TSAG
TRANSPORTATION SAFETY ADVANCEMENT GROUP
Promoting Technology - Protecting Travelers

Infrastructure to Responder (I2R) White Paper

March 18, 2019

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A Community of Transportation Professionals

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Introduction

Infrastructure to responder (I2R) applications include responder-centric and vehicle-based infrastructure to responder (I2R) applications to improve responder safety and situational awareness on the scene of highway incidents; en route to the scene and en route 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. I2R uses information available through the emerging digital infrastructure, technology, and applications to push warnings and information to responders through handheld or worn devices and to response vehicles at, or en route to, the scene. I2R includes device-to-device and digital infrastructure to device applications. The digital infrastructure provides a connection that includes the Internet of Things (IoT), Smart Cities/Communities applications, and geospatial and off-system data that provide a foundation for scene critical information for the operations and safety of responders.

Examples of information that could be made easily accessible to on-scene responders through I2R 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

I2R and the Digital Infrastructure

As U.S. DOT, vehicle manufacturers, technology and app developers, and smart community planners work to support highway automation and enhanced connectivity, opportunities to support responders through I2R applications increase. A digital infrastructure that connects across civil infrastructure systems and vehicles; integrates sensing technology; collects, processes, and analyzes data; and communicates directly with responders has enormous implications for situational awareness and responder safety through the delivery of a wide variety of mission-critical information.

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.

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 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 on scene and en route. Vehicle manufacturers are pursuing connectivity using short range or broadband 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.

Opportunities for Future I2R

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

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 (such as personal IoT devices, sensors in and on persons in vehicles), that information can also become available in the response system.

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.

5G

One of the significant opportunities for expanding the digital infrastructure and providing new information sharing capacity lies in the evolution to 5G communications. 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 computing 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.

Challenges to Implementing I2R

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.

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, gaps in the system in more rural areas 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, 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, an expansion of communication networks, standards, and interfaces to support interoperability are needed to integrate and share information. Public safety answering points (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 automatic crash notification 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 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, it 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.

Sample Use Cases of I2R on Highway Incidents

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 roadway 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.

Use Case1: Rural I2R

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.

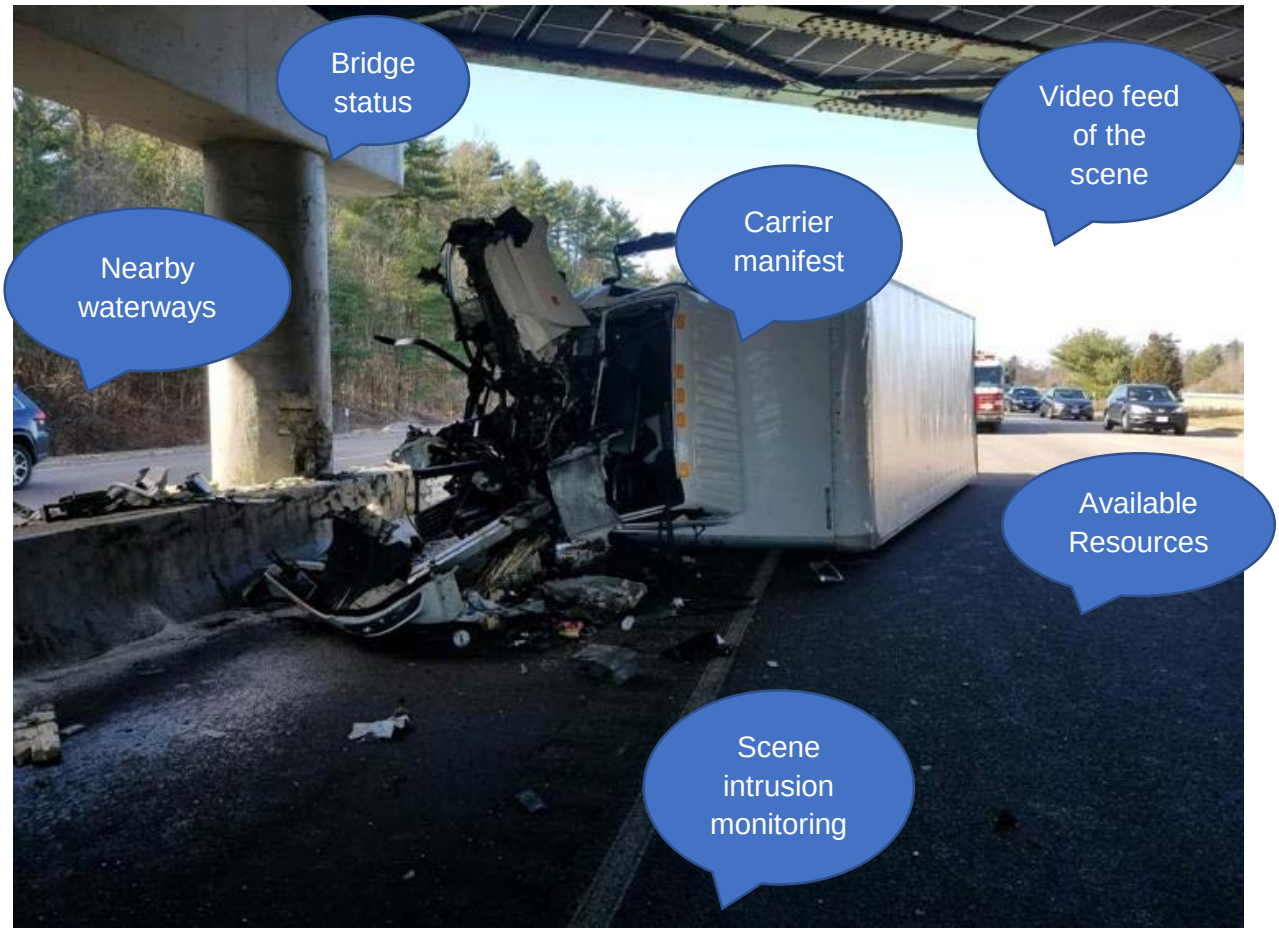

Photo: Mansfield Fire Department, MA

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.

Use Case 2: Urban I2R

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 en route and responders at the scene.

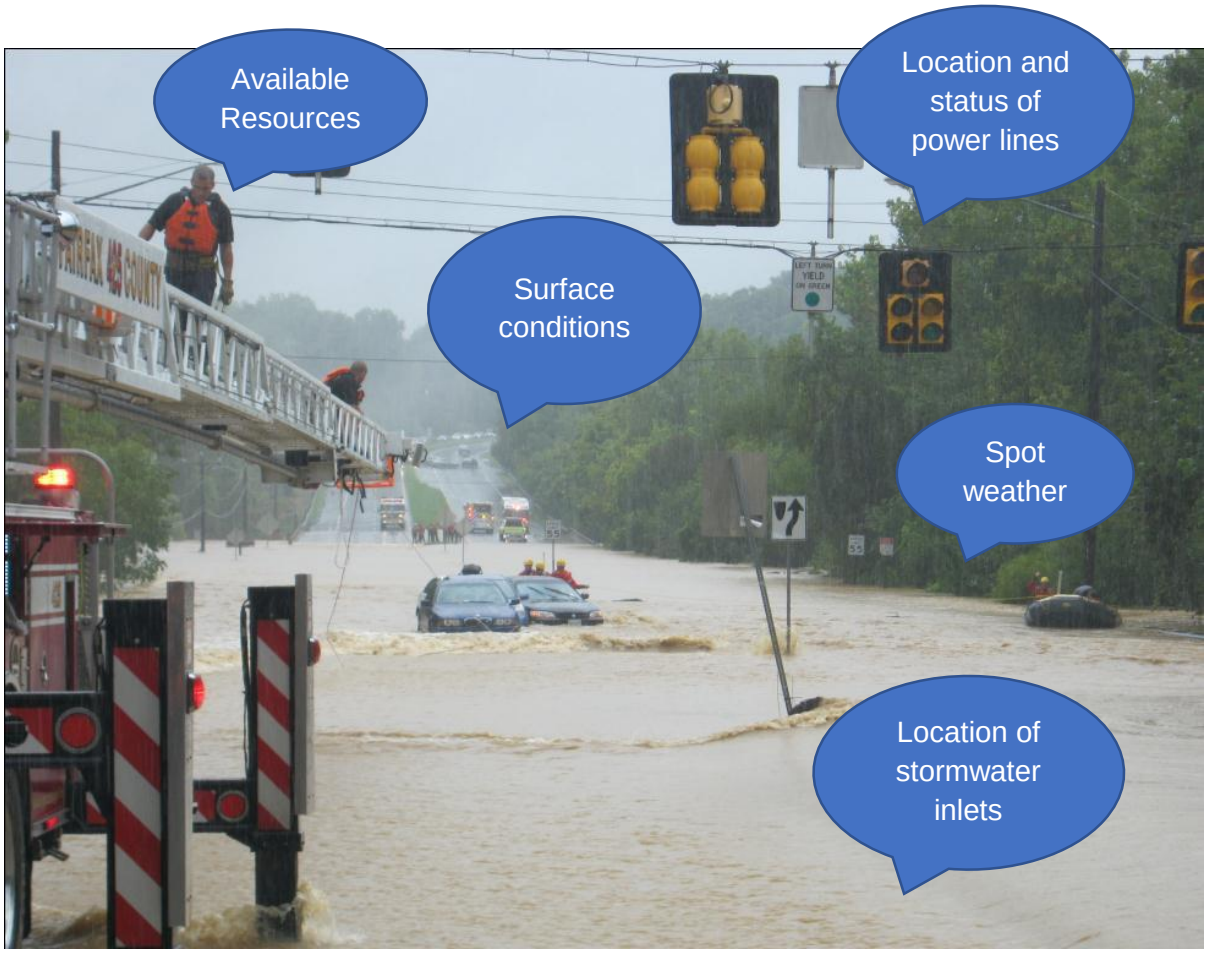

Photo: FEMA/Scott E. Schermerhorn

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.

Hardware

Research is needed to determine the best information delivery mechanism — handheld, body-worn, in vehicle — from the digital infrastructure to responders. Each of these three options has advantages and limitations and is more appropriate for different activities associated with incident response, 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 potential source, 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 distracting. 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 and 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.