial Technologies for Emergency Communications: the WISECOM Project

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## ABSTRACT

In this paper, the main concepts of the Wireless Infrastructure over Satellite for Emergency COMMUNICATIONS project (WISECOM) are presented. These concepts rely upon the idea of a light and rapidly deployable system that can be autonomously used in remote areas where telecommunication networks have broken down to provide access to emergency telecommunication services using a large set of wide-spread telecommunication technologies such as GSM, UMTS, WiFi, WiMAX, and TETRA and a satellite back-hauling link. In the paper, a detailed description of the whole WISECOM system is provided, with emphasis on the WISECOM Access Terminal, the unit deployed on the disaster area and interfacing the selected satellite system to different wireless local access technologies. Then, three relevant and realistic examples of configuration of the WISECOM system (GSM, UMTS and TETRA over satellite) are detailed.

## General Terms

Design, Experimentation, Security.

## Keywords

Emergency communications, satellite backhauling, GSM, UMTS, TETRA, Inmarsat BGAN, DVB-RCS.

## 1. INTRODUCTION

Disasters are often combined with the destruction of the local telecommunication infrastructures, 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 coordinate their efforts.

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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 rapidly set up anywhere in the world where there is satellite coverage.

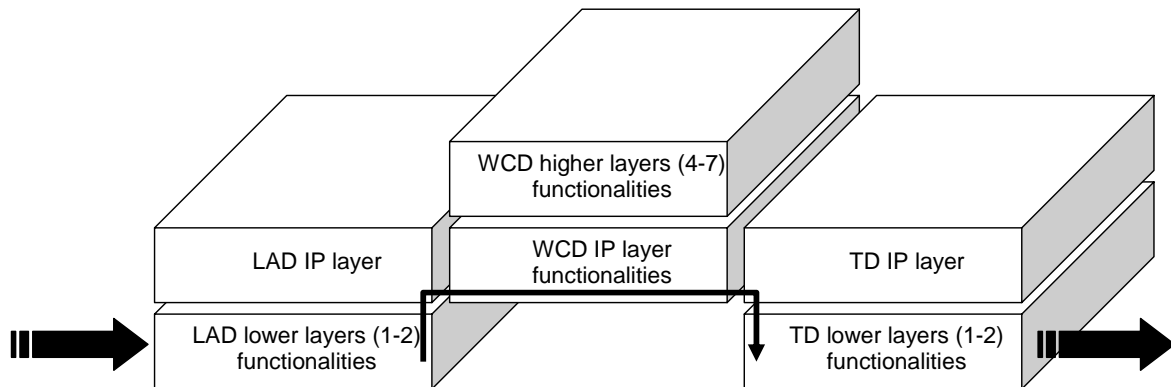
In fact the currently existing solutions to overcome the communication problems use satellite phones in the first hours after the disaster. With the help of more complex and bulky technologies ([1],[2]) it is also possible to rebuild and deploy a wireless telecommunication infrastructure to transmit 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, and focuses on two particular European broadband portable satellite systems: Inmarsat BGAN [6] and DVB-RCS [5]. WISECOM also incorporates Location-Based Services (LBS) 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, i.e. when rescue teams have already started organized relief work, 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 (several days after the disasters).

The aim of this work is also to put the basis for a standardized

Interconnect) protocol stack. For this analysis we can divide the



**Figure 1. WISECOM Access Terminal (WAT) Protocol Architecture.**

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 core part of the system, which is the WISECOM Access Terminal (WAT); we then present some details of the system architecture for three particular cases in section 3 showing how terrestrial technologies can be backhauled over satellite. We drive the conclusions of the work in section 4.

## 2. The WISECOM Access Terminal

The WAT (or WISECOM Access Terminal) is the physical device which is brought to the place of the disaster by the 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).

The WAT spans over three domains:

- the Local Access Domain (LAD) enabling local connection of the end users thanks to heterogeneous wireless technologies,
- the WISECOM Client Domain (WCD),
- the Transport Domain (TD), consisting in the WAT of one satellite terminal (BGAN or DVB-RCS) enabling long range back-hauling over satellite.

For this reason the WAT 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.

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 by those standards (e.g. GSM, IP, etc). 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 functions 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

seven layers of the ISO/OSI into the three following groups:

- lower layers (physical and link layer, layers 1-2),
- 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 protocol architecture is shown in Figure 1.

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 the 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 Figure 1.

It has to be mentioned here that beside the WAT, the associated ground network infrastructure should be present in a disaster safe place, so that end-to-end telecommunication services can be successfully provided. With this respect, the WISECOM server is the counterpart of the WISECOM client. It performs interface with the satellite gateways, traffic routing, classification, shaping, queuing, scheduling, format conversion, billing and monitoring, and of course interface to a wide set to telecommunication ground

networks such as Public Switched Telephone Network (PSTN), Integrated Services Digital Networks (ISDN), Packet Data Networks (PDN) such as IP networks, Public Land Mobile Networks (PLMN). In addition, in order to guarantee a high availability of the system, most of the components of the WISECOM server shall be redundant. Nevertheless, in case of break down of the WISECOM ground network, the WAT shall still be able to support local communications.

## 2.1 Overview of the WAT Local Access

### Domain functionalities

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 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).

## 2.2 Overview of the WISECOM Client

### Domain functionalities

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 or data, 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 [4]): Data flow classification, IP 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 Network Address Translation (NAT) 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, thanks to a local LBS server mirroring information contained in the disaster safe segment of the network,
- 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 the IETF Session Initiation Protocol (SIP, [7]), timers may be adapted to the longer satellite delays.

## 2.3 Overview of the WAT Transport Domain functionalities

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: L2 scheduling and resource management (this module is very important, as it is responsible of gathering the needed physical resources, i.e. satellite capacity, to transmit the traffic, and of mapping the IP queues to appropriate L2 classes), address resolution, L2 security.

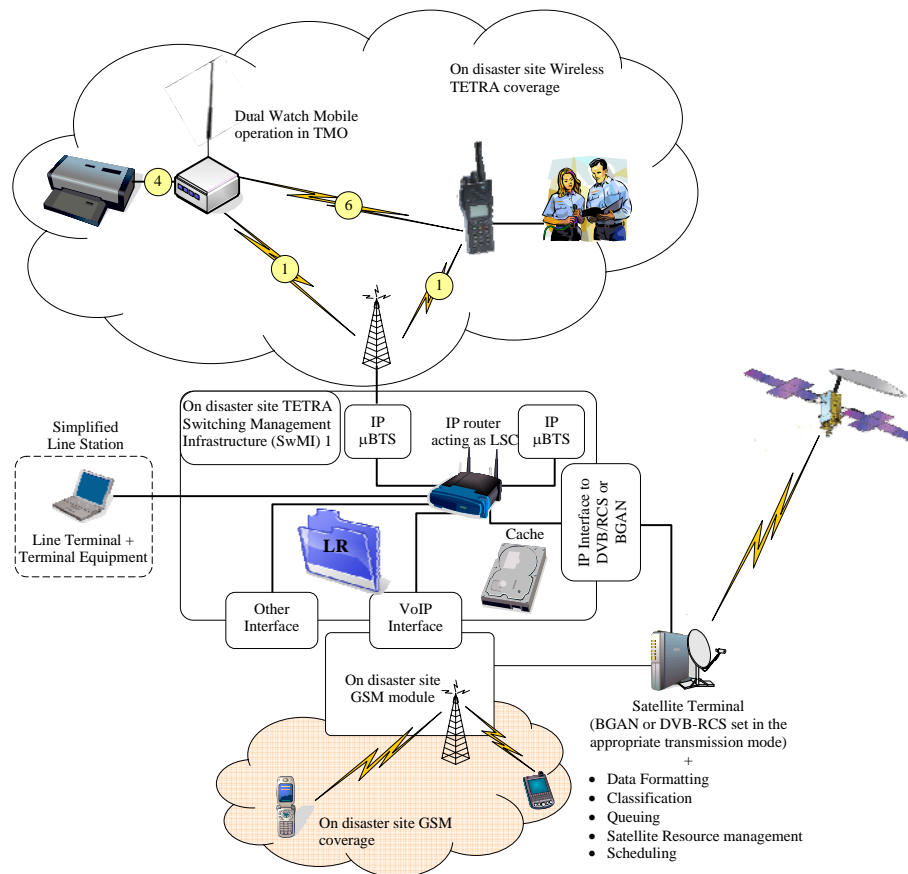


Figure 2. WISECOM TETRA architecture on the on disaster site segment.

### 3. System Configurations

The key element of WISECOM is to allow end users to flexibly access the network using their own, standard devices thanks to the support of a large set of wide-spread local wireless technologies, such as GSM, 3G/UMTS, WiFi, WiMAX and TETRA. Nevertheless, these standards are in steady evolution. For instance GSM, basically designed to support voice applications in a circuit mode, includes now GPRS and EDGE and many more options. Also, WiFi is a subset of the 802.11x-family [8] and is offered in a variety of different options. The WISECOM system also needs to evolve, and to become compatible with the future wide-spread wireless telecommunication technologies. However this document, being of more generic nature, will not aim to specify this type of details.

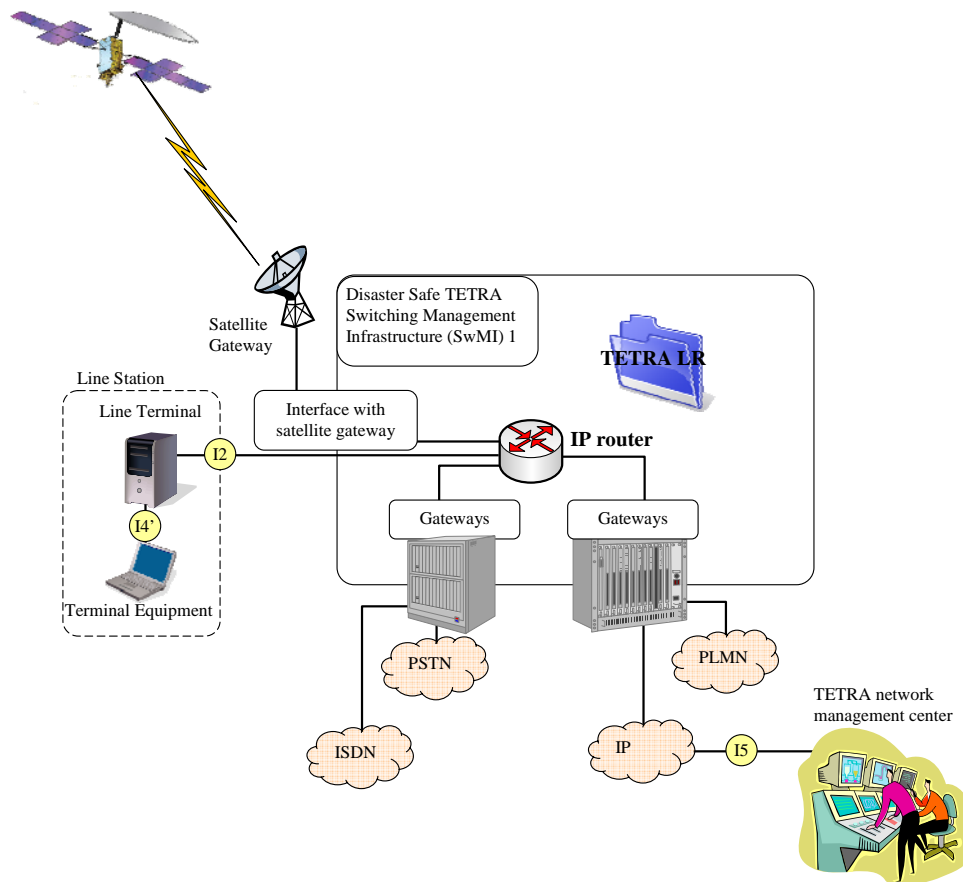
Still, it is worth dwelling on some overall aspects. In short, there is in general a need for an Inter-Working Unit to secure efficient networking. This section will look into the impacts that these issues have on the WISECOM system architecture for three particular access technologies when they are backhauled over satellite: GSM, UMTS and TETRA which seems particularly relevant.

#### 3.1 GSM over satellite

In GSM the Base Transmitter Station (BTS) is connected to a Base Station Controller (BSC) using the *Abis* protocol. From the BSC, the core network is interconnected via the *A* and *Gb* protocol to the Mobile Service Switching Center (MSC) and Gateway GPRS Support Node / Serving GPRS Support Node (GGSN/SGSN).

The Siemens nanoGSM picocell used in WISECOM comes with IP interfaces, implementing *Abis* over IP networks for interconnection. This technology encapsulates the *Abis* traffic in IP datagrams, such that the *Abis* traffic can be routed between BTS and BSC over conventional IP networks. As satellite systems focus today largely on Internet provisioning, this technology is suited for backhauling of the GSM networks of most of today's satellite networks.

WISECOM satellite backhauling solution is interconnecting the *Abis* protocol over satellite. It divides the Base station subsystem (BSS) functions into a BSC at the remote site (which terminates signalling and control to the base station BTS) and a ground BSC (which performs data transcoding and routing to the core network elements). The ground BSC connects via standard interfaces *A* to the master switching centre and interface *Gb* to the GPRS service / gateway nodes (SGSN/GGSN).



**Figure 3. WISECOM TETRA architecture on the disaster-safe segment.**

About the generated voice communication traffic, IP encapsulation also raises the problems of satellite bandwidth optimization and of overhead when small voice packets are periodically transmitted. With this respect, RTP/UDP/IP header compression (header reduced from 40 bytes to 2 bytes) and voice call multiplexing are performed.

### 3.2 UMTS over satellite

The WISECOM 3G/UMTS architecture is based on the 3GPP Release 7 model. The picocell based on 3WayNetworks technology is used as radio front-end towards the 3G/UMTS mobile phones. The picocell features one UMTS radio bearer.

The 3G/UMTS picocell is connected through Ethernet to a PC-based server, called Terminal Side Satellite 3G Server (TSSS). From TSSS, UMTS signalling and traffic is forwarded via a satellite modem and corresponding satellite Ground Station to a Network Side Satellite 3G Server (NSSS). The NSSS is installed at operator or customer site and is connected to the satellite ground earth station by IP network. From the NSSS traffic is sent to a SIP interworking function and Media Gateway. Both systems, the TSSS and NSSS are managed via the Element Management System (EMS).

The TSSS router provides Quality of Service routing functions and advanced compression schemes. Services can be controlled manually by a control panel or automatically depending on

position or time. Access to local content is provided. For voice services local calls are also possible without going over the satellite.

The 3G/UMTS picocell (Node-B) assembles several functions of a UMTS network. It comprises the Node-B radio access point and the radio network controller (RNC). Voice services are switched and eventually transcoded in the master switching centre (MSC). Data services are sent to the Gateway GPRS Support Node / Serving GPRS Support Node (GGSN/SGSN). Voice and data are sent as IP packets through the terminal-side Satellite 3G server over the satellite to ground networks. As satellite systems focus today largely on Internet provisioning, this technology is suited for backhauling of the UMTS networks of most of today's satellite networks.

The picocell supports approximately 10 parallel voice calls with AMR coding (expected 20 calls in the next future). It supports data services with High Speed Down-link Packet Access (HSDPA) bit rates up to 3.6 Mbps.

### 3.3 TETRA over satellite

Following the discussion about GSM and UMTS and the possible integration of a backhauling satellite segment in these cases, we would like to focus with some more details on TERrestrial Trunked RADIO (TETRA, [9]). Figure 2 and Figure 3 represent the envisaged solution for TETRA over satellite in the

WISECOM framework, on the on disaster site segment and on the disaster safe segment respectively. These solutions are based on an "all IP" architecture, simplifying the conception of the system. In case of WISECOM, the critical issue is to split the Switching and Management Infrastructure (SwMI) and its set of functionalities into two sections, one on the on disaster site segment and the other on the disaster safe segment.

The SwMI encompasses all the ground equipments, such as the Base Transceiver Station (BTS), the Local Switching Center (LSC), the Location Register (LR), the Main Switching Center (MSC), and also the different gateways (or Media Gateways) performing the necessary data format, protocol and address conversions needed to reach other end users in different networks (PSTN, ISDN, PDN such as IP networks, PLMN). In addition, the SwMI contains a Local Control Facility (LCF) and an Operation and Maintenance Center (OMC), as well as network and subscriber management functionalities.

On the on disaster site segment, a TETRA IP micro BTS (e.g. BESCOM IP TETRA micro BTS or DIGICOM 25 THALES IP TETRA micro BTS [10]) might be used and connected to a router acting as a Local Switch Center (updated by the remote network management function) using information from a local Location Register and accessing data saved in a cache. The router can also connect the micro BTS to the other modules in the WISECOM client for e.g. connection to the local GSM network or to the local WiFi network. On the on disaster site segment, it might also be possible to connect a simplified Line Station for a restricted amount of extra-communication services, for instance ambulance listening or call restriction.

The flow of IP datagrams that may be backhauled over the satellite system shall be processed (together with other data flows received by the GSM or WiFi or other modules) by another entity being responsible of the scheduling of this data flows over the satellite link. In this entity, data conversion for transmission over the satellite system, classification, queuing, dropping and scheduling have to be performed, as well as the reservation of satellite resources.

On the disaster safe segment, the TETRA SwMI is located in the WISECOM server and should implement the following functionalities:

- Interface with the satellite gateway,
- Interface with the ground networks with the help of adapted gateway (PSTN, PLMN, ISDN, IP).

It is again supposed that the interface with the satellite gateway will be provided with IP datagrams, since a whole IP TETRA SwMI is taken into account in this architecture.

Finally, the TETRA network management center may be distant to the WISECOM client, and may be managed with the use of standard protocol (SNMP) over the Internet.

BGAN is able to use a packet transmission mode, which can be used to carry the IP datagram between the different network entities of the all IP TETRA SwMI located on the one side in the on-disaster site segment and on the other side, on the disaster-safe segment. This may be performed using correct interfaces in the on-disaster site and disaster-safe segment.

Similarly, TETRA over DVB-RCS will use the intrinsic capabilities of the DVB-RCS / DVB-S terminals to transmit and receive IP datagrams over MPEG, using also an appropriate interface.

So this TETRA architecture with satellite backhauling is perfectly compatible both with BGAN and DVB-RCS technologies.

## 4. 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 to organize 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 wireless terrestrial technologies and a common IP interface to backhaul them over different broadband satellite system. In the paper the general concept was first presented and then three examples (GSM, UMTS and TETRA) were considered in more detail.

## 5. ACKNOWLEDGMENTS

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