Dedicated Short Range Communication

1st Affan Ahmet Bedri Topal
Computer Engineering
Yildiz Technical University
Istanbul, Turkey
19011504
bedri.topal@std.yildiz.edu.tr

2nd Semih Erken
Computer Engineering
Yildiz Technical University
Istanbul, Turkey
19011503
semih.erken@std.yildiz.edu.tr

3rd Mehmet Alperen Ölçer
Computer Engineering
Yildiz Technical University
Istanbul, Turkey
20011023
alperen.olcer@std.yildiz.edu.tr

4th Şevval Bulburu
Computer Engineering
Yildiz Technical University
Istanbul, Turkey
19011038
sevval.bulburu@std.yildiz.edu.tr

5th Emirhan Karadeniz
Computer Engineering
Yildiz Technical University
Istanbul, Turkey
18011041
emirhan.karadeniz@std.yildiz.edu.tr

***Abstract*—This document is a model and instructions for LaTeX. This and the IEEEtran.cls file define the components of your paper [title, text, heads, etc.]. *CRITICAL: Do Not Use Symbols, Special Characters, Footnotes, or Math in Paper Title or Abstract.**

***Index Terms*—component, formatting, style, styling, insert**

I. Introduction

Dedicated short-range communication (DSRC) is a technology used in vehicles to communicate with other devices and is being developed for use in the United States and other countries. Its primary purpose is to support collision prevention applications through frequent data exchanges between vehicles and roadside infrastructure. The United States Department of Transportation (DOT) estimates that DSRC-based vehicle-to-vehicle (V2V) communication has the potential to prevent 82% of crashes involving unimpaired drivers in the United States, potentially saving thousands of lives and billions of dollars. The National Highway Traffic Safety Administration (NHTSA) within the DOT plans to decide in 2013 whether to use regulations to require or encourage the deployment of DSRC equipment in new vehicles in the U.S. In the DSRC collision avoidance system, each equipped vehicle continuously broadcasts its location, speed, and acceleration to other nearby DSRC-equipped vehicles within a range of a few hundred meters. These vehicles also receive similar broadcasts from their neighbors. Using this information, each vehicle can calculate the trajectory of its neighbors and compare it to its own predicted path to determine if there is a potential collision risk. In addition to communication between vehicles, DSRC also allows for communication with roadside units (RSUs) that can provide information such as the layout of an approaching intersection, traffic signal status, and the presence of hazards such as disabled vehicles or emergency vehicles. If a vehicle using DSRC detects a potential collision or other hazard, such as running a red light, the on-board system can provide warnings to the driver through various means, including audio, visual, and haptic feedback. These warnings can range in intensity from informational to cautionary to urgent. While DSRC devices must follow specific interoperability standards for communication, the internal system for calculating hazards and issuing warnings is determined by the vehicle's manufacturer.

II. Deployment of DSRC and Infrastructure

The SAE has established a specification called "J2735D: Dedicated Short Range Communications (DSRC) Message Set Dictionary" to standardize the communication of information such as SPaT (Split Phase and Timing) between vehicles and traffic signals. This specification is commonly used in current generation DSRC radios, which typically have an on-board processor to facilitate communication with traffic signal controllers. The -085 processor is a device that can monitor a traffic signal cabinet and communicate with OBUs (On-Board Units). It is installed directly into the traffic cabinet and connected to a central system cloud. This processor can send information to the traffic operations department responsible for managing the device, as well as receive input from connected vehicles. It serves as a bridge between the traffic signal cabinet, the central system, and connected vehicles.

III. Applications of DSRC

A. Categories of DSRC

There are two broad categories of DSRC: Vehicle-to-Vehicle (V2V) communication and the Vehicle-to-Infrastructure (V2I) communication.

- V2V communication refers to the communication between two or more vehicles, frequently using wireless technology like Dedicated Short Range Communication (DSRC) or cellular networks. Vehicles can communicate information with one another about their location, speed, and trajectory in real-time using this type of communication. V2V communication can assist increase traffic flow and road safety by enabling vehicles to communicate with one another and make more effective routing decisions. It can also help prevent collisions by enabling cars to recognize and avoid them.

- V2I communication refers to the communication between vehicles and infrastructure, such as traffic lights, road signs, and other types of roadway equipment. Vehicles are able to receive information from the infrastructure about traffic conditions, construction zones, and other forms of alerts through the use of DSRC or other wireless technologies in this type of communication. By enabling real-time vehicle adaptation to changing road conditions, vehicle-to-infrastructure (V2I) communication can assist increase traffic efficiency and road safety. It can also support cutting-edge transportation services like autonomous driving and intelligent transport systems.

B. *Typical or Potential Applications of DSRC*

Electronic toll collection, cooperative adaptive cruise control, intersection collision avoidance, approaching emergency vehicle warning, automatic vehicle safety inspection, transit or emergency vehicle signal priority, electronic parking payments, commercial vehicle clearance, in-vehicle display of road signs and billboards, traffic data collection, rail intersection warning, blind spot warning, sudden braking ahead warning, and rollover warning. For electronic toll collection (a V2I application), an early form of DSRC (CEN-DSRC) is still commonly utilized today. However, V2V applications won't be fully effective until a sizable portion of vehicles on the road are outfitted with DSRC devices. The National Highway Traffic Safety Administration (NHTSA) declared in 2014 that it would mandate V2V technology for all vehicles and light trucks sold in the United States [2]. This requirement's implementation date has not yet been given a firm date.

C. *Some of Applications*

- Forward Obstacle Detection and Avoidance: The DSRC channel is utilized to transmit traffic updates or accident warnings back through moving vehicles to alert drivers to potential dangers. Adaptive cruise control systems can be improved through communication with cars directly behind or in front of an automobile. The driver can be alerted to hazards or impediments hundreds of feet in the distance ahead thanks to information shared between vehicles.
- Approaching Emergency Vehicle Warning: DSRC would allow for vehicle-to-vehicle communication to be used to send information about an approaching emergency vehicle forward through traffic. By doing so, it would be easier for the emergency vehicle to get through and less dangerous for other vehicles.
- Cooperative Adaptive Cruise Control : When adaptive cruise control fails to function well because of the radar's line-of-sight scanning, the cooperative adaptive cruise control system is useful. The DSRC system alerts the adaptive cruise control system of any slow-moving vehicles immediately around the turn as the automobile approaches a tight curve.
- Safety for pedestrians and bicyclists: In 2013, Honda showed how a car with DSRC technology could identify a pedestrian using a DSRC-enabled smartphone [9]. Using DSRC technology, a proprietary smartphone application establishes the location of the surrounding cars as well as the position, direction, and speed of the pedestrian. The device warns the pedestrian via a repeating, loud beep and a warning on the screen of their smartphone in the case of an impending collision as detected by the smartphone application. The technology warns the driver of the impending collision at the same time with an auditory alarm and visual warnings on the heads-up display and navigation screen of the car. The vehicle may also learn whether the pedestrian is texting, listening to music, or making a phone call in addition to the standard safety alerts.
- Hazardous Driving Conditions Warning: DSRC systems can be used to track dangerous driving conditions and inclement weather. With the help of V2I systems, weather stations may provide traffic authorities with data so they can adjust speed restrictions and issue warnings to vehicles. In V2V systems, vehicles that lose traction (due to water or ice) can communicate warnings to other vehicles nearby. Although V2V DSRC systems are still in their infancy, significant development is being made in this area. There are joint research initiatives underway, particularly in Europe, to advance system development at every level, from infrastructure to in-car hardware and software. Many of the major automakers in the globe, such as BMW, Daimler, Ford, GM, Honda, Mitsubishi, Nissan, Toyota, Volvo, and Volkswagen, are also working on DSRC systems.

IV. DSRC Standards

A. *Physical Layer*

The DSRC (Dedicated Short-Range Communications) Physical layer is defined in the IEEE 802.11 standard, with amendments in IEEE 802.11p, and is used for communication between vehicles and infrastructure in intelligent transportation systems. The Physical layer is divided into two sublayers: the Physical Medium Dependent (PMD) sublayer, which interfaces directly with the wireless medium, and the Physical Layer Convergence Procedure (PLCP) sublayer, which defines the mapping between the MAC (Media Access Control) frame and the basic PHY layer data unit, the OFDM (Orthogonal Frequency Division Multiplexing) symbol. The PMD sublayer utilizes OFDM, a technique that allows multiple carriers to be transmitted in parallel over a single channel, with each carrier modulated using a different set of parameters. This allows for high data rates and efficient use of the available bandwidth. The DSRC Physical layer supports several different modulation and coding techniques, as well as different channel widths, which can be selected depending on the specific requirements of the application. The PMD transmitter function processes the MAC frame into an OFDM symbol and modulates the subcarriers using one of the supported modulation techniques. The PMD receiver function demodulates the received signal and extracts the MAC frame from the OFDM symbol. The PLCP protocol is responsible for the interaction between the MAC layer and the PMD sublayer, including the mapping of MAC frames to OFDM symbols and the exchange of control information between the two layers. The PLCP protocol also includes the functions of preamble generation and detection, which are used to synchronize the transmitter and receiver. In addition to these basic functions, the DSRC Physical layer also includes provisions for error detection and correction, power control, and channel selection, among other things. It is designed to operate in the 5.9 GHz frequency band, which has been allocated for use in intelligent transportation systems in many countries. The DSRC Physical layer is intended to provide reliable, high-speed communication between vehicles and infrastructure in these systems.

B. Data Link Layer

The DSRC Data Link Layer consists of the Logical Link Control (LLC) and Medium Access Control (MAC) sub-layers. The LLC sub-layer has been adapted from the IEEE 8088.2 specifications for connection-less and connection-oriented services. The MAC sub-layer caters for efficient contention mechanisms to avoid and resolve data collisions in multi-lane environments. The DSRC Data Link Layer has been designed in a medium-independent way, i.e., the parameters can be adapted to both media available for the DSRC.

1) LLC: The DSRC Logical Link Control (LLC) protocol is responsible for controlling the flow of data between two devices over the DSRC communication link. It is a data link layer protocol in the OSI model and is responsible for establishing, maintaining, and terminating logical connections between devices. The LLC protocol provides several key functions, including:

- Connection establishment: The LLC protocol establishes a logical connection between two devices before data can be transmitted between them.
- Flow control: The LLC protocol helps to prevent data loss by regulating the flow of data between devices, ensuring that the receiving device has sufficient buffer space to store incoming data.
- Error detection and correction: The LLC protocol includes error detection and correction mechanisms to ensure the integrity of transmitted data.
- Sequence numbering: The LLC protocol uses sequence numbers to ensure that data is transmitted and received in the correct order.

The DSRC LLC protocol is an important part of the overall DSRC communication system, and it plays a key role in enabling reliable and efficient communication between vehicles and transportation infrastructure.

2) MAC: The DSRC MAC protocol is based on half-duplex TDMA. The beacon (as primary station) offers two different types of up-link windows to vehicles: public and private windows.

- A public window consists of time slots (public slots), which may be accessed by every vehicle within the communication zone. Together with the Beacon Service Table, which holds information about the valid application and protocol parameters at a specific beacon site (such as length of public and private windows), public windows are offered periodically by the beacon to newly arriving vehicles (address acquisition or connection phase).
- A private window allocation reserves a time period for one specific vehicle and therefore protects it against data collisions after the address of a vehicle is known (transaction phase). To avoid unnecessary delays during the address acquisition phase, it is essential to avoid and resolve collision situations effectively. By randomly distributing the transmission of newly arriving vehicles over several public slots the probability of data collisions can be reduced. This improves the DSRC MAC performance. (See also pages on ALOHA, stability, collision resolution, and stack algorithms for a generic treatment.)

a) Open-Road Frame: In contrast to the asynchronous DSRC MAC protocol, the TDMA protocol proposed for the ITS communication architecture is based on a fixed frame structure, the so-called Open-Road Frame, which consists of the following elements:

- a Reader Control Message (RCM),
- several Data Slots (DS), and
- several Activation Slots (AS).

The activation slots are used for the transmission of the ID of newly arriving vehicles (similar to public slots in the DSRC approach). The data slots may be used for down-link transmissions or are reserved by the beacon for up-link transmissions (similar to private windows). Reading the RCM, the vehicles get to know the assignment of down-link and up-link slots. As the data slots have a fixed length and the frame structure is fixed, data slots, which do not need be used completely or not at all, produce a certain overhead especially for single application scenarios. From a performance point of view, the DSRC MAC solution offers more flexibility for optimization especially for applications with a high priority as Automatic Fee Collection. This is because the assignment of public and private windows can be adapted to the actual traffic situation easily. Nevertheless, the DSRC MAC protocol can also be used in a synchronous mode by setting the BST retransmission intervals to a fixed length.

V. DSRC Spectrum

The DSRC is achieved over reserved radio spectrum bands, which differ in North America, Europe, and Japan. DSRC spectrum bands are allocated by the U.S. FCC and Industry Canada in North America, the Electronic Communications Committee of the European Conference of Postal and

Telecommunications Administrations (CEPT) in Europe, and the Ministry of Internal Affairs and Communications (MIC) in Japan. The FCC has designated the ”5.9 GHz band,” or the spectrum between 5.850 GHz and 5.925 GHz, for DSRC operation in the United States. Using a 5-MHz guard band at the low end, this spectrum is split into seven 10-MHz channels. It is also possible to create 20 MHz channels from pairs of 10 MHz channels. Due to the need to support a variety of parallel application types and because physical testing indicates that this channel width is well suited to the delay and Doppler spreads that will likely be experienced in the vehicular environment, the majority of DSRC testing in the US has been conducted on 10 MHz channels. It is still uncertain, though, if the added capacity of a 20 MHz channel would be a better way to address channel congestion issues, particularly in the channel used for V2V safety communication (possibly Channel 172). For a certain number of frame transmissions per second, the collision probability is decreased since a frame with a given modulation and coding transmits over a 20 MHz channel in about half the time it does on a 10 MHz channel. On the other hand, a 20 MHz channel has more noise for a given background spectral density and may present a bigger difficulty in particular settings, such as inter-symbol interference because the delay spread is greater than the reduced cyclic prefix length. Some DSRC bands, such as those in North America at 902-928 MHz, Europe at 5795-5815 MHz, and Japan at 5770-5850 MHz, are currently in use for applications like electronic toll collection. The remaining DSRC allotted spectrum bands, however, are not currently in use.

VI. DSRC Message Set

Each message type indicated in Fig. 1 has a specific format that is defined by SAE J2735. A group of data structures known as data elements and data frames are defined as the building blocks of each message. In the J2735 standard, a data element is the simplest type of data structure. One or more data pieces or other data frames make up a data frame, which is a more complicated data structure. Each data element and data frame has a defined semantics (length, format) according to the J2735 standard. The J2735 standard’s Basic safety message may be its most crucial one. It transmits the sending vehicle’s position, dynamics, system status, and size, which together make up the core state information. Additionally, it can convey more information if necessary. Two sections make up the BSM. Every BSM must send the critical state information in Part I. Compactness and effectiveness are highlighted in the data structure for Part I. Part II is an optional section where extra data frames and elements may be added. The four data elements most frequently discussed for inclusion in Part II of the BSM are compiled in the data frame ”VehicleSafetyExtension”. VehicleSafetyExtension frame may or may not be present in a particular BSM, and a given VehicleSafetyExtension frame may be made up of any arrangement of the four data elements.

Message Type	Purpose
A La Carte Message	Generic message with flexible content
Basic Safety Message	Conveys vehicle state information necessary to support V2V safety applications
Common Safety Request	A vehicle uses this to request specific state information from another vehicle
Emergency Vehicle Alert Message	Alerts drivers that an emergency vehicle is active in an area
Intersection Collision Avoidance	Provides vehicle location information relative to a specific intersection
Map Data	Sent by RSU to convey the geographic description of an intersection
NMEA Corrections	Encapsulates one style of GPS corrections – NMEA style 183
Probe Data Management	Sent by RSU to manage the collection of probe data from vehicles
Probe Vehicle Data	Vehicles report their status over a given section of road; aggregated to derive road conditions
Roadside Alert	Sent by RSU to alert passing vehicles to hazardous conditions
RTCM Corrections	Encapsulates a second style of GPS corrections – RTCM
Signal Phase and Timing Message	Sent by RSU at a signalized intersection to convey the signal’s phase and timing state.
Signal Request Message	A vehicle uses this to request either a priority signal or a signal preemption.
Signal Status Message	Sent by RSU to convey the status of signal requests.
Traveler Information	Sent by RSU to convey advisory and road sign types of information

Fig. 1. Message types of DSRC

VII. Security

The general topic of security in vehicular networks is a complex subject. This subsection explains how the basic principles are applied in the specific case of the IEEE 1609.2 [3] standard: Security Services for Applications and Management Messages. As this paper is being written the IEEE 1609.2 standard is in draft stage. Some changes are likely during the balloting process, which is expected to be completed in 2011. IEEE 1609.2 defines standard mechanisms for authenticating and encrypting messages, especially WSMs and WSAs. This subsection focuses on authentication of a vehicle safety message, i.e. a Basic Safety Message (BSM) carried in a WSM. In addition to the algorithm and frame formats currently defined in IEEE 1609.2, the general area of BDSRC security[involves other issues as well. A cooperative U.S. DOT and automotive industry project called V2V-Communications Security [36] is developing solutions related to the following open questions: a) , b) type of Public Key Infrastructure (PKI), e.g., policy regarding Kenney: Dedicated Short-Range Communications (DSRC) Standards in the United States Vol. 99, No. 7, July

2011 — Proceedings of the IEEE 1175 certificate validity, certificate encryption, and certificate revocation, c) , and e) detection and reporting of misbehaving DSRC devices. Some of the solutions to these open issues may eventually be reflected in the IEEE 1609.2 standard, while others will likely be documented in government regulations.

- type of wireless communication to be used between a vehicle and the security infrastructure [i.e., Certificate Authority (CA)]
- type of Public Key Infrastructure (PKI), e.g., policy regarding Kenney: Dedicated Short-Range Communications (DSRC) Standards in the United States Vol. 99, No. 7, July 2011 — Proceedings of the IEEE 1175 certificate validity, certificate encryption, and certificate revocation
- protecting the privacy of vehicle drivers and owners
- the physical security of DSRC devices
- detection and reporting of misbehaving DSRC devices.

Some of the solutions to these open issues may eventually be reflected in the IEEE 1609.2 standard, while others will likely be documented in government regulations.

References

[1] J. B. Kenney, "Dedicated Short-Range Communications (DSRC) Standards in the United States," in Proceedings of the IEEE, vol. 99, no. 7, pp. 1162-1182, July 2011, doi: 10.1109/JPROC.2011.2132790.

[2]

[3]