Support for Resilient Communications in Future Disaster Management

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Abstract. Disasters are often accompanied by damage to critical infrastructure, including (wireless) communications infrastructure. Our solution for emergency communications is based on advanced networks: Generalized Access Networks (GANs), Body Area Networks (BANs) and Vehicular Networks, to support dynamic, resilient communication services for disaster management.

Keywords: Disaster management, health monitoring, wireless communications, GAN, BAN, Vehicular Networks, MANETS, Resilience, QoS.

1 Introduction

Wireless communications have been widely deployed in disaster management. Experience around the world however shows that communication and coordination continue to present major challenges. Problems are compounded if communications are disrupted through destruction of infrastructure. Digital solutions for emergency communications have not resolved all the issues; problems such as network congestion, loss of connectivity and indoor and underground coverage continue, resulting in difficulties for first responders at the scene and for incident commanders. We present a solution to support dynamic, resilient communication services for disaster management. The work is based on the MOSAIC project's Major Incident Scenario [1-2].

2 Proposed Solution

In our solution, emergency services personnel and vehicles are equipped with Body Area Networks (BANs) and Vehicular Networks which comprise nodes that connect to form mobile ad hoc networks (MANETS) to support intra- and inter-service communications. MANETS may provide the only communication possibility for emergency services by providing islands of communication whereby personnel at the scene can communicate. Further, these ad hoc networks should discover and communicate with any surviving telecommunication infrastructure, connecting over damaged infrastructure networks with disaster and emergency services' coordination centres. Such a solution must support resilience mechanisms providing fast connectivity restoration, resulting in a self-healing communication environment. The advanced networking technologies needed to realise this solution are described below.

Body Area Networks (BANs). A BAN is a body worn network of communicating devices (eg. sensors, actuators). A BAN may communicate wirelessly with external networks. In 2001 BANs were proposed to support Virtual Trauma Teams [3]; a casualty attended by an ambulance team would be fitted with a trauma patient BAN which would measure vital signs and transmit them to the hospital. Each paramedic would be equipped with a paramedic BAN effecting A/V communication with the hospital. These BANs were implemented and trialled during the IST MobiHealth project. The MobiHealth trauma trials involved a single casualty and one ambulance team. In IST MOSAIC this scenario was extended to cover a major incident, where multiple teams from different emergency services cooperate during first response. The futuristic MOSAIC scenario shows wearable microelectronics incorporated into the uniforms of the emergency services personnel to support biosignal monitoring, positioning and A/V communication with control centres. Firefighter BANs would also include environmental sensors and paramedic BANS would also be able to discover/query casualties' BANs, link BAN data with the EMR and enable telepresence and an augmented reality experience for hospital staff. The BANs communicate with the emergency vehicles to provide an ad hoc communications network at the scene.

*Wireless Vehicular Net*works range from vehicular area networks (VANs), for communication between persons, equipment and devices located in the vicinity of the vehicle, to ad-hoc networks for inter-vehicle communication and vehicle to infrastructure communications. Vehicular networks make use of different wireless technologies (eg WiFi IEE802.11, WiMAX, Bluetooth and Zigbee, GPRS, or UMTS/W-CDMA), as well as domain-specific technologies such as TETRA and satellite links. IEEE802.11p [4] is the main wireless technology for vehicle to vehicle communication and the two main standards are IEEE WAVE [5] and ISO CALM [6]. In a disaster we envision a large hybrid ad-hoc and infrastructure network providing ad-hoc communication between vehicles of the different emergency services, vehicle to infrastructure, and vehicle to emergency services personnel. In addition, a wide range of sensing systems (such as rapidly deployed sensors to detect toxic gases and high temperatures in the incident area, including cameras and robots with sensor and information processing units) will be part of the combined network supported by the vehicular networks.

Generalized Access Networks (GANs) allow ubiquitous connectivity to ad-hoc networks. The Generalized Access Network (GAN) proposed provides an enhancement to the 3GPP General Access Network [7] using a radio access method which utilizes unlicensed spectrum on an all IP-based based broadband transport network. This is a B4G architecture, including mobile and wireless access networks, based on a flexible, seamless all-IP infrastructure with enhanced interworking features and global roaming for all supported access technologies. The supported radio access methods include wireline and radio access methods and are based on existing radio technologies using licensed and unlicensed spectrum, sharing the same network infrastructure among different operators and supporting appropriate levels of security and QoS. The approach is based on separating physical networks into a number of overlay networks to support, for example, separation of multiple mobile virtual operators and the formation of service networks and Virtual Private Networks (VPNs). The system incorporates: *a GAN operator* with a common infrastructure supporting multiple radio interface technologies through which mobile hosts and several forms of ad-hoc networks are attached, eg. Mesh networks, Wireless Sensor networks, BAN and PAN; *different forms of ad hoc communication*, involving emergency services personnel and vehicles; *multiple radio technologies* for communication with remote centres using the different GAN system and radio interfaces. Any existing radio technology can be supported, eg. TETRA, Zigbee, Wibree, Bluetooth, WLAN, GSM/GPRS, UMTS/W-CDMA, CDMA2000, UMTS/HSPA, WiMax, LTE or UMB. A GAN should be able to satisfy the following critical requirements: (1) Security support; (2) Resilience support; (3) Mobility and load distribution support; (4) Network management support; (5) Ad hoc networks for emergency management support. Some solutions that can be used within the GAN to satisfy these requirements are: (a) for support of strict QoS requirements in combination with the requirement on supporting different communication modes it is recommended to use MPLS in combination with RSVP-TE for point to multipoint traffic engineering label switched paths and MPLS multicast label; (b) for support of mobility requirements it is recommended to use the generic PMIP with multicast support; (c) for support of security, it is recommended to use IPSec combined with security solutions applied for MPLS.

3. Conclusions and Discussion

The challenges relating to emergency communications are being tackled by governments, industry, standards bodies and NGOs, and by many international fora, conferences and researchers. The IASC Working Group on Emergency Telecommunications addresses regulatory, operational and technical aspects of telecommunications for disaster relief. The Major Incident Medical Management and Support procedures have been adopted as a military standard in the UK, Netherlands, Italy and Sweden and are used in NATO training. Many research projects focus on the technical challenges surrounding communication and related ICT issues. The success of emergency response depends on access to timely and reliable information, however networks and systems are constrained by extreme operating conditions. The Hyperion projects investigate adaptive agent-based information management systems for enhancing quality and resilience of information made available to defense users [8]. Simulation tools, important for training responders in different emergency situations, may also be used as a means to evaluate alternative actions during operation. Examples are tools for real-time evaluation of optimal evacuation routes [9] and an on-line decision support system [10]. In [11] a multi-agent simulator is integrated with a real wireless sensor network. Robots equipped with wireless communications to create ad-hoc communication networks to assist trapped victims are proposed in [10]. In this paper we address part of the problem by proposing a combination of advanced networking technologies to support *communication and reliable transfer of information* during first response. We believe the proposed solution supports the identified requirements by enabling ubiquitous connectivity to ad-hoc networks, resilience in the face of damaged infrastructure, mobility and load distribution and adaptive network management. Major and critical challenges remain; they include: ensuring security of the emergency communications services, especially crucial in case of terrorist attack, and quality assuring correct system behaviour in such dynamic adaptive distributed systems.

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