Advanced Mobile Communications for Emergency Management and Crisis Response

Michael Bowman, PhD
Murray State University
michael.bowman@murraystate.edu

Abstract

Reliable communications can be a matter of life-and-death during an emergency or crisis. First responder communication system interoperability, coverage, and flexibility are among the most critical issues evident from events such as the terrorist attacks of September 11 2001, the Indian Ocean Tsunami of 2004, and Hurricane Katrina.

Murray State University and research partners are addressing these issues under grants from the U.S. Department of Homeland Security. Cooperating with government officials and first responders, the team has prototyped, demonstrated, and operated robust yet affordable mobile communications systems particularly well suited for field operation in rural environments and small communities. Work has progressed beyond demonstrations to deployments with first responders for actual emergencies, and initial sales of the systems.

The developed system is called the Man-portable and Interoperable, Tactical-Operations-Center (MITOC). MITOC is a suite of mobile communications gear that upon arrival at an emergency is quickly transfigured into a robust communications infrastructure including satellite communications, wireless LANs, Internet access, radio interoperability, VoIP, and other services essential for organizing and executing crisis response.

Work is currently focused on: the integration of rapidly expandable coverage using mesh network technology that stretches the MITOC wireless bubble right to the site of an emergency; advanced services and applications; and integration into other emergency response systems. This paper describes requirements for mobile communications for emergency management; the current capability of MITOC; initial manufacturing and sales of the current system; and future research directions.

Background

During a typical day in today's world, we sit at our desks and communicate with the rest of the world with a few mouse clicks or by pressing a few buttons on a phone. If we move out to the parking lot wireless networks and mobile phones maintain our connectivity. Even in the most remote areas, satellite phones or briefcase sized satellite terminals can keep us connected. These systems have become the backbone for business, government, and social interaction. Yet in just an instant a natural disaster, industrial accident, or terror attack can leave us disconnected. Reliable communications can be a matter of life-and-death during an

emergency, but as seen repeatedly across the globe, even our best equipped and trained government agencies and first responders (police, fire, rescue, medical, etc.), can struggle to communicate during a crisis.

To compound matters, many people do not live in hyper-connected urban areas. Even in fully developed nations, smaller communities and rural areas rarely have robust communications infrastructures or widespread wireless access. In sparsely populated regions of the United States such as the southwest, homes and structures with landline telephones can be few and far between. In these areas cellular and high speed internet service is unprofitable and therefore rarely available and few local or regional government agencies utilize satellite communications. Radios traditionally used by first response personnel can be severely restricted by terrain features such as hills. Even during day-to-day emergencies such as fires, hazardous material spills, and vehicle accidents, first responders are often unable to adequately communicate. Further, communications among first responders to an emergency continue to be severely hampered by radio interoperability issues.

Recognizing these realities an academic research consortium which included Murray State University, the University of Louisville, and the Kentucky Community and Technical College System (KCTCS), in cooperation with national, regional, and local emergency management organizations, has developed and demonstrated robust, reliable, and affordable mobile communications systems specifically designed to support small towns and rural communities during emergencies. This paper describes the capabilities and architecture of the Man-portable and Interoperable Tactical Operation Center (MITOC) which was funded by the U.S. Department of Homeland Security. [1] MITOC is a modern mobile communications infrastructure that can be transported in a single small vehicle and hand-transferred by two people, that upon arrival at an emergency can be quickly transformed into a robust command post with satellite communications, wireless networks, radio interoperability equipment, laptop computers, and other systems essential for organizing and executing emergency management and crisis response in even the harshest and bare-boned environments. The initial project was recently concluded after three years of successful demonstrations, field use, and initial sales. New, related research grants were recently awarded to the team and current research is focused on providing first responders with enhanced situational awareness and services via the MITOC communications infrastructure.

Mobile Communications for First Responders

In response to high profile problems and failures in emergency management systems during the past decade, many researchers and commercial entities are proposing complex methodologies and architectures for addressing the issues described above. Several commercial companies have publicized prototypes for new systems that will be available "soon," usually without providing information on cost or delivery dates. At the same time our research consortium, with a few critical commercial partners, has rapidly designed, built, tested, and demonstrated at several high profile public events and actual local and regional emergencies, an affordable, effective, mobile communications infrastructure for first responders. We have also demonstrated the system is ready and suitable for mass production and sale by taking orders, assembling, and delivering systems to government and commercial customers. MITOC provides the on-scene incident commander an integrated, all terrain, self powered, world-wide communications capability.

The MITOC research effort has addressed several of the most critical mobile communications lessons learned from September 11th and Hurricane Katrina. Cooperating with numerous law enforcement, fire safety, rescue, ambulance, military and emergency management organizations the system has been prototyped, demonstrated, and now field tested as providing affordable, robust, and reliable mobile communications particularly well suited to support small and rural communities.

Funded by the U.S. Department of Homeland Security, this work has resulted in the MITOC family of systems. MITOC is a suite of portable "modules" containing essential communications equipment and information technology that fits easily in a standard Sport Utility Vehicle (SUV), boat, trailer, or small aircraft. The team's current operational version of MITOC which responds to actual emergencies is housed in a Chevrolet Suburban SUV called the Mobile Telecommunications Equipment Laboratory, or METL. Thirty minutes after arrival at a scene MITOC transforms into a robust, modern command post equipped with satellite based voice and data communications, a wireless local area network (LAN), portable phones for local or long distance calls, laptop computers, radio interoperability equipment, and other systems essential for organizing and executing emergency management and crisis response. The MITOC modules can be operated right from the transporting vehicle, or carried indoors for operation from a structure.

Requirements

Since 2001, U.S. panels and committees such as the Hart-Rudman Commission [2], and the 9/11 Commission [3] have issued reports stressing the need to improve emergency response by providing key information technology to first responders. Focusing most closely on supporting incident commanders, recommendations include:

- Integration of voice and data communications among local, regional, and national organizations
- Immediate on-scene access to response guidelines and status of local assets
- Ability to refine, update and manage content from the field
- Real information sharing for collaboration across jurisdictions and agencies
- Improved and automated project and resource management
- Mapping and common-operational-picture (COP) support
- Access to intelligence and analysis
- Decision support technology

Few communities in the United States report having achieved more than one or two of these technology-based attributes in actual practice, especially at the on-scene incident command level. It is only in major cities such as New York or Los Angeles that there is evidence of deployment ready, integrated, and multifaceted tools to support emergency management and crisis response. Typically, you may see one or more of these information technologies available at a fixed Emergency Operations Center (EOC) in a major city; or in very large, tractor-trailer or recreation vehicle (RV) sized, expensive, road-bound command posts supporting Federal or State agencies. National agencies and the military are typically best

equipped with mobile command posts. [4] At the same time, small urban and rural communities in the U.S. are unlikely to have any capabilities beyond the traditional law enforcement, fire, rescue, and ambulance service call and dispatch centers. Technology is available, but it is generally not affordable and not suitable for use by first responders in these communities.

Research Goals and Methods

The principal goal of the first three years of MITOC research has been the design, implementation, test, deployment, and evaluation of mobile, interoperable, and affordable voice, data, and video communication tools for on-scene incident commanders and first responders. A secondary goal of the project has been the development and evaluation of standardized tactics, techniques, and procedures (TTPs) for the effective use of advanced information technology and communication systems to enhance the performance of incident commanders, responding personnel and support agencies. Further, a stated high priority research goal was that eventual production versions of MITOC were to be highly effective, yet still affordable for small and rural communities, and small organizations.

Since inception, the MITOC project has not been a traditional academic research program. Instead, it is rapid prototyping using a *design-build-test-use-fix* model. The program involves close and regular coordination with local, regional, and national first-response personnel to rapidly and incrementally evolve a suite of advanced information technology tools that these personnel are willing to use in real-world operations. These functional experts often can not describe the tools that they need, but they immediately recognize them when they see them, and recognize when something is not working adequately.

Our rapid prototyping process typically consists of:

- Interviewing functional experts to document their requirements
- Brainstorming solutions, many of which are procedural rather than technical
- Design, integration, and test of solutions
- Demonstration, field use, and evaluation by functional experts
- Fixing failures and adding required capabilities identified by functional experts

Evolved MITOC Configuration

During the first three years of the project, MITOC evolved continuously. With primary emphasis on providing a communications infrastructure the overall goal is to provide an incident commander an integrated package of complimentary public-safety oriented services, tools, and capabilities. MITOC has been and remains an entirely commercial off-the-shelf (COTS) system housed within rugged transport cases. Figure 1 is a photo of a recent configuration. The evolving architecture has generally included:

- Satellite communications terminals
- Radio base stations configured for a user's jurisdiction

- An IP based radio interoperability system programmed to support the radio frequencies in a user's area
- An Internet router
- An Internet server
- A wireless local area network
- A Voice-over-IP (VoIP) telephone switch
- Mobile power
- Ancillary equipment and tools such as wireless and wired VoIP phones, a portable weather station, office equipment and supplies, field table and chairs

Figure 1: MITOC V.4.0 Electronics Suite

A design priority for MITOC is to keep components modular and interchangeable. Radios in production MITOCs for example are customized to meet the requirements of a user's jurisdiction. The current MITOC prototype includes a Kenwood base station and handheld radios operating in the 50, 150, 450 and 800 MHz ranges that suit local jurisdictions. Other radio systems, primarily for data transmission, have been successfully trialed in MITOC including 900 MHz transceivers for relaying Internet access from a remote satellite dish to the MITOC operated in a fixed structure. Such a radio can also be used to transmit LAN connectivity to remote users working at a distance from the primary MITOC wireless "bubble."

Radio interoperability is arguably the most recognized problem area in public safety communications and is a priority capability for MITOC. A number of commercial solutions exist to convert analog radio inputs to digital signals, organize the digital signals into Internet Protocol (IP) packets, and route IP packets to analog output radios for retransmission to appropriate parties on a tactical channel.

Several available radio interoperability systems were considered and tested for use in MITOC. Each has it own features, price, or performance advantages. The Telex-Vega IP-233 was selected for the MITOC prototype due to its flexibility and an ability to serve as an on-scene tactical dispatch system. While a variety of commercial systems are available and all promise turn-key operation, pre-deployment setup, field use, and on-the-fly reconfiguration of these systems is problematic and significant pre-crisis planning, training and rehearsal is necessary to ensure their successful field use.

MITOC has utilized a Cisco 2811 series router which has multiple features including: built-in network security with Virtual Private Networking, and Cisco Call Manager Express Voice-over-IP (VOIP) telephony. Production versions of MITOC can include lower cost Linksys or Adtran routers.

Cellular mobile communication is provided by a Junxion broadband cellular appliance that combines two or more separate cellular carrier signals into a redundant data stream that can burst up to 4-6 Mbps.

Primary long range, non-line-of-sight (NLOS) communication is currently provided by a 1.3 meter self erecting, auto-locating, satellite dish providing 2 Mbps download and 512 Kbps upload, mounted on the roof of the METL vehicle. A Hughes BGAN (Broadband Global Area Network) portable satellite terminal provides a back-up NLOS capability. Figure 2 is a photo of MITOC mounted in an SUV with the 1.3 satellite dish erected.

Figure 2: MITOC Satellite Dish Erected

The MITOC Wireless "Bubble"

A primary capability of MITOC is providing a "bubble" of secure wireless Internet connectivity. The MITOC secure wireless network provides authorized users access to all MITOC applications from wireless capable computers, laptops, or PDAs. This allows on-scene collaboration through instant messaging which contributes to reducing radio traffic.

Early MITOC versions utilized a Cisco 2.4GHz broadband wireless router for the wireless network. Current versions use the Rajant Breadcrumb® MESH wireless system for robust security, greater range, and more flexible coverage. This system utilizes small, rugged, battery-powered access points that can be distributed around an emergency scene to extend the wireless bubble to best support the incident. The early MITOC operational concept and technology limited the use of the wireless bubble to personnel working within a few hundred meters of the MITOC electronic equipment suite. While this provided a very significant capability, in the event of hazardous situations like fires and chemical spills it did not support responders working in the immediate scene of the emergency. The concept of meshed wireless networking and the adoption of the Rajant Breadcrumb® have changed this situation dramatically.

The ability for an incident commander at a command post, and a responder working in the immediate presence of a hazard, to share a network enabled common operational picture is a critical new capability. In addition to traditional voice communications, the new concept and technology allows video surveillance data; sensor data; text messaging; internet access; and other operational information to be shared over a common wireless mesh network infrastructure. Figure 3 is a photo of an open and a closed Breadcrumb® case.

Figure 3: Rajant Breadcrumb®

MITOC currently utilizes Rajant Breadcrumb® SE models. They are equipped with two radios and two network interface cards. The system is packed in a rugged plastic case that is 8.25” x 6.5” x 3.5” in depth. With batteries, each weighs about 2.5 lbs. They are easily stored, transported, and emplaced. A single switch turns them on, upon which they self initialize and join the network. A fully charged 9 Volt battery will operate the system for up to 10 hours of steady traffic. Internally, the Breadcrumbs® have an Intel XScale PXA255 processor, 32 MB of RAM, and run the Linux operating system. Breadcrumbs® implement the 256 bit Advanced Encryption Standard to secure communications. [4]

Experimentation and operational use of the SE model Breadcrumbs® suggest a unit has a range of about ½ mile over open terrain, and that six units easily provide a square mile of dense coverage in a typical suburban area with moderate/average LOS obstructions.

Example Operational Scenario

MITOC systems have deployed and supported numerous real-world missions such as security operations at the Kentucky Derby, and a large scale train derailment with a hazmat spill and fire, with up to six Breadcrumbs emplaced to extend the MITOC wireless bubble. Figure 5 is a photo of MITOC at a law enforcement exercise.

An example typical deployment of MITOC begins with the report of a train derailment and hazardous material spill. Members of our research team are called to respond and support the operation. For a toxic hazmat situation, the incident command post will be positioned upwind a mile or more from the event, and with intervening terrain or buildings to shield the command post from possible fire or blast dangers. In the event that power and communications are disrupted or unavailable, MITOC provides the responders a full suite of world wide voice and data communications at the command post. From the command post, hazmat team members in full protective garb will travel to the incident scene, periodically turning on and dropping off Breadcrumbs® along their route. At the scene of the spill the team members will communicate by voice and text message back to the command post via the deployed Breadcrumbs®. Surveillance cameras and chemical sensors they deploy at the scene will provide critical data to the incident commander at the command post via the Breadcrumbs®. After determining the nature of the spill, hazmat team members will access instructions for neutralizing the spill on their PDAs and laptops without ever leaving the scene, via the Internet access provided by the Breadcrumbs® and MITOC.

Figure 5: MITOC Operated Outdoors

Production and Sales of Systems

A total of twelve MITOC systems have been ordered and to date eight have been assembled and delivered. Initial MITOC orders came primarily from state and local government agencies, but the most recent orders have come from energy and utility companies that will use their MITOCs to support continuity and service recovery operations. Production MITOC units are currently assembled by research personnel at Murray State University. In addition to hardware configured to the specification of each customer, system documentation, training, and support is provided by the research team. While no commercial production facility has been established at this point, a commercial partner focused on sales and marketing has been established. It is expected that this commercial partner will eventually establish a production facility and take over training and support responsibilities.

New Research Directions

The initial three year DHS research grant for MITOC ended in March of 2008. In May of 2008, the MITOC research team which now primarily includes Murray State University, KCTCS, and a commercial partner, Elantech Software Engineering Solutions of Greenbelt Maryland, was awarded a new two year research grant by DHS through the National Institute of Hometown Security. The MITOC will provide the communications infrastructure for the new effort, but the research now focuses on the development of a system and tools to improve the capacity of incident managers to monitor and respond to emergency situations through improved situational awareness and data fusion. The new project will leverage lessons learned from military research, development, and operations where information technology and communications systems have been used to provide situational awareness to penetrate the 'fog-of-war'. In addition to this primary research project, MITOC and the lessons learned from the completed project will be used to support DHS funded projects at the University of Louisville, and Western Kentucky University.

Conclusions

MITOC provides a highly capable, field tested, and affordable mobile operations center for an emergency incident commander. Our recently completed three year research project has explored the challenges and potential benefits of providing an incident commander a full suite of communications and information technology tools regardless of the location or circumstances of an emergency. Most recently, we have extended the MITOC communications infrastructure from the incident command post to the actual scene of the emergency or hazard with wireless mesh networking. Results indicate that wireless mesh networking is a technically suitable, yet affordable approach with significant potential payoffs. MITOC research is continuing under a new two year DHS research grant through which we will research new approaches to providing an on scene incident commander with improved situational awareness and decision support through MITOC communications capabilities, sensor integration, and data fusion.

References

[1] Bowman, Graham, Gantt, *Robust and Affordable Mobile Communications for Emergency Management*, International Journal of Emergency Management, Volume 4, Issue 4, 2007, p 649-669.
[2] Hart-Rudman Commission, *Road Map for National Security: Imperative for Change*, The Phase III Report of the U.S. Commission on National Security in the 21st Century, 31 January 2001, http://www.fas.org/irp/threat/nssg.pdf, last accessed 2/28/2008.
[3] The National Commission on Terrorist Attacks Upon the United States, *The 9/11 Commission Report*, New York: W.W. Norton & Company, Inc., 2004.
[4] Gourley, S. *'Golden Guardian 2006' U.S. Army North Prepares for Disaster Response*, ***Army***, AUSA, Arlington, February 2007, 34-40.
[5] Rajant Corporation (2006). Model Comparisons. From http://rajant.com/comparisons.htm last accessed February 28, 2008

Michael Bowman, PhD is an Assistant Professor of Telecommunications System Management at Murray State University where he teaches graduate and undergraduate courses in Telecommunications, Information Assurance, and Computer Science. He earned a PhD in Information Technology from George Mason University in 2002.