A Short Range Vehicle to Infrastructure System at Work Zones and Intersections

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ABSTRACT

Traditional safety countermeasures at work zones include setting up special signs, installing barriers and a lower speed limit in work zones. For stop sign areas, usually our countermeasure is to remove all the obstructions. For signalized intersections, we usually improve the safety by setting up the signal lights in an optimized layout. However, many accidents still happen despite of these traditional methods. Radio Frequency Identification (RFID) can provide effective solutions to improve the operations in work zones, stop sign areas and signalized intersections. The purpose of this research is to identify how to improve the traffic safety and achieve better air quality in these areas by using RFID. With the implementation of such advanced warning system, it is envision that crash rates at woke zones and intersections will be greatly reduced and the surrounding environment will be improved.

Keywords: Vehicle to Infrastructure Communication, RFID, Work Zone, Stop Sign

1. TRAFFIC SAFETY ISSUES AND NEEDS OF ADVANCED TECHNOLOGIES

Based on statistics, traffic accidents and fatalities are always important issues in traffic operations, especially in special areas such as work zones, stop sign controlled unsignalized intersections, and signalized intersections. In 2010, 32,885 people died in motor vehicle traffic crashes in the United States and 1.10 deaths per 100 million vehicle miles traveled [1].

For the period 1998-2007, nearly 413,461 fatalities occurred in the U.S. with nearly 9,900 (2.4%) fatalities occurring near work zone [2]. Similar situations happen in intersections. There were 6,758 peoples killed in motor vehicle traffic crashes at intersections [3]. Intersections account for a small portion of the total highway system, yet intersection related crashes constitute more than 50 percent of all crashes in urban areas and over 30 percent in rural areas [4], [5]. Further, approximately 90% of intersection fatalities occur at unsignalized intersections in rural area, and approximately 60% occur at unsignalized intersections in urban area [6].

For years, traffic engineers have been employed a series of safety strategies such as setting up special signs, barriers and lower speed limits in work zones; remove obstructions for stop signs at unsignalized intersections; and properly design, install, and control signal lights in optimized modes at signalized intersections.

For example, Transportation Research Board proposes a series of countermeasures to enhance the safety at intersections [7], including: (1) reduce frequency and severity of intersection conflicts through traffic control and operational improvements; (2) reduce frequency and severity of intersection conflicts through geometric improvements; (3) improve sight distance at signalized intersections; (4) improve driver awareness of intersections and signal control; (5) improve driver compliance with traffic control devices; (6) improve access management near signalized intersections; and (7) improve safety through other infrastructure treatments. For work zones and unsignalized intersections, there are also similar detailed countermeasures.

Even though the occurrences of crashes in work zones and intersections in recent years indeed illustrate a trend of slight decrease [1], there are still strong needs to introduce advanced technologies to enhance the safety of vehicles while driving. Assuming that there are smart "eyes", "ears", and even "noses" that can help drivers to fore-see, fore-hear, and fore-sense any dangers from other vehicles and surrounding infrastructure, drivers may be much better prepared to manipulate vehicles to avoid possible crashes and incidents. The short range Vehicle to Infrastructure (V2I) communication is one of the right tools to equipment drivers with those smart sensors [8].

2. RESEARCH OBJECTIVE

The research objective is to develop a short range communication system so as to provide warnings to drivers when approaching specific locations such as work zones and intersections.

3. THE DEVELOPED RFID BASED V2I COMMUNICATION SYSTEM

The developed wireless communication system contains the RFID based hardware system and the associated software system. The functions of this system fit into the basic needs of a V2I communication system.

3.1 The V2I Communication System

Vehicle-to-infrastructure communications for safety is the wireless exchange of critical safety and operational data between vehicles and highway infrastructure, intended primarily to avoid or mitigate motor vehicle crashes but also to enable a wide range of other safety, mobility, and environmental benefits.　V2I communications apply to all vehicle types and all roads, and transform infrastructure equipment1 into "smart infrastructure" through the incorporation of algorithms that use data exchanged between vehicles and infrastructure elements to perform calculations that recognize high-risk situations in advance, resulting in driver alerts and warnings through specific countermeasures.　One particularly important advance is the ability for traffic signal systems to communicate the signal phase and timing (SPAT) information to the vehicle in support of delivering active safety advisories and warnings to drivers.　Early implementation of the SPAT application can enable near-term benefits from V2I communications in the form of reduced crashes, which in turn demonstrate benefits that can help accelerate deployment.

The vision of V2I Communications is that a minimum level of infrastructure will be deployed to provide the maximum level of safety and mobility benefits for highway safety and operational efficiency nationwide.　Importantly, V2I communications have the potential to resolve an additional 12 percent of crash types not addressed under V2V communications. V2I Communications for Safetyis a key technology in the USDOT's Connected Vehicles Program, and is complimented by the V2V communications research.　While the primary goal is safety, V2I communications are also significant in improving mobility and environment by reducing delays and congestion caused by crashes, enabling wireless roadside inspections, or helping commercial vehicle drivers identify safe areas for parking.

The objectives of the V2I Communiications for Safety research program are fourfold: (1) building from the research results under the prior Vehicle Infrastructure Integration (VII) program and VII proof-of-concept test, to complete the development and testing of the V2I communications technologies, advanced applications, and standards for national interoperability—in particular, the SPAT capability; (2) to develop a rigorous estimation of safety benefits and develop a regulatory/policy guidance versus market position in support of deployment, (3) to provide tools and information that support infrastructure deployments nationwide, and (4) and to ensure appropriate strategies are implemented for privacy, security, system certification and accessibility, scalability, governance structures, public acceptance, and a sustainable marketplace that can effectively propel deployment.

Because of the great variety of vehicle and infrastructure safety systems now installed and planned for the future, the focus on consistent, widely applicable standards and protocols is

critical.   Additionally, the research will concentrate on the key FHWA and FMCSA application areas of interest, including intersection safety, run-off-road prevention, speed management, and commercial vehicle enforcement and operations.

3.2 System Components of the RFID Based V2I System

The proposed system has several important components including: RFID emitter, RFID receiver, GPS receiver, computer processing software and database. The RFID tag is placed on the roadside, which can be detected by the receiver (the readers) installed inside the vehicles. In the meantime, the GPS unit reports the geographical locations of the vehicles. The on board computer checks if the tag signal(s) are approaching based on the tag and GPS information received. If the tag ID is a valid one based on the tag inventory database search, proper voice prompts and visual warning message will be provided to drivers.

3.3 The Designed Software System

The Visual Basic (VB) programming tool is used to develop the DSAS and relevant software components are used in this program for proper function. Microsoft Communications Control (MSCOMM) is used to communicate with GPS unit; Microsoft Data Access Object (DAO) is used to communicate with database; Microsoft MapPoint is used to navigate and display the map view; and Microsoft Winsock Control is used to communicate with the short-range communication devices. Those are major components of the software system.

The RFID device used is an Ethernet based RFID system, so Microsoft Winsock Control is used to communicate with RFID receiver. RFID receiver can upload information to onboard processing computer every second. As soon as this system detects the signal from the tags, this system begins to give visual display and voice prompts to the drivers.   For the hardware RFID, in the test of work zone area and stop sign intersection, the portable and flexible tags are installed on roadside infrastructures. The RFID based DSAS has been successfully tested as pilot studies on traffic signal warnings, work zone lane closed and speed limited information warnings, and e-stop sign warnings.

4. TEST DESIGNS

5. TEST RESULTS

The pilot test of this system was conducted by selecting total 50 test subjects based on 2010 census data rate related to different ages, gender, education, and etc. in Houston. Results indicate that significant effects on vehicle trajectories, speed and acceleration/deceleration rate, and the Vehicle Specified Power (VSP) were observed. With DSAS, drivers tend to drive even smoother with lower acceleration/deceleration rates. Most subjects agree that DSAS is useful and will eventually help enhance safety and reduce the offense of traffic laws. The subjects feel comfortable with no extra stress or workload. The use of DSAS changes the VSP

and Operating Mode ID Bins, resulting in the reduction of vehicle emissions, per the Environmental Protection Agency (EPA) emission software - MOVES.

In the test of stop-sign intersection, the distributions of the locations where vehicles started to decelerate with and without the RFID based DSAS for all right turn movements in the tests are seen that the locations changed from 237ft (without DSAS) to 258 ft (with DSAS, a 21 ft increase), meaning that the warning message from DSAS did have impacts to drivers under this situation.

In the test of signalized intersection with DSAS, the average speed of passing signalized intersection is lower than that without DSAS. The average speed was calculated based on 200 runs by ten drivers. The standard deviation with DSAS is smaller than without DSAS. The comparison of deceleration rates of the two scenarios shows that the average deceleration rate and standard deviation with DSAS is smaller than without DSAS.

For the test of work zones, after analyzing the GPS data in the test location, most of the participants can reduce their speed to the speed limit when they hear the warning. The DSAS has significant impact on vehicle speed. The locations to decelerate in response to the in-vehicle warning message moved back along upstream directions, and the deceleration rates in response to the first and second warning sign of work zone increased when using DSAS.

The average distances (377ft, 696ft, and 1251 ft) to upstream reference point for vehicles to decelerate when seeing the three work zone traffic sign (for the case without DSAS) are larger than the distances (304ft, 702ft, 1134ft) when receiving the in-vehicle warning signs from DSAS. This means drivers all decelerated earlier before entering the work zone area, which is a safer situation. In order to determine the impacts of DSAS on vehicle emissions, analyzed the GPS data and calculated VSP values for two different scenarios: with DSAS and without DSAS. Based on binning standard of the EPA new emission estimation model MOVES, the VSP distribution and the associated emission rates in the operating mode 30 bins were calculated. The emission rates used for emission estimation were calculated from the database of using the Portable Emission Measurement System (PEMS) derived by a car (Modal: Nissan Altima, Year: 1999, Mileage: 80,000 mile). The ANOVA analysis shows that CO_2/CO/HC emission rates are statistically significant (p-values: 0.023, 0.004, 0.024, and, respectively.) The emission rate of NO_x is statistically promising (p-value=0.224).

According to the post survey of pilot test, 90% of the subjects believe that this system is useful or extremely useful. 100% of the test participants agree that DSAS can make them more aware of the traffic signal at intersection.100% of the test participants believe this system does not make drivers stressful.

6. CONCLUSION

This research has great impacts on both safety and air quality in work zones and intersections. With the implementation of such advanced warning system, it is envision that crash rates at

woke zones and intersections will be greatly reduced and the surrounding environment will be improved.

7. ACKNOWLEDGMENT

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