Are low cost accountability, communications, and management systems for emergency first responders using 3G and 4G cellular technologies feasible?

Kenneth Coleman

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ARE LOW COST ACCOUNTABILITY, COMMUNICATIONS, AND MANAGEMENT SYSTEMS FOR EMERGENCY FIRST RESPONDERS USING 3G AND 4G CELLULAR TECHNOLOGIES FEASIBLE?

by

Kenneth J. Coleman

Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Networking and Systems Administration

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ABSTRACT

Reliable, easily deployed communication networks are a necessity for emergency responders as the coordination of their efforts and their safety depend on it. As a volunteer firefighter, this researcher is aware of the shortcomings of the current communication technologies presently deployed, and the risks it poses to firefighters. Some studies have proposed deployment of sophisticated hybrid mesh networks and mobile ad hoc networks that allow for location tracking, environment and personnel vital signs monitoring, and data communications. Unfortunately the cost of these systems and required training in use of the equipment inhibits their adoption and wide scale deployment across the nation’s emergency responder agencies. We are surrounded by secure, reliable cellular network technologies that meet our voice and data communication needs, yet current studies focus on building network infrastructures from the ground up and discussing how to address the security and performance issues of their proposed networks. This study proposes the use of the existing cellular network architecture already in place across the nation as a foundation to explore the feasibility of a low cost communication, management and accountability system utilizing 3G and 4G technologies and architecture.

Keywords: Cellular, 3G, 4G, EMS, Firefighters, Accountability
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CHAPTER 1: INTRODUCTION

Emergency first responders including police, firefighters, and emergency medical technicians depend on reliable communication, accountability, and management systems in order to coordinate responses to critical situations safely and efficiently. Three critical performance needs cited as top priority by emergency responders includes range, speed, and availability of the communications network. Managing emergency responses and implementing an accountability solution rely upon capabilities of the communication systems in place.

Physical environment, the human element, and current technology systems in use affect performance of the emergency responder technology systems. Lack of interoperability between radio systems continues to pose a significant hurdle for first responders. ([1], 51). In addition, range and reliability of current communication and accountability systems in use vary and many deteriorate depending on the distance between operating units, and the composition of the structure, man-made or natural. Society needs a universal standard in communication and accountability systems for emergency first responders to best manage incidents and minimize risk of failure or injury to responders. Formal adoption requires a cost friendly standard in order to not discriminate against emergency responder agencies with fiscal constraints, and remain practical for use in emergency situations. Proposed solutions and frameworks to date unfortunately are pricey due to equipment costs and training needs, sometimes impractical for use at an emergency.

Past studies for improving communication systems of emergency first responders have proposed extending the range of existing radio communication equipment and improving the routing of wireless data to reduce interference, through the real-time deployment of mobile ad hoc network access points. To further address the issue of emergency scene management and accountability, use of Geographic Information Systems (GIS) technology, the Global Positioning Satellite system (GPS), and sensor technology has been suggested for location tracking and monitoring of emergency responder movements at an incident.
Some studies proposed improvements to emergency responder communication, management, and accountability systems that primarily focus on collaboration between base stations, e.g. dispatch center, and command units at the scene of an emergency, e.g. fire chief, for dispatching and coordinating emergency vehicles and equipment. These new systems require acquisition of high cost equipment and establishment of a mobile network capable of operating under high demand usage. Newer technologies require resources that may inhibit the acquisition of equipment, including training costs to learn those new technologies. ([1], 51). Deficiencies in coordination of emergency management tasks result due to the lack of emphasis placed on the infrastructure supporting the emergency communications and accountability networks. These studies fail to address shortcomings to communication, management, and accountability systems for emergency responder personnel.

Additional research into the merits of a low cost communication, management, and accountability system for emergency first responders that provide a benefit to the responders on scene conducting operations must come to fruition. As a volunteer firefighter, this researcher understands that funding and training needs prohibit the upgrade of equipment and technology systems. Funding for training and equipment presents a challenge to volunteer fire departments located in suburban and rural areas. Instead of focusing on creating new mobile network infrastructures and deploying equipment that will require a large time and money commitment, it would serve a benefit to look at current network infrastructures already in place. By utilizing current network technologies in place, the need to invest large amounts of money into new systems, equipment, and training no longer exists. Past studies have offered minimal consideration on the use of existing communications architecture, such the national cellular networks employing 2G, 3G, and in some places 4G technologies. 3G networks, a wide area cellular technology, boasts a network of thousands of tower sites yet this existing network remains underutilized. ([13], 16). Cellular technologies can benefit the emergency first responder because both data and voice transmissions are supported through its architecture.
This study will focus on firefighters and emergency medical services, exploring low cost solutions for emergency first responder communication, management, and accountability systems using cellular technologies, to determine feasibility in the field of operations. The solution must adapt to changing environments without significant performance issues. In an era of cost savings and fiscal restraint, can firefighters and emergency medical services harness the power of cellular technology to make low cost solutions available to more departments?
CHAPTER 2: RELATED WORK

Numerous surveys and studies have analyzed what emergency responders require to perform their jobs efficiently. Exploring technology used (i.e. satellite, wireless networks, radio networks, etc.) and what, if any, improvements in communications and or multi-network functionality can be made to unite emergency responders and assess scenes before arrival, needs to occur. How do technological obstacles and physical barriers undermine efforts to improve the emergency communications network? Once on scene, how do accountability systems keep personnel safe? Obtaining answers to these questions will help us determine if a less costly solution is possible to address responder communication deficiencies.

An assessment of the scene before arrival would benefit first responders. Currently responders rely upon telephone calls and the caller’s interpretation of events to assess the seriousness of a situation. An Internet-based Next Generation 911 system (NG 911) undergoing testing across the U.S. would allow 911 centers to receive and send images and videos along with voice communications to emergency first responders. ([29]). In its infancy, functionality of the Next Generation 911 continues to grow because of the eleven million dollar grant from the U.S. Department of Transportation over the next two and half years to implement the enhanced 911 system in rural areas. Officials hope that GPS functionality of today’s mobile phones will be able to interact with the NG 911 system to provide caller location. ([29]). The new system may be costly, but the need to improve response abilities of emergency first responders remains an important priority of many municipalities. A continued participation of municipalities in the testing process promises a successful implementation of a Next Generation 911 system nationwide in the future.

Current communication systems also pose problems to emergency first responders. For example, firefighters entering a building observe deterioration in radio communications based upon factors including structure type and distance
from the incident command center. Responders measured losses of up to 50 dB during a radio propagation study of a 14-story apartment complex. ([2], 85). A study by Souryal and the research team proposed a multi-hop wireless environment to extend radio coverage with a structure. The deployment model tested the multi-hop wireless environment adaptability to changing conditions, provided end-user sensory data, two-way text communications, and RFID tags for localization purposes. ([2], 86).

During the simulation, researchers attempted to find a relationship between signal strength and conditions in the hi-rise structure. The relationship between noise and interference, and received signal strength on wireless reliability underwent quantitative analysis. Results showed that the study validated the real time deployment prototype as an effective solution for improving responder communications in harsh environments. However, additional work, including the placement of access points for range extension, and an increase in bandwidth from 900 MHz to 2.4 GHz to accommodate both voice and video transmissions, remained. ([2], 90).

Other studies proposed integration of Geographic Information Systems (GIS) to assist emergency responders in coordination of communication efforts on scene. Geospatial information is a critical component of decision making in crisis management, allowing incident commanders to coordinate with personnel in the field using computers and portable devices to pinpoint operations using end-user sensory data (i.e. pointing to a location on a map and displaying that location to command headquarters). ([24], 327). While improved GIS systems may serve emergency responders well, the ability to locate personnel at a scene remains a hurdle. A study conducted by Lei and Hui tested three wireless network protocols: Wireless Application Protocol (WAP), Java 2 Platform Micro Edition (J2ME), and i-Mode mobile Internet, seeking the best performing protocol on a Global Positioning Satellite (GPS) enabled phone of an emergency responder in the field. After qualitative comparison of protocol features such as range of the
protocols, GPS accuracy, and usability of the device (small screens on mobile phones), the researchers concluded further study would not be feasible due to those scientific problems. ([23], 914). Physical environment and distance affected range of the protocols, which proved too short for effectiveness in an emergency responder environment. The small screens of mobile phones made reading maps, GPS beacons, and other information difficult and impractical in harsh physical environments.

The flow of information between emergency response agencies needs attention. To determine the best technology for our responders, we need to understand the process of transmitting and processing of information. A problem with testing new communications technology lies in the hefty cost for new equipment and the ability to conduct testing during real situations. The Disaster Response Information Flow and Technology Simulator architecture proposed by researchers would allow testing of a model for GIS integration into simulated agent-based framework without the prohibitive cost or interference incurred of a live testing environment. ([25], 919). The framework contains a flaw; it uses GPS for its transmitters which limit bandwidth availability. In other words, data and voice communications could not transmit concurrently on such a system. Robinson and Brown raised awareness to flexible framework architecture and open the door to additional research for determining the best functionality and needs for emergency first responders when it comes to communication systems.

Accountability systems for firefighters and emergency first responders also need to embrace the digital age. Monitoring physiological information of first responders and the ability to provide health information to emergency medical personnel at a moment’s notice must become reality. One such study underway includes the physiological monitoring of firefighters at the Boston, Massachusetts and Oxnard, California Fire Departments. After all, over 62% of all firefighter fatalities occur due to overexertion or stress between the initial call dispatch and the return to the firehouse. ([21, 110]). In its infancy stages, this study requires
the manual downloading of physiological data, activity logs, and calls logs daily. A system that would communicate this information into a data collection source, e.g. database through an automated process promotes greater efficiency. While monitoring physiological data is important, it is noteworthy to observe that this data alone cannot predict if a firefighter will succumb to stress or overexertion. Keeping this in mind, the ability to monitor physiological data of a responder and look up one’s medical history on the go could assist incident commanders in determining whether a responder is at an increased risk of harm due to pre-existing conditions or symptoms.

Additional studies have distributed surveys to first responders, wanting to learn perceptions on the information responders receive, and the information that responders need. One study used an exploratory data analysis approach, intending to test survey responses for statistical consistency and developing a baseline. ([30], 159). Survey responses from that study revealed that information received by emergency responders does not meet expectations. Another study conducted in November 2009 discovered that 72% of emergency call centers for police, fire, and medical services confirmed areas of poor network coverage. ([15], 85).

Social media slowly emerged as a credible tool of the emergency services environment. Internet chat rooms, Twitter, and phone texting have aided in contacting the authorities as well as dispatching emergency crews to a scene. In 2009, an message to actress Demi Moore’s Twitter account containing suicidal threats from a “fan” or “follower” led to the tracking down and hospitalization of the ill individual. ([15], 85). During the shooting rampage at Virginia Tech, students used Facebook to communicate information about the ongoing situation to friends and family who could in turn notify law enforcement, firefighters, and the emergency medical technicians on scene with an incident play-by-play.
Texting remains the most popular tool, with usage in the United States soaring from about 400 per day during the earlier part of the 2000s to about 4.5 million texts per day currently, per Forbes.com. ([15], 86). Its potential use at 911 call centers has been hailed by those hearing impaired or deaf individuals, but to date, cost has inhibited much enhancement of 911 centers across America.

Cellular technology has been embraced as a necessary, future part of emergency communication networks. Back in 1996 during the early days of cellular technology, the Federal Communications Commission created docket 94-102 to address compatibility of cellular phones with the 911 system, and the ability for the cellular phone to provide caller location to 911. ([15], 86). Today about 88.1% of U.S. counties possess some form of an enhanced 911 system that provide for caller location tracking via cellular phone. The development of applications including Google Maps enables cellular service users to track friends and family. In the case of emergency services, the whereabouts of personnel in the field can also be tracked.

Emergency responder communication systems are slowly creeping forward into the twenty-first century. Communication systems must be widely deployable, reliable, and operate seamless with other networks and systems. ([26], 90). Frameworks created to allow for the simulation of emergencies and disasters, and the testing of new technologies need development. Incorporating the functionality of everyday equipment, i.e. cell phones, to transmit data or using GPS to determine location of an individual slowly blends into the emergency responder system paradigm. Despite the studies dedicated to emergency responder communication systems, no significant contributions exist. Enhanced 911 communication systems incorporated into current alert systems for first responders would serve a great benefit. As a volunteer firefighter, the ability to assess a scene (or receiving the correct location from a GPS system) before responding provides the opportunity to determine call priority. Does the car accident require lights and siren approach, or a non-emergency no lights or sirens
Such an enhanced dispatch system would serve this benefit. These studies did not examine the current equipment in use by emergency responders nor the practicality of such technology at emergency scenes. Physical barriers such as buildings or the earth are discussed but the presence of water, heat, and other phenomena are not addressed. The current communications infrastructures in place and incompatibilities with other technologies remain unanalyzed. How are personnel accounted for at emergency scenes and how safe are firefighters and fellow emergency responders? This researcher recognizes the need to further research this subject and proposes a usable, reliable system to meet the needs defined by emergency responders on the front lines.
CHAPTER 3: METHODOLOGY

3.1 Overview

The proposed study will determine feasibility of a low cost communication and accountability system for emergency first responder agencies using cellular technologies. Findings will assist future researchers on applicability of cellular technologies to serve the needs of the emergency first responder accountability, communication, and management system. These needs will be ascertained by a survey administered by this researcher along with an analysis of systems currently in existence and other methodologies proposed by other researchers. The proposed system would be low cost and utilize the existing and possible future benefits of cellular network architecture. Data collected through experiments using open source applications for the iPhone 3G on the AT&T cellular network will determine success of this proposal.

3.1.1 Survey Environment

In order to propose the foundations for a low cost accountability, communications, and management system for emergency first responders, this researcher implemented a mixed methods research method using elements of quantitative statistical research with a qualitative participatory and philosophic study. The first part of the study combined self-administered questions, randomly distributed by mail and online, with structured observations. ([27]). Emergency first responders within the Rochester metropolitan area and the New York City metropolitan area were the targeted survey population.

3.1.2 Survey Purpose

The goals of the survey were to:

- Determine the communications network technology in use by emergency responder agencies, specifically fire departments, in New York State.
• Determine the strengths and weaknesses of the respective networks in service and deployed at emergency response scenes.
• Determine the factors that affect the selection and deployment of existing communication networks.

3.1.3 Survey Procedure

A four phase administration process implementation required an advance letter of notice sent to all survey targets, followed by mailing of the survey a week later, a reminder follow-up post card five business days later, and finally a handwritten note and questionnaire with a pre-addressed return envelope with postage five business days later. ([28]). The cross-section survey asked emergency responders about their communication equipment, the strengths and weaknesses, and what improvements and features they would want to see in an enhanced emergency first responder communication system, using a rating scale of “strongly agree” to “strongly disagree”. Responses to the survey remained anonymous except for demographic data such as locale type, e.g. urban, suburban, rural and population served, in order to determine how factors such as locale type affected responses to the survey. Survey feedback was complimented with observations by firefighters and the public.

3.1.4 Survey Validity

Factored into the merit of the feedback received were ethical considerations and threats to data validity. Some municipalities declined to participate in this study for reasons they respectively chose not to elaborate upon. The fear that positive feedback on a specific product might be misconstrued as an endorsement was considered, although this researcher did not think it would be much of a concern. A significant emergency response event and performance of the communication systems used during the disaster could also bias the feedback of responders participating in the surveys. In addition, would feedback from an emergency responder agency with a large coverage area in terms of population carry more weight in the study than agencies covering a smaller population
area? Equal weight was applied to all emergency responder agencies with large and small coverage areas.

3.1.5 Survey Findings

The survey was distributed to thirty fire departments located in Western New York and the New York City metropolitan area. Nine departments returned surveys, while the remainder provided a written declination or failed to reply altogether. After the collection of survey results, feedback was compared with that of past studies which have proposed solutions to enhance emergency first responder accountability, communications, and management systems. This step assisted in determining where efforts needed prioritization in order to provide an accountability, communications, and management system meeting the requirements specified by the survey participants.

Surprisingly, the results collected from the survey did not support the needs cited in previously conducted surveys. One hundred percent of survey responders felt that their existing communication systems satisfactorily met operational needs but noted shortfalls in range and inability to improve equipment due to costs. The departments that responded were less concerned about the performance of current communications systems, and expressed greater interest in improved accountability systems. In terms of enhanced 911 systems, responders to the survey expressed satisfaction with their current level of incident notification, whether by voice and/or alpha page, or cell phone text alerts. Also, survey responders stressed importance in accountability of personnel arriving at scene, for purposes of assigning jobs, and having current health information available for each arriving responder in anticipation of medical emergencies at a scene. Responses to the survey called for a more automated accountability system free of human intervention, e.g. manual placing of accountability tags on a fire truck or an incident command board. Seventy five percent felt strongly that financial constraints prevented a necessary move to automated accountability systems.
Figure 1 - Survey of Communication Systems for Emergency First Responders

Figure 1 illustrates the survey responses regarding performance of emergency first responder communication systems. Responders agree that performance of communication systems are satisfactory and strongly agree that cost hinders improvements and updates to existing systems. In Figure 2, responses indicate that there is agreement upon satisfactory performance of accountability systems for emergency first responders, however there is dissatisfaction in ease of use and inability to update or purchase new accountability systems due to cost.

Past studies focused on the deployment of wireless ad hoc networks and mesh networks to provide communication services within a structure or an
underground scene where emergency operations might be conducted. Challenges to this type of solution include network setup in a timely manner, and acquiring the equipment necessary to communicate on this network. Setting up a mobile network requires the purchasing of equipment which may not be accessible to volunteer fire departments with limited funding. In rural areas, the feasibility of transporting needed equipment to a scene, due to road conditions or other environmental factors requires consideration. Once on scene, how and can the mobile ad hoc network communicate with other networks to summon mutual assistance or notify other emergency authorities of an on scene crisis?

Little research has been conducted so far into the use of the cellular network framework during emergency operations. Most populated areas in the United States have at minimum 2G cellular coverage with metropolitan areas boasting 3G coverage. Slowly, 4G is starting to deploy in selected markets. Cellular phones such as Apple’s iPhone or Motorola’s Droid support WiFi connectivity in addition to simultaneous voice and data communications. Better utilization of the cellular network framework already in place rather than consumption of resources into development of costly mobile networking solutions benefits volunteer departments and other fiscally challenged emergency responder agencies.

Few studies have sought to establish simple, cost effective, yet powerful accountability systems. Research conducted into the use of Geographic Information Systems (GIS) to locate firefighters via GPS in structures, or sensor technology to measure vital signs of personnel continues to make progress in the effort to improve accountability systems. Incident commanders that responded to the survey conducted in this research study indicated need for an accounting of personnel arriving on scene. Once provided an assignment, the incident commander(s) and team of emergency responders indicated satisfaction with communication systems. In addition, incident commanders did not appear overly concerned about monitoring the condition of firefighters performing their jobs, instead relying on feedback from the firefighter if feeling ill. One respondent identified the ability to provide emergency medical staff on scene, e.g. EMTs,
with the medical information of a patient if necessary, as critical. The ability to view the normal vital signs readings of firefighters would assist emergency medical staff in determining whether vital signs collected for firefighters at the emergency scene call for advanced medical treatment.

Several fire departments responded to the survey indicating the need for improved accountability systems. Most departments indicated use of a radio based system in combination with cellular text message/SMS dispatch messages to dispatch fire or medical calls. Once arrived on scene, emergency personnel provide physical accountability tags to a specific individual, e.g. Safety Officer, or place in a specific location, e.g. accountability tag key holder on the responding fire apparatus or ambulance before entering a location or approaching a potentially hazardous environment.

The need for an improved accountability system exists for two main reasons: human error and performance of existing communication equipment including radios. Survey responses indicated that radios do not always perform well in basements, certain structure types, and rural areas. While most surveys reported that communication equipment performed adequately, some cited cost as prohibiting upgrades for equipment. While current accountability systems were rated as good or adequate, difficulty in maintaining accountability with little manpower at an emergency scene posed a dilemma. Many departments responding to the survey use accountability boards where responders provide a physical tag before engaging an incident. As personnel are assigned jobs by the incident commander, the safety officer in charge of accountability manually updates the accountability board. Firefighters and other personnel on scene report back to the safety officer after completion of an assigned task, and at the end of the job to pick up their accountability tag. In areas where firefighters respond in privately owned vehicles or a shortage of responders to a scene exists, manually updating an accountability board proves a challenge. A system that does not require human management of personnel assignments and location would serve a great benefit.
The need for availability of responder medical information at an incident scene should exist, noted one survey response. After periods of intense physical exertion and exposure to extremely hostile atmospheres, firefighters are required to report to rehabilitation areas. In rehabilitation areas, firefighters replenish their fluids, and if necessary, may seek medical treatment for any injuries or illnesses incurred during the emergency operations. To properly assess the physical condition of firefighters in rehabilitation, emergency medical personnel on scene would benefit from a solution that provides convenient yet secure access to firefighter medical records. By having a baseline to compare against, medics could determine the seriousness of a firefighter's health condition and make a better decision on course of treatment. The development of a mobile web application to meet this need is discussed in an upcoming section.

In regards to other components requested for an automated accountability system, such as an electronic sign in/sign out board for personnel, this researcher’s opinion supports the idea that Radio Frequency Identification (RFID) technology would provide for a better solution to this need versus a cellular technology solution. When responding to an emergency scene, pulling out a phone and loading an application to “check in” is not practical, especially when the firefighter is suiting up in gear. A non hands-on solution using passive RFID technology would be more appropriate for an electronic sign in/sign out accountability solution. RFID technology will not be discussed further in this study. Instead, this study will primarily focus on the merits of a functional, low cost accountability and communication system using cellular technology for emergency first responders. Included in this research will be the testing of a mobile phone application allowing emergency medical staff to retrieve health information about firefighters seeking treatment at a scene.

3.2 Proposed Framework for Testing Cellular Based System Overview

In order to evaluate the merits of low cost cellular network based accountability, communications, and management systems, experiments
conducted in training scenarios and simulations intended to measure the following:

- Performance of location-tracking via GPS enabled cellular phones.
- Availability and reliability of voice and data transmission in different environmental conditions (heat, cold, moisture).
- Use of cellular technology within an automated accountability system.
- Sign in / Sign out process for responders at an incident.
- Provide medical information for responders receiving rehabilitation treatment after periods of intense physical exertion.

3.2.1 Purpose

These training scenarios and simulations attempted to mimic the environment at an emergency scene, where possible, to test the performance of cellular technology as a viable voice and data transmission, versus the traditional method of communication, the radio system. The ability to use cellular technology within an accountability system is also tested, via location tracking, and through an emergency medical service application on an iPhone.

3.2.2 Procedure

The first experiment focused on the use of location tracking via GPS enabled cellular phones as an accountability tool for first responders on scene. A large part of maintaining scene safety and accountability lies in knowing where your personnel are located. Since a low cost accountability system remains a primary focus of this research, the free location tracking tool Google Latitude was used. The iPhones that participated in the test included those with GPS service enabled through the AT&T Wireless cellular service provider, and those with “location tracking” enabled which utilized cellular tower triangulation to provide an approximate location of the cellular phone.
In order to conduct the location tracking experiment, the following resources were required:

- 3 firefighters with a GPS enabled or location tracking phone.
  
  o iPhone 3G used as the GPS enabled/location tracking phone.

- 1 safety officer with access to a wireless computer, laptop, or cellular phone.
  
  o Dell Latitude 620 used with wireless access.

- Google account to access the Latitude gadget.
  
  o All parties needed to establish a “friend” relationship on Google Latitude in order to track each others’ movements.

For test scenario one, two firefighters were placed in a living room next to each other on the bottom floor of a two story home. The Type III-B construction home, similar to the one illustrated in figure 3 below, contained unprotected combustibles consisting of brick or block walls with a wooden roof or floor assembly not protected against fire. [18]. This type of construction is common for older buildings and while the brick walls may survive a fire for up to two hours, the internal structure and framework would succumb to fire and heat damage in a short amount of time. A third firefighter stood about twenty feet away in a walk-in closet. The firefighters transmitted their locations via their location-enabled iPhones. A safety officer outside the structure connected to Google Latitude via a Dell Latitude 620 laptop and via an iPhone 3G. Firefighters conducted several evolutions where they crawled around the ground floor to mimic realistic
movements of personnel during an emergency operation and the safety officer was responsible for tracking their locations via the laptop and iPhone.

The second test scenario maintained similarities to the first scenario except for the construction type of the commercial building, Type III-A, considered protected combustible. Protected combustible structures are built with brick or block walls with wooden roof or floor assemblies which have one hour of fire protection for the structural frame and ceiling/roof protection. [18]. An example of Type III-A construction is illustrated in figure 4 above. Three firefighters in separate rooms conducted searches about twenty feet apart, while the safety officer positioned about seventy feet away in the main lobby monitored the movements of the firefighters.

This study’s second round of experiments tested the performance of cellular technology as a viable voice and data transmission tool, versus the traditional radio system. To measure the performance of cellular technology as a data transmission tool, a free iPhone application named Bluetooth Chat (BTchat), developed by Philipp Kolb, evaluated Bluetooth functionality of the iPhone 3G. Voice communications using Bluetooth were evaluated with the Walkie Talkie Free application, created by Brady Archambo for the iPhone.
The experiments were conducted in a typical two story home, under normal conditions and an environment where water vapor mist simulated smoke. No testing with fire, extreme heat, or real smoke occurred.

For the first data transmission tests, two Apple iPhones installed the BTchat application. Bluetooth discovery between the two devices took longer than expected, approximately one minute. Once the Bluetooth discovered the two devices, a test communication via data (text message) sought to verify successful pairing. After confirming successful pairing, messaging between the two phones via Bluetooth began, increasing distances between the devices and adding physical obstructions, e.g. walls, doors, and floors. One firefighter remained stationary in the kitchen while another firefighter traveled between the bedroom, the living room, and then down into the basement.

Next, the use of iPhones as Walkie Talkie radios as an effective communication tool for firefighters within a building as a conduit to transmit information to the incident commander outside the structure underwent testing. In order to conduct the Walkie Talkie experiment, the following resources were required:

1. One firefighter with the Walkie Talkie Free application installed on the iPhone.

2. One incident commander with the Walkie Talkie Free application installed on the iPhone.

The firefighter and incident commander initialized the Walkie Talkie Free application on their phones outside of a standard two story home and paired using Bluetooth. Once established by a link that took about a minute or so to occur, the firefighter and incident commander exchanged communications every five feet while increasing the distance between each other in an effort to determine range within the home and the quality of communication.
3.2.3 Findings

The test scenarios examining the use of GPS or location tracking cellular phones and a free tool such as Google Latitude proved impractical and ineffective as a reliable accountability tool. Google Maps tool does not, rather, cannot, display blueprints or detail oriented close ups of locations. In the example snapshot shown, this researcher’s location in the building during scenario number two provides no value due to vagueness and lack of precision in location tracking by the cellular technology and Google Latitude. Also, the ability to accurately account all the firefighters in confined areas becomes compromised with map labels stacked on top of each other. In scenario one, again an approximate location shown lacks specific details, proving unreliable for accountability.

Without the aid of building blueprints and pinpoint GPS accuracy, the use of cellular GPS or location tracking technology would not serve any benefit in an accountability and management system. Figure 5 on the following page displays the lack of preciseness in location tracking for the Google Latitude application.

Findings in the BTchat experiments discovered that in direct line of sight, the phones communicated in text message chat up to a distance of about seventeen feet. The introduction of walls and doors interfered with Bluetooth pairing between devices. No significant decrease in performance occurred with the addition of the water vapor mist machine in terms of communications successfully transmitting between paired iPhones. The use of iPhones for viewing messages during an emergency response by firefighters proved impractical, with visual impediments (smoke, small screen, SCBA mask) and an inability to type on the iPhone keyboard with work gloves, making this solution undesirable.

During the Walkie Talkie simulation, communication remained clear up to twenty five feet until the firefighter entered a closet. Once in the closet, the pairing between the two iPhones terminated and re-establishing the pairing required a direct line of sight between the two iPhones and about a minute to relocate each other.
3.3 **Mobile Web Technology Using Cellular Systems Overview**

After completing the testing of low cost communication and location tracking tools for cellular devices, focus turned towards development of a mobile application providing medical information about emergency first responders at a scene. Development of this application was driven by feedback from survey responders who cited the need to access medical information of firefighters at a scene. The ability to access basic medical information about firefighters would allow emergency medical personnel an ability to prescribe better guided treatment. Most emergency medical responder agencies do not have immediate access to a patient’s medical history, and must request the information from the patient if possible. Properly assessing a patient’s condition at a scene could save a trip to the hospital or indicate an urgent need for transport.

In order to keep the medical information/accountability application low cost, the back end database and web server of this mobile web application used open source software. Pursuing a mobile web application versus an application specific for a device such as the iPhone would make the application versatile across multiple phones and cellular carriers. For the simulation, Apache Server 2.2.14 was used under Mac OS X version 10.5.8 with a 2.4 GHz Intel Core 2 Duo and 1 GB 800 MHz DDR2 SDRAM. MySQL Community Server (GPL) version 5.1.47 powered the database back end. PHP version 5.2.12 provided for the scripting interaction between the web application front end and the MySQL database back end.
3.3.1 Virtualization

The database that contained the firefighter medical information was stored in four tables within an MySQL database named testfdapp. These four tables were named personnel, pInfo, ffStatus, and ffAccount. The personnel table stored the emergency responder’s last name, first name, and badgeID, also set as the primary key. Badge ID numbers made for unique identifiers to fire department members. pInfo stored health information about the firefighters, including age, weight, resting pulse rate, blood pressure, and a free form comments field to document a condition, e.g. asthma. Both tables’ structures are displayed in figure 6 below. The ffStatus table stored information about a firefighter’s status, whether classified as an interior structural firefighter, an exterior firefighter, or other classification. Figure 7 displays the structure of the ffStatus table.

![Figure 6 - Structure of pInfo and personnel tables](image-url)
When a firefighter arrives for medical care, the ambulance crew opens up this project’s customized application, *Fire Rescue MedLink*, on their iPhone. The application receives the firefighter’s badge ID, often displayed on a firefighter’s helmet or accountability tag, and submits the query for processing by the web application. After querying the MySQL database with the supplied badge ID, medical information about the firefighter, minus his or her name becomes available to the medical technician. As an added feature, the program saves queries so retrieving information about a firefighter becomes a one touch process. If there is no data available, the application of course returns no data. This information would benefit the medical staff in coordinating the best possible treatment without compromising the patient’s condition further.

Illustration of the application in use is described below through screen shots and captions. The screenshots are provided through the iPhone Simulator version 3.1(139.1) developed by Apple Inc and simulating the iPhone OS 3.0(7A341)
The first screenshot of figure 8 displays the welcome screen of the application. In the second screenshot, the user enters the badge ID for the emergency responder requiring assistance, in this example #408. Data entry is redundant but required to ensure the correct badge number is entered. Once the badge ID is entered twice, the user presses the save button on the screen. The third screenshot illustrates the saved data entry as a touch button on the phone. To retrieve data about the emergency responder with badge #408, the user would press the button for 408. The click event generates a query string that is processed by a PHP script and passed to the mySQL database, where results are retrieved. Figure 9 illustrates a query string formed when the button for badge ID #408 is pressed.
Figure 10 displays the PHP code used to provided the feedback requested by the user on the phone screen.

```php
while($row = mysql_fetch_array($result))
{
  echo "<b>Badge ID: </b>" . $row['badgeID'];
  echo "<br/>
  echo "<b>Status: </b>" . $row['status'];
  echo "<br/>
  echo "<b>Age: </b>" . $row['age'];
  echo "<br/>
  echo "<b>Weight: </b>" . $row['weight'];
  echo "<br/>
  echo "<b>Resting Pulse: </b>" . $row['restpulse'];
  echo "<br/>
  echo "<b>Blood Pressure: </b>" . $row['bp'];
  echo "<br/>
  echo "<b>Comments: </b>" . $row['nComments'];
  echo "<br/>
}
```

Figure 10 - PHP code for application output

The query results are returned to the user and displayed in figure 11 below.

![Image of results on phone screen]

Figure 11 – Results displayed on phone screen

As the application is used in the field, past searches are saved for easy touch access. Searches are sorted from lowest to highest with a scrollable screen to navigate to the members with higher badge numbers. In the event the list of past searches becomes unmanageable, the user can press the Clear All Previous Searches button to clear the searches.
CHAPTER 4: RESULTS AND DISCUSSION

The testing of a low cost location tracking tool using solely 3G and 4G cellular technology on a GPS enabled cell phone confirmed that a low cost option is neither readily available nor feasible at this time due to poor performance. In the study *Real-time deployment of multihop relays for range extension* conducted by Souryal et al, the research team achieved real time localization through the use of RFID sensors and end user sensory equipment on the gear of emergency first responders or mobile access points. If the iPhone 3G incorporated RFID technologies, transmission of location data for the firefighter using the cellular phone’s connectivity to the Internet via a WiFi connection or 3G/4G cellular network, onward to a monitoring station or incident command, becomes reality. However, the need to drop mobile access points to extend range within a structure or incident scene adds a burden to responders since placement is essential to maintain a successful flow of information on the network and poor placement would render this solution ineffective. Setting up a mobile ad hoc network would also incur additional cost that this study seeks to limit. We attempted to mimic a low cost geographic information system setup using Google Maps and Google Latitude, which is no cost to the user; however GPS accuracy and usability of the cellular phone for the incident commander rendered this particular solution ineffective. A cellular phone provides for increased mobility over a computer or laptop, especially when moving around at an incident. The small screen of a phone unfortunately would make the already inaccurate location tracking of personnel via GPS through the cellular phone even harder to follow.

Would investment in a paid GPS/location tracking solution for cellular phones provide greater accuracy in determining positioning of personnel at an emergency scene? After examining several paid GPS/location tracking solutions for cellular phones, this researcher has concluded that a paid GPS location would not offer a location tracking system with greater accuracy in positioning. Unfortunately, most cellular phones and their supporting networks do not allow
GPS applications access to the phone’s GPS coordinates at this time. Instead, cellular networks are only required to track cellular phones and callers within 100 meters of a location. Paid applications, including Family Tracker and GPS Tracking, utilize the same GPS functionality as our low cost Google Latitude solution, using the cellular phone’s built in GPS receiver to approximate the location of the phone within 100 meters. See figure 12 below for screen shots of the Family Tracker and GPS tracking application. Hence, there is no gain in using a cellular technology based paid GPS/location tracking technology.

Cellular network technologies must allow access to a phone’s GPS data to extract the coordinates of the phone’s position. Exact coordinates would allow emergency responder agency map software to pinpoint the locations of personnel at a scene, rather than the generic location. One can envision such a valuable solution as incurring considerable costs once available to the public, as the map software would need regular updates to reflect construction and building changes, and remain compatible with different cellular phone technologies and networks.

![Family Tracker and GPS Tracker screenshots](image)

Figure 12 - Family Tracker and GPS Tracker screenshots respectively [32]
The ability to access a cellular phone’s GPS data was not available on the sole cellular provider used in this study, AT&T. Future research needs to consider other cellular network providers including Verizon and Sprint/Nextel. Spatial positioning within a building must also be considered with a location tracking solution. Accessing GPS data from a cellular phone may provide exact coordinates for an individual’s location, but positioning within a building, e.g. on the first floor or on the fourteenth floor, would remain unattainable without incorporating a supporting technology such as radio frequency identification (RFID). Whereas GPS can provide directional location within a building, e.g. east or north wing, RFID sensors could report one’s floor or room location. GPS and RFID technology complement each other for the purpose of precise location tracking and may provide the basis for a future low cost location tracking solution using cellular technology for emergency first responders.

Use of 3G/4G cellular technology for low cost radio communications as walkie talkies also proved inconclusive. The process of pairing the two phones via Bluetooth consumed valuable time, and unfortunately, only two devices could successfully pair at any single moment. At the scene of an incident with multiple emergency responders, this solution would not work. Plus, the short range of the Bluetooth protocol, approximately 30 feet, and normal barriers within a home including walls, ceilings, and roofs, cannot be penetrated. Also since Bluetooth operates in the 2.4 GHz band as does household devices including cordless phones and microwaves, use of these respective devices can affect quality of communication over Bluetooth.

An iPhone application to provide medical information about firefighters to qualified medical personnel on scene at an incident proved to be the most conceivable contribution to a low cost accountability system using 3G/4G cellular technology. Requiring only a cellular phone with access to the Internet via 3G/4G cellular technology, the Fire Rescue MedLink application could retrieve a quick snapshot of a patient’s health records that would offer guidance for an optimum course of treatment. The program provided a one touch search history so that
departments that receive dedicated medical support, e.g. a community ambulance corps or an ambulance squad within the fire department itself, could simply tap the badge number of a patient firefighter rather than enter the badge number into the application for query. While simulation of this application was successful, use in the field would determine whether it is deemed useful by qualified medical personnel and technicians.
 CHAPTER 5: CONCLUSION

This study suggests that the proposal of a low cost communication and accountability system using cellular technology for emergency first responders does not make par at this current time for location tracking and electronic sign in/sign out accountability systems. Simulations confirmed that several low cost solutions were unable to deliver information reliably and with the accurate drill down detail required for real-time emergency management and accountability. Improvement of data and radio communications for conducting emergency operations and location tracking/positioning does not seem possible without deployment of access points and other network equipment, lending support to the study by Souryal et al. Deployment of said equipment would pose significant costs to an emergency first responder agency, unfortunate since cost was cited by responders as the biggest obstacle to procuring upgrades and newer communication technologies.

Fortunately, this study provided successful testing of a cellular phone application that provides information about an emergency responder’s health to medical specialists in the field. The simulated use of the phone application for determining the condition of a firefighter and helping to direct a preferred course of treatment, yielded positive results. The cost of implementing this solution would be relatively cheap as open source resources, Apache and MySQL server, were used and support for both products is free via forums and documentation libraries. Also, the application would require minimal or no training, which also keeps costs low. Such an application could utilize cellular technology with 3G/4G technology and would provide a low cost solution to emergency responder agencies.
CHAPTER 6: CONSIDERATIONS AND FUTURE WORK

As emergency responder systems join the digital age, efforts are being developed to enhance 911 call center technologies and improve location tracking and dispatching of personnel to emergency scenes. This type of system utilizes broadband connections to support network communications. For emergency medical personnel, patient care records (PCRs) that were originally handwritten are now in electronic form and can be signed off with a signature pad in the ambulance. Fire officers can download emergency manuals or blueprints of buildings to laptops, PDAs, or cellular phones in the field, to assist in management of a scene. Electronic PCRs or blueprints of buildings do not require an Internet connection and in addition to being successful tools to the emergency responder, do not require connection to a network in order to be used in the field. When accounting for personnel at scenes, the current method is the use of accountability tags and accountability boards managed by designated safety officers. This system works best for departments where there are plenty of responders to an emergency scene to “manage” the accountability board. If there are not enough hands on deck to manage the assignment of resources at an incident, the safety of personnel may be compromised and the efficiency of the operation compromised by confusion. An electronic sign in/sign out system would assist in gauging what personnel was present on scene, and assist in handing out assignments. Without the aid of RFID technology within cellular phones to communicate with sensors on a fire truck or ambulance as part of an automated process, it would be incredibly difficult for a responder to clock in or clock out of an incident. Hanging an accountability tag on a truck prior to assisting at a scene would be preferable to manually engaging the phone to submit a text message to sign in/out or opening an application that provides similar functionality.

RFID technology would be an essential component of any cellular based management and accountability network for emergency first responders. Current proposals of RFID sensor technology in location tracking systems involve
dropping sensors within a building and the wearing of sensory devices on responder equipment, e.g. turnout gear. A mobile ad hoc network deployed at the scene would provide the connectivity necessary to process the movements of personnel via the readings from the sensors. If cellular phones had RFID functionality, the movements of firefighters could be transmitted via the phone’s 3G/4G connection via the Internet, eliminating a need for equipment to support a mobile ad hoc network. Or, sensor devices could be placed on fire trucks or ambulances that could be read by a responder’s cellular phone and scanned information, e.g. truck name, could be transmitted along with date and time, using the network connectivity provided through the phone’s service on a 3G/4G network. The next version of Apple’s iPhone, 4G, is to have built in RFID functionality. Testing the built in RFID functionality to read sensors and communicate that information using the phone’s network connectivity would be a great contribution towards the use of cellular technology for low cost accountability and management systems.

The Fire Rescue MedLink application if deployed would need to meet HIPAA and HITECH provisions. HIPAA, the acronym for the Health Insurance Portability and Accountability Act of 1996, is a Federal law containing provisions for the protection against unauthorized disclosure of individually identifiable health information, and held organizations liable for unauthorized disclosures. In 2009, the Health Information Technology for Economic and Clinical Health Act, known as HITECH, added new provisions to HIPAA that now allowed victims of unauthorized health information disclosures to hold individuals as well as organizations liable in civil court for monetary restitution. HITECH also established stricter standards for maintaining information security and stiffening penalties for non-compliance.

Currently, the application communicates to the back end database via an insecure HTTP connection over port 80, with no authentication challenges. Before deployment to production, database roles would need to be set to ensure that only authorized individuals and agencies had access to the database. Also, past
searches are stored for reuse if needed, perhaps this is an unnecessary feature. The communication made available to users of the application, emergency medical responders, does not include personally identifiable information other than badge number, which would be meaningless outside the emergency responder environment. Emergency first responders including firefighters and emergency medical workers are already bound by HIPAA to maintain scene information confidentiality, and extending it to the cell phone application with the HITECH provisions would not be problematic or unenforceable. Preferably, transmission of information between the application and back end database would be encrypted over secure HTTP or an OpenSSL connection. Development of a better GUI to present search results in a easier to read format would prove this application an asset to the emergency responder community and raise awareness of the benefits of cellular network connectivity in an electronic accountability and management system without the added costs of expensive networking equipment.

Emerging Healthcare Solutions Inc. (EHSI) plans to release a Smartphone application called e-911 in late 2010. This application would allow emergency responders access to an individual’s critical medical information by dialing 911 using an automated system. [31] It serves the same benefits as the application proposed by this researcher in providing critical medical information quickly to responders at an emergency. Released in October 2010, little is known about the workings of the application and the format in which the application transmits data to the responders. The announcement of this application will raise awareness and encourage further development of similar solutions, including use of cellular and wireless networks as proposed in this research, to fine tune delivery of critical medical information vital to medical staff during an emergency.
CHAPTER 7: WORKS CITED


[29] Ellis, Cynthia M.. "New 911 technology is call of the future: Officials

