

AUTOMATED CRASH NOTIFICATION VIA THE WIRELESS WEB: SYSTEM DESIGN AND VALIDATION

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ABSTRACT

This paper reports on a research effort which seeks to dramatically reduce Emergency Medical Services (EMS) response time by developing and testing an Automated Crash Notification System (ACN) – an advanced in-vehicle system which automatically transmits the location and severity of a crash to EMS personnel. Existing ACN systems are expensive, tend to be available only for luxury car models and are not, in general, suitable for retrofit. This paper discusses the design, development, and testing of a new approach to ACN which combines emerging low cost single chip / chip sets for wireless Web communication, GPS position location and crash detection for low cost Automated Crash Notification.

INTRODUCTION

With the advent of trauma centers, the fatality rate of persons reaching a hospital after a car crash has dropped dramatically over the last twenty years. However in 1999, over 17,000 crash victims died in the U.S. before ever reaching the hospital [1]. Undoubtedly, some fraction of these deaths resulted from catastrophic crashes. However, many of these deaths can be attributed to the failure of Emergency Medical Services (EMS) personnel to reach the victim during the so-called “Golden Hour” after the accident when emergency medical treatment is most effective. National statistics clearly show that despite a growing wireless communications network and the availability of medivac transport, the time to notify emergency personnel of a crash and respond to the crash victims can be quite lengthy. For fatal crashes in the U.S., the average pre-hospital time is approximately 30 minutes in urban areas and 1 hour in rural areas [2].

Currently, emergency personnel must rely on passing motorists, highway patrols, and traffic reporters to report crashes. Often the individual reporting the emergency may not know where he or she is, let alone be able to direct help to his or her location. These delays can be especially lengthy in rural,

relatively unpopulated, areas where a crash site may go undetected for hours – and occasionally days.

Crucial to getting help to a crash victim is prompt notification that (a) a crash has occurred, (b) the location of the crash, and (c) some measure of the severity or injury-causing potential of the collision. Automated Crash Notification Systems capable of performing many of these tasks have been installed as expensive options on a limited number of high-end luxury cars. The OnStar System, for example, costs an estimated \$700 for installation, carries a \$200-400 annual fee, and is currently offered only for select General Motors models [3].



Figure 1. The Objective of Automated Crash Notification is to Improve Emergency Response Times.

The idea behind Automated Crash Notification is to equip cars with a crash sensor which can detect that an accident has taken place, and automatically notify the emergency medical personnel of the severity and precise location of the accident. Once activated, an Automated Crash Notification system would automatically transmit a signal to a 9-1-1 dispatch center, where an electronic map pinpoints the signal location. Precise location of the traveler in trouble enables rapid emergency response. More advanced

sensors can also estimate the injury-producing capability of the crash. The first estimates of the number of potential lives saved by ACN technology are 3000 lives per year [4].

Under the sponsorship of the New Jersey Department of Transportation, Rowan University has undertaken a research effort to design, build, and test a low cost Automated Crash Notification system that combines wireless communications and Global Positioning Systems with a network of inexpensive sensors for crash detection. The purpose of the system is not only to shorten the time it takes to notify authorities of the crash event, but to improve the quality of the response.

OBJECTIVE

The objective of this paper is to present the design of a low-cost Automated Crash Notification (ACN) System, and the results of performance tests to date.

SYSTEM REQUIREMENTS

The system is composed of two major subsystems: (1) the Mobile Unit which is installed in the occupant compartment of the vehicle, and (2) the Base Station which is responsible for receiving distress calls from the Mobile Units and reporting their location to emergency response dispatch personnel. This section describes the requirements of each of these subsystems.

Mobile Unit Functional Requirements

The mobile unit is responsible for detecting a crash, determining the location of the crash, and communicating crash severity and crash site location to the Base Station. Figure 2 presents the system architecture of the proposed device. The system consists of a single chip embedded microcomputer which is connected to a crash sensor, a Global Positioning System (GPS) sensor, and an embedded wireless modem. In the event of a crash, the crash sensor(s) will detect the vehicle impact, and output a signal proportional to the deceleration of the vehicle. The crash sensor signal output will be continuously monitored by the microprocessor which will decide whether or not a crash has taken place. Upon detecting a collision, the microprocessor will poll the GPS sensor to determine the final resting position of the car. The microprocessor will then use its wireless modem to establish a communications link with the Base Station. Once a link has been established, the Mobile Unit will transmit crash site location and the crash pulse to the Base Station. Ideally, the entire

process, including linkup, will be completed within 30 seconds after the crash occurred – giving EMS personnel a crucial edge in rapidly reaching the crash victim

The mobile unit will be installed either under the driver's seat or in another occupant compartment location. Locating the mobile unit in the occupant compartment will provide an accurate measure of the deceleration experienced by the occupants in a crash, and will protect the mobile unit with the same structural cage which protects the occupants.

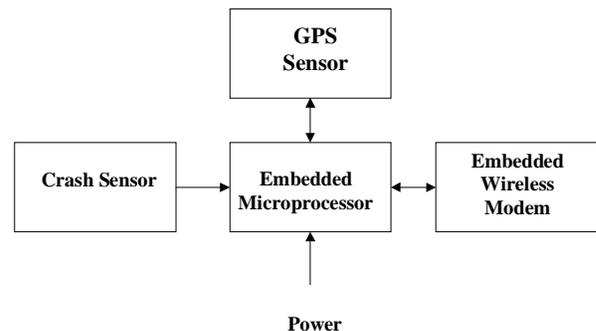


Figure 2. Mobile Unit Architecture.

Note that there is some degree of overlap between the Mobile Unit and components in late model cars. Since the early 1990's, all passenger vehicles sold in the U.S. have been required to have airbags. Increasingly, the sensors used in these systems are electronic sensors of the type to be used in this program. However, modification or connection to the airbag or any other safety systems of the car has been strictly avoided in the Mobile Unit for liability reasons. Eventually, automakers may choose to use these sensors to drive both airbags and ACN systems of the type discussed here in production cars. However, the Mobile Unit has been designed to be completely independent of all in-vehicle systems with the exception of the car battery.

Base Station Functional Requirements

The Base Station system will (1) receive the simulated emergency call over the Mobile Unit, (2) receive GPS data and crash severity from the simulated crash site, and (3) display the location and severity of the simulated crash using computerized maps for Emergency Response Team dispatch. Design concerns will include how best to present crash location and severity to the Base Station

operators, and ensuring that large numbers of calls can be handled simultaneously.

The long term objective of the ACN system, which must be addressed by follow-on research efforts, will connect the Mobile Units with existing or expanded 911 systems. However, this effort will require coordination with existing 911 system operators and careful attention to how best to present crash information graphically to operators who are more accustomed to receiving voice-only calls. This promises to be a difficult issue and is the focus of government-industry partnerships such as the National Mayday Readiness Initiative [5]. The Base Station developed here will provide an early evaluation of possible 911 operator user interfaces. The Base Station may also be suitable for limited field testing of the system for captive fleets such as the State Police.

Wireless Web Communication

One key enhancement of this system over existing ACN concepts is Mobile Unit-to-Base Station communication over the wireless web. Existing ACN systems are typically based upon circuit-switched communication in which the wireless network assigns a dedicated frequency to the call between the car and the base station. There are only a limited number of these frequencies. When they are expended, as many mobile phone users have experienced, the result is that phone calls do not connect. In the Rowan system, on the other hand, each car has a unique IP address and wireless communication is conducted using packet switching. In packet-switching, the signal is divided up into individual packets of data, tagged with the address of the destination, and transmitted over a common channel shared with other users to the destination computer which reassembles the message. The result is a continuous Web connection between the mobile unit and the base station which avoids the dial-up delays which are inherent in circuit-switched designs. Unlike the circuit-switched design which has the potential for phone call contention problems, the number of accidents which can be handled by a Web based ACN Base Station is, in general, limited primarily by the bandwidth of the Base Station Internet connection.

Wireless Data Protocol. The system will use Cellular Digital Packet Data (CDPD), sometimes referred to as a Wireless IP connection, to transmit data between the Mobile Unit and the Base Station. CDPD is a cutting edge wireless communications protocol which allows direct connection of remote devices to the

Internet. In addition to CDPD, the Mobile Unit has been designed for adaptation to other wireless communications options, including CDMA (Code Division Multiple Access) Data, GSM (Global System for Mobile Communications), and emerging third generation wireless protocols, e.g. GPRS (General Packet Radio Service) and W-CDMA (Wideband Code Division Multiple Access).

Message Content. After detecting a crash, the Mobile Unit must transmit a message to the Base Station which describes the crash location and severity. Knowledge of the crash location allows the EMS center to dispatch EMS crews to rescue the crash victim. Knowledge of the crash severity provides the EMS center with an early snapshot of the seriousness and potential injury consequences of the accident. The message to the Base Station will include both these data facets as well as information detailing the time of the crash and a description of the car. Crash location can be as straightforward as the GPS location longitude and latitude. Crash severity will be provided for each crash sensor, and will be either the delta-velocity or the crash pulse along each axis. It should be noted that while inclusion of the crash pulse requires transmission of a longer message, the crash pulse typically provides sufficient information to infer whether the car struck a tree or another car (which may require additional EMS personnel). Inclusion of crash severity for each axis allows the Base Station to distinguish between frontal and the potentially more serious side impacts.

RESULTS

This section summarizes the design of the Mobile Unit, Base Station, and the results of performance tests of the integrated system.

Mobile Unit.

The Mobile unit, shown in Figure 3, contains a two-axis silicon accelerometer, embedded 8-channel GPS system, embedded Z-World Z180 microcomputer, and embedded wireless modem. All components are mounted on a custom printed circuit board which was designed at Rowan, and constructed by an outside fabrication facility.



Figure 3. Mobile Unit: Research Prototype.

Power for this system was provided by the car 12-volt electrical system. Note that per our design guidelines this was the only interconnection between the Mobile Unit and the car. Power from the car battery was conditioned as necessary before input to the Mobile Unit electronics. Storage of backup power in a small onboard battery is currently being implemented to permit successful operation of the Mobile Unit even if car battery power were lost because of the crash.

A crash algorithm, a software module in the microprocessor, was developed to detect a crash while avoiding false alarms. The Mobile Unit must be able to distinguish between actual crashes and low-severity crashes or non-crashes such as panic braking or backing into a shopping cart. To detect a crash, the microprocessor samples the accelerometer output at 1000 Hz (1 sample per millisecond). Based upon examination of National Highway Traffic Safety Administration crash tests coupled with crash test modeling, the crash detection algorithm was designed to signal that a crash has occurred if a 10-miles/hour change in velocity occurs in under 50 milliseconds. To put these time intervals in perspective, the typical frontal-barrier crash has a duration of approximately 150 milliseconds while panic braking requires over 1000 milliseconds.

To ensure that the first prototype would not have shielding problems, the electronics were mounted in a casing machined out of single block of aluminum. The casing was machined on a CNC vertical milling center from drawings developed in Pro/Engineer. Later casing designs will be developed using lighter weight materials that provide comparable shielding.

Base Station

In the event of a crash, the Mobile Unit and Base Station will communicate using wireless Cellular Digital Packet Data (CDPD) technology over analog cellular networks. CDPD is a new wireless Web access technology with widespread coverage in the eastern United States. CDPD allows a direct TCP/IP link to be established between the mobile unit and base station. Using CDPD, the base station is designed as a Web Server, and the Mobile Unit reports a crash to the Server via a wireless Internet connection. This approach allows the base station to monitor multiple vehicles involved in crashes without the requirement for banks of dedicated phone lines. When the Base Station receives a message from a Mobile Unit, the Base Station displays the crash location and severity on a commercially available mapping product.



Figure 4. Base Station: Research Prototype

Performance Testing

To check the communication between the Mobile Unit and the Base Station, the completed prototype was tested in tracking mode. In this test, the Mobile Unit and associated antennas were mounted in a car, and the Mobile Unit was switched to its special diagnostic-tracking mode. When in tracking mode, the Mobile Unit automatically reads the GPS and transmits its location every second. Note that tracking mode is a research diagnostic only: this mode will not be included in the production prototype. During the test, the car with installed Mobile Unit was driven on a 10-mile circuit around Rowan University. From the continuously updated

map on the Base Station, we were able to track the student team as they drove from street to street, and even identify which lot they parked in upon their return.

Using a six-meter drop tower constructed for this task, the research team is currently subjecting the Mobile Unit to foam-covered barrier impacts up to 30 km/hr. These tests are designed to evaluate the survivability of the electronics to impact as well as testing the ability of the system to detect and report collisions of this magnitude. Impact tests to date have successfully tested the Mobile Unit at severities up to 10 G – with tests planned up to 30 G.

Following the completion of this project, future work will include a second research phase which will perform operational field testing of the ACN concept in 1000 ACN-equipped cars. The location of the cars will be geographically chosen to produce a fleet mix representative of New Jersey's mix of urban and rural highways. The second phase will also conduct additional laboratory performance testing of the ACN at the higher impact severities attainable in staged crash tests and HyGe sled tests.

CONCLUSIONS

This paper has presented the results of a research project to design, develop, and test a low cost Automated Crash Notification system that combines wireless communications and Global Positioning Systems with a network of inexpensive sensors for crash detection. Efforts to date have successfully designed and constructed a working prototype system. Successful operation of the prototype has been demonstrated in establishing a wireless web connection between the Mobile Unit and the Base Station. This paper has discussed the system requirements, summarized the design of the Mobile Unit and Base Station, and presented the results of performance tests to date.

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