Modular Communications Relay: A toolkit for the "last klick" problem.

The problem

During an emergency, communication and coordination become both more vital and more difficult. In addition to the chaos of the event itself, many of the communication mechanisms that we normally depend on are likely to be degraded or unavailable.

Electrical utilities can fail or become dangerously unstable causing injury and damage to sensitive equipment. Cell phone networks and Internet connectivity can be degraded physically or may become hopelessly overloaded as panicked citizens flood these networks attempting to contact loved ones or search for vital information about the event.

First responders often find it difficult to communicate with each other because the systems they use every day are incompatible with systems from other responding agencies; or because they are suddenly forced to operate outside the range of their usual infrastructure.

Then there is the problem of communicating with the public. Most people have sophisticated mobile devices that will have become unusable because their networks are unreliable or because their batteries have died. In a modern society that depends almost exclusively on Internet driven media devices ordinary broadcast receivers are becoming scarce.

Solutions that don't work

A growing list of solutions have been proposed. Unfortunately, most of the proposals receiving serious attention are unworkable because they fail to recognize real-world constraints.

"Harden What We Have"

Solutions that require commercial providers to build-in extra capacity for emergency traffic are directly opposed to the commercial provider's profit motive and are difficult to verify. Both the cost of the additional capacity and the amount of additional capacity available can only be practically sourced by the providers themselves and at best can only be estimated. How much extra capacity is enough?

In order to maximize their profits commercial connectivity providers must eliminate both diversity and excess capacity from their networks. On the other hand, redundancy and diversity are required for a network to remain resilient – even more so in an emergency.

Any network provider must constantly balance these opposing forces. Reliability is crucial but only to the point that it does not affect profitability. It has to be "good enough." The risk of a failure under normal conditions must be balanced against the cost of mitigating that risk.

Estimating the risk of failure under emergency conditions is more difficult because, by definition, emergencies are unusual events. The best anyone can do is make an educated guess about what might happen in an emergency and then make another educated guess about what would be required to compensate. So, adding a requirement for additional emergency capacity injects uncertainty and a conflict of interests into a formula that is already obscure, convoluted and contentious.

“The Universal Option”

Solutions that require the universal adoption of exotic equipment are so expensive that many groups cannot afford them. Potential adopters are faced with dismantling existing systems that represent a significant investment and are widely trusted and understood by their users. These factors make universal adoption unachievable so the interoperability problem these exotic systems are intended to solve is instead worsened by adding yet another type of equipment to the mix.

Every major radio manufacturer has some version of the universal solution: “Switch everyone to our new radios and all problems will be solved...” These solutions come backed with well funded lobbyists, white papers, research projects, demonstrations, requirements, specifications, and testimonials that drive the decision process toward the vendor's product line.

When configured properly these devices are said to securely connect to anything from any vendor, at any time, under any conditions, without fail. The reality is far more complex than the marketing materials suggest.

The feature set required to meet such a wide range of use cases is extensive and exotic. These exotic features add to the complexity of the equipment making it expensive, difficult to operate, difficult to integrate, and therefore difficult to adopt.

Added complexity, liability, and intellectual property concerns also create barriers that discourage other vendors from creating compatible hardware. As a consequence these systems are never widely deployed and instead tend to become technological islands. In an emergency situation it is likely to be difficult to locate compatible equipment and even more difficult to find operators qualified to cope with unusual circumstances.

“The Cloud”

Solutions that depend on centralized resources and “cloud based” infrastructures are also unworkable. In an emergency situation, especially during the first 24 hours, it is likely that these centralized resources will simply be unreachable. Any communication, coordination, or management system that depends on “cloud services” or otherwise on the Internet or cell phone networks may be crippled by a lack of connectivity.

Cloud based solutions seem attractive because on the surface they appear to be robust, feature rich, and affordable. In truth they are, but only when a reliable Internet connection is available. To be fair, many of these systems offer some limited capability when connectivity is lacking, but making use of that ability usually requires that important features are disabled and that all local hardware is updated before going offline.

In an emergency there may not be sufficient notice to prepare a “cloud based” system for off-line use. In addition, the loss of important system features will force operators to abandon their usual procedures causing errors, increasing workloads, and potentially causing the system to be more of a burden than a benefit.

What is needed

The breakdown of critical infrastructure during an emergency has the potential to create large numbers of isolated groups. This fragmentation requires a bottom-up approach to coordination rather than the top-down approach typical of most current emergency management planning. Instead of developing and disseminating a common operational picture through a central control point, operational awareness must instead emerge through the collaboration of the various groups that reside beyond the reach of working infrastructure. This is the “last klick” problem.

While hardened, well organized control and communications facilities will survive the onset of emergency situations they are likely to be blind to conditions in the field for extended periods. Each isolated group will likewise be cut off from these resources and may be forced to operate independently for extended periods.

Planning that takes this isolation into account can go a long way to making these remote operations successful. General operating plans can help to coordinate response efforts operating in the blind, however the details of those operations cannot be predicted because they will be highly dependent upon the circumstances and resources at hand.

First responders found in these circumstances must be able to make the best use of the resources available to manage logistics, secure critical resources, improvise workable communications mechanisms, and coordinate with secondary responders and other groups.

Wherever possible and practical, meaningful connections to working infrastructure and/or established emergency response centers may be established on a limited basis through the innovative use of various technologies available in theater. The key is having the tools to make the most of those local resources.

“The MCR – a Modular Communications Relay”

In order to address the “last klick” problem and improve the resources available to emergency responders, we have been developing the MCR concept. The MCR will be a rugged, portable toolkit for solving many of the problems that occur when first responders find themselves beyond the edge of working infrastructure. It is composed of three major sections that are built up from open-source or readily available components.

The goal is to make it possible for anyone with a little bit of technical skill to assemble an MCR out of “off the shelf” components and to configure it using open source hardware and software. Depending upon how these components are sourced it should be possible to assemble an MCR for a few thousand dollars – a small fraction of the cost of many interoperability solutions. Of course we also expect fully assembled units with professional support to be made available by ourselves and others. By using readily available components and an open-source model we hope to solve the problems of affordability, availability, and accessibility. Our hope is that anyone who might foresee the need for an MCR will be able to afford it and find a suitable source, training, and support.

The base of the MCR is an intelligent power gateway that is capable of harvesting energy from a wide variety of sources and converting it into safe usable power for the MCR's other functions. Using advanced components like super-capacitors in combination with lightweight LiFePO batteries under computer control, the intelligent power gateway will be able to safely accept power from dirty, intermittent power sources (hand-cranked generators, solar blankets, wind-mills, small gas powered generators, automotive batteries, etc.) even if those sources are unstable and unreliable. It will, of course, also accept mains power whenever it is available.

In addition to accepting power from almost any available source, the MCR's intelligent power gateway will be able to provide safe charging facilities for radios, cell phones, and other mobile devices. If desired it will provide sufficient power to operate Ham Radio equipment producing up to 100W, or if necessary will operate the basic functions of the MCR for up to 24hours running only on it's internal battery.

The next major section of the MCR is a hardened, low-power computer "brain" that manages the MCR's technology and provides additional resources to the operator. The purpose of this part is to reduce the training required to operate the MCR by providing a user-friendly "personality" that is simple and intuitive. For example, the "brain" will automatically sense when various power sources are available and will see to it that they are used appropriately even if they are connected incorrectly. In addition it will take steps to prioritize the use of available battery power to optimize reliability, performance, and battery life.

Another feature of the "brain" is to provide access to a wide range of digital resources that are stored on the MCR and to see that these resources are kept up-to-date continuously whenever the system is able to connect to the Internet or other suitable networks. This feature ensures that the MCR is ready to operate off-line without any notice.

The third major section of the MCR is a communications network facility consisting of a hardened high performance router / application server, a network switch, a mesh network node, a WiFi hot spot, and a RoIP (Radio Over IP) gateway. This combination of components can be configured by the "brain" to operate based on available power and to utilize a wide range of communications facilities if they are available.

The RoIP component in particular can be used to bridge incompatible radio systems into one or more channels so that responders from different services can gain the ability to communicate directly simply by providing a donor radio. The off-the-shelf devices we have considered for this component offer 4 channels and can be packaged with connectors for a wide range of popular radios. Our goal will be to provide enough connectors to cover more than 90% of the most likely use cases. Of course this configuration will be customizable by the owner of the MCR as needed.

When more than one MCR is available within radio range, the mesh radio node will automatically form a network between the other visible MCRs. This will make it possible to bridge additional donor radios into the system and will extend the range of the network and the connected radios.

It's worth noting that the MCR will be designed to be easily hoisted into the air using any available tree or structure so that the range of all connected radios and the mesh node can be extended. If a qualified operator is available (such as a Ham Radio Operator) then they will be able to easily modify the facilities of the MCR to further extend the range by modifying the settings of various components, adding directional high-gain antennas, or otherwise.

If a suitable back-haul network becomes available via satellite, wired Internet, or otherwise then any of the MCR nodes will be able to act as a gateway for the other visible MCRs. This makes the MCR an ideal toolkit for establishing an ad-hoc network during the first few hours of an event or longer if required.

The WiFi hot-spot component can be used to provide secondary responders and the public (if desired) access to local resources and applications available on the MCR or in the ad-hoc network. This can be useful for broadcasting information, providing local communications facilities using smart-phones and other mobile devices that are in range, or collecting useful data about local conditions from these devices, other sensors, and volunteers.

"A flexible platform"

With an open, flexible platform like the MCR in place it should be possible to create applications that build comprehensive situational awareness from the bottom up. Individual MCR nodes would be designed to operate independently to develop a local user defined operating picture. Utilizing any available connectivity – including intermittent Internet connectivity or connections with other MCR nodes – the local operating pictures can be aggregated, shared, and communicated to other systems.

In one example, an MCR might ride along in a vehicle that travels between various camps delivering supplies and personnel. As this mobile MCR connects with others MCR nodes in the camps it visits it can collect and distribute situational data between those nodes.

While the mobile MCR is in range of a local mesh network there will be a high bandwidth connection between itself and the local MCR nodes. That bandwidth can be used to synchronize a significant amount of data which the mobile MCR can store and then forward to other nodes as they become visible. Through this automated process the collected data can eventually be distributed throughout the community of MCR nodes and networks perhaps eventually reaching central authorities via Internet connections at the edges of the event.

Another similar example might leverage the periodic use of communications drones or satellite connections as power and conditions permit. Software on the MCR could prioritize messaging traffic to maximize the use of this limited intermittent connectivity.

In some cases it should be possible to customize the MCR concept to provide a range of additional functionality. Some MCRs might be configured with environmental sensors, specialized communications equipment, or even robotics that might be useful in special circumstances and venues. Indeed, once the basic platform is in place it's open nature can be extended in virtually any way the operator might desire.

"Portable, flexible, and reliable"

The design goals of the MCR project are to create a rugged, portable, toolkit for communications, coordination, and power management in an emergency. In the hands of a first responder with very little training it will provide interoperability between otherwise incompatible radio systems, effective independent operation for collecting data and building situational awareness, and the ability to create ad-hoc networks for sharing information and leveraging local resources.

- Operates for up to 24 hours without additional power sources if necessary.
- Built-in applications server for managment tools and information sharing.
- Automatically builds ad-hoc mesh networks with other MCRs.
- Provides a WiFi access for nearby smart-phones and mobile devices.
- Provides interoperability using donor radios and RoIP gateways.
- Rugged construction easily hoisted up available structures for extended range.
- Fits in a vehicle mountable back-pack weighing less than 20Kg.
- Affordable and built from open, "ordinary" components.