An Overview of Emergency Communication Technologies in Australia

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Paper presented at the Australian and New Zealand Disaster and Emergency Management Conference, Gold Coast (QLD), 30 - 31 May 2016

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Abstract: This paper presents a brief overview of communication technologies and infrastructure available for emergency operations in Australia. It also highlights significant issues in current operational solutions and explores future technologies that can be used to address these challenges.

Keywords: Emergency Communication, Software Defined Networking, Big data, Software Defined Radio, 5G

Introduction

Australia is considered to be the most fire-prone country on earth. The threat of natural disasters such as bushfires and floods affect many communities. Effective emergency operations are critical to minimise the loss from natural disasters since first responders need to exchange information (i.e., voice and data) in a timely manner to develop situational awareness and coordinate relief efforts. However, natural disasters often result in widespread degraded communications infrastructure while placing exceptional demands on that same infrastructure (FCC/FEMA 2012). Furthermore, natural disasters or other emergency events are usually unplanned by definition, causing panic conditions. In large-scale natural disasters, different organisations may be involved with disparate technologies and communication systems. Security requirements including communication and information protection can exacerbate the interoperability issue. For example, interoperability issues were the main factors causing the numerous breakdowns of communication systems during emergency operations in Australia over the last few years (ABC Adelaide, 2015; Hyde, 2013).

Communication technologies have evolved rapidly over the last decades. There are a number of contemporary wireless personal communication devices (mobile phones, personal computers, personal digital assistants and other devices) employing advanced communication technologies that can be used in emergencies. These include cellular networks (NGMN, 2015; APCO 25, 2016), wireless broadband networks (IEEE-SA, 2012), radio links utilising VHF/UHF voice and data networks (SINCGARS, 2015), and satellite communications (Kose et al., 2012). Building resilient emergency communication networks that can cover the large geographical regions in Australia is challenging as these technologies are predominantly

designed for commercial or military use.

In this paper, we provide a literature survey of the current technologies and research activities to address the communication challenges in emergency operations in Australia. Our main sources are published research papers, government reports, and international technical standard documents. A similar survey for emergency communications in the European and the USA regions is provided in (Baldini et al., 2014). The main differences between this paper and the study in (Baldini et al., 2014) are the focus on emergency communications in Australia and recent developments in Software Defined Radio, Software Defined Networking and fifth generation cellular technology (5G).

Operational Communication Requirements

The communications requirements for an emergency operation are scenario dependent. We summarise below two of the most basic services and their requirements.

1. Voice: This is the primary form of communication. The essential attributes for emergency voice communication are fast-call setup, high audio quality, emergency alerting and support for secure/encrypted communications (Budka et al., 2011). Voice connections require a stringent bound on a maximum drop rate of 5% and a maximum delay of 40 milliseconds (ms) to ensure comprehension (Department of Homeland Security, 2007). Voice traffic rate is in the order of kbps. Call setup time needs to be below 400 ms, much lower than requirements for commercial networks. Voice can be set up in a group call in emergency situations and call prioritisation is often required in case of congestion. Push-to-Talk (PTT) is half-duplex voice communication and is widely used in emergency communications.
2. Data: Data services are becoming more important in modern emergency communications. These include data messaging, video streaming, location data and others. Each of these services requires specific Quality of Service (QoS) requirements. Video requires Mbit/s data rate whereas location services only require Kbit/s. Messaging is non-interactive data that can contain text or image and generally requires very low bit rate.

Current Communication Systems

Emergency communication systems are traditionally built for and dedicated to one or a few organisations in each state. The small volumes of equipment in each case results in the dynamics of a niche market. The configuration and deployment of these networks are therefore, expensive even with the provision of free wireless spectrum (ACMA, 2012).

Government Radio Networks

The Government Radio Network (GRN) incorporates multiple inter-linked sites across Australia, organised at the state level, which provide a range of radio communications services for government and public services.

Its aim is to consolidate resources into a common network with greater coverage and reliability than separate smaller networks managed independently by the individual services. It also offers effective communication between services and agencies, facilitating coordination of actions when multiple service branches or emergency units are involved.

Most GRNs in Australia are built on the APCO 25 (P25) standard (APCO 25, 2016). P25 requires a fixed network infrastructure with a set of base stations, each covering a range of a few kilometres depending on the terrain. P25 uses Frequency Division Multiple Access (FDMA) access method and QPSK-C modulation. Radios can communicate in analogue mode with other P25 radios. It mainly supports voice but data transmission is also possible with rate of up to 9.6 kbps. P25 supports a rich set of services including messaging, group calls, and broadcast. Data is transferred using the Internet Protocol (IP), which allows running a multitude of applications.

For example, in South Australia all emergency services and some government agencies use the SA-GRN, a network of over 200 radio sites linked together to form a voice, data and paging network that covers approximately 96% of the population of South Australia and more than 226,000 sq km of landmass (SA-AGD, 2015). There are approximately 20,000 active devices across more than 20 agencies. The network is currently undergoing a major upgrade with an expected completion date in 2017 (SA-AGD, 2015).

The GRN in other states generally exhibit commonality with the SA GRN approach although there are some differences related to historical developments and local priorities (GRN, 2016). The NSW GRN is also a P25-based solution and is currently one of the largest in the

world. It includes coverage of Canberra and the Australian Capital Territory (ACT). The Victorian Government Radio Networks include the Melbourne Metropolitan Radio (MMR), the Victorian StateNet Mobile Radio Network (SMR), and Regional Mobile Radio. Queensland uses the Government Wireless Network (GWN) and Western Australia uses the WA Emergency Radio Network (WAERN). Tasmanian emergency services use the Trunk Mobile Radio Network that employs a Gateway to enable interoperation between otherwise separate radio communications for their emergency services. Northern Territory Police, Fire & Emergency Services (NTPFES) employ a P25-based digital radio network solution across emergency services.

Commercial Cellular Networks

Commercial cellular wireless networks like UMTS and LTE have not been designed for emergency purposes but provide an important communication option during emergencies. There are significant coverage overlaps between GRNs and commercial cellular networks, especially in high population density areas. Agencies (e.g. SAPOL mobile data terminals) are increasingly using commercial cellular networks due to the lack of coverage and low data rate of the GRNs.

Services that require data communication in South Australia often have a dedicated terminal for the Telstra NextG network in addition to a GRN adapter. For example, South Australian Ambulance Services (SAAS) ambulances are fitted with the Motorola XTL-2500 digital radio and two XTS-2500 hand-held radios for accessing GRN, but also a Motorola Mobile Data Terminal (MDT) to access the 3G network. These data connections cater for a range of in-vehicle applications such as incident dispatch and mapping functions integrated with the South Australia Computer Aided Dispatch (SACAD) system (SA-AGD, 2015).

Governments around the world have been advocating for adapting cellular technology for emergency communications. The United States Federal Communications Commission (FCC) white paper for Public Safety and Nationwide Interoperable Broadband Network (FCC, 2010) recommended that emergency communications leverage the advantage of the fourth generation cellular technology (LTE). Even though FirstNet is building a US wide coast-to-coast public safety network based on LTE broadband technology (FirstNet, 2016), there are still major challenges that can hinder efficient operation of such networks. The main challenges with adopting cellular technology for emergency communication in Australia

include the significant cost of providing universal coverage, and the lack of network resiliency and severe network congestion during natural disasters such as bushfires (ABC Adelaide, 2015).

Satellite

Satellite networks provide the advantage that they do not rely on terrestrial infrastructure like cellular or GRN networks. They have a very large coverage and therefore, are particularly useful in natural disaster scenarios. Satellite solutions can provide a full suite of voice and data solutions to support operations in the early phase of an emergency. Users accessing satellite services require a dedicated user terminal or satellite dish. Satellite broadband services have limited capabilities compared to terrestrial broadband solutions.

Satellite communications have wider role than facilitating communications in remote areas – during catastrophic events that disable terrestrial services; there is often no other reliable option. For example, communications breakdowns occurred during the Pinery bushfire in South Australia, November 2015 (ABC Adelaide, 2015).

There are now several organisations offering competitive commercial satellite solutions for emergency communications in Australia. For example, Australian Satellite Corporation (ASC) offer a number of turnkey solutions for the emergency response sector, including rapid auto deploy systems and special satellite plans that take into account infrequent operational requirements. Despite these competitive offerings, satellite connections can have high latency due to the transmission times between the user terminal and satellite and the satellite and ground station. Satellite communications are also susceptible to atmospheric conditions such as heavy rain, humidity and bushfire smoke (Vallado et al., 2014). Furthermore, mobile satellite devices are often more expensive, larger, and more power-hungry than their terrestrial counterparts, which makes them less attractive for many first responders.

Two-way Radio Communications

Two-way radio communications that can be used in emergency situations include HF, VHF and UHF (non-GRN) technologies. UHF and VHF radios provide short range, line-of-sight communications. The most common systems use the UHF Citizen Band (CB) that does not require a license. They typically operate with a range of 15km with a 5W radio, the

maximum legal power for UHF CB radio. While relatively unreliable as a mode of primary communication in an emergency, they can function as a backup communication method when other methods fail.

HF radios provide long-range communications person-to-person, or person-to-base. Compared to UHF units they are more expensive, bulkier, heavier and require a license. HF radios can operate beyond line-of-sight (BLOS) using one of two possible propagation modes. The first mode is called a "ground wave" and follows the contour of the ground for a short distance (1-5 km) depending on conditions, even further if over the sea. The second is the "sky wave" and reflects off the ionosphere for a narrow band of frequencies that are dependent on various environmental conditions. These conditions include time of day, season of the year, time in solar sun spot cycle (an 11-year long cycle), weather effects, as well as other more subtle phenomena. The achievable ranges depend on angle of incidence, transmit power and frequency. A particularly useful technique uses what is called the "near vertical incidence sky wave" (NVIS), which enables communication out of deep gorges and over mountain ranges.

There are also a number of services on HF that can be useful in remote areas, such as weather forecasts and radiophone systems (these allow you to connect an HF radio into the standard telephone network). Although HF radio properties seem to be well suited to emergency communications scenarios, they do have limitations and in particular, effective use of an HF radio technology requires considerable knowledge and training.

Cross Technology Issue: Interoperability

In addition to issues specific each individual technology discussed in previous sections, interoperability between the technologies is a major challenge in emergency communications.

The use of commercial protocols and systems has made the deployment of emergency communication equipment much easier, but introduces its own challenges. Common networking equipment is not purpose built to survive the rigours of an emergency environment, and is usually intended to be installed and maintained by specialist IT staff, not the emergency crews that have traditionally run such networks. One of the most difficult aspects of operating emergency networks is the ability to integrate different networking technologies and to rapidly reconfigure networks to adapt to a changing environment. The lack of interoperability between communications networks was found to have seriously

impacted on the emergency response in the 2013 Tasmanian bushfire (Hyde, 2013).

There are proprietary devices that can switch communications traffic between packet radio networks such as Motorola VALR mission critical architecture (Motorola, 2013) and Harris Corporation's VIDA mission-critical platform (Harris Corporation, 2012). However, they still require manual intervention and are often slow. The requirement for at least near real-time response for many of the supported systems thus presents substantial challenges for emergency communication systems.

Future Technologies

Significant research efforts (Fantacci et al., 2016; Rawat et al., 2015; Sbeiti et al., 2016; Mahilescu et al., 2015; Baldini et al., 2014; Ghafoor et al., 2015) have tried to address one or more of the issues identified in the previous sections. We summarise here the research areas with real potential for improving emergency communications in Australia, including 802.11 wireless networks, Software Defined Radio (SDR), Software Defined Networking (SDN), Data Science, device-to-device communications and the fifth generation mobile networks (5G).

Wireless Mesh Networks (WMN) and Mobile Ad-hoc Network (MANET)

A cost effective and infrastructure-less approach to provide temporary coverage in an expedient manner is to use wireless, mobile temporary and ad-hoc communications (Portman et al., 2012).

Wireless Mesh Networks (WMNs) and Mobile Ad-hoc Networks (MANETs) can provide wireless network coverage of large areas without relying on a wired backbone infrastructure or dedicated access points. In WMNs, a collection of wireless mesh routers provides network access to wireless clients, similar to access points in traditional wireless local area network (WLANs). However, communication between these mesh routers is achieved via the wireless network, typically involving multiple wireless hops. One or multiple mesh routers that are connected to the Internet can then serve as gateways and provide Internet connectivity for the entire mesh network.

WMNs/MANETs can be deployed as a temporary network created for a specific incident only (SAFECOM, 2004). This type of network is necessary when fixed infrastructure

networks are unavailable at the incident scene, either because they have been destroyed or they simply do not exist. Temporary networks allow first responders to share mission critical data and to coordinate their recovery efforts.

Unmanned Aerial Vehicles (UAVs) can be used to extend the reach of WMNs and MANETs (Sbeiti et al., 2016). Queensland Fire and Emergency Services (QFES) intend to use the unmanned aircraft to respond to emergencies by the end of the year. Queensland University of Technology-based Australian Research Centre for Aerospace Automation (ARCAA) recently became the first research facility in Australia to gain Civil Aviation Safety Authority (CASA) certification to fly unmanned aerial vehicles (UAVs).

Despite the great promises of WMN and MANET technologies as a low cost solution for emergency communication in Australia, no large-scale deployment is yet known. There are now several commercial WMN and MANET solutions available (Aruba Networks, 2012). Among the multiple challenges facing WMN technologies are the complexity, scalability, security and resiliency issues. Multiple research programs worldwide are addressing these challenges including the South Australian based Serval project (Gardner-Stephen et al., 2012).

Software Defined Radio

The concept of software-defined radio (SDR) was initiated by Mitola (Mitola, 1993) to signal the shift from hardware designed radio components (e.g. mixers, filters, amplifiers, modulators/demodulators, detectors, etc.) to systems where the majority of the functionality is defined in software. The main idea is to have a single communication device that could run different waveforms in software.

For emergency communications, such a device will be able to interoperate with different wireless communication systems. By allowing the possibility of upgrading the waveforms with the software updates, SDR is a great investment choice for emergency organisations by prolonging the useful service life of communication systems.

Prototypes of emergency communications systems using SDR have been developed in Europe and Japan (Baldini et al., 2014b; Ghafoor et al., 2015). Even though the commercialisation of SDR has recently accelerated with military products from Thales (AN/PRC-148 JEM) and Harris (Falcon III AN/PRC-152(C)), wide spread deployment of

SDR in emergency communication still faces serious challenges including meeting the computational requirements, security and RF hardware design issues (Ulversoy et al., 2010).

Software Defined Networking

Similar to SDR, Software Defined Networking (SDN) provides a method to programmatically control networks, making it easier to integrate multiple systems, deploy new applications and services as well as tune network policy and performance. SDN enables users of network hardware can fully control their networks without being constrained by the proprietary controls traditionally inherent in the networking.

Technologies to build SDN networks are now available (McKeown et al., 2009; Gude et al., 2008) with a range of successful commercial applications developed (Jain et al., 2013; Davy et al., 2012; Krey et al., 2012). These implementations, however, operate in environments that are different to emergency operations. They rely on a reliable and fixed infrastructure to collect information about the network and disseminate instructions to the network elements. Extending the current SDN technologies to provide reliable and robust communication networks for emergency operations is the focus of much current research.

In (Mahilescu et al., 2015), a Radio Integration Unit (RIU) was developed to support multiple network connections with different wireless technologies and thus, allowing for interoperability between these networks. The RIU unit was built over the SDN OpenvSwitch implementation and RYU controller. The RIU can make the best decisions when transferring data over either the GRN network, 3G mobile connections, or even a (more expensive) satellite connection depending on the coverage, bandwidth requirements and cost considerations.

Big Data and Data Science

Effective responses in emergency situations are reliant on the availability of archived information as well as on the effective, real-time integration and blending of data streaming from various channels including sensors, satellites, social media feeds, photos, video and smart phones (Fosso-Wamba et al., 2012). Data Science techniques such as Machine Learning algorithms can then be applied to derive insights and make predictions to guide intervention. Big Data systems such as those developed by Palantir (www.palantir.com) and Terra Seismic are being used to predict disasters due to human activity and to monitor

satellite data and environmental factors in real time to predict earthquakes, respectively.

Large-scale data processing requires agile, centrally managed networks with decentralised domains. As mentioned previously, current networks do not meet these as well as scalability requirements. However, SDN can enable networks for "Big Data" by allowing for changing traffic patterns, enabling access to geographically distributed servers/databases and public/private clouds as well as providing bandwidth on demand (Bushong et al., 2013). The IBM platform Big SQL, is an example where big data analysis based on Hadoop has been integrated with SDN (Menezes et al., 2014).

Fifth Generation Mobile Cellular Technology (5G)

As the fourth generation (Long Term Evolution) mobile cellular networks are being rolled out, research into the fifth generation (5G) is well underway. The first commercial 5G networks are expected to be available in 2020. Supporting emergency communications is one of 5G main use cases (NGMN, 2015).

By leveraging advances in SDR, SDN, big data and other technologies 5G is able to provide robust communications in case of natural disasters such as bushfires and floods. One of the promising technologies that is being considered in the future 5G standard Long Term Evolution (LTE) Release 13 and beyond is Device-to-Device communications (D2D). D2D can be used for different proximity-based services where the users locate their neighbours and benefit from various services like social apps, and alert messages. More works (Nishiyama et al., 2014; Gardner-Stephen et al., 2012) have developed a prototype of D2D relaying smartphone that enables sending out emergency messages from disconnected areas (e.g., mountains, islands) and sharing of information between people gathered in evacuation centres. In addition to basic communications (e.g., voice, text messages), Search and Rescue (SAR) would also be enhanced via location information (NGMN, 2015).

Summary and Conclusion

In this paper, we have explored the current state of emergency communication systems in Australia and provide an overview of the technologies and their limitations. An analysis of the advantages and value proposition of advanced networking technologies such as WMN, SDR and SDN has been articulated. This has been done in the context of providing

synergistic benefits through enabling other advanced technologies like Big Data Analytics. These technologies will become integral parts of the fifth generation mobile networks (5G).

Acknowledgement

The authors would like to acknowledge the support of the Australian Research Council through grant LP140100489.

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