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IEEE 802.11p based WAVE Protocol for Railroad Applications

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Abstract: - In this paper, a study on Wireless Access in Vehicular Environment (WAVE) for railroad application is presented. WAVE communication is developed for vehicular communication and based on IEEE 802.11p technology. Whereas Intelligent Transport System (ITS) using WAVE has been developed very much, WAVE applications for railroad have not been studied. When WAVE is used in railroad applications, safety needs to be considered with highest priority. WAVE protocol for railroad applications needs to fully take safety requirements into account. In this paper, we propose possible WAVE protocol architecture and technical considerations for WAVE railroad application.

Keywords: - *IEEE 802.11p, WAVE, Railroad*

I. INTRODUCTION

Wireless Access in Vehicular Environments (WAVE) consists of IEEE 1609 series standards [1-4] and IEEE 802.11p [5] standard. WAVE is designed to be appropriate for vehicular wireless communication. WAVE standards support both Vehicle to Vehicle (V2V) communication and Vehicle to Infrastructure (V2I) communication. In order to support both V2V and V2I communications, IEEE 802.11p standard adopted modifications based on IEEE 802.11 standard. WAVE was developed for Dedicated Short Range Communication (DSRC) [6-7] and is being used as a highway tolling system [8]. As a solution to Intelligent Transportation Services (ITS), various methods using WAVE have been studied.

In this paper, technical considerations (e.g., protocol architecture, QoS requirements, etc) for WAVE railroad applications are presented. First, after careful analysis on the protocol architecture, a possible protocol architecture is proposed. Second, based on USA Federal Communications Commission (FCC)'s recommended WAVE channel allocation, possible channel allocation for WAVE railroad application is proposed. Third, Medium Access Control (MAC)/ Physical layer (PHY) technical considerations are presented. The presented technical considerations are to meet the requirements of WAVE railroad applications.

II. WAVE RAILROAD PROTOCOL

WAVE railroad protocol architecture is shown in Fig. 1. PHY and MAC employ IEEE 802.11 basic standard and IEEE 802.11p amendment [5]. Since WAVE utilizes multi channels, multi-channel operation is standardized with IEEE 1609.4 [4]. Transport layer/WSMP layer and Logical Link Control (LLC) related protocols are specified in IEEE 1609.3 [3]. Applications should be located on top of transport layer and WSMP layer. Therefore, railroad application should be located same as other WAVE applications, e.g., fee collection, safety application using SAE J2735, etc as shown in Fig. 1.

FCC allocated 7 channels of 10MHz for WAVE as shown in Fig 2. As FCC allocated, Ch. 172 can also be used for V2V safety communications for railroad and Ch. 178 can be used for high-power, longer distance safety related communications. By allocating Ch. 172 and Ch. 178 for safety channels, normal ITS users can share safety related information with railroad users. Ch. 178 can be allocated for railroad control information, e.g., train control, as a Control Channel (CCH). Ch. 174, Ch. 176 (20MHz Ch. 175) and Ch. 180, Ch. 182 (20MHz Ch. 181) are proposed to be allocated for broadband services such as surveillance video, IP telephony and so on as Service Channels (SCH). As an aggregation of two 10MHz channels, 20MH channels can be used.

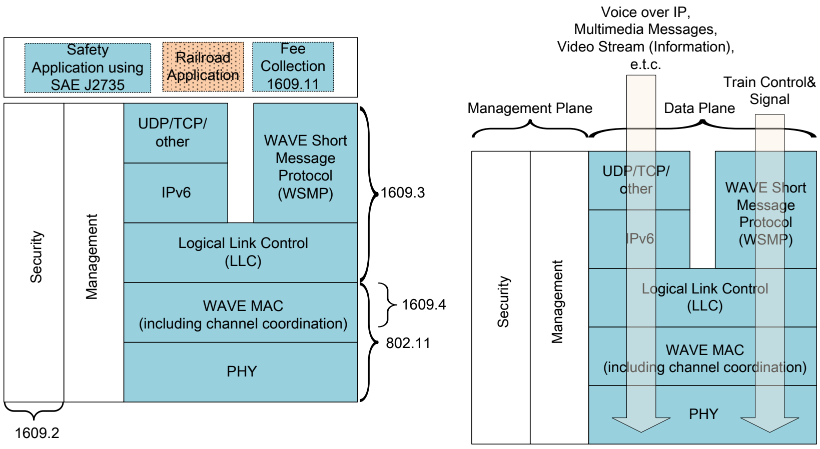

Fig. 1. WAVE standards and railroad application

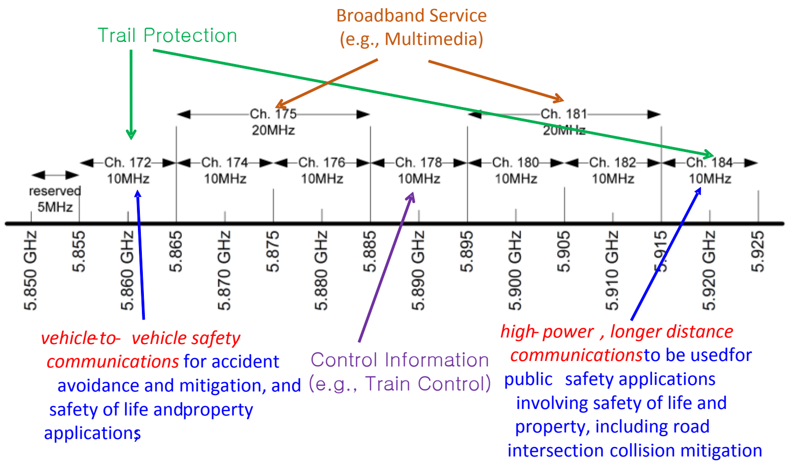

Fig. 2. Multi-channel allocation for railroad application

When 20MHz channel (which are aggregation of two 10MHz channels) is used, transmission range could be reduced due to wide channel bandwidth. Whereas approximately 1km transmission range is normally used for cell design with 10MHz channel, less than half km transmission range can only be used with 20MHz channel.

Global System for Mobile communication – Railroad (GSM-R) is widely used wireless standards for railroad wireless communication in many countries. Table 1. lists railroad related services in GSM-R and their possible WAVE implementations. Since WAVE system is IP based system, call related railroad services, such as Voice Group Call Service (VGCS), Voice Broadcast Calls (VBS), Functional Addressing (FN) and Railroad Emergency Calls (REC) can be implemented by extending Session Initiation Protocol (SIP). Priority and Pre-emption (eMLPP) can be implemented by using IEEE 802.11p access class. In order to utilize IEEE 802.11p, railroad applications should be classified into 4 access classes and mapped to IEEE 802.11p access classes. Since IEEE 802.11p does not provide tight delay control as GSM-R, eMLPP of WAVE could not fully meet the requirements of railroad application. Therefore, in depth study on the performance needs to be performed.

Table 1. WAVE features and their possible implementations.

GSM-R Features	WAVE Features
Voice Group Call Service (VGCS)	Session Initiation Protocol (SIP) based VoIP service extension
Voice Broadcast Calls (VBS)	Session Initiation Protocol (SIP) based VoIP service extension
Priority and Pre-emption (eMLPP)	Priority services according to IEEE 802.11p Access Class
Functional Addressing (FN)	Session Initiation Protocol (SIP) based addressing
Location Depending Addressing (LDA, eLDA)	WAVE Application service
Railway Emergency Calls (REC, e-REC)	Session Initiation Protocol (SIP) protocol & IEEE 802.11 Emergency call setup based VoIP service extension

Medium Access Control (MAC)/ Physical layer (PHY) of IEEE 802.11p needs to be carefully designed in order to meet the requirements of railroad applications. Since MAC and PHY of IEEE 802.11p cannot be modified, their parameters to meet the requirements of railroad applications need to be controlled using MAC/PHY primitives. Especially, multichannel operation defined in [4] needs to be carefully designed to meet the delay requirements of railroad applications. MAC/PHY technical considerations are summarized as follows:

- WAVE Multichannel operation and delay bound
– Single-PHY operation in relation with delay bound
– Multi-PHY operation in relation with delay bound
- Multi-PHY
– Suitable for simultaneous railroad WAVE applications
– Multiple channel operation (CCH, SCH) implementation
– MAC addresses pseudonymity
- IPv6 Support
– IPv6 support of RSU
– WSA Router Advertisement feature support
– Required for railroad IP services
- CCA level should be modified for railroad services
– Receiver sensitivity Threshold should be adjustable
– In case of co-existence with other WAVE systems, this feature is required for optimal railroad WAVE performance
- EDCA Support
– Railroad traffic for WAVE service should be selected
– Railroad traffic should be classified and mapped to EDCA Traffic Classes
▪ Mapping considering Traffic characteristics and Vital/Non-vital traffic classes
✓ AC_VO: (Vital and Voice) or (1st priority control traffic)
✓ AC_VI: (Vital and Video) or (2nd priority control traffic)
✓ AC_BE: Non-vital and not (control or voice or video)
✓ AC_BK: Do not allocate
- WSMP for railroad application
– Provider Service Identifier (PSID): 4 Octet
– PSID for railroad application should be defined and implemented

III. CONCLUSION

In this paper, WAVE protocol architecture, WAVE channel configuration, MAC/PHY technical considerations for WAVE railroad applications are proposed. In order to draw proposal, careful analysis on the existing WAVE protocol architecture is performed. Based on the analysis of the protocol architecture, a possible protocol architecture is proposed. Based on USA Federal Communications Commission (FCC)'s recommended WAVE channel allocation, possible channel allocation for WAVE railroad application is also proposed. Lastly, in order to meet the requirements of railroad applications, MAC/PHY technical considerations are presented.

IV. ACKNOWLEDGEMENTS

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