Innovative Technology for Disaster Area Communications: Background and Recommendations

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Communications are vital to successful relief efforts before, during, and after a natural or man-made disaster (“Emergency Communications,” n.d., “Emergency communication system,” 2015). Infrastructure, if it existed prior to the disaster, is often severely impacted by the disaster. Consequently, improving communication networks in disaster situations is an important goal of many relief organizations, and research continues to attempt to improve reliability, scalability, and interoperability of these emergency communication networks (“Wireless mesh network,” 2015). UNICEF is often a first responder to natural disasters in developing countries, providing emergency medical assistance to victims of the disaster and requires reliable communication systems to coordinate efforts with both UNICEF members and other relief organizations.

According to UNICEF, an effective disaster area communication network for their organization must have the following attributes:

* Self-contained: Due to the fragile nature of infrastructure in disaster areas (Fragkiadakis, Askoxylakis, Tragos, & Verikoukis, 2011), it cannot assume the existence of any existing infrastructure to operate successfully, including power.
* Interoperable: Communications during relief efforts for many recent disasters have suffered from lack of hardware interoperability (“Emergency communication system,” 2015; Manoj & Baker, 2007), or an inability for devices from one network to work with another network for the purposes of voice and data transmission.
* Redundant: Redundancy is the “duplication of critical components…of a system with the intention of increasing reliability” (“Redundancy (engineering),” 2015) and is important because of the unpredictability of the geographic and social area surrounding a natural disaster.

**Mobile Communication Centers**

To ensure availability of a communication network in a disaster area, many relief organizations deploy a communication hub housed in a vehicle that can create an ad-hoc network using aid worker’s devices or existing infrastructure as nodes. Due to this lack of reliance on existing communication nodes, these networks are typically deployed after a disaster strikes, which can hinder implementation if one is looking to offset the costs over a period of time. For the purposes of this paper, I define such mobile communication centers (MCCs) as a communication network infrastructure housed in a vehicle or other mobile enclosure. 911-NOW is one such network created by Bell Labs that aims to provide “capacity and coverage on demand” for voice and data transmissions during disaster recovery operations; this modular ad-hoc system can expand to accommodate the on-the-ground needs of aid workers as they become known (Abusch-Magder et al., 2007). Cisco’s Network Emergency Response Vehicle (NERV) is another example (“How Cisco brings communications to disaster relief efforts,” 2015).

The biggest challenge to MCCs is their lack of flexibility when it comes to reaching disaster victims in remote or inaccessible areas (Ruengsatra, Nakorn, Piromsopa, & Rojviboonchai, 2015). For example, during the 9/11 crisis it would have been impossible to station an MCC close enough to ground zero to reach any potential victims or devices inside the collapsed towers. While this flexibility ensures that MCCs are more stable compared to other technologies, it’s a tradeoff that many humanitarian organization would rather not have to make.

**Hybrid Mesh Networks**

A mesh network is a setup where each node in the network acts as both a client and a server and is responsible for sharing data throughout the network (“Mesh networking,” 2015); peer-to-peer networks are probably the most common example of mesh networking. Wireless mesh networking refers to using primarily or exclusively wireless nodes in the network model (“Wireless mesh network,” 2015), so I define a hybrid mesh network (HMN) as a network that utilizes both wired and wireless network nodes. HMNs are even starting to experiment with aerial nodes (Ruengsatra et al., 2015) to create a more flexible network. These networks can use existing infrastructure or create a new one, and because they can both self-heal and self-form (“Wireless mesh network,” 2015), they have a high level of reliability and redundancy.

Implementation is the biggest challenge to HMNs (“How Disaster ‘Mesh’ Networks Provide Critical Value in Disasters [A Primer],” n.d.; Manoj & Baker, 2007). The more nodes in an HMN, the better the network is for all users (“Network topology,” 2015), so not only can these be costly to implement if not using existing infrastructure but it requires a larger rescue team to be effective. Commotion Wireless estimates that costs can be high when looking at individual components (“The Cost of Mesh Networks | Commotion Wireless,” n.d.), but radio and other wireless hardware modularity cost has decreased tremendously in recent years (“Mesh networking,” 2015) so the net effect is a lower cost system overall. Some systems, such as LDLN, aim to simplify the implementation of mesh networks so that less technical people can setup and use a mesh network specifically in disaster situations (“LDLN: Off-Grid Communications for Disaster Relief Agencies,” n.d.).

**Amateur Radio**

Amateur or “ham” radio refers to non-commercial radio communication between individuals (“Amateur radio,” 2015). These radio networks are not typically associated with government or consumer communications, and such decentralization lends itself well to disaster relief communications (Chief of Wireless Telecommunications Bureau & Chief of Public Safety and Homeland Security, 2012). In the United States, ham radio operators have been helping during natural disasters since 1910 (Coile, n.d.) and the federal government recognizes their unique ability to provide communication when other newer technologies fail (Chief of Wireless Telecommunications Bureau & Chief of Public Safety and Homeland Security, 2012). Amateur radio operators in the United States regularly compete in the “Field Day” where over 30,000 operators practice and encourage emergency communication preparedness (“Field Day (amateur radio) - Wikipedia, the free encyclopedia,” n.d.).

Radio is not limited to voice transmissions, but can also transmit data through packet radio. Packet radio is a mode that is most commonly used to create computer networks in amateur radio, and is especially useful in emergency communications because each radio “station” acts as a repeater sending the signal further on (“Packet radio,” 2015). While this method is slower than traditional wireless methods of data transfer, it doesn’t require internet or cellular structure, something which is typically lacking at disaster sites (Chirgwin, 2014; Satea Hikmat Alnajjar, 2013).

**Recommendation**

The ideal approach to an effective disaster area communication network must be self-contained, interoperable, and redundant. Because disaster areas are unpredictable with regards to infrastructure reliability and availability, effective communication networks must be self-contained and not rely on external systems. Providing infrastructure will always be more expensive than utilizing existing, but the ever decreasing costs of networking hardware will continue to improve the situation. Cheaper costs will also lead to more potentially available nodes in a network, which increases redundancy and stability across the whole network. When integrating with existing systems or coordinating with other aid workers, interoperability has been the single most consistent challenge to communication networks during the most recent natural disasters. Investing in systems and nodes that are interoperable with other systems currently in use will lead to more effective communication networks in disaster relief areas.

The only innovative technology that meets all these demands is amateur packet radio. Not only is this technology already successful in disasters such as Hurricane Katrina, the Tōhoku earthquake and tsunami, and 9/11 (“Amateur radio,” 2015, “Amateur radio emergency communications,” 2015; Chief of Wireless Telecommunications Bureau & Chief of Public Safety and Homeland Security, 2012; Coile, n.d.), but these networks are inexpensive to setup (Dave, 2011) and have recreational goals geared to emergency preparedness (“Field Day (amateur radio) - Wikipedia, the free encyclopedia,” n.d.).

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