Satellite Based Infrastructure for Emergency Communications

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ABSTRACT – 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 coverage and robustness towards the destruction. Katrina wiped out 3 million telephone lines took out 38 emergency 911-call centers and impaired more than 1,000 cellular towers. There were major gaps in communication between different entities operating in the disaster recovery, that resulted in a series of logistical errors and let to a chaotic situation that required massive aid to control. The EU Commission states: "Recent large catastrophes and crisis 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; an acronym for Wireless Infrastructure over Satellite for Emergency Communications. This paper presents the WISECOM project, an initiative for outlining global requirements for emergency communications in light of initiatives by the UN, EU, ETSI and others, and discusses the potential impact WISECOM may have for the use of satellites in disaster recovery.

Nomenclature

DVB-S	=	Digital Video Broadcasting – Satellite
DVB-RCS	=	Digital Video Broadcasting – Return Channel Satellite
EU	=	European Union
UN	=	United Nations
GSM	=	Global System for Mobile Telephony

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ETSI	=	European Telecommunication Standards Institute
WISECOM	=	Wireless Structure over Satellite for Emergency Communications
BGAN	=	Broadband Global Access Network
WAT	=	WISECOM Access Terminal
UMTS	=	Universal Mobile Telephone System
LAN	=	Local Access Network
VoIP	=	Voice over IP
QoS	=	Quality of Service
WiMAX	=	Radio communications standard IEEE 802.16
Wi—Fi	=	Radio communications standards IEEE 802.11

I. Introduction

EMERGENCY situations are cases where 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. Both in a pre- and post-disaster phase, communication links are essential. Following a disaster, be it natural or caused by man, the usual telecommunication infrastructure, if previously existing, can break down. Disasters may also happen where such infrastructures did not exist beforehand. In the situation in focus, our assumption is that common infrastructures for telecommunications are limited or non-existent. There could be several reasons for this and the unavailability could be short- or long-term. Victims of a disaster will not normally own other communication equipment than mobile phones (e.g. GSM) for voice. There are more than 1 billion GSM phones in the world, in comparison to less than 1 million satellite phones. For this purpose it is considered extremely useful to be able to connect GSM users, and in the future UMTS users, to the network specifically in cases of emergency. Such connection will help the rescue work, and may ultimately save both lives and preserve nature. Rescue workers may have more specialized equipment, e.g. combined GSM / GPS (or Galileo) phones. For data communication one can expect Wi-Fi, or in the future probably WiMAX, access.

The key problem to be solved here is how to as quickly as possible deploy a temporary infrastructure for voice and data communications. One that is available to users without dedicated end-user terminals such as e.g. specific satellite phones. In an emergency situation there may be victims, alive, and with GSM phones. However, if the existing GSM network infrastructure has been destroyed, the phones are of no value in informing rescuers of the situation and location of the victims. Limited battery life points to the need for a very rapid deployment of new access possibility. Rescue workers can in this way attempt contact with known victims and Location Based Services may help pinpoint the location of a phone.

The primary challenge to be addressed by WISECOM becomes one of deploying GSM and Wi-Fi/WiMAX coverage rapidly. WISECOM will also add intelligent location determination features at higher layers (network, system) to the rapidly deployable communication infrastructure in order both to help locate victims and to aid the Search and Rescue operations. The targeted infrastructure will cover bi-directional communication needs for voice and data and will be scalable, covering the needs for a few persons to larger groups. It shall comprise equipment that is easy to carry by a person, ideally as a carry-on cargo on planes. The infrastructure should cover the immediate needs in the first hours and days following an emergency. Furthermore, the system will integrate location-based services

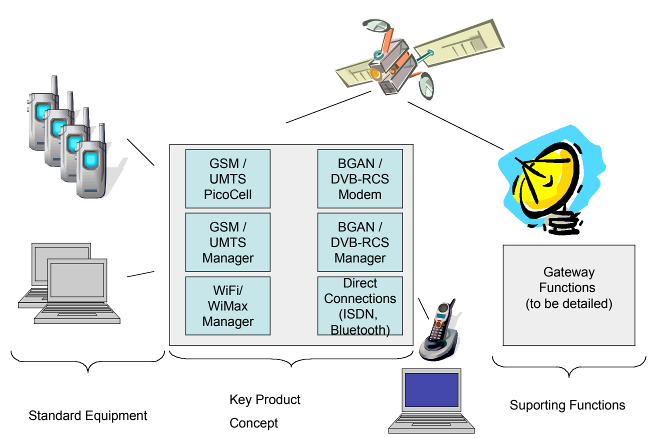

Figure 1: WISECOM client architecture Objective

assisting Search and Rescue operations for emergency scenarios.

A secondary objective is to study and develop 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. For full integration into the existing rescue systems, several aspects are implemented.

WISECOM will be tested in emergency simulations under stress, and WISECOM will clearly help to solve societal problems in emergency and disaster situations. Any person with an appropriate cell phone (normally GSM) may take advantage of the WISECOM deployable infrastructure in a relevant situation. Victims able to call out may do so, they may be paged and called by rescue workers or family, and together with the use of LBS solutions, the chances of finding and saving them will be improved. In addition, disaster recovery personnel will be able to be reachable and traceable under situations where this could in extreme cases imply the difference between life and death.

Table II-1: Classification of Disaster Scenarios

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

II. Disaster Scenarios

Katrina wiped out 3 million telephone lines, took out 38 emergency 911-call centers, impaired more than 1,000 cellular towers, and major gaps in communication resulted in a series of logistical errors that led to a chaotic situation that required massive aid to get under control.

EU Commission says “Recent large catastrophes and crisis situations like the Tsunami and Katrina dramatically showed the importance of communication to prevent the deaths of thousands of people.”

UN states that a global Emergency Communications provider is desperately needed.

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.

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. 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.

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.

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 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.

The WISECOM system enables the use in emergency situations of a wide set of telecommunication applications, ranging from voice services to the transfer of data and the location-based broadcasting of information to on-site 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.

III. WISECOM 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, 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 inter-work between the various access and transport solutions, as well as providing additional functionality, binds the two domains together in the WAT.

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 neighboring 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.

Two main segments are defined in WISECOM:

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

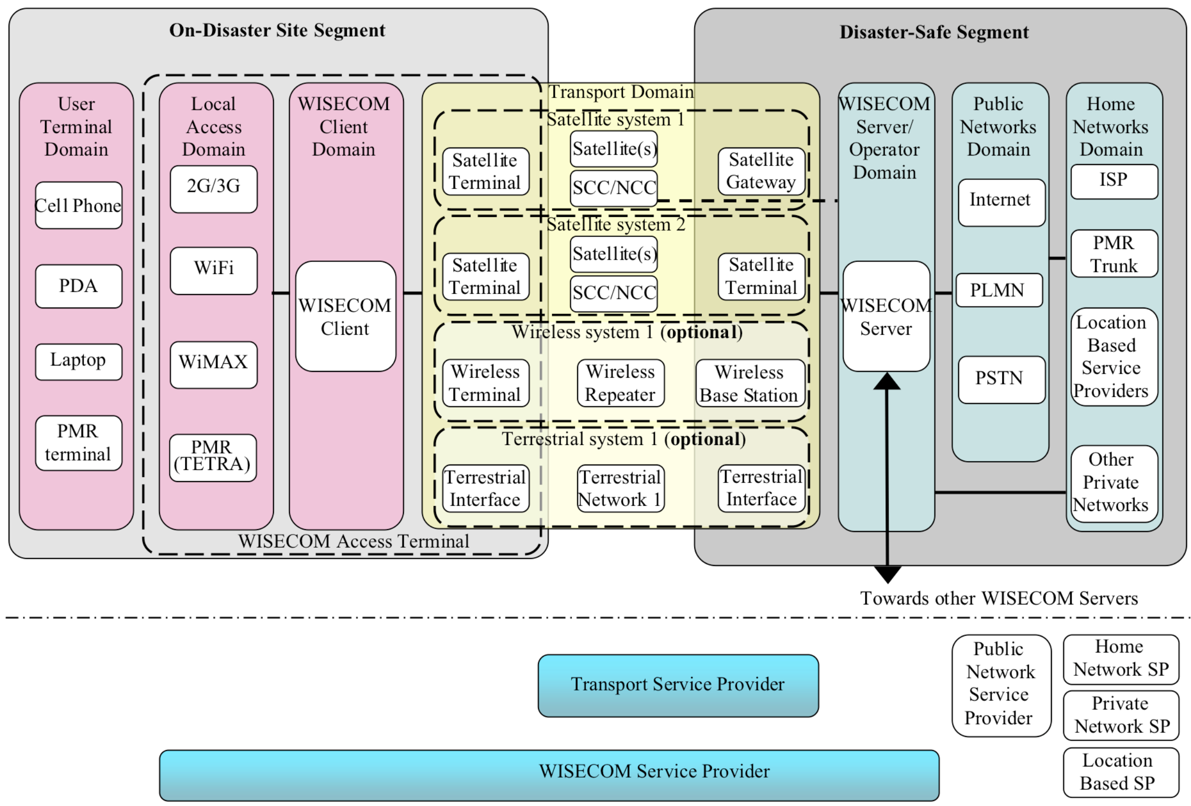

Figure 2: WISECOM Functional architecture.

D. WISECOM Access Terminal and Client

The 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 (Wi-Fi, WiMAX) to the public networks (Internet, PSTN).

The WAT spans over three domains:

- Local access domain
- Remote client domain
- Transport domain

It can be thought as a combination of three modules: one interacting with the Local 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. 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.

E. WISECOM server

The WISECOM server is one of the key subsystems of WISECOM. Most communication, authorizations and services are provided or through the WISECOM server. The WISECOM server interfaces the transport and public/home networks domains. These domains contains several entities (satellite system 1, 2, …) and new interfaces may be added to the system. The WISECOM server holds and proposes many services and functionalities to all WISECOM users and interacts with service providers. Therefore the WISECOM server is designed to:

- Have high availability: the WISECOM server implements hot redundancy of its critical items and is able to prevent itself from networks threats mostly from public networks.

- Centralize WISECOM relevant information : user management, network policies, network security and grants, IP and voice addressing plan are defined in harmony with each others. The coherency of the whole information is mandatory is implement and maintain a WISECOM server.
- Be open and flexible: WISECOM server implements interoperable and standardised technologies. It is likely that more interfaces shall be connected is the future, and the ease of integration of these interfaces depends on the architecture of the WISECOM server.

Protocol functionality includes QoS mapping, Routing and Security, while Inter-working functionality includes:

- Satellite - GSM Network interworking. The Abis over IP signalling between the remote BTS and the WISECOM server is minimal where the WISECOM server will pretend like a standard BTS towards the land based BSC (spoofing). The WISECOM GSM IWU will in addition re-code voice to/from the original codec used by the MS before/after interfacing the BSC. The recoding is only necessary when the MS in operation is not configurable or support the low bandwidth codec's of choice over satellite.
- WISECOM SIP server: The WISECOM VoIP SIP server will serve SIP calls from the WISECOM client towards other IP phones, GW PLMN/PSTN. The WISECOM client will contain a SIP server for local traffic and routing traffic to the WISECOM SIP server for other disaster proof traffic.
- WISECOM Image server. The WISECOM image application server has two interfaces, one to receive images and a web interface to display and control the image download. In addition the image application server will have map (LBS) to show the web user the image location.
- WISECOM client LBS server. The Location Based Services server will provide GSM and GPS location services to the WISECOM client(s).
- WISECOM Satellite resource management. The WISECOM server must monitor its satellite backhaul type and capabilities setting up necessary capabilities based on enabled services and backhaul capabilities.
- WISECOM congestion control. The congestion control is controlled and configured based on the satellite resource management. The WISECOM services all consume bandwidth when in operation. Dependant on satellite backhaul type, its subscribed bandwidth and instant bandwidth allocation the different services might meet congestion. For real time applications like GSM voice and VoIP this can be partial solved using QoS. In addition the different services should reside in a prioritizing table dependant on importance for the WISECOM client users. This should be configurable via the WISECOM client or server or both. I.e. some WISECOM client can be configured for multiple voice

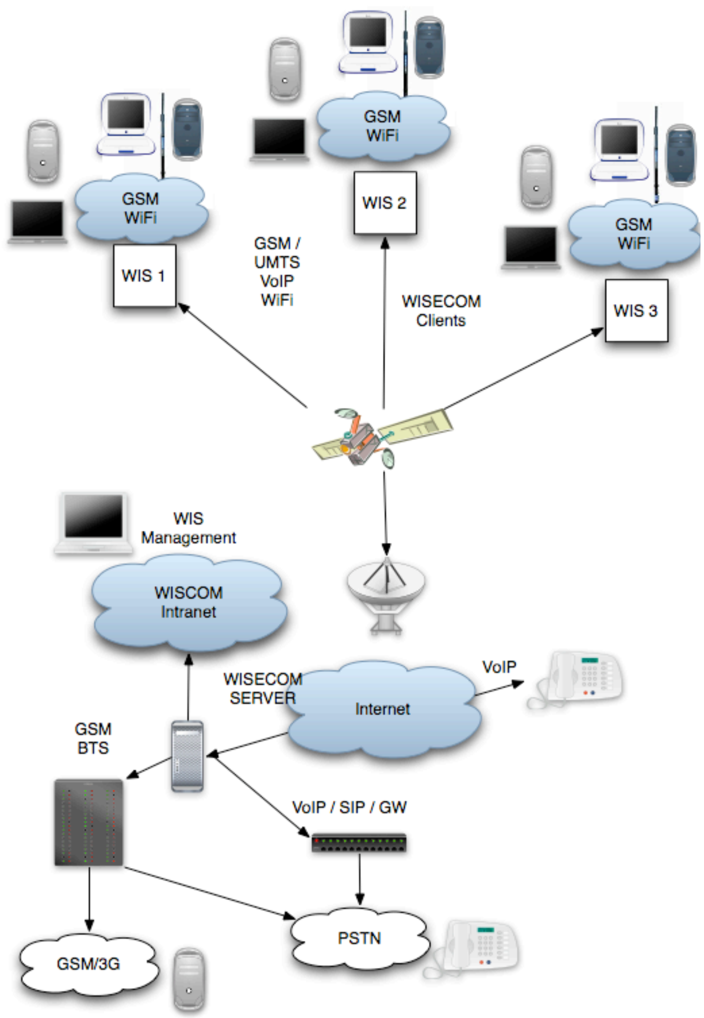

Figure 3: WISECOM overall architecture.

where other traffic is only possible if spare bandwidth is available others for just one voice call channel with for instance LBS services, imaging as main capabilities.

IV. WISECOM Applications

The WISECOM system differentiates itself from other communication systems by supporting dedicated Emergency Communications applications. One such application is the ASIGN application (Advanced Satellite-based Image Communication for Global Networks) developed by AnsuR. ASIGN is developed for Telemedicine applications, in order for an expert, e.g. a medical doctor, to support rescue forces in the field. Another application is the Location Based Services, developed by Reach U.

A. Location Based Services

The WISECOM LBS system is a server-based solution, consisting of two servers: one at the global WISECOM Server site (managed directly by the WISECOM Operator / Service Provider), and another on the WISECOM Client site, as part of the WAT. The two servers exchange information over the WISECOM satellite communication channel, or in principle over another transport domain channel. LBS Web Application, allows to:

- View locations of rescue teams on map
- View locations of legacy mobile phones on map (specific phones), get bulk location information (e.g. list of all MSISDNs in the disaster area)
- View geomessages (locations marked by rescue teams) on map
- Add new geomessages, share these with all rescue teams or send them to specific rescue teams
- Send SMS messages to legacy phones, to specific phones or bulk sending (e.g. broadcasting emergency alerts)
- View on-line external local data (e.g. weather, seismic info, air pollution etc) on map to use it for decision support, if the data is available

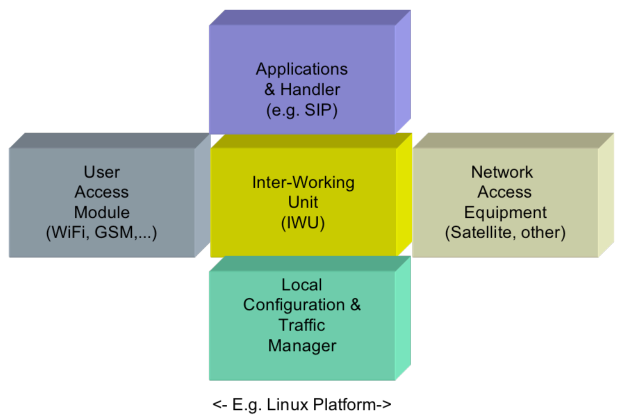

Figure 4: Schematic WISECOM Access Terminal

B. Image Communications

ASIGN images can be instantaneously transferred via satellite (e.g. BGAN) from anywhere in the world via a server on the Internet to anywhere in the world. This is done via Wi-Fi access from camera to a computer, via satellite link to the Internet and via the Internet so a secure server. ASIGN is a spatial multimedia application over satellite. Location coordinates are used both for the image content processing and can be used for crating multicast distribution lists. When present at the server, the embedded location information can in turn trigger automatic download of information such as maps, weather forecasts and other information as desired of the areas where the photographs are taken. Information can also be added manually, like voice comments and text input. The result is a bundled information packages. Any amount of processing can in principle be applied, like automatic feature extraction and recognition.

When processing is complete the information can be sent back to the remote site as required. It can also be sent to other, similar sites in a region, for instance if there is a major operation where different units would need access to information from other units in the area. ASIGN will thus also help coordinate information to units in the field, securing receive the same information.

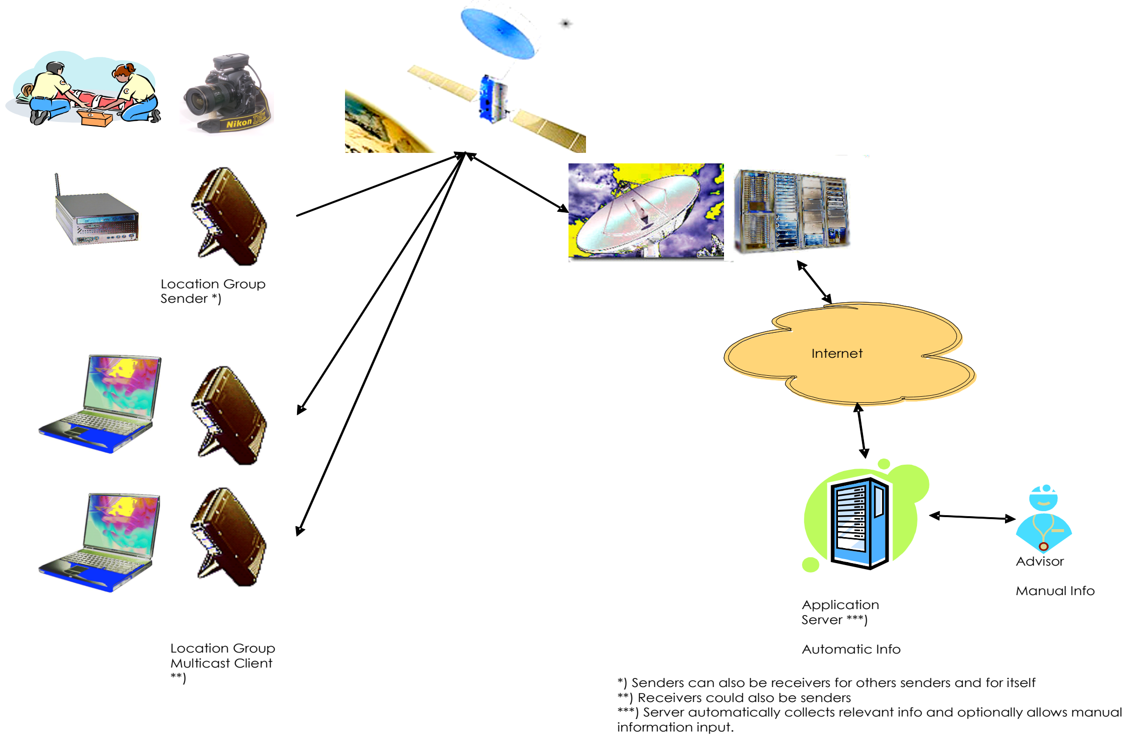

Figure 5: Application of image communications in WISECOM

V. Conclusion

WISECOM is an open architecture initiative for global emergency communications. Looking at the current reality of emergency communications, it is easy to conclude that satellites are a necessary and fundamental element, but their integration with terrestrial technologies both for rescue workers and victims is needed. If dedicated access equipment is required, then usually the victims are not server, nor does it help collaboration among the various rescue and aid organizations where we too often see incompatible equipment. There is presently no global harmonization and no widely accepted way of organizing the re-establishment of a telecommunication infrastructure in a post-disaster situation. The WISECOM project proposes a model which includes the existing state of the art, but allows upgrade with future technologies. WISECOM is at the same time general enough to accommodate the complex interactions between rescue teams and different service providers, in both a hierarchical and distributed fashion. WISECOM should be considered in future standardization activities. A concept based on pre-positioned satellite based equipment, ad-hoc and global emergency communications operators should be considered.

VI. Acknowledgment

The authors acknowledge the work of the whole WISECOM project team.

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