Infrastructure to Responder (I2R) Technical Memo

FINAL

March 18, 2019

Table of Contents

Introduction 1
- ITS Architecture for Incident Scene Safety Monitoring 2

Current Research 3
- Highway Automation 3
- Digital Infrastructure 5
- Public Safety Applications 7

Responder Interface Technologies 11
Expert Panel Input 11
Opportunities and Challenges for Future I2R 12
- Opportunities 12
- Challenges 14

Use Cases 15
- Rural I2R Use Case 15
- Urban I2R Use Case 17

Research and Development Needs 18
- Hardware 18
- Data integration 18
- User needs 18
- User interface 19

References 20

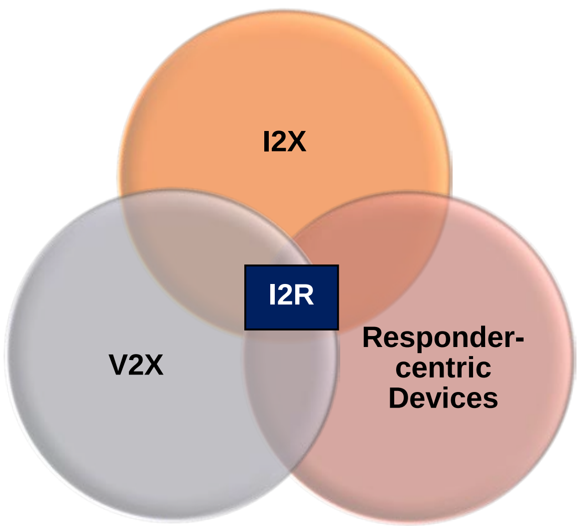
Infrastructure to Responder (I2R)
Technical Memo
FINAL

March 18, 2019

Introduction

The Transportation Safety Advancement Group (TSAG) provides important input to the U.S. Department of Transportation (U.S. DOT) Intelligent Transportation Systems (ITS) Joint Program Office (JPO) by identifying and promoting technology applications that address our nation's surface transportation safety challenges. TSAG is a group of volunteer members representing a wide range of public safety and transportation organizations, whose mission is to identify and advance technologies to improve public safety response and efficacy in transportation systems and promote transportation safety and efficiency in concert with the U.S. DOT ITS JPO.

This project looks at responder-centric and vehicle-based infrastructure to responder (I2R) applications to improve responder safety and situational awareness on the scene of highway incidents and en route to the scene or to a medical receiving facility. The specific focus of I2R sits at the intersection between infrastructure to everything (I2X), vehicle to everything (V2X) and responder-centric devices.



The increasing availability of data, analytics, and connectivity can enhance the safety and situational awareness of responders to highway incidents. This project focuses specifically on the emerging and future technology and applications that push warnings and information to responders through handheld or worn devices and to response vehicles at the scene or en route. The I2R focus includes device-to-device and digital infrastructure-to-device applications. By considering digital infrastructure in the definition, opportunities abound for information beyond sensors, such as geospatial and off-system data, that are critical to the operations and safety of responders.

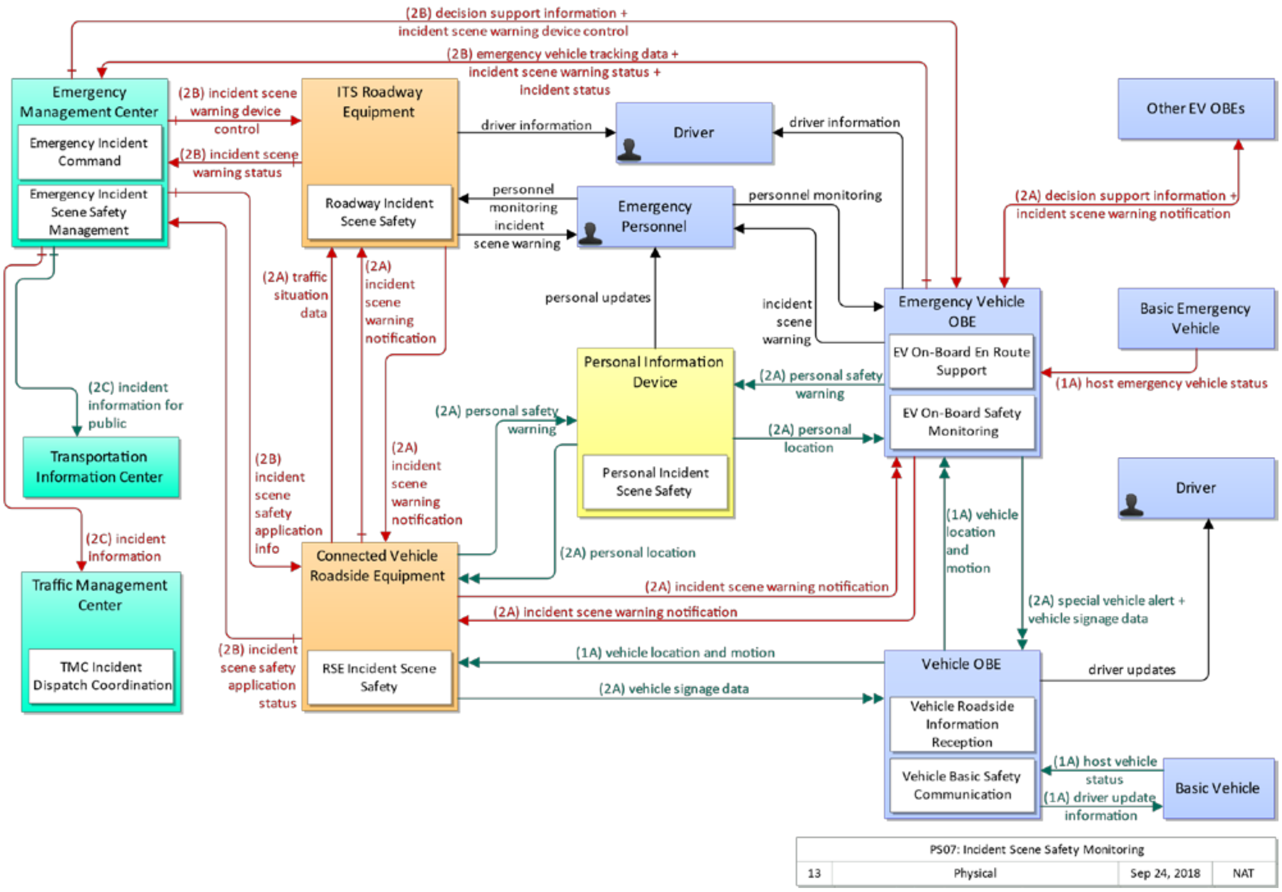
Examples of information that could be made easily accessible to on-scene responders include the following:

- Information on the proximity of hazards (e.g., storm water inlets or hazardous materials)
- Information on change of conditions (e.g., freezing temperatures or rising water)
- Notification of structural instability or damage
- Incident scene vehicle intrusion warnings
- Response route conditions
- Damage to utility networks
- Changes to dynamic message signs
- Traffic conditions on response routes

ITS Architecture for Incident Scene Safety Monitoring

The National Intelligent Transportation Systems (ITS) Architecture provides a framework for planning and deploying ITS applications in a consistent manner across agencies and jurisdictions. The National ITS Architecture program supports and guides agencies in collaborative planning, design, and operations of technology applications to address transportation challenges. The National ITS Architecture continues to evolve to include connected vehicle requirements, meet technology advancements, and comply with FHWA regulations.

The Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT Version 8.2) includes service packages that focus on specific ITS functions and their associated devices. The service package on Incident Scene Safety Monitoring employs technologies to provide warnings and alerts related to incident scene operations. This includes warnings to drivers in the incident area and to responders on scene. The diagram below shows the functional interface between infrastructure, vehicles, communications centers, and responders (in vehicles and through personal information devices).



Opportunities exist to expand ITS applications and evolve scene-safety through additional technologies and expansion of future ARC-IT frameworks. Examples of applications that connect responders to information from roadside equipment, sensors, and connected vehicles are discussed later in this document.

Current Technology and Applications

Extensive research is underway in the areas of highway automation, digital infrastructure, and the Internet of things (IoT) that is directly related to the focus of this project. A general overview of these areas of research is provided here as the basis for defining future opportunities for I2R applications that support public safety in transportation.

Highway Automation

“U.S. DOT’s role in transportation automation is to ensure the safety and mobility of the traveling public while fostering economic growth. As a steward of the nation’s roadway transportation system, the federal government plays a significant role by ensuring that automated vehicles can be safely and effectively integrated into the existing transportation system, alongside conventional vehicles, pedestrians, bicyclists, motorcyclists, and other road users. U.S. DOT also has an interest in supporting innovations that improve safety, reduce congestion, improve mobility, and increase access to economic opportunity for all Americans. Finally, by partnering with industry in adopting market-driven, technology-neutral policies that encourage innovation in the transportation system, the Department seeks to fuel economic growth and support job creation and workforce development." (U.S. DOT, October 2018)

FHWA defines highway automation as the "use of electronic or mechanical devices to operate one or more functions of a vehicle without direct human input," and notes that the term generally applies to all modes.

National Dialogue on Highway Automation

In 2018, the Federal Highway Administration (FHWA) held a series of workshops, referred to as the National Dialogue on Highway Automation, to engage partners, stakeholders, and the public in a conversation on how to safely and efficiently integrate automated vehicles on the roadway system. The purpose of these workshops was, in part, to help FHWA set its research priorities to meet the changing needs associated with highway automation. One of the sessions focused on what was referred to as a transportation digital infrastructure, which is needed for connected and automated vehicles (CAV) as well as to support I2R applications. The following is an excerpt from the read-ahead material for that workshop.

"A National Transportation Digital Infrastructure Framework is a potential organizing concept describing the readiness of the nation's roadway network for automated driving systems and other emerging aspects of the internet of things applied to surface transportation. This conceptual national framework recognizes the potential need for a ubiquitous nationwide digital equivalent to the Interstate Highway System to enable development of interoperable, market-based digital infrastructure solutions. FHWA's working concept does not envision the federal government directly building or operating a national transportation digital infrastructure framework. Components may include the following:

1. Infrastructure Systems Interface – connectivity across civic infrastructure systems, and between those systems and the digital environment.
2. Infrastructure Sensing – integrated and remote technologies to detect and monitor the physical condition of the infrastructure systems and the services they directly support.
3. Communications – diverse media integrated into networks to carry data and information that is being transmitted and received.
4. Data Collection and Processing – computing capabilities to organize and transmit data multi-directionally among infrastructure systems, organizational decisionmakers, and communities.
5. Analytics – tools and techniques for deriving actionable intelligence from data and information.
6. Mapping – static and dynamic georeferenced information.
7. Organizational and Community Interface – connectivity between the digital infrastructure framework and both public agencies and the larger transportation community."

The development of a digital infrastructure dovetails with I2R by supporting the delivery of a wide variety of mission-critical information, such as infrastructure status and geospatial data, and the communications and analytics framework to support responder safety.

Connected vehicle (V2X)

Connected vehicles are a significant driver in advancing a digital infrastructure. V2X includes connectivity between vehicles and the infrastructure (V2I), vehicles and vehicles (V2V), and vehicles and other connected objects. Research in V2X is looking at the opportunities and needs in all of these areas, including data sharing, data analytics, security, communication, and connectivity. Standard message sets are being developed to communicate between vehicles and the infrastructure or other devices. These message sets include signal phase and timing, signal status, roadside alerts, intersection collision avoidance and other operational messages. V2V safety messages addressed in standards include forward collision warning, do not pass warnings, and left turn assistance. These messages can be used by responders to enhance situational awareness and safety. Vehicle manufacturers are pursuing connectivity using either short range or broadband and there is some debate on the future direction of connected vehicle (CV) technology. Cellular V2X technology offers a flexible connectivity platform with a range of technical benefits such as longer distances, enhanced reliability, and higher data capacity. DSRC is an existing technology supported by current and planned roadside units deployed in dozens of states. Research and debate are ongoing with a desire to use these technologies to support roadway safety and the evolution of connected vehicles.

Digital Infrastructure

I2X

Infrastructure-to-everything (I2X) includes transportation sensors and communication devices that relay information to vehicles or to servers that can then process and use the information to make decisions in real time or identify trends for future management or planning decisions. I2X data can be direct machine-to-machine (M2M) communications or can be relayed through a network. Wireless sensor networks can be used to monitor the environment and the highway infrastructure. Current technology is largely sensor based, relaying information from roadside units to a vehicle or other receiver. Expansion of the digital infrastructure and the migration to 5G communications provides a much broader view of I2X that includes a range of data sources and data types beyond roadside units. I2X offers an opportunity to provide data from other connected services such as the electric grid, utilities and telecommunications services. Connected cities/communities are looking at opportunities for sharing data that can be packaged into applications for a wide range of users.

DSRC

Dedicated short-range communications (DSRC) provides two-way wireless communications that allows very high data transmission in V2V and V2I connectivity. DSRC operates on the 5.9 GHz radio frequency band and offers low latency and high reliability in a secure network. DSRC works in short to medium distances with little interference. DSRC communication is designed to work through transponders which are placed either in the vehicle (on-board units) or as roadside units. The U.S. DOT Joint Program Office for ITS has sponsored a connected vehicle pilot program in New York City, Tampa Florida, and Wyoming to test V2I communication and investigate best practices in connected vehicle technology, including DSRC. Data collected from vehicles through DSRC can provide information on roadway conditions to traffic management centers and between vehicles.

C-V2X

C-V2X refers to vehicle-to-everything technology. C-V2X functions in four different transmission modes. The first mode is direct communications between users (vehicle-to-vehicle, vehicle-to-infrastructure, and between vehicles and other road users). In this mode, the communication link is direct and its only relationship to cellular networks is that it uses the same waveform and time division concept of LTE; it does not need to make use of a SIM card. The second mode includes wide area access via the core network and this is often called vehicle-to-network (V2N). This wide area network mode of C-V2X does require network infrastructure and a SIM card, and can be simply regarded a natural evolution of cellular networks with some vehicle-specific features. This mode allows vehicles to receive information such as traffic and road conditions in the area.

Mode 3 is a direct communication mode of C-V2X that requires local infrastructure to 'referee' the time slots. Mode 4 includes a specification for distributed algorithms implemented between vehicles without network assistance. PC5 Mode 4 uses Global Navigation Satellite System (GNSS) receivers for synchronization instead of relying on cellular network coverage. The automotive industry in specific has shown Mode 4 specifications in light of the given availability of common spectrum. Operation in this mode does not require use subscription with mobile network operators and from a safety proposition, the common spectrum, combined with well-defined and standardized interfaces and minimum performance specifications on top of an LTE modem generally featured in new cars, enables vehicle safety communication.

5G

5G wireless broadband promises faster, more responsive, and reliable connectivity and new applications. 5G networks operate in a high-frequency spectrum and require hundreds or thousands of small cells attached to infrastructure such as signal, telephone, light poles, and buildings. This fifth generation of mobile cellular is comprised of a dense network of cells that will replace today's large cell towers and provide a more targeted and efficient use of spectrum. 5G will be able to support streaming video, large quantities of data, interconnected sensors, and the Internet of Things (IoT). It will support vehicle-to-vehicle (V2V) connectivity and smart city solutions and allow for real-time incident video sharing, remote health monitoring, and new data sharing applications. The conversion to 5G technology will take time and extensive investments in infrastructure to build the network with initial urban markets beginning to implement 5G today.

Cloud and edge computing

Data collection, sharing, and analysis is evolving through cloud and mobile edge computing. IoT, roadway sensors, and data warehouses provide extensive data that can be used to support real-time incident management and enhance safety. Cloud storage and computing can provide a reservoir of data for I2R applications that can dramatically change the types of applications and information available to on-scene responders, enhancing situational awareness and access to online resources. Cloud and edge computing go beyond the limits of machine-to-machine (M2M) communication to allow immediate access to a wide range of data types and sources. Edge computing allows extensive, localized collection of data to be analyzed close to the source and shared in near real time through the cloud. This level of analysis and connectivity offers enormous opportunities for I2R and the safety of responders and the public on highway incidents.

Smart cities

Smart cities initiatives use data available from the public, connected devices, and sensors to effectively manage transportation, electrical, water, public safety, hospitals, and other public services. It brings together IoT information and communication technology to monitor conditions and make informed decisions on network management and operations. As communities increase the collection and use of data from a wide variety of networks and devices, opportunities expand for the kind of data available to support I2R applications. This might include changes in roadway conditions, potential threats from a damaged power line, or impending weather events. The data may also provide real-time status reports from medical receiving facilities or emergency resource availability. New cloud-based services, IoT, sensor networks, and 5G communications can be used to leverage the data collected in smart city initiatives to enhance situational awareness and responder safety.

Public Safety Applications

There are a number of research and development initiatives related to responder connectivity and safety. These are being conducted by government, industry, and non-profit organizations interested in taking advantage of advances in technology to enhance incident response and public and responder safety. Christian Militeau's presentation "M2M and the Internet of Things (IoT): The Impact on Public Safety," presented at the Association of Public-Safety Communications Officials Emerging Technology Forum in 2015, offers a view on how the connected technology of sensors and devices can be used to enhance situational awareness and responder safety.   The exchange of data across a network of connected electronics and sensors provided some of the early applications of IoT in public safety. This presentation addressed a number of public safety applications, some of which apply to transportation-related incidents. It also presents a future for public safety service connectivity that includes mission critical voice, messaging, media, and data communications. The media and data components will become more accessible with the advancement of 5G broadband and may include incident photos, live videos feeds, geospatial data, IoT and M2M data, supplemental data, and data analytics.

Efforts are underway in various organizations to plan for and advance public safety applications using IoT and the digital infrastructure. The following discusses a number of these:

CARMA

FHWA has developed the Cooperative Automation Research Mobility Applications (CARMA) platform to support collaboration to improve transportation efficiency and safety. CARMA enables automated driving systems (ADS) to initiate cooperative tactical maneuvers with other vehicles and roadway infrastructure though connectivity and communication. The CARMA platform is vehicle and technology agnostic and is focused on research and development of cooperative automated driving system. CARMA is developing a number of use cases, including one for traffic incident management that provides new strategies for first responder interacting with ADS. This research could include I2R-specific applications to enhance situational awareness and responder safety.

Internet of Lifesaving Things

The National Public Safety Telecommunications Council Public Safety Internet of Things (IoT) Working Group is looking at public safety's use of IoT. The purpose of this working group is to examine the state of IoT and identify issues for consideration by the NPSTC Governing Board. The working group recently completed development of eight use cases that look at IoT solutions for various public safety scenarios. These use cases consider IoT data interoperability and the use of sensor systems and related safety applications to provide data to public safety agencies in an emergency. They are also looking at what standard operating procedures may be needed within response agencies to support the use of IoT in public safety applications.

A series of IoT webinars was developed by International Wireless Communications Expo that addresses "IoT Promises and Challenges and Connectivity" and "The Internet of Life Saving Things." The first webinar presents IoT ecosystems that include sensor, devices, and controllers; networks; edge, gateways, and analytics; analytics and applications; and users. The Internet of lifesaving things is a subset of IoT that connects to first responders to provide information. Future applications that support responder safety, such as heads-up display on glasses or helmet face shields, body-worn health sensors, can be combined with smart building and smart city data to provide real-time streaming video and geospatial information about the infrastructure and environment. The second webinar focuses on the communication networks needed to support the expanding responder connectivity opportunities, including direct connections, gateway access, and the promise of 5G LTE.

The National Emergency Number Association (NENA) has a Working Group on IoT and Apps. The Working Group is developing a document describing the impact of IoT devices and emergency applications on Next Generation 911, in cooperation with the National Public Safety Telecommunications Council other public safety organizations. The document will provide guidance to 911 professionals, application and device vendors, and data management and monitoring entities for NENA-endorsed products and applications.

Mission Critical Communications

Mission critical communications has traditionally focused on radio voice communication. As increased data and video information become available, consistent and expanded connectivity becomes increasingly important. Advances in broadband communications are impacting MCC with more changes promised with the implementation of 5G LTE. The First Responder Network Authority (FirstNet) is an independent authority within the U.S. Department of Commerce that was formed to develop, build, and operate a nationwide broadband network for first responders. FirstNet provides a broadband communication network dedicated to public safety. The focus is on reliability and secure and interoperable communications. It is working to provide expanded, reliable incident communications to support mission critical voice communications, priority network access, and enhanced data sharing and situational awareness. As 5G is rolled out, it presents opportunities for new services, applications, and data that may impact how Public Safety Answering Points (PSAPs) function. There will be a need for data analytics centers to provide real-time analysis and data integration during incidents; a function that could be done as part of a PSAP or as an adjunct to the PSAP.

National Institute of Standards and Technology (NIST)

The U.S. National Institute of Standards and Technology (NIST) is conducting research in a number of areas that relate to this project. The Global City Teams Challenge program, led by NIST in partnership with the U.S. Department of Homeland Security Science and Technology (DHS S&T), National Science Foundation, International Trade Administration, and National Telecommunications and Information Administration, enables local governments, nonprofits, academic institutions, technologists, and corporations to form project teams, or clusters, to work on IoT applications within city and community environments. The Public Safety SuperCluster (PSSC) is focused on identifying technologies, processes, and strategies to enhance public safety and resilience within smart communities and improve preparedness, response and recovery. It is focused on the integration of IoT technologies and is working to develop, integrate, and pilot applications with first responders.

The NIST Public Safety Communications Research Division is studying ProSe (proximity services) technology associated with the next generation cellular broadband service. The focus of the research is on direct communications between response personnel on an incident without the need for an intervening network. ProSe has been found to have a reduced coverage range for direct mode communications compared to its predecessor technology. This is potentially problematic if the range is substantially shorter than current direct mode communications. They are also looking at reliability, impacts of system self-noise, and standard definitions for direct mode to ensure ProSe meets user expectations.

The NIST Public Safety Communications Research Division's First Responder Personal Area Network project is working to identify and address barriers in the assimilation and utilization of IoT data during incident operations, looking at interoperability between platforms and data accessibility.

Department of Homeland Security (DHS) Science and Technology (S&T)

DHS S&T's mission is to enable effective, efficient, and secure operations across all homeland security through science, engineering, analytics, and innovation. S&T works with response agencies to improve safety, communication, and information sharing. The First Responder Resource Group is made up of 140 first responders who work with S&T to identify high priority capability gaps and define operational requirements for technologies to fill those gaps.

DHS S&T established the Smart City IoT Innovation (SCITI) solutions lab to focus on the integration of technology into public safety applications through validation and go-to-market support. DHS S&T describes the lab as a place "where commercialization meets public safety." One area in which SCITI is exploring new capabilities is in a body-worn interoperable platform that integrates personal area network communications with third-party sensor packages. The Smart Hub communicates with smart city and smart building technologies for enhanced situational awareness and mission-critical operations.

Another DHS S&T initiative that relates to this project is Datacasting to broadcast real-time video and critical data using the existing digital television spectrum. This project looks at an alternative to sharing video and data over existing public safety networks by using TV spectrum using less bandwidth. Datacasting uses available spectrum no longer needed for television programming by reallocating a portion of the spectrum. Datacasting can transmit video, data, and other critical information without relying on or overloading other communication channels.

Open Geospatial Consortium

The Open Geospatial Consortium (OGC) is an international industry consortium of more than 500 companies, government agencies, and universities whose mission is "to advance the development and use of international standards and supporting services that promote geospatial interoperability." OGC recently published an "Incident Management Information Sharing (IMIS) Internet of Things (IoT) Architecture Engineering Report" that discusses issues associated with sharing networked sensor technologies in support of incident management. It includes a transportation incident scenario and a broad range of sensor and IoT applications to support incident response and management. Josh Lieberman, Director of OGC's Innovation Program, conducted research on geospatial incident information sharing while a senior research scientist at the Harvard CGA. This research focused on near real-time information in the context of emergency situations to support responder safety. An overview of this research is available in the presentation "Internet of Things (IoT) Meets Sensor Web Enablement: First Responder Pilot," available on YouTube. This research looks at how to provide responders actionable information in an interface that is useable on scene.

Smart Mobility Applications

Research is also occurring in private industry to support smart mobility in transportation agencies. Some of the companies working in this area include AT&T, Panasonic, Verizon, and Amazon Web Services.

AT&T's Smart City Initiative includes applications in digital infrastructure, smart cities operations, and structure monitoring. The digital infrastructure area includes sensor installation, information gathering, and analytics. They are also looking at how near real-time data can be used to address traffic-related issues. The smart cities operations applications include a near real-time view of critical resources and service delivery, and their structure monitoring services include remote monitoring of structures in near real-time. Each of these has a potential for enhancing safety for incident responders through increased situational awareness with the development of responder-specific interface applications.

Panasonic's Smart City Solutions is working to integrate smart city solutions and connect cars and roads. They are developing an application for the Colorado Department of Transportation to share real-time data across vehicles, infrastructure, and people to improve safety and transportation operations.

Verizon's Smart Communities offers intelligent lighting, intelligent video, intelligent traffic management, traffic data services, and a real-time response system that may have future applications to support responders in making informed decisions on scene. For example, the real time response system provides a holistic view of a partner city and supports inter-agency collaboration, enhances situational awareness, and improves decision-making by integrating computer-aided dispatch, GIS, sensors, third-party databases, and other information into a common platform.

Amazon Web Services focuses on cloud technology to leverage existing data sources, integrating additional datasets, accessing sensors, and providing analytics to support smart, connected and sustainable cities. Their Emergency Aware Service platform applies algorithms and analytics to IoT data and feeds them to responders to support real-time decision-making. They offer a number of other public safety applications that include flood detection, fire detection, vehicle mobile hotspot, gunshot detection, and mass alerts.

Responder Interface Technologies

Connected responder technologies include handheld radios, cellular phones, and sensors; body worn devices such as heads-up displays, personal area networks and warning devices; and vehicle-mounted devices that provide video and geospatial scene information.

Handheld devices include radios, cell phones, sensors, or other application specific devices. These devices must be able to withstand the harsh environment of roadway incidents and useable with standard personal protective equipment such as gloves and eye protection. Applications are needed to provide an effective user interface that distills data into actionable information specific to the location and the incident.

Body-worn technologies include heads-up displays in glasses or visors, environmental and health sensors, and personal area network technology. Body worn devices can be voice or motion activated and keep responders hands-free on devices while accessing information. The kind of information that could be accessed through these devices includes geospatial, weather, infrastructure, and other data available on vehicle-mounted devices through the heads-up display or sent digitally by the PSAP. Work area intrusion and infrastructure stability warnings can be provided as auditory warnings to inform responders on scene of safety threats.

Vehicle mounted devices can be larger than handheld or body-worn devices, although space is limited in response vehicles. In-vehicle technology can provide access to data, voice, video, and photos and provide incident network capabilities to enhance communications across agencies and personnel on scene.

Expert Panel Input

In developing this technical memo, TSAG invited leaders in the fields of communications, data analytics, and public safety to participate in a discussion on September 25, 2018. The meeting was intended to bring responders and industry together to explore new ideas, identify areas of greatest need, and highlight emerging technology capabilities for future applications. The focus included brainstorming future applications to improve the safety and situational awareness for emergency responders on highway incidents.

Participants on the Expert Panel discussion included the following individuals:

Barry Fraser, NPSTC IoT Work Group
Skip Yeakel, Volvo
Mike Brown, IAFC
Nick Nudell, Paramedic Foundation
Jim Misner, Qualcomm
Barry Einsig, Cisco
Dean Skidmore, IoT+LTE Consulting Group
Dia Gainor, NASEMSO
Nancy Pollock, APCO

Some of the areas of greatest need identified by the group looked at connectivity and interoperability on scene; the integrity of information (accuracy and timeliness); security and cybersecurity; quick identification of resource needs; vehicle and passenger information; on-scene accountability, especially on extended responses; alternate route and access information for responders; structural hazards; scene weather, surface conditions and hazards; and information overload.

Discussion of future I2R opportunities included the need for different graphical user interfaces (GUIs) for different users, that can provide data only as requested or needed and supported by machine learning. The advancement of 5G enhanced mobile broadband service, increased data through vehicles, sensors and IoT, and edge and gateway analytics offer increasing access to real-time mission critical data. Some of the existing challenges to advancing I2R applications relate to the need for a PSAP or data analytics center to manage data as a centralized hub of information; current lack of ubiquitous connectivity in the field; and potential evidentiary and cybersecurity issues with direct communications.

A follow-up conversation with Dean Skidmore addressed opportunities arising from smart cities initiatives as more information is digitized and data cuts across silos of disciplines and applications. Opportunities also exist in coordination with DOTs and the energy sector to leverage the public safety framework for smart cities interoperability.

Opportunities and Challenges for Future I2R

Opportunities

As communication networks, data analytics and integration, and data gathering improve and expand, there are opportunities for developing responder-centric applications to enhance safety on roadway incidents.

5G
One of the significant opportunities for expanding the digital infrastructure and providing new information sharing capacity lies in the evolution to 5G communications. As previously noted, 5G will allow much larger data streams, video sharing, and multi-functional connectivity for responders in the field. 5G enabled devices – handheld, worn or in-vehicle – will be able to communicate more actionable information faster. Currently, 5G is being installed in a few initial cities with a national rollout of 5G over the next few years. Once in place, 5G will allow text-to-911 service; live, streaming video and incident photos that can be accessed by responders in the field; access to large data sources; and enhanced communications.

Mobile cloud computing
Mobile cloud uses a combination of mobile computing, cloud computing, and wireless networks and offers the opportunity for data analytics and access to cloud-based data sources such as infrastructure information, traffic data, the status of medical receiving facilities, occupancy data of buildings in the event of an evacuation, and sensor data.

Edge computing
Mobile edge, or multi-access edge computing (MEC) provides cloud computing capabilities at the edge of a network, including at the edge of a cellular network. It enables processing and analytics to occur closer to users, reduces congestion, and improves application performance. This allows third-party application developers and content providers to use the network, providing an opportunity for responder-focused applications to expand in the MEC distributed computing environment. Third-party applications that support the safety of traffic incident responders can take advantage of MEC to provide mission-critical information more quickly.

Smart communities
As more communities take advantage of smart technology, more data will become available that can be used to enhance incident response. This may include the status of utilities in the vicinity of an incident, the location of response personnel and equipment, or infrastructure damage at the scene. By monitoring, analyzing, and sharing this information, smart communities can provide a data source for developing responder-centric applications that share physical infrastructure information with responders.

IoT
The Internet of things (IoT) includes sensors that are placed in the field to collect specific incident-related information such as traffic, weather, or structural conditions. Additional information can be collected from other connected devices that may include smart city technologies and consumer devices. As more IoT devices are employed in the public (personal IoT devices, sensors in and on persons in vehicles), that information can also become available in the response system.

Challenges

There are a number of challenges to be overcome to take advantage of the emerging technological advancements that will enable I2R applications. These include both technological and institutional challenges, discussed below.

Connectivity

Connectivity is essential to the full develop of I2R potential. FirstNet provides priority connectivity to its users but is dependent on current broadband wireless service which has limitations on coverage, particularly in remote and rural areas. The evolution of 5G offers greater speed and bandwidth but is going to take time for full implementation. Because 5G requires a higher density of smaller antennae, there is a potential for gaps in the system in more rural areas that would be filled by 4G technology until 4G is rolled up into 5G.

Data security and privacy

Security and privacy are continuing concerns with data collection, management, and distribution. Cybersecurity and evidentiary integrity and data storage costs and management are also problematic with direct communications. These issues must be addressed to ensure acceptance of new applications by responders.

Data and network integration

With increasing sources of data from sensors and databases, and expansion of communication networks, standards and interfaces to support interoperability are needed to integrate and share information. PSAPs may take on an expanded role as data analytics centers, collecting, analyzing, and distributing mission critical information. This would require expanded capabilities, technology, costs, and staffing which could be supported to some degree with artificial intelligence or machine learning applications to support staff in a more complex environment.

NG911

In order for sensor data or other information collected through IoT devices to be provided to responders through the PSAP, information from the devices must be sent with the 911 call. Information may include automated crash notification (ACN) data from the vehicle, photos, messages, and other IoT data. NG911 will allow data to be sent with 911 calls. Data sent with calls can then be sent to responders through the FirstNet system from the PSAP. In order to fully integrate data, messaging, and video in 911 calls, implementation of NG911 must be realized.

User acceptance/change management

New technology is not always welcomed in the field, particularly if it is seen as complicating response or increasing information overload. Applications must be simple enough to be easily used in the field with targeted information and push notifications. They must be sophisticated enough to process extensive information sources and provide location and incident-specific information in initial feeds, allowing users easy access to secondary information depending on change of condition or incident focus.

User acceptance will come through training, use cases, familiarity with new applications and ease of use. It will also be necessary to modify agency standard operating procedures (SOPs) to include emerging technologies and integrate their use into training and response.

Field conditions

User interfaces that work within an incident environment present a number of challenges. Responders function in challenging and harsh environments and use personal protective equipment that may limit the use of traditional interfaces such as touch screens. It is also important that responders, PSAPs and operations centers share data in unified displays to maximize efficiency and minimize the time needed to access mission critical information.

Application development

To develop I2R applications that take advantage of the full range of IoT, network and geospatial data, will require an open ecosystem for application and device developers. It will also require adequate interest and demand from the response community to stimulate investment by potential developers.

Use Cases

One way to help responders understand the potential for I2R technologies is to look at use cases in which data and applications support response and enhance safety. There are two use cases presented here, one for a rural highway incident and the other for an urban highway incident. Each lays out an example of how a developed digital infrastructure and responder-centric applications can be used to improve situational awareness, resource allocation, and safety.

Rural I2R Use Case

This use case looks at the potential information available to responders using I2R applications during a crash on a rural highway. In this scenario, a tractor trailer has hit an overpass on a rural highway, dislocating a bridge pier and bursting into flames. The local PSAP has been alerted by a 9-1-1 call from passers-by. Local fire-rescue has responded to the scene and is using a number of applications to augment its initial windshield survey and response. Given the location of the incident, the condition of the overpass, and potential environmental threats, responders are using I2R applications to determine and mitigate additional safety threats. The PSAP is sending information and data received from other intelligent devices and technology such as traffic, road sensors and weather sensors.

Upon arrival, fire/rescue finds a fully involved tractor trailer under an overpass. As the first unit arrives a warning is received on vehicle-mounted and handheld devices that the bridge is structurally compromised. Second-in units are directed to approach the incident from the opposite direction to avoid passing under the overpass. Fire/rescue suppresses the fire and extricates the driver. Due to the extent of injury and the location of the incident in a remote rural area, air evacuation is required to transport the driver to a Level 1 Trauma Center. Geospatial data available to fire/rescue and the ambulance service push information on the closest predetermined landing zone to the PSAP for dispatch of air response.

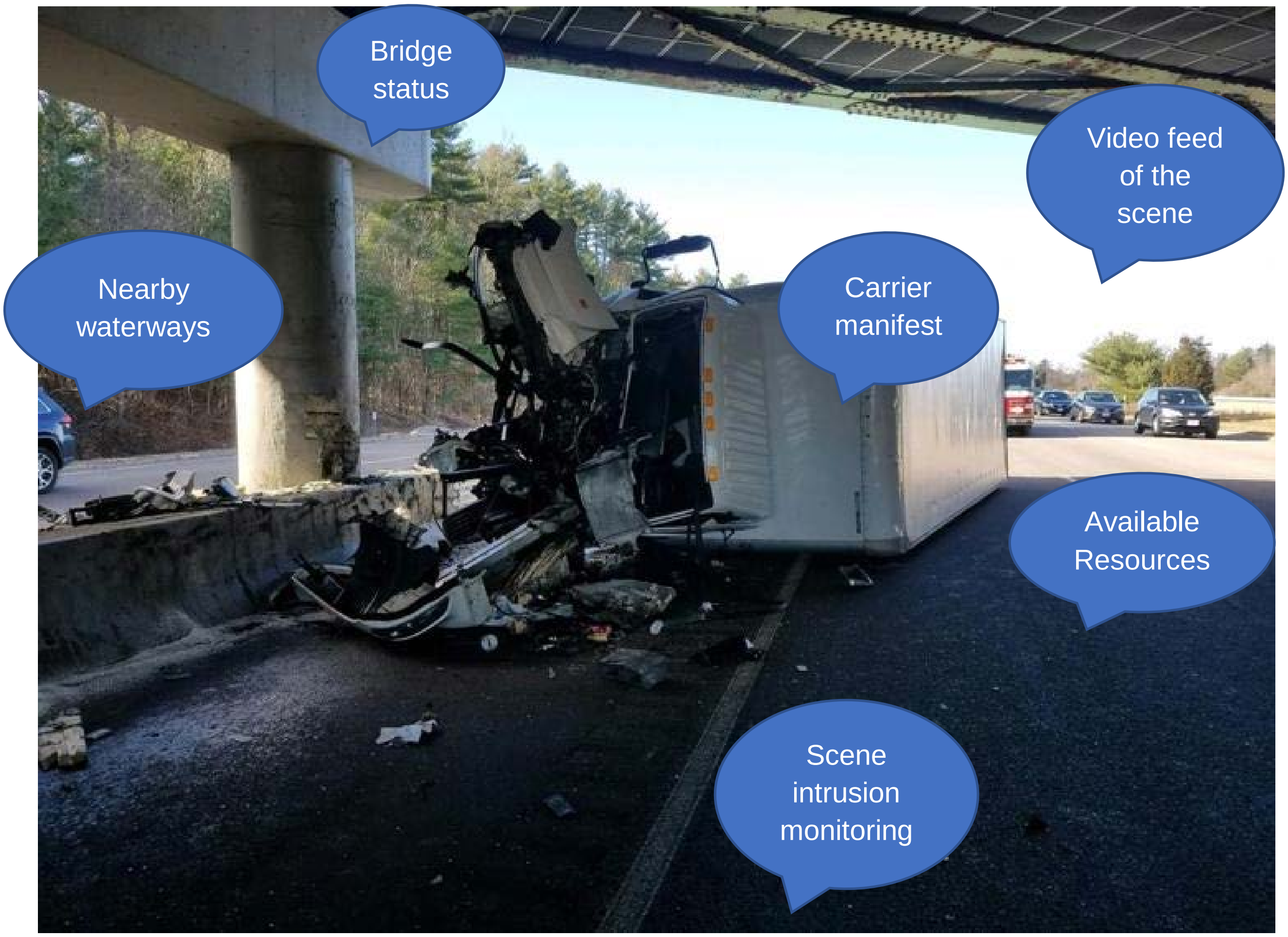


Photo: Mansfield Fire Department, MA

Incident command is able to monitor the scene from a safe distance using a video feed from a camera mounted on the underpass as part of the DOT's traffic monitoring program. Command accesses data from weather and roadway sensors to determine if weather will impact response or hazardous materials containment, and to consider the number and location of vehicles within a one-mile radius of the scene. This feed comes into the vehicle and handheld devices through a response application that integrates infrastructure sensors and data and delivers actionable information based on the location of responders. The application also provides infrastructure status (including the structural damage to the bridge) and information on traffic on the highway and overpass roadway. Using the application, command creates a geofence around the scene to monitor for vehicle intrusion into the incident work area. Because the incident included fire suppression and a diesel spill, responders are able to use the geospatial data in the application to determine the threat of hazardous materials entering a nearby waterway and take containment actions. To ensure that there are not additional complications or threats from the cargo, responders check the carrier manifest through a portal on the response application.

Urban I2R Use Case

The urban use case looks at roadway flooding with multiple vehicles involved and stranded motorists. In this scenario, heavy rains have flooded an urban highway causing fast rising water during the afternoon peak hour. Vehicles unable to avoid the flooded area have become stranded with water continuing to rise. Initial responders confirm the information received by the PSAP that 12 motorists are stranded in their vehicles needing rescue.

Accessing their emergency response applications, incident command is able to determine the availability of water rescue equipment and personnel to support the rescue of stranded motorists. Response personnel attempting to wade into the area receive a warning on their body-worn device that there is a stormwater intake nearby, creating a safety risk to responders and motorists who leave their vehicles. Command checks the location and status of power lines in the area to be sure there is not a risk associated with down power lines in the area. Responders receive a warning of increasing rain and rising flood waters from flood sensors in the area. Incoming units and on-scene responders receive a warning that temperatures are dropping and roadway sensors indicate that the highway surface is beginning to freeze, creating a hazard for vehicles in route and responders at the scene.

Photo: FEMA/Scott E. Schermerhorn

Research and Development Needs

Successful integration of I2R technology into daily use on transportation incidents will require ongoing research in hardware, data collection and integration, user interfaces, and most importantly user needs, to determine the most effective way to deliver mission critical information from the digital infrastructure directly to responders on scene and en route to the scene.

Hardware

An area that requires additional research is in determining the best delivery mechanism – handheld, body-worn, in vehicle – for delivering information from the digital infrastructure to responders. Each of these three options have advantages and limitations and is more appropriate for different activities associated with responding to an incident, on-scene command and operations activities, and transporting patients from the scene. For example, information appropriate for en route to or from an incident may appropriately be delivered in vehicle while safety alerts or time sensitive situational awareness information needs to be delivered directly to response personnel through handheld or body-worn devices.

One of the greatest hardware challenges, particularly for handheld and body-worn devices is in addressing the harsh environmental conditions associated with traffic incidents (temperatures, precipitation, lighting, etc.) and user interface limitations associated with personal protective equipment (gloves, eye protection, heavy clothing, etc.). Information that needs to be delivered directly to personnel in the field must overcome these challenges to ensure information is delivered effectively.

Data integration

With increasing data sources from roadway and environmental sensors, smart community networks, geospatial databases, V2I feeds, crowdsourcing, and other connected devices, it is important to identify the full range of available data and data sources, determine the availability of data from each of the potential sources, consider sharing restrictions (legal, institutional, structure, platform, etc.) and prioritize sources for integration.

Integrating data from the various sources will require an understanding of the disparate data structures, architectures, and collection processes to bring together data into valuable and meaningful information. This could include cloud-based collection and analytics or could be accomplished through networking various sources. It will be important to create an open data environment to allow the development of applications that can draw from all of the critical data sources.

User needs

Identifying what responders need in terms of mission critical, actionable information is essential for developing meaningful user applications. One of the challenges in determining user needs is bridging the gap between what is available now and what is possible. Users may not have a sense of the variety and depth of data currently and potentially available through the digital infrastructure. It is essential to engage the response community in exploring the opportunities available through emerging data sources and expanding communications. Without this interaction, opportunities for life saving applications will be missed and go undeveloped or unused.

In addition to understanding user needs and potential applications, it is also important to determine the best delivery mechanism for each type of information based on the role of the user, the time sensitivity of the information, etc. Perspective on user needs and delivery options must be based on responder experience in order for new technologies and applications to be fully embraced.

User interface

User interface is also critical to acceptance and use of I2R technology. Ease of use is essential to ensure that any new devices or applications are more helpful than distractive. An extra second spent trying to access scene information is a second of delay in time-critical response. Responder interfaces must focus on providing essential information in a timely manner without extraneous data that distracts from the task at hand. Applications must avoid information overload and should be developed using artificial intelligence or machine learning to anticipate what information is critical to different users at different points in the response.

A consortium of users, network service, data providers, and application developers should be brought together to determine information needs, address technical and institutional barriers, and build support for research and development of I2R devices and applications. TSAG's member constituencies include academic and research organizations, emergency communications, emergency management, emergency medical services, fire/rescue, law enforcement, technology and telematics, and transportation operations. This broad representation of interests and abilities provides a strong foundation for exploring the challenges and opportunities of I2R to enhance situational awareness and public safety on our nation's roadways.

References

Colorado Department of Transportation, CDOT-Panasonic V2X https://www.codot.gov/news/2018/july/cdot-and-panasonic-take-first-steps-to-turn-i-70-into-connected-roadway

First Responder Network Authority, https://firstnet.gov/

Lieberman, Josh, “IoT Meets Sensor Web Enablement: First Responder Pilot,” https://www.youtube.com/watch?v=S1HvC3RAH8I

Militeau, Christian, “M2M and the Internet of Things (IoT): The Impact on Public Safety,” https://techforum.apcointl.org/wp-content/uploads/2D-Militeau-M2M.pdf

National Dialogue on Highway Automation, https://ops.fhwa.dot.gov/automationdialogue/

National Public Safety Telecommunications Council, Public Safety Internet of Things Working Group, http://www.npstc.org/IoT.jsp

NIST Communications Technology Laboratory, Public Safety Communications Research Division, ProSe (Proximity Services) https://www.nist.gov/ctl/pscr/prose

NIST Global City Teams Challenge, “Blueprint for Smart Public Safety in Connected Communities, An Initiative of the Global City Teams Challenge,” https://pages.nist.gov/GCTC/uploads/blueprints/20170824-PSSC_Blueprint_20170823_FINAL.pdf

NIST Global City Teams Challenge, Transportation and Public Safety Superclusters https://pages.nist.gov/GCTC/super-clusters/

Schumann, Greg, Josh Lieberman, ed., “Incident Management Information Sharing (IMIS) Internet of Things (IoT) Architecture Engineering Report,” 2018 Open Geospatial Consortium, http://docs.opengeospatial.org/per/16-014r2.html

U.S. DOT, “Preparing for the Future of Transportation: Automated Vehicles 3.0,” October 2018, https://www.transportation.gov/av

Zeto, Mike, “The Internet of Lifesaving Things: Smarter Cities, Smarter Response,” http://about.att.com/newsroom/internet_of_lifesaving_things.html