Communications in Emergency and Crisis Situations

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Abstract. In emergency and crisis situations (ECS) like earthquakes, tsunamis, terrorist attacks, it is very important that communication facilities are operative to provide services both to rescue teams and civilians. In ECS it is very common that communication premises are often unable to provide services, either due to physical damages or traffic overload. In such a case there is the need for rapid reestablishment of communication services. In this paper the communication services that can be exploited for ECS mitigation are discussed. The usage scenarios of such services are studied. Following that and looking from a network perspective view an ECS communication network architecture is presented. This architecture aims to provide seamless interoperability of varies communication technologies often present in ECS

Keywords: Emergency, Crisis, Disaster, Critical Infrastructure, Heterogeneous Networks

1 Introduction

A primary challenge in responding to Emergency and Crisis Situations (ECS) is communication which plays a crucial role. Emergency response is an open field for new innovative technologies due to the demanding nature of emergency operations. In the case of an ECS telecommunication infrastructure might be inoperative or have poor Quality of Service (QoS) to provide the required services. In ECS, different Emergency Response Authorities (ERA) are involved (civil protection, police, rescuers e.t.c.). This rises a major challenge regarding ECS communication infrastructures, the challenge of interoperability.

ECS management and mitigation is strongly related to the coordination of the authorized personnel. For example in the 9/11 terrorist attack at the World Trade Center some of the police warnings were not heard by firefighters resulting in several casualties [1]. Thus communication infrastructure reliability is a key factor in such circumstances [2].

The primary technological challenge after a disaster is the adequate operation of the existing communication systems and/or the rapid deployment of emergency communication infrastructure for both first responders and civilians.

The scope of studying communication scenarios in emergency and crisis situations is to acquire the necessary infrastructure specifications for emergency communications. In the case where fixed communication infrastructures have fail, the rapid deployment of an emergency communication platform could be the way to re-establish communication services [3, 4].

This paper studies the communication scenarios in emergency situations and presents a network architecture for emergency communication network. In section 2, the communication services utilized for disaster mitigation are analyzed. Emergency communication usage scenarios are described in section 3. In section 4, a network architecture to fulfill usage scenario requirements is presented. Finally in section 5 there are the conclusions.

2 Communication Services utilized for disaster mitigation

Efficient ECS response can utilize various communication services that provide text voice and video exchange. In this section ECS communication services in context to ECS mitigation are presented.

2.1 Video Communication

Since first responders often need to share vital information, the transmission of real time video to a control center could be necessary. A typical scenario includes the transmission of live video footage from a disaster area to the Fire Department's command center and/or to the nearby-located fire fighters.

2.2 Push to Talk

Push-to-talk (PTT) is a technology that allows half-duplex communication between two users, where switching from voice reception mode to transmit mode takes place with the use of a dedicated momentary button. PTT works in a walkie-talkie fashion having several features and benefits [5]. PTT is a widely used service to ERAs and has to be taken into account in ECS communication infrastructures.

2.3 Audio/voice communications

This service provide fullduplex voice channels unlike PTT. Public safety communication require novel full-duplex speech transmission services for emergency response [6].

2.4 Real time text messaging (RTT)

Text messaging service is an effective and quick solution for sending alerts in case of emergencies. Typical examples can include: (i) individuals reporting suspicious actions to the police, (ii) people affected by a disaster communicating with their relatives, (iii) authorities informing the public about possible disasters. Types of text messaging can be SMS, email and instant messages.

2.5 Broadcasting and Multicasting

Broadcasting is the ability to transmit information to all users, while multicasting is the ability to send information to a group of users. Both functionalities, if supported by technology, can enhance public safety and rescue operations. For example, suspicious actions outside a bank can trigger the transmission of live video footage to the nearby police cars (multicasting).

2.6 Localization services

Location information may be of great importance for disaster relief efforts. During emergency operations, victims locations can guide first responders to provide immediate medical support. Location information can be obtained using several technologies [7].

2.7 Transmission of status information

Status information refers to the status of several types of objects within a jurisdiction area. For example, in public safety operations, a sensor network can broadcast information related to the environmental measurements, the level of water etc.

3 Emergency communications usage scenarios

Efficient ECS management is based on the efficient organization and cooperation of various ERAs in every country. To prepare the Civil Protection in dealing with ECS, the cooperation of ERAs at local, regional, national and European levels is tested in ECS scenarios [8]. The evaluation of the results of such drills increase ERAs readiness and give feedback about the usage of emergency communications. In this section emergency usage communication scenarios are presented.

3.1 Mobile emergency responder usage

The emergency responder usage scenario involves access to services and applications by emergency responders. The key characteristic from the user point of view is to have seamless handovers without service interruptions or QoS degradation.

Mobile emergency responder usage refers either to the mobile or nomadic usage. In the mobile usage scenario the user is moving at a pedestrian / vehicular speed and has active service sessions. In the nomadic usage scenario the user suspend his applications and resume them in a later phase (for example when an ECS responder team move from one site to another).

To satisfy the above usage of the ECS network requirements are:

- **Interoperability.** Responders from diferent ERAs should be able to comunicate with each other although they migh have different type of equipment (Equipment that operates in different frequecny bands for different authorities which seem to be a common case).
- **QoS support.** Efficient and scalable QoS support, including prioritization, controlled jitter and latency and improved loss packets for voice and multimedia traffic [9].A Network traffic monitoring and tuning mechanism should introduced to provide the requested QoS.
- **Security and Privacy.** Mechanisms for secure and fast handoffs between heterogeneous networks and different operators supporting automatic reauthentication during handover to ensure user and application security.
- **Reliability availability.** The services should be available at all times and from all locations. The system should be able to adapt to varying network conditions.
- **Scalability.** In order to support load and area coverage growth as ECS mitigation is carried out.
- **Location Services.** Knowing the location of the responders in the disaster site is very important for efficient coordination. Location data should be transmitted to both fixed and mobile coordination centers.
- **Mobility.** Especially in the case of the mobile usage scenario where a responder moves into a large disaster site.

3.2 Fixed command/coordination center

This is the case of an emergency response command center in the premises of a civil protection authority, which is interconnected both to the wireless emergency response communication network, and to the national civil protection authorities.

The fixed command center coordinates the emergency response efforts and teams by delivering services such as VoIP, multimedia content sharing, peer to peer file sharing, tele-medicine services, and intergovernmental communications.

The network requirements derived from this scenario are listed below:

- **Interoperability.** The different ECS network providers (different ERAs) should cooperate to provide services. A coordinator of one authority should be able to communicate with responder teams of other authorities.
- **QoS support.** Efficient and scalable QoS support.Network traffic monitoring to estimate network's load.
- **Security and Privacy**. This is very important especially in the case that sensitive data are being transferred (for example when tele-medicine applications are used)
- **Reliability/Availability**. Fixed coordination center relies on fixed network infrastructures. In case of infrastructure failure, alternative communication equipment should be available.

3.3 Mobile command/coordination center

This is the case of an emergency response command center on a vehicle, which is located in a strategic spot close or within the disaster scene and coordinates the emergency responders locally. It is interconnected to the wireless emergency response communication network, and to the national civil protection authorities. The nomadic command center coordinates the emergency response efforts and teams by delivering services such as VoIP, multimedia content sharing, peer-to-peer file sharing, tele-medicine services, and intergovernmental communications.

The network requirements derived from this usage are listed below:

- **Interoperability.** To be able to operate with all available wireless access technologies and to connect to the wired network infrastructure if available.
- **QoS support.** Efficient and scalable QoS support to provide classification to various responder teams.
- **Security and Privacy.** Mechanisms for secure and fast hand-offs between heterogeneous networks and different operators supporting automatic re-authentication during handover to ensure user and application security.
- **Reliability/Availability.** The services should be available at all times and from all locations. The system should be able to adapt to varying network conditions.
- **Scalability.** In order to support load and area coverage growth as ECS mitigation is carried out.

3.4 Victim communications

This usage scenario refers to communications capability between rescue workers and civilian victims. This communication can take place only with end user commercial devices such as cellular phones or Wi-Fi enabled mobile devices (Smart phones, Tablets, laptops etc.). This is a significant usage scenario, since current emergency response communications do not consider civilian victims communication. In this scenario, the victims are able to have direct communications with rescue workers to seek or guide assistance without the need of specialized communication equipment. The requirements derived from this scenario are listed below:

- **Ubiquitous Access.** The network should be easily accessible from everybody.
- **Interoperability.** All end user devices such as cellular phones, PDAs etc should be able to operate in the ECS network.
- **QoS support.** The network should incorporate mechanisms for user prioritization to give priority to incidents requiring immediate response.
- **Security and Privacy.**The network should provide mechanisms for protecting victims privacy and should provide resilience to operational anomalies and security attacks.
- **Reliability/Availability.** The services should be available at all times and from all locations.

– **Mobility.** Civilians can be anywhere in the disaster scene.
– **Location Service.** The system should autonomously detect and report the user position in order to guide the rescue teams.

The requirements of the four above presented ECS communication usage scenarios are summarized in Table1.

Table 1. Requirements of Usage Scenarios

Requirements	Usage Scenarios			
	Mobile Responder	Fixed Coordination Center	Mobile Coordination Center	Victims Communications
Ubiquitous Access				•
Interoperability	•	•	•	•
QoS Support	•	•	•	•
Security and Privacy	•	•	•	
Reliability/ Availability	•	•	•	•
Scalability	•		•	
Location Services	•			•
Mobility	•			•

3.5 Video surveillance/emergency scene video monitoring

The ECS communication network can be applied for video surveillance applications by civil protection authorities. This type of usage differs from the previous four because video surveillance may be used not only in crisis situations but in a routine daily operation. The various ERAs can use this type of service to monitor places of interest as a precaution measure. In addition video surveillance can be used with specialized image recognition software to produce alarm services (for example to detect a fire and give an alarm to the fire department). In the case of a disaster, emergency scene monitoring can be very useful for disaster mitigation and responder teams coordination.

The preliminary requirements for the operators of the video surveillance application include the following:

– A large number of cameras are needed to provide enough coverage which leads to a high density network.

- Relatively high video quality that is high frame rate and high video resolution.
- High administration flexibility. Several authorities will be selected as administrators and they have to be able to access previous video captures or real-time events if special conditions occur. The members of the administrative groups might change during an event.
- High accessibility of the service. Civil protection authorities want to be able to access real time video from the command centers. In emergency conditions, the administrators of the system should be able to access the surveillance system through mobile computers.

4 Emergency Communication network Architecture

In the ECS, emergency response does not take place all at once. In the beginning ECS responders arrive at the disaster site and operate independently. These teams gradually become part of coordinated action plan by a central disaster management entity, which requires more time to set up its infrastructure in place and become operational.

Traditionally ECS responders are using PTT service for their communication and unfortunately the various ERA used communication technologies lacks interoperability. Approaching this scenario from a networking perspective, different responder teams form independent Mobile Ad-hoc NETworks [10] (MANETs) A MANET is a type of network, which is typically composed of peer nodes. When the nodes are located within the same radio range, they can communicate directly with each other using wireless links. This direct communication is employed in a distributed manner without hierarchical control. The absence of hierarchical structure introduces several problems, such as configuration advertising, discovery, maintenance, as well as ad hoc addressing, self-routing and security.

A high-level emergency response network model is illustrated in Fig.1. According this approach, the network is based in the deployment of special ECS nodes that can be deployed in or near the disaster area. These nodes integrate various communication technologies such as Wi-Fi, GSM, VHF,TETRA, Satellite, and Radio Broadcasting. Each node utilizes mesh networking capabilities to interconnect to each other. A mesh network consists of mesh routers that form a network with very similar networking attributes and characteristics of a static wireless ad hoc network. The mesh routers can function either as gateways to the wired Internet, and/or as wireless access points for mobile mesh clients.

ECS nodes can use the installed communication technologies to provide all the types of services described in section 2. ECS nodes acts as a mesh router-gateway for different technologies to provide seamless interworking. For example a coordinator located in a remote coordination center can establish voice communication with a responder that is part of an established MANET which is based in VHF PTT technology. A MANET node can be also considered as a mesh client and can perform seamless handovers between the ECS nodes.

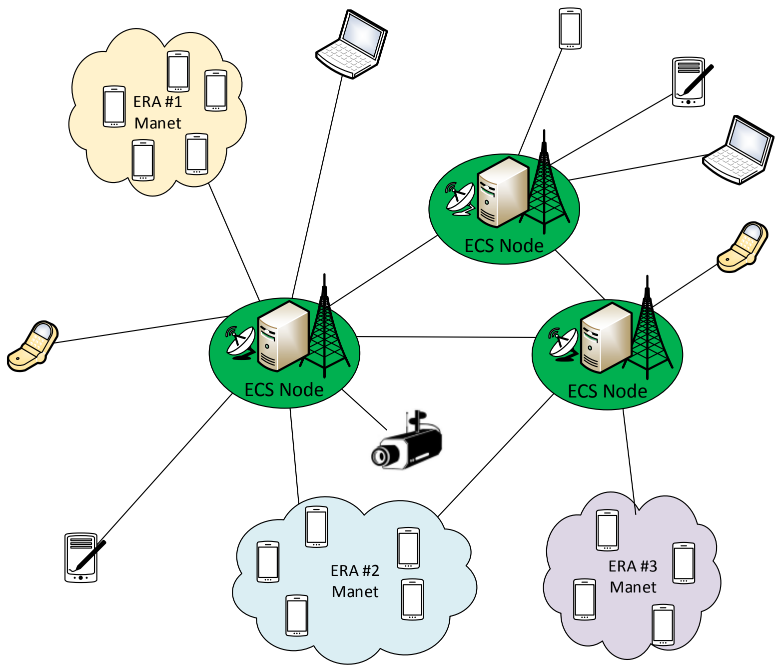

Fig. 1. Architecture of the emergency response network

GSM technology can be used from civilians to connect to the ECS network. This is very important as GSM terminals (mobile phones) are widely available from everyone and this way there is no need for purchase special equipment. In additional internet enabled devices such as smartphones or laptops can provide location services for the civilians rescue. Broadcasting techniques such as FM Radio Broadcasting can be utilized to transmit vital information.

Due to the fact that in disaster management, different emergency response authorities (police, first aid, fire departments etc.) are involved, the ECS nodes may belong to multiple operators (different emergency response authorities), and they cooperate to provide aggregate networking services to all of their mesh clients. Their networking cooperation model can be based on default agreements or, in case of multinational authorities, on agreed procedures technically similar to roaming of cellular networks. This way wireless clients can be associated with one or more operators.

The mesh network, which forms the wireless backbone of the emergency response communication system, provides various services to its clients such as Internet access, real-time communications, video streaming etc. In this approach, the mesh network is also designed to provide QoS applications with client mobility support. This way mobile mesh clients can perform seamless handovers between access points.

The proposed emergency response communication system can benefit applications and services such as:

- Multimedia exchange and sharing, of user-created content, such as pictures and videos taken by the first responders in the disaster scene. The main network requirements for multimedia sharing include high uplink throughput, and ubiquitous broadband access.
- Seamless service delivery across different network technologies: The presented emergency response architecture involves networking over heterogeneous access technologies and their integration with wired networks.
- Increased mobility: The proposed architecture aims to support seamless mobility through application-layer mechanisms, while guaranteeing the required QoS [11].
- Context-dependence: The support of ubiquitous broadband access service [12] for fixed, nomadic and mobile first responders and civil protection authorities can benefit other context-aware services, not necessarily designed for emergency response operations.

In addition to the above, all services and applications can benefit from the proposed emergency response system in terms of reduced cost, enhanced availability and coverage, and enhanced reliability.

5 Conclusions

The history has shown that in disaster and/or crisis situations communication plays a crucial role. In this paper the communication issues in disaster and/or crisis situation are addressed. First the communication services that can utilized for disaster mitigation are presented. Then usage scenario and need of both authorities and civilians of emergency communication infrastructures are discussed. Based on that and from the network perspective of view an emergency communication infrastructure architecture is presented.

The presented network architecture provide interoperability between different communication technologies. It utilises mesh networking capabilities to provide seamless handoffs between heterogeneous networks and different operators (This is the case when different authorities co-exist in the disaster scene). The presented architecture can be used either in the existing fixed and wireless infrastructure or to provide a rapid deployable communication platform to support emergencies and/or disasters.

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