



Project Number: MQF-IQP 2823

EMS Communication Systems Data Analysis

An Interactive Qualifying Project


Submitted to the Faculty of the

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the degree of

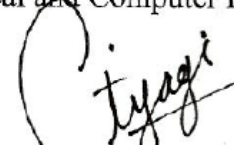
Bachelor of Science

By



Ali Zain Akhtar

Electrical and Computer Engineering



Charvi Tyagi

Electrical and Computer Engineering



Anubhav Prasad

Mechanical Engineering

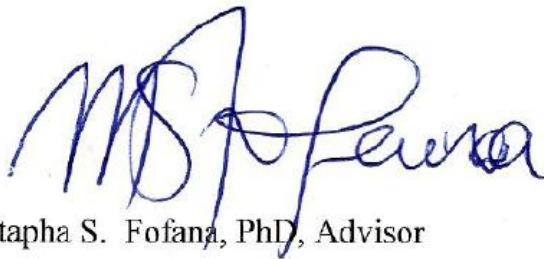


Nishan Srishankar

Aerospace Engineering

MIRAD Laboratory, April 30, 2013

Approved By:



Professor Mustapha S. Fofana, PhD, Advisor

Director of MIRAD Laboratory, Mechanical Engineering Department

ABSTRACT

The purpose of this project is to examine and analyze various aspects of the Emergency Medical Services (EMS) communication system within the United States, and identify areas that can be improved. The EMS encounters a large amount of emergency calls almost on a daily basis. Therefore, it is important that the communication system is as efficient as possible. Main focus of this project is to implement creative solutions in order to improve the average response time of the ambulances. By deeply investigating the different phases of a typical response in an emergency situation, an attempt can be made to eliminate any time lags we discover. The project includes different stages of analysis and the methods used to achieve our main focus.

Current operation and maintenance of EMS communication system in and around the city of Worcester will be studied. This will include input and retrieval of information, data storage, costs, infrastructure, modes of communication, and current technology of the EMS. We will also conduct interviews and analyze case studies relating to emergency medical situations. The results of the analysis will help us derive potential delay factors and help us gain an understanding of what areas need more focus. Using these delay factors delay differential equations were formulated which can be used to reduce the time response.

A small-scale central database was also created which will serve as a medical library for authorized medical personnel. The database will store the medical records of all the people of United States. This will help the EMS extract urgent information and medical record of the patient at any time to speed up the process of treatment. After the research, analysis, planning, and testing, our project will help develop a solid method and understanding of feasible solutions to improve the existing EMS communication systems. These solutions include the delay differential equations and the medical database.

TABLE OF CONTENTS

<i>Abstract</i>	<i>iii</i>
<i>Table of Contents</i>	<i>iv</i>
<i>List of Figures</i>	<i>viii</i>
<i>List of Tables</i>	<i>xi</i>
<i>Acknowledgement</i>	<i>xii</i>
CHAPTER 1. 9-1-1 RESPONSE TIME & EMS ASSESSMENT	1
1. Introduction.....	1
CHAPTER 2: EMS AND PATIENT-CENTRIC QUALITY CARE	3
2.1 Introduction.....	3
2.2 Emergency Medical Services in Massachusetts	4
2.1 Private and Public EMS services	6
2.2 System Operations and Monitoring of calls for 9-1-1.....	7
2.3 Maintenance of 9-1-1 Communication Systems	10
2.4 Storage of Data and Information.....	13
2.5 Data Input and Retrieval	14
2.6 Central Medical Emergency Direction (CMED)	16
2.2.8 Communication systems in EMS	23
2.2.9 Cost of EMS Services	24
2.3 Infrastructure.....	24
2.3.1 UHF Ambulance Radios	25
2.3.2 CMED Trip Record Tracker	28
2.3.3 CMED Operator Position Equipment	29
2.3.4 Hospital Capacity Website.....	30
2.3.5 Health and Homeland Alert Network (HHAN)	30

2.3.6 Satellite Phones	31
2.3.7 Ambulance Task Force Radios	33
2.4 Potential Delay Factors	33
2.4.1 Navigation problems	34
2.4.2 Location of the Patient	35
2.4.3 Climatic Factors	39
2.5 Interviews.....	40
2.6 Case Studies	43
2.6.1 Case Study 1, California.....	43
2.6.2 Case Study 2, Colorado.....	44
2.6.3 Case Study 3, NYC World Trade Center Attack & Hurricane Katrina	46
2.6.4 Case study 4, York County, New York.....	49
2.6.5 Case Study 5, Computer Virus, New Zealand and Australia	50
2.6.6 Case Study 6, Las Vegas	51
2.6.7 Case Study 7, National Highways in USA.....	52
2.6.8 Case Study 8, Mortality Rate vs Response Time	54
2.7 Region wise Analysis of EMS in the United States.....	55
2.7.1 Eastern United States	55
2.7.1.1 Analysis of EMS in New Jersey	56
2.7.1.2 Analysis of EMS in Virginia	60
2.7.2 Southern United States Analysis	63
2.7.2.1 EMS Analysis of Texas	64
2.7.3 Western United States Analysis	68
2.8 Time Delays in EMS Communication.....	71

CHAPTER 3: RESULTS AND SOLUTIONS	74
3.1 Active Communication	74
3.1.1 Mobile Hotspots	75
3.1.2 Public Access to Communication and Communication System Integration.....	77
3.1.3. Ambulance Communication Centers	78
3.1.4 Dispatch Time Interval Performance	78
3.1.5. Ambulance Territories.....	79
3.1.6 UHID (Universal Healthcare Identifier)	80
3.1.7. Emergency Vehicle Preemption (EVP).....	85
3.2 9-1-1 Medical Library.....	94
3.2.1 PIDAC.....	95
3.2.1.1 Python code for PIDAC.....	95
3.2.2 Patient Data Information (PDI)	96
3.2.3 Health Insurance Information (HIA).....	101
3.2.4 Periodic Health Information (PHI).....	104
3.2.5 Extracting Information of another user	107
3.3 Wireless Communication.....	109
3.3.1 Introduction	109
3.3.2 Wireless transmissions:	117
3.4 IPW 9-1-1 Haptic System	119
3.5 Next Generation 9-1-1	124
3.5.1 Next Generation 9-1-1: The Transportation Problem	127
3.5.2 An Outdated 9-1-1 System.....	127
3.5.3 Limited Emergency-Call-Center Capabilities	128
3.5.4 Limited Call Processing Capabilities	128

3.5.5 Institutional Barriers to National Transition	129
3.5.6 Next Generation 9-1-1: The ITS Opportunity	130
3.6 Next Generation 9-1-1: Research Findings and Test Results	132
3.6.1 Definition of a Comprehensive Future Vision for NG9-1-1	132
3.6.2 Validation of NG9-1-1 Architecture	133
3.6.3 Identification of New Capabilities	134
3.6.4 Validation of PSAP Call Taker Software.....	134
3.6.5 Validation of Core NG9-1-1 Functions and Features	135
3.6.6 Increase in System Reliability.....	136
CHAPTER 4: CONCLUSION	137
REFERENCES	139

LIST OF FIGURES

Figure 1: Massachusetts EMS regions	5
Figure 2: Schematic Representation of a typical 9-1-1 system.....	8
Figure 3: Screenshot of one of the screens of a 9-1-1 communication system.....	9
Figure 4: Costs of Maintenance (left) and Personnel Salaries (right).....	11
Figure 5: E-911 calls by type dispatched at Schenectady County	12
Figure 6: Routine 9-1-1 Call Flow Diagram.....	21
Figure 7: The communication system in an ambulance owned by UMass hospital, Worcester ..	25
Figure 8: Motorola Centracom II console setup as a mobile dispatch setup	29
Figure 9: CMED Towers and Hospitals in Massachusetts and surrounding states	31
Figure 10: Globalstar GSP-1600 handheld mobile unit and Globalstar GSP-2900 fixed satellite phone.....	32
Figure 11: A Fire truck having problems reaching a location because of static traffic	34
Figure 12: Traffic Preemption device installed on traffic light post.....	35
Figure 13: Ambulance facing problems due to a severe snow storm	40
Figure 14: Ambulance Crash Site in California.....	43
Figure 15: Police Department reaching the shooting scene in Aurora, Colorado	45
Figure 16: Head on collision involving an ambulance on a car on a highway, USA	54
Figure 17: The total EMS providers in Virginia Localities	62
Figure 18: The Southern United States.....	64
Figure 19: Per Capital Costs of EMS in Texas.....	66
Figure 20: Time Response of EMS Services in Texas segregated by service area	67
Figure 21: Representation of Western United States	69

Figure 22: Close Loop Block Diagram showing the three system time delays	73
Figure 23: An onboard Mobile Gateway	75
Figure 24: Global Patient Identifiers Inc. Website- The company that sponsored the Volunteer Universal Healthcare Index.....	81
Figure 25: Intelligent Intersection Block Diagram	86
Figure 26: Traffic Preemption Device	88
Figure 27: Advanced GPS Systems	89
Figure 28: Electronic Patient Care Reporting Device.....	92
Figure 29: Python Programming Language	94
Figure 30: Python SHELL Window	96
Figure 31: Python Code for Database	99
Figure 32: Display screen after entering patient details.....	100
Figure 33: Invalid Patient Number popup	101
Figure 34: Python code for Health Insurance Information	103
Figure 35: Python SHELL display for HIA	103
Figure 36: Program kill option after unsuccessful login.....	107
Figure 37: Complete display of patient information.....	107
Figure 38: New Patient Login Command	108
Figure 39: Full Duplex Wireless Walkie Talkie	110
Figure 40: Regional Relay System	113
Figure 41: Radio Base Station	114
Figure 42: Typical Mobile Station	115
Figure 43: Typical Portable Radio	115

Figure 44: Two-way communication on one frequency	116
Figure 45: Digital and Analog Signals.....	118
Figure 46: NEST flow diagram.....	120
Figure 47: NEST connection flow	124
Figure 48: Call Flow and Elements of NG9-1-1.....	125
Figure 49: System Interface in NG911	126
Figure 50: Evolution to Changes to 9-1-1 Systems and Technologies	130

LIST OF TABLES

Table 1: Frequencies assigned to different CMED regions in Massachusetts.....	22
Table 2: Specific CMED frequencies for Worcester, MA.....	23
Table 3: EMS analysis of some cities in Western United States.....	70

ACKNOWLEDGEMENT

Our IQP group would like to extend a special thanks to the UMass Memorial Emergency Medical Services team especially Chief Stephen Haynes for his support that helped us start our project. Our IQP group would also like to thank the Worcester Police Department for giving us in depth details about 9-1-1 and allowing us to visit their control room. Our heartiest thanks goes out to our advisor for the project Professor M.S. Fofana whose constant guidance and support was invaluable to our project. His constant inputs throughout the project were critical in the successful completion of this project. Lastly, we would like to thank everyone who was involved in this project and helped us make this project a success.

CHAPTER 1. 9-1-1 RESPONSE TIME & EMS ASSESSMENT

1. Introduction

Medical emergencies are an everyday occurrence at any 9-1-1 Public Safety Answering Point (PSAP) in the United States. The 9-1-1 call-takers encounter a vast amount of emergencies in their line of work with 200 million calls per year in the United States. Therefore, it is highly important that the Emergency Medical System (EMS) should be as efficient as possible. EMS is a specially organized system that provides personnel, facilities, and equipment for the coordinated delivery of sudden emergency medical services within a geographical area. In order to be effective, any emergency system needs to do three basic things: First, identify when someone dials the emergency number on any telephone. Second, route the call to the nearest answering point based on the call's originating location. Lastly, notify the appropriate agency as quickly as possible so it can respond to the emergency. Over the years, many improvements have been made to the EMS and the 9-1-1 network is being upgraded on a regular basis. For example, most 9-1-1 systems now automatically report the telephone number and location of 9-1-1 calls made from wire line phones, a capability called Enhanced 9-1-1, or E9-1-1. However, further enhancements can be made to the system with implementation of new technology (American College of Emergency Physicians [4]).

The primary objective of our project is to study aspects of digital 9-1-1 communication within the United States. Attempts were made to derive a solution to improve the average 9-1-1 time response. An important objective of the project was to evaluate which aspects among the entire time response process need improvement. The time lag between a call to 9-1-1 and the arrival of the ambulance to the location is a critical aspect that can be improved the most. We

attempted to make the 9-1-1 system and the EMS more effective by creating a new central database which may serve as a sample medical library (Patient Health Library) for authorized medical personnel. The database stores the medical records of every citizen in the United States which will help the 9-1-1 call taker and the medical personnel to pull out the medical record of the patient at any time to speed up the process of treatment.

Chapter 2 contains the analysis and evaluation of the data collected for our study. This includes the workings of the 9-1-1 communication systems- such as the modes of communication to the Dispatch Units at the 9-1-1 center, the operations and monitoring of the vital calls made, maintenance of the system and finally the organization of the caller-database. This section also dealt with current technology, more precisely, the transient time response of a 9-1-1 call.

In Chapter 3, the possible solutions and evaluations were drafted, to recommend feasible changes to improve the existing communication systems and hence the current response time of the EMS systems. Each possible solution was explicitly discussed. This included the planning, identification of the deliverables that the current system provides, evaluation of the logical event sequences required to produce these deliverables and an estimation of the resource and financial requirements. This chapter also includes a sample database designed by our team for easy access of patient information. We formulated delay equations to deal with each component of the 9-1-1 system individually. An analysis of the Next Generation 9-1-1 or NG9-1-1 was also done to study the progress being made in the infrastructure and how our solutions can be incorporated to enhance the performance of the system furthermore.

CHAPTER 2: EMS AND PATIENT-CENTRIC QUALITY CARE

2.1 Introduction

The EMS communication process begins when a person calls 9-1-1 for immediate assistance. If the person seeks immediate medical attention, the call taker in the 9-1-1 call center dispatches an ambulance and any other emergency service as may be necessary. Dispatching ambulances varies between regions; for example in Central Massachusetts, 9-1-1 calls are routed to Framingham and then to the Worcester police department. The Worcester Police Department then dispatches an ambulance from one of any available third-party ambulance companies, such as those provided by UMASS Memorial Hospital. Other areas may have specified federally funded ambulance companies that provide service for the city or region (WORCESTER EMS-UMass Memorial EMS [58]).

The ambulance leaves to attend the patient on receiving the distress call. On arrival at the emergency scene, the EMT's determine the how critical the person's condition is and then classify it on a priority scale of one to three. Priority level one is the most critical and immediate life threatening situations such as cardiac arrest. Priority level two is life threatening condition and includes conditions like strokes, unstable trauma, and joint dislocations. Priority level three is non-life threatening condition. Conditions such as minor fractures come under priority level three. The EMT's communicate the patient's priority level to the CMED. The CMED then directs their communication to a hospital through a specific channel while still monitoring the call. The EMTs communicate critical information about the patient including age, sex, date, time, primary complaint, and the priority of the situation to the hospital. When all the essential data is acquired, CMED terminates communication and the hospital prepares for the incoming patient.

2.2 Emergency Medical Services in Massachusetts

The Office of Emergency Medical Services in Massachusetts aims to stimulate a statewide Emergency Medical Services (EMS) system that helps reduce the number of cases of premature death and disability from acute illness and injury by organizing the local and regional EMS resources. There are many guidelines and regulations established by the state of Massachusetts to make the flow of communication smooth between the patient, the 9-1-1 dispatch center, the Emergency Medical Technicians (EMT), and the hospitals. Without such guidelines, it would be impossible to communicate efficiently and in an organized way (Office of Emergency Medical Services [6]).

In Worcester, MA, the first 9-1-1 ambulance service was operated by the Worcester Police Department in the 1960's and early 1970's. The Worcester City Hospital provided one or two basic life support (BLS) ambulances per shift to cover Worcester in 1977. By mid-1980's, the entire staff had shifted to all-intermediate or paramedic, and the service has remained advanced life support (ALS) capable to this day. The number of ALS units in the city has increased to 4 providing service 24 hours a day in response to the increasing number of emergency calls (WORCESTER EMS-UMass Memorial EMS [58]). In 2001, the UMass Memorial EMS took over the responsibility for 9-1-1 ambulance service in Shrewsbury, MA, where 1 unit is in-service 24-hours a day. Additional units are added in case of special events or if the need arises. The Worcester Fire Department and Shrewsbury Fire Department provide the first responder service. Worcester EMS is one of the few remaining EMS services in Massachusetts that maintain a two-paramedic crew configuration on our advanced life support

ambulances. The service is not only provided in Worcester, but also to neighboring communities (WORCESTER EMS-UMass Memorial EMS [58]).

Figure 1 shows the five EMS regions that Massachusetts has been divided in to: Western Mass EMS Committee Inc., Central Mass. EMS Corp., North East EMS Inc., Metro Boston EMS Council Inc. and South Eastern Mass. EMS Council.

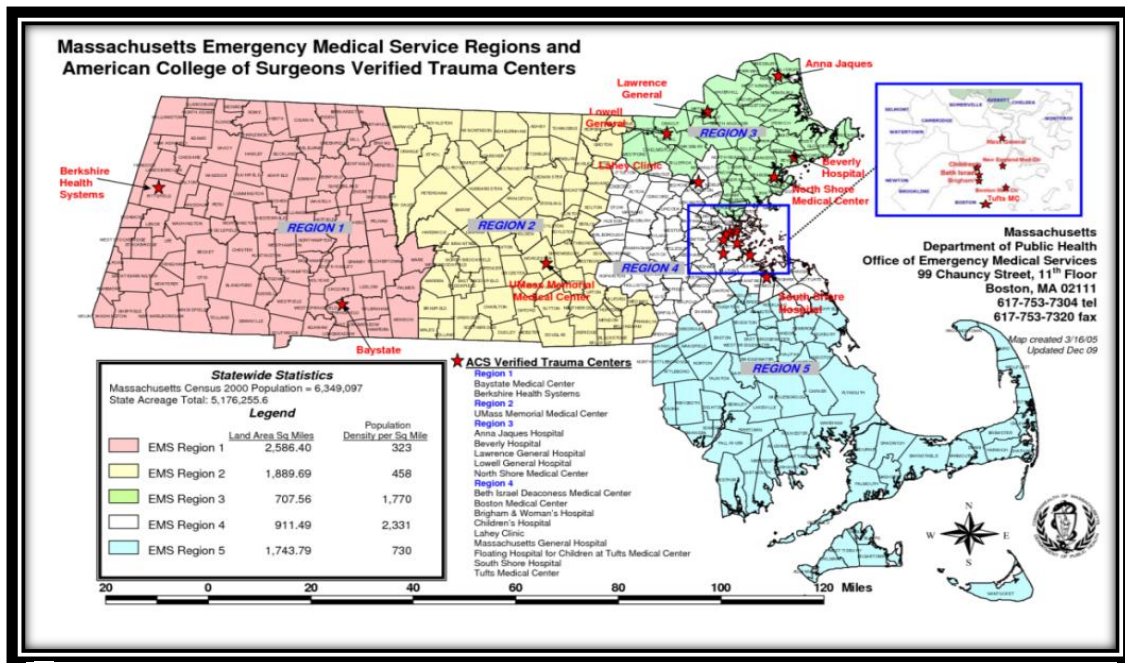


Figure 1: Massachusetts EMS regions

EMS region 1 or the area in pink has a land area of 2586.40 sq. miles and the population density per sq. miles is 323. There are five regions in Massachusetts. Western Massachusetts EMS serves Region 1, which includes Berkshire County, the majority of Franklin County, Hampden County and Hampshire County (Western Massachusetts Emergency Medical Services Inc. [11]). EMS region 2 or the area in yellow has a land area of 1889.69 sq. miles and the population density per sq. miles is 458 (EMS Region II Communications Plan [12]). EMS region 3 or the area in green has a land area of 707.56 sq. miles and the population density per sq. miles is 1770. EMS region 4 or the area in white has a land area of 911.49 sq. miles and the

population density per sq. miles is 2331. EMS region 5 or the area in blue has a land area of 1743.79 sq. miles and the population density per sq. miles is 730 (Massachusetts Emergency Medical Service Regions and American College of Surgeons Verified Trauma Centers [9]).

In Worcester and Shrewsbury, the 9-1-1 calls for EMS help is first received by the municipal police department or communications center, and is then forwarded to the EMS Communications Center for prioritization and dispatch. All UMass Memorial EMS resources are controlled from the same EMS Communications Center which is located at UMass Memorial Medical Center – University Campus (WORCESTER EMS-UMass Memorial EMS [58]). Worcester EMS personnel's are capable of communicating via VHF, UHF, and 800 MHz radio to each of the public safety agencies. The EMS ambulance fleet consists of 15 Class I transport ambulances and 3 Class V non-transport SUV's that are used mainly by the supervisors (WORCESTER EMS-UMass Memorial EMS [58]).

2.2.1 Private and Public EMS services

State governments have the option to choose between a private firm and a municipal agency to provide EMS services to a city or a region. State governments choose provider type based on the capability of handling difficult situations and the quality of the service provided.

Public and private providers differ from each other essentially: the private providers can provide services beyond a specific area, while the public agency is restricted to its particular city of operation. This causes variances between public and private providers in the size of population they serve. As the private firm is capable of serving a larger population, it can reduce the average cost of capital, technological research, and other investments. The appeal of these economies of scale to a city will depend in large part on the extent to which frequent

implementation of technologies and innovations are vital to the public service. Moreover, to the extent that scale advantages are local, the proximity of the other cities served by the private firm will also affect the cities' choices of provider type (Department of Health, The District of Columbia [28]).

2.2.2 System Operations and Monitoring of calls for 9-1-1

9-1-1 Enable offers four key security desk routing and notification options as part of its E911 solutions: security desk call monitoring, security desk call delivery, email crisis alerts, and automatic screen pops. All or some of these notification options are available as features of 9-1-1 Enable's Emergency Gateway or Emergency Routing Service. An organization may choose to implement any combination of these routing and notification options to help improve on-site coordination amongst rescue teams and reduce response times when seconds count (Research and Innovative Technology Administration [23]).

Security desk call monitoring allows personnel to listen in on 9-1-1 calls sent to the local PSAP. The call is routed to both the PSAP and security desk using three-way call conference, with security personnel on one-way mute. Security desk call monitoring can be enabled using either the EGW or the ERS. Unique security desk monitoring rules may be configured per ERL. 9-1-1 calls may be directly delivered to on-site security personnel. This allows security personnel to properly assess the situation prior to connecting the caller to the local PSAP. Unique security desk routing rules may be configured per ERL, and location-based routing can be enabled for non-emergency calls to local security. (Research and Innovative Technology Administration [23]).

Figure 2 shows the schematic representation of modes of 9-1-1 communications. These are Cellular, Voice Over Internet Protocol, Telematics, and wired calls.

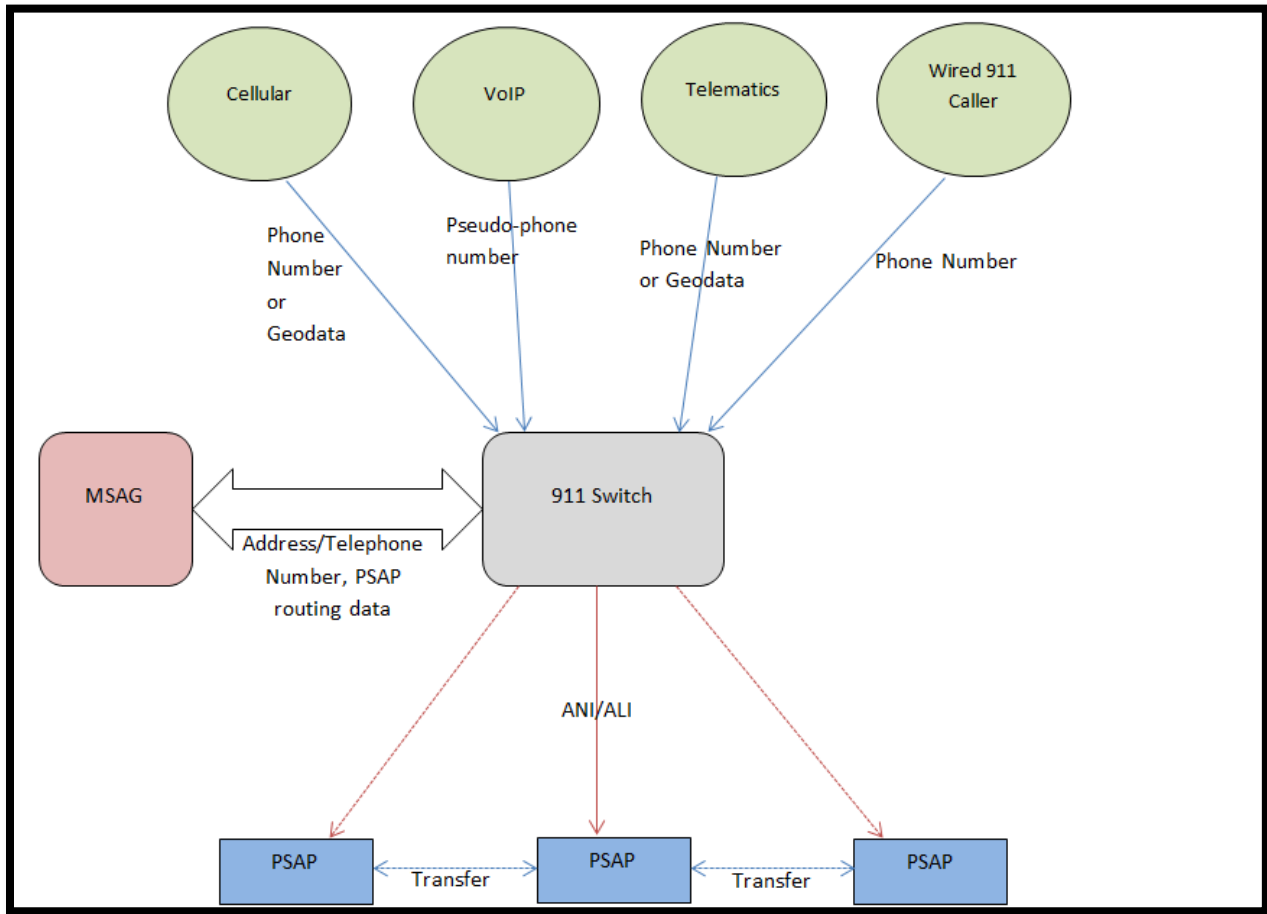


Figure 2: Schematic Representation of a typical 9-1-1 system

In the figure 2, Security desk call routing can be enabled using either the Emergency Gateway (EGW) or the Emergency Reporting System (ERS). Both the EGW and the ERS can deliver email alerts to designated distribution lists based on a 9-1-1 caller's ERL. Email alerts include the caller's name, callback number, and location information, and can be directed to alpha-numeric pagers, smartphones, or SMS gateways. Desk Alert is an optional component of the EGW. It is an application installed on Windows-based security desk workstations. In the event of a 9-1-1 call, a screen pop instantaneously appears on the security desk monitor,

notifying personnel of an emergency call in progress. Information provided by the pop-up screen includes the caller's name, callback number, date and time of call, and location information. Desk Alert also includes a configurable URL link, which can point to a campus map, contact list for medical emergencies. Figure 3 shows the screenshot of a 9-1-1 system display. The screen shows the different options available to the call taker. We see that the address is displayed on the left side, options like hold, flash, priority and conference which are available to the call taker.

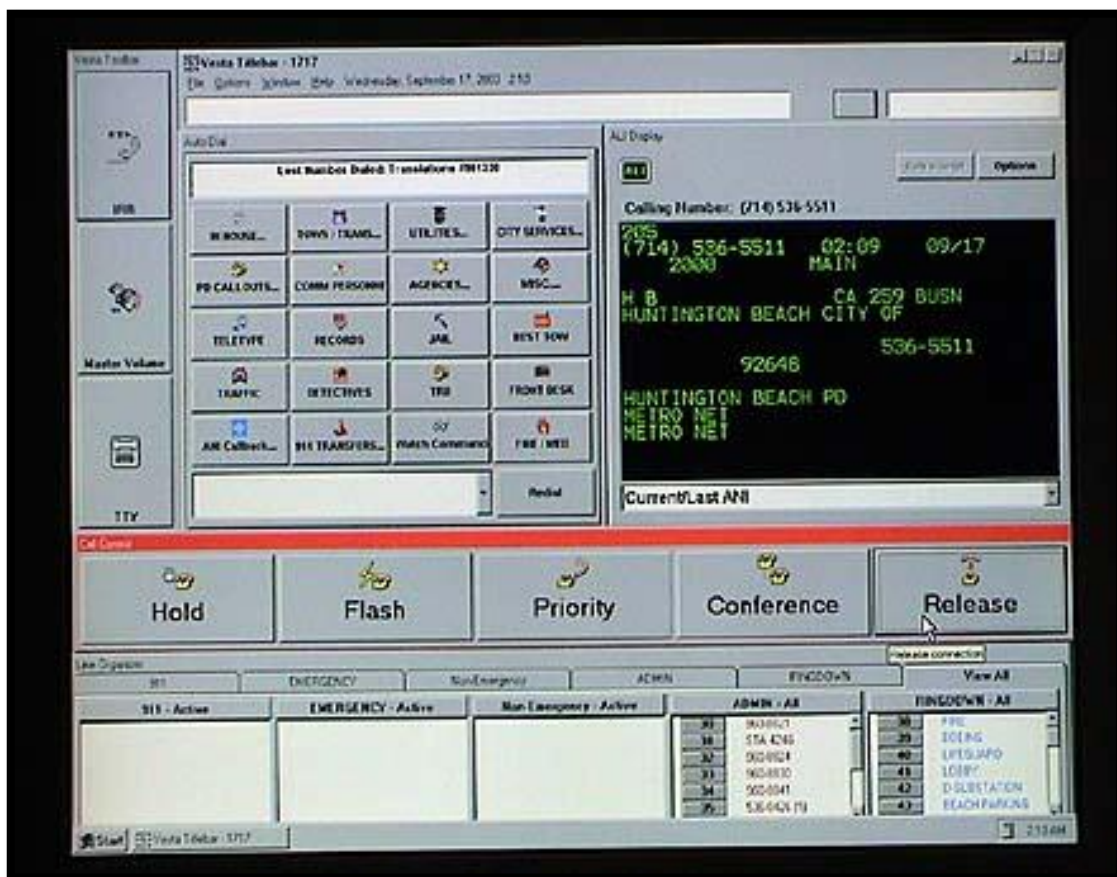


Figure 3: Screenshot of one of the screens of a 9-1-1 communication system

2.2.3 Maintenance of 9-1-1 Communication Systems

The main responsibilities of in order to manage and sustain a perfectly operating Emergency Communication Systems include management of the Enhanced 911 (E-911) database, equipment maintenance, integration of operations between dispatch towers and public awareness,. Equipment maintenance involves maintaining radios, weather broadcasting equipment and ambulances (Research and Innovative Technology Administration [23]).

The communications staff/technicians are responsible for server administration and maintenance for the communications center. These includes maintenance of server/client hardware for the 911 dispatch center, maintenance of security and networking equipment and critical emergency backup power systems for the 911 dispatch center.

The following information is based on the report submitted on December 11, 2008, by the New York State Technology Enterprise Corporation (NYSTEC) to Schenectady County. It serves as a blueprint to estimate costs of maintenance of EMS Communication Systems throughout the United States. The Schenectady County, New York (Schenectady County-Departments Communication System- E911[22]), for example, created the Communications Department in the late 1990's following County Legislature, to ensure that the above tasks were undertaken. Additionally, this department maintains liaisons with the County and Town planning staff for real estate developments, ensuring that there would be no gridlock or choked traffic flow due to construction, and also making recommendations on new street names that will not be confused with existing ones (Research and Innovative Technology Administration [23]).

There are two further teams that are required to maintain the communication systems; The Radio Maintenance and Support staff divisions.

- The Radio Maintenance Division, is a part of the 911 department and designs, installs and maintains county radio communication systems. Technicians install and repair squad mounted and handheld radios for public safety. They also ensure that the remote radio tower sites, computer-aided dispatch systems, and associated hardware are operating and functional.
- The Support Staff Division provides administrative support to the 911 Emergency Communication and Radio Maintenance divisions for accounting, payroll, purchase and statistical record-keeping functions.

Equipment Repairs/Maintenance	Annual (2008) Costs	Personnel	Salary	Number	Cost (2008)
CAD Operating Annual Costs	\$ 50,000	Director	\$ 85,000	1	\$ 85,000
Mapping System Maintenance	\$ 50,000	Systems Director	\$ 78,000	1	\$ 78,000
911 System Maintenance	\$ 45,000	Secretary	\$ 30,000	1	\$ 30,000
911 Second Tier Maintenance	\$ 40,000	Dispatch Supervisor	\$ 45,000	5	\$ 225,000
System Hardware Replacement	\$ 5,000	Dispatcher I	\$ 37,500	21	\$ 787,500
Console Maintenance	\$ 40,000	Dispatcher II	\$ 42,000	25	\$1,050,000
Call Taking Protocol Systems Maintenance	\$ 24,000	Shift Differential	\$ 65,000	1	\$ 65,000
Total	\$ 254,000	Overtime	\$140,000	1	\$ 140,000
		Longevity	\$ 60,000	1	\$ 60,000
		First Year Attritions Offset	\$ 34,000	3.5	\$ 119,000
		Total-Salary			\$2,401,500
		Total-Benefits			\$1,068,500
		Total-Personnel Services			\$3,470,000

Figure 4: Costs of Maintenance (left) and Personnel Salaries (right)

The figure 4 above show the exact tangible costs for maintaining the 911-Communications Department of Schenectady County and include maintenance as well as personnel costs. It serves to show the breakdown of the expenditure used in maintenance especially in equipment failure and upkeep.

Schenectady County E-911 PSAP Call Data					
	City of Schenectady	Rotterdam	Niskayuna	Glenville	Princetown
Population (2000)	61821	28316	20295	28183	7940
Agencies Dispatched	City Police and Fire	Town Police, Fire and EMS	Town Police, Fire and EMS	Town Police, Fire and EMS	New York State Police, Town Fire and EMS
Annual Wired E-911 calls (2007)	24,986	5,269	3,847	6,797	780
Annual Wireless E-911 calls (2007)	29,225	1,528	751	1,361	490
Total Wired and Wireless E-911 calls (2007)	54,211	6,797	4,598	8,158	1,270
Rate of 911 calls per capita	0.88	0.24	0.23	0.29	0.16
Cost per 911 and 7-digit calls	\$ 8.63	\$ 18.31	\$ 14.94	\$ 10.12	
Cost per Capita	\$ 28.66	\$ 27.14	\$ 29.23	\$ 27.94	
Average rate of 911 calls per hour	6.19	0.78	0.52	0.93	0.14

Figure 5: E-911 calls by type dispatched at Schenectady County

The enhanced, 9-1-1 Response systems allows for instantaneous emergency calls that automatically record the telephone number you are calling from, address at which the telephone is located and which police, fire and medical agencies respond to which address. The figure above gives the exact number of calls (by type) that was dispatched at the Schenectady County (in 2008), and give a good idea robustness of the E-911 system, and hence will enable us to visualize the costs of maintenance of this system. There are three main communication media for Enhanced 9-11 Response Systems (Research and Technology Administration [22, 23]):

- 1 Wireless
- 2 Wired/Landline
- 3 Media for persons with disabilities

Wireless

This displays the wireless caller location on a map using information provided by wireless carriers. It also further segregates the information based on the age and type of telephone used (e.g. a pie-shaped sector for older phones pinging off a specific cell tower), and is accurate to up to three meters.

Landline/Wire Line

This network is constantly maintained to provide emergency help effectively. Dialing 911 connects one to a PSAP dispatcher to route the call to local agencies. The dispatcher verifies the caller's location, determines the nature of the emergency and decides which emergency response teams should be notified. Which Enhanced 911 capabilities, PSAP staff are able to call back, should the call be disconnected, and also know where to send emergency services personnel.

911 Calling for Persons with Speech or Hearing Disabilities

To further improve emergency call handling for persons with speech or hearing disabilities- Video Relay Service (VRS) and Internet Protocol (IP) Relay service providers to provide regular ten-digit telephone numbers to their subscribers so that subscribers' emergency calls, along with the ten-digit number and location information, automatically route to the appropriate PSAP(Research and Innovative Technology Administration [23]).

2.2.4 Storage of Data and Information

911 Communications Centers receive, and prioritize calls from the public and dispatches personnel for situations that require police response or directs calls that do not require police response to the proper agency. Centers also deal with requests for 9-1-1 tapes and Computer Aided Dispatch printouts for citizen and law enforcement personnel and takes reports on non-emergency crimes (EMS Communications IQP[24]).

- The Validation Unit maintains the quality (measured by timeliness of information transfers and the accuracy/validity of information) of the Department's records entered into the database. This unit monitors the Criminal History Record Information (CHRI) files for the entries made and ensures that proper procedural protocol is followed.
- The Communications Training Unit provides and assists with training of all employees dealing with dispatching in the Communications department; this process also includes providing certification for 9-1-1 and dispatch.
- Electronic Maintenance installs and maintains the various communication equipment-radio systems, transmission equipment, data terminals including the public messaging systems. This department also monitors alarms for the city and monitors alarm receivers for City facilities.

2.2.5 Data Input and Retrieval

EMS medical care providers manually enter medical care information into Electronic Patient Care Reporting (ePCR). This ePCR takes into account the entire process of patient care: from the dispatch of emergency vehicles and personnel, location, vital signs to patient treatment and transport. Naturally, it also obtains basic patient information such as name, date of birth and medical information (Fierce Gov. IT [25]).

The Homeland Security Department of Health Office published a means to evaluate and describe the above implemented system. The Privacy Office Official Guidance Report (June 2010) submitted by the Homeland Security Department of Health Office explain that “The Privacy Impact Assessment” (includes electronic data stored in the ePCR and also paper records held by

the EMS provider) allows for tracking data quality, and reviewing of clinical performances, and allows for continuous performance improvement (Fierce Gov. IT [25]).

Patients' medical records are confidential, sensitive and private in nature. To ensure that doctor-patient confidentiality will not be breached, the Electronic Patient Care Reporting system was reevaluated to identify potential risks, as well as corresponding counteracting strategies (to minimize adverse effects of breached information).

Risks to the system can vary from accidental unauthorized disclosures, incorrect data entry by personnel to malicious viruses or unauthorized system access (breach of data security). These risks are mitigated, by providing privacy and security awareness training for all users of the ePCR system. Furthermore, end-users were limited to the level of data that was accessible to read/write (e.g. users have role-based access, so medical care providers will only be able to access specific patient data). Designated users such as EMS Coordinators, Administrators, Medical Directors will have full administrative access to all component records to ensure proper standards of data entry and processing is maintained.

Additionally, the DHS set up the First Responder Coordination branch to run reports and queries (for quality control), and to ensure that data entry/processing adheres to protocol and any established standards. Any irregularity is informed to the administration to be resolved (Fierce Gov. IT [25]).

DETAILS STORED:

- Patient name.
- Patient case/identification number
- Account of the illness or injury.

- Date of birth
- Gender.
- Address (residential or business, if/as relevant).
- Type of injury.
- Current medications.
- Allergies.
- Past medical history.
- Assessment of injury.
- Chief complaint.
- Vital signs.
- Treatment provided and/or procedures.
- Medication dispensed.
- Discharge instructions for follow-on care.
- Patient's health insurance information

2.2.6 Central Medical Emergency Direction (CMED)

Central Medical Emergency Direction (CMED) relies on a network of radio towers set up strategically throughout Central Massachusetts. Central Medical Emergency Direction (CMED) serves as a communications link between all ambulances and all hospitals in a specific area. The main purpose of CMED is to assist EMS personnel with communication during emergencies. Routing communication from the ambulance through CMED before it reaches the hospital helps to maintain a clear procedure for EMS communication and helps reduce frequency congestion by controlling the use of medical radio channels. An ambulance contacts CMED via radio through

the towers that are set up. A hospital is informed about the arrival of a patient in this manner. CMED makes communication for ambulances much easier and efficient (EMS Communications IQP [24]).

CMED was established in Massachusetts in the 1970's to organize the EMS structure for the entire state since each city runs its emergency services differently. For example, ambulances in Worcester are dispatched through the Police department whereas the ambulances in Boston are dispatched through the fire department. Some cities like Natick use public ambulances while other cities like Millbury use third party ambulances like UMASS and AMR. The state of Massachusetts is divided into five different regions each with their own CMED station. Each regional CMED has several UHF and VHF channels to provide adequate coverage over the entire geographic region while also maximizing the available frequencies (The Massachusetts Emergency Medical Services Radio Communications Plan [10]).

.

The steps of the 9-1-1 call where CMED functions are stated as follows:

1. Citizens Call 9-1-1 Public Safety Answer Point (PSAP): The efficiency of the EMS services depends on the fact if people to be able to contact the EMS services in time. They should be able to recognize a medical emergency and then immediately call the telephone number for the local EMS agency. The most common emergency number is 9-1-1.

2. Public Safety Answer Point (PSAP) contacts Ambulance Dispatch Center: After receiving the call from the person, the 9-1-1 Dispatch center call taker dispatches an ambulance and any other resources as maybe necessary.

3. Ambulance Picks up Patient and contacts CMED: The EMT's cannot call the hospital directly by using cell phones or any other communication device. They communicate with the hospital through the CMED center, by calling the center on the common calling channel of the CMED radio network.

4. CMED captures priority status about patient: CMED then assesses the condition of the patient based on the information it receives and assigns a priority number. The priority number can affect the transport of the patient. The priority levels ranges from level one to level four; level one being the most critical.

Following is a list of the priority levels and their descriptions:

I - PRIORITY ONE (Immediate Life Threatening)

Priority one requests immediately connects to medical control request and override other traffic as needed.

Examples for priority one cases are:

- Cardiac Arrest
- Unstable Cardiac
- Major Head Injuries
- Multiple Trauma
- Unstable GI Bleed
- Acute Pulmonary Edema
- Respiratory Arrest
- Airway Obstruction
- Anaphylaxis

II - PRIORITY TWO (Life Threatening)

Connect as soon as possible to receiving facility.

Examples for priority two conditions are:

- Suspected Cardiac
- CVA
- Coma (unknown etiology)
- Unstable Trauma
- Unstable Medical (e.g., hypoglycemia)
- Symptomatic Cervical Injuries
- Suspected Fractures/Dislocations of Joints

III - PRIORITY THREE (Non-Life Threatening)

Connect to receiving facility as soon as med channel is available.

Examples for priority three conditions are:

- Minor Lacerations and Soft Tissue Injuries
- Suspected Minor Fracture without Circulatory or Nervous System Compromise

IV- PRIORITY FOUR (Stable)

Connect only if no other traffic requires a channel.

Examples for priority four conditions are:

- Interagency Transfers
- Direct Admissions

5. Ambulance request connection to hospital from CMED: The ambulance calls a regional CMED Center to connect to a hospital's emergency department. When the connection with the hospital is activated, ambulance personnel have a communications link with the medical control point that was established by the CMED.

6. CMED patched ambulance to hospital: The CMED is in charge of providing the link of communication between the ambulance and the hospital's emergency department as the EMT's are not allowed to contact the hospital directly via cell phone or any other means.

7. CMED monitors hospital to ambulance communication: CMED guides the ambulance to the hospital. They provide the fastest and most appropriate route based on the patient's priority level. The CMED also monitors the communication between the ambulance and the hospital to make sure there is no kind of interruption or break in the call.

8. Communication terminated once all necessary information is relayed: After CMED collects all the necessary information about the patient and all important conversation between the ambulance and hospital is communicated, CMED can terminate the communication. The necessary information CMED needs to acquire before terminating communication includes age, sex, complaint, date and time.

Figure 6 shows the routine 9-1-1 call is directed and what actions taken in each step.

PROTOCOL

Project: Massachusetts Emergency Medical Services Communication Manual
Use Case: Routine 911 call
Actor(s): Ambulance, CMED, Hospital
Last Updates: February 8, 2006

Use Case Pre- Conditions: 1) Ambulance is dispatched to the scene of a 911 call
Use Case Post-Conditions: 1) Response to 911 call complete

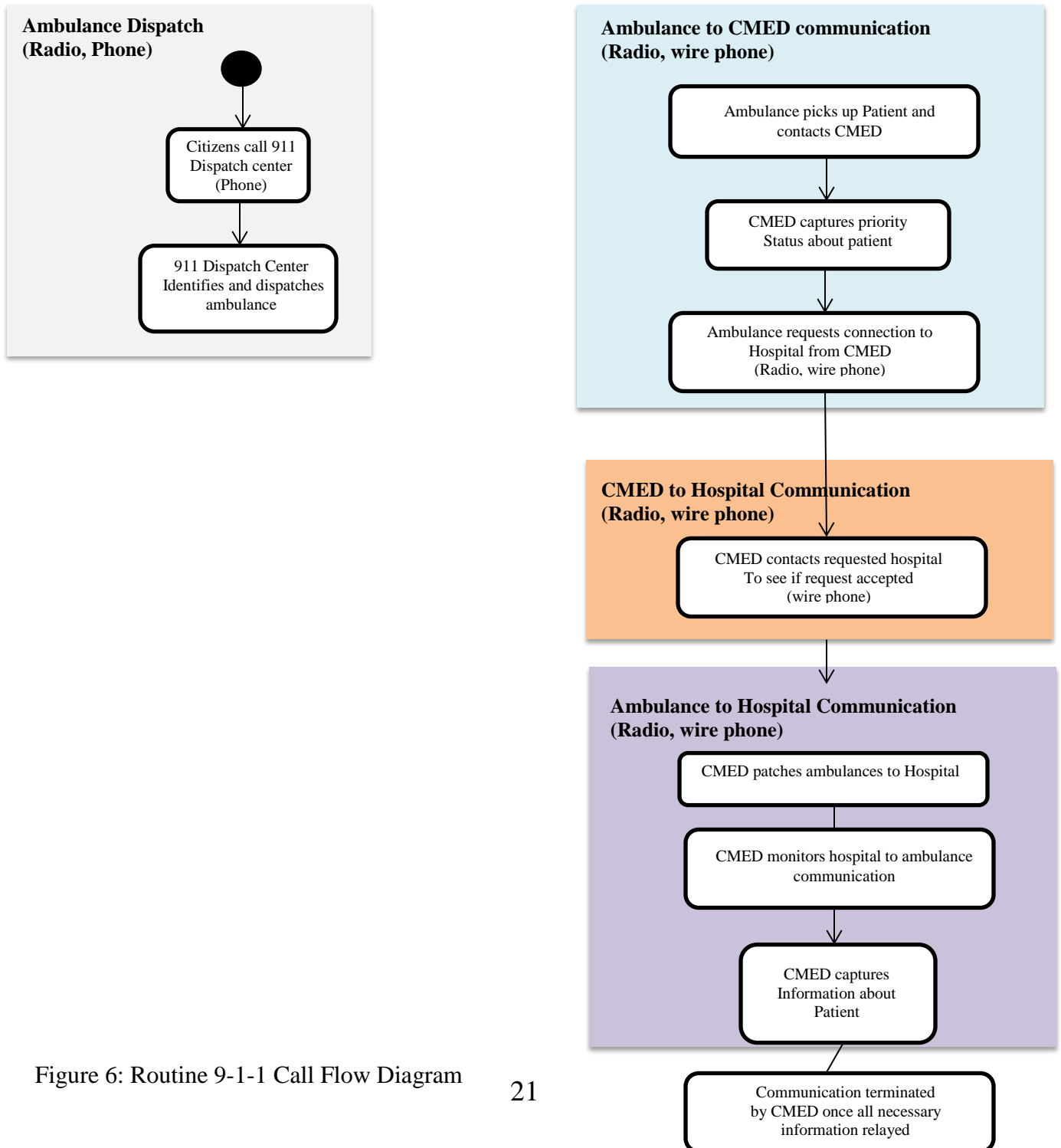


Figure 6: Routine 9-1-1 Call Flow Diagram

Frequencies of CMED region in Massachusetts

Use of CMED is particularly important during a mass causality incident. Since CMED is responsible for locating hospitals and if the number of patients in a massacre is a lot then CMED can direct those patients to the hospitals in the regions nearby as well. Table 1 is a table showing the channels assigned of some CMED in Massachusetts (cmemsc.org[18]). It gives a detailed explanation of the frequencies assigned to each CMED regions for the state of Massachusetts.

Channel	CMED / Hosp Freq.	Ambulance Frequency
CMED1	463.0000	468.0000
CMED2	463.0250	468.0250
CMED3	463.0500	468.0500
CMED4	463.0750	468.0750
CMED5	463.1000	468.1000
CMED6	463.1250	468.1250
CMED7	463.1500	468.1500
CMED8	463.1750	468.1750
CMED	Region / PL Tone	
Pittsfield	Region 1 - 167.9	
North Hampton	Region 1 - 173.8	
Springfield	Region 1 - 151.4	
Worcester	Region 2 - 186.2	
Lawrence	Region 3 - 156.7	
Boston	Region 4 - 151.4	
Plymouth	Region 5 - 179.9	
Fall River / N.B.	Region 5 - 156.7	
Barnstable	Region 5 - 173.8	
Statewide	All - 192.8	
Sturdy Hospital	123.0	

Table 1: Frequencies assigned to different CMED regions in Massachusetts.

Table 2 below shows the specific frequencies and channels of the CMED centers in the city of Worcester (US Environmental Protection Agency[19]).

Bank/Zone 1	Reg 2 Worc	Worcester (+)		Home Bank				
		14-Character 2-Line Mobile Display	Channel Name	Receive Frequency	Receive PL/DPL	Transmit Frequency	Transmit PL/DPL	Special Info
1	Wor MED 1N	MED 1N	Worcester CMED MED 1N	463.000	2Z/110.9	468.000	2Z/110.9	
2	Wor MED 2N	MED 2N	Worcester CMED MED 2N	463.025	2Z/110.9	468.025	2Z/110.9	
3	Wor MED 3N	MED 3N	Worcester CMED MED 3N	463.050	2Z/110.9	468.050	2Z/110.9	
4	Wor MED 4N	MED 4N	Worcester CMED MED 4N	463.075	2Z/110.9	468.075	2Z/110.9	15 second TOT
5	Wor MED 5N	MED 5N	Worcester CMED MED 5N	463.100	2Z/110.9	468.100	2Z/110.9	
6	Wor MED 6N	MED 6N	Worcester CMED MED 6N	463.125	2Z/110.9	468.125	2Z/110.9	
7	Wor MED 7N	MED 7N	Worcester CMED MED 7N	463.150	2Z/110.9	468.150	2Z/110.9	
8	Wor MED 8N	MED 8N	Worcester CMED MED 8N	463.175	2Z/110.9	468.175	2Z/110.9	
9	Wor MED 9N	MED 9N	Worcester CMED MED 9N	462.950	2Z/110.9	467.950	2Z/110.9	
10	Wor MED 10N	MED 10N	Worcester CMED MED 10N	462.975	2Z/110.9	467.975	2Z/110.9	
11	Wor MED 12	MED 12	Worcester CMED MED 12	463.0125	2Z/110.9	468.0125	2Z/110.9	
12	Wor MED 22	MED 22	Worcester CMED MED 22	463.0375	2Z/110.9	468.0375	2Z/110.9	
13	Wor MED 32	MED 32	Worcester CMED MED 32	463.0625	2Z/110.9	468.0625	2Z/110.9	
14	Wor MED 42	MED 42	Worcester CMED MED 42	463.0875	2Z/110.9	468.0875	2Z/110.9	
15	Wor MED 52	MED 52	Worcester CMED MED 52	463.1125	2Z/110.9	468.1125	2Z/110.9	
16	Wor MED 62	MED 62	Worcester CMED MED 62	463.1375	2Z/110.9	468.1375	2Z/110.9	
17	Wor MED 72	MED 72	Worcester CMED MED 72	463.1625	2Z/110.9	468.1625	2Z/110.9	
18	Wor MED 82	MED 82	Worcester CMED MED 82	463.1875	2Z/110.9	468.1875	2Z/110.9	
19	Wor MED 92	MED 92	Worcester CMED MED 92-Direct	462.9625	2Z/110.9	462.9625	2Z/110.9	
20	Wor MED 102	MED 102	Worcester CMED MED 102	462.9875	2Z/110.9	467.9875	2Z/110.9	

Table 2: Specific CMED frequencies for Worcester, MA

2.2.8 Communication systems in EMS

In present days, the ambulances use a mix of wideband of bandwidth 25kHz and narrowband radios of bandwidth 12.5khz as the main mode of communication with hospitals,

dispatch centers and CMED. These bands should be able to operate without any error with at least a capacity of 450-512 MHz (UHF) and a channel capacity of 200, or more.

Massachusetts is transitioning the from wideband radio receivers to narrowband ones. According to the regulations, no new wideband radios can be installed in ambulances from January 2011 and starting from January 2013, all wideband ambulance communication will stop (The Massachusetts emergency Medical Services Radio Communication Plan[10]). As part of new requirements, the FCC has allocated a spectrum of frequency below 800MHz as part of the Private Land Mobile Radio (PMLR) spectrum.

2.2.9 Cost of EMS Services

Emergency Medical Services (EMS) transport cost recovery, sometimes referred to as an EMS transport fee, is the process of obtaining financial reimbursement for the cost of providing medically necessary ambulance transportation. Medicare, Medicaid, and the majority of private insurance policies allow for reimbursement for this service. The EMS transport cost recovery program is designed using compassionate billing practices to ensure that no one suffers financial hardship as a result of the program. There will be no charge for emergency medical care treatment if the patient is not transported.

2.3 Infrastructure

The Massachusetts Department of Public Health Office of Emergency Medical Services (MDPH) is responsible for setting the standards and minimum requirements for infrastructure

used in EMS communications (The Massachusetts emergency Medical Services Radio Communication Plan[10]).

2.3.1 UHF Ambulance Radios

The communication systems have changed from a wide band to a narrow band in Massachusetts. This change has been sanctioned by current FCC regulations and will improve EMS radio communication capabilities between ambulance services and CMED centers. To ensure radio equipment is functional in this narrow band infrastructure, the MDPH has established minimum requirements for new radio purchases (The Massachusetts emergency Medical Services Radio Communication Plan[10]). This will ensure that the equipment used by ambulances will have the ability to use the current and future EMS radio infrastructure. Following these radio equipment requirements is important for the continuation of high quality emergency medical service delivery within Massachusetts. Figure 7 below shows the communication system installed in the ambulances at UMass dispatch center, Worcester.



Figure 7: The communication system in an ambulance owned by UMass hospital, Worcester

The standards the MDPH has established for U.H.F two way radios for ambulances ensures that all equipment's purchased to be installed and used in ambulances have the necessary capabilities of operating in existing and planned radio channels within Massachusetts. These standards set the reference point necessary to maximize the value and that are spent for equipment purchases. All equipment purchased by Federal or private funds should pass these minimum standards. This is to ensure reliable ambulance-to-hospital communications throughout Massachusetts and with other public safety agencies both within Massachusetts and nationally.

The minimum standards described by MDPH are stated as follows (The Massachusetts emergency Medical Services Radio Communication Plan[10]):

Minimum Requirements: Ambulance services are responsible to equip the appropriate vehicles with mobile radios. These radios can be used to dispatch the ambulance to the scene of a medical request and must be capable to enable communication with the appropriate CMED Center.

Required Minimum Equipment Capabilities: The following minimum capabilities are necessary features required to effectively implement reliable ambulance-to-hospital communications, as well as achievement of communications interoperability amongst various public safety agencies.

- Subscriber equipment shall be capable of operation from 450 MHz thru 512 MHz without performance degradation.
- Subscriber radio equipment shall have a channel capacity of 200, or greater.
- Subscriber radio equipment shall have the ability to have its channels programmed into a minimum of 10 zones, each containing a minimum of 20 channels.

- Subscriber radio equipment shall have an alphanumeric display capable of displaying a minimum of 8 characters, used for channel/zone naming.
- Subscriber radio equipment shall be capable of operating on any of the 38 E.I.A. standard C.T.C.S.S. or 83 D.C.S. codes; programmable on a channel-by-channel basis and including the ability to utilize different codes for transmit and receive or the ability for a channel to receive in the carrier squelch mode while transmitting a C.T.C.S.S. or D.C.S. code.
- Subscriber radio equipment shall have, as its maximum transmitter output, a power of between 25 watts and 50 watts. Reduced transmit power levels that are programmable on a channel-by-channel basis are desirable but not required.
- Subscriber radio equipment shall conform to Mil Specifications 810 C, D, E and F.
- Subscriber radio equipment shall be capable of supporting wideband F.M. (25 KHz channel) operation.
- Subscriber radio equipment shall be capable of supporting narrowband F.M. (12.5 KHz channel) operation.
- Subscriber radio equipment shall be equipped with an automatic time-out-timer that will turn off the transmitter, and audibly alert the user, once a predetermined period of continuous transmission has expired; desirable to have timed period programmable on a channel-by-channel basis, but in no event any longer than 90 seconds.
- Subscriber radio equipment shall be capable of supporting conventional analog operation.
- Subscriber radio equipment shall have a minimum receive audio output of 10 watts.

Minimum Technical Performance Specifications: The following technical specifications for subscriber radio equipment have been developed to ensure reliable communication while being operated throughout Massachusetts.

Receiver

- 20 dB Quieting Sensitivity (25 KHz channel) 0.4 μ V
- 12 dB SINAD Sensitivity (25 KHz channel) 0.3 μ V
- Intermodulation Rejection 75 dB
- Spurious Rejection 80 dB
- Selectivity (25 KHz channel) 80 dB
- Selectivity (12.5 KHz channel) 65 dB
- Distortion at Rated Audio Output <5%

Transmitter

- R.F. Power Output (maximum) 25-50 watts
- Frequency Stability 2.5 ppm
- Emission (Conducted & Radiated) -70 dBc
- Deviation Limiting (25 KHz channel) +/- 5.0 KHz
- Deviation Limiting (12.5 KHz channel) +/- 2.5 KHz
- Operating Temperature Range -20° F to +135° F
- Power Supply (nominal) 12 Vdc Negative Ground
- Maximum Current Draw 13 Amperes

2.3.2 CMED Trip Record Tracker

One task of a CMED Center is to direct and facilitate ambulance response as they transport patients from the scene of an emergency to a hospital. During an EMS transport, EMTs

talk to the CMED Center initially and then to a hospital. During this communication, CMED Centers capture information about the transport on a trip record. Currently each CMED Center uses a different method for tracking this information. These systems do not have a formal name and are not standardized across CMED Centers (The Massachusetts emergency Medical Services Radio Communication Plan[10]).

2.3.3 CMED Operator Position Equipment

CMED center radio infrastructure differs from center to center. It could be base stations, switch matrix and communication consoles. Although these devices are similar in technology, they are different for each CMED center. With the exception of Metro Boston, all of the Regional CMED Centers use Motorola Centracom II Communications Consoles. Boston utilizes a united console and switch matrix manufactured by Penta (The Massachusetts emergency Medical Services Radio Communication Plan[10]). Figure 8 shows the Motorola Centracom II console which is used as a mobile dispatch setup for EMS communications.



Figure 8: Motorola Centracom II console setup as a mobile dispatch setup

2.3.4 Hospital Capacity Website

The Hospital Capacity Website is a system used to capture and report hospital status to the EMS Systems. The system is also used as an inventory resource for hospital bed availability. Hospital bed availability will become increasingly important in deciding where EMS units transport patients, since, on a daily basis, it addresses emergency department overcrowding and, also in the event of a public health disaster, it addresses diminishing health care resources. If the incident is anticipated to require statewide bed availability resources, EPB on-call person may be contacted 24 hours per day, 7 days per week (The Massachusetts emergency Medical Services Radio Communication Plan[10]).

2.3.5 Health and Homeland Alert Network (HHAN)

As a secure application interfaced with a wide range of devices (e.g. pager, fax, phone, email, wireless), the HHAN provides continuous, secure, bi-directional communication and information sharing in support of aspects of emergency response, including but not limited to, mass casualty incidents, patient surge events or acts of terrorism. HHAN also provides assistance for the following: response planning, educational services, disease surveillance, laboratory reporting, and epidemiologic investigation. The core functionality of the HHAN will provide a secure means to utilize the following (The Massachusetts emergency Medical Services Radio Communication Plan [10]):

- A role-based user directory containing the contact information of all appropriate Commonwealth personnel

- User-specific, rapid communication distribution for emergency situations (can alert via phones, fax, email and pager)
- On-line news postings for low priority information dissemination

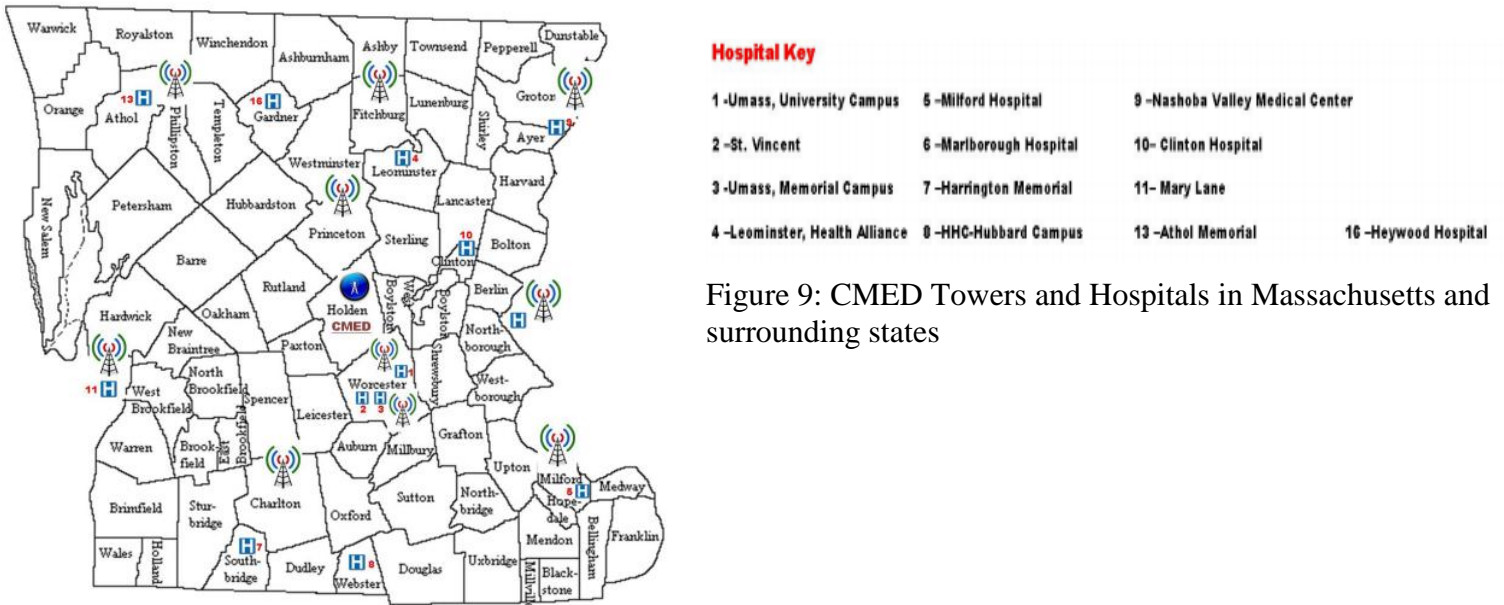


Figure 9: CMED Towers and Hospitals in Massachusetts and surrounding states

Figure 9 is a representation of the CMED towers and hospitals that are present in Worcester.

2.3.6 Satellite Phones

Each of Massachusetts hospitals, CMED centers and selected partner organizations has satellite phones for use in the event of an emergency. These satellite phones enable to communicate via satellite connections that are much more stable and reliable than commercial telephone service. MDPH, hospitals, and CMED Centers can use these satellite phones as an additional method of communication during emergencies, when conventional phone services (landlines and wireless) may be unavailable.

Equipment Description

- 1 Globalstar GSP-1600 handheld mobile unit or equivalent: MDPH has a Globalstar unit for making calls for both hospitals testing, as well as for emergency use as needed. MDPH uses the Globalstar unit to contact hospitals on the same Globalstar network where in-network rates apply.
- 73 Globalstar GSP-2900 Fixed Satellite phones or equivalent: Assistant Secretary for Preparedness Response (ASPR) participating hospitals has one fixed satellite phone unit and antenna. Figure 10 below shows the wireless mobile units and the fixed satellite phone (Make-Globalstar that present in hospitals.



Figure 10: Globalstar GSP-1600 handheld mobile unit and Globalstar GSP-2900 fixed satellite phone

Globalstar phones can be interfaced as a trunk line for phone switches, either key systems or PBX. This allows the satellite connection to be accessible from multiple telephone sets within the building. The satellite phone connection can be interfaced to standard phone equipment including cordless telephones and answering machines. Additionally, the Globalstar phones are able to be enhanced to become capable of transmitting data via satellite connection.

15 MSV phones, MSAT G2 model or equivalent: A key feature of these units is that they offer push-to-talk capability. EMS Regional Offices, CMED Centers and MDPH locations all have MSV phones (The Massachusetts emergency Medical Services Radio Communication Plan[10]).

2.3.7 Ambulance Task Force Radios

The MDPH, the Department of Fire Services, DCR, and MEMA have collaborated to build out the tower infrastructure and supply radio equipment that uses the VHF (150MHz) frequency range. To this end, 136 VHF mobile radios (model VX-4204) and accompanying tactical radio cases were purchased in 2005. This radio hardware allows responders to utilize the VHF (150MHz) radio system to communicate while they are moving around the Commonwealth. Radios were issued to all Ambulance Task Force leaders and alternate leaders. Each Regional EMS Office keeps two radios to serve as replacements for any that need service. The radio also has features including special signaling protocols and a radio-to-radio cloning feature for dynamic reprogramming which is useful in the event of a large-scale incident (The Massachusetts emergency Medical Services Radio Communication Plan[10]).

2.4 Potential Delay Factors

The potential delay factors which cause trouble in EMS communication are examined in detail in this section.

2.4.1 Navigation problems

Our study of the 9-1-1 system shows that the travel of the EMS vehicle from the dispatch location to the patient's location and then to the hospital requires more time than any other part of the process. There can be a lot of factors which can influence the time of travel for the ambulance to reach the hospital. One of the toughest issues to deal with is when the ambulance encounters a street with static traffic of vehicles on both sides of the road (EMS Communication IQP McCann, C., Hanson, S & Olivarez, N. (2011) [24]).

Figure 11 shows a fire truck and ambulance are stuck in traffic due to encroachment on the last lane which is meant for emergency vehicle. This results in loss of critical time.



Figure 11: A Fire truck having problems reaching a location because of static traffic

There remains no scope for a vehicle to make way for the ambulance until the vehicles around it provides enough space to navigate. Also travelling on a narrow street during rush hours

can create many obstacles for the ambulance driver. Although many laws have been framed by the government to improve this situation like requiring drivers to pull over on to the side of the road when an ambulance is approaching and installing traffic preemption devices, it has not been completely successful in reducing time delays as most times, there are unforeseen circumstances in navigation which causes the delay. Figure 12 shows the traffic preemption device which is installed in all traffic light posts. The device starts alarming off when there is an ambulance or fire truck that is approaching.



Figure 12: Traffic Preemption device installed on traffic light post

2.4.2 Location of the Patient

As stated by the operators, the first piece of information they have to obtain during the telephone interviews is where to send the ambulances.

“It is our duty to understand exactly where the accident happened by the end of the telephone interview otherwise it is impossible to direct the vehicles. You can’t move if you don’t know where to go.”

The operator's first question is about the patient's location. The priorities for the emergency service are to guarantee assistance, and to send an ambulance to the patient. The first priority is to obtain the patient's location as the call may be interrupted due to the caller's hysteria or problems with telephone communication. The site of the accident has to be clearly located by the operators, according to criteria set out in a precise protocol, identifying the village, the street name, and the house number (which we call "digital landmarks"). The call-takers usually use specific speech to obtain the details of the patient's location. For example, they ask the caller to specify the name on the bell if the patient is in a place of residence, or the kilometer if the patient is along a road. The protocol the operators have to refer to about the patients' location is designed with the idea that information will be ready to be used and processed. However, locating a patient is seldom an easy process. Commonly the callers, especially those in rural areas, give out information about the location they live in not using addresses, but describing buildings, signs, structures which are supposedly more visible or known. The visual experience is a decisive orientation element for them, a kind of experience related not to abstraction, but to a practical knowledge that involves sight, habit, perception of elements that we define "analogical landmarks".

For example:

Call# 1: O\ Operator; C\ caller

1. O\ 118

2. C\ I'm calling from O. [the name of the village]. My cousin A., fifty years old, doesn't feel very well. He is lying down on the sofa

3. O\ O., what is the name of the street?

4. C\ O., we are in the lower part [of the village]. Do you know the umbrella factory?
 5. O\ No, you have to tell me the street name
 6. C\ Yes, if you come to the umbrella factory. Do you know where B.'s factory is?
-

The caller immediately says the village name, but it is very hard for the operator to obtain the name of the street. The woman, probably living in an unknown area, offers an “analogical landmark” (the umbrella factory) instead of the street name because, from her point of view, the factory best defines the location. In this situation, the operator has to repeatedly ask for the street name.

In conclusion, the “analogical landmarks” is an important element in the process of locating a patient, even if protocol doesn't require it. The operator usually mixes informal and formal procedures in order to improve the service, actually increasing the patient's survival chances and/or reducing injuries. The EMS's organizational structure provides for a precise distribution of competences in the control room. To guarantee the rescue activities, the emergency service requires that different kinds of skilled operators cooperate. The service's organizational structure is based on the territorial knowledge provided by several tools (maps, street indexes, and computers) that are supposed to be consistent with the location activities. The maps are certainly useful, but are of little help in making decisions when conditions change, for example due to road maintenance. As the control room staff widely recognizes, the maps are abstract representations, far removed from concrete circumstances, and the rescue activities depend to a high degree on the personnel's knowledge of the territory in order to reduce the rescue time.

In short, the essential knowledge that enables the proper functioning of the EMS is transversely shared by personnel, callers and tools. In the common effort of locating the patient, the callers and the call-takers use both formal and informal procedures, building an ad hoc, temporary community of practice. This community benefits from the merging use of two positioning systems, which make it possible to code the territory by means of addresses and mark some elements of it with concrete landmarks. During the telephone interview both of them are mutually engaged in guaranteeing the medical assistance, and share the same repertoire in locating the patient. Moreover, according to our data the caller's competence in locating a patient is fully recognized by the EMS staff. As a general rule, the operators don't rely on callers' descriptions of patients' conditions, because the caller is usually unable to report the medical symptoms in a useful way. On the other hand, during the process of obtaining addresses or adjacencies, the carefulness of the caller's description about the location of the patient is never questioned. Supported by technology enabling interactive shared knowledge, the callers are accepted in the knowledge community of the call-takers, a communication network that connects people with questions to people with answers. Relying on their everyday life and/or professional experience, the callers' and the call-takers' expertise on the territory can vary widely. Moreover, the relevance of the expertise is subject to the social distribution of knowledge. According to circumstances, the call-taker could be more or less of an expert than the caller about the accident area, implying major changes in call management. For example, if the call-taker knows the area very well, he doesn't need more specifications from the caller. Consequently, the cooperative work to locate the place is reduced to the minimum.

The control room operators' work repeatedly goes through the space in and outside of the control room. Their work creates a hybrid space in which the representation of the events

happening outside of the control room is coherent with the activities in the control room. The tools, the personnel's knowledge of the territory, and the documents used, integrated and created, build a frame on which to create spaces of intervention. Moreover, locating the patient proves to be an emerging phenomenon as a collaborative job. The rescue intervention is a multi-layered process involving various subjects: the control room operators, the callers, the rescue teams, and different agencies.

2.4.3 Climatic Factors

Climate can have a major influence on the travel time of an ambulance from the dispatch location to hospital. The type of climate can cause a significant delay. With an increase in the surrounding temperature, many ambulances can overheat causing parts of the ambulance to deteriorate quickly like the tires. Prolonged exposure to such climate can permanently affect the quality of the parts. Therefore it is very important to conduct regular vehicle checks for ambulances in areas of extreme heat. In areas where the weather is extremely cold and there is snow for most parts of the year, ambulances face a lot of trouble. Engines can fail to start up if the vehicle remains outside for a long time and travel is difficult if the ambulance is moving on a road covered with snow. There is a chance the ambulance will not be able to climb uphill as the tires will skid off the snow, or will travel with a slower speed. But milder winters, reductions in the number of cold days, delays in winter freezing, and earlier spring thaws may reduce cold-weather damage to vehicles (US Environmental Protection Agency [19]). Figure 13 shows how an ambulance navigates its way through a severe snow storm. This results in a loss in time as the ambulance has to navigate slowly.



Figure 13: Ambulance facing problems due to a severe snow storm

2.5 Local 9-1-1 Center Interview

As stated in the abstract, facts were gathered using a series of different interviews. For this purpose, our group visited local 9-1-1 center on the 13th November, 2012 and met the people in charge of the center. We asked them a series of questions to collect more information regarding the working of a 9-1-1 dispatch center.

The authorities were kind enough to explain to us the entire procedure of 9-1-1 working and how the Worcester EMS is structured and functions. They told us when an emergency call is taken, the fire department and EMS dispatch their vehicles at the same time. The fire trucks reach at the scene or incident earlier than the EMS dispatches. This is because the fire department has a 4 minute time response time while the EMS dispatches have an 8 minute time response. Since the fire fighters reach at the scene of incident early, they interrogate the place and pass on the information to the EMS which can come in handy to the EMTs. In the city of Worcester, there are 4-5 functional ambulances depending upon the time of the day.

UMass is the primary provider for EMS personals in the city of Worcester. The authorities told us Worcester has a backup 9-1-1 emergency center as well where 9 people stationed all the time. When the 911 center takes a 7-digit call, the call is heard not only by the call taker in the main 9-1-1 center but also by the crew stationed at the backup. We asked them regarding the training of the call-takers, peak hours of duty and no. of different incidents that get recorded every year. They told us they roughly take almost 80,000 9-1-1 calls and 300,000 7-digit calls every year. 25,000 calls are EMS requests out of which 22,000 are actually taken. There are 40,000 calls for the fire department and 122,000 for the police department. The thing to be noted here is that one phone incident can be considered as both a fire and police department case or a fire, police department and an EMS case. So we cannot sum up these raw numbers and to get a total number of phone calls. Regarding the employees stationed at the center, the authorities told us they have three 8 hour shifts every day and there are 9-13 people stationed at the place all the time. To qualify to be a call taker at a 911 center, every employee has to have a compulsory 9-1-1 training along with 40 hours of basic help communication training. After that the Worcester department personally trains the newly hired employees for almost 2.5-4 months themselves.

We also asked the authorities regarding the linguistic skills of the all takers. They told us they have only 2 bi-linguistic people but they do not prefer to use them. This is because if there is a mistake in translation by the translator while taking the emergency call, it becomes a liability and a legal issue. To take care of that Worcester Police Department uses PIECAPP which can detect 183 different dialects. If the person on the phone has a different dialect, the Worcester Police department contacts PIECEAPP which then sends in the appropriate person for the translation. This way the liability issues don't fall under the Worcester Police Department.

The authorities told us that the Worcester Police Department is trying to get a contract with company named SMART911. Nashville 9-1-1 center is already using the SMART911. What SMART911 does is it asks people of community to log into their system and provide their basic information and medical history. SMART911 then stores all these records. If the person calling 9-1-1 has their information stored in SMART911, the system will detect the number the person is calling from and pull out all of his stored data. This gives the call taker an edge to decide what to do regarding the complaint of the caller. If the person calling is someone who just tried a failed suicide attempt, they do not transfer that persons call to anyone because they want to keep talking to the person on the phone. Otherwise for all other EMS requests they conference call with the EMTs so that they too can listen to the information the caller is providing. The city of Worcester has three 9-1-1 offices. One is located in Auburn Mall, one in Greendale Mall and another one in the Worcester Police Department.

We were also informed about new software the Worcester 9-1-1 department is using right now. The software is named TRAPCALL. When a person calls the 9-1-1, they only get the place from where the call was made. If the person making the call is travelling, the 9-1-1 department will not be able to track the person down. For that purpose they use TRAPCALL. What TRAPCALL does is take satellite snapshots of the place where the person is at the moment with brief intervals of time. This makes it easier to track the person down or get to know the exact location he is travelling to. According to the authorities at the 9-1-1 center, they do not have to worry about the financial issues of the 9-1-1 center in Worcester since 9-1-1 is controlled by the State and the State pays for its billings. The only thing they have to worry about is the efficiency of the call takers.

2.6 Case Studies

In order to get a better understanding of the project case studies were needed to be examined. We researched on a number of case studies and some of them related the area of research for this project. This section contains the case studies which deals with the problems we are trying to improve for this project.

2.6.1 Case Study 1, California

In California, an accident involved the need for an EMS ambulance. The accident ended with the patient in the ambulance dying. A car driving through an intersection crashed into the ambulance flipping the ambulance on a side. The patient couldn't bear the accident and was pronounced dead at the scene of incident. The firefighter and the EMT riding in the ambulance were sent to the hospital since they sustained minor injuries (EMS Communication IQP McCann, C., Hanson, S & Olivarez, N. (2011) [24]). Figure 16 shows the ambulance crash site in California that is discussed in case study 1.

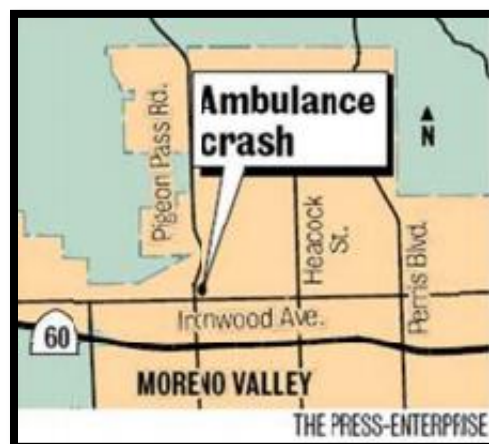


Figure 14: Ambulance Crash Site in California

This accident brings out many problems which ambulances now days. Right now ambulances are permitted to proceed with caution through intersections. This accident involves a driver who was going right because he had a green light but he couldn't see the ambulance coming from the other direction even though the sirens and lights of the ambulance were actively operating. Now a days sound proof cars are being used a lot too. This raises another concern for the ambulances since those car drivers cannot listen to the sirens of the ambulance and it increases the chances of collisions.

The accident itself caused the harm which could have been prevented otherwise. The EMTs and the Firefighters in the back of the ambulance do not usually wear seatbelts while taking care of the patient. In this very case, the patient was suffering from a cardiac arrest which is a very critical situation and requires extra care from the EMTs and the firefighters. Any accident involving an ambulance transporting a patient will not only cause harm to the Firefighters, EMTs and the patient but also to anyone who is travelling with the patient because it is most likely they won't be wearing a seat belt as well. For the patient, as he is already in harm because of the cardiac arrest in this situation, the accident can be fatal like in this case. It caused the patient to die. This sort of death is extremely unlucky and could have easily been avoided if the ambulance or the system was to be able to warn the traffic regarding the presence and the direction of the ambulance.

2.6.2 Case Study 2, Colorado

Minutes after the shooting in the movie theatre in Aurora, Colorado, police officers called on emergency dispatch teams to tend to the wounded. Even though there was a two-person team

a few miles away (without any priority emergencies), it took more than twenty minutes for dispatchers to ask the Cunningham Fire Protection District and other agencies to provide aid.

By the time this crew arrived, it was more than half-an hour after authorities received word of shots fired (EMS, Emergency Medical Services JMES.com[26]). This massacre left twelve dead and dozens wounded, though it was debated upon, that a faster response time could have saved more lives. On the police radio transmissions, officers said they lacked sufficient medical support for about 30 minutes after the 9-1-1 calls came flooding in around 12:39 a.m. and that medical teams didn't report getting inside the theater for about 24 minutes (EMS, Emergency Medical Services (JMES.com[26])). Figure 17 shows police personnel outside the shooting scene in Colorado as he tries to call for an ambulance dispatch.



Figure 15: Police Department reaching the shooting scene in Aurora, Colorado

Dispatchers began their response by quickly sending one ambulance to the scene, followed by another about three and a half minutes into the response. A third ambulance soon followed. Additionally, the Cunningham unit, which was mentioned above, was not called for by Aurora Officials/Police Department and were idle for around 15 minutes, as both departments operate separately (hence creating overlapping redundancy). A police communications officer or

a 9-1-1 operator receives the earliest notification of accidents. They depend on the caller for specifying injuries. If the caller does so, an EMS dispatcher is notified, but if not, the police officer might wait before contacting EMS, resulting in additional delays.

2.6.3 Case Study 3, NYC World Trade Center Attack & Hurricane Katrina

Traditional telecommunication networks were overloaded during the September 11, 2001 attacks on the World Trade Center (National Emergency Communication Plans [27, 28]). Operators were overwhelmed with the sheer volume of calls, because of phone networks being congested, and because of the confusing information being received. Interdepartmental help (between emergency services personnel) were limited by a lack of interoperability between departments. Many fire-fighters died when the towers collapsed because they couldn't receive the warning, police officers received from the New York City Police Department helicopters (National Emergency Communication Plans [27]). When Hurricane Katrina, hit New Orleans, emergency communications systems were destroyed. These included power stations, internet servers, mobile towers and essentially 911 communication services.

During the World Trade Center Attack there were some understandable communication bottlenecks (National Emergency Communication Plans [28]).

- EMS Chiefs who responded to the attacks had difficulty in maintaining communications due to the sheer volume of radio traffic. This was partially caused by the usage of the same radio frequency for command channels (point-to-point communication among EMS Chiefs and officers at an incident), and citywide channels (between personnel and dispatch across a city). To relieve congestion, the Manhattan South Borough Channel was

opened for communication between Dispatch and responding ambulances- however, many units weren't tuned to this new channel and continued to use the citywide channel degrading information communication.

- During day-to-day operations EMS personnel arriving for duty log into the Computer-Assisted Dispatch System with radio and ambulance unit numbers. The system maintains a database of personnel with assigned ambulances etc. However, during this incident, some personnel responded without radio information, and hence personnel tracking was constrained.
- Volunteer and Self-deployed ambulances (not part of the 911 EMS system), responded to the incident, without the coordination and direction of EMS dispatch and hence degraded the ability to maintain control.

“If Hurricane Katrina or 9/11 happened today, the results, from a communications standpoint, would largely be the same,” Vanu Bose, CEO of Vanu (Vanu [29]) (a wireless communications systems company located in Cambridge Massachusetts) declared. During such a disaster, the failures of communications systems are hinged on either the loss of power or the loss of cables that carry signals from the stations. In the case of Hurricane Katrina, although carriers had very robust cell towers above the flood level, cables connecting the towers were underwater and hence out of service.

In February 2012, the U.S. Congress set aside \$7 billion for a “First Responders Network Authority,” This is a federal office that is responsible for building a nationwide emergency network to enhance interoperability across agencies and allow for widespread coverage. To ameliorate these extreme situations, a Computer-Aided Dispatch system is used (though it would

need further improvements). The CAD systems used type-codes for Location, Reporting Party and Incident are the main fields that have to be populated by type-codes. (e.g. BURG for Burglary.)

The following shows a typical Computer-Assisted Dispatch (CAD) system printout. The dispatcher's screen show available personnel and so will be able to continue the call from the call-taker and dispatch units. It consists of modulus that provide services at multiple levels in a dispatch center- such as call input, dispatch, status maintenance, field unit status and tracking.

```
-----  
LOCATION - 1400 Madison  
RP      - Doe, John, 555-5555, 1404 Madison  
INCIDENT - BURGLARY (in progress)  
SYNOPSIS - "Caller reports a possible burglary in progress based on seeing  
individuals inside the residence/Caller advises 2 persons inside the location  
and call advises the current residents are on vacation."  
-----  
-----  
INCIDENT # - 554123  
LOCATION    - 1400 Madison  
RP        - Doe, John, 555-5555  
INCIDENT  - BURGLARY (In Progress)  
SYNOPSIS  - "Caller reports a possible burglary in progress based on seeing  
individuals inside the residence/Caller advises 2 persons inside the location  
and call advises the current residents are on vacation."  
UNITS     - 746 (Pri), 749 (Cov)  
-----
```

Units available - (3)

Units out of service - (2)

749 - Not Avail. Inc # 554122

Regardless of such systems present, instability in the modes of communication and the inability to handle an overload of phone calls during severe emergencies resulted in a delay in 911 and emergency communication systems.

2.6.4 Case study 4, York County, New York

On October 27, 2002, seven members of a York County Amish family travelling on the Norman Wood Bridge were severely injured when a passenger van slammed into their horse-drawn buggy. The collision threw the entire family onto the bridge and resulted in the deaths of the father and two of the five children. The accident was categorized as a Class I MCI (Mass Casualty Incident) by EMS dispatchers. Many fire companies, ambulance, and rescue-helicopter crews from the neighboring York and Lancaster counties responded to the crash, which happened just east of the York County line (Gladwin County Record and Beaverton Clarion, Gladwin MI [30]). The location of the crash presented an unique problem to EMS dispatchers and personnel, as it was on a section of highway between the York and Lancaster counties. This resulted in confusion and misunderstanding in knowing which authority was responsible for responding to the MCI, hence resulted in a long time response.

2.6.5 Case Study 5, Computer Virus, New Zealand and Australia

In 2011, a computer virus disabled the automated response system of St. John Communication centers across New Zealand, and to the New South Wales County of Australia. This was the second incident since December 2009, when an USB drive was responsible for introducing the Conficker virus to the Waikato District Health Board computers in December 2009. This virus disabled the computer networks for two days, affecting more than 6000 staff and thousands of patients who had procedures delayed. In New South Wales, the government launched an inquiry into the glitch that shut down the paramedic computer dispatch system, which resulted in officials reverting to co-ordinate paramedics and ambulances via a lengthy manual, paper-based system (St John | Computer Virus Hits Ambulance Services [31]).

Jillian Skinner, the opposition Health Spokeswoman remarked that the virus' effects "could potentially cost lives", as the computer-aided dispatch system (which allows ambulances to respond to critically ill patients) completely failed. While the system was being purged of the virus, emergency calls were still being answered and logged manually. Luckily, The general manager of operations for Ambulance of New South Wales, Mike Willis remarked, "It's important to note that at no time during that shutdown procedure were any triple-zero calls or in fact the integrity of our operation breached,".

When St. John's hospital receives an emergency call, an ambulance is alerted via a Mobile Data Terminal (MDT). The Mobile Data Terminal is an on-board computer, which displays information and vital aspects about the emergency.

However, during the week when the system was affected by the Conficker virus, ambulance officers were called via station phones and emergency information was relayed in person. It is

surprising that even though antivirus software protected the MDT and dispatch system, paging and radio services were adversely affected (St John | Computer Virus Hits Ambulance Services [31]).

A Hamilton IT expert said that it was surprising to notice the power outage in the emergency center as this robust system that is capable of handling heavy call volumes and transfer of information, would have been heavily protected by security systems. "Without forensic access to the system it's hard to gauge what went on, however in most cases a virus is transferred from a memory stick plugged into the system," he said. "One would expect a system like this to have strict controls around memory stick use."

2.6.6 Case Study 6, Las Vegas

Five people were hurt and a woman died after an accident Tuesday, September 4, 2012 morning in an accident involving an ambulance in Las Vegas. The woman was the patient in a Medic West ambulance when it was hit by a red pickup about 10:30 a.m. at Craig Road and Decatur Boulevard in the northwest valley. The ambulance, which also was carrying two North Las Vegas firefighters and two Medic West paramedics, tipped onto its side, Las Vegas police said. The woman was treated at the scene by the firefighters and taken to Mountain View Hospital. She died a short time later. It was unclear whether she died from injuries suffered in the crash or her prior medical condition. The pickup's driver was taken to University Medical Center in serious condition. The firefighters and paramedics also were taken to UMC and were in stable condition. North Las Vegas officials said the firefighters "selflessly ignored their own conditions" and treated the woman until additional paramedics arrived. In a statement by Jeff

Hurley, president of the North Las Vegas Firefighters Local 1607, Hurley said Tuesday's accident could have been prevented. He blamed the deaths on deep budget cuts to emergency staff and equipment, noting the North Las Vegas department lost six of its eight ambulances. The statement said the Fire Department's ambulances are larger and designed differently than the one that tipped on its side. The North Las Vegas department's ambulances were equipped "with multiple harnesses to handle these type of emergencies," the statement read. Hurley added: "These cuts are affecting us in more ways than we ever imagined."

2.6.7 Case Study 7, National Highways in USA

The following is a collection of data that the National Institute for Occupational Safety and Health (NIOSH) identified. 27 EMS worker fatalities in ambulance crashes were reported in the National Highway Traffic Safety Administration's Fatality Analysis Reporting System (FARS) for 1991-2000.

Overall--During 1991-2000, 300 disastrous crashes occurred which involved occupied ambulances, resulting in the deaths of 82 ambulance occupants and 275 occupants of other vehicles and pedestrians. Twenty-five ambulance crashes accounted for the 27 EMS worker fatalities. In two of the incidents more than one EMS workers were killed, and 23 incidents involved single EMS worker deaths. Breaking down the EMS crash incidents into further small groups will help us examine the detail more closely.

Vehicles - Using the make, model and weight code for trucks and vehicle identification number data, one ambulance (4%) was identified as Type I (truck chassis with patient

compartment attached), five (20%) as Type II (van with extended roof) and 11 (44%) as Type III (cutaway van chassis with patient compartment attached). Eight (32%) were not classifiable with the information available.

Roadway/Environmental Conditions - Eighteen of the twenty-five fatality incidents (72%) occurred at non-interchange (all roadways on the same level), non-junction locations--or, more simply put, did not occur at intersections. The remaining seven incidents (28%) took place at intersections or were intersection- or crossover-related. Of the 300 total crashes, 132 (44%) occurred at non-interchange, non-junction locations; 134 (45%) occurred at non-interchange intersections. Fifteen of the 25 fatal crashes (60%) took place in daylight; 18 (72%) in normal ("fair") weather; 17 (68%) on straight, level roadways; and 18 (72%) on rural roads.

Ambulance Role (Striking vs. Struck) - Designating a vehicle as "striking" does not necessarily mean that vehicle was at fault. For example, in a head-on collision between two vehicles, both vehicles can be considered as the cause of the accident. In 233 (78%) of all 300 crashes involving fatalities, the ambulance was a striking vehicle; for those 25 in which an EMS worker was killed, the ambulance was a striking vehicle in 20 (80%). Three of the incidents in which an EMS worker was killed were defined as "non-collision" (12%), and two of the ambulances (8%) were struck by other vehicles (Response Time Effectiveness: Comparison of Response Time and Survival in an Urban Emergency Medical Services System – BlackWell [11]). Figure 18 shows how a car ran in to an ambulance head on during night on a highway.



Figure 16: Head on collision involving an ambulance on a car on a highway, USA

2.6.8 Case Study 8, Mortality Rate vs Response Time

A study was done to determine the effect of current Response Times on survival in an urban EMS system. The study was conducted in a metropolitan county (population 620,000) where the EMS system is a single-tier, paramedic service and provides all service requests. Nine out of ten times, response time specifications required for county agreement including 10:59 minutes for emergency life-threatening calls (priority I) and 12:59 minutes for emergency non-life-threatening calls (priority II). All emergency responses whether of priority I or priority II were transported to a Level 1 trauma center emergency department over a six-month period. This way evaluation was done to determine the relation between specified and subjectively assigned response times and survival. In those six months, five thousand, four hundred twenty-four transports were reviewed. Out of these, 71 patients did not survive. There was no difference noted in median response times survivors (6.4 min) and non-survivors (6.8min) (probability = 0.10). Furthermore, there was no significant difference noticed between observed and expected deaths (probability = 0.14). However, mortality risk was 1.58% for patients whose response time exceeded 5 minutes, and 0.51% for the patients with response time of less than 5 minutes

(probability = 0.002). The mortality risk curve was generally flat over response time's intervals exceeding 5 minutes.

The conclusions drawn from this case study were a lot more different than what everyone had been suggesting about time response. In this observational study, emergency calls with response times of less than 5 minutes were related with improved survival when compared with calls where response times exceeded 5 minutes. Variables other than are also important for survival, there is little evidence in these data to suggest that changing this system's response time specifications to times less than current, but greater than 5 minutes, would have any beneficial effect on survival.

2.7 Region wise Analysis of EMS in the United States

In this section, we will break up the United States in to three distinct regions- Eastern United States, Western United States, and Southern United States. Each section will then be further subdivided state wise and the analysis of the EMS in select states will be done.

2.7.1 Eastern United States

Eastern United States comprises of 26 States that lie east of the Mississippi river where 58.28% of the total population of American citizens reside. With the majority of the US population residing in the eastern United States in only about 12% of the total land area, the population density is very high in this region. Therefore, this region has the highest probability of contributing to EMS situations in the country theoretically. Major cities like New York, Chicago, Philadelphia, Boston, and Baltimore, Memphis, Washington DC, Miami, Atlanta, Tampa, and Detroit lie in this region. With so many major urban cities in this region, the MES

services should be as efficient as possible since the number of minor and major accidents, unexpected events and human health problems are very high.

2.7.1.1 Analysis of EMS in New Jersey

In 2006, the State of New Jersey decided to conduct a study to assess its Emergency Medical Services (EMS) system. The study was mandated by the New Jersey State Legislature to review the current EMS system and determine immediate and future needs. New Jersey has a two-tiered EMS system that provides basic and advanced life support services. The New Jersey EMS systems consists of more than 25,000 volunteer and career providers, including first responders, emergency medical technicians (EMTs), paramedics, nurses, and physicians. The New Jersey's Office of EMS (OEMS) maintains the certification of 1,500 paramedics, 22,000 emergency medical technicians (EMTs), and the licensure of more than 3,000 vehicles, including mobility assistance vehicles, ambulances, mobile intensive care units, specialty care transport units, and air medical units.

The population density differs greatly between the northern and southern regions of New Jersey. This variation affects the demand and delivery of EMS services throughout the state. At present, New Jersey has no state EMS medical director nor does it have a regional EMS system. The lack of statewide medical direction results in a loss of transparency that has led to fragmentation of EMS medical oversight, especially between ALS and Basic Life Support (BLS) services. New Jersey's State oversight is highly centralized and with little coordination between state, regional, local, and volunteer agencies. TriData suggests that New Jersey restructured their EMS system by creating a regional approach that will decentralize daily management of EMS by creating three geographical regions.

The New Jersey EMS system must change to continue effective delivery of pre hospital care. The system's financial structure, decline in volunteer membership, lack of comprehensive legislation, and weakened ALS system is in near crisis. One particular issue encountered by New Jersey EMS leaders involves the public's acceptance of EMS, which has led to changes in expectations of quality care, the role that EMS should play in our healthcare system, and how EMS is best provided. These are critical as citizens of and visitors to New Jersey are dependent on the expedient and reliable response of EMS personnel for the provision of pre hospital care and transport to an appropriate medical facility. In addition, changes in social, technological, educational, environmental, and political aspects of emergency care require governmental entities to rethink how EMS should be regulated. This includes medical oversight of patient care, EMS system design, stewardship of access, economies of scale, and the integration of new technologies that enhance patient care and information management. Factors such as an increase in demand for EMS among the senior citizen population, the growing number of underinsured and uninsured citizens, and tighter operating budgets challenge governmental and private providers to provide competent EMS services at a reasonable cost. Public expectations are not easy to respond to as their impression of EMS is different from what actually occurs. Until recently, the media portrayed EMS systems as always prepared, always staffed, and usually within a few minutes of any emergency. Save rates from cardiac arrest were shown as high and emergency departments were always standing by with a full team of experts ready to save almost everyone who arrives. The challenges and opportunities that face New Jersey EMS can be summarized in by five major items:

1. The need to sustain EMS organization's capabilities and mission in the face of growing resource needs and reimbursement constraints.

2. Meeting the multifaceted workforce crisis that exists throughout the country.
3. Ensuring patient safety and good clinical outcomes; reducing variability in quality and cost; and demonstrating positive impact on the health status of individuals, families, and communities.
4. Redesigning EMS systems and processes, building new operating models, and overcoming technical and cultural obstacles along the way.
5. Maintaining access to capital to enable needed investments in facilities, technology, and equipment.

Basic Structure of New Jersey EMS

The New Jersey EMS system is two tiered and provides both Basic and Advanced Life Support services. Responding to over 800,000 requests for service each year, the New Jersey EMS operating staff includes more than 25,000 volunteers and career providers, including first responders, EMTs, paramedics, nurses, and physicians. The New Jersey Office of EMS (OEMS) maintains the certification of more than 22,000 Emergency Medical Technician–Basics (EMT–B), 1,500 Emergency Medical Technician- Paramedics (EMT–P), and the licensure of more than 3,000 vehicles, including mobility assistance vehicles, ambulances, mobile intensive care units, specialty care transport units, and air medical units.

Basic Life Support – Basic Life Support (BLS) services in the State of New Jersey are generally responsible for patient hospital transports. BLS providers include both career and volunteer operators. Career operators are licensed BLS providers that charge fees for services provided. These agencies originally operated primarily within larger cities, such as Trenton, Newark, and Camden, but in recent years have spread into suburban and rural areas. Volunteer

services that wish to charge fees for services must first be licensed then fall under the same rules as commercial providers. All hospital or municipal-based services must be licensed regardless of their fee-for-service status. Volunteer agencies, on the other hand, do not charge for services and are not regulated by the state. This approximately includes 400 members of the New Jersey State First Aid Council (NJSFAC) and over 110 providers that are neither licensed by the NJOEMS nor members of NJSFAC. Because the state does not regulate volunteer providers, it is difficult to assure quality, staffing levels, or equipment standards.

Advanced Life Support – Dispatched only to life-threatening incidents, Advanced Life Support (ALS) providers offer the highest level of pre hospital care. ALS service in the State of New Jersey is provided by paramedics and Mobile Intensive Care Registered Nurses through Mobile Intensive Care Units (MICU) and JEMSTAR helicopters. MICUs are operated by licensed, acute-care hospitals and are bound by a state-issued certificate of need, which allocates sole-provider service areas to specific hospitals. These ALS units are generally prohibited from transporting patients, unless no BLS ambulance is available.

In conclusion, the New Jersey EMS system is in need of an overhaul. The state's investment into the EMS system is the only way that significant change is likely to occur. County governments should be encouraged to become involved in the oversight of EMS. Investment of dollars at this level may improve the EMS economies of scale and benefit local municipalities. Above all, it will likely guarantee good EMS care to the citizens of New Jersey. As part of the change needed there is a critical need to overhaul the state EMS information system. A requirement should be put in place for the submission and analysis of EMS data. Analyzing what EMS does is a key to determining an appropriate system design.

2.7.1.2 Analysis of EMS in Virginia

Joint Legislative Audit and Review Commission (JLARC) staff found that Virginia's EMS system is currently in a state of transition. Training requirements for EMS staff are increasing, and in many areas of the State, EMS is moving from a free service provided by volunteers to a service that bills for the care it provides and uses paid staff to ensure the availability of a high level of emergency medical care 24 hours a day, seven days a week.

Overall, this report found that all Virginians have access to some level of emergency medical services. However, the availability of advanced life support providers, particularly paramedics (the highest skill level of EMS provider), varies substantially across the State. The time it takes for an ambulance to respond to a 911 call also varies across the State; response times are longer in some parts of the State due to factors such as terrain, population and traffic densities, and EMS agency staffing levels.

Virginia's EMS system is well above the national average in the number of emergency medical vehicles and personnel relative to the population served. In 2003, the Commonwealth was ranked first in the nation in the ratio of population per emergency vehicle, with one vehicle for every 1,749 residents, and tenth in the ratio of population per certified EMS personnel, with an average of one certified EMS provider for every 215 people. These excellent national rankings do not mean that vital EMS resources are uniformly distributed within the State; in fact, the ratio of providers to population varies from a high of one provider for every 70 people in Surry County to a low of one provider for every 1,211 residents in Manassas. In 2003, the average reported time required for a unit to arrive on scene after it was dispatched was approximately 12 minutes, and 72 percent of all reported responses were provided in less than 10

minutes. Less than one percent of the reported responses took more than one hour from the time the unit was dispatched until it arrived on scene.

There are places in Virginia where response times may be longer, due to a combination of factors such as terrain, population and traffic densities, and EMS agency staffing levels. This is important because the patient's chance of surviving major injuries is much greater if treated at an appropriate facility within the first hour after the incident (the "golden hour"). All localities have access to some level of EMS, although 53% of all Virginia paramedics (the highest skill level of EMS provider) are in just 14 localities, and 12 localities have no paramedics. Overall, most EMS providers are located in the State's major population areas (see map below). In many areas of the State, EMS is available only because individual residents have volunteered and organized themselves to provide the services – there is no State requirement for EMS to be available. While State law directs the Board of Health to develop a comprehensive and coordinated system of EMS, no agency, either State or local, is required to actually provide emergency medical services. Local governments provide EMS in 84 localities, but have played only a minimal role in other areas. For example, 18 localities (13 counties, three cities, and two towns) were reported as having provided less than \$10,000 in financial support to the volunteer EMS agencies operating within their jurisdictions, according to grant applications filed by the agencies. Figure 17 shows the EMS providers in the localities in Virginia. The average number of providers in each locality is 239.

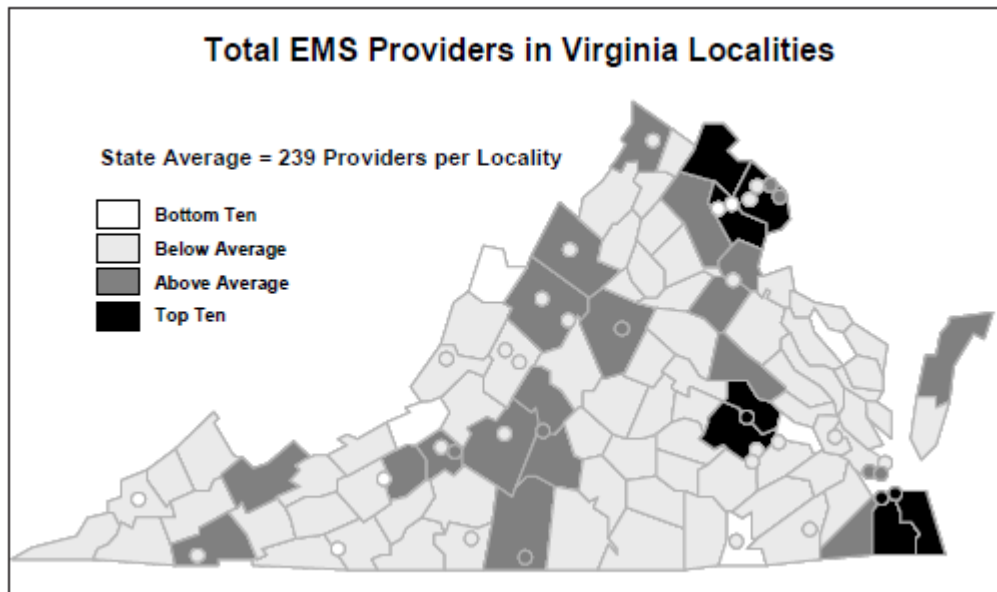


Figure 17: The total EMS providers in Virginia Localities

In a well-functioning EMS system, when an individual experiences a medical emergency, the EMS system is quickly accessed by calling 911, appropriate resources are immediately dispatched to the scene, pre-arrival instructions to start care and treatment are provided to the caller, well-trained personnel arrive within minutes and provide care at the scene, and the patient is quickly transported in a properly equipped ambulance (ground or air) to the most appropriate hospital or trauma center, where the patient receives the required treatment. When a larger-scale incident occurs, a coordinated response from neighboring EMS agencies brings skilled people and the required equipment to the scene, and patients are quickly transported to appropriate hospitals and trauma centers.

The EMS system in Virginia is varied and complex. EMS services are locally based, and only certified personnel can provide emergency medical care. The Office of Emergency Medical Services (OEMS) within the Virginia Department of Health is responsible for certifying EMS personnel, licensing EMS agencies, and issuing permits for EMS vehicles. Although local units of government are not required to ensure that such services are available, EMS services appear to be available in all localities.

One way of assessing the effectiveness of Virginia’s EMS system is by analyzing the quality of patient care provided once the responding agency is on-scene. Despite numerous anecdotal accounts of 911 calls that went without the arrival of an EMS responder, and of regional variations in patient survival rates based on the distribution and availability of EMS personnel, there is insufficient data at the State level to perform any systematic review of patient outcomes resulting from the level of emergency medical care provided statewide or locally. Without patient care data there is no way to determine the appropriateness of the level of care provided and it is not possible for local governments to make decisions on the effectiveness of their own or volunteer organizations, or to determine the appropriate level of local investment in the provision of emergency medical services.

The OEMS patient pre-hospital care reporting (PPCR) system has insufficient data for analyzing response times or patient outcomes at the local level, as previously noted, and the State does not have any formal mechanism for tracking unanswered calls for assistance. While there are informal feedback mechanisms through which an agency’s operational medical director (OMD) is able to monitor the quality of patient care provided for their specific agency, there is no unified data system that allows for analysis of this information at the State level. There is very limited documentation of the performance of the EMS system across the State, and no unified data system capable of analyzing EMS resources, equipment, response times, and outcomes.

2.7.2 Southern United States Analysis

The Southern United States consists of sixteen states, as defined by the United States Census Bureau. As of 2010, 37% of all U.S. Citizens (est.115 million people) live in the South, “categorized” in three smaller units: (Population Distribution and Change[32,33])

- The South Atlantic States: Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia and Delaware
- The East South Central States: Alabama, Kentucky, Mississippi and Tennessee
- The West South Central States: Arkansas, Louisiana, Oklahoma and Texas



Figure 18: The Southern United States

While the South is among the fastest growing areas in the United States, with rapid economic growth, it also has a higher poverty rate and a lower cost of living than the rest of the United States. This will naturally mean that to cater for densely populated cities (which also have a relatively low cost of living), a good Emergency Medical System will have to have been implemented. One of the best ways in analyzing the efficiency of the EMS systems are to understand response times and functionalities (Texas Department of State Health Services[33]).

2.7.2.1 EMS Analysis of Texas

The Texas EMS systems have improved drastically over the last 40 years, from a transportation service, to medical transportation, to out-of-hospital healthcare. As late as the 1960's EMS was not seen as a vital component of healthcare, rather as transportation means (Texas Department of State Health Services [33]). Until the 1970's most ambulances were

operated by funeral homes, with the funeral home receiving a phone call from the local law enforcement agency. Usually, the ambulance had a basic radio system on police frequency which were used while responding and transporting patients to the hospital. However, the hospital did not know if the patient was en-route, until the ambulance arrived on site (Washington State Department of Health [34]).

One of the important pieces of information provided during an emergency call is the location of the person requiring assistance. At many 9-1-1 communication centers, call-takers are automatically provided with the caller's telephone number and location through Automatic Number Identity (ANI) and Automatic Location Identity (ALI), via a system known as Enhanced 9-1-1 mentioned previously. However, this facility is not available throughout Texas, so callers without E9-1-1 must give exact locations to ensure a quick response time, on top of the fact that many areas in Texas, still lack sufficient dispatching services.

With Public Safety Answering Points (PSAPs), EMS calls are answered by personnel with differing levels of education, experience etc., so will hence have different abilities to provide potentially life-saving instructions via telephone. Additionally, in Texas, much of the EMS firms are dispatched by local law enforcement, and hence dispatching EMS is a secondary function to the routine dispatching of law enforcement personnel (Time Response Ambulatory Calls Evaluation [53]).

“Public access is the ability to secure prompt and appropriate care regardless of socioeconomic status, age or special need”. One challenge includes that fact that Texas is a bilingual state (English and Spanish), and a large portion of Texan population is a minority. The language barrier emerges from the fact that solely Spanish-speaking residents comprise of more

than 20% of the population of rural Texas. Public access is constrained when callers jam lines with non-emergency calls, which lead to EMS teams unable to prioritize between emergencies.

The costs of emergent care in Texas reaches into hundreds of millions of dollars each year- with expenses going towards maintaining ambulances and medical equipment, training EMS personnel, improving communication capabilities to name a few. EMS providers finance these operations via tax revenues, billings, subsidies, grants and reimbursements. However, because EMS is not a mandated service in Texas, most communities chose to avoid the cost of providing any EMS services, and depend instead on volunteer EMS services resulting in the fact that funding programs don't cover the true costs of providing trauma care in a community, let alone developing a system to co-ordinate efforts between departments. The statistics below in figure 19 show the estimated per capita costs of EMS in Texas (which comes to around 14 cents per day per person (Time Response Ambulatory Calls Evaluation [34])).

Per Capita Costs of EMS	
Budget	\$ 1,796,289
Less expected Revenue	\$ (700,000)
Total	\$ 1,096,289
Number of hours in a year	8,760 hours
Cost per hour	\$ 125.15
Number of people in a county per 2000 census	21804 people
Cost (per day per person)	\$ 0.13775 (~14 cents per day per person)

Figure 1914: Per Capital Costs of EMS in Texas

EMS Response Times by Trauma Service Area, 2002

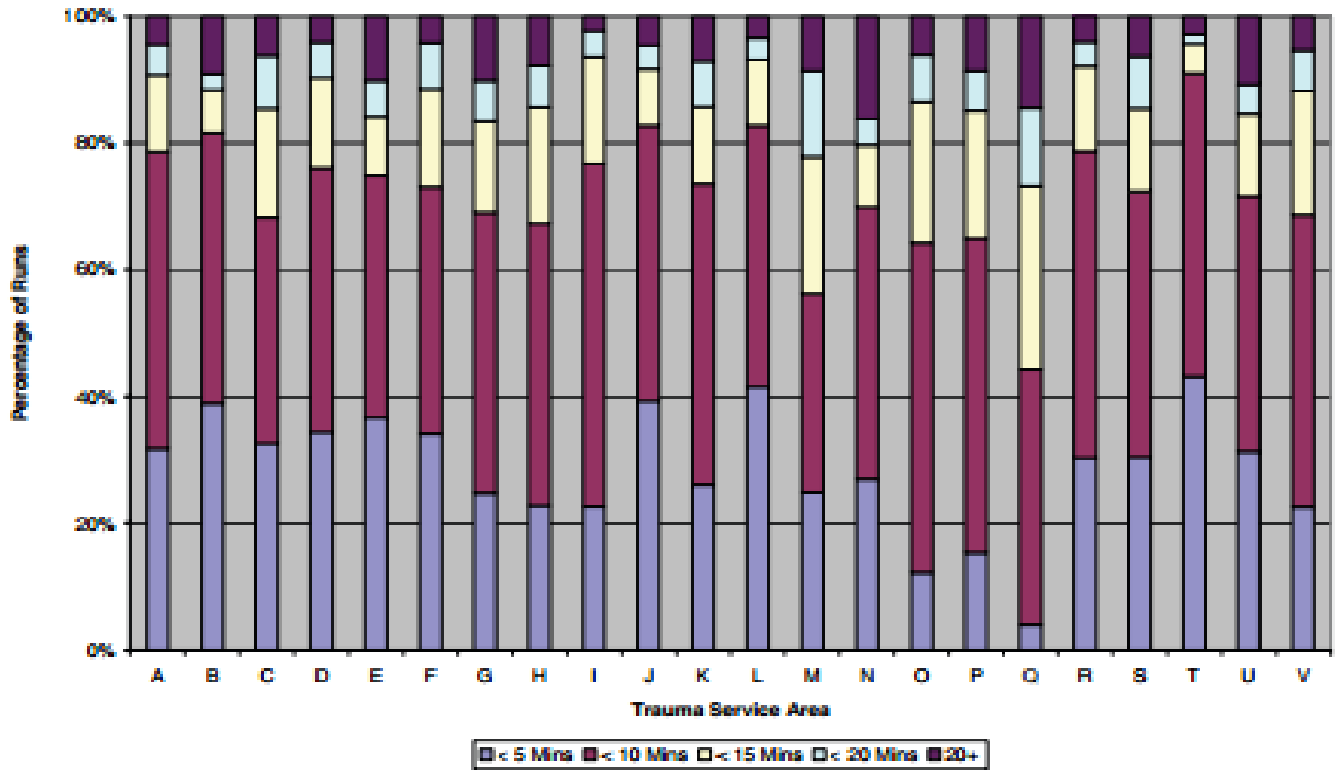


Figure 2015: Time Response of EMS Services in Texas segregated by service area

The figure 20 displays the response times of EMS services segregated by service area. There are areas throughout frontier Texas that have patient response times of up to 136 minutes (2 hours and 16 minutes) and hospital transport times of up to 132 minutes (2 hours and 12 minutes). Additionally, 157 of the 254 Texas counties currently have response times in excess of 10 minutes, while 151 counties have transport times greater than 20 minutes (Time Response Ambulatory Calls Evaluation [33]).

For metropolitan areas, the response times are moderate between 5-8 minutes, though for outlying areas it is between 15-30 minutes. Such a long response time, can be devastating for the patient.

2.7.3 Western United States Analysis

The Pacific Coast, most commonly known as the West Coast, includes many states on the Western side of America. The ideal West Coast is thought to be as the three states of Washington, Oregon, and California. The noncontiguous states such as Alaska and Hawaii do boarder the Pacific Coast, but do not fall under the category of West Coast. According to the U.S. Census group the three states of California, Oregon, and Washington form together as the Pacific region. The states of Nevada and Arizona are also considered as the west Coast because they are greatly influenced by the West Coast states, especially from California. These regions are fairly new due to the fact that the history of these regions was discovered after the East Coast.

Although there is no official, Federal or State standard for response times for ambulances in US, standards do exist amongst communities and EMS provider Organizations. However, these regulations are not based on a single standard and that is why standards vary quite frequently not only within states, but also amongst states. It is a General consensus that time-response for ambulances in emergency calls should be within 8 Minutes 90% of the time, although, that is easier said than done. These responses vary significantly during times of crises as cities find it difficult to meet all demands and regulations at the same time. The most pronounced problem, however, is that the data is highly unreliable. EMS service providers don't always record the times with accuracy. Moreover, the data that is publicly presented is even more skewed as sometimes only the data which shows efficient and favorable response-times is revealed. In an article in 'USA Today' (2005) Robert Davis says, "The best test of an emergency medical system is how many 'savable' victims of sudden cardiac arrest it actually saves. These

patients must be reached and shocked with a defibrillator within six minutes, or they almost always die” (USA Today). Figure 21 shows the part of USA which is defined as the West Coast.



Figure 2116: Representation of Western United States

In the article “The Price of Just a few Seconds Lost: People Die” (2005) Robert Davis points out that the majority of the nation’s largest cities save emergency 6-10 percent of emergency cardiac arrest cases, when around 20% or more could be saved. USA Today’s analysis shows that “Few cities know exactly how long their emergency crews take to reach cardiac arrest victims, and most are selective about how they portray their performance. Only nine of the 50 largest cities track their response times precisely enough to know how often emergency crews reach the victims of cardiac arrest within six minutes” and “Most other U.S. cities don’t know their response times, refuse to disclose them or use imprecise measures that are meaningless in determining whether emergency crews reach victims in time to save them. This situation persists even though research clearly has shown that precise measuring improves performance and saves lives. Houston, for example, went from a near-zero survival rate for

sudden cardiac arrest to 21% after it started to measure and fix problems that became clear (USA Today).”

Larger cities in the west coast have bigger problems and these are less susceptible to change. With that in mind, the survey provides evidence that these cities have the best Utilization of the call-to-shock measurement and the highest survival rates. Seattle has been outstandingly above average amongst the nation’s 50 biggest cities. Seattle has a 45% survival rate and on average they were able to reach the scene within 8 minutes and 46 seconds to perform the procedures for victims in cardiac arrest. In this time, the CPR takes about 90 seconds alone. Table 3 facts and figures of EMS performances in some major cities.

Cities with Precise Time Response Measurements and Survival Rates				
	Survival Rate	1 st Responders Response Time	Advanced Life Support Response Time	Time to Shock
Seattle	45%	87% within six minutes	86% within ten minutes	78% within nine minutes
San Francisco	22%	90% within 7 minutes 30 seconds	90% within 8 minutes	N/A
Tucson	12%	82% within 6 minutes	93% within 10 minutes	N/A
San Diego	N/A	90% within 8 minutes	90% within 12 minutes	N/A

Cities with Imprecise Time Response Measurements and Survival Rates				
	Survival Rate	1 st Responders Response Time	Advanced Life Support Response Time	Time to Shock
Portland	49% arrive at hospital with pulse	90% within 6 minutes 30 seconds	90% within 6 minutes 30 seconds	90% within 9.61 minutes
Colorado Springs	6.4% arrive at hospital with pulse	4.86 minutes on average	7.02 minutes on average	6.6 minutes on average
San Jose	5.5% arrives at hospital with pulse	Contract with fire department require responses within eight minutes	Contract requires ALS units to respond within twelve minutes	N/A
Los Angeles	Currently studying	62% within six minutes	91% within ten minutes	N/A

Table 3: EMS analysis of some cities in Western United States

However, survey shows that some of these cities have made the best utilization of the call-to-shock measurement and have the highest survival rates. “Seattle had a 45% survival rate, highest among the nation's 50 biggest cities. On average, Seattle's Emergency crews took 8 minutes 46 seconds to shock victims of sudden cardiac arrest.

2.8 Time Delays in EMS Communication

Through our research, interviews we conducted and our Advisor Prof. M.S. Fofana's work in systems delays, we were able to target the three possible time delays in the EMS system. The three kinds of delays are:

1. Communication Network Tolerance Time Delay (CNTTD)
2. System Drift Time Delay (SDTD)
3. Vulnerability Uncertainty Time Delay (VUTD)

The Communication Network Tolerance Delay is the time delay that system encounters when the flow of call is still in the 9-1-1 system before the call is forwarded to the first responder. There can be a large volume of calls at an instantaneous time. The different modes of call could be:

- Voice Over Mobile Phone (VOMP)
- Voice Over Land Phone (VOLP)
- Voice Over Radio Frequency (VORF)
- Voice of Haptic Mail (VOHM)

- Voice Over Internet Protocol (VOIP)

All these calls need to be organized before it is transmitted to the 9-1-1 call taker and then needs to go through a series of processes to make the call faster and easier. For this purpose Actuators, Sensors, and a decision making process (Hopf Decision Making Process) needs to be installed and implemented.

The next type of delay is the System Drift Time Delay which relates to the time delay when the call is being transferred from the First Responder to the Hospitals, Personal Clinics or Pharmacies. This could prove to be a very fatal delay as this would involve transferring the patient from the scene of emergency for treatment. The call needs to go through the actuators, sensors and the Hopf Decision Making process before being received by the Hospitals to make the process faster.

The third kind of time Delay is the Vulnerability Uncertainty Time Delay (VUTD) which could arise due to any unpredictable factor like signal failure, power cuts, equipment failure and wrong transfer of calls etc. There needs to be a contingency backup for such kind of failures to ensure the call cycle is complete without any compromise in time.

Our group will analyze each of these delays in detail and come up with solution supported by mathematical computations in the next chapter. Figure 22 is a block diagram that has been designed by our advisor to explain the stages of 9-1-1 call and how each section can be handled individually to reduce the time delays.

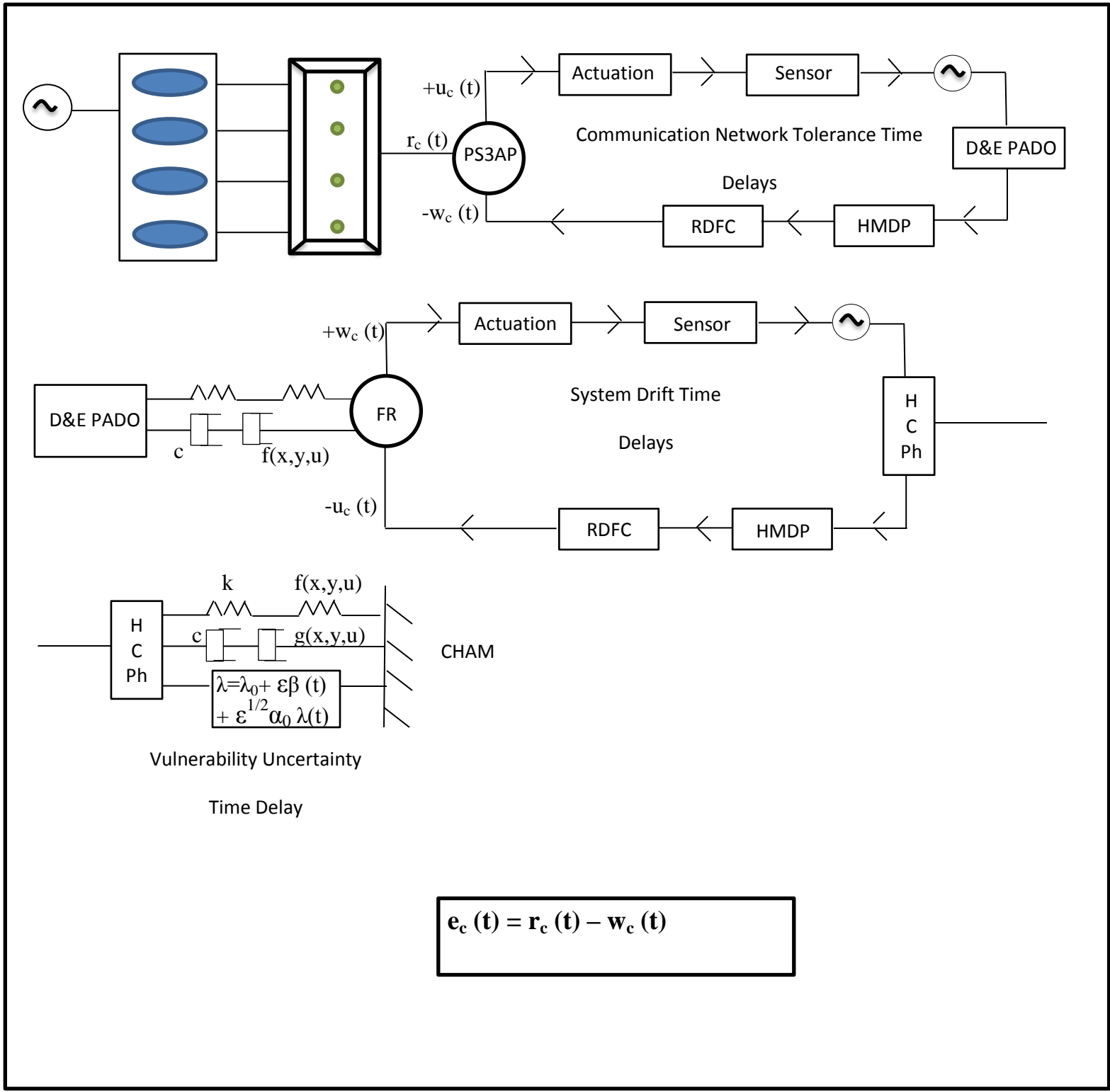


Figure 22: Close Loop Block Diagram showing the three system time delays

CHAPTER 3: RESULTS AND SOLUTIONS

3.1 Active Communication

From the research conducted regarding the response times around the United States, it has come to our attention that though the standard response times are less than ten minutes, in most response scenarios particularly the optimistic response times are usually between ten and fifteen minutes. The sample time response is show below (Times and Intervals Associated with Cardiac Arrest - UW Departments [40]).

- 1 Time interval from witnessed collapse to making 911 call- approximately 1 minute
- 2 Call received at 911 PSAP, and emergency medical dispatch at ambulance communications center is brought online- approximately 30 seconds
- 3 Inquiry (medical questions) by emergency medical dispatcher until appropriate ambulance units are selected and notified- approximately 30 seconds
- 4 Ambulance and first responders notified to first units on scene, assuming little or no traffic on roads (not rush hour), and good infrastructure- approximately 5 minutes and 30 seconds
- 5 First unit on scene to patient contact, assuming a single-storey residential structures, no obstructions and an open door- approximately 1 minute
- 6 Patient contact to CPR started or defibrillator shock given- approximately 1 minute

This sample scenario has an elapsed time response from the 911 call to first intervention of 8 minutes and thirty seconds, which is much more than the recommended 5-minute target set by

the 2007 Consortium of U.S. Metropolitan Municipalities' EMS Medical Directors (Times and Intervals Associated with Cardiac Arrest - UW Departments [40]).

To get this time interval to 5 minutes, the first crew would need to be on scene within two minutes of being notified (assuming all other time intervals are kept constant). This is nearly impossible to achieve at a reasonable cost. This is ignoring the 1 minute time delay from the witnessed collapse to the time the 911 call was placed (in effect changing the time response to 9 minutes and 30 seconds).

In this chapter, we will discuss various feasible options to improving the response times in EMS systems. A longer emergency response interval is much less expensive but can devastatingly harm patients with time-sensitive problems (heart attacks or strokes). A shorter emergency response interval is good for patients with such time-sensitive issues, but may cost the community more than what it is willing to pay for. In effect a perfect balance between the time-response and costs must be found so that what citizens expect from a customer service perspective and what they are willing to pay for (e.g. implementation of said technology), through user fees and taxes.

3.1.1 Mobile Hotspots

An onboard Mobile Gateway (oMG) provided communication platform that can provide a secure wireless Wide Area Network for a system of vehicle. It functions as a Multi-radio Mobile router and a Broadband Access Point (In Motion Technology -OnBoard Mobile Gateway [41]). The figure on the next page shows the onboard Gateway, and shows that the platform is portable, and relatively easy to setup.

Mobile Hotspots allow for operations that are paperless, wireless and highly efficient-reducing response times, lowering inventory and administrative costs. This is done by turning each ambulance into a mobile wireless hotspot, hence transmitting real-time patient information, vitals etc, and vehicle information to emergency rooms and ambulance dispatchers (In Motion Technology -OnBoard Mobile Gateway [41]). Figure 23 shows the onboard Mobile Gateway device installed.



Figure 173: An onboard Mobile Gateway

This gateway provides a connection between the ambulance and local hospitals so emergency rooms can prepare for incoming patients. Personnel in ambulances can instantaneously transmit patient information and vitals so authorized doctors can direct medics on how to initiate first-aid and prepare for surgery etc. if necessary. This data transmission, reduces what is known as the “curb-to-balloon-time”, as the data is sent en-route to the hospital, so there is little/ no waiting time, between when the patient arrives in the hospital, to when surgical procedures commence(In Motion Technology -OnBoard Mobile Gateway [41]).

3.1.2 Public Access to Communication and Communication System Integration

Although many people have access to EMS systems via 911 or E-911 systems, many counties have not implemented Position Location technology for cell phone users. The State Emergency Number Board is assisting local 9-1-1 centers with implementation of this capability. Additionally county 911 centers should centrally dispatch all emergency service agencies and should integrate entities such as police, fire and EMS. Such central dispatch will ensure proper interagency communication and interoperability. Even though the EMS Telecommunications Act of 1977 supports the creation of a Regional Communication Centers, (RCCs) that serves as communication hubs for regional EMS systems.

The following excerpt is taken from the Tennessee Trauma Care System Plan, June 2004(Tennessee Trauma Care System Plan [42]), and helps define the responsibilities and functions of regional EMS systems with regards to communications integration.

“A regional EMS system is a multi-county system comprised of all hospitals, ambulance services, dispatch centers and related entities that functions as an interactive emergency medical network coordinated through a RCC for the purposes of providing information and allocating/coordinating medical resources. An RCC is an entity with a regional mission and focus that coordinates hospitals, ambulance services and other medical resources, in real time, to optimize emergency patient care in situations where local governments and health care providers request assistance. The RCC’s will therefore coordinate all EMS and hospital resources that respond to any mass casualty events. Statewide implementation of the RCC system is essential for effective operation of the trauma care system in both routine and disaster operations.”

3.1.3. Ambulance Communication Centers

All Ambulance companies will need to provide Emergency Medical Dispatch on their 7-digit calls, and additionally be required to obtain and maintain accreditation by the International Academies for Emergency Dispatch (and optimally submit a timetable for reaching that goal). To maintain consistency, all Dispatch for all calls (911 and 7-digit) at various PSAPs and Ambulance Communication Centers should be using the same computerized software for dispatch- ProQA or AQUA. Furthermore, all PSAPs and ambulance communication center CAD systems should be time synchronized so that the variance does not exceed five seconds from Coordinated Universal Time (UTC), in order to maintain proper records of time response and use this information to ameliorate time responses.

3.1.4 Dispatch Time Interval Performance

Establish performance standards for dispatch time interval performance on 9-1-1 calls. The following are suggested starting points for discussion on such standards and are based on NFPA Standard #122118 and were obtained from an analysis conducted in 2005 (Paramedic Response Time: Does It Affect Patient Survival-July 2005[43]):

- a) 9-1-1 PSAP Initial Call Processing Interval should not exceed 45 seconds with at least 95% reliability (i.e., 9-1-1 first ring to call transfer to emergency medical dispatcher at ambulance dispatch center). This is based on NFPA Standard 1221, which states:
 - i) “NFPA 6.4.2 Ninety-five percent of alarms shall be answered within 15 seconds, and 99 percent of alarms shall be answered within 40 seconds”

ii) “NFPA 6.4.5 where alarms are transferred from the public safety answering point (PSAP), the transfer procedure shall not exceed 30 seconds for 95 percent of all alarms processed.”

b) For the process now in place, where EMD is provided at the ambulance communications center, the secondary call processing interval should not exceed 60 seconds with at least 95% reliability (i.e., emergency medical dispatcher call received to ambulance and fire unit notification).

3.1.5. Ambulance Territories

Ambulance territory lines, which are established by the respective municipalities and councils, should determine which ambulance service receives a 911 call that triages as an emergency response. If explicit territory lines are not specified, it can result in adverse consequences such as decreasing the economic efficiency, the quality of patient care and creating public safety risks.

When a 911 caller asks for an EMS response, they can ask for whatever ambulance service they want, completely ignoring ambulance territory lines and regardless if the call triages as an emergency or not (Paramedic Response Time: Does It Affect Patient Survival-July 2005[43]).

The PSAP will transfer the call to the specified ambulance service and that service can respond its own ambulance.

Unfortunately, most of the times, this transfer would result in a larger time response and any harm from the delay has already occurred. If that happened to be a call for an extremely time sensitive medical condition (e.g., cardiac arrest), the harm may be significant. Additionally, if the

ambulance service (which receives a call for a location outside its designated territory, it would send its own units as well as notifying other ambulance services/dispatch that covers the call location. Now as two ambulances are responding to the same call, the risk of emergency vehicle/wake effect crashes drastically increases. This unnecessary redundancy can lead to unfortunate consequences for the second unit responding to the same call results in a longer response interval to an overlapping call for a time-sensitive medical condition.

A solution for this redundancy would be as follows. On a call that triages for an emergency response, if a caller requests an ambulance service that is different than what their location designates, the caller should be informed their preferred ambulance service will be notified of the request by the PSAP. The designated ambulance service for that area will be given the call. It will then be up to the requested ambulance service to contact the caller to see if they would still like them to respond.

3.1.6 UHID (Universal Healthcare Identifier)

A UHID (Universal Healthcare Identifier) System (pilot project) has been successfully used with EMS Providers and hospitals in Orange County, Florida for many years. This identifier will allow the linking of time-data from many different sources of an EMS Call. It will allow for system performance to be measured for the time of collapse to the start of CPR etc even when it is made by a bystander to the arrival of EMS crews, in effect allowing for time data measurements and hence improvements.

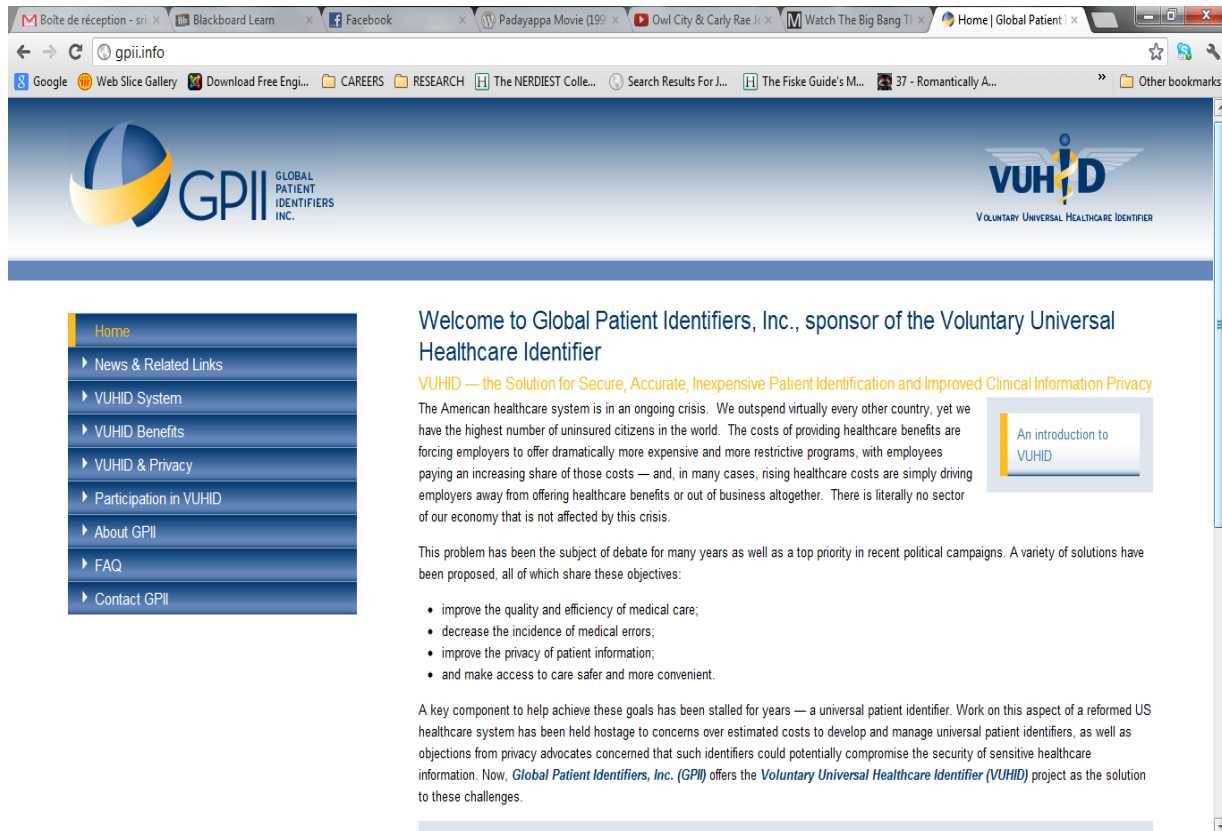


Figure 24: Global Patient Identifiers Inc. Website- The company that sponsored the Volunteer Universal Healthcare Index

Dr. Barry Hieb of Sunquest Inc (NCVHS Home Page - Sample Universal Healthcare Identifier [44]) proposed a sample UHID consisting of a sixteen digit sequential identifier, a period that serves as a delimiter, a six (6) digit check- digit and a six (6) digit encryption scheme.

Additionally Encrypted UHID's (EUHIDs) were included for hiding the individuals while linking information (NCVHS Home Page - Sample Universal Healthcare Identifier [44]). The UHID aims to organize patient information for medical record keeping. It can support both manual and automated record collection, and deal with the ease of storage and retrieval of these data. The UHID also can identify, organize and link information and records across multiple

episodes and sites of care and support an collection of Health information for Analysis-and group patients on regions, diseases, treatments, outcomes for research, planning and preventive measures.

The implementation of an UHID requires a Central Trusted Authority for processing the high volumes of requests for a UHID. It will also be responsible for issuing the sequential ID's (both for the UHID and the EUHID), computing check-digits, choosing the encryption series, and a proper decryption scheme. It comes to fact that to set up a nation-wide UHID system, a Central Trusted Authority would most definitely be needed. The Authority would need to include missing patient identifier fields such as the identification information, record locations, provider information. It would have to develop a technology infrastructure- the software application, communication systems and access levels and most importantly enact privacy and security legislation (NCVHS Home Page - Sample Universal Healthcare Identifier [44]).

Components of an UHID

- 1 Identifier. An unique 29-character ID format (16 digit sequential ID followed by a six digit check-digit and a six digit encryption scheme and a period delimiter) provides ample capacity
- 2 Identification Information- Contains a database for the patient's identifying data elements such as name, date of birth, sex, record addresses. In the current proposal the Sample UHIDs will be stored in a data base and linked with patient's identification information. However, this requires a Central trusted authority for administration, but does not indicate whether such a database/authority will be local, regional, or central.

- 3 Encryption Schemes- A six digit encryption scheme capable of generating multiple UHID's for a single patient. Additional Encrypted UHID's have been decided upon to protect vital customer information.

The UHID should be:

- Accessible: This is dependent upon the establishment of the trusted authority and the network infrastructure.
- Identifiable: This will depend on the identification information that the trusted authority links to the Sample UHID.
- Linkable: The Sample UHID has the ability to function as a data element and support the linkage of health records in both manual and automated environment. Additionally with the use of a database system, the UHID should be able to map current healthcare identifiers and is geared solely for the purpose of healthcare applications.
- Secure: UHIDs also include an Encrypted UHID, which secures operations through the use of encryption and decryption processes. The encryption scheme should hide the identity of the individual when linking information. However, public disclosure of a patient identifier without any risk to the privacy and confidentiality of patient information depends suggested access levels and legislations.
- Deployable: UHIDs are capable of implementation using technologies such as scanners and bar code readers.
- Centrally governed: The entire UHID database should be centrally governed and require separate administration. It should also be able to be operated on a wide area computer network.

- Robust- This system should be able to support patient identification for a foreseeable future, and be able to handle an incremental implementation- in bidirectional mapping between the pilot UHID program and existing patient identifier programs which can co-exist during a transitional phase.
- Cost-effective: UHIDs can support the functions of an unique patient identifier. However, it should be feasible enough, with the benefits of such a system outweighing the costs of technology and administrative infrastructure, development of the database system, communication networks, access levels and security measures.

Strengths:

- 1 A sample UHID is a pioneer system without any known limitations and fully takes advantages of existing technology. It is also projected to offer the capacity to handle the nation's population for the foreseeable future.
- 2 It avoids crossover problems from an existing system that cannot be corrected retrospectively.
- 3 The six-check digit scheme provides for a high level of accuracy. Additionally the encryption scheme maintains the confidentiality of patient information.

Weaknesses:

- 1 The length of the sample UHID makes is less user-friendly for manual entry as it is subject to human transcription and transposition errors.
- 2 A brand-new untested system may have unforeseen bottlenecks when implemented nationwide.

- 3 Lack of existing infrastructure and procedures. The UHID system requires the development of a plan for implementation for the trusted authority, organizational structures etc.
- 4 Costs- The planning, design, development and implementation will require substantial investments and a longer time frame than enhancing an existing identification system.

The drawbacks can be minimized by the establishment of implementations teams to work on the infrastructure of the Central Trusted Authority, development of policies and procedures, timeliness etc.

3.1.7. Emergency Vehicle Preemption (EVP)

The EVP System allows for the normal operation of traffic lights at an intersection to be preempted to assist in the movement of emergency vehicles- mainly by stopping on-coming/conflicting traffic and allowing the emergency vehicle right-of way in turn helping to reduce response (GTT: Building Critical Traffic Connections. Emergency Vehicle Preemption [45, 46, 47, 48, 49]).

There are four main methods this could be done:

- 1 Acoustic: Systems in this type override the traffic system when a specific pattern of wails from the siren of an emergency vehicle is picked up. It is fairly inexpensive to integrate into existing infrastructure as the ability to use siren-based equipment has already been incorporated into emergency vehicles (EMTRAC Systems [46]). Major disadvantages include the fact that sound waves can be reflected off buildings or other large vehicles causing a preemption event in the wrong direction, also, due to the Doppler

effects and due to acoustic sensors being very sensitive, the preemption may be activated in response to a siren that is still very far off (GTT: Building Critical Traffic Connections. Emergency Vehicle Preemption [45]). Figure 25 shows us the Intelligent Intersection explained in a block diagram.

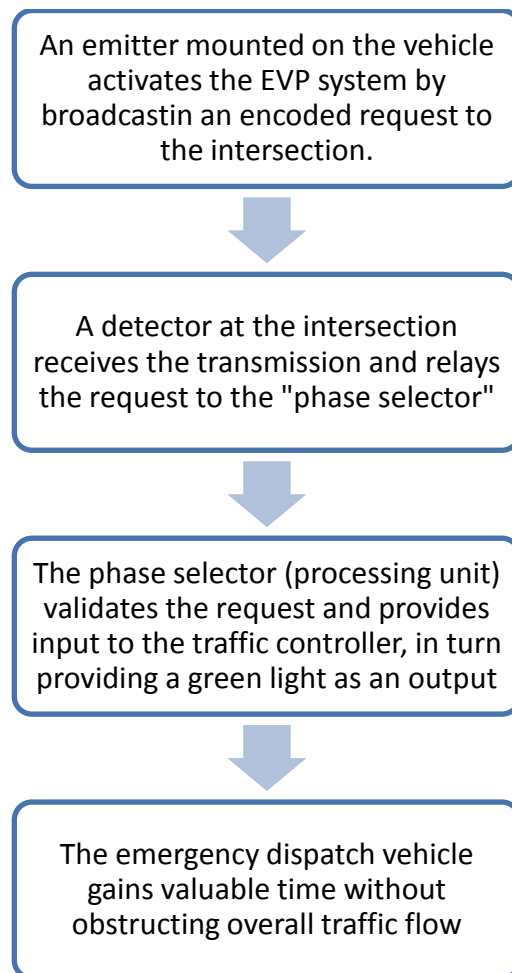


Figure 25: Intelligent Intersection Block Diagram

The siren activated EVP system utilizes the siren on an emergency vehicle to initiate a specializes signal timing to hold or bring up a green light at an intersection as quickly as possible. This would be made possible with microphones in advance of the intersection to

pick up the sound of the siren, additionally, an indicator lamp in the emergency vehicle provides feedback to the driver as to whether the controller has picked up the signal/call and is or isn't responding. Each digital siren detector has a reception range of approximately 1000-1200 feet (GTT: Building Critical Traffic Connections. Emergency Vehicle Preemption [45]).

This system consists of the following sub-parts:

- 1 SONEM 2000 Digital Siren Detectors.
- 2 SONEM 2000 Controller Unit.
- 3 SONEM 2000 System Software and manual.
- 4 Confirmatory Lights (Flood Lamp Type).
- 5 EVP Detector Cable (2/c #14).

The first siren activated Emergency Vehicle Preemption was tested by Mn/DOT in Bemidji during the fall of 1997. The preliminary tests showed that the system was feasible and user-satisfactory. In 1999, Mn/DOT issued a memorandum which defined how EVPs could operate in Minnesota, frequency for optical emitters, use of indicator lights, and appropriate operation with various intersection phasing (Manual on Uniform Traffic Control Devices (MUTCD) 2003 Edition Revision 1 Chapter 4F [48]).

However in 2001, a field evaluation conducted by the Office of Traffic Engineering and ITS to examine the performance of the siren activated system (in Bemidji, Fosston and Bagely) for a nationwide implementation showed a wide variation in activation distance and some cases of in operation caused by faulty implementation, inadequate testing , siren performances and mounting (GTT: Building Critical Traffic Connections. Emergency Vehicle Preemption [48,49]).

2 Line-of-sight: Such emergency vehicles utilize an emitter which sends a narrowly-directed signal of invisible infra-red light or visible strobe light towards traffic lights to obtain preemption. The emitter transmits the signal in pulses at a specific frequency (10Hz for a low-priority signal or 14Hz for a high-priority signal), which is picked up by a compatible traffic signal preemption receiver. Once the vehicle with the active line-of-sight emitter has passed the intersection, the receiver no longer senses this overriding signal and allows normal traffic operations to continue. The disadvantages of such a system are that it is dependent on lighting and atmospheric conditions (e.g. direct sunlight into an emitter, or heavy rain or snow), which may cause undesired activation or reduce the reception range. Additionally, this system will not work on curved roads or in the cases where a larger vehicle in the front of an emergency vehicle blocks the signal (GTT: Building Critical Traffic Connections. Emergency Vehicle Preemption [45]). The following figure 26 shows the line-of-sight traffic signal preemption receiver mounted on horizontal pole near the intersection traffic lights.



Figure 186: Traffic Preemption Device

3 Global Positioning System: Requires specialized software and a communications platform to determine the velocity and displacement vectors of the activating vehicle,

which traffic lights need to be preempted and the ability for central command to promptly activate the desired traffic lights. In densely populated cities, it would be hard to obtain the four required GPS satellite signals for location triangulation. This system also has a single-point of failure, (if redundant hardware is not installed) if the primary system controller is offline, all traffic preemption functions within the entire traffic network covered by GPS fails (GTT: Building Critical Traffic Connections. Emergency Vehicle Preemption [45]). The hardware used in the GPS based, Emergency Vehicle Preemption system is shown in the figure 27.



Figure 197: Advanced GPS Systems

- 4 Localized Radio Signals: Uses a short-range radio signal of 900MHz bandwidth and uses a directional signal transmitted from an emitter (but is not blocked by visual obstructions, lighting or atmospheric conditions). This has adjustable range (by varying the signal strengths) and collision avoidance between emergency vehicles due to the Doppler Interactions of conflicting preemption radio signals.

Currently Optical/Sound-based EVP systems can be installed on traffic signals when requested by local government agencies. These agencies are responsible for all initial costs such as the purchase and installation of the EVP system. ADOT (an organization which maintains traffic signals) remains responsible for the maintenance of the EVP systems in the controller cabinets and the detectors attached to the traffic signal masts.

Some additional operational features/needs for Emergency Vehicle Preemption users may include (GTT: Building Critical Traffic Connections. Emergency Vehicle Preemption [48,49]):

- 1 Emergency vehicle routes and directions. This information will be useful in relaying to Central Command which emergency vehicles are approaching the intersection in need for preemptive action.
- 2 Anticipated speed of emergency vehicles. This information will be very useful in determining the activation distance required based on the velocities of the emergency vehicle. In effect, this will eliminate the disadvantage of acoustic emitters and sensitive detectors which would sometimes be activated even when the emergency vehicle is far off.
- 3 Detailed logs and reports can be used for continuous improvement of the EVP system as they show signal and vehicle activities.
- 4 Preemption-request points can be based on time-of-day to account for peak-period rush hours.

- 5 Requests can be sent to multiple intersections simultaneously to clear gridlock from subsequent intersections and side roads
- 6 Signals used uses AES encryption for maximized security.

Benefits of EVP systems

- 1 Priority control requests can be tailor-made to allow different responses to different emergency vehicles.
- 2 Using the EMTRAC system software, precise control of priority-detection approach areas allows for individualized customization of specific zones in cities
- 3 System has a communication range of around 3,600ft without the use of range-extending equipment.
- 4 Completely automated system, which requires no driver interaction to operate.

3.1.8. Electronic Patient Care Reporting

Currently most ambulances use a tablet-based electronic medical record system to document patient care out in the field. EMS data from these computers are faxed to the Emergency departments of receiving hospitals. In order for the hospital to have electronic records, the hard copy of the EMS report has to be scanned back to obtain a digital format. This is naturally very cumbersome and time consuming, and would hinder feedback from the hospital to the EMS (and pre-hospital care). An automated software system should be used that can allow EMS tablets to electronically transfer data to the hospital records (a field-by-field data transfer such that the

information can be manipulated) (McCann, Connor, Hansen and Olivarez - EMS Communications IQP (2011) [51, 52]). Figure 28 shows an ePCR being used by an EMS personnel.



Figure 2820: Electronic Patient Care Reporting Device

The Field-Based ePCR (electronic Patient Care Reporting) is a pre-hospital patient-care data collection and reporting solution. It allows medical personnel to quickly generate real-time reports in a mobile environment using a tablet or rugged-notebook, as shown in the above figure. The ePCR system in the above image uses a touch screen tablet interface.

The ePCR software has an easy, visual interactive interface, allows for rapid-entry pen or touch screen entry options, and supports GPS and wireless connectivity. The software contains

automated data validation to ensure completeness of records, and also has many data entry shortcuts. In addition, it can capture electronic signatures in the field for verification and personnel can also generate automated narratives particularly for a length incident involving the patient's care (McCann, Connor, Hansen and Olivarez - EMS Communications IQP (2011) [52]).

Some of the other features available in various ePCR software include (McCann, Connor, Hansen and Olivarez - EMS Communications IQP (2011) [51, 52]):

- Runs on PCs, Tablets, Macs, iPad, and almost on all OS
- Manage Crew information of each Unit
- Impression data
- Cardiac data,
- Assessment and injury data per body region
- Patient care data including medications, procedures, doses, routes, locations, attempts, vitals, and more
- Transport and transfer of care data to hospital and insurance company
- Capture data for supplies & medicine used during transiting patient
- Patient and call narrative
- Insurance payment authorization and signatures
- Refusal of service information and signatures
- To the point and eye catching Reports.

3.2 9-1-1 Medical Library

PIDAC (Patient Information DATA Assimilation Library) is a database which helps the user retrieve information of every patient who has ever visited a hospital in a certain area. It helps keep record of all the patients. 9-1-1 already uses some kind of database for this purpose but we decided to design our own database which can be better than any database 9-1-1 is using right now.

Only authorized personals will have access to this database. Each personal will have their own authorization number to access the main information of patients. That helps us make sure the information stored in the database is safe and is not being used for any illegal purposes in a wrong manner.

This database is created using PYTHON programming language version 2.7.3. PIDAC is originally our own database. Figure 29 displays the logo for the PYTHON programming language.

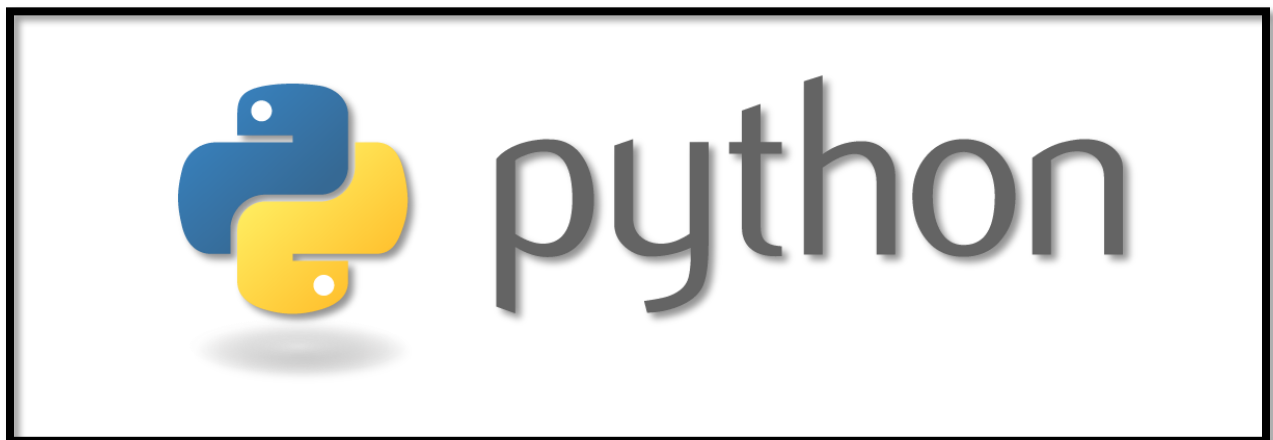


Figure 2921: Python Programming Language

3.2.1 PIDAC

Python programming language is used to design this database. PIDAC is divided into three different parts. Following are the three parts of our Interactive Qualifying Project:

- Patient Data Information (PDI)
- Health Insurance Information (HIA)
- Periodic Health Information (PHI)
- Fourth Part

Each of the parts above has their own distinctive features. Similarly their respective code is divided into three different parts as well.

3.2.1.1 Python code for PIDAC

As described above the program has three parts to it. However there is a fourth part as well, which is the backbone of the database is. This fourth part doesn't have a name associated to it. It is the global part of the code which includes lists of patients and their information. This is the information which we are using in the database records.

3.2.2 Patient Data Information (PDI)

The first part of the program deals is the most important part. The user has to use the function

iqp() in the SHELL window of python to run the program.

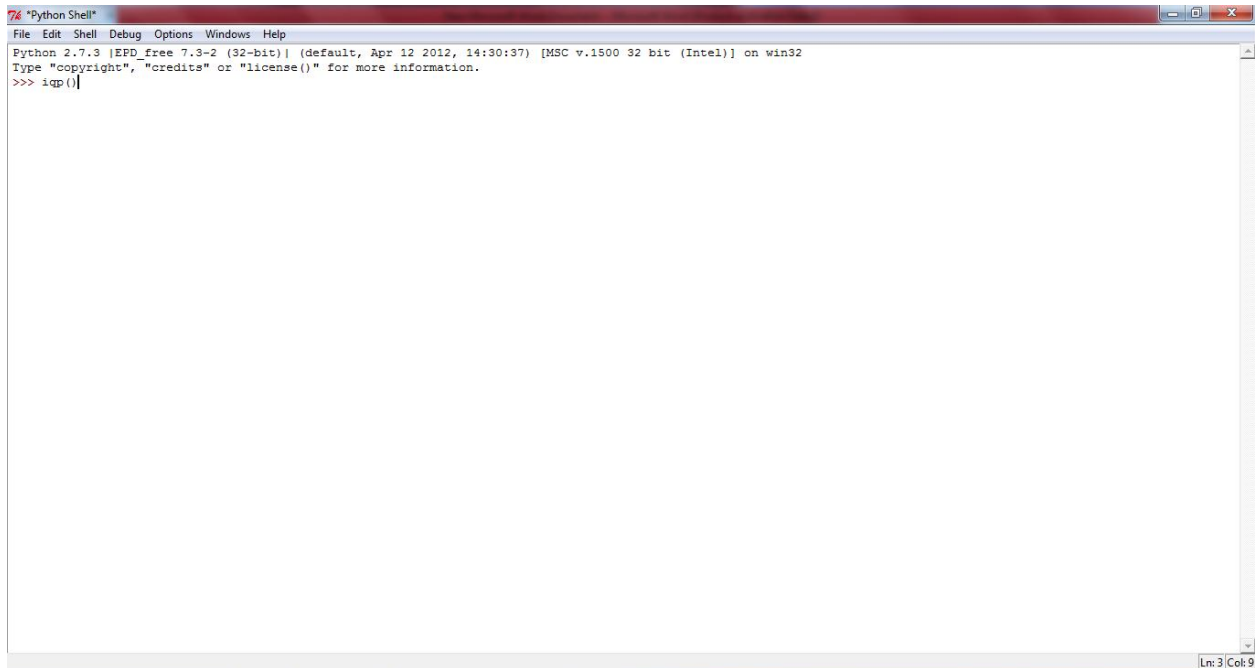


Figure 30: Python SHELL Window

Figure 30 shows the terminal window of python where instructions are entered for program to begin.

After calling the function the program displays the date of the day and a welcome message. All the patients in the system are given a specific Identification number as their programming identity. This ID number help the program retrieve information relating that patient. The program prompts the user to enter the ID number a patient. The user will always be an authorized 9-1-1 personal or an authorized medical personal. This ID number is used throughout the whole program until the user has extracted all the information relating the patient.

In case of our program we used WPI student ID numbers as dummy Identification numbers for the patients.

The code for this main part of the experiment is shown below.

```
def iqp():

    count = 1 # This counter keeps track of valid and invalid patient ID numbers
    print ("02-11-2013")
    print ("Welcome to the PIDAC")
    print ("Patient Information DATA Assimilation Library")
    print ("\n")

    while True:
        x = raw_input("Enter Patient ID: ") #Asks user to enter the patient ID number
        print ("\n")
        print ("PDI (Patient Data Information)") #Opens up PDI from global list enrollment
        print ("\n")
        for e in enrollment:
            count = 1
            if x == e[30:39]: #If ID number matches the ID number of the patient it prints all the
following statements
                print ("Name of the patient: " + str(e[9:28]))
                print ("Sex: " + str(e[64:70]))
                print ("DOB: " + str(e[86:96]))
                print ("Marital Status: " + str(e[119:127]))
                print ("Weight: " + str(e[76:80]) + "lbs")
                print ("City: " + str(e[99:110]))
                print ("State: " + str(e[111:113]))
                print ("College: " + str(e[4:8]))
                print ("Degree: " + str(e[0:2]))
                print ("\n")
                print ("Contact Information: ")
                print ("Email address: " + str(e[40:60]))
                print ("Cell phone #: " + str(e[131:143]))

            iqp1(x) #calls another function to pull out the HIA of patients
            print ("\n")
            abc = raw_input("Do you want to extract information of another patient?: ")
            if abc == 'Y' or abc == 'y':
                count = 0
```

```

else:
    print ("Thank you for using PIDAC")
    abd = raw_input("Do you want to log off? : ")
    if abd == 'Y' or abd == 'y':
        quit()
    count = 0 #sets count = 0
    break
if count == 1: #This was the counter used initially, program loads this command if user
enters invalid ID number
    print ("Invalid ID no.\n")
    count = 0

```

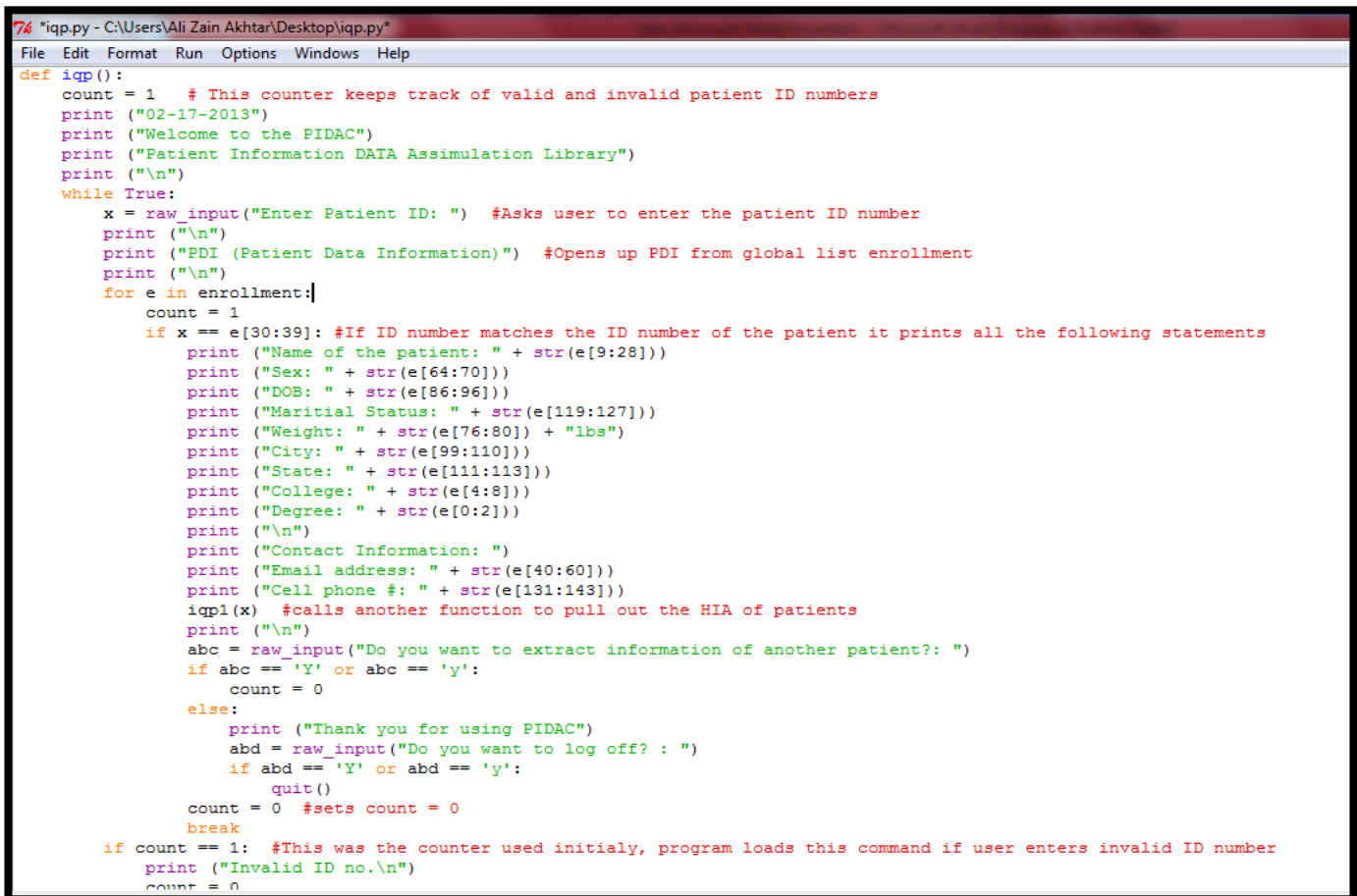
Since PDI is the first part of the program it displays a message telling the user he has entered the Patient Data Information part of the program. The program then enters a **For** loop which goes through a global list in the program named **Enrolment**. This part of the code provides the user with all the basic information of a patient. This information is divided further into two parts. The two parts are:

- Basic Information
- Contact Information

Basic Information provides the user with information regarding Name of the patient, date of birth of the patient, sex, marital status, weight and height of the patients. Inches and Pounds are the parameters used to describe the height and weight of the patient respectively. This part of the database also displays the City and the State the patient is from. It also displays the College the patient went to and the highest degree of education earned from that college or university.

The second provides the user with the basic contact information of the patient. This includes the cell phone number of the patient and his or her email address.

Following figure 31 displays the how the Python code for the first part of the experiment appears in the Python window



```
iqp.py - C:\Users\Ali Zain Akhtar\Desktop\iqp.py
File Edit Format Run Options Windows Help
def iqp():
    count = 1 # This counter keeps track of valid and invalid patient ID numbers
    print ("02-17-2013")
    print ("Welcome to the PIDAC")
    print ("Patient Information DATA Assimilation Library")
    print ("\n")
    while True:
        x = raw_input("Enter Patient ID: ") #Asks user to enter the patient ID number
        print ("\n")
        print ("PDI (Patient Data Information)") #Opens up PDI from global list enrollment
        print ("\n")
        for e in enrollment:
            count = 1
            if x == e[30:39]: #If ID number matches the ID number of the patient it prints all the following statements
                print ("Name of the patient: " + str(e[9:28]))
                print ("Sex: " + str(e[64:70]))
                print ("DOB: " + str(e[86:96]))
                print ("Marital Status: " + str(e[119:127]))
                print ("Weight: " + str(e[76:80]) + "lbs")
                print ("City: " + str(e[99:110]))
                print ("State: " + str(e[111:113]))
                print ("College: " + str(e[4:8]))
                print ("Degree: " + str(e[0:2]))
                print ("\n")
                print ("Contact Information: ")
                print ("Email address: " + str(e[40:60]))
                print ("Cell phone #: " + str(e[131:143]))
                iqp1(x) #calls another function to pull out the HIA of patients
                print ("\n")
                abc = raw_input("Do you want to extract information of another patient?: ")
                if abc == 'Y' or abc == 'y':
                    count = 0
                else:
                    print ("Thank you for using PIDAC")
                    abd = raw_input("Do you want to log off? : ")
                    if abd == 'Y' or abd == 'y':
                        quit()
                count = 0 #sets count = 0
                break
        if count == 1: #This was the counter used initially, program loads this command if user enters invalid ID number
            print ("Invalid ID no.\n")
            count = 0
```

Figure 221: Python Code for Database

After the basic contact information the program prompts the user to another part of the database name **iqp1** in this case. The part of the code after calling the function is still part of this first part but it deals with closing the database or repeating the whole process. This part of the database will be described at the end. Figure 32 displays the image obtained on the python shell when the user runs the program for a patient with WPI ID number 160021326.

```
*Python Shell*
File Edit Shell Debug Options Windows Help
Python 2.7.3 [EPD_free 7.3-2 (32-bit)] (default, Apr 12 2012, 14:30:37) [MSC v.1
500 32 bit (Intel)] on win32
Type "copyright", "credits" or "license()" for more information.
>>> ===== RESTART =====
>>>
>>> iqp()
02-11-2013
Welcome to the PIDAC
Patient Information DATA Assimilation Library

Enter Patient ID: 160021326

PDI (Patient Data Information)

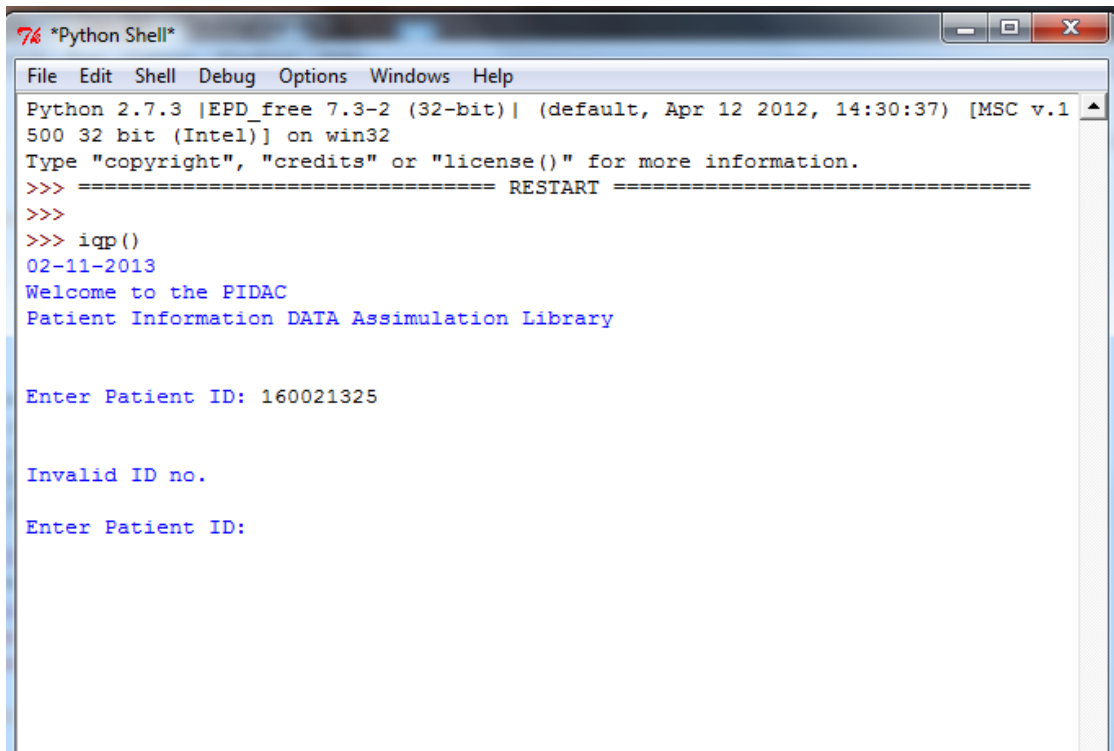
Name of the patient: Akhtar, Ali
Sex: MALE
DOB: 10/28/92
Marital Status: Single
Weight: 198 lbs
City: Worcester
State: MA
College: WPI
Degree: BS

Contact Information:
Email address: azakhtar@wpi.edu
Cell phone #: 774-232-785

Do you want patient's health insurance information [Y/N]: |
Ln: 33 Col: 58
```

Figure32: Display screen after entering patient details

If the user enters an invalid ID number the program tells the user it is an Invalid ID number and prompts the user to enter a patient ID number again. Following figure 33 shows this feature of the program.



```
*Python Shell*
File Edit Shell Debug Options Windows Help
Python 2.7.3 |EPD_free 7.3-2 (32-bit)| (default, Apr 12 2012, 14:30:37) [MSC v.1
500 32 bit (Intel)] on win32
Type "copyright", "credits" or "license()" for more information.
>>> ===== RESTART =====
>>>
>>> iqp()
02-11-2013
Welcome to the PIDAC
Patient Information DATA Assimilation Library

Enter Patient ID: 160021325

Invalid ID no.

Enter Patient ID:
```

Figure 33: Invalid Patient Number popup

3.2.3 Health Insurance Information (HIA)

This part of the database lets the user learn about the medical insurance records of the patient. As we can see from the figure above, the cursor is at the position where the program is asking the user if he or she wants to retrieve information relating patient's health insurance. If the user enters 'Y', the program send the user to the second part of the database by calling the function **iqp1()**.

Following is the code for the second part of the database.

```
def iqp1(n):
    print ("\n")
    y = raw_input("Do you want patient's health insurance information [Y/N]: ")
    print ("\n")
```



```

print ("-----")
print ("HIA (Health Insurance Administration)")
if y == 'Y' or y == 'y':
    for idx in health:
        if n == ((idx[0:9])):
            print ("\n")
            print ("Insurance Company: " + str(idx[11:29]))
            print ("Policy #: " + str(idx[31:39]))
            print ("Is patient's medical expenses covered by Insurance? " + str(idx[40:44]))
            iqp2(n) #calls another function for PHI information of a patient
else:
    return

```

This part of the program first makes sure if the patient entered ‘Y’ as an answer to the previously asked question. If that is the case, the database displays patient’s medical insurance information. It tells the user about the name of the company from which the patient bought his health insurance. It shows the policy number of the insurance and whether or not the patient’s medical expenses are covered by the health insurance. Iqp(2) is a command in this part of the program which call another function and lets the user enter the third and final part of the database. Following figures 34-35 show the python code and display results in the Python shell for this part of the code respectively.

```
*iqp.py - C:\Users\Ali Zain Akhtar\Desktop\iqp.py*
File Edit Format Run Options Windows Help

def iqp1(n):

    print ("\n")
    y = raw_input("Do you want patient's health insurance information [Y/N]: ")
    print ("\n")
    print ("-----")
    print ("HIA (Health Insurance Administration)")
    if y == 'Y' or y == 'y':
        for idx in health:
            if n == ((idx[0:9])):
                print ("\n")
                print ("Insurance Company: " + str(idx[11:29]))
                print ("Policy #: " + str(idx[31:39]))
                print ("Is patient's medical expenses covered by Insurance? " + str(idx[40:44]))
                iqp2(n) #calls another function for PHI information of a patient
    else:
        return
```

Figure 234: Python code for Health Insurance Information

```
*Python Shell*
File Edit Shell Debug Options Windows Help
02-11-2013
Welcome to the PIDAC
Patient Information DATA Assimilation Library

Enter Patient ID: 160021326

PDI (Patient Data Information)

Name of the patient: Akhtar, Ali
Sex: MALE
DOB: 10/28/92
Marital Status: Single
Weight: 198 lbs
City: Worcester
State: MA
College: WPI
Degree: BS

Contact Information:
Email address: azakhtar@wpi.edu
Cell phone #: 774-232-785

Do you want patient's health insurance information [Y/N]: y

-----
HIA (Health Insurance Administration)

Insurance Company: Harvard Pilgrim
Policy #: 99-23543
Is patient's medical expenses covered by Insurance? Yes

Do you want patient's medical history? [Y/N]:
```

Figure 245: Python SHELL display for HIA

3.2.4 Periodic Health Information (PHI)

Periodic Health Information or PHI is the third and last part of the database. As we can see from the figure above, the cursor is at the position where the program is asking the user if he or she wants to retrieve information relating patient's medical history. If the user enters 'Y', the program sends the user to the third part of the database by calling the function **iqp2()**. Before entering into the core part of the function, the program asks the user to enter a valid authorization number. This is because medical history of patients is confidential information and only authorized persons have access to it. So to make our database more secure we entered this security question which asks the user to enter their valid authorization number. All the persons who will be allowed to access this information will have a authorization number for themselves. In case of our database, it is the zip code of the city. If the user enters a valid authorization number, the database displays the medical records of the user. If the user enters an invalid authorization number, the database prints out a prompt message saying:

“Invalid authorization number”

“You have 2 more chances”

If the user continues to enter an invalid authorization number for 3 consecutive times, the program closes and automatically logs the user out of the program for security purposes. The code used for this purpose is shown below:

```
def iqp2(m):
    print ("\n")

    ask = raw_input("Do you want patient's medical history? [Y/N]: ")
    print ("\n")
    counter = 1 #counter used to check whether the authorization ID f user is valid or not
```

```

print ("-----")

print ("PHI (Periodic Health Information)")
print ("\n")

if ask[0] in 'yY':
    count = 3 #counter used to calculate no. of terms a user can enter their counter number
    for idn in range(3):
        if counter == 1:
            authorization = raw_input("Please enter a valid ID number for your authorization: ")
            if authorization == '01609':
                print ("\n")
                for line in history:
                    if m == line[120:129]:
                        print ("Date      Incident      Location      Doctor      Evaluation
Hospital")
                        print (str(line[0:9]) + " " + str(line[10:27]) + " " + str(line[30:45]) + " " +
str(line[49:64])
                            + " " + str(line[68:85]) + " " + str(line[89:118]))
                        counter = 0
            else:
                count = count - 1
                print ("\n")
                print ("Invalid Authorization No.")
                print ("You have " + str(count) + " more attempts left")
                print ("\n")
                if count == 0:
                    print ("You have been blocked from this program for next 30 minutes")
                    quit()
        else:

            return

```

The second “if else” statement in the code above deals with the security of the database.

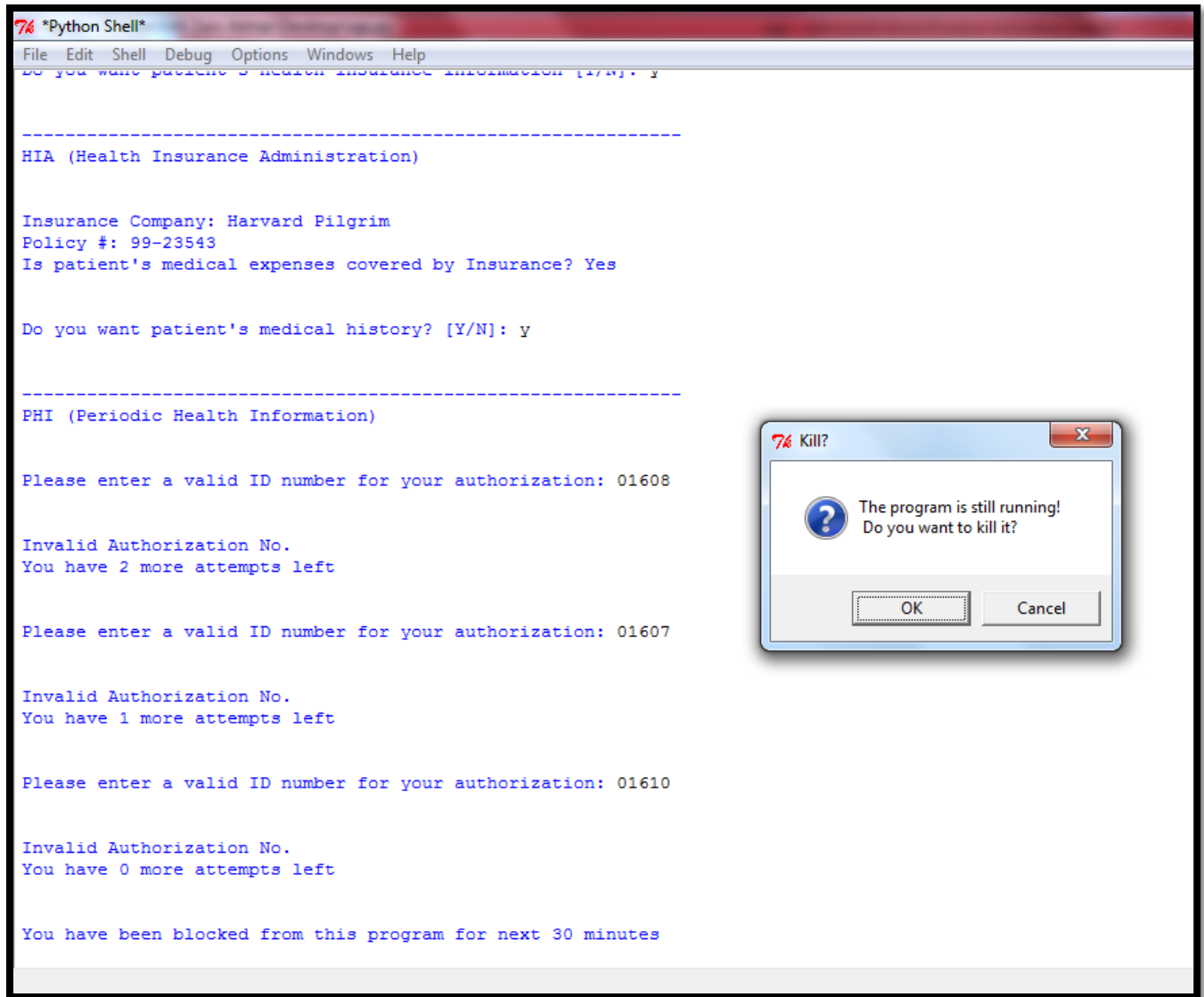


Figure 36: Program kill option after unsuccessful login

The figure 36 also displays a new small window. The user has to press 'OK' on this window and it causes the database to close and the user automatically gets logged of because of several invalid attempts for the authorization number.

If the user is an authorized personal and enters a valid authorization number, the database displays the whole medical history of the patient. The same code from above is used to obtain this data. Following figure 37 shows the output result on python SHELL window.

```
*Python Shell*
File Edit Shell Debug Options Windows Help
---
DOB: 10/28/92
Marital Status: Single
Weight: 198 lbs
City: Worcester
State: MA
College: WPI
Degree: BS

Contact Information:
Email address: azakhtar@wpi.edu
Cell phone #: 774-232-785

Do you want patient's health insurance information [Y/N]: y

-----
HIA (Health Insurance Administration)

Insurance Company: Harvard Pilgrim
Policy #: 99-23543
Is patient's medical expenses covered by Insurance? Yes

Do you want patient's medical history? [Y/N]: y

-----
PHI (Periodic Health Information)

Please enter a valid ID number for your authorization: 01609

Date          Incident          Location          Doctor          Evaluation          Hospital
05/18/09      Car Accident      Cambridge,MA      Dr. M Fofana    Broken Ribs         Tufts Medical Hospital

Do you want to extract information of another patient?: |
```

Figure 37: Complete display of patient information

3.2.5 Extracting Information of another user

As seen from the figure displayed above, when the database is done showing results for a specific patient, it asks the user if he or she wants information of another patient. If the user enters 'N' or 'n', the database asks the user another question if he or she wants to log off. If the user enters 'Y', the database closes.

If the user enters 'Y' as an answer to the first question, the database goes through the whole three stages again. It keeps going through all the stages until the user themselves log off. Following is the code for this specific part of the program which is in our main function **iqp()**:

```
print ("\n")
abc = raw_input("Do you want to extract information of another patient?: ")
if abc == 'Y' or abc == 'y':
    count = 0
else:
    print ("Thank you for using PIDAC")
    abd = raw_input("Do you want to log off? : ")
    if abd == 'Y' or abd == 'y':
        quit()
count = 0 #sets count = 0
break
```

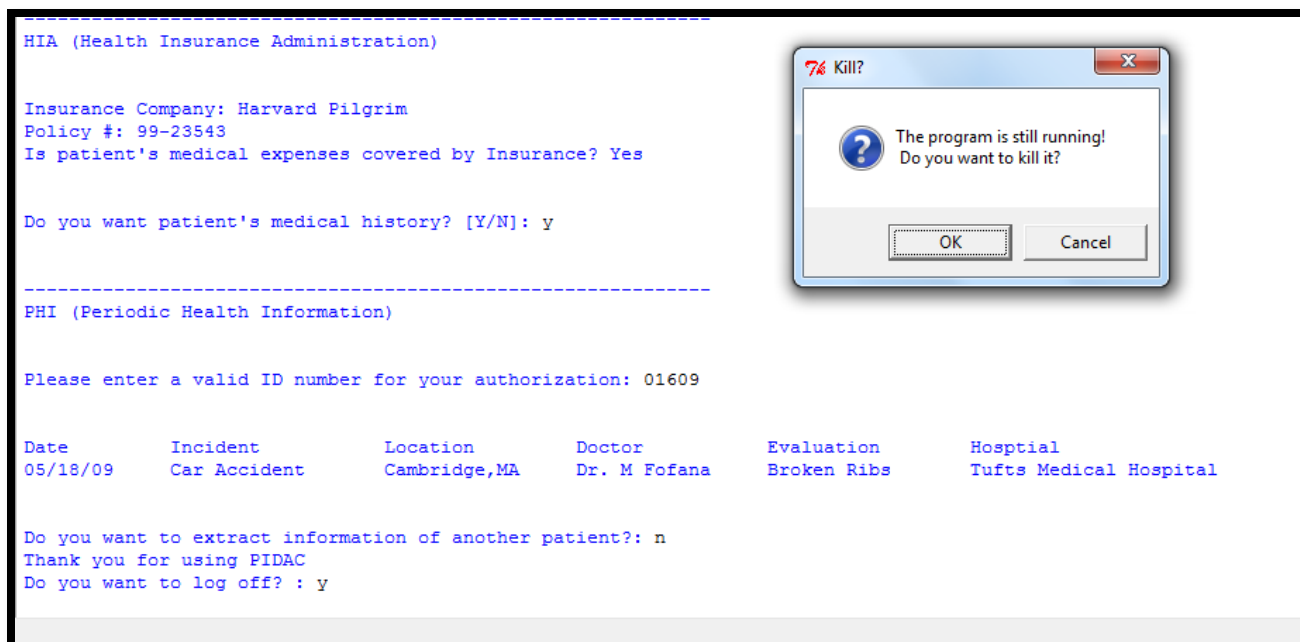


Figure 38: New Patient Login Command

Figure 38 shows the terminal window that appears when the programs is tried to kill in between.

3.3 WIRELESS COMMUNICATION

Wireless communication is an essential part of EMS communication. This section provides an overview of basic signal processing and wireless communication.

3.3.1 Introduction

Our goal is to find a way to improve communication between EMTs and drivers and the hospital. There are a few methods of communication and requirements already out there, including medical telemetry, full-duplex radio operation, and vehicular repeater systems operating in conjunction with mobile relay stations. A full Duplex Wireless Walkie Talkie is shown in figure 42. In the future, more advanced systems may be implemented such as trunked system operations, picture and video transmissions, computer and data interface, computer report generating systems, satellite and geo-positioning interface, and access to multiple public and private wireless communications systems and paging systems (The National Association of State Emergency Medical Services Directors, 1995[55]). These systems cannot be implemented everywhere. Each area has to consider compatibility factors that will provide the most effective EMS communication system. Different communication systems have to work together and personnel in each EMS communicating agency must realize that their system is part of a bigger system that is interrelated with other systems and operations around it. For complete success and cooperation, local areas should have a larger-scale plan so they are aware of their surrounding teams. Usually, interference and miscommunication between systems is what leads to delay in attending victims or even a loss of life. In the past, EMS providers had to come up with their own plans and communicate with each other since there was no large-scale guidance. The lack of

an approach, especially in medical emergencies, leads to confusion and disorganization and can result in serious repercussions due to delay of even a few seconds. Time is a critical factor.

The communication between an ambulance and a hospital and between EMTs is often mistaken as a simple two-way radio system, when there is actually a lot more to it. EMS communication is the exchange of all the information necessary to attend to the medical situation. It starts with the occurrence of a medical emergency and includes different phases including detection, reporting, response, medical direction, and coordination with other departments (The National Association of State Emergency Medical Services Directors, 1995[55]). The communication is required all throughout the treatment of the patient at the scene and during transportation to the hospital. The EMS must be coordinated with other public safety services, including the fire department and law enforcement. Once the incident is completely resolved, only then can the process be completely stopped. EMS communication has to be capable of responding to a wide variety of needs immediately and effectively. Figure 39 shows the IC-V85 walkie talkie which is a fully duplex wireless device.



Figure 39: Full Duplex Wireless Walkie Talkie

It is important to identify the roles of different people within the communication loop. The EMS communication planners should only focus on the “who, when where, why, and what” part of the situation. Only the technical wizards will concentrate on the “how” part. The planners will consider who needs to communicate, where they will be located when they communicate, what equipment will be used, etc. But they should not be overwhelmed by the details of “how” they will communicate.

For effective EMS communications, there are a few main categories that must be fulfilled. Public access to the EMS system, dispatch and coordination of the vehicles, people, and equipment, information exchange between personnel and hospital including the use of EKG telemetry when required, interagency communication and lastly, the education of communication users. Dispatchers and personnel are required to complete a certification and need to be educated with equipment use and terminology. Even citizens need to be educated so they know when and how to call, whom to call, and what to expect in a medical emergency situation. If this outline is followed, an effective method can be implemented on a daily basis.

The sequence of the EMS communications is as follows: it starts from the scene where the emergency occurs. The victim(s) need immediate help and the people involved should know to call 9-1-1. Once the dispatcher is informed, they contact necessary teams and direct them to the scene. While help is on the way, the dispatcher may provide “pre-arrival instructions” to ease the pain of the victim(s). Once the medical team has arrived at the scene, they will need to communicate with the hospital and provide continuous patient condition status. Before departing the scene with the patient, the medical team must update the hospital with the status and the estimated time of arrival (The National Association of State Emergency Medical Services Directors, 1995[55]). The communication continues during the transportation so the hospital is

updated. Depending on the seriousness of the patient's condition, sometimes the ambulance has to travel to a different medical facility where the patient can be given a higher level of care. In that case, the medical team has to communicate with that facility for coordination and directions. Once the patient is at the hospital, the medical team leaves the hospital and must report its operational status to the dispatcher.

Radio communication is one of the most important forms of communications for the EMS. There are few radio frequencies dedicated to EMS and each frequency has many users. To avoid interference, statewide coordination of radio frequencies is important. The two-way voice communication is the basic form; however, there are advanced medical communications which are part of a larger network, including EKG telemetry, data communications, and wide-area radio coverage through the use of mobile relays. All dispatchers are trained in using radios and have proper license to operate. It is important to listen on a frequency before transmitting as to avoid interference with radio traffic in progress. Radio propagation studies deal with complex mathematical processes. Many technical and geographical aspects will have an impact on the system's reliability. The study includes an analysis of the quality of radio coverage and performance from a transmitter site. A few parameters have to be taken into consideration including, ground elevation above sea level, surrounding terrain, receiver noise environment, antenna type, and many more (The National Association of State Emergency Medical Services Directors, 1995[55]). Depending what needs to be tested, a study can be conducted for different scenarios. For example, it may be important to study how well signals can be transferred when two or three fixed points are involved. The quality and reliability of a radio transmitter play a large role. The area of radio geographic coverage between a base-station and a portable radio can

be calculated by formulas and models which obviously cannot be easily explained and are beyond the scope of this report.

An EMS communication cycle usually requires more than one service area when trying to contact different departments to attend the scene of emergency. When more than one service area is required, it is called a regional system as shown in figure 43. With this system, there are many strategically located mobile-relay stations that provide wide-area radio coverage in several regions (The National Association of State Emergency Medical Services Directors, 1995[55]). EMS units in each service area are given access to the channels. The central medical emergency dispatch centers (CMEDs) in both areas are always in contact with each other resulting in better coordination within the area. In a highly dense population area, additional radio channels may be required. Figure 40 shows the signal relay system that consists of all institution of EMS like CMED, hospitals, scene or emergency etc.

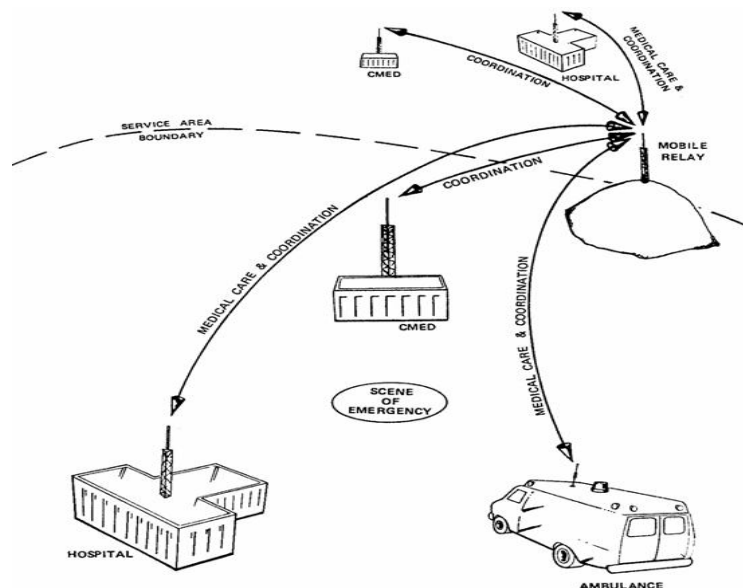


Figure 250: Regional Relay System

The Federal Communications Commission (FCC) permits the use of mobile relays and duplexed communication which helps eliminate the need for telephone lines which are not as reliable since they can be disconnected during an emergency. The current FCC rules clearly differentiate among EMS communications and other types of medical interactions. The basic outline of how a channel is assigned is as follows: When a medical team in an ambulance needs to connect to a hospital within another county, the team contacts the county CMED. The initial contact is monitored by all neighboring area CMEDs. The hospital and the ambulance are then provided a working channel assignment and they proceed with their communication. All surrounding CMEDs are made aware of the channel in use and will not assign the channel for the duration of the communication. Once the ambulance communication is finished, the channel is back in the pool of available frequencies and ready to be used again (The National Association of State Emergency Medical Services Directors, 1995[55]).

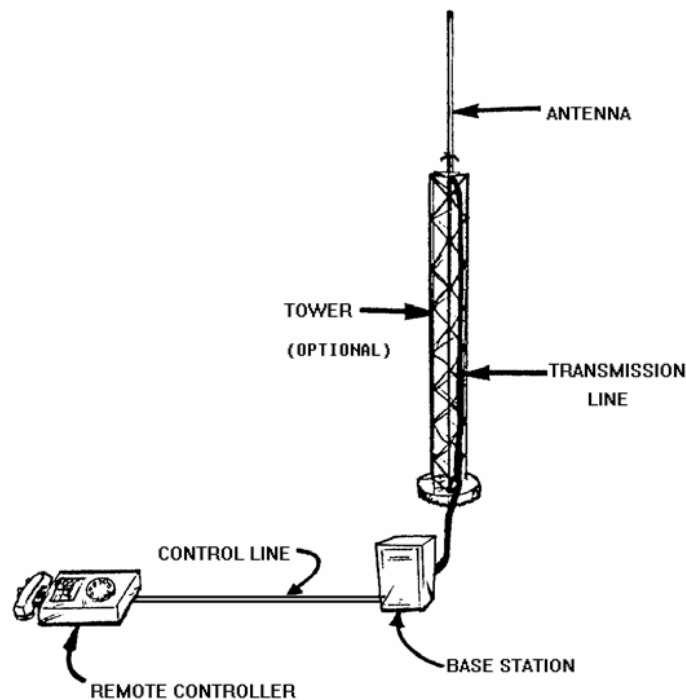


Figure 261: Radio Base Station

Figure 43 shows a basic system that might be installed in a hospital, and includes an antenna, radio tower support, an RF transmission line connecting the base radio station to the antenna, and a remote controller. In order to establish proper communication, a radio transmitter and a radio receiver are required within a certain range of each other and at the same frequency. The figures 42 provide a visual representation of a typical mobile station, a portable radio, and how information is transferred.

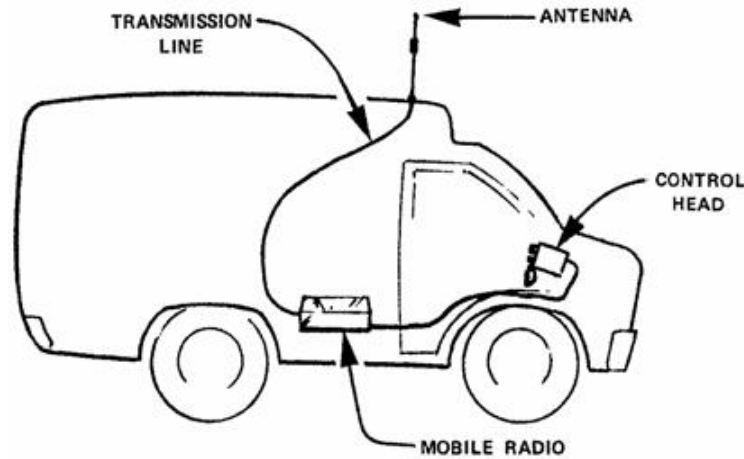


Figure 272: Typical Mobile Station

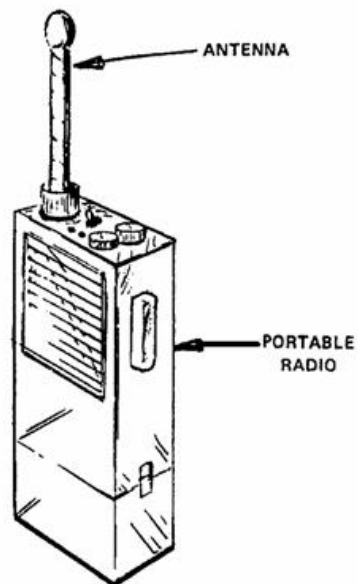


Figure 283: Typical Portable Radio

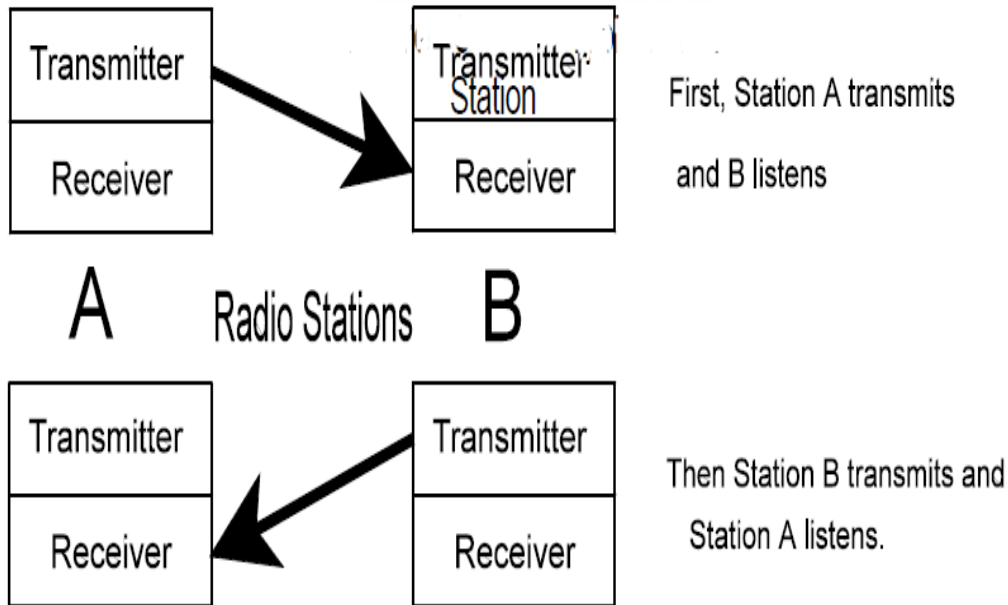


Figure 294: Two-way communication on one frequency

Figure 44 represents a two-way communication on one frequency. Specific to Massachusetts' EMS radio communications plan, Ultra High Frequency (UHF) frequency pairs MED 9 (462.950/467.950 MHz) and MED 10 (462.975/467.915 MHz) are in use (The National Association of State Emergency Medical Services Directors, 1995[55]). The two channels are restricted to only emergency medical operations. The chart below describes a high level protocol used to respond to call. It states that CMED determines the priority status of the patient before transferring the call. There are four priority categories: Priority one is immediate life threatening and CMED immediately calls in for ambulance, overriding other traffic if necessary. Examples are major head injuries, cardiac arrest, multiple trauma, airway obstruction, etc. Priority two is life threatening and CMED needs to connect as soon as possible to medical team. Examples are coma, unstable trauma, suspected cardiac, etc. Priority three is non-life threatening and CMED

will connect to receiving facility as soon as a channel is available. In this case, the patient is usually in stable trauma and may suffer from minor fracture or lacerations and soft tissue injuries. Lastly, priority four is for stable patients with no major concerns and are connected only if no other traffic requires a channel.

3.3.2 Wireless transmissions:

To understand signal processing and wireless communications, some basic understanding is required of analog and digital signals. Analog signals, also known as continuous time signals, take an audio or video signal and translate it into electrical pulses. For example, human voice is an analog signal. Digital signals, also known as discrete time signals, break the signal into binary format and present the data as “1”s and “0”s (Analog and Digital Signals. ThinkQuest[58]).

All wireless communications require digital signals, such as cell phones and radios. A good example of analog vs. digital is a clock. A clock with the moving hands is an analog representation. A digital clock displays the numbers and decimal. Below is an example of what a digital vs. analog signal may look like. Figure 45 shows us the difference between digital and analog signals.

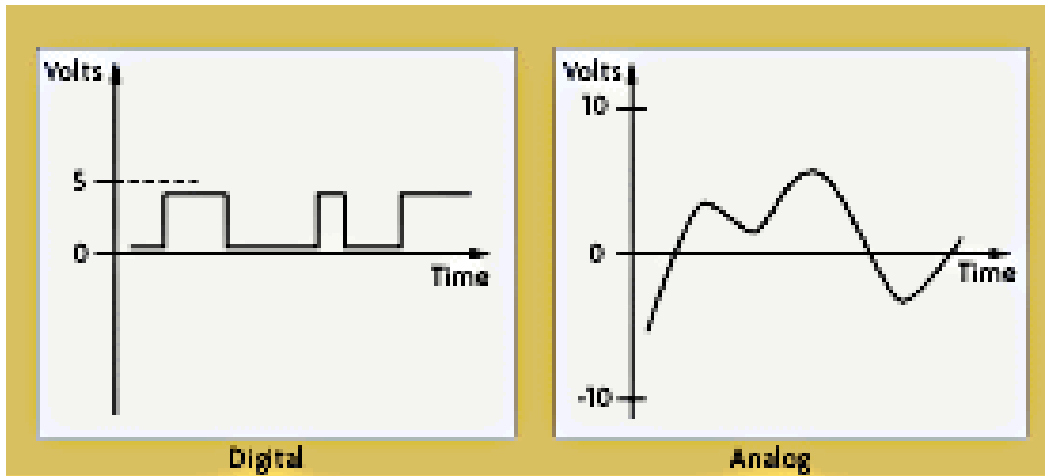


Figure 45: Digital and Analog Signals

Analog radios process sounds into patterns of continuously varying electrical signals, similar to sound waves, and then transmit the signal on a single R.F. carrier. When listening on an analog radio, you are to the electrical radio waves that are directly coming from the radio station. They might, however, pick up interference from other stations and can make sound unclear. In digital radios, the sound is translated into electrical signals, which correspond to one of four distinct levels or frequencies, which resemble digits, and then the information is transmitted on a single R.F. carrier wave and processed by a digital receiver (Levesque and Pahlavan “Wireless Information Networks” [57]). This type of radio has a clear sound and less interference compared to the analog radio. However, it has much higher energy consumption. It is important for EMS to choose the best type of transmission that will involve the least amount of interference. During an emergency, there is no room for error and immediate communication is required. Radios seem to be the best option for a reliable, two-way communication between different medical teams and dispatchers. It seems to have worked well for EMS in the past and is the most reliable and effective method.

3.4 IPW 9-1-1 Haptic System

The IPW 9-1-1 Haptic System is a human computer influence interaction system. This system is based on a control system. Control system is a collection of elements or components put together to obtain a particular outcome. The Haptic System will have the ability to influence the time delays. The elements of the Haptic system are:

1. Callers: (VOLP – Voice Over Land Phone)
(VOIP - Voice Over Internet Protocol)
(VOCP – Voice Cell Phone)
2. Actuators: a) Amplifiers
b) Motors
c) Power Transmitting Devices/ Mechanisms
d) Mechanical and Electrical Energy Components
3. Equipment: a) Data acquisition
b) Reports and Process
c) Assimilation of data – Analysis
4. Sensors
5. Controller
6. Hopf – Markov Decision Process(HDMP): Collection of parameters that may influence the delay
7. Corrective actions

NEST: Network, Equipment, Services, Technology

EDARPA (Elements). Figure 46 is a schematic representation of the communication components and the flow of signal.

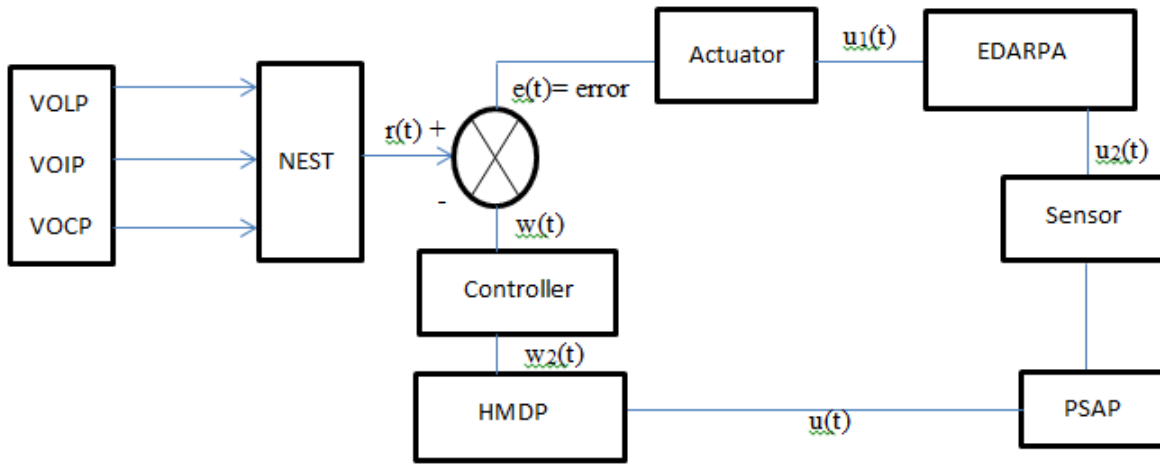
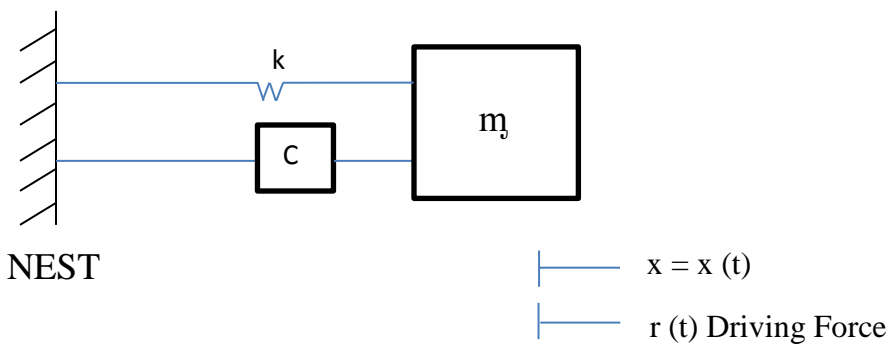


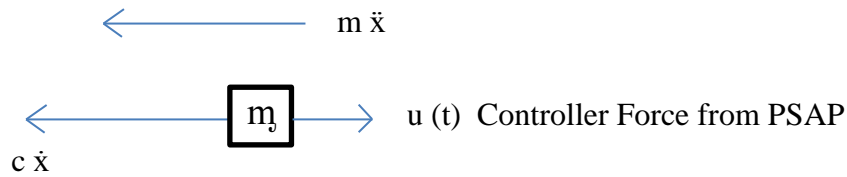
Figure 46: NEST flow diagram

$$\Gamma(t) = h + C_{SC} (\text{communication delay}) + C_{CD} (\text{human factor delay}) + C_{CA} (\text{communication delay}) + \lambda (t) (\text{System disturbance delay})$$

$$e(t) = r(t) - w(t) \text{ Driving Force} = \text{feedback}$$

1. Mass of calls = density x volume (Population)
2. Damping coefficient C $F_d = c v = c \dot{x} \rightarrow u(t)$





$$\sum F = ma = m \ddot{x}$$

$$\text{Non Linear Equation: } \ddot{x} + \frac{c}{m} \dot{x} + \frac{k}{m} x = \frac{1}{m} (r(t) - u(t))$$

$$\frac{c}{m} = \frac{c}{m} \cdot \frac{2w}{2w}$$

$$= \frac{c}{2m} \cdot 2w \sqrt{\frac{k}{m}}$$

$$= \frac{c}{2m} \cdot 2w \frac{\sqrt{m^2}}{\sqrt{k}\sqrt{m}} = \frac{c}{2\sqrt{km}} \cdot 2w$$

$$\frac{c}{m} = 2w$$

$$\text{Linear Equation: } \ddot{x} + 2\gamma w_0 \dot{x} + w_0^2 x = \frac{w^2}{k} (r(t) - u(t))$$

Control Force of PSAP

$$u(t) = \mu(1 - \varepsilon d)x(t) + \alpha x(t)(t - Ch + C_{SC} + C_{CD} + C_{CA})$$

$\alpha = 0$ (no delay)

$r(t) = \text{known} = \text{constant}$

$$\ddot{x} + 2\gamma w_0^2 \dot{x} + w_0^2 x = \frac{w_0^2}{k} (u(t))$$

If $\alpha = 1$ $C_0 = h + C_{SC} + C_{CD} + C_{CA}$

$C_{vd}(t) = \text{uncertainty delay} = \varepsilon \sigma(t)$

$$u(t) = \mu(1 - \alpha)x + \mu\alpha x(t - (C_0 + \varepsilon\sigma(t)))$$

$$\ddot{x} + 2\gamma w_0^2 \dot{x} + w_0^2 x = -\frac{w_0^2}{k} (\mu(1 - \alpha)x(t) + \mu\alpha x(t - C_0 - \varepsilon\sigma_0(t)))$$

$$\ddot{x} + 2\gamma w_0^2 \dot{x} + w_0^2 x = -\frac{w_0^2}{k} (\mu(1 - \alpha)x(t) + \mu\alpha x(t - c_0)) \text{ set } \varepsilon = 0$$

Try $x(t) = e^{\lambda t}$

$$x(t - c_0) = e^{\lambda(t - c_0)}$$

$$x = e^{\lambda t} \cdot e^{-\lambda t}$$

$$\dot{x} = \lambda e^{\lambda t}$$

$$\ddot{x} = \lambda^2 e^{\lambda t}$$

$$1) \quad \lambda^2 + 2\gamma w_0 \lambda + w_0^2 \left(1 + \frac{\mu}{k}(1 - \alpha)\right) + \frac{w_0^2}{k} \mu \alpha e^{-\lambda c_0}$$

(Transcendental Characteristic Equation)

$$\text{Real Coefficient} \quad M = -w^2 + w_0^2 \left(1 + \frac{\mu}{k}(1 - \alpha)\right) + \frac{w_0^2}{k} \mu \alpha \cos(wc_0)$$

$$\text{Imaginary Coefficient} \quad N = 2\gamma w_0 w - \frac{w_0^2}{k} \mu \alpha \sin(wc_0)$$

As $M=0$ and $N=0$

$$1. \quad \frac{w_0^2}{k} \mu \alpha \cos(wc_0) = w^2 - w_0^2 \left(1 + \frac{\mu}{k}(1 - \alpha)\right)$$

$$2. \quad \frac{w_0^2}{k} \mu \alpha \sin(wc_0) = 2\gamma w_0 w$$

$$1^2 + 2^2 \quad \left(\frac{w_0^2}{k} \mu \alpha\right)^2 = (w^2 - w_0^2(1 + \frac{\mu}{k}(1 - \alpha)))^2 + (2\gamma w_0 w)^2$$

$$\left(\frac{2}{1}\right) \quad \tan(wc_0) = \frac{2\gamma w_0 w}{w^2 - w_0^2(1 + \frac{\mu}{k}(1 - \alpha))}$$

$$\tan(wc_0) = \frac{2\gamma w_0 w k}{w_0^2 \cdot \mu \alpha \cos(wc_0)}$$

$$\sin(wc_0) [w_0^2 \mu \alpha \cos(wc_0)] = 2\gamma w_0 w k \cos(wc_0)$$

Rewrite (1)

as

$$\frac{w_0^2}{k} \mu \alpha ((1 - \alpha) + \cos(wc_0)) = w^2 - w_0^2 \quad (3)$$

$$(2) \quad \text{as} \quad \frac{w_0^2}{k} \mu \alpha \sin(wc_0) = 2\gamma w_0 w$$

$$\text{Divide } \frac{4}{3} \quad \frac{\sin(wc_0)}{(1-\alpha)+\cos(wc_0)} = \frac{2\gamma w_0 w}{w^2-w_0^2}$$

$$\text{Therefore,} \quad \tan \frac{(wc_0)}{2} = \frac{2\gamma w_0 w}{w^2-w_0^2}$$

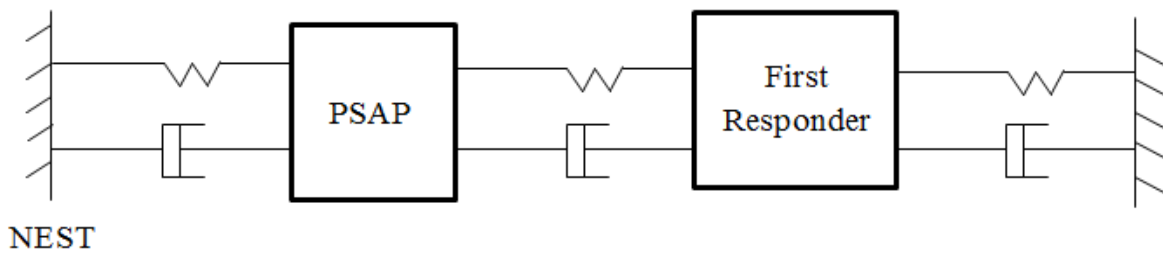


Figure 47: NEST connection flow

3.5 Next Generation 9-1-1

The 9-1-1 systems in present times are built, operated and maintained locally, usually by counties, but sometimes by municipalities and states. There is a need to upgrade the current 9-1-1 systems in order to keep handling the level of traffic, and also to upgrade to the latest requirements: video handling, transfer of photos and text, and the ability to switch 911 calls among communication centers (United States Department of Transportation [23]). Figure 48 shows the call flow and components in the Next Generation 9-1-1 communication system.

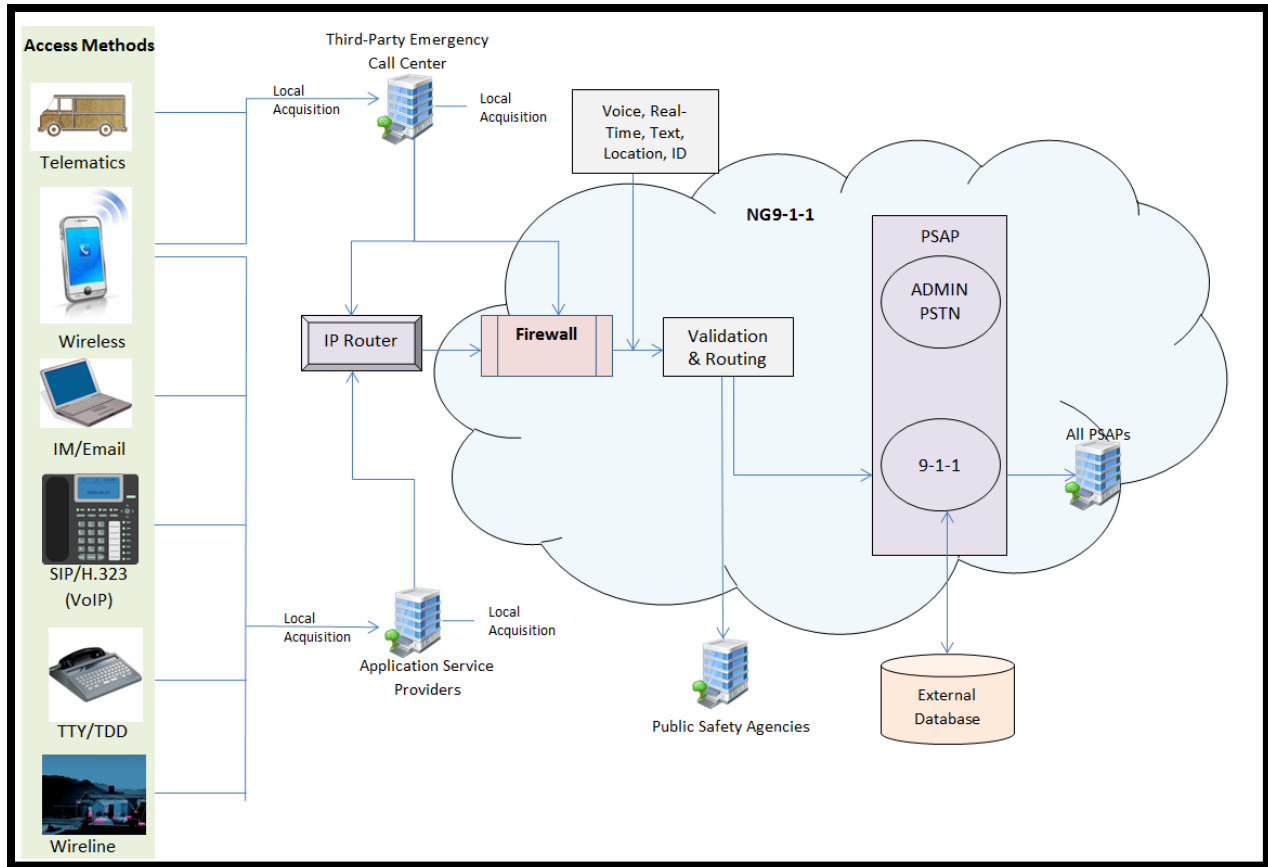


Figure 48: Call Flow and Elements of NG9-1-1

This project of improvement has become known as Next Generation 9-1-1, or NG911. The main points of the project are:

- Standardizing the underlying technology of the nation's separate 911 systems, most likely using IP technology and Internet-based communication links
- Creating more centralized databases of information to handle calls
- Interconnecting PSAPs to allow unlimited transfers of calls, distribution of overflow 911 calls, to other centers, and other call-handling features

- Allowing the 911 system to accept and handle advanced information from citizens, including video, photos, text messages, etc.
- Interconnecting with private services, such as telematics providers, to handle automatic crash notification (ACN) and other similar data.
- Adding advanced features to the 911 system, such as automatic routing for languages, mapping, medical info storage, etc.

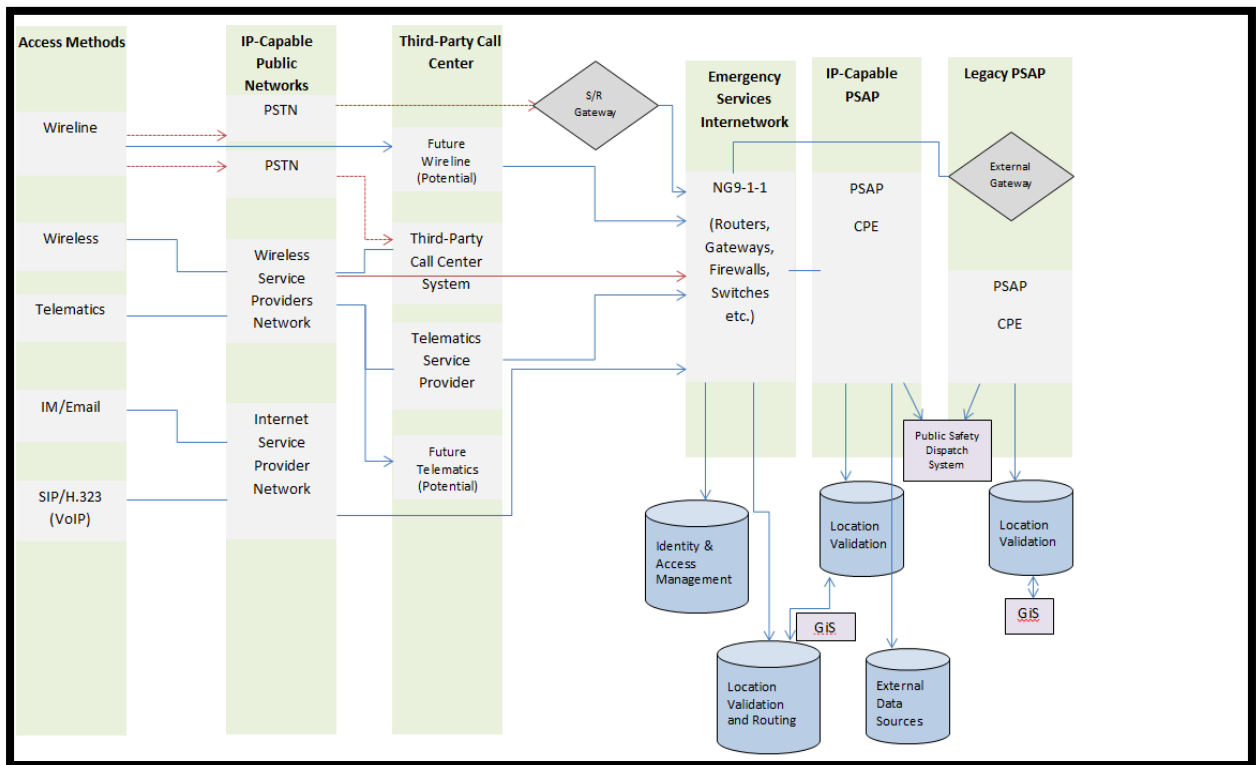


Figure 4930: System Interface in NG911

Figure 49 shows the system interface that is being used by the NG9-1-1 system

3.5.1 Next Generation 9-1-1: The Transportation Problem

The 9-1-1 system has made advancements for more than 40 years. This time frame saw rapid advancements in the telecommunications technology allowing the citizens to call a number for help using a wide variety of devices and locations. Citizens who call 9-1-1 from mobile devices during emergencies expect better connections to the 9-1-1 system than the current system. Because text, data, images, and video are increasingly common in personal communications and vehicle-based safety services, citizens further expect that the 9-1-1 system can accommodate these dynamic communications modes (United States Department of Transportation [23]).

However, the older, analog-based infrastructure and equipment used by emergency call centers (known as Public Answering Service Points [PSAPs]) has not kept up with new technology capabilities and cannot easily connect with a wide range of devices on the market today.

3.5.2 An Outdated 9-1-1 System

The PSAPs mostly use older, analog-based infrastructure and equipment. The system hasn't changed much since it was first established in 1968 (United States Department of Transportation [23]). As a result, the current system is not designed to accommodate emergency calls from the range of new technologies in common use today including:

- Laptops, Internet Protocol (IP) phones, IP wireless devices, or other devices that deliver audio, data, video message, picture message, and live video

- Cellular devices that transmit SMS and data and text messaging
- Third-party call centers that employ telematics (e.g., Automatic Collision Notification), audio, and/or data as part of their client services, such as General Motors' OnStar service
- IP and Video Relay Services (VRS) that assist the deaf and hard-of-hearing community (text and video)

PSAP's have limited capacity to identify the location of a caller who calls using a wireless device. The call taker requires the person to give him the location details which can end up wasting valuable transport time (United States Department of Transportation [23]).

3.5.3 Limited Emergency-Call-Center Capabilities

Existing 9-1-1 call centers are incapable of some critical functions such as:

- The option to link with one another during emergencies. This is needed specially when there is a shutdown in one part of the country or there is a natural calamity so terrible that systems in that region cannot function at all.
- The ability to stream video, teleconference and better interpreting services meet the need of the deaf/hearing people during emergencies (United States Department of Transportation [23]).

3.5.4 Limited Call Processing Capabilities

In context of today's expectations existing 9-1-1 software and call taker business processes face critical limitations:

- The original software was not designed to answer or process a variety of multimedia data (e.g., voice, text messages, images, and video) and, in particular, to accommodate how call takers address data received simultaneously from multiple sources.
- There are limited linkages to supplemental or supportive data such as: interactive maps; links to reference data on a particular location, surrounding hazards, or inputs that could change the emergency response or improve responder safety; and decision support on important questions to ask callers to enhance information on the situation.
- Call taker software is not designed to transfer calls when the volume of callers exceeds the available resources (United States Department of Transportation [23]).

3.5.5 Institutional Barriers to National Transition

In previous decades, each introduction of a new technology – for instance, wireless/cellular or Voice over Internet Protocol (VoIP) – has required system modifications at the thousands of 9-1-1 systems and PSAPs across the Nation. Not only has this approach been costly, it has meant that changes have not evolved equally in all parts of the country. However, in evaluating the opportunity for transitioning the entire nation to a new system, it is recognized that there are multiple paths to the nationwide implementation of NG9-1-1. Although the NG9-1-1 system is envisioned as an interconnected system of local and regional emergency services networks ("system of systems"), network boundaries of emergency services may vary depending on local requirements and organizational frameworks. Also, the path to consistent, nationwide implementation is highly dependent upon age of the underlying infrastructure, funding, policies, and priorities of the 9-1-1 Authorities. The figure 52 provides a graphic illustration of the

evolution of technologies and changes to the 9-1-1 system since the 1960s. Mobile and vehicle-based technologies are yet to be fully incorporated into a 21st century 9-1-1 system.

Collectively, these technology and system challenges prevent the easy transmission of data and critical sharing of information that can significantly enhance the decision-making ability, response, and quality of service provided to emergency callers. Figure 50 below shows how modes of communication transformed from 1968 to the 21st century.

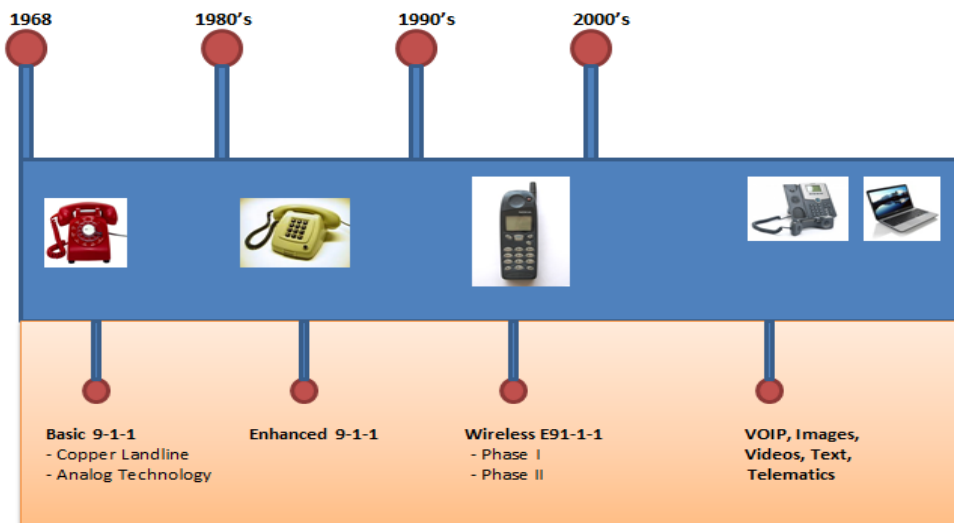


Figure 310: Evolution to Changes to 9-1-1 Systems and Technologies

3.5.6 Next Generation 9-1-1: The ITS Opportunity

ITS offers innovative technology solutions to address system and technology challenges to enable the existing 9-1-1 system to deliver the next generation of capabilities and services. By capitalizing on recent technology advances, the ITS Program has delivered a Next Generation 9-1-1 (NG9-1-1) system design that, when implemented, will:

- Enable 9-1-1 calls from any networked device based on the development of a flexible, open, non-proprietary architecture.
- Provide quicker delivery and more accurate information to responders and the public alike. Delivery will incorporate better and more useful forms of information (real-time text, images, video, and other data).
- Establish more flexible, secure, and robust public safety answering point (PSAP) operations with increased capabilities for sharing of data and resources, and more efficient procedures and standards to improve emergency response
- Maximize the use of available public capital by facilitating increased coordination and partnerships within the emergency-response community. This will result in operating and maintenance cost savings.
- Enable call access, transfer, and backup among PSAPs and between PSAPs and other authorized emergency organizations that are geographically separated.
- Enable greater interoperability of the network (a system of systems) through the incorporation of industry standards The NG9-1-1 Initiative has coordinated engagement on standards across the Nation and with other emergency services network providers within North America (Canada and Mexico), recognizing the global impacts of routing emergency calls in an IP environment.

For transportation, updating to an NG9-1-1 system is a critical component in enabling 9-1-1 callers to quickly send more accurate and more useful forms of information about traffic incidents and crashes to 9-1-1 emergency call centers (United States Department of Transportation [23]). For example, the NG9-1-1 system will be able to:

- Handle a 9-1-1 call from a personal digital assistant (PDA) or computer
- Receive automatic crash notification data (on speed, vehicular rollover status, or crash velocity) sent through a third-party service provider such as General Motors' OnStar
- Receive photo images, data sets, and medically relevant data that can be routed to appropriate emergency medical services

Moreover, NG9-1-1 will provide a tool for sending location-targeted hazard alerts and evacuation guidance to motorists and other mobile device users through reverse messaging.

3.6 Next Generation 9-1-1: Research Findings and Test Results

3.6.1 Definition of a Comprehensive Future Vision for NG9-1-1

The Next Generation (NG9-1-1) Initiative has produced one of the first studies that defines and documents a comprehensive future vision for the existing 9-1-1 system (United States Department of Transportation [23]).

- The public awareness generated by the Initiative has alerted 9-1-1 stakeholders that a fundamental transformation of the way 9-1-1 calls are originated, delivered, and handled is underway.
- The NG9-1-1 Initiative facilitated requirements setting with a large and diverse group of stakeholders whose interests at times might conflict.
- The results of the NG9-1-1 effort have helped communities become more engaged in the issues and challenges that face the existing 9-1-1 system and to discuss and plan for a future system. The NG9-1-1 tests and demonstrations created a sense of urgency and

movement within the community to get more people involved and start discussing the issues as a community.

3.6.2 Validation of NG9-1-1 Architecture

The NG9-1-1 architecture has been validated through a set of proof-of-concept (POC) tests. Twenty-six (26) professional call takers, dispatchers, and supervisory individuals were trained to assist the NG9-1-1 Initiative team with the POC testing (United States Department of Transportation [23]). Using seven laboratory test scenarios and eight PSAP test scenarios, tests on the NG9-1-1 prototype system revealed:

- The new design is capable of accommodating calls from a wider range of devices. All five public safety answering points (PSAPs) were able to receive cellular calls, instant messaging, legacy 9-1-1 calls (wire line), telematics (automatic crash notification), Voice over Internet Protocol (VoIP) calls, and live video feeds. Importantly, the prototype system allowed PSAPs to identify the caller's location and to route the call to the most appropriate response center based on the caller's location.
- The POC included 320 individual tests in the laboratories and the PSAP facilities with 280 (87.5 percent) successfully passing the test criteria. Some examples of results are:
 - The ability to transmit test telematics data (speed, vehicular rollover status, and crash velocity) was successfully tested. The test system demonstrated the ability to easily and automatically transfer this important data associated with a vehicle crash to the PSAPs.
 - The ability to identify the test caller's location was successfully tested for wire line, wireless, and Internet Protocol (IP)-based calls.

- The ability to send and receive voice, video, data, and text (through instant messaging and short message service) was successfully tested, although issues arose with bandwidth and video streaming methods that caused some video-based calls to fail.

3.6.3 Identification of New Capabilities

POC testing revealed that the NG9-1-1 System provides important new capabilities. For example (United States Department of Transportation [23]):

- Tests showed that PSAPs can link with one another during emergencies, unlike in the past when calls would dead-end at the PSAPs with no way to provide back-up for one another during widespread emergencies such as hurricane evacuations.
- Tests showed that the NG9-1-1 system will have the ability to accommodate streaming video and automatic teleconferencing with interpreting services to better meet need of the deaf/hearing community during emergencies. However, the tests also revealed that PSAPs will require upgrades and technological improvements in order to offer these services.

3.6.4 Validation of PSAP Call Taker Software

POC testing validated that the PSAP call taker software works.

- The new call taker software was designed to assist in consolidating and presenting emergency information received via new technologies in an efficient format. The proof-of-concept tests revealed that the system is capable of assisting call takers with the greater amount of data; instead of 'data overload', the data was presented in a manner that

did not cause undue confusion. Importantly, the orientation to the new software was quickly accomplished, indicating that the call taker software is easy-to-understand and the data displayed are straightforward.

- Including call takers in the testing process provided valuable feedback about the functionality that someday they will come to depend on. Their input regarding needs and difficulties in the early stages helped to identify the current system problems that are addressed by the new technologies.

3.6.5 Validation of Core NG9-1-1 Functions and Features

The NG9-1-1 Initiative POC tests validated that core NG9-1-1 functions and features work (United States Department of Transportation [23]).

- Key features of the system were demonstrated to show how they enabled emergency calling from a variety of devices and forwarding caller information to the most appropriate call center. POC testing revealed that the system design, requirements and features accurately reflect the needs of the stakeholder community and bring together industry-accepted best practices for implementing complex IP-based solutions.
- The NG9-1-1 was designed to be an open and accessible system. NG9-1-1 system was developed using industry-accepted best practices for networking and designing an IP-based system, industry-accepted standards, and off-the-shelf hardware and software. The POC validated that the NG9-1-1 system can connect with a wide array of devices and technologies.

3.6.6 Increase in System Reliability

The NG9-1-1 system provides new capabilities for stakeholders, while expanding resiliency and redundancy for the public.

- With a transition to an NG9-1-1 system, PSAPs will have the capability to communicate with one another during daily operations and emergencies, unlike today, where call centers typically cannot interoperate with nearby agencies, making it difficult to provide back-up for one another during widespread emergencies such as hurricane evacuations. No longer is a PSAP tied to a specific facility with dedicated telecommunications circuits; NG9-1-1 provides access to systems and networks without regard to geographic boundaries.
- The deaf/hearing-impaired community, historically underserved by the 9-1-1 system, relies heavily on texting capabilities for communications.
 - The NG9-1-1 system can not only accommodate the receipt of text messages from a range of devices used by the deaf community, but can accommodate streaming video to broaden type of the information that can be sent.
 - Stakeholders from this community have provided input and recommendations at multiple points throughout the NG9-1-1 Initiative regarding accessibility needs; they will remain a constant source of feedback as NG9-1-1 solutions are implemented.

CHAPTER 4: CONCLUSION

The objective of our project at the beginning of the year was to analyze all aspects of communications in the field of Emergency Medical Services. This included communications from the patient to the 9-1-1 call center, the call center to the First Responder, the first responder to the ambulance, the ambulance to the CMED and the CMED to the hospitals. After our interviews with the Worcester EMS Chief at UMass Memorial Hospital, we came to the conclusion that communications with the drivers of the ambulance and reducing the different kinds of time delays are a major concern. Our research showed us that even though the 9-1-1 call centers are being equipped with the latest modes of communications, the basic infrastructure has not changed much since it was first established. In the present day when everyone is connected with one another through video calls, text messages, and various other modes, it would be appropriate to try and establish similar lines of communications for the ambulances. Enabling a feature like video and teleconferencing while the ambulance is on its way to the hospital would be of great help.

Our advisor suggested us to look in to a wireless transceiver system that would allow the driver of an emergency vehicle to share the location and direction with other ambulances. During our research, we came up with a new program the government is coming up with called the Next Generation 9-1-1 system or the NG9-1-1 system. All outdated mechanisms and equipment's of 9-1-1 communications are looked to being replaced with the latest modes of communications and enable a wider array to communication options like video and teleconferencing. One big flaw the 9-1-1 system currently has is that when a person calls the 9-1-1 emergency line using a wireless device, the call taker has to ask the person the location and details of the person since such

details are stored in the system under wired lines. In an age of such advanced technology, the call center may lose valuable time in relaying the information to the First Responder which might be critical. Such issues are addressed in the NG9-1-1 Plan. When we interviewed the Worcester 9-1-1 call center chief, we were informed that the 9-1-1 system cannot be accessed for our study since it was against government regulations. Our objective was to find the kind of delays within the systems and come up with control equations for it. We thus worked on creating our own sample database using Python programming language and created a sample emergency environment to compare the time differences. Though our database was not as advanced as the one the 9-1-1 system uses, we were able to highlight the kinds of delays the system encounters. Such kind of technical delays could be handled using a closed loop involving equipment's like actuators, sensors, Hompf Markov Decision Making Process. With the help of our advisor, we formulated a set of control equations that could help reduce time delays. These equations are related to the field of signals. Our group will continue to test these equations and comparing them with the original system to check if any difference is made.

We have come a long way in our project and learnt a lot about the entire system, government regulations, human factors that affect the process. We will continue working to create a system which addresses all the flaws and test it in a real life environment.

REFERENCES

- [1] Grant, Casey and Brian Merrifield. "Analysis of Ambulance Crash Data." *NFPA*. Fire Protection Research Foundation, Sep 2011. Web. 5 Dec 2012. <<http://www.nfpa.org/assets/files/research%20foundation/rfambulancencrash.pdf>>.
- [2] Peleg, Kobi and Joseph S. Pliskin. "A geographic information system simulation model of EMS: Reducing Ambulance Response Time." *The American Journal of Emergency Medicine*. 22.3 (2003): 164-170. Web
- [3] "EMS Portfolio Overview." *MedicalTeams*. Medical Teams International, Jul 2007. Web. 8 Dec 2012. <<http://www.medicalteams.org/docs/ems/ems-portfolio-overview.pdf?sfvrsn=0>>.
- [4] "What is EMS?" *DHEC*. American College of Emergency Physicians , Nov 2012. Web. 7 Dec 2012. <http://www.scdhec.gov/health/ems/what_is_ems.htm>.
- [5] Philip, Leone. "Review of Emergency Medical Services in Virginia ." *JLARC*. Commonwealth of Virginia, 15 Nov 2004. Web. 9 Dec 2012. <<http://jlarc.state.va.us/Reports>>.
- [6] *Office of Emergency Medical Services*. (n.d.). Retrieved from <http://www.mass.gov/eohhs/gov/departments/dph/programs/hcq/oems>
- [7] "Police, Fire, and Ambulance Dispatchers." *United States Department of Labor*. 29 Mar 2012. Web. 5 Dec 2012. <<http://www.bls.gov/ooh/>>.
- [8] "9-1-1 Operations Center." *Nashville.gov*. Metropolitan Government of Nashville and Davidson County, Web. 5 Dec 2012. <<http://www.nashville.gov/ecc/operations.asp>>.
- [9] "Massachusetts Emergency Medical Service Regions and American College of Surgeons Verified Trauma Centers." *Mass.Gov*. N.p., n.d. Web. 18 Apr. 2013
- [10] "The Massachusetts Emergency Medical Services Radio Communications Plan." 1 Mar 2010. Web. <http://www.mass.gov/eohhs/docs/dph/emergency-services/radio-communications-plan.pdf>
- [11] "Western Massachusetts Emergency Medical Services Inc." *Home*. N.p., n.d. Web. 18 Apr. 2013.
- [12] "EMS Region II Communications Plan." *Central Mass EMS Corp. Web Site*. 1 Sep 2011. Web 15
- [13] Nov 2010. <<http://www.cmesc.org/cmed/RegionIICommunicationsPlan.pdf>>.

- [14] "Map of Massachusetts EMS Regions (PDF)." *Docstoc - We Make Every Small Business Bette*.
- [15] 2011. Web. 29 Oct 2012. <[http://www.docstoc.com/docs/44924247/Map-of-Massachusetts-EMS-Regions-\(PDF\)>](http://www.docstoc.com/docs/44924247/Map-of-Massachusetts-EMS-Regions-(PDF)>).
- [16] J. Augustime, James. "Someone's been shot." An EMS case study. "*EMS, EMTs & Paramedics - Prehospital Emergency Medicine / EMSI*. 1 Dec 2011. Web 5 Dec 2012.
- [17] "Central Mass: Region II Communication System." *Central Mass EMS Corp Web Site*. 2011.
- [18] Web. 30 Oct 2012. <<http://www.cmemsc.org/cmed/about-cmed.shtml>>
- [19] "Transportation Impacts & Adaptation | Climate Change | US EPA." *US Environmental Protection Agency*. 14 Jun 2012. Web. 15 Nov 2012. <<http://www.epa.gov/climatechange/impacts-adaptation/transportation.html>>.
- [20] Davis, Robert. "USATODAY.com." *USATODAY: Latest World and US News - USATODAY.com* USATODAY, 20 May 2005. Web. 6 Dec 2012. <<http://usatoday30.usatoday.com/news/nation/ems-day1-cover.htm>>
- [21] D. McDonald, Sheriff Joseph. "Plymouth County Sheriff's Department." *Plymouth County Sheriff's Department*. 2011. Web. 29 Oct 2012. <http://www.pcsdma.org/Mass_CMED_Network.asp>.
- [22] "Schenectady County - Departments - Communications Systems - E911." *Schenectady County*. Web. Nov 2012. <<http://www.schenectadycounty.com/FullStory.aspx?m=93&amid=414> >.
- [23] *Research and Innovative Technology Administration (RITA) - United States Department of Transportation (USDOT, US DOT or DOT)*. (n.d.). Retrieved from <http://www.its.dot.gov/NG911>
- [24] McCann, C., Hanson, S., & Olivarez, N. (2011). *EMS Communications IQP*. Retrieved from http://www.wpi.edu/Pubs/E-project/Available/E-project-050711-170940/unrestricted/EMS_Communications_IQP.pdf
- [25] "DHS sets up ePCR to store medical information." *Government IT, Gov. Tech, IT in Government --- Fierce Gov. IT*. Web. <<http://www.fierceregovernmentit.com/story/dhs-sets-ePCR-store-medical-information/2011-09-07>>.

- [26] "Ambulance Crews Close to Colorado Shooting Delayed in Being Dispatched - News - @ JEMS.com." *EMS, Emergency Medical Services - JEMS - Training, Paramedic and EMT News, Products, Resources, EMS Jobs @ JEMS.com*. Web. Dec 2012.
<<http://www.jems.com/article/news/ambulance-crews-close-colorado-shooting>>.
- [27] "National Emergency Communications Plan." *Homeland Security*. Web. Dec 2012.
<http://www.dhs.gov/xlibrary/assets/national_emergency_communications_plan.pdf>.
- [28] "What is EMS? | doh." *doh | Department of Health*. The District of Columbia, n.d. Web. 18 Apr. 2013.
- [29] "Vanu - Wireless Communication Systems." Vanu - Home. Web. <<http://www.vanu.com/>>.
- [30] "Amish family injured in accident Saturday - Gladwin County Record and Beaverton Clarion: News: amish, clare county sheriff department, gladwin county record, record and clarion, gladwin record." *Gladwin County Record and Beaverton Clarion: Gladwin, MI, news, sports, obituaries & classifieds*. Web. Oct 2012.
<http://www.gladwinmi.com/news/amish-family-injured-in-accident-saturday/article_0df607f0-ed33-11e1-a718-001a4bcf887a.html>.
- [31] "St John | Computer Virus Hits Ambulance Services | Stuff.co.nz." *Stuff.co.nz - Latest New Zealand News & World News, Sports News & NZ Weather Forecasts*. Web. Dec 2012.
<<http://www.stuff.co.nz/waikato-times/news/5953497/Computer-virus-hits-ambulances>>.
- [32] "Population Distribution and Change: 2000 to 2010." 200 Census Briefs. (March 2011): Web.<<http://www.census.gov/prod/cen2010/briefs/c2010br-01.pdf>>.
- [33] "Home - DSHS EMS & Trauma Systems." *Texas Department of State Health Services*. Web. Nov 2012. <<http://www.dshs.state.tx.us/emstraumasystems/default.shtm> >.
- [34] "Emergency Medical Services (EMS) Systems :: Washington State Dept. of Health." *Home: Washington State Dept. of Health*. Web. Dec 2012.
<<http://www.doh.wa.gov/PublicHealthandHealthcareProviders/EmergencyMedicalServicesEMSSystems.aspx>>.
- [35] Brodsky, Harold. "Delay in Ambulance Dispatch to Road Accidents.." *Psychology and Behavioral Sciences Collection*. American Journal of Public Health, Jun92, Vol. 82 Issue 6, p873-875, 3p, 3 Charts, 1 Graph. Print

- [36] "City of Boston Emergency Medical Services." *2011 Annual Report*. Web. Dec 2012. <http://www.cityofboston.gov/Images_Documents/2011_Boston_EMS_Annual_Report_tcm3-32900.pdf>.
- [37] "Emergency Medical Services." *Privatization and Prehospital Emergency Medical Services*. Web. Nov 2012. <<http://www.iaff.org/tech/PDF/Monograph1.pdf>>.
- [38] "Delay in Ambulance Dispatch to Road Accidents." *American Public Health Association - American Public Health Association*. Web. Sep 2012. <<http://ajph.aphapublications.org/doi/pdf/10.2105/AJPH.82.6.873>>.
- [39] "Boston EMS 2011 Annual report." Cityofboston.gov, 2011. Web. <<http://www.cityofboston.gov/EMS/>>
- [40] "Survive Cardiac Arrest- Times and Intervals Associated with Cardiac Arrest." UW Departments Web Server. Web. <<http://depts.washington.edu/survive/time-intervals.php>>.
- [41] Take Your Business On The Road - In Motion Technology.OnBoard Mobile Gateway. Retrieved January 2013, from <http://www.inmotiontechnology.com/datasheets/oMG.pdf>
- [42] "A Communications Systems Integration." Tennessee Trauma Care System Plan, Section III. Prehospital Care. Tennessee: Tennessee Department of Health, July 2004. 16. Web. <<http://health.state.tn.us/ems/PDF/g4024233.pdf>>.
- [43] Pons, P., Haukoos, J., Bludworth, W., Cribley, T., Pons, K., & Markovchick, V. (July 2005). Paramedic Response Time: Does It Affect Patient Survival? *Acad Emerg Med*., Retrieved , from http://www.denveremresearch.org/phocadownload/outcomes/articles/paramedic_response_time_does_it_affect_patient_survival.pdf
- [44] NCVHS Home Page. Sample Universal Healthcare Identifier (UHID). Retrieved January 2013, from <http://www.ncvhs.hhs.gov/app7-2.htm>
- [45] GTT: Building Critical Traffic Connections. Emergency Vehicle Preemption. Retrieved January 2013, from <http://www.gtt.com/emergency-vehicle-preemption>
- [46] EMTRAC Systems - Priority Management and Monitoring Systems. EMTRAC Systems - Priority Management and Monitoring Systems - Emergency Vehicle Preemption (EVP).Retrieved February 2013, from <http://www.emtracsystems.com/evp.html>

- [47] Gross, D., & Gross, J. (2000, 26). USPTO Patent Full-Text and Image Database. United States Patent: 6326903 Emergency vehicle traffic signal pre-emption and collision avoidance system. Retrieved February 2013, from <http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=%2Fnethtml%2FPTO%2Fsrchnu.m.htm&r=1&f=G&l=50&s1=6326903.PN.&OS=PN/6326903&RS=PN/6326903>
- [48] Manual on Uniform Traffic Control Devices (MUTCD) - FHWA.FHWA - MUTCD - 2003 Edition Revision 1 Chapter 4F.Retrieved February 2013, from <http://mutcd.fhwa.dot.gov/HTM/2003r1/part4/part4f.htm>
- [49] Spencer, W. How Traffic Lights Work. Tech-Faq Retrieved from <http://www.tech-faq.com/how-do-traffic-lights-work.html>
- [50] Specializing in Electronic Patient Care Reporting and EMS Billing. EPCR EMS Software. Retrieved January 2013, from <http://www.ePCR.com/>
- [51] EASM Online ePCR Software. Retrieved January 2013, from <http://www.aristatechnologies.com/easm-online-web-ems-solutions.html>
- [52] McCann, Connor, Steve Hansen and Nathan Olivarez. *EMS Communications IQP*. (2011): Web.<http://www.wpi.edu/Pubs/E-project/Available/E-project-050711-170940/unrestricted/EMS_Communications_IQP.pdf>.
- [53] Barua, Soumit , Sayok Chattopadhaya, Ankush Yuvraj Patil and Dillon Sarkar. *Time Response Ambulatory Calls Evaluation*.(2012): Web.<http://www.wpi.edu/Pubs/E-project/Available/E-project-053012-014020/unrestricted/TRACE_IQP.pdf>
- [54] *Worcester Emergency Communications*. Worcesterma.gov, Web. <http://www.worcesterma.gov/emergency-communications>
- [55] Planning Emergency Medical Communications. Vol 1. Carlsbad, CA: The National Association of State Emergency Medical Services Directors, 1995. Print.
- [56] "Analog and Digital Signals." ThinkQuest. Web. 18 Feb 2013. <http://library.thinkquest.org/27887/gather/fundamentals/analog_and_digital.shtml>.
- [57] Levesque , Allen H. and Kaveh Pahlavan. "Wireless Information Networks." New York. Wiley. 1995
- [58] WORCESTER EMS - UMass Memorial EMS. (n.d.). Retrieved from <http://www.umassmemorialems.com/what-we-do/worcester-ems/>