Appendix B:
Vehicle Safety Applications

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1 Introduction

This appendix provides a general description of each selected vehicle safety application. The applications are classified as safety-related and non-safety-related.

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2 Safety-Related Applications

2.1 Intersection Collision Avoidance (ICA)

The following ICA applications were evaluated based on their ability to reduce traffic accidents at intersections.

2.1.1 Traffic Signal Violation Warning

The traffic signal violation warning application uses infrastructure-to-vehicle communication to warn the driver to stop at the legally prescribed location if the traffic signal indicates a stop and the system predicts that the driver will be in violation. The in-vehicle system uses information communicated from infrastructure located at traffic signals to determine if a warning should be given to the driver.

2.1.2 Stop Sign Violation Warning

The stop sign violation warning application uses infrastructure-to-vehicle communication to warn the driver if the distance to the legally prescribed stopping location and the speed of the vehicle indicate that a relatively high level of braking is required for a complete stop. The in-vehicle system uses information communicated from the infrastructure to provide the warning to the driver. Digital maps and GPS could be used as an alternative to DSRC communications.

2.1.3 Left-Turn Assistant

The left-turn assistant (LTA) application provides information about oncoming traffic to assist in making a left turn at a signalized intersection without a phasing left-turn arrow. Information is obtained by the infrastructure system, which uses sensors and/or DSRC communications to detect vehicles approaching from the opposite direction. This information is then used in the turning vehicle to provide gap information to the driver to assist in deciding when to turn.

One potential application is an in-vehicle system that determines a need for information about approaching traffic near an intersection based upon the driver's activation of the left-turn signal. The traffic data is gathered automatically by the infrastructure system, which detects the location and movement patterns of oncoming vehicles using vehicle detection sensors. The infrastructure system transmits the data to vehicles at regular intervals via DSRC, and the in-vehicle system provides the relevant information to the driver.

2.1.4 Stop Sign Movement Assistant

The stop sign movement assistant application provides a warning to a vehicle about to cross through an intersection after having stopped at a stop sign. Information is obtained from the infrastructure system, which uses sensors or DSRC communications to detect vehicles moving through an intersection. The application warns the driver when proceeding through the intersection is unsafe because traffic is approaching the intersection.

2.1.5 Intersection Collision Warning

The intersection collision warning application warns drivers when a collision at an intersection is probable. Infrastructure sensors and/or DSRC communications can be used to detect all vehicles, their positions, velocity, acceleration, and turning status when approaching an intersection. The infrastructure unit or the in-vehicle unit determines when a collision is imminent and issues a warning to either a specific vehicle or all drivers in the vicinity, depending on the warning strategy.

One potential application is an infrastructure system that determines the location of vehicles through infrastructure sensors (radar, cameras, etc.) and transmits this information to vehicles in the vicinity. If the in-vehicle application determines that a collision is imminent, it provides a warning to the driver.

2.1.6 Blind Merge Warning

The blind merge warning application provides a warning to the driver if a vehicle is attempting to merge from a location with limited visibility and another vehicle is approaching and is predicted to occupy merging space. Vehicles notify the roadside infrastructure unit of their velocity, acceleration, heading, and location. Based on the information sent from the vehicles and knowledge of the road, the roadside unit calculates whether a collision is imminent. The roadside unit notifies both the merging traffic and the right-of-way traffic of potential collisions. The roadside unit provides an all-clear signal when there is no approaching traffic.

2.1.7 Pedestrian Crossing Information at Designated Intersections Warning

The pedestrian crossing application provides an alert to vehicles if there is danger of a collision with a pedestrian in a designated crossing. The presence of a pedestrian is detected through infrastructure sensing equipment, including the "walk" button that pedestrians press before crossing an intersection. A broadcast message with information regarding the pedestrian is transmitted from roadside units to vehicles approaching the crossing area.

2.2 Public Safety

The following applications were evaluated based on their ability to improve general public safety.

2.2.1 Approaching Emergency Vehicle Warning

The approaching emergency vehicle warning application provides a warning to the driver to yield the right-of-way to an approaching emergency vehicle. The emergency vehicle broadcast message could include information regarding its position, lane information, speed, and intended path. The in-vehicle system uses this information to alert the driver.

2.2.2 Emergency Vehicle Signal Preemption

The emergency vehicle signal preemption warning application permits an emergency vehicle to request right-of-way from traffic signals in its direction of travel. This application allows the emergency vehicle to override intersection signal controls. An intersection-mounted roadside unit verifies that the request was made by an authorized source and alters the traffic signal and timing to provide right-of-way to the emergency vehicle. This application may need to be integrated with the approaching emergency vehicle warning application.

2.2.3 SOS Services

The SOS services application is an in-vehicle system that send emergency (SOS) messages after airbags are deployed, and a rollover or other life-threatening emergency is sensed. An occupant could also initiate the message for a non-crash-related medical or other emergency.

- ***Vehicle-to-infrastructure:*** The emergency message is sent from the vehicle to a roadside unit and then forwarded to the nearest local authority for immediate assistance.
- ***Vehicle-to-vehicle****:* The emergency message is sent from the vehicle to a passing vehicle, which stores and then relays the message when in range of a roadside unit. The message is then forwarded to the nearest local authority for immediate assistance.

2.2.4 Post-Crash Warning

The post-crash warning application is an in-vehicle system that warns approaching traffic of a disabled vehicle stuck in or near traffic lanes, as determined using map information and GPS. The application assumes communication, digital map, and GPS are still operable and may require a bottom-mounted antenna for rollover situations. This application will have the greatest benefit in poor visibility and inclement weather situations and may reduce the potential for a secondary crash.

- ***Vehicle-to-infrastructure****:* The disabled vehicle transmits its position, heading, and status to a nearby roadside unit. The unit broadcasts a warning message to vehicles approaching the accident scene and discontinues broadcast when the accident is cleared.
- ***Vehicle-to-vehicle:*** A disabled vehicle warns approaching vehicles of its position.

2.3 Sign Extension

The following sign extension applications were evaluated based on their ability to reduce traffic accidents and improve general safety.

2.3.1 In-Vehicle Signage Warning

The in-vehicle signage application provides the driver with information typically conveyed by traffic signs. Roadside units mounted at key points along the roadway send messages to approaching vehicles. In-vehicle signage features safety-critical information such as:

- ***School zone warning****:* alerts drivers that they are near a school.
- ***Animal crossing zone information****:* alerts drivers that animals tend to cross the road in the near vicinity.
- ***Sign information****:* provides information concerning dips, rough road, sudden turns, and other roadway and infrastructure characteristics.
- ***Keep clear warning****:* warns drivers that the vehicle is parked or standing in an area that should be kept clear.

2.3.2 Curve Speed Warning – Rollover Warning

The curve speed warning application aids the driver in negotiating curves at appropriate speeds using information communicated from roadside units located ahead of approaching curves. On-board vehicle information such as speed and acceleration are used to determine if the driver needs to be alerted.

2.3.3 Low-Parking-Structure Warning

The low-parking-structure warning is an in-vehicle system that provides drivers with information concerning the clearance height of a parking structure. A unit mounted on or near the parking facility provides clearance height information and location to vehicles in

the area. The in-vehicle system uses this information to decide whether to provide the driver with a warning before entering the parking structure.

2.3.4 Wrong-Way-Driver Warning

The wrong-way-driver warning application warns drivers that a vehicle is driving or about to drive against the flow of traffic. The vehicle senses its own right-of-way violation through precise positioning technology and map database data. If a right-of-way violation is sensed, the driver of the errant vehicle receives a warning, and that vehicle broadcasts information regarding its location, direction, speed, etc., to vehicles near the at-risk area.

2.3.5 Low-Bridge Warning

The low-bridge warning application provides drivers, especially of commercial vehicles, with warning messages when approaching a bridge of low height. The application is implemented with roadside units close to the bridge. Each vehicle determines whether a warning is issued to its driver.

2.3.6 Work Zone Warning

The work zone safety warning application refers to the detection of a vehicle in an active work zone area and the indication of a warning to its driver. Roadside units broadcast the warning data to vehicles as they approach a work zone or construction zone.

2.3.7 In-Vehicle Amber Alert Warning

The amber alert warning application sends alert information to the in-vehicle unit. The amber alert response program uses law enforcement and media resources to notify the public when children are suspected of being kidnapped. A sought-after vehicle could be excluded from receiving the message.

2.4 Vehicle Diagnostics and Maintenance

The following diagnostic and maintenance applications were evaluated based on their ability to improve safe vehicle operation.

2.4.1 Safety Recall Notice

The safety recall notice application distributes safety recalls through DSRC communications sent directly to vehicles via roadside units and/or in-home PCs. A safety recall reminder requiring immediate attention can be provided through a warning lamp or other methods.

2.4.2 Just-in-Time Repair Notification

The just-in-time repair notification application communicates in-vehicle diagnostics to the infrastructure and advises the driver of nearby available services. The roadside unit can pass information to an OEM technical support center for assessment. This information could be used to advise the driver of potential maintenance required.

2.5 Information From Other Vehicles

The following applications were evaluated based on their ability to reduce traffic accidents and improve public safety.

2.5.1 Cooperative Forward Collision Warning

The cooperative forward collision warning application is designed to aid the driver in avoiding or mitigating collisions with the rear end of vehicles in the forward path of travel through driver notification or warning of the impending collision. The system does not attempt to control the host vehicle in order to avoid an impending collision. This application is an enhancement of the radar-based forward collision warning system and would use information communicated from neighboring vehicles via vehicle-to-vehicle communication.

Using data regarding position, velocity, heading, yaw rate, and acceleration of other vehicles in the vicinity along with its own position, dynamics, and roadway information, the vehicle determines whether a rear-end collision with the lead vehicle is likely. The host vehicle also transmits position, velocity, acceleration, heading, and yaw rate to other vehicles.

2.5.2 Road Condition Warning

The road condition warning application is an in-vehicle system that uses on-board systems and sensors to detect marginal road conditions and transmit a road condition warning to other vehicles via broadcast. Road condition information can be used by vehicle safety applications in the receiving vehicle. The application can be designed calculate maximum speed recommendations based on road conditions and upcoming road features and notify the driver appropriately.

2.5.3 Emergency Electronic Brake Lights

The emergency electronic brake lights application is an in-vehicle system that sends a message to vehicles following behind the vehicle that brakes hard. This application helps the drivers of following vehicles by giving an early notification of the lead vehicle braking hard even when visibility is limited. This information could also be integrated into an adaptive cruise control system.

2.5.4 Lane Change Warning

The lane change warning application is an in-vehicle system that provides a warning to the driver if an intended lane change may cause a crash with a nearby vehicle. The application receives periodic updates of the position, heading and speed of surrounding vehicles via vehicle-to-vehicle communication. When the driver signals a lane change intention, the system determines and predicts the presence or absence of adequate gap between vehicles in the adjacent lane that will permit a safe lane change. If the gap between vehicles in the adjacent lane will not be sufficient, the system warns the driver that a safe lane change is not possible.

2.5.5 Blind Spot Warning

The blind spot warning application provides a warning when a driver intends to make a lane change and the driver's blind spot is occupied by another vehicle. The application receives periodic updates of the position, heading and speed of surrounding vehicles via vehicle-to-vehicle communication. When the driver signals a lane change intention, the application determines the presence or absence of other vehicles in his blind spot, and warns the driver appropriately.

2.5.6 Highway Merge Assistant

The highway merge assistant application warns a vehicle on a highway on-ramp if another vehicle is in its merge path (and possibly in its blind spot). The merging vehicle uses its navigation information to recognize that it is on an on-ramp. The in-vehicle system monitors information received from other vehicles in the area regarding their position, speed, and heading. The system warns the driver if one of the vehicles is in the merge path and is considered a potential collision threat.

2.5.7 Visibility Enhancer

The visibility enhancer application senses poor visibility situations such as fog, glare, and heavy rain either automatically or via user command. Vehicle-to-vehicle communication is used to obtain position, velocity, and heading of nearby vehicles. The application uses this information with its own GPS and map database for visibility enhancement that may range from simple to complex implementations.

2.5.8 Cooperative Collision Warning

The cooperative collision warning application collects surrounding vehicle locations and dynamics and warns the driver when a collision is likely. The vehicle receives data regarding the position, velocity, heading, yaw rate, and acceleration of other vehicles in the vicinity. Using this information along with its own position, dynamics, and roadway information (map data), the system determines whether a collision with any vehicle is likely. In addition, the system transmits position, velocity, acceleration, heading, and yaw rate to other vehicles.

2.5.9 Cooperative Vehicle-Highway Automation System (Platoon)

The platoon application provides both positional and velocity control of vehicles to operate safely as a platoon on a highway. Platooning requires vehicle-to-vehicle communication and may include vehicle-to/from-infrastructure communication. Functioning only in a control role, the application improves highway traffic flow and capacity by allowing short-range headway distance following in platoon architecture. The application combines vehicle data with position and map data. By reducing the amount of time a human controls the vehicle, the application reduces opportunities for driver error. Vehicles with this application may be required to use dedicated highway lanes. Longitudinal control of the vehicle is provided in order to maintain the short-range headway following within a platoon (similar to adaptive cruise control). Lateral control via automated steering provides lane-keeping and lane change maneuvers of platoon vehicles in a coordinated manner.

2.5.10 Cooperative Adaptive Cruise Control

The cooperative adaptive cruise control (ACC) application uses vehicle-to-vehicle communication to obtain lead vehicle dynamics and enhance the performance of ACC. Enhancements that could be made to ACC include stopped-vehicle detection, cut-in vehicle detection, shorter headway distance following, improved safety, etc. The application can be enhanced by communication from the infrastructure, which could include intelligent speed adaptation through school zones, work zones, off-ramps, etc.

2.5.11 Road Condition Warning

The road condition warning application provides warning messages to nearby vehicles when the road surface is icy, or when traction is otherwise reduced. Road condition warning may be implemented with roadside units mounted along the road at points where the road condition could change rapidly, such as bridges, low points, weather-related high frequency accident areas. The road surface condition would need to be determined by using infrastructure sensors for moisture, temperature, etc. A warning message is sent to nearby vehicles when the road surface traction is considered low enough to constitute a driving hazard.

2.5.12 Pre-Crash Sensing

The pre-crash sensing application provides a warning to prepare the vehicle and occupants for imminent, unavoidable collisions. This application could use DSRC communication in combination with other sensors to mitigate the severity of a crash. Countermeasures may include: pre-tightening seatbelts, air bag pre-arming, front bumper extension, etc.

2.5.13 Highway/Railroad Collision Warning

The highway/railroad collision warning application aids in preventing collisions between vehicles and trains on intersecting paths.

- ***Infrastructure-to-vehicle:*** This application uses information communicated from roadside units located near railroad crossings. The communicated information from roadside units would include data about approaching trains such as position, heading, and velocity.
- ***Vehicle-to-vehicle****:* This application will use information communicated from a train. The communicated information would include data about the approaching train such as position, heading, and velocity.

2.5.14 Vehicle-to-Vehicle Road Feature Notification

The road feature notification application is in-vehicle system that senses the road features such as grade, curve, etc. that exceed pre-set limits and transmits the information to other vehicles via broadcast. All vehicles within a certain area of the same road feature will be notified. The road feature information can be used by vehicle safety applications in the receiving vehicle. An application can be designed to work in the vehicle to calculate maximum speed recommendations based on road features such as road curvature ahead and notify the driver appropriately.

2.5.15 Cooperative Glare Reduction

The cooperative glare reduction application is an in-vehicle system that uses DSRC to automatically switch from high beams to low beams when trailing another vehicle. Each vehicle broadcasts its position and heading in low-light situations. If one vehicle calculates that another vehicle in front of it is within a specified range, it will switch from high to low beams.

3 Non-Safety Applications

3.1 Traffic Management

The following applications were evaluated based on their ability to improve traffic flow.

3.1.1 Intelligent On-Ramp Metering

The intelligent on-ramp metering application is infrastructure system that uses vehicle-to-infrastructure communication to measure real-time traffic density on the highway and dynamically alters on-ramp metering signal phasing. It is assumed that the infrastructure will make periodic point-to-multipoint broadcasts requesting the information from nearby vehicles. Vehicle-to-infrastructure communication from nearby highway traffic permits the ramp meter controller to adjust the signal timing based on real-time traffic flow and thereby improves traffic flow.

3.1.2 Intelligent Traffic Flow Control

The intelligent traffic flow control application is an infrastructure system that uses vehicle-to-infrastructure communication and thereby facilitates traffic light signal phasing based on real-time traffic flow. It is assumed that the infrastructure will make periodic broadcasts requesting the information from nearby vehicles. Vehicles send a message regarding their position, heading, and speed to the traffic signal infrastructure, which processes the information from each direction and determines the optimal signal phasing based on the real-time information.

3.1.3 Free-Flow Tolling

The free-flow tolling application is designed to reduce congestion and improve traffic on toll roads. The application uses communications for toll collection without the need for toll plazas along the roadway. The application can be designed to eliminate the need for vehicles to stop at toll plazas, thereby reducing stop-and-go traffic near toll collection areas.

3.2 Information from Other Vehicles

The following applications were evaluated based on their ability to improve driver comfort and enhance safety vehicle operation.

3.2.1 Instant Messaging

The instant messaging application is an in-vehicle system that enables a driver to send an instant message to another vehicle. A driver can send a message to a corresponding vehicle if the driver notices any problem such as a flat tire, missing gas cap, open trunk, etc. The message could be chosen from a list of pre-defined or customized messages. The interface for the sender of the message (i.e., how to identify the target vehicle) is not defined.

3.2.2 Adaptive Headlamp Aiming

The adaptive headlamp aiming application allows vehicles to aim their headlights in the direction of travel and more effectively illuminate the road ahead. Roadside units communicate road features that enable vehicles to appropriately aim their headlights. As an alternative to DSRC, digital maps could be used.

3.2.3 Adaptive Drive Train Management

The adaptive drive train management application is designed to improve fuel economy, emissions, and transmission shifting performance. This system uses information provided by the infrastructure regarding road features ahead to assist the engine management system of a vehicle in stabilizing its transmission. Roadside units communicate road features that enable the vehicles to anticipate appropriate shift patterns. As an alternative to DSRC, digital maps and GPS could be used.

3.2.4 Enhanced Route Guidance and Navigation

The enhanced route guidance and navigation application sends up-to-date and localized navigation information to vehicles via roadside units. Information that could be sent includes construction advisories, detours, right and left turn restrictions, and parking restrictions. This information may be temporary or too recent to appear in published navigation maps. Roadside units send enhanced route guidance and navigation information to the vehicle, which processes it and possibly merges it with its navigation system.

3.2.5 Point-of-Interest Notification

The point-of-interest notification application is a roadside unit system that provides information to passing vehicles periodically via broadcast. The information can describe features about the local area or services that are provided in the near vicinity. This application would relieve the driver from searching for a specific type of service.

3.2.6 Map Downloads and Updates

The map application downloads maps to a vehicle. A roadside unit can update a vehicle's existing maps. The kind of information provided varies with the type of roadside unit. Other units could allow entirely new maps to be bought and downloaded. If specific queries can be made from the vehicle or if a transaction is performed, two-way communication is required.

3.2.7 GPS Correction

The GPS correction application is a roadside unit that is pre-programmed with its precise location and gives this information to passing vehicles. Based on GPS coordinates and the time stamp of the message from the roadside unit to the vehicle, the vehicle can calculate its position more accurately using DGPS techniques. This application is particularly useful when the vehicle is far from a commercial DGPS station or when the differential signal is difficult to receive.