Public Protection and Disaster Relief by Satellite-based Communications Network

Yong-Min Lee
Satellite & Wireless Convergence Research Dept.
Electronics and Telecommunications Research Institute
Daejeon, Republic of Korea
ymlee01@etri.re.kr

Bon-Jun Ku and Do-Seob Ahn
Satellite & Wireless Convergence Research Dept.
Electronics and Telecommunications Research Institute
Daejeon, Republic of Korea
bjkoo@etri.re.kr, ahnds@etri.re.kr

***Abstract*— Various communication means which are not only possible technologies of the moment but also from a peanut-size network to an extensive scale should be integrated for public protection and disaster relief (PPDR). Wireless fixed ad hoc network and mobile ad hoc networks is useful to quickly establish an instant communications system to support emergency management and the urgent missions in the incident disaster area. The competent area network is used for dedicated communication and information sharing between rescue teams and 3G/4G mobile networks could be deployed to expand local networks reaches the working terrestrial base stations. To interconnect the long distance remote disaster site and cover the wide area a satellite system is mainly used for transferring the collected data by sufficient link capacity. The example of homogenously integrated network for PPDR is described and IP-based satellite network is proposed to provide emergency management services which facilitate the matter of high data rate and quick deployment.**

Keywords- PPDR; disaster; management; satellite-based communication; interated; network

I. INTRODUCTION

Almost every day, many kinds of disaster are reported by newspapers, radio and television channels from over the world. A disaster can be defined as "A serious disruption in the functioning of the community or a society causing wide spread material, economic, social or environmental losses which exceed the ability of the affected society to cope using its own resources"[1].

A disaster is a result from the combination of hazard, vulnerability and insufficient capacity or measures to reduce the potential chances of risk. Various disasters like earthquake, landslides, volcanic eruptions, fires, flood and cyclones are natural hazards that kill thousands of people and destroy billions of dollars of habitat and property each year. The recurrent occurrences of various natural and manmade disasters like the December 2004 Tsunami, the bomb blasts in the cinema halls of Delhi and many such incidences have diverted our focus towards safety of one's own life.

Disasters are as old as human history but the dramatic increase and the damage caused by them in the recent past have become a cause of national and international concern.

Communication means provide the critical path for relief in emergency and disaster situations. Once a disaster has occurred, however, local infra structure – including microwave, cellular and other most communications facilities are destroyed. In the immediate aftermath of such a major emergency situation, one of the reliable solutions of communications is satellite-based communication.

Satellite technology can provide narrowband and broadband IP communications (Internet, data, video, or voice over IP) with speeds starting at 64 Kbps from handheld terminals up to 4 Mbps bi-directional from portable VSAT antennas normally. Fixed installation can bring the bandwidth up to 40 Mbps [2].

In fact, a disaster can be occurred very variously – various size, place, causes, etc. but it should be effectively controlled and managed in any emergency and disaster situations. This discussion would be complete with the quick and reliable establishment of a temporary communications network which has feasible technologies to support emergency management.

The aim of this paper is suggesting a complete wireless communications solution that can be deployed immediately, reliably, and easily before/after disaster. For this work all different systems should be hierarchical and enabling an interworking properly between different technologies as well as communication devices.

This paper is organized as follows: Section 2 introduces the recent trends of disasters and the needs of telecommunications hierarchy during a disaster situation, Section 3 explores the integrated PPDR network to mitigate the unpredictable disaster effectively and also suggests a hierarchical architecture of integrated PPDR network, and Section 4 discusses IP-based satellite network for PPDR as a generic solution for provision of multimedia services via satellite access network.

II. DISASTER TRENDS AND TELECOMMUNICATIONS HIERARCHY

A. Trends of Disasters

Over the past decade we have seen an increase in the intensity of natural disasters worldwide as shown in Fig. 1. Through the media, and for some of us, through firsthand experience, we have witnessed the awesome force of nature. In the recent past, we have had natural disasters created by the tsunami in Asia, the earthquake in Pakistan, and the hurricane Katrina in the US. These caused unprecedented devastation and great loss of life which have been etched in our minds due to the magnitude of the devastation. Disaster impact statistics show the global trend – there are now more

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disasters but fewer people die in proportion, even though more population is affected and economic losses are increasing [3].

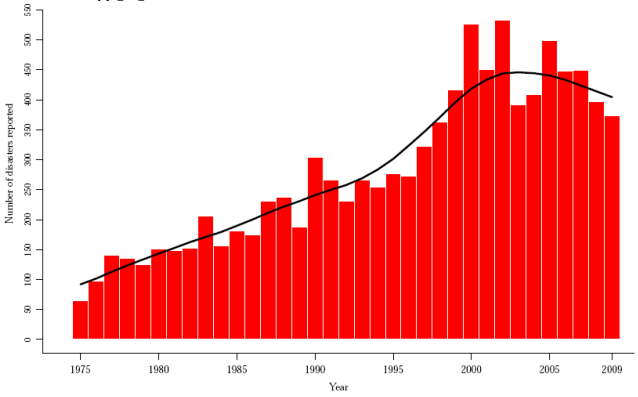

Figure 1. Number of natural disasters reported 1975-2009 (Source: EM−DAT: The OFDA/CRED International Disaster Database − www.emdat.be − Université Catholique de Louvain, Brussels – Belgium)

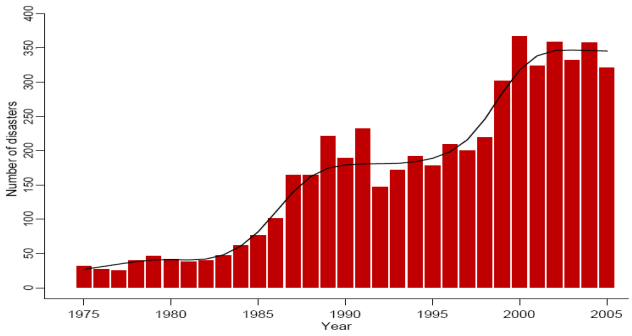

Figure 2. Technological disasters reported 1975-2005 (Source: EM-DAT: The OFDA/CRED International Disaster Database - www.em-dat.net - Université Catholique de Louvain, Brussels – Belgium)

Technological disasters often resulting from major accidents associated with industrialization and forms of technological innovation have significant socio-economic and environmental impact. Although technological hazards have been part of society for hundreds of years, the trends are showing an increasing impact in Fig. 2 [4].

Technological advancements, specifically in the energy, transport and industrial sectors, are developing innovations with associated risks that are not always understood or heeded. The adverse effects of some technological disasters, both on society and on the environment, can considerably outlast the impacts associated with natural disasters.

Comparing the last three decades, the trend shows an increase in the number of natural hazard events and of affected populations. Even though the number of disasters has more than tripled since the 1970s, the reported death toll has decreased to less than half. This is among other factors due to improved early warning systems and increased preparedness. This statistic varies enormously depending on region and figures used. One need to bear in mind those large disasters is rare events that defeat any statistical analysis in the short term. Perhaps more significant in the life of many are those daily disasters, generally underreported and not reflected at all in global figures on losses, but accumulating to probably large tolls of both economic and health losses.

B. Telecommunications Hierarchy for Disaster Situation

In the recent trend, disaster management has emerged as an important management system to cope with any disaster events. Efficient disaster management shall able to estimate the scale of disasters and its quick responses in any incidents. Nowadays, the system of disaster management is purely a scientific phenomenon. There are three phases of disaster management which are namely Pre-Disaster Management, During-Disaster Management and finally Post-Disaster Management [5]. Pre-Disaster Management is a vital phases of this entire management system. It includes the preparation of various action plans by the relevant organizations and their objective is to minimize the risk and hazards from the specific disaster's events. The second phases of its managements are to provide responses at the time of disaster and last phases include how to tackle with the operation of relief & rehabilitation. It is really understood that the perfect Pre-Disaster Management helps with the efficient disaster management system in the strategic time.

Many types of wireless communications can help to coordinate an effort of the disaster management inside and/or outside disaster area to bridge the disaster zone to the other zone, providing telecommunications, broadcasting, logistic, and tele-medical support. Furthermore, in many scenarios, especially in disaster situations, wireless represents the only viable delivery mechanism [6].

Generally speaking, the wireless solutions in the management of emergency situations have been identified for a long time. Nowadays, however, just one wireless solution could not be capable of delivering the services to cover the complex emergency situations which are being wide area, underground area, and under constructed infra area for instance. In these areas communications networks could be either unavailable to damage and congestion or totally missing.

Very hierarchical telecommunications infrastructure is needed and it should be operated organically. Immediate availability, rapid deployment, and reliability are key factors for communication network infrastructure in emergency situations. In order to keep the telecommunications infrastructure hierarchically, it is acquired a particular significance in terms of various facets, which can be summarized as follows:

- A mobile ad-hoc network should be rapidly deployed in a disaster area.
- Broadband services (Multimedia, Internet, Telemedicine, etc.) should be deliverable to monitor the disaster situation deeply.
- Operator's terminal should be equipped with portable, compact, and easy-to-use as well as interconnected all operators.

Table I shows the comparison of mobile ad hoc network (MANET), terrestrial, and satellite system as a means of telecommunication for PPDR.

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TABLE I. COMPARISON OF MANET, TERRESTRIAL, AND SATELLITE SYSTEM

	MANET	Terrestrial	GEO Satellite
Typical Cell Size	No cell	0.1-1 km	400km min.
Service Coverage	Varies	< 1 km	Up to global
Maximum Transmission rate per user	Varies from node scenario < 100 kbps	Spot service 155Mbps	Quasi-global 155 Mbps
System Deployment	Flexible, a set of mobile hosts	Serveral base stations before use	Flexible, but long lead time
Estimated Cost of Infrastructure	Low	Varies	High

III. INTEGRATED PPDR NETWORK

Disasters generate intense human need for communication to coordinate response activities to convey information about affected groups and individuals, and as a panic reaction to crisis. The critical disasters are the most intense generators of telecommunication traffic, and the resulting surge of demand can clog even the most well-managed networks. In addition, for economic reasons, most communications networks are engineered for peak load at levels well beneath the demands placed on them during disasters.

Generally, most of disaster might be occurred in small area which can be covered by terrestrial communications network. But sometimes the terrestrial infrastructures are damaged or missing and high risk areas damaged by disaster on the ground need to be deeply monitored in particularly. In this case satellite network can offer a stable and wide range of services. Such services may be particularly valuable where the terrestrial network is damaged severely.

So, in order to mitigate the unpredictable disaster effectively a public protection and disaster relief (PPDR) network should be integrated by various communication means which are not only possible technologies of the moment but also from a small-size network to an extensive scale in terms of coverage, data rate, and users.

A. *Incident Area Network (IAN)*

When a disaster occurs, a commonly accepted concept is to need a communication infrastructure that is rapidly deployable at the disaster site and able to interconnect organically among the personnel of emergency agencies such as police, fire fighter, a first-aid team, etc [7].

The quick deployment, availability, and reliability of such emergency communication network in disaster situations is of great values considering life and property of the distressed.

Wireless fixed ad hoc network and mobile ad hoc networks as shown in Fig. 3 can be quickly established as an instant communications system to support emergency management and the urgent missions in the disaster relief situation. Especially mobile ad hoc networks could be considered as a ultra-fast deployable network by automatically establishing “self-healing” network and “moving hot spot”.

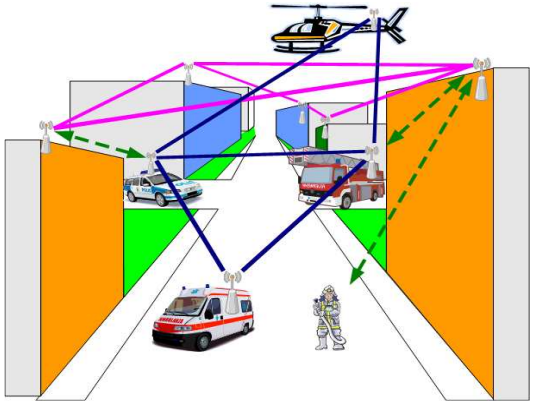

Figure 3. Wireless fixed ad hoc network and mobile ad hoc networks

This kind of ad hoc networks can be applicable to “mobile robotics” such as hazardous material removal, anti-terrorist action, rescue in hazardous locations, and remote inspection as well as “remote patient monitoring” in terms of blood pressure, cardiac activity, encephalographic data, body temperature, and positioning.

B. *Competent Area Network (CAN)*

Dependent on the nature of a disaster, there are usually many personnel requiring communications and because of the urgency of communications, a good Grade of Service (GoS) is required. These factors mean that a significant amount of network capacity needs to be available throughout the disaster and affected areas to support effective PPDR communications.

Generally the mobile telecommunications network will not have the capacity to provide effective PPDR communications because most of them located in a disaster area have been designed to support normal traffic loads [8]. Therefore, the dedicated communication network is needed to be secure communications to provide stable and additional capacity in competent area.

TETRA system shown in Fig. 4 is the preferred technology for constructing a competent area network because TETRA has some advantages over other technologies which are very fast call set-up and provide a number of fall-back modes such as the ability for a base station to process local call unlike most cellular technologies.

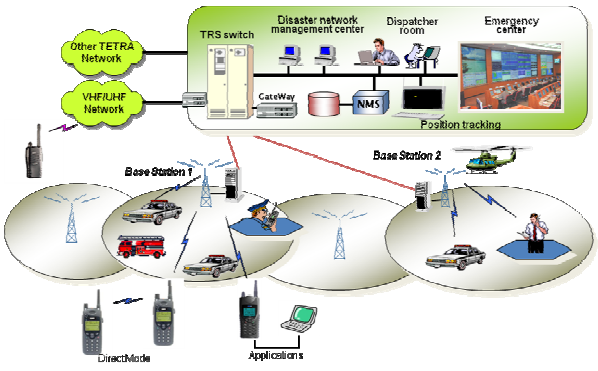

Figure 4. Competent area network by TETRA trunking system

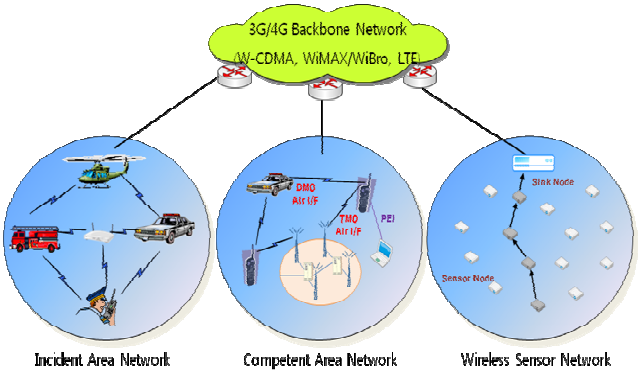

Figure 5. Extended area network by 3G/4G networks

C. *Extended Area Network (EAN)*

Telecommunication technologies used for emergency telecommunications are often no different than those used for routine public safety telecommunications.

3G/4G mobile systems using W-CDMA, WiMax, LTE technologies could be easily deployed to expand local networks reaches the working terrestrial base stations. These wireless technologies are likely to be combination of narrowband, wideband and broadband, and nature of application use public or private networks in order to establish the extended area network (EAN) as shown in Fig. 5.

- Public: GPRS and 3/4G
- Private: Wideband TEDS and Broadband PPDR

D. *Wide Area Network (WAN)*

Satellite communication is still unbeatable for broadcast and multicast services for wide area – especially cost per delivered bits independent of user position and number of users inside wide coverage area.

Furthermore satellite communications have not only high data rate capacity and long distance transmission compared other terrestrial networks but also robustness against most natural or man-made disaster that can be harmful to terrestrial infrastructure.

In addition, WAN including satellite system have own advantages which other network is not easy to provide as follows.

- Disaster prediction and detection – meteorological and earth exploration satellite services
  - Operated in the main by government and international agencies
  - Play a major role in prediction and detection of disasters (such as hurricanes, earthquakes and tsunamis, floods, fires, dangerous pollution, etc.)
- Disaster alerting – broadcasting, fixed, mobile and related satellite services
  - Alert the central/regional/local authorities responsible for warning the public – broadcasting, fixed, mobile, fixed/mobile-satellite systems
  - Issue warnings to the people likely to be affected
  - Broadcasting (sound and television)
  - Mobile (such as TV, Radio, DMB, SMS/Cell broadcasting)
- Disaster relief – amateur, broadcasting, fixed, mobile and related satellite services
  - Earth exploration satellite – damage assessment and relief planning
  - Fixed/mobile satellite – to rapidly restore communications capabilities, coordination of relief activities

E. *Example of Integrated PPDR Network Architecture*

Emergency telecommunications should cover all communication services, including voice and non-voice, data, location, and so forth.

The need for emergency telecommunications includes many scenarios ranging from a minor road traffic accident, for example, to a major incident like a passenger train crash, a terrorist incident, a natural disaster (e.g. an Earthquake, Tsunami).

In order to consist of the integrated PPDR network as shown in Fig. 6 and to manage the network systematically, “Standards” for emergency communications and “Standard Operation Procedure (SOP)” are essentially needed.

While the different technologies are used, the followings are basically considered to guarantee access and successful interconnection.

- Interoperability of diverse communications systems and diverse protocols
- Interagency and cooperation between organizations
- Rapid deployment

A SOP is a set of written instructions that document a routine or repetitive activity followed by an organization to deal with the emergent situation effectively. SOPs define precisely how operations were to be conducted and also describe clearly what is expected and required of personnel during emergency response and non-emergency activities.

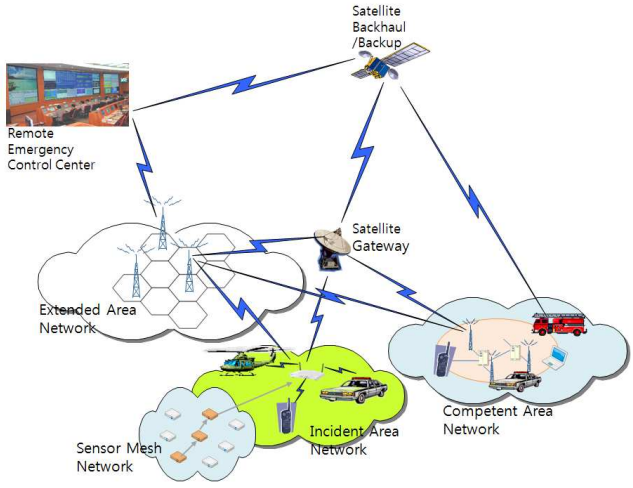

Figure 6. Conceptual architecture of integrated PPDR network

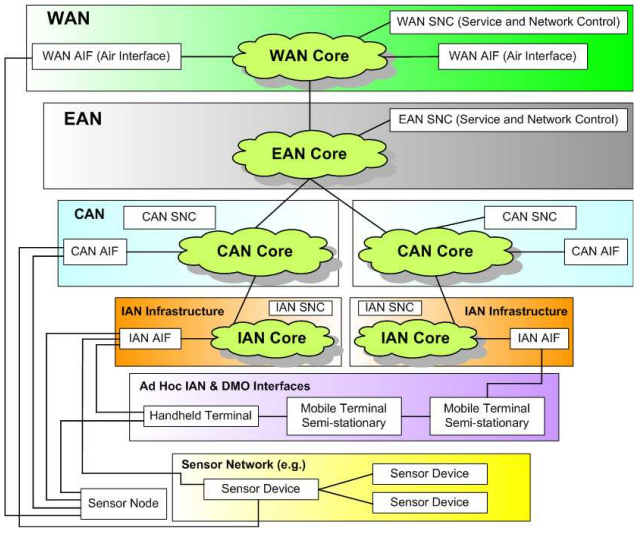

Figure 7. Hierachical architecture of integrated PPDR network

Since a disaster occurs, different and consecutive phases can be identified for the network deployment of rescue teams in the disaster area. So the reactive mechanism should be used for the rescue and recovery of any disaster by optimal hierarchical communication network.

The proposed hybrid system architecture which is for the formation of tree structure as shown in Fig. 7 provides a strong mobility management support in order to bring seamless mobility to PPDR communication network.

IV. IP-BASED SATELLITE NETWORK FOR PPDR

The broadband multimedia satellite system is intended as a generic solution for provision of multimedia services via satellite access networks. It is required that repletion and enlarging the role of broadband mobile wireless internet through the satellite communication which has mobility, wide coverage and broadband channel as following aspects.

- Wireless internet service requests increasing the bandwidth and users also request high speed services as wire network
- Necessity of technique development for getting over the limitations of current mobile communications and Wireless LAN technologies
- Necessity of network device techniques for providing high quality of multimedia services via mobile wireless internet
- Satellite communications make possible for using whole the country and providing broadband internet multimedia services

In fact, a satellite network can offer large bandwidth and allow small aperture antenna as well as even hand held terminal like terrestrial terminal that could provide a various multimedia services for PPDR.

IP-based architecture for broadband satellite access is as shown in Fig. 8 for broadband PPDR services and it can be adapted independently to the particular GEO or LEO satellite technology adopted in the satellite link [9]. This rapid deployable IP-based satellite network can provide the following advantages.

- Point-to-Multipoint burstable remote emergency Control Center- to-Incident Site
- Dedicated SCPC Point-to-Point Circuit
- Data Rates up to 5 Mbps [9]
- Quality of Service (QoS) support for voice & video
- IP-based flexible voice and data termination
- Real-time monitoring and reporting
- Seamless global coverage

This IP-based satellite communication capabilities-fixed and mobile is vital for effective multimedia communication, especially in video transmission and high data rate broadcasting as well as data collection, distress alerting, position location and coordinating relief operations in the field.

Recently a number of companies – including TerreStar Global – are planning to focus on the provision of PPDR services by mobile satellite services (MSS). They enable the satellite and terrestrial communications networks to provide a ubiquitous platform for communications and data transfer by integration of mobile satellite and ground component technologies.

In case of this the unique benefit to PPDR services of MSS/CGC(Complementary Ground Components) is the ability for the user to seamlessly switch between using the terrestrial component to connect a call and using the satellite to connect a call, thus providing network redundancy in times of need. These technological and regulatory factors combine to increase connectivity for emergency responders in service coverage.

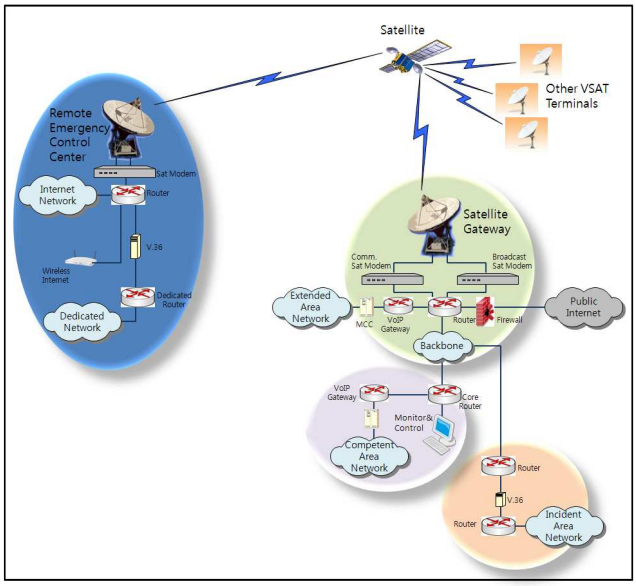

Figure 8. IP-based Satellite Network Configuration for integrated PPDR

V. CONCLUSIONS

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 [10]. The objective of this paper is to describe briefly the existing communication technologies for disaster management and to suggest the satellite-based PPDR (for public protection and disaster relief) communications network as an integrated system which is integrated not only possible technologies of the moment but also from an ad hoc network to an extensive scale network. It can be used for wideband applications (e.g. wireless transmission of large blocks of data and video) and/or broadband applications (e.g. high-speed data, high quality digital real time video and high volume data exchange) dependent on the use of spectrally efficient technologies and insuring interoperability like a IP-based satellite system. Such a system could be quickly set up anywhere in the disaster area where there is satellite coverage. The aim of this paper is also to identify possible candidate system when the draft standardization on PPDR communications for next generation is developed in Korea.

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