

Intelligent Routing and Notification System for Emergency Services Vehicles

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ABSTRACT

An innovative program is described to improve emergency vehicle deployment by automatically alerting all other nearby vehicles on the road as to the presence and intention of the emergency vehicle. Since the use of audible sirens has somewhat marked effectiveness nowadays, in selecting the most practical automated method to notify most drivers a review is given of the various data-links that are available today, including plans for new standards. The research presented concludes that use of today's newer vehicle data-links is currently ineffective due to the fragmentation and, in many cases, low adoption rates, including satellite radio, HD and conventional radio, automatic cruise control radar, and vehicle telematics. None of the newer digital data-links in use today are each capable of reaching more than a few percent of all users on the road, so a notification system that relies on breaking through or working on these channels will have very limited effectiveness, practical implementation issues aside. The new IEEE vehicle data-link standards offer the potential, but, based on the research presented, any reasonable amount of adoption is 15 years or more into the future. Therefore, the system under development and deployment described in this paper focuses on the ubiquitous cellular telephone and techniques are described to relay an emergency vehicle's siren through these devices to help clear the road ahead for emergency services vehicles.

INTRODUCTION

Lt. Chapman of the DC Fire and Emergency Medical Services Department wrote about the difficulties encountered in getting appropriate driver and vehicle reaction to emergency sirens [1]. He stated that he would like to see the decibel level of audible warning devices reduced on emergency vehicles, but as a former driver in the D.C. Fire and Emergency Medical Services Department he advocates turning them up even louder instead. He described the frustration for emergency services when they are trying to get to someone in need and are blocked by a driver with his or her windows up, music blaring, perhaps a cell phone conversation in progress and what seems to be a

complete disconnection from the world. He pointed out that the evolution of emergency vehicles once used only a bell rung by hand to clear the way. He went on to ask if science will provide an answer, such as a simple visual system that could alert drivers to the approach of an emergency vehicle.

Driver distractions are generally related to loud music, audio from movies or television (assuming the driver is not viewing the video source) and cell phone conversations. Music sources include CD, MP3, and radio including AM, FM, HD, or satellite transmission (XM/Sirius). The system under development, described in this paper, uses intelligent techniques to determine which cell users are in the path of the vehicle and targets only those cell devices to relay the siren. The relaying is virtual as it is intended to use siren or similar ring-tones that respond to the emergency notification to the user's cell phone number. The system makes use of calls, broadcasts, SMS messaging, text messaging, Push to Talk (PTT), e mails, and other means of cell phone communication.

CURRENT VEHICLE SYSTEMS

A summary of the various onboard systems and the types of data-links available to vehicles is summarized in Table I. While there are many different ways to broadcast or message the driver of a vehicle the overall all adoption rate of any one system is low; i.e., some users have HD radio, some have conventional radio, others have satellite radio, but there is no practical way to tap into or effectively use these existing systems in a small region that would communicate with a meaningful number of vehicles. Therefore, it is more practical as discussed below to make use of personal mobile devices to have any reasonable impact over the next 15 – 20 years. A discussion of each data-link and the adoption rate is presented.

HD RADIO - HD Radio technology allows stations to simulcast compressed digital audio and traditional analog audio, without changing to new frequency bands. As of 2007, over 1200 AM and FM stations are broadcasting with HD Radio technology, with over 500 FM stations offering more than one digital channel per FM frequency, thus doubling or tripling the number of programs available to

listeners. Most of the stations that have adopted the technology are FM, while AM stations have been slower to upgrade. As with traditional AM, FM and TV broadcasting, HD Radio programming is free and supported either by commercial advertising or public broadcasting. As for new digital TV standards, consumers must upgrade to a new receiver in order to receive digital broadcasts.

HD uses Orthogonal Frequency-Division Multiplexing (OFDM), a digital multi-carrier modulation scheme, which uses a large number of closely-spaced orthogonal sub-carriers to carry data. These sub-carriers typically overlap in frequency, but are designed not to interfere with each other as would be the case with traditional frequency division multiplexing and may be efficiently separated using a Fast Fourier Transform (FFT) algorithm.

TABLE I. CURRENT VEHICLE EQUIPAGE

Link	Frequency	BW/Data Rate	U.S. Equipage
IEEE 1609	5.9 GHz	75 MHz	New trial standards, so very low current adoption.
Telematics	2G – 3G	144kbps – 3 Mbps	4M
HD Radio	AM FM Bands	Video @ 255kbps, music @ 44 kbps; voice, 20 kbps; 16 kbps for low quality audio.	4.2M
FM AM Radio	88-108 MHz FM 520-1610 kHz AM	15kHz FM 5kHz AM	Unknown, but considered to be very high > 90% due to technology maturity.
ACC Radar	76.5 GHz	250 MHz	Unknown, but considered very low as technology is new.
Satellite Radio	2.3 or 1.4 GHz	≤ 44 kbps	20.5M

Each sub-carrier is modulated with a conventional modulation scheme maintaining data rates similar to conventional single-carrier modulation schemes in the same bandwidth. OFDM has developed into a popular scheme for wideband digital communication, whether wireless or over land lines, used in applications such as digital television and audio broadcasting, wireless networking and broadband internet access. HD has a low adoption at this time in the United States compared to conventional analog radio.

SATELLITE RADIO - The two major satellite radio companies continue to invest in their technology, infrastructure, and services. Recently, Sirius filed an application to launch and operate a new non geostationary orbit satellite (FM-6) to replace two existing non-geostationary satellites (FM-1 and FM-2) that are currently in operation. FM-6 would be placed half way between where FM-1 and FM-2 operate today. The launch is expected to take place in 2010. Sirius had already been granted authority to launch a geostationary satellite (FM-5) which will significantly alter its existing satellite

constellation, resulting the in the eventual constellation of three satellites; two non geostationary satellites (FM-3, FM-6) and one geostationary satellite (FM-5). FM-6 will have twice the transmit power of FM-1 and FM-2. The digital throughput is 1.35 Mbps and the additional capacity will be used to provide more audio channel programming and data; but is currently providing three compressed video channels primarily for vehicle back seat viewing. Each video is compressed to approximately 255kbps. Presently, music is compressed to 44 kbps; voice, 20 kbps; and 16 kbps for low quality audio such as traffic and weather, implying a spare capacity of 585 kbps, enough for 13 more music channels.

VEHICLE TELEMATICS - Telematics systems are seen as a major source of new revenue for automobile manufacturers. Telematics proponents view the car as a platform through which to sell not only wireless safety and security services, but also various other pay for service applications including e-mail, stock quotes, and Internet services. Telematics is projected to be a \$13 billion a year industry in the United States by 2010. Worldwide, telematics is predicted to grow to a \$41 billion market by 2010, as Japanese and Western European consumers try to battle gridlock with real-time traffic report and navigation applications. It is believed that there are two million subscribers as of March 2008 for GM's OnStar service and a similar number using other services.

VEHICLE WIRELESS STANDARDS - Newer, more flexible, vehicle data-link systems are on the horizon aimed at bringing new standards for vehicle data transfer, including the IEEE 1609 standard [2]. This program involves many participants from local and federal government and private industry and envisions a future in which intelligent vehicles routinely communicate with each other and the transportation infrastructure in real time. A newly published set of IEEE standards, based on IEEE 1609 Wireless Access for Vehicular Environments (WAVE), defines architecture and a complementary set of services for secure vehicle-to-vehicle and vehicle-to-infrastructure wireless communication. The IEEE 1609 standards are designed to provide the foundation for a broad range of applications in the transportation environment, including vehicle safety, public safety, communication fleet management, automated tolling, enhanced navigation, and traffic management.

WAVE technology (also called Dedicated Short Range Communications or DSRC) is a short-to-medium-range radio link and operates at 5.9 GHz as authorized by the U.S. Federal Communication Commission (FCC) for intelligent transportation systems. Built on popular Wi-Fi standards using IEEE 802.11p, WAVE operates in a spectrum of 75 MHz at 5.9 GHz, reserved by the FCC specifically for high priority highway safety messages which may also be used for private applications. In addition to giving drivers information to help them reach

their destinations safely and efficiently, WAVE radio will open a range of transportation applications, such as Internet access, arranging for lodging, and ordering goods and services in transit. IEEE 1609 standards include:

- IEEE 1609.1, "Trial-Use Standard for Wireless Access in Vehicular Environments (WAVE) - Resource Manager," which describes the flow of the command-response interchange between multiple remote applications and the resource manager.
- IEEE 1609.2, "Trial-Use Standard for Wireless Access in Vehicular Environments - Security Services for Applications and Management Messages," which covers methods to make WAVE messages secure against eavesdropping, spoofing and other attacks.
- IEEE 1609.3, "Trial-Use Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services." IEEE 1609.3 is part of a standards family to support vehicle-to-vehicle and vehicle-to-roadside communications that will allow motor vehicles to interact with each other and roadside systems to access safety and travel-related information.
- IEEE 1609.4, "Trial Use Standard for Wireless Access in Vehicular Environments (WAVE) – Multi-channel Operation," which provides an interface to the medium access control of the communication stack and provides for multi-channel operation versus the single channel of IEEE 802.11p.

A fifth standard is underway as an architecture document that will give an overview of WAVE systems and their components and operation, as well as a context to better understand the content of other WAVE standards and IEEE 802.11. In assessing these and other new standards, it is important to note how long it takes for a refresh of vehicles on the roads, as the average age of a car is now over 9 years and increasing, as shown in Table II [3].

Therefore any technologies or systems that rely on new integrated systems will not see full benefits for 15 – 20 years from now. The average number of vehicles owned per household is also on the rise, shown in Table III [4]. That report shows that the number of cars owned per U.S. household has increased by over 60% between 1969 and 2001.

ON-BOARD SYSTEMS

Other on-board vehicle sensors include forward-looking radar as well as rear facing collision sensors [5]. While those devices are coming more commonplace in new vehicles there is no readily available market information on their adoption rates, although generally it is thought that

many newer cars will have them available in an integrated fashion.

TABLE II. AVERAGE VEHICLE AGE

Median Age of Automobiles and Trucks in Operation in the United States			
	Cars	Lt Trucks	All Trucks
1995	7.7	7.4	7.6
1996	7.9	7.5	7.7
1997	8.1	7.3	7.8
1998	8.3	7.1	7.6
1999	8.3	6.9	7.2
2000	8.3	6.7	6.9
2001	8.3	6.1	6.8
2002	8.4	6.6	6.8
2003	8.6	6.5	6.7
2004	8.9	6.4	6.6
2005	9.0	6.6	6.8

VEHICLE EQUIPAGE

Table III shows a Department of Transportation report on the number of vehicles on the road by type [6]. The same report allows the estimation of overall vehicle occupancy, which is 1.59 people per vehicle (excluding busses and public transport). As shown in Table IV, this is a gross median value per vehicle and may have no useful statistical meaning, but it does show, not surprisingly, that there is generally more than one person in each vehicle.

TABLE III. VEHICLE AVAILABILITY BY HOUSEHOLD

Vehicle Availability by Household		
	Vehicles per household	Licensed drivers per household
1969	1.16	1.65
1977	1.59	1.69
1983	1.68	1.72
1990	1.77	1.75
1995	1.78	1.78
2001	1.90	1.75

SOURCE: 1969, 1977, 1983, 1990, 1995—U.S. Department of Transportation, Federal Highway Administration, *Summary of Travel Trends, 1995 Nationwide Personal Transportation Survey* (Washington, DC: 1999). **2001**— U.S. Department of Transportation, Bureau of Transportation Statistics, *Highlights of the 2001 National Household Travel Survey* (Washington, DC: 2003).

CELL PHONE USE

STATISTICS - As reported by the Washington Post, a milestone has been passed with more than 3.3 Billion active cell phones on a planet of some 6.5 billion humans in a period of about 26 years [7]. This is the fastest global diffusion of any technology in human history, and industry experts predict another billion users by 2010 and the final billion or so with a few years thereafter. It is certainly the case that most U.S. adults carry an active cell phone, or

those driving and riding in vehicles. Coupled with the research noted above, it is therefore reasonable to assume that there is generally more than one, or at generally least one active cell phone in a vehicle on the road.

CELL PHONE LOCATION TRACKING -

Localization-based systems are network-based, handset-based, or hybrid. The handset based unit calculates its own position and the other techniques use various other methods to pinpoint the cell phone. The accuracy of each technique varies as follows:

- Cell and enhanced cell identification; the accuracy of this method can be as good as a few hundred meters in urban areas.
- TDOA - Time difference of arrival; the network determines the time difference and therefore the distance from each base station to the mobile phone.
- TOA - Time of arrival; similar to TDOA, but this technology uses the absolute time of arrival at a certain base station rather than the difference between two stations.
- AOA - Angle of arrival; locates the mobile phone at the point where the lines along the angles from each base station intersect.
- E-OTD; similar to TDOA, but the position is estimated by the mobile phone, not by the base station. The precision of this method may vary from 50 to 200 m.
- Assisted-GPS; uses an operator-maintained ground station to correct for GPS atmospheric errors. This accuracy can be as good as just a few meters.
- GPS with in-built GIS databases.; these units potentially provide far better positioning accuracy as they combine the satellite navigation with the smoothed tracking and the road network database, similar to that found in today's onboard automobile systems. These newer popular phones offer the ability to determine location very precisely.

TABLE IV. VEHICLE OWNERSHIP

	Number	Vehicle-Miles Traveled	Person-Miles Traveled	Avg. Vehicle Occupancy*
Cars	136.6 M	1.69 Trillion	2.67 Trillion	1.58
Light Trucks	95.3 M	1.06 Trillion	1.837 Trillion	1.73
Motorcycles	6.2 M	10.77 Billion	13.68 Billion	1.27
Heavy Trucks	8.5 M	222.29 Billion	222.29 Billion*	1
Total*	246.6 M	2.98 Trillion	4.74 Trillion	1.59

Notes: * denotes assumptions and derived data not included in the source report. Public transportation is excluded from this assessment as it would have unreasonably skewed the numbers of cell phones per vehicle upwards.

Using mobile phones to send alerts in some form of broadcast are used for other applications. For example, in Orlando, an emergency warning system is used for storm alerts [8]. Residents wear the equivalent of tornado-warning sirens on their hips during the hurricane season, and services provide alerts for tornado watches and warnings by e-mail and on electronic devices such as cell phones, pagers and PDAs. This type of system is a broad county by county solution and not necessarily real time. Other systems for mass alerting are now being used at Universities after various major incidents over the past few years. For example, there is an emergency warning cell phone test messaging system in place at Tennessee Tech University. Also Amber alerts use cell phone SMS broadcasting.

SYSTEM DEPLOYMENT FOR EMERGENCY SERVICES -

As shown in Figure 1, when an incident is reported, an emergency vehicle is dispatched and is tracked by various means. If the route of the emergency vehicle is known either from the driver, dispatch, or on-board navigation and routing system, then vehicles in the zone ahead are notified. If the route of the emergency is not known, then probable routes are estimated based on a-priori and other information. Vehicles estimated to be in the possible zones ahead of the emergency vehicle are notified and notifications cease once the destination is reached.

If the intended route of the vehicle is not known, the route is iteratively estimated as the vehicle proceeds en route. As the vehicle approaches an intersection, two zones are established, one for the first wave of siren forwarding and the other for the second wave of siren forwarding. This scenario is when the intended route of the emergency vehicle is not known, which is not always the case, as the route may be part of a satellite navigation GIS route or a dispatch-preferred route. Once the vehicle proceeds beyond the first intersection, the second zone may be automatically modified so as not to alert non-intervening vehicles or cell users.

Traffic flows in the intervening zones are determined using average velocity, track history, and dwell time of users. If there is an intervening user or users in the zone of interest, the user is determined to be a vehicle or not based on velocity, a priori information, height, and other information. The user is then notified by sending a message such as an SMS, call, or PTT, to cause the siren or similar ring-tone on the mobile device to activate. The system will continue to notify users until the destination of the emergency vehicle is reached.

Other cell phone users, based on their a-priori information may be determined not to be possible intervening vehicles, for example they may be office workers in adjacent buildings or high above in office buildings. Therefore, calls or notifications will not be made to those cell phones. A-priori information includes 3-D

position (i.e., including height) and the velocity of a track of the cell phone over a short period of time.

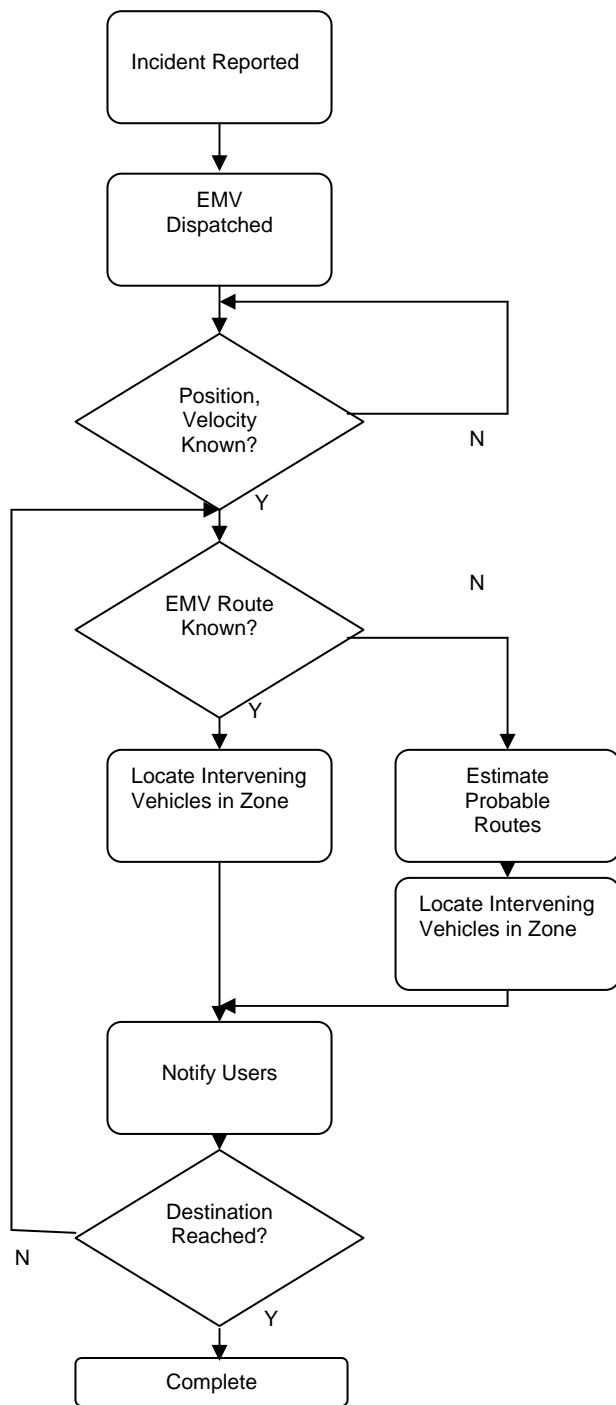


Figure 1. Auto Routing System

In other variations of the system, the route of the emergency vehicle is either estimated or known and the zone between the emergency services and the incident has been determined. As the emergency services vehicle proceeds along the route, calls are made to intervening vehicles, triggering siren ring-tones alerting them to the approach of an emergency services vehicle. Based on a-

priori information and general location of the users it is determined they are vehicles and must be notified.

In another application of the same system, once an incident is reported the emergency vehicle is dispatched. Traffic flows in the intervening zones are determined using average velocity, track history, and dwell time of users. Intervening users in the zone of interest are determined to be a vehicle or not based on velocity, a priori information, height above road level, and other information. The user is then notified by sending a message such as an SMS, call, or PTT, to cause the siren or similar ring-tone on the mobile device to activate. The system will continue to notify users until the destination of the emergency vehicle is reached.

CONCLUSIONS

Following an assessment of various vehicle data link and sensor systems it is concluded that there is insufficient equipage of any vehicle technology type in order to broadcast emergency services information to a meaningful number of vehicles on the road. While this may change in the future due to the introduction of new vehicle data links, it is unlikely to have a meaningful impact for the next 15 years or so, based on average vehicle age and new technology adoption by users.

An innovative system using cell phone technology to relay emergency sirens to the drivers of vehicles is described. The system uses intelligent techniques so as to locate and identify specific cell phone users that are in the path of an emergency vehicle. In addition, the system uses route estimation techniques to estimate and determine the path of the emergency vehicle. System modeling is underway to quantify the effectiveness, and trials in urban areas are being planned for 2009.

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