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ABSTRACT

OnStar has always believed in the need for an embedded vehicle connection to fulfill the promise of telematics, which is the delivery of safety, security and information services to mobile customers. This was OnStar's premise at its inception in 1996, and the belief persists even today. With the planned launch of Advanced Automatic Crash Notification, OnStar and General Motors are poised to facilitate potential advances in the fields of vehicle safety and emergency medical response. These advances are made possible through the use of an embedded telematics system.

Critical crash data on qualified crashes regardless of airbag deployment may result in improved response time to the crash scene with the appropriate resources, as well as one-step routing to the correct emergency care facility. Moreover, the destination hospital can prepare for anticipated injuries predicted from the crash data. The ultimate benefits of these advances can however, only be reaped if the telematics module is embedded in the vehicle, and if the various stakeholders, across the medical emergency information chain, have the foresight to partner together to create open standards for crash data formats and protocols, and standards based national emergency network solutions.

INTRODUCTION

The cornerstones of telematics are safety, security and peace of mind; and Automatic Crash Notification (ACN) ranks as the service upon which telematics customers place the highest value. (See Figure 1)

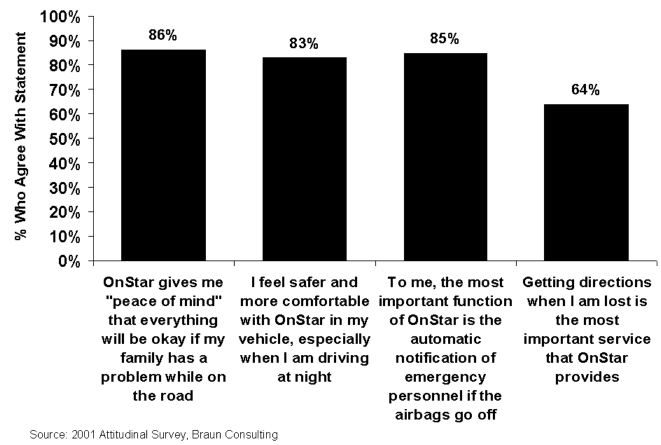

Figure 1: OnStar Subscriber Opinions of Safety Services

It is no surprise therefore, that OnStar is evolving its existing ACN service to the next generation Advanced Automatic Crash Notification (AACN) service.

While it is difficult to place an exact value on the significance of AACN, it does provide automotive companies with an enhanced opportunity to influence the events that ensue following a crash, when working together with the emergency response community.

Consider the following:

- According to the National Highway Traffic Safety Administration 2001 Annual Assessment of Motor Vehicle Crashes, 42,116 people were killed and 3,033,000 people were injured in vehicle crashes during 2001[1].
- The average length of time between fatal crash occurrence and arrival at a hospital emergency room is approximately 35 minutes in an urban area and 52 minutes in a rural area. Moreover, the arrival

of appropriate pre-hospital immediate care at an accident scene often exceeds the "Golden Ten Minutes" concept[2].

- Although less than 25% of total crashes occur in rural areas, they account for 60% of the nation's fatalities[2].

By providing faster notification of the accident location and crucial crash severity information as in the new generation advanced solution, AACN systems have the potential to improve emergency response. And, the implementation of these types of features into the vehicle may have an impact for OEMs as a vehicle differentiator in today's competitive new and used vehicle markets.

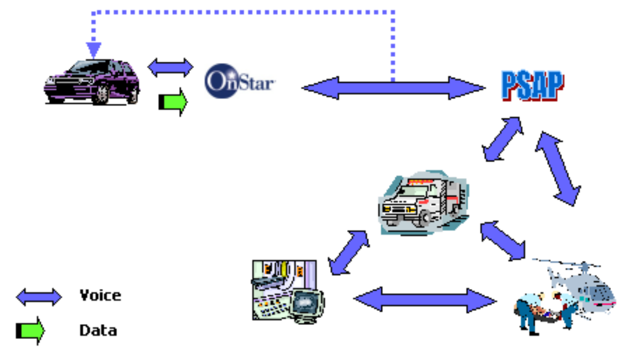

Figure 2: ACN systems today send signals to a customer service center when an impact causes an airbag deployment in the vehicle.

FIRST GENERATION ACN SYSTEMS

In 1996, General Motors OnStar introduced one of the first examples of ACN systems offered in the marketplace. The first generation ACN service entails an automatic call being placed by a telematics equipped vehicle to the Customer Service Center (CSC) upon the deployment of any airbag in the vehicle (Figure 2). The call made by the embedded module transmits the location of the vehicle along with an alert that a crash has occurred. The CSC advisor engages the vehicle occupant(s) in some preliminary communication and then confirms that the notification is not a false alarm. The advisor communicates the crash information to the appropriate Public Safety Answering Point (PSAP) or 911-dispatch center. The dispatcher can also be conferenced in to the voice call established into the crashed vehicle.

OnStar is the leader among Telematics Service Providers (TSP) delivering ACN services. Currently, over two million OnStar subscribers on the roads in the United States and Canada drive vehicles equipped with first generation ACN systems. The number of vehicles with ACN will continue to increase dramatically. OnStar is available on 44 GM models in the 2003 MY, as well as 11 models manufactured by a range of other OEMs.

Currently, OnStar responds to approximately 500 airbag deployments per month.

Other Telematics Service Providers (TSP) such as ATX Technologies also offer ACN systems on some luxury production vehicles.

NEXT GENERATION AACN SYSTEMS

OVERVIEW

AACN enhances existing ACN by incorporating additional technology enhancements. It will notify the CSC of a larger number of crashes by including notifications due to qualified rear, side and frontal impacts regardless of airbag deployment. As rollover sensing becomes available, it may also send notifications of a vehicle rollover. Furthermore, the system distinguishes between the type(s) of impact events and will transmit additional information related to the severity of the crash. The launch of this new system paves the way for further advancements in the field of emergency response.

SYSTEM COMPONENTS

<u>Sensors</u>

The new AACN system uses a collection of crash sensing devices that work in an integrated fashion to sense and discriminate between front, side and rear impacts, deployments and rollovers, as available.

The Sensing Diagnostic Module (SDM), which can aggregate information from a variety of sensors, is the computational engine for the AACN system.

The SDM itself contains internal accelerometers that measure the magnitude and direction of the impact forces that are experienced by a vehicle during a crash. These forces contribute to the nature and severity of the vehicle crash.

The SDM uses these accelerometers to estimate a quantity called Δv, which quantifies the change in velocity of the vehicle over time as a result of the impact.

Airbag Deployments

The new AACN data message broadly classifies which airbags deployed, e.g. left front, right side. For dual stage frontal bags, it further distinguishes between first and second stage deployments. It may indicate a rollover or near rollover event, if rollover sensors are available, as well as non-deployment events that exceed an established threshold.

Telematics Module

The telematics module receives the crash data sent by the SDM and places it in non-volatile memory to be transmitted to the CSC along with the location of the vehicle measured via the Global Positioning System (GPS).

A preliminary set of computations is carried out in the telematics module. Primarily, the Δv vs. time information is processed to derive the value of max Δv for each of up to two impacts associated with a specific incident. This exercise is done to minimize the payload being transmitted to the CSC, as transmission bandwidth considerations make it impractical to send the entire Δv buffers in a timely manner, and design considerations dictate that the data transmission should be completed as quickly as possible prior to establishing voice communication. In essence, the computations yield a max Δv. Trauma surgeons have conducted research to indicate that the nature of severe injuries is highly correlated with this value[3, 4].

Vehicle Bus Architecture

A serial data bus vehicle networking architecture is a pre-requisite for transmitting crash information through the vehicle to the OnStar module.

Conventionally, vehicle modules have been connected with each other over discrete data connections. In-vehicle networking or multiplexing using serial data connections has several benefits, including:

- Decreased number of dedicated wires decreasing cost and weight, while increasing reliability and serviceability.
- Flexibility with contenting and functionality.

Typical standards for networking include the SAE J1850 or Controller Area Network (CAN) standards.

Crash Sequence

Figures 3 through 5 delineate the sequence of steps following a crash that lead to the virtually instantaneous flow of data through the vehicle over its serial data bus, and the delivery of data to the telematics module for communication to the CSC over the wireless network.

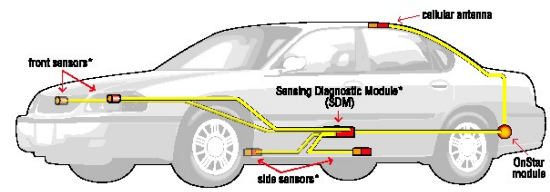

Figure 3: The GM AACN system uses front and side sensors as well as the sensing capabilities of the SDM itself. The accelerometer located within the SDM measures the impact force.

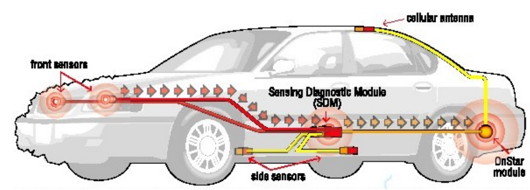

Figure 4: In the event of a moderate to severe frontal or side impact crash, data is transmitted from the affected sensors to the SDM. The SDM sensor also can identify a rear impact of sufficient severity. Regardless of whether the airbags deploy, the SDM transmits crash information to the telematics module.

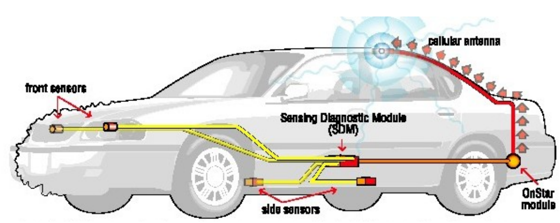

Figure 5: When a crash occurs, the telematics module will send a message to the CSC over a cellular connection, if a connection is available. After a brief data exchange, voice communication is established between the advisor and the vehicle occupants. The advisor verifies that there is no false alarm and contacts the appropriate 911-dispatch center. The advisor verbally communicates crash information and vehicle location to the 911 dispatcher.

Once a cellular connection is successfully established, a brief data transmission exchange occurs between the vehicle's telematics module and the data backend of the

CSC. The call is then switched to voice, and the advisor can conference in the appropriate PSAP identified in the Telematics Service Provider's PSAP database.

The advisor Graphical User Interface (GUI) will have a simplified representation of the crash information that indicates:

- Magnitude of Impact Force
- Direction of Impact force,
- Seatbelts status (as available),
- Seat occupancy (as available),
- Rollover & Final Rest Position Status (as available),
- Severity of crash as denoted by a standard NHTSA algorithm, and
- Other crash data.

Advisors will communicate pertinent crash data to the appropriate PSAP near the scene of the accident. The information communicated by the advisor will be limited to objective data that is not subject to any subjective interpretation on the advisor's part. Instead, advisors will leave the critical dispatch decisions and protocols to the experts, the PSAPs and the medical community.

All decisions on what subset of crash information to verbally communicate to the PSAP will be shaped by the dispatch needs of the PSAP community.

Crash Severity

The trauma community has extensively studied automobile crashes and their outcomes with the objective of correlating pre-crash and crash characteristics to the type and severity of injuries incurred by the vehicle occupants.

The NHTSA supported URGENCY algorithm is an existing computation that can take crash characteristics as inputs and produce the probability of casualty as output[3, 4]. Typical inputs into the algorithm include:

- Δv,
- Seatbelt status of the occupant(s),
- Side impact and/or rear damage to the vehicle, and
- Curbside weight of the vehicle, etc.

The output probability of casualty is defined on a continuous scale of 0 to 1.

The prediction of casualty and injury from this algorithm serves as a standard and common interpretation that may be used by all TSPs to communicate the severity of the crash. While this is only a statistic and not an exact predictor, when used in conjunction with other crash information such as Δv, it can help provide objective information about the crash that can provide the PSAP and medical communities with valuable clues useful in making prudent dispatch decisions.

These inputs into the dispatch protocol may result in the shortening of the timeframe required to:

- Send the appropriate level of response to the scene of the accident;
- Transport the crash victims to the appropriate emergency care facility; and may therefore reduce the system time interval between the occurrence of the crash and the initial emergency resuscitation conducted on the crash victims upon arrival at the final destination hospital.

Public Safety Answering Points (PSAPs)

Initially, the crash information transmitted by the AACN system will be communicated verbally to the PSAPs. In the future this information may be posted to a secure web server involving secure, authenticated delivery to PSAPs with a specified preference of a pull or a push of data. A pull would imply proactive intervention on the part of the PSAP to request the crash information, whereas a push would have the information delivered without any intervention by the PSAP.

In either scenario, the information will ultimately only be as valuable as the number of dispatchers who integrate it into their emergency dispatch protocols and leverage its full efficacy.

The above statement therefore contains the implicit assertion that the choice of specific data elements that will be communicated to the PSAPs must be defined in close collaboration with PSAPs and the medical community that ultimately treats the crash victims.

The medical and emergency response communities have long been interested in the genre of crash information that the AACN system will mostly deliver. These communities will undoubtedly continue to play a leadership role in defining standards for new dispatch protocols that will optimally utilize AACN information.

INITIAL SYSTEM DIAGRAM

The initial system diagram for AACN looks very similar to that depicted in Figure 2, with the caveat that additional information flows between the vehicle and the CSC and similarly between the CSC and the PSAP.

VISION: DERIVE MAX VALUE FROM AACN

The initial launch of AACN is a major achievement in the continued progression of automotive emergency response. To realize the maximum value and vision of AACN, a variety of technology and organizational enablers need to be instituted. Some of the salient enablers are described below. They can be broadly categorized into technology and organizational enablers.

TECHNOLOGY ENABLERS

Wireless Data Transmission Protocols & Solutions

Today, the quantity of data transmitted over a wireless network is limited by the network's bandwidth. For AACN, data transmission time to the CSC should be minimized so as to establish voice communication between the vehicle occupants and CSC advisor followed by the communicating with the PSAP without any significant delay. Similarly, once voice communication is established, it should be maintained.

As higher data rates for wireless transmission protocols become a reality, so also will the possibility of communicating larger data buffers from the vehicle to the CSC without interfering with the timely establishment of voice communication with crash victims. Some typical protocols that will enhance data transmission rates significantly are QNC, 1xRTT, 3xRTT, VoIP. Wireless data providers are currently working to implement these protocols ubiquitously in the United States.

While high bandwidth transmission protocols from the vehicle in a timely fashion presents one possible solution, SVD presents yet another. The capabilities presented by this nascent technology may permit the use of the voice channel to send data at the same time that the advisor is verbally communicating with the vehicle occupants and contacting the appropriate PSAP. A solution using this technology could offer significant flexibility to call center solutions because subsequent data queries after the establishment of voice communication would be easier to conduct. SVD technology must be perfected prior to being ubiquitously rolled out.

Secure Intelligent Internet Connectivity

The widespread utilization of crash information provided by disparate TSPs depends on the development of a centralized, secure access repository of crash data built in accordance with open standards and protocols. Such a secure web-server could potentially be owned and managed by a state entity such as United States Department of Transportation (USDOT).

Initially, the functionality of such a website would be targeted towards any PSAP with secure Internet access. In the future, crash information could be treated as a dynamic record with real time inputs from and outputs to various entities such as TSPs, PSAPs, EMS professionals, hospital ERs and surgeons.

Each authorized user could customize his/her browser's view in accordance with the recommended medical response protocols as well as targeted information needs.

Authorized users with read access could also define whether they want to pull the crash information or want it pushed to them. Moreover, they could define the triggers for pulling or pushing the data. Similarly, users with write access could have some flexibility in defining how they would write to an existing accident record.

Intelligence associated with the data warehousing and distribution capabilities would greatly enhance the utility of such a solution. For example it could use crash location to correlate entries from different sources that happen to be referring to the same crash incident. It could also notify pre-specified emergency contacts of the accident via a pre-specified push channel such as email, page, or SMS messaging.

Standard Data Schema Over Open Data Protocols

Regardless of the point or method of entries for crash information related to a crash record, a standardized data schema and open data protocols could greatly simplify the transmission and receipt of data for all concerned.

With this in mind, OnStar has been collaborating with its partners as well as other TSPs under the auspices of the COMCARE Alliance to create an XML data schema[5] that can eventually serve as a common language for data formatting and content for all entities with secure read/write access to a crash record.

Standardized PSAP Database

Currently, TSPs including OnStar and ATX manage and maintain individual PSAP databases covering U.S. and Canadian 911 dispatch centers. The OnStar database contains approximately 5,500 unique entries.

Several efforts are underway in the emergency response community to coordinate efforts that will establish a standard, centralized PSAP database that can be accessed by all TSPs alike. One such effort is the PSAP Registry by National Emergency Number Association (NENA).

An alternative approach to the solution is to centralize and offer connectivity at the national level to the regional PSAP databases that implicitly reside in the regional wireline 911 networks and are used for routing wireline/less 911 calls.

National 911 Network Connectivity & ALI Database

In addition to delivering crash data to PSAPs and other interested entities in the emergency response and medical communities, by posting to a secure webserver, OnStar would like to provide location information to the PSAPs in the manner and format with which their Computer Aided Dispatch (CAD) systems are most familiar.

The wireline 911-network functionality is being extended to accommodate wireless 911 calls. For an overview of the changes being made, refer to the TIA document for E911 Phase 2[6]. These changes however, do not take into account the special challenges associated with a

TSP's emergency calls. The primary differences arise because the emergency wireless call originated by the vehicle leaves the local geographical region to enter the TSP call center often across the country. Local 911 networks are just that, local. 911 trunks across the nation are not connected with each other, nor are 911 tandems (selective routers) that route emergency calls.

An entirely different network solution might need to be devised to overcome these challenges until such a time that the 911 networks can be connected at a national level and common standards and protocols can be established for routing the calls and accessing the ALI database.

One such solution could involve leveraging the existence of networks that unlike the 911 networks are already connected at a national level.

Migrating and Refining the URGENCY Algorithm

The establishment of a centralized, secure, national web-server may facilitate the migration of the URGENCY computations from the telematics providers backend to the national facility. This should help ensure that all incoming TSP data will be uniformly processed and interpreted prior to delivering a probability of casualty to the PSAP, EMS responders or hospital.

The current versions of the algorithm were derived by using the existing data in the National Accident Sampling System (NASS) database. This data consists mostly of inferred data, e.g. Δv is inferred from the crush of the vehicle, instead of being directly measured. Refinements achieved by utilizing measured, as opposed to inferred crash data, will further improve future credibility of the probability of casualty prediction.

Continually Advancing Sensor Technologies

The evolution of the AACN system will be an iterative process. Feedback from medical research and newly developed dispatch protocols will indicate the necessity for further information from the vehicles.

The launch of AACN will provide valuable insight into the next level of vehicle sensor technologies that can provide additional value to the emergency response community and the affected crash victims.

ORGANIZATIONAL ENABLERS

Advanced Dispatch Protocols

Crash information delivered by the AACN system will add value to decision making on two entirely different time scales:

1. The lead-time involved in the dispatch of appropriate response to the accident scene.
2. The lead-time before the crash victims reach the appropriate health care facility.

The PSAP and medical communities should collaborate with the TSPs and other relevant players to determine the respective subsets of crash information provided by the AACN system that can be quickly and effectively integrated into the decision making at the two levels.

Collaboration to Develop Standards & Open Systems

In addition to national standards for common dispatch protocols, technical solutions utilized in the transmission of data and routing of emergency calls should be standardized to the extent possible and maximum connectivity at a national level ascribed to the recommended solutions which must be architected to open design specifications. This should allow for improvements of system operation over time.

Vehicle functionality and features as well as call center service delivery can be considered competitive attributes of automotive OEMs and TSPs respectively and competitive market forces can be expected to lead to better products.

By contrast, the formats and protocols required for crash data transmission and distribution to the emergency response community are far from competitive. In fact, it is in the best interest of each player within the domain to adhere to mutually agreed upon, open standards for crash data distribution.

Entities such as the National Emergency Number Association (NENA), Association of Public Safety Communications Officials (APCO), Communications for Coordinated Assistance and Response to Emergencies (ComCARE) Alliance, etc. have created technical forums that are addressing these very issues and striving to create de facto data standards that should eventually evolve into widely accepted industry standards.

The need for collaboration on standards for emergency data distribution extends to other third party technology solution providers as well. There is a burgeoning awareness that the creation of proprietary, closed or regionally distinct (as opposed to nationally extensible) solutions will not merit long term viability.

FUTURE VISION SYSTEM DIAGRAM

Figure 6 provides a vision of what a future system diagram could be. Various emergency response entities will have secure read and write access as appropriate to crash information. As more knowledge is acquired about the vehicle and its occupants, the new information can be aggregated into a dynamic crash record that is ultimately delivered to the trauma surgeons treating the crash victims. The dynamic crash record can be maintained at a secure web server, which is managed by an agency such as the USDOT. Simultaneously location information is also populated into a national ALI databases that is linked to state and regional ALI databases. AACN calls are routed to the PSAP over 911 trunks and the appropriate PSAP is determined by the PSAP database implicitly maintained in the nationally connected 911-network.

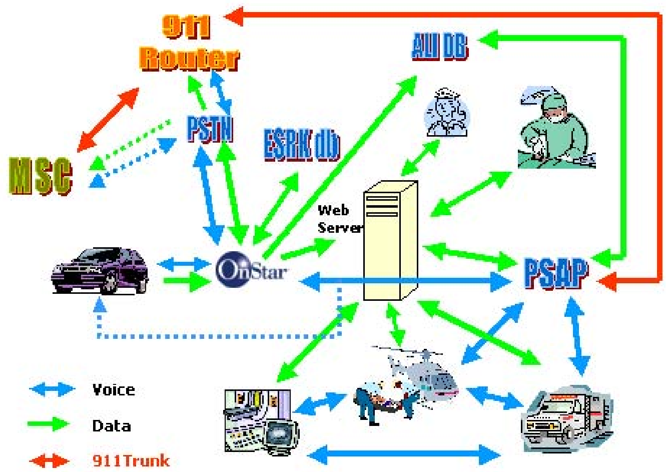

Figure 6: Vision system diagram for flow of crash information that is dynamically accessed and updated by various emergency response entities.

AACN CONTINUES THE ARGUMENT FOR TELEMATICS

As indicated in the paper's introduction, it is difficult to determine the direct value resulting from the inclusion of AACN in vehicles. It is however, safe to assume that the benefits of AACN to a brand, to consumers and to the telematics industry have the potential to be significant.

Today, the telematics industry is still in its early stages. The planned launch of AACN on GM vehicles in the 2004 MY, is a prime example of collaboration between the OEM and a TSP to further the capabilities of telematics within a vehicle line up.

AACN is yet another proof point that telematics is an enabling technology for OEMs and consumers.

For OnStar, the addition of AACN continues to support the OnStar business model, which is built on the core foundation of a consumer desire for safety, security and peace of mind in the vehicle.

OnStar has been demonstrating to the automotive industry the potential benefits of telematics for the past seven years. It has built a solid suite of services based on safety and security, and established partnerships with some of the premier OEMs in the industry.

CONCLUSION: A CALL FOR PARTNERSHIP

AACN offers a step in the right direction for emergency response and the future of telematics. Going forward, its success will be determined by the extent of collaboration that ensues between the stakeholders. Collaboration can create efficient, open standards for formats, protocols, and technological solutions to transmit and distribute crash notification and information (voice and data) to the appropriate entities, and competitively benefit all entities that use the standards.

ACKNOWLEDGMENTS

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

1xRTT: 1 times Radio Transmission Technology

3xRTT: 3 times Radio Transmission Technology

ACN: Automatic Crash Notification

AACN: Advanced Automatic Crash Notification

ALI: Automatic Location Identification

APCO: Association of Public Safety Communications Officials

CAD: Computer Aided Dispatch

CAN: Controller Area Network

ComCARE: Communications for Coordinated Assistance and Response to Emergencies

CSC: Customer Service Center

DB: Database

EPAD: Emergency Provider Access Directory

ER: Emergency Room

ESRK: Emergency Services Routing Key

GPS: Global Positioning System

MY: Model Year

MSC: Mobile Switching Center

NASS: National Accident Sampling System

NENA: National Emergency Number Association

NHTSA: National Highway Traffic Safety Administration

OEM: Original Equipment Manufacturer

PSAP: Public Safety Answering Point

PSTN: Public Switched Telephone Network

QNC: Quick Net Connect

SVD: Simultaneous Voice and Data

TSP: Telematics Service Provider

USDOT: United States Department of Transportation

VoIP: Voice over IP

XML: Extensible Markup Language