Safety and Mobility Advances

through Maricopa County, Arizona's SMARTDrive Program: A Look at the Anthem Connected Vehicle Test Bed

By Faisal Saleem and Larry Head

Maricopa County, Arizona, USA is the fourth most populous and fastest growing county in the United States. It is comprised of 25 cities and towns and is built upon an extensive regional transportation network of freeways and arterial roads that serve as the backbone for connectivity for the Phoenix, AZ metro area. Growth is not a new concept to Maricopa County, and the Maricopa County Department of Transportation (MCDOT) has been developing solutions to improve traffic management in the region for more than 20 years.

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One of MCDOT's key strategies to achieving seamless transportation was to implement the SMART (Systematically Managed Arterials) corridor program. This program promotes improved safety and mobility on the arterial corridors through efficient traffic signal operations on the region's approximately 3,500 traffic signals. Through regional funding and collaboration through AZTech, a regional traffic management partnership jointly led by the Maricopa County Department of Transportation (MCDOT) and the Arizona Department of Transportation (ADOT), several regional corridors were deployed with advanced traffic controllers, a fiber communications backbone, and integrated signal timing strategies. As a result, the SMART corridors, such as Bell Road, saw a reduction in travel time by 27 percent, although the average daily traffic (ADT) more than doubled. The next advancement on Bell Road is deployment of adaptive signal control technology (ASCT) on 50 traffic signals. The Bell Road system is planned to be fully implemented by early 2018.

The advent of connected vehicle technology has provided MCDOT the opportunity to develop next generation intelligent transportation systems (ITS) to achieve a new level of seamless transportation systems. MCDOT, ADOT, and the University of Arizona have formed the Arizona Connected Vehicle Coalition to develop, deploy, and test applications that will further advance the traffic signal safety and provide efficient mobility in a multimodal environment. Through this partnership, the MCDOT SMARTDrive Program^{SM} was launched. Originally created to improve emergency responder safety and mobility at intersections, the MCDOT SMARTDrive Program allows for two-way communication between vehicles and roadway infrastructure by using dedicated short range communications (DSRC), a component of the U.S. Department of Transportation (USDOT) multimodal intelligent traffic signal systems (MMITSS). MMITSS prioritizes traffic flow and pedestrian movements to improve safety and mobility.

To test MCDOT's SMARTDrive Program applications, the Arizona Connected Coalition deployed the Anthem Connected Vehicle Test Bed. Anthem is located in northern part of Maricopa County. It is a vibrant community of about 27,000 residences and includes 15 schools, more than 300 store-front businesses, numerous churches, parks, and other amenities. The Anthem Test Bed consists of 5.3 miles of arterials and functions in a "live" operational environment so that realistic data is gathered and analyzed for greater progress. The key components of the Test Bed include:

- Road Side Equipment (RSE): Eleven signalized intersections equipped with DSRC radios;
- Deployment of the MMITSS and other connected vehicle applications including incident, school zone, and work zone warnings and the emergency vehicle alert message;
- Representative On Board Equipment (OBE): Equipped emergency vehicles, trucks, and transit vehicles are used to demonstrate and test traffic signal priority logic;
- Field test for multimodal users including passenger cars, freight vehicles, emergency, transit, and pedestrian applications;
- Pedestrian crosswalk application using smartphones to display crossing status and assist pedestrians in crossing at signalized intersections;
- Collection of detailed vehicle and traffic operations data for real-time performance measures and post-operational analysis; and
- System backhaul and remote access capabilities to the system development team.

The Anthem Test Bed provides a real-world environment to support the development of signal control applications, evaluate the benefits, and provide a connected vehicle test bed for future applications. Table 1 are highlights of the evolution of the MCDOT SMARTDrive Program.

Table 1. Highlights of the evolution of the MCDOT SMARTDrive Program

Objectives	Implementation
2007—2009 Develop and Test Prototype Applications	• Researched best practices, standards, and refined Concept of Operations • Developed prototype applications for traffic signal priority, freeway on-ramp signal priority, mobile incident warning, and automated traveler alerts • Demonstrated proof of concept at MCDOT test bed • Presented findings at local, national, and international levels
2009—2010 Demonstrate Signal Priority for Multiple Vehicles	• Conducted live intersection test at 67th Avenue/ Southern Avenue in Phoenix, AZ • Tested multiple vehicles arrivals on conflicting, concurrent, and the same approach • Developed applications for in-vehicle display • Evaluated and documented outcomes
2011—2012 SMART*Drive* Field Test	• Developed and implemented a Connected Vehicle technology test bed at signalized intersections in Anthem, Arizona • Demonstrated the signal priority and traveler information applications in a 'live' traffic operations environment
2012-2017 Operate and Expand Test Bed	• National Test Bed for the Multi-Modal Intelligent Traffic Signal System (MMITSS), one of the Dynamic Mobility Applications in the USDOT's program • MMITSS is sponsored through the Connected Vehicle Pooled Fund • Integrated I-17 freeway interchange into the Test Bed • Added in-vehicle school zone and work zone alerts

Applications

The national Connected Vehicle Pooled Fund selected the Anthem Test Bed, along with the California Department of Transportation (CALTRANS) test bed, to deploy and test the USDOT MMITSS application. The project was jointly funded by the USDOT and Pooled Fund members including MCDOT. The project was awarded to the University of Arizona team for design, development, and deployment of the MMITSS application.

The MMITSS architecture is shown in Figure 1 and illustrates the three key MMITSS architecture elements: the on-board equipment (OBE), roadside processor and equipment (RSE and MRP), and the central system. Software components are deployed on each of the key architecture elements. There are two kinds of components: MMTISS traffic control algorithms (shown with thick black borders in Figure 2) and MMTISS interface and general connected vehicle components. The interface components allow the MMITSS system to acquire data and actuate controls, as well as to interface to the two DSRC communication channels that are used. The MMITSS traffic control components implement the new

Dr. Larry Head, University of Arizona, provides an in-vehicle demonstration of the MMITSS application at the Anthem Test Bed.

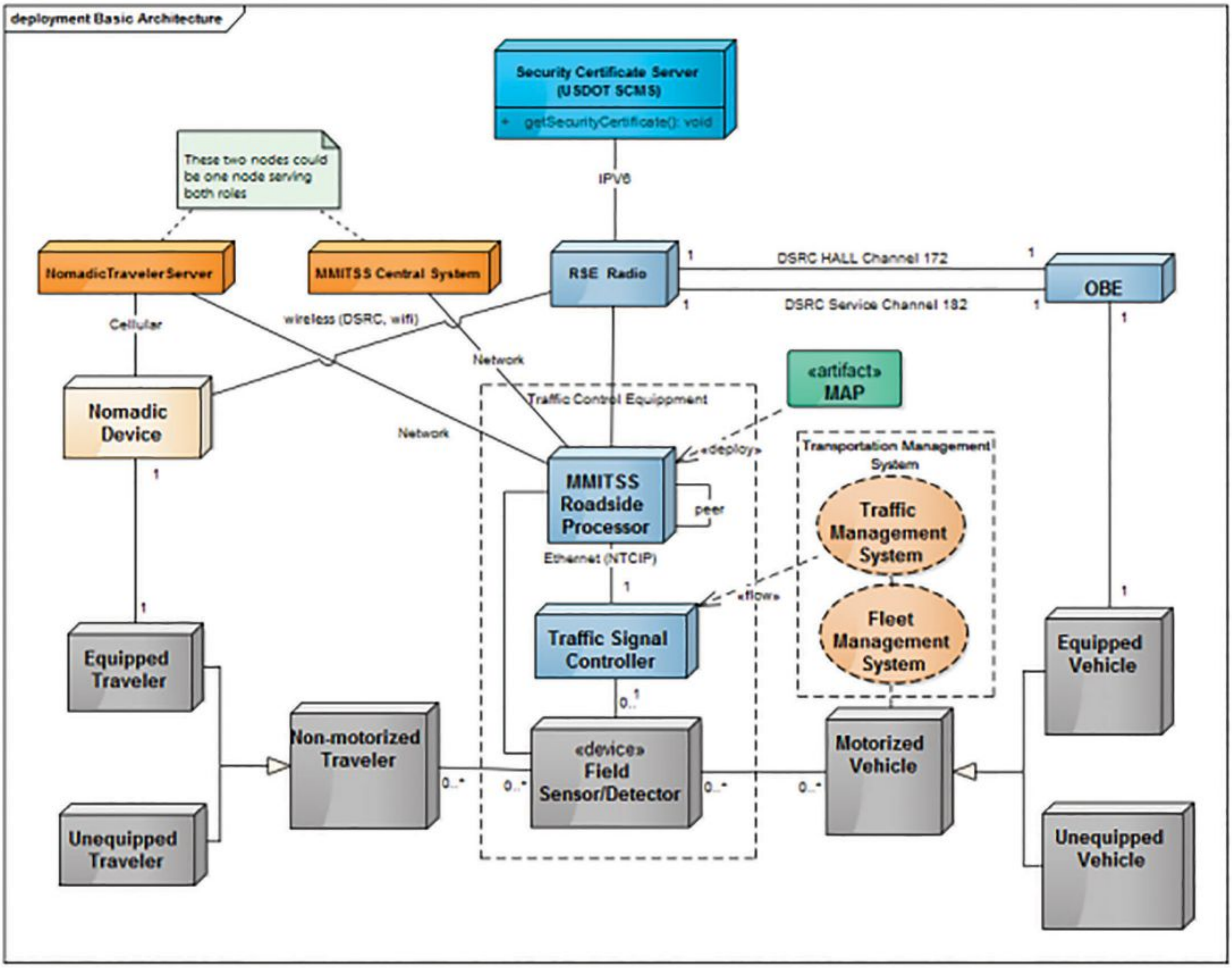

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Figure 1: MMITSS Architecture[1]

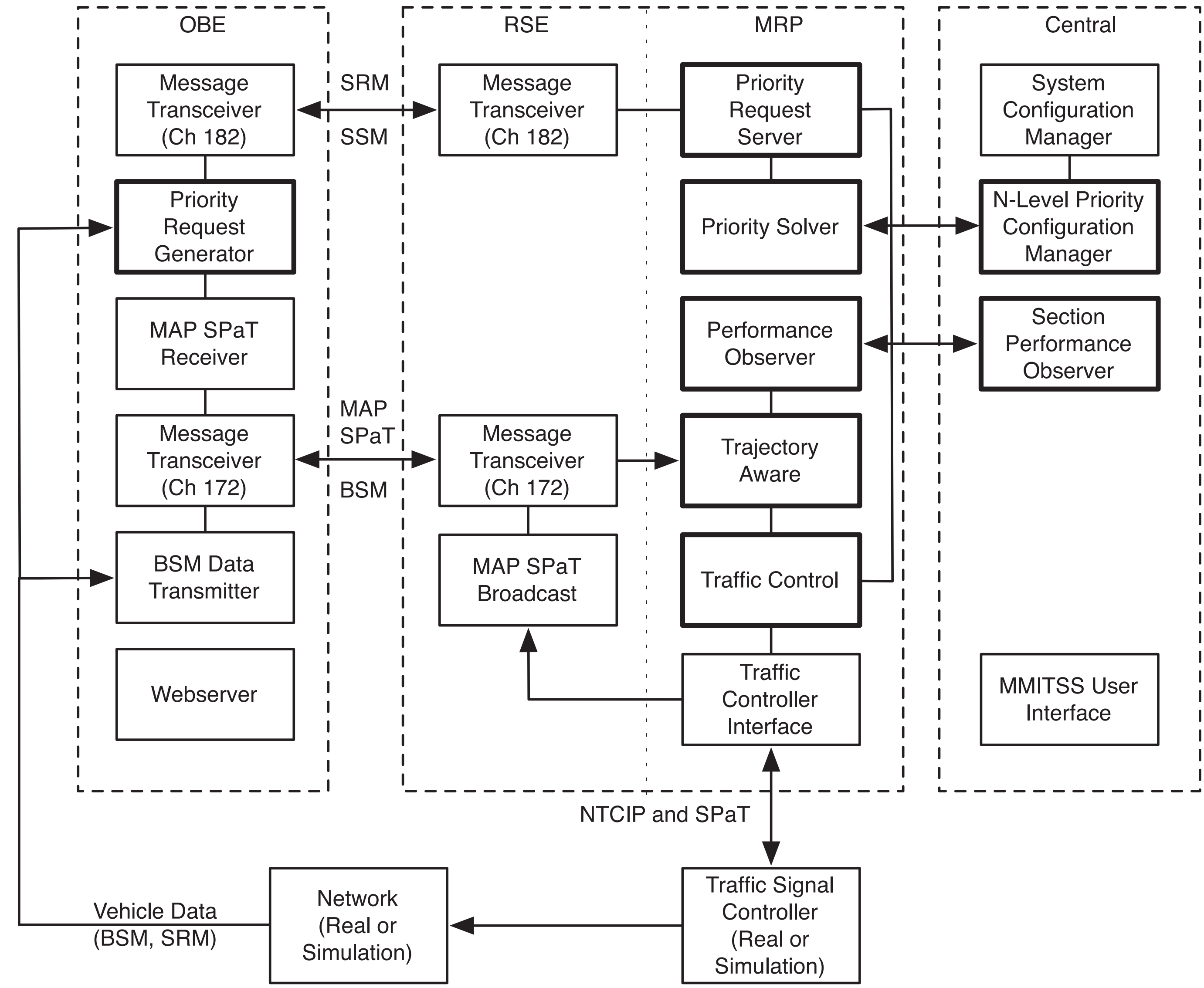

Figure 2: MMITSS Components

control algorithms developed to use the connected vehicle data. The detailed design of MMITSS is available in open source through the USDOT Open Source Application Development Portal (OSADP) at www.itsforge.net.

An important concept adopted in the MMITSS prototype was the concept of multiple levels of importance for different modes in traffic control. An operating agency should have the ability to determine which mode should be the most important and which should be the least important when serving multiple requests at one time. For example, in one corridor, coordination might be the most important consideration during the AM and PM peak commute times or during an incident on a parallel freeway. In the off-peak times, the priority might favor transit vehicles in an urban shopping/school area or might favor freight in a commercial warehouse/factory area. The ability to establish a "priority policy" would allow the operating agency to have a powerful tool for traffic management.

When completed, the MMITSS prototype application proved the concept of vehicle-to-vehicle and vehicle-to-infrastructure communication in the Anthem Test Bed. The application was demonstrated using four vehicles: a Valley Metro bus, Daisy Mountain Fire truck, and two MCDOT Regional Emergency Action Coordinating Team (REACT) vehicles which were equipped with on-board equipment. The RSE equipped intersections along the test bed recognized the approaching equipped vehicles and made the decision on how to best serve the vehicles with priority green based on the priority policy criteria; in this case, priority for the fire truck and emergency REACT vehicles, and then the transit bus. In

A demonstration of a DSRC-equipped fire truck and MCDOT REACT Incident Response Vehicles receiving higher priority.

approaching any of the intersections as a single vehicle, say the bus only, the intersection recognizes the request from the bus and either extends the green, or, if sufficient time is available, first serve, the minimum green on the side street and then returns to the requested green for the approaching bus. When the intersection is approached by more than one test vehicle, depending on speed, distance from the intersection, current status of the signal timing, and priority level of the vehicle, the intersection provides green to best accommodate the approaching vehicles with fire trucks and REACT vehicles receiving the highest priority, followed by the transit bus.

The second implemented application demonstrated the use of a handheld device to assist with visually impaired and limited mobility pedestrians at intersection cross-walks. The pedestrian green and count down information currently shown on the signal head at the other side of the intersection is now also shown directly on the hand held device. The intersection recognizes the direction in which the device is pointed to tell the user whether it is safe to proceed in the requested direction. In further development of this technology, the user will register with a service provider and the intersection will recognize the specific need of the user when pedestrian green is requested and will, for example, extend the green for a user with mobility limitations.

The third set of applications implemented at the test bed provide in-vehicle work zone ahead, school zone, and incident warning alerts to approaching vehicles leveraging infrastructure to connected vehicle communications. An emergency vehicle alert (EVA) is provided from fire trucks and react vehicles to provide an in-vehicle alert using vehicle to vehicle communications.

Outreach and Public Education

Adopting new technology such as connected vehicle technology requires a committed investment in upgrading signal and intersection infrastructure. To promote this progress in departments of transportation across the country, the Arizona Connected Vehicle Coalition has held more than 100 connected vehicle demonstrations and presentations to share its experience. The coalition has presented to industry professionals, students, elected officials, and the media to explain the development, deployment, and testing of this new technology.

One of the more recent demonstrations was the first Signal Phase and Timing (SPaT) Challenge national workshop held on March 3, 2017 on behalf of AASHTO, ITE, and the vehicle-to-infrastructure (V2I) Deployment Coalition at the Arizona ITE-IMSA Spring Conference. The purpose of the SPaT challenge is to encourage cooperation and uniformity among the state and local public sector transportation infrastructure owners and operators in order to deploy DSRC technology along roadway corridors. The DSRC broadcasts real-time SPaT messages to connected vehicles. The critical value of uniformity is to standardize the message and format of V2V transmissions. This uniformity will create an information environment in which vehicle and device manufacturers can create and implement applications to improve safety, mobility, and the environment.

Lessons Learned

Several important institutional and technical lessons have been learned from the Anthem Test Bed. Leveraging and formalizing the partnership with the University of Arizona has benefited the advancement of connected vehicle research as well as development of the MMITSS application to improve transportation efficiency and safety. The MMITSS application is being deployed at several locations in the nation. Technically, the DSRC radios performance was satisfactory under the relatively high temperature environment in Arizona. However, for the agency technical staff, there is a need for well-defined and documented procedure for troubleshooting and providing system maintenance. Some radios demonstrated performance issues with radio range and it was not clear to the technician on how to approach troubleshooting the problem in a systematic way.

Creating MAP messages to support connected vehicle applications is new for public agency staff. There is a need for standardized mapping procedure. The mapping for the Anthem test bed was

DSRC radio installed on a traffic signal luminaire arm.

University of Arizona Ph.D. student Sara Khosravi demonstrates the pedestrian smart phone application to Siva Narla, ITE.

originally done using an approach developed by DARPA for the Grand Challenge in 2007. As the standards evolved, the mapping was updated.

The applications require sustained testing and several iterations are needed for the software refinements. The real world operational environment offered by the Anthem Test Bed provided the University of Arizona research team the opportunity to test and improve the applications based on actual field results.

The MMITSS application successfully demonstrated reduction in travel time for transit buses and freight trucks. The project also contributed in the enhancement of the SAE J2735 standard for the DSRC message sets. Specifically, with respect to messages defined as part of the priority request and acknowledgement in the MMITSS application. The test bed also supported the development of MCDOT staff capacity building with connected vehicle technology. **itej**

Tampa's THEA Connected Vehicle Pilot Program team visited the Anthem Test Bed.

In addition to educating other transportation officials, MCDOT and the Arizona Connected Vehicle Coalition are working to educate the public about the safety, mobility, and environmental benefits of connected vehicle technology. Most recently, MCDOT produced an animated video (available at http://bit.ly/2syAwOg), showing the value of the MCDOT SMARTDrive Program. Additional videos are planned to simply explain the value connected vehicles bring to the motoring public.

learn more

Reference

1. University of Arizona (Lead), University of California PATH Program, Savari Networks, Inc., Econolite, 2016. Multi-Modal Intelligent Traffic Signal System - Detailed System Design.

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