DSRC/WAVE (Wireless Access in Vehicular Environments)

1st Faruk Veli Özdemir
Yıldız Technical University
İstanbul, Turkey
veli.ozdemir@std.yildiz.edu.tr

2nd Kerim Sadıkoğlu
Yıldız Technical University
İstanbul, Turkey
kerim.sadikoglu@std.yildiz.edu.tr

3rd Furkan Bingöl
Yıldız Technical University
İstanbul, Turkey
furkan.bingol1@std.yildiz.edu.tr

4th Yusuf Kıran
Yıldız Technical University
İstanbul, Turkey
yusuf.kiran1@std.yildiz.edu.tr

5th Yusuf Taha Kara
Yıldız Technical University
İstanbul, Turkey
taha.kara@std.yildiz.edu.tr

***Abstract*—Wireless vehicular networks operating on the dedicated short-range communications (DSRC) frequency bands are the key enabling technologies for the emerging market of intelligent transport system (ITS). The wireless access in vehicular environments (WAVE) is significantly different from the Wi-Fi and cellular wireless networking environments. The specifications defined by IEEE802.11P and IEEE1609 represent the most mature set of standards for DSRC/WAVE networks. This paper provides an overview of the current state of the art, and analyses the potential differences between application requirements and what can be offered by the current WAVE solutions. It is shown that the current solutions may be inadequate for large-scale deployment. The primary challenge is to develop scalable, robust, low-latency and high-throughput technologies for safety applications that will significantly reduce collisions and save lives and property loss. Further research ideas are proposed to address this challenge**

I. Introduction

WAVE introduces enhancements to IEEE Std 802.11™ in order to support communications with:

• Short latency (approximately 100 microseconds to 50 milliseconds)

• Ranges from one meter up to 1000 meters

• WAVE devices installed in vehicles operating at speeds up to 200 km/h.

• Multipath and Doppler shift (typically encountered by a STA mounted on a vehicle operating on a roadway with other vehicles and traveling in urban, suburban, and rural terrain)

The goal of WAVE is to provide seamless, interoperable services to transportation. These services include vehicle-to-roadside as well as vehicle-to-vehicle communic ations described in the US National Intelligent Transportation Systems (ITS) Architecture and others contemplated by the automotive and transportation infrastructure industries. Many of the applications envisioned for WAVE are designed to improve vehicle safety. This is the basis for the US Federal Communications Commission (FCC) allocating a licensed 5.9 GHz band for Dedicated Short Range Communications (DSRC), now termed WAVE operations. To simplify interoperability between different automobile manufacturers for WAVE-based Intelligent Transportation Systems (ITS) applications, the entire protocol suite is being standardized. The layers above the PHY and MAC are outside the scope of IEEE Std 802.11™ and are mentioned here to provide a more complete description of how P802.11p relates to a WAVE system. While these upper layers are part of the overall WAVE system architecture, there is no intent to limit the P802.11p operation to these higher layers. The P802.11p standards may be used by different protocols and services of layers above that of IEEE Std 802.11™.

The WAVE system concept was developed after reviewing hundreds of potential applications ranging from various forms of collision avoidance techniques to entertainment. Most of these applications required communications capabilities that could not be met with existing technologies. (See 11-05-0445-00-000p-TGp Overview.ppt. and 11-05-0446-000p-wave-operational-concepts.ppt.) An ASTM DSRC (WAVE) standards development activity resulted in the publication of ASTM E2213-03 which incorporated IEEE P802.11a after a test and analysis effort demonstrated it most closely met the require¬ments. This ASTM effort also resulted in formal rules by the US Federal Communications Commission for the use of the 5 GHz ITS Radio Service band within the United States.

NOTE—ASTM. E2213-03 is available from the American Society for Testing and Materials (ASTM) International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA, 19428-2959 USA. Their website is: www.astm.org. The STA located on the roadside or above the roadway is called the Road-Side-Unit (RSU) and the STA mounted onboard the vehicle is called the On-Board-Unit (OBU) as shown in Figure 1. A common requirement for WAVE systems is that the communications are highly localized. An example of usage is at a toll collection station, where the communication zone is designed to be less than the length of a single car to assure that vehicles are charged only once. Next generation toll collection systems are open road tolling (no toll booths) with vehicles trav¬eling at speeds of up to 200 km/h. The complete transaction must be completed in less than 100 ms, which demands very low latency. Low latency is also required for other applications such as collision avoidance and miti¬gation at intersections. Typically, an IEEE Std 802.11™

association is measured in seconds, not millisec¬onds, so some new "fast association" capability is required. This has lead to the development of an alternative to the traditional usage of a beacon to initiate an association leading to the formation of a BSS.

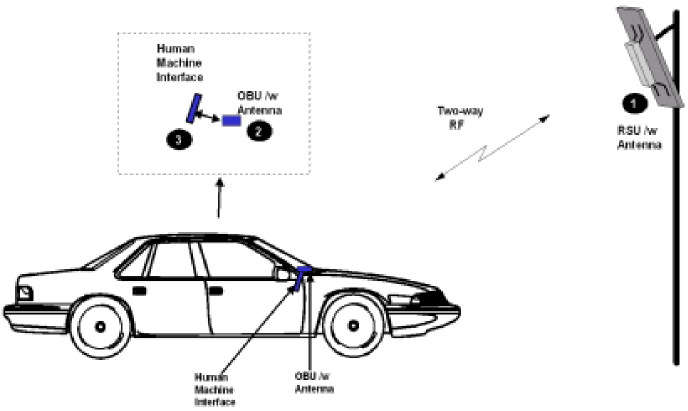

Fig. 1. Relationship between roadside and on-board STAs.

For many anticipated WAVE applications, for example, collision avoidance, there is also the need for vehicles to communicate with each other directly. This can involve a very large number (hundreds) of vehicles that are within range and interacting, with new vehicles entering and leaving the communication zone of any one vehicle every second.

II. OVERVIEW

Provision of externally-driven services to vehicles has been limited because of the lack of ubiquitous high-speed communications between vehicles and service providers, and the lack of homogeneous communications interfaces between different automotive manufacturers. The IEEE 1609 Family of Standards for Wireless Access in Vehicular Environments (WAVE) completely address the latter issue, and provide a sufficient foundation regarding the organization of management functions and modes of operation of system devices to address the former.

III. WAVE STANDARTS

WAVE provides a communication protocol suite optimized for the vehicular environment, employing both customized and general-purpose elements. The components of the system, as defined in standards, are shown in Figure 1.

The IEEE 1609 Family of Standards for Wireless Access in Vehicular Environments (WAVE) defines the architecture, communications model, management structure, security mechanisms and physical access for high speed (up to 27 Mb/s) short range (up to 1000m) low latency wireless communications in the vehicular environment. The primary architectural components defined by these standards are the On Board Unit (OBU), Road Side Unit (RSU) and WAVE interface.

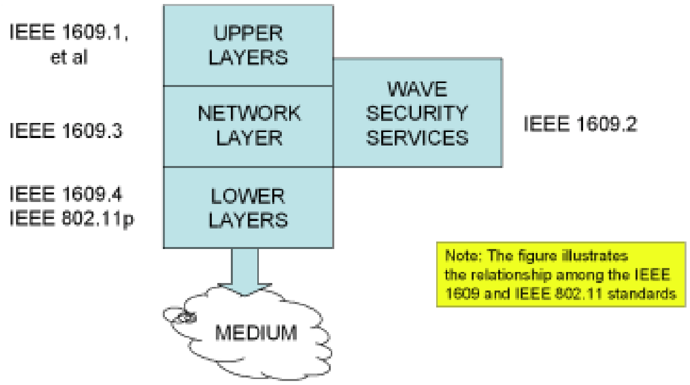

Fig. 2. WAVE standards

These standards also define how applications that utilize WAVE will function in the WAVE environment as illustrated in IEEE 1609.0, based on the management activities defined in IEEE P1609.1, the security protocols defined in IEEE P1609.2, and the network-layer protocol defined in IEEE P1609.3. Lastly, they provide extensions to the physical channel access defined in IEEE 802.11 to support the WAVE standards in IEEE P1609.4.

-IEEE Std 1609.1™-2006 describes the services and interfaces, including security and privacy protection mechanisms, associated with the DSRC Resource Manager operating at 5.9GHz.

-IEEE Std 1609.2™-2006 specifies a range of security services for use in the WAVE environment including:

• Secure message formats and processing of secure messages, within the DSRC/WAVE system

• Methods for securing WAVE management messages and application messages, with the exception of anonymity-preserving vehicle safety messages

• Administrative functions necessary to support the core security function

-IEEE Std 1609.3™-2007 defines services, operating at the network and transport layers, in support of wire¬less connectivity among vehicle-based devices, and between fixed roadside devices and vehicle-based devices using the 5.9 GHz WAVE mode. This includes the management of the WAVE BSS (WBSS).

-IEEE Std 1609.4™-2006 describes multi-channel wireless radio operations that use the IEEE P802.11p, WAVE mode, medium access control and physical layers including the operation of control channel and service channel interval timers, parameters for priority access, channel switching and routing, management services, and primitives designed for multi-channel operations.

IV. WAVE SYSTEM ATTRIBUTES

This subclause describes important aspects of the WAVE system, which may be used as a base for better understanding the material in subsequent clauses.

A. Channel types

For the purposes of this standard, WAVE distinguishes between two classes of radio channel: a single con¬trol channel (CCH), and multiple service channels (SCH). By default, WAVE devices operate on the control channel, which is reserved for short, high priority, application and system control messages. Service channel visits are arranged between devices via a WBSS in support of general-purpose application data transfers. See IEEE Std 1609.4™-2006 for more information.

B. Communication protocols

WAVE provides two protocol stacks: standard Internet Protocol (IPv6) and the unique WAVE Short Mes¬sage Protocol (WSMP) designed for optimized operation in the WAVE environment. WAVE short mes¬sages (WSMs) may be sent on any channel. IP traffic is allowed only on SCHs. In addition to these traffic types, system management frames are sent on the CCH as described in IEEE Std 1609.4™-2006. WSMP allows applications to directly control physical characteristics, e.g., channel number and transmitter power, used in transmitting the messages. A sending application must also provide the MAC address of the destination device, including the possibility of a broadcast address. WSMs are delivered to the correct appli¬cation at a destination based on Provider Service Identifier (PSID) (essentially the Application Service Access Point) which is a globally unique value managed by the IEEE Registration Authority. The PSID is used not only for internal routing with a device, but also so that devices entering a new communication zone can very rapidly (using only the data contained within an announcement message) know if there is a peer application of interest present. WSMs are designed to consume minimal channel capacity, so are allowed on both the CCH and SCHs.

C. Communication service types

Applications may choose to send their traffic in the context of a WAVE BSS (WBSS), or not. If they do not employ a WBSS, their communication options are limited to WSMs sent on the CCH. Participating on a WBSS allows applications to use either WSM or IP traffic on the SCH associated with that WBSS. Partici¬pating devices periodically visit the designated SCH in order to exchange data. A WBSS is established to support traffic to/from specific applications, and its presence announced for other devices with compatible applications to join. A persistent WBSS is announced periodically, and could be used to support an ongoing service of indefinite duration, such as general Internet access. A non-persistent WBSS is announced only on WBSS initiation, and might be used to support a WBSS with limited duration. Operation on one WBSS consumes the resources of one device PHY. More on the use of WBSS in WAVE is found in IEEE Std 1609.4™-2006.

D. Device WBSS roles

Devices may take the role of either provider or user on a given WBSS; this is determined by the role chosen by the application operating through the device. The provider device generates the announcements that inform other devices of the existence of the WBSS, and the presence of the associated application service(s). The user role is assumed by any devices that join the WBSS based on receipt of the announcement. A device may change roles as it participates on different WBSSs over time. The terms provider and user do not imply any particular behavior of the applications once the WBSS is initiated or joined.

E. Priorities

The concept of priority is used in multiple ways. Applications have an application priority level, which is used by Networking Services to help decide which applications have first access to the communication ser¬vices, e.g., which application's WBSS to announce/join in case of a conflict. In addition, the lower layers use a separate MAC transmission priority to prioritize packets for transmission on the medium. IP packets are assigned the MAC priority associated with the traffic class of the generating application. The MAC priority for WSM packets is assigned by the generating application on a packet by packet basis. Any relationship between application and transmission values is within the application, and outside the scope of this standard. See IEEE Std 1609.4™-2006 for more on MAC transmission priority.

F. Channel coordination

WAVE channels are coordinated based on sync intervals that are synchronized using a common system time base preferably generated by a global time reference (e.g., UTC/GPS). A sync interval is composed of a CCH interval followed by an SCH interval. During the CCH interval, all devices monitor the CCH. Devices participating in a WBSS will utilize the SCH designated for that WBSS during the SCH interval. See IEEE Std 1609.4™-2006 for more information.

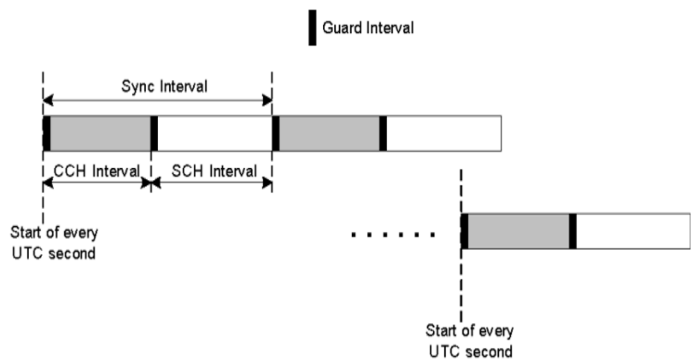

Fig. 3. IEEE Std 1609 Sync Tolerance

G. WBSS initiation

This subclause provides a description of WBSS initiation from the application perspective, and ignores some of the detailed processing at lower layers, such as addressing, security credentials, and time synchroni¬zation verification. A

WBSS is triggered by a provider application via a request to the WAVE Management Entity (WME, defined in IEEE Std 1609.3™-2007) using WME-Application.request. The request specifies the persistence, the MAC address (which may be unicast or broadcast) of the intended recipient devices(s), the number of announcement repetitions, and the SCH to be used. (Optionally, it may direct the WME to choose the "best available" SCH.) These WBSS parameters are transmitted in a WAVE Announcement, in the Provider Service Table component of the WAVE Service Information Element (WSIE). See IEEE Std 1609.3™-2007 for more information. On receipt of an announcement, the receiving WME checks whether a provider application, defined by the PSID in the announcement, is of interest to any locally registered user applications. When a match is found (and assuming the WME's check of credentials, priority, etc., are satisfied), the WME will take one of two actions, depending again on an application registration parameter. In the simple case, the WME will gener¬ate the necessary MAC primitives to cause the local device to join the WBSS, i.e., to tune to the correct SCH at the correct time, and to set any other lower layer configuration appropriately to support the communica¬tions. Alternately, if the application has chosen, it must confirm the joining of the WBSS. This gives the user application an additional level of control, for example allowing it to decline to participate in a service if it has recently accomplished any objectives it might have on that WBSS. Upon decision to join, the WME sends a notification to the local application. The announcement is the only WAVE message sent over-the-air when setting up a WBSS; there is no lower-layer over-the-air coordination used to confirm the WBSS initiation.

V. Who uses them?

This family of standards should be used by transportation, automotive and traffic engineers involved with the design, specification, implementation, and testing of WAVE devices. Network engineers, hardware engineers, and application designers supporting Intellidrive (SM) will use these standards as they define the communications architecture for DSRC - based V2V and V2I interactions, and as the basis for the lowlatency interface design of On-Board and Roadside devices. Intellidrive application designers may use the standards to provide the basis for interface definitions between system components, and as a framework for application architecture.

VI. How are they used?

Collectively the IEEE 1609 Family of Standards for Wireless Access in Vehicular Environments (WAVE) describes wireless data exchange, security, and service advertisement between vehicles and roadside devices, and those layers of the applicable protocols that Intellidrive applications may require access to when communicating with vehicles. They describe the physical mechanism of communication, as well as the command and management services, and provide two options (WAVE short message and IPv6) for communicating between vehicles and between vehicles and roadside devices. These standards provide the basis for the design of applications interfacing with the WAVE environment, and provide network services so that applications can be seamless without regard to specific manufacturers, including data storage access mechanisms, device management, and secure message passing.

References

[1] Morgan, Yasser L. "Improving the LEACH protocol on wireless sensor network." 2015 23nd Signal Processing and Communications Applications Conference (SIU). IEEE, 2015.

[2] Laberteaux, Kenneth, and Hannes Hartenstein, eds. VANET: vehicular applications and inter-networking technologies. John Wiley & Sons, 2009.

[3] Shladover, Steven E., and Swe-Kuang Tan. "Analysis of vehicle positioning accuracy requirements for communication-based cooperative collision warning." Journal of Intelligent Transportation Systems 10.3 (2006): 131-140.

[4] Li, Yunxin Jeff. "An overview of the DSRC/WAVE technology." International conference on heterogeneous networking for quality, reliability, security and robustness. Springer, Berlin, Heidelberg, 2010.

[5] Yang, Kai, and Xiaodong Wang. "Cross-layer network planning for multi-radio multi-channel cognitive wireless networks." IEEE Transactions on Communications 56.10 (2008): 1705-1714.

[6] Hubaux, Jean-Pierre, Srdjan Capkun, and Jun Luo. "The security and privacy of smart vehicles." IEEE Security & Privacy 2.3 (2004): 49-55.