Wireless Networks for Disaster Relief

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Abstract

Communication systems during disaster relief operations are crucial. The wireless systems are expected to perform at their best in hostile conditions with limited resources since thousands of lives are at stake. Past tragedies like tsunami in 2011, Sept-11 attacks, Hurricane Katrina have highlighted the serious flaws in the existing communication systems. In response to these tragedies, researchers are coming up with better solutions for wireless networks. In this paper, we first go through some general requirements for the performance of a network in disaster relief operations. The scope of this paper is to give an overview on these technologies in disaster relief operations. An overview of some of technologies that are being analyzed for disasters is given. Next, a few products currently being implemented for disaster relief operations are analyzed and lastly, various wireless applications that are in use are discussed.

Keywords:

Wireless in disaster relief, Wireless disaster relief, Self-Powered Wireless Communication, LTE, LTE disaster relief, disaster relief, Vodafone Instant Networks, Vodafone Instant Networks mini, Instant Networks, BRCK, disaster relief applications

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1. Introduction

Various man-made and natural disasters have highlighted a need for more effective systems to aid in warning and rescue operations. There are two common problems that come up during disasters. The first is the lack of communication systems to send disaster warnings and to transmit emergency information that aid rescue in operations. The second is lack of access to affected areas for the rescue operations due to the dangers involved.

During disasters, the Local Area Networks (LANs) are also affected and they cannot be used for communication during disaster.

Rescue operations take place under hostile conditions and the in order to cope, the networks deployed should be robust and resilient. To ensure this, general understanding of the design requirements of a network to be established during disasters is needed. An emergency network has to conform to a strict Quality of Service (QoS) to ensure optimized performance with limited resources. A stringent time constraint must be maintained as lives are at stake. In the general requirements section, a overview of these requirements are given.

The networks currently used during disaster relief have a number of issues which include but are not limited to interoperability of devices between first responder organizations, network congestions and network speed. Suggested future network technologies and applications that currently implemented are also discussed.

2. General Requirements

Unlike wireless communications in an organization or general communications, the wireless networks used in disaster relief have specific needs to be fulfilled. The requirements are discussed based on research for China's Broadband Wireless Trunking project whose major goal is application of wireless technology for Public Protection and Disaster Relief [Shao13].

- **Wireless communication techniques:**
  Although the current implementation for communication during disaster relief is based on Terrestrial Trunk Radio which uses narrowband techniques, Long Term Evolution (LTE) is expected to be the primary technique for future implementations.
- **Spectrum Sharing:**
  Finding an optimal way to share the spectrum is very important, since the resources available during disaster recovery would be limited but the demand would be very high.
- **Dispatch and control:**
  In a typical emergency communication system, the messages are routed hierarchically through a chain of dispatch. The communication infrastructure being implemented needs to support the hierarchical dispatch and control structure.
- **Provide Integrated Services:**
  Converging voice, data and video information and integrating all communications from the multimedia dispatch center would enable fast and effective real-time decision making.
- **Security and Reliability:**
  Reliability of an emergency communication network is important as it would be required to operate in hostile environments.The messages exchanged could be classified information, hence security is crucial in these networks.
- **Scalability and reconfiguration:**
  The scale and nature of each disaster would be different and emergency networks deployed should be easily reconfigurable and scalable to accommodate these requirements.
- **Communication and response:**
  The communication and response in an emergency network would be real-time and having low latency is crucial. As seen above, the wireless networks deployed in disaster areas should be more advanced as a whole with a major focus on optimizing the use of limited resources. The currently implemented network solutions have limited capabilities and need to be upgraded. In the next section, we discuss briefly about solutions suggested for disaster relief.

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3. Technologies recommended for disaster relief in future

In this section, a few alternatives for existing technologies are discussed. The one of the main issues with existing technology for disaster relief is lack of reliable support for data communication. Although existing PMR based technologies do support data communication, the these networks get congested easily when the data traffic increases. The other issue with the existing wireless technology is lack of wireless access in inhospitable terrains. When access is restricted to rescue personnel for a particular location, they would be unable to set up emergency communications network which would in turn delay all other activities. Alternatives for these issues are discussed below.

3.1 Self-Powered Wireless Communication Platform (SPWC)

The main aim of a SPWC is to create a self-sustaining and fast-deployable network to aid in relief operations. Flying objects that use Low Altitude Platform (LAP) to communicate directly with the ground units are recommended for this process. During disaster response, time is crucial in saving lives and it is unrealistic expect significant power back up. SPWC might be the most economical solution.[Taeho11]

In SPWC, Unmanned Aerial Vehicles (UAV) are deployed in LAP as opposed to High Altitude Platform since the High Altitude Platform need to satellite to host the networks which significantly increases the cost. The LAP allows direct communication with the ground equipment which is not supported by High Altitude Platforms. Cellular technology is recommended for communication.

There are two types of communications used:
(i) Air to Ground Communication - for the UAV to communicate with the ground equipment using 2G or 3G
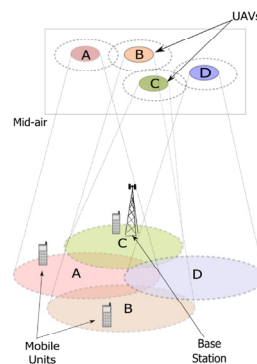(ii) Air to Air Communication - for the UAV to communicate with each other using a wireless mesh.

Figure 1 Self Powered Wireless Communication System

In the above figure, if user B wants to communicate with user A, information is passed from user B to the UAV B which then passes the information to UAV A and finally, UAV A passes the information to user A. One or more of the UAVs (eg. C) would be equipped to communicate with the outside world and the other UAVs are required to pass data to the outside world through these UVAs (in this case, C).

The researchers are at early stages of prototyping. In their prototype, GSM is being used for air-to-ground communications. Using GSM allows the researchers to use open-source projects to implement base stations and more than 70% of the world uses GSM. IEEE 802.11s standard is used. The IEEE 802.11s is incomplete but the researchers were able to gain access to a working code for the standard in Linux Kernel. For a flying object, the researchers are experimenting with both, a tethered approach and a UAV object. In tethered approach, a tethered balloon is used with a flying object. Although it does not require power to keep it in air, it is not easy to deploy.

SPWC would not just be an economically viable solution, it would also provide access to areas that are restricted to relief workers because of the dangers involved. During disasters, a lot of lives are lost since they are unable to be rescued on time. This technology would be able to provide crucial information under these circumstances for the first responders and could save a lot of lives. In the next section, we see LTE as an alternate technology for data communications during disaster relief.

3.2 Long Term Evolution (LTE)

The currently implemented Private/Professional Mobile Radio (PMR) based technologies for Public Protection and Disaster Relief (PPDR) have a rich set of applications for voice-centric services. As the world is becoming more data-centric, future demands are shifting focus from voice-centric to data-intensive applications for PPDR. A few attempts have been made to improve the functionality on PMR with wide-band capabilities but solutions lag behind the existing commercial wireless networks. In this section, we see a proposed solution that uses Long Term Evolution (LTE) in PPDR. It is not used as a replacement for PMR but as a technology that would work along with it in PPDR for data-centric applications. [Ferrus13]

The LTE provides connectivity between the User Devices (UD) and the IP networks. It provides high rate at very low latency and these connections can be used by almost any application that uses IP communication. LTE is basically divided into two parts: the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) and the Evolved Packet Core. The E-UTRAN contains the base stations called the evolved NodeBs (eNBs) that implements the radio protocol stack and it is responsible for radio transmission. The EPC consists of PDN Gateway for IP connectivity to external IP networks, Serving Gateway to handle user traffic to or from E-UTRAN and Mobility Management Entity which takes care of control information. The Evolved Packet System (EPS) bearer services between the UD and the PDN Gateway is used to establish IP connectivity, where EPS bearer is the Quality of Service control.

During disasters, it is absolutely crucial that the important calls are always established. LTE can be used to support Multimedia Priority Services (MPS). MPS specified by 3GPP is a subscription based service that can be used during network congestion to deliver and complete high priority tasks. A set of priority levels would be created, QoS parameters would be defined for each priority level and assigned to the MPS subscribers. The decision making on the QoS parameters would be supported by the Policy and Charging Rules Function.
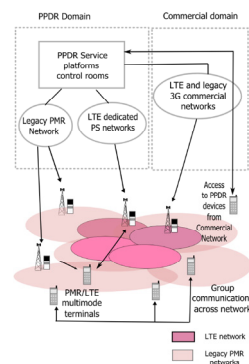

Figure 2 Suggested system for PPDR using LTE

Disasters are unpredictable and lack of coverage, damaged infrastructure, etc can make it almost impossible to provide support for the first responders even if dedicated PSNs are in place. The figure depicts shows an overview of the system suggested for future PPDR networks. The PPDR services platform would be accessed by both, the commercial networks as well as the emergency services. The Legacy PMR network (like TETRA, TETRAPOL, Project 25, et) and dedicate LTE dedicated PSN would be used for disaster relief and interact with the ground units to transfer emergency messages.

In order to implement the above solution, appropriate spectrum bands need to be identified. Although traditionally PPDR has always been allocated exclusive-use spectrum band, spectrum-sharing has been

suggested in light of growing competition for spectrum band and the high fluctuations in the band usage. A spectrum of 10+10Mhz in 700 MHz band exclusively for PPDR has currently been allocated in United States. For spectrum sharing, the most recommended options are TV whitespaces and the second is temporary licensed access to shared spectrum. Apart from the above recommendations, additional spectrum of 1 GHz would also be used for local area communications.

As of January 2013, more than 100 LTE networks have been deployed and LTE has been endorsed as the broadband standard for PPDR communications by the National Safety Telecommunications Council and other organizations in US. LTE is gaining momentum as the preferred technology for data communications in PPDR. ASTRID, the Belgium national provider of mission critical applications has unveiled it plan to use LTE to provide data communications to it PPDR users.

3.3 Self Powered Micro Wireless Ballooned Network

The idea for self ballooning in disaster relief was created as a means to solve the problem encountered by Wide area Disaster information Network (WDN). The WDN is effective in providing resident safe information and video communications between the disaster information center and evacuation places. The WDN relies on wired as well as wireless communication and is also affected by disasters and the self powered supplied micro wireless ballooned network has been proposed by Japanese researchers to solve this problem.[Arimura13]

The components self powered micro wireless balloon network are: multiple wireless balloon access nodes, fixed access point and end devices (mobile PC and IP telephones). During disasters, the wireless balloon nodes connect with each other in the sky to form large ad-hoc networks which are used for emergency communications. The nodes are powered by a solar panel power supply unit or by a power battery for emergency or vehicle on the ground via a very thin wire. The recommended height for the balloons is 40-100 m.
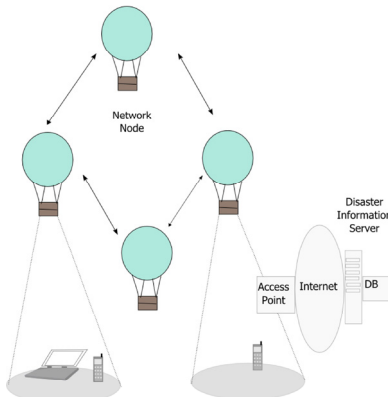

Figure 3 Wireless Ballooned Network for disaster relief

The above diagram gives a visual idea on the self powered wireless ballooned network. Two types of high-speed wireless LANs are used in communication, one for horizontal communication and the other for vertical communication. The commercially available balloons are fitted with wireless LANs with auto-configuration function and launched in the air. The auto-configuration function would enable the device to automatically connect to other LANs based on the power of the signal. A horizontal communication is established by launching a number of balloons into the sky forming an ad-hoc network which is organized into a minimum spanning tree configuration. The vertical communication establishes a connection between the balloon nodes in the air to the Internet or Wide Area Network through the access point.

The mobile PC is used to access data information like the rescue information, shelter information, relief goods information, etc. The VoIP are used when the networks are congested for voice communications. An omni-directional camera could be attached to the balloon nodes and visual information on the disaster area could be transmitted to first responders and other rescue teams.

A prototype for the system was created. The researchers used IEEE 802.11j in frequency band of 2.4 GHz, 250 mW signal power at 54 Mbps and covered a distance of 600 m for horizontal communication. For vertical communication, IEEE 802.11b,g in 4.9 GHz frequency band, 10 mW signal power, data rate of 54 Mbps and maximum distance coverage of 100 m was used. The maximum communication distance was evaluated and was determined to be 600 m for this system. It was also determined that as the number of hops increased the throughput decreased (from 18.3 Mbps to 7.83 Mbps) and the response time increased (from 20 ms to 250 ms). The video performance of the cameras were analyzed to be sufficient to transmit videos in real-time (with frame rate of 10-15 frames per second).

The researchers determined the system to be a useful option for disaster relief as the statistics listed above were in the desired range. The decrease in throughput and increase in response time were not significant enough to affect performance in disaster relief operations. The self powered wireless ballooned network is organized in the sky and hence is not affected by land based disasters which makes them a reliable option for disaster relief. The networks are formed instantly based on the signal power using the auto-configuration function. They are suitable for emergency communications in disaster areas and they can especially be useful in places where human access is limited.

In this section, we have focused on some possible future technologies for wireless in disaster relief. As seen above, the reasons to implement SPWC and Self Powered Micro Wireless Ballooned Network are very strong. It would be critical in disaster areas when human access is restricted due to the dangers involved. Furthermore, LTE was discussed as an alternate technology for data-centric applications. While PMR has a rich set of voice-based applications and is expected to remain as the primary voice based standard for PPDR applications, it is not very efficient in handling data communications. In the next section, some wireless products that are currently being used for disaster relief are discussed.

4. Wireless Products for Disaster Relief

A few products that target disaster relief are already available and are being implemented.Of these, the BRCK, Vodafone Instant Networks (VIN) and Vodafone Instant Network mini are interesting products that are very effective. While the VIN is focused on large scale relief operations, the BRCK focuses on providing network access to individuals. The VIN mini, which is almost the size of a ruck sack enables wireless access in hard to access environments. More information on these products and their applications are discussed below.

4.1 Vodafone Instant Networks

The VIN is an ultra-portable GSM network unit for emergency communications. The GSM unit weighs less than a 100 kg and comes in 4 packs. These devices easily fit into the back of a car, can be transported in commercial flights and are great for deployment in disaster hit areas. The networks can be established in less than 40 minutes of reaching the site and covers a radius of around 5 km. [VIN] The VIN components include a Base Transceiver Station Radio Frequency (BTS RF) unit that facilitates communication between user devices and the network, a Rectifier to convert AC to DC, genset and battery pack for power and an antenna for transmission.

On November 2013 Typhoon Haiyan hit the Philippines, took more than 6000 lives, with over 1000 people missing and property damage of around 1.5 Billion dollars. People were stranded without any communication to the outside world and unable to receive help. In a few days, Vodafone dispatched the VIN to the Philippines. Setting up the network finally enabled communication with the aid agencies, with the families of the victims and slowly helped them to begin rebuilding their lives.[VIN][Lee13]

This is not the first time these portable mobile network units have been used for disaster relief. In February 2012, the VIN was used to aid relief operations and to assist in delivering food after a severe drought at Kaikor, Northern Kenya [VIN]. Vodafone India also set up VIN in Chhatrapur, Ganjam district, India to provide

assistance after the cyclone Phailini hit India which prompted the largest evacuation in past 23 years [Bafna13].

4.2 Vodafone Instant Network mini

In February 2014, Vodafone unveiled VIN mini to establish emergency communications in areas that are very hard to reach. It is around 11 kg in weight and can be setup in less than 10 minutes by 1 person. It can be deployed by non-technical people. It is not a replacement for VIN. The VIN mini was developed by Vodafone Spain in collaboration with Huawei and Telecoms Sans Frontieres.

The VIN mini can cover an area of about 100 meter radius and once deployed, it uses the satellite to host the network. Although the network does not support data to avoid congestion, it can currently support SMS and up to 5 concurrent voice calls using secure 2G GSM connection. A Vodafone SIM card or the SIM card of a local partner is required to access the network. In developing countries, its common for people to have multiple SIM cards to compensate for patchy networks. There would also be a public access point where they provide the SIM cards for free to anyone who does not have the SIM card.The VIM has been tested and is ready for deployment. [Collins14] [Curtis14]

4.3 BRCK

The BRCK, a battery-powered modem/router was created by Ushahidi, Kenyan-based company, was initially created as a solution to frequent network outages that they faced in everyday life. It has a battery backup of about 8 hours and provides seamless connection between the Wi-Fi, Ethernet and 3/4G. Although created on a much smaller scale with limited power, this portable can be used by individuals during disasters. [Ushahidi13]

The BRCK uses IEEE 802.11 b/g/n wireless standard. It uses 10/100 Mbps WAN/LAN port and accommodates Wifi Bridge and Client modes. For security, it uses WPA/WPA2 PSK, WPA Enterprise, and WEP Encryption. The BRCK uses quad-band GPRS/EDGE in 850/900/1800/1900 MHz and HSPA with HSPA/UMTS is 900/1900/2100 MHz used. BRCK vMNO is build in the device for global connectivity without SIM cards. [BRCK]

The products mentioned in this section are unique and very effective innovations by the respective companies. Apart from hardware based products discussed above, there other software based products which use wireless communications that are just as important. The next section give a brief overview on some of these products.

5. Applications Currently used in Disaster Relief

In response to various disasters, both man-made and natural, a number of companies and some individuals are providing solutions by creating applications that use mobile and wireless technology for disaster warning and relief operations. The applications currently used during disaster relief and emergency focus mainly on early warning information and emergency response information. Some of these are discussed below.

Wildfires in the western United States during the summer of 2012 in Colorado, which caused a loss of a lot of lives and property worth millions of dollars, accentuated the need for a reliable warning system. The alert systems being deployed at the time were landline-based telephone warning systems which was not effective as the emergency information did not reach the victims. The Department of Homeland Security's Science & Technology Directorate (DHS S & T) and Federal Emergency Management Agency (FEMA), collaborated with the mobile service providers to create Wireless Emergency Alerts (WEA). The phones need to be WEA enabled. During an emergency, an authorized government agency would send the emergency messages via. the mobile service provider. [Anderson13][WEAS]

LiveSafe is an application that focuses on campus safety was created by Kristina Anderson. It enables two-way communication between the campus police and the students using email, voice or push notification via Wi-Fi

or data connections. Kristina, a survivor of the Virginia Tech shooting in April 2007 who was shot 3 times in the incident, feels that an application like this could have given her and her classmates the opportunity to get to safety. She was shot at 9:30 am but the first shooting had occurred at 7:05 am. Despite a two and half hour time difference, no one in her class was aware of the shootings prior to the gunman entering her class. A number of colleges have started adopting mobile applications for emergency responses. [Fox13]

Following the earthquake in Haiti (2010), Google Inc. crisis response team which created software tools to aid in emergencies. The Resources page displays information critical to the particular disaster, The Person Finder application enables the victims to get in touch with friends and families and the Crisis Map displays important location based information like shelters, etc. [Google]

Apple has launched various applications in the App Store that target disaster warning and response. ubAlert, is a global disaster warning application that aim to provide emergency warnings in a timely manner by processing data from various global institutions[Apple1]. Quake Watch is an application that is used to monitor the earthquakes all over the world [West13]. Shelter View is used to find the nearest shelters for the victims in disaster areas. [Apple2]

Communities and Governments around the world are adopting wireless communication for emergency response and disaster relief. For example, the Bangladeshi Government has announced a variation of the normal SMS for emergency warnings. In order to ensure that more people see the warning messages, they do not go to the inbox but flash on the user screen. [West13]

Wireless technologies are becoming more prevalent in disaster relief and warning as they are being proven to be indispensable in emergencies. Wireless technology is the ideal option for these situations since the Local Area Networks and landline-based telephones are also affected or in the worst case, completely collapse. In the next section, a brief summary is provided.

6. Summary

Ensuring strong communication during disaster relief is very important for rescue operations, to locate and give aid, provide access, etc. Tragedies caused by man-made and natural disasters have highlighted serious flaws in the systems currently in place and the need for more effective disaster warning and response system. The overview of the design requirements for emergency networks has shown that the wireless communications currently used in organizations are not very effective for emergency situations. Wireless networks are currently undergoing extensive research to create better wireless systems for disasters and the results can be seen in products like VIN.

Wireless networks that handle data traffic well are required as the current solutions focus more on voice communication. Network congestion is another issue that needs to be resolved. The main challenge is to meet these needs under unpredictable conditions and very limited resources. A lot of progress has been made in wireless technology for disaster relief and the ongoing research in this area is very promising.

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List of Acronyms

- AC - Alternaing Current
- BTS RF - Base Transceiver Station Radio Frequency
- DC - Direct Current
- DHS S&T - Department of Homeland Security's Science & Technology Directorate
- FEMA - Federal Emergency Management Agency
- GSM - Global System for Mobile communications
- LTE - Long Term Evolution

- LAN - Local Area Networks
- QoS - Quality of Service
- UAV - Unmanned Aerial Vehicles
- LAP - Low Altitude Platform
- PPDR - Public Protection and Disaster Relief
- PMR - Private/Professional Mobile Radio
- PSN - Public Safety Networks
- SPWC - Self-Powered Wireless Communication Platform
- VIN - Vodafone Instant Networks
- WEA - Wireless Emergency Alerts

Last Modified: April 30, 2014
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