Proceedings of the 2003 Systems and Information Engineering Design Symposium
Matthew H. Jones, Barbara E. Tawney, and K. Preston White, Jr., eds.

INTEGRATED PEER-TO-PEER APPLICATIONS FOR ADVANCED EMERGENCY RESPONSE SYSTEMS PART I: CONCEPT OF OPERATIONS

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ABSTRACT

The catastrophes of September 11, 2001 put Arlington County's emergency response system to the test. They revealed capabilities and limitations otherwise overlooked during previous standard emergency response assessments. There were three key issues in the response to 9/11 that are recurring in jurisdictions across the nation: 1) reliance on voice-oriented communications; 2) limited situational awareness; and 3) lack of interoperability. A concept of operations integrating current commercially available technology in a system designed for the emergency response coordinator addresses these issues. To visualize this concept, a Graphical User Interface that displays the required functionalities described in the concept of operations will be presented. High-ranking emergency response personnel from Arlington County, Virginia have conveyed that this solution is, indeed, feasible. The next step towards implementation should include exploring peer-to-peer networks in integrating the technologies described.

1 PROBLEM STATEMENT

Arlington County's *After-Action Report* for the 9/11 disaster, as well as reports discussing problems faced by other emergency response jurisdictions, have identified three major problem areas of emergency response prevalent across the country: 1) voice-oriented communications; 2) limited situational awareness; and 3) interoperability. Reliance on voice communications such as landlines, cellular phones, and radio poses problems when these channels become clogged, as was the case on 9/11. In addition, voice communication by itself limits the richness of information that can be communicated during an emergency response. Lastly, interoperability is a key issue in emergency response when a disaster involves more than one department, jurisdiction, or agency. Currently, most organizations have no means of communicating with other organizations. Harnessing the potential of currently available technology into an integrated concept of operations can successfully address the issues of voice-oriented communications, limited situational awareness, and lack of interoperability.

2 ARLINGTON COUNTY, 9/11, AND THE AFTER-ACTION REPORT

The 9/11 disaster tested every aspect of the Washington Metropolitan Area emergency response system, engaging departments, jurisdictions, as well as local, state, and federal agencies; it revealed capabilities and limitations that may otherwise have been overlooked during a simulated exercise. After 9/11, Arlington County commissioned the *After-Action Report* prepared by Titan Systems Corporation, which found that despite the high level of preparedness, uncoordinated communications among emergency responders impaired the overall efforts. Many of the key challenges faced by emergency responders fell into one of the three main categories mentioned above: 1) overtaxed voice-oriented communications; 2) limited situational awareness; and 3) lack of interoperability. Each of these problems could be addressed with an improved communications system.

Sole reliance on voice-oriented communications posed a problem for Arlington on 9/11. According to the *After-Action Report*, communication at the scene was an impediment to efficient emergency response. "Radio traffic overwhelmed the system to the extent that foot messengers became the most reliable means of communicating. Radio communications inside the Pentagon were, for the most part, impossible. Where line of sight could be achieved, 'talk around' was minimally effective" [Titan Systems Corporation, 2002]. Emergency Medical Service (EMS) providers stated they did not rely on radios to transmit information because "ambient noise sometimes made it hard or impossible to talk on the radio" [Titan Systems Corporation, 2002]. Parallel to that, cellular telephones were not useful as calls jammed local towers.

The report also noted that deployment information from the Emergency Communications Center (ECC) to emergency response units was delayed and incomplete due to jammed voice-oriented communications. It recommended that "every firefighter and EMS responder should have a pager to receive dispatch notices both on and off shift" [Titan Systems Corporation, 2002]. In addition, one of the most common recommendations by the responders themselves was that Arlington County EMS units should be equipped with mobile data terminals (MDTs) to transmit and receive information to the ECC in text format. Specifically, many EMS responders believed that MDTs would have substantially augmented the dispatch system [Titan Systems Corporation, 2002]. The *After-Action Report* also suggested that the Emergency Operations Center (EOC) should incorporate computer-based communications that would enable "rostering, automated notification, operations checklists and journals, action tracking, and report generation" [Titan Systems Corporation, 2002]. Information from the EOC would then be accessible to anyone on the Local Area Network or with access to the Internet. This would allow the county leadership to access the information from their offices, homes, or mobile locations. Such systems could be customized so appropriate information is available to the press, neighboring jurisdictions, and other government agencies.

In addition, Arlington's officials recognized the need for improved situational awareness for crisis managers. This includes real-time voice and video feeds between the scene of a disaster and the command center as well as real-time asset location information. On September 11, the mobile onsite command center was moved, and this caused temporary confusion among uninformed personnel. This would not have been a problem if there was a tracking system in place. In addition, the radio dispatch system did not include location displays; the report recommended that "the ECC radio dispatch system should be upgraded and integrated with those of other local jurisdictions and include an automated vehicle locator system" [Titan Systems Corporation, 2002]. Video feeds from the scene and the surrounding areas can be used to improve situational awareness as well. The report recommended that "closed circuit television cameras should be installed at strategic locations throughout the county so traffic flow can be monitored from the EOC" [Titan Systems Corporation, 2002]. EMS responders could also use video feeds from different angles of the scene to monitor incident operations on an integrated visual display rather than reconstructing the information from many radio frequencies.

The lack of radio interoperability between departments, jurisdictions, and agencies was another problem that exists on a national scale. The report recommended that fire and rescue organizations need interoperable radios [Titan Systems Corporation, 2002]. In addition, many different providers of medical treatment were on-site, resulting in problems of communication and coordination of activity. Many other organizations used equipment incompatible with the Arlington County Fire Department or preprogrammed in ways that limited communications. Subsequently, equipment interoperability continues to be an issue.

3 OTHER JURISDICTIONS

The City of Detroit highlighted the same issues of interoperability and limited information sharing within its emergency response system. Detroit is planning to implement new ideas for improving its emergency response division. In April 2002, Detroit's Mayor Kwame M. Kilpatrick announced a plan to establish new homeland security initiatives which involves connecting the radio systems used by police, fire, and EMS personnel, as well as expanding Detroit's wireless data transmittal systems [Government Technology, 2002]. A month after this plan was announced, the city's emergency response personnel relocated to a new communications center and upgraded electronic systems for better service. The ten-point action plan affirms the importance in coordinating efforts in emergency response.

Officials in Oakland County, Michigan have also made plans to address their interoperability issues by adopting a new emergency radio system that will link police and fire department personnel. According to Police Chief William Dwyer, "Nothing is more important in effective and efficient public safety emergency response than the radio communications system that links the responders to each other" [Martindale, 2002]. They have realized that poor communications have been blamed for numerous tragedies and they hope to prevent this type of disaster by addressing the issue before it becomes a real problem.

Other emergency response jurisdictions across the country face similar issues. In New York City, Commissioner Nicholas Scoppetta said that he had made improved communications one of his most urgent priorities because

the response to the attack on the World Trade Center was plagued with communications problems [Dwyer, 2002]. Specifically, the Police and Fire Departments barely spoke to each other and did not coordinate their rescue plans. The state of Arizona also faces issues with emergency response interoperability. In her keynote address to the fourth annual Conference on Public Service and the Law School at UVA on, March 15, 2003, Janet Napolitano, Governor of Arizona highlighted interoperability as a major issue for Arizona emergency response. She talked about how the police and fire departments cannot communicate effectively because of their distinct radio channels, creating major problems for homeland security. She stated that this is an issue that needs to be addressed in the face of wartime and heightened terrorist activity.

4 RECURRING ISSUES IN EMERGENCY RESPONSE

The summaries below describe each key issue as well as solutions comprised of commercially available technology.

4.1 Voice-Oriented Communications

There are several issues posed by using only voice-oriented communications, such as landlines, cell phones, and radios. These channels can easily become overloaded during a large-scale disaster like 9/11. Because the public also relies heavily on voice communications, these lines are easily overloaded and require many levels of redundancy to ensure reliability in a crisis. In addition, reliance on voice communication limits the flow of information; these alternative forms of information can be very useful during an emergency response. Information from different media such as maps, images, text messages, video feeds and conferencing, statistical data, and location tracking can provide crisis managers with a more comprehensive understanding of a disaster with minimal time and effort. They would be able to analyze the information for themselves instead of relying on other's interpretations. This presents a need for an alternate form of communication that would allow for the transfer of different information formats. Because words and sounds may not adequately describe a situation, voice-oriented communications contributes to the next issue of limited situational awareness.

4.2 Limited Situational Awareness

Situational awareness allows crisis managers to know what is going on where at all times; this leads to more timely and informed decision making. Currently, this ability is limited by the reliance on voice-oriented communications; there is only so much information that can be obtained over the phone or via a foot messenger. Many commercially available applications can be applied to increasing situational awareness in emergency response. Video distribution from onsite cameras can allow for a visual survey of a disaster scene from multiple views. Real-time GPS-based location information of onsite assets such as responder personnel, vehicles, and supplies can allow for more efficient tracking and allocation of resources. Wireless communications for onsite connectivity provides freedom of movement for emergency responders while maintaining communication with managers. Crisis managers can receive maps and statistics for the site in order to make more informed decisions. An onsite scout can snap a picture of a possible suspect and send it to others for analyzing. All of these capabilities can be used to effectively improve situational awareness for crisis managers to aid in decision-making.

4.3 Interoperability

Lastly, interoperability is a key issue in emergency response when a disaster involves more than one department, jurisdiction, or agency. Currently, most emergency response organizations have no means of communicating with other emergency response and peripheral organizations. Police and Fire Departments communicate on different radio channels and cannot interoperate. Beyond traditional emergency response agencies, there are no lines of communications set up to connect other relevant players to emergency response if and when needed. For example, if a disaster involved a main water line, there is no efficient way in which a police officer can contact the appropriate personnel in the public works department since these employees tend to work without a dedicated phone-line. On the other hand, making every possible player in every possible scenario a permanent part of an interoperable system would be infeasible; maintaining such an enormous network of connections between so many people would ultimately prove to be inefficient and insecure. What is needed is a system that dynamically connects people and allows immediate communications only on a per need basis. This system will allow the police officer to contact the utility personnel and other relevant players when she needs to, disabling and freeing the connection when the communication is over. Interoperability seems to be the problem that is most widely faced across the nation, but solving these three problems go hand in hand for improving emergency response overall.

5 THE GRAPHICAL USER INTERFACE: A VISUALIZATION OF THE CONCEPT

The concept of operations described above addresses key issues in emergency response. This solution was visualized using a Graphical User Interface (GUI) that was intended for use by response coordinators. Response coordinators typically stay in one place during an emergency. Therefore, they are better candidates for a computer-based interface than first responders out in the field. This GUI, designed specifically for response coordinators, harnesses the potential of currently available technology by incorporating video, audio, location tracking, and other capabilities. A screen shot of the main screen can be seen in Figure 1.

Figure 1: Screen shot of main screen

To address voice-oriented communications, the GUI includes an interface to connect users through video conferencing. The Communications Bar can be seen in Figure 2 below. A user could initiate a video conference by choosing a person from a list of all emergency responders and clicking the "Connect" button. Because this list of responders would be very large, a user can filter the list of names by department (fire, police, EMT, etc.) and district. In addition, the user can add a department or entity to the communications list by typing in the name of the department or entity and clicking the "Add Department" button.

Figure 2: Communications Bar

The design also includes interfaces for sending text messages, video clips, images, and other data files to anyone in the system. These capabilities would allow for communicating information that cannot be conveyed by audio alone.

These capabilities also improve situational awareness. In addition to streaming video and the other forms of data that can be transmitted, the GUI also provides the ability to track assets (such as vehicles, personnel, and supplies) and send and receive geographically based messages. A map is located in the center of the main screen in Figure 1. Figure 3 shows the map by itself. The locations of assets are marked by dots on the map. The colors of the dots correspond to the type of unit associated with that dot (e.g. fire = red, police = blue, paramedics = green). Other structural assets are also available on the map, namely schools, hospitals, and utilities. The three buttons at the bottom of the map ("Show Schools", "Show Hospitals", "Show Utilities") allow a user to access this location information. If the user needs to gain more information about a particular location, he/she could simply click on the dot for more details in a pop-up window. This new window gives a brief synopsis of the emergency scene, the person in charge of the scene, and links to more information or live video feeds from the scene if available. These capabilities can improve situational awareness by providing needed information about an event.

Figure 3: The Location Awareness Map

All of these capabilities allow crisis managers to better manage a disaster scene; however if the managers become overloaded with information, the situation awareness level remains stagnant or degrades. This presents a need for fil-

tering and organizing information, the importance of which is parallel to acquiring and delivering more information. The GUI incorporates a grouping functionality in the interface for access control. This functionality organizes the flow of information so that users are not overloaded with unnecessary information. It separates information by placing users into distinct groups in which communication is contained based on functionality and rank. The grouping interface can be seen in Figure 4.

These groups consist of emergency responders that have similar functions and thus need to see the same information. For example, a group called "Fire" would contain members who need to see information about fire-related activities. Users (managers) can add and delete members from groups, add new groups, and delete groups based on the status of an emergency. This grouping flexibility provides the much needed dynamic interoperability that many jurisdictions are striving to achieve.

Arlington County emergency response personnel have provided continuous feedback during the GUI design process. The positive feedback received recommends that the solution is feasible within the context of Arlington County emergency response.

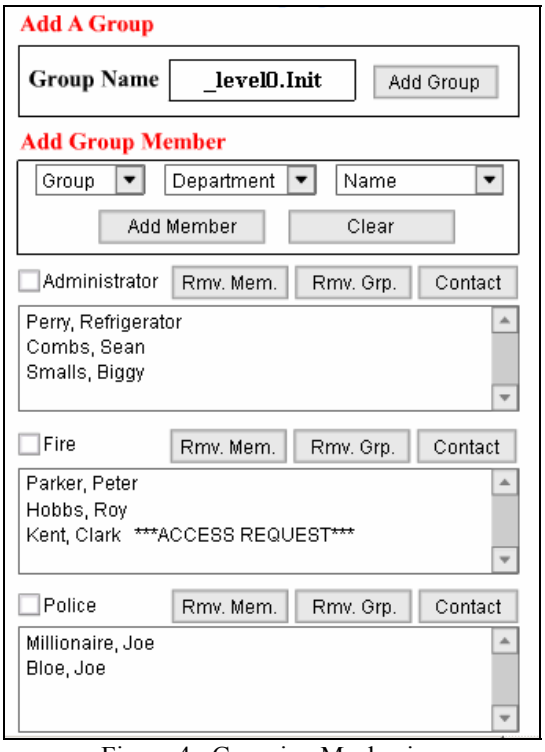

Figure 4: Grouping Mechanism

6 CONCLUSION

A review of the current state of emergency response around the nation has revealed three recurring issues that can be addressed with new capabilities and systems: 1) over reliance on unreliable voice-oriented communications; 2) limited situational awareness; 3) lack of interoperability. Various ways to mitigate these problems include current commercially available technology applied to emergency response activities. The Graphical User Interface visualizes the concept of operations for using these technologies to address these issues. The next steps towards implementing this system for use in emergency response would be to explore the technical approach to developing such a system.

The concept of operations relies upon the availability of an adaptable communications infrastructure. The flexibility of a peer-to-peer (P2P) architecture makes such communication possible. P2P networks are dynamically stable, server-less networks that do not rely on the performance of any single entity. They can quickly adapt to changing user bases and network organizations. Users can add to and drop out of a system without significantly affecting the system performance. The flexible structure is suitable for the dynamic and unique activities of emergency response while also meeting stringent requirements for information management and real-time information transfers. The flexibility of P2P networks would allow for spontaneous connectivity between anyone involved in an emergency response to facilitate communications and information transfer. A P2P network also provides an expandable structure for additional features to address future emergency needs as they arise. This approach addresses the problem of interoperability through the universality and consistency provided by the internet.

In summary, the problems that have arisen in emergency response can be addressed with an ideal concept of operations, and visualized with the proof-of-concept GUI. The GUI demonstrates how technology can fit together and work for emergency response managers. Close interaction with high-level Arlington County emergency response personnel has verified the feasibility and necessity of these recommendations.

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