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Reliable WAVE Communication for Railroad Applications

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Abstract: - In this paper, reliable WAVE communication method is proposed for railroad applications. In order for WAVE to be used for railroad applications, system reliability must be provided because railroad WAVE is very closely related to passenger safety. WAVE reliable communication has not been fully considered. In this paper, network configuration, protocol architecture, and WAVE communication protocol for reliable communication are proposed. Since WAVE channel allocation is dependent on nations' regulation, some countries may allocate redundant WAVE channel but some countries may not allocate redundant WAVE channel. Therefore, in this paper, both reliable WAVE communication protocol with one WAVE channel and with multiple WAVE channels are proposed. The proposed scheme can be utilized regardless of WAVE channel availability and the railroad WAVE system configuration can be very flexible due to the flexibility of the proposed protocol. The proposed architecture and protocol is not confined to railroad applications, typical Intelligent Transports System (ITS) is able to adopt the proposed scheme for reliability.

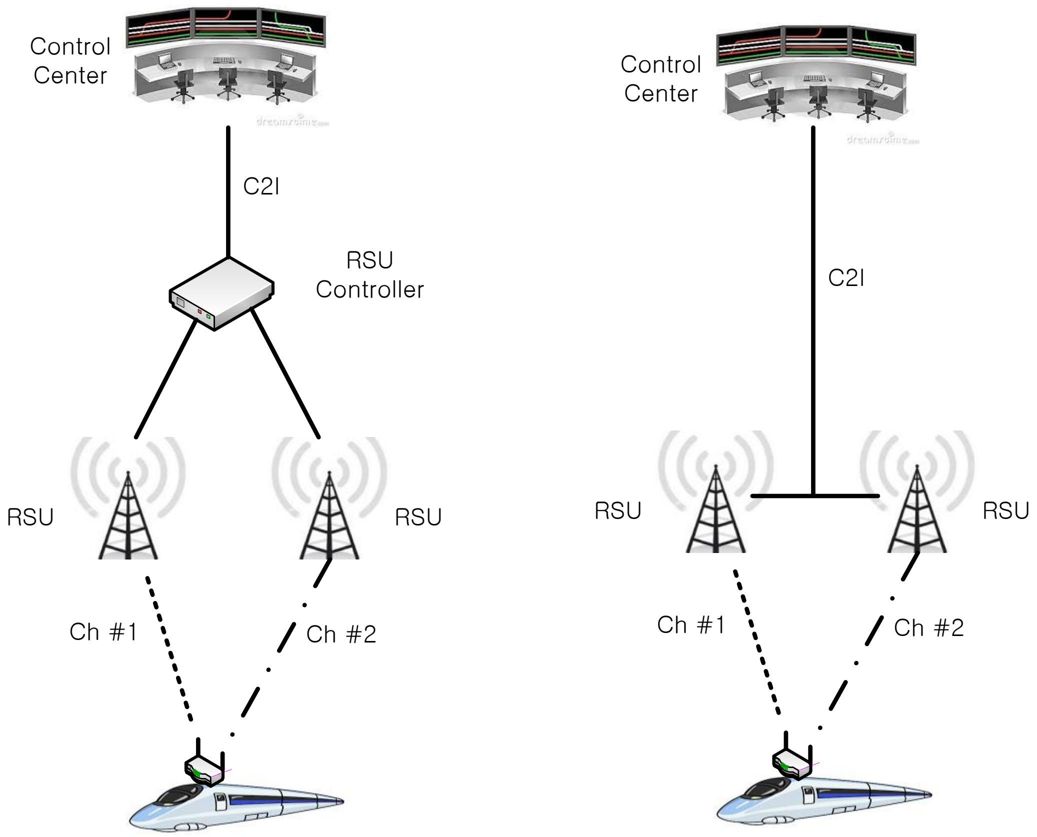
Keywords: - *IEEE 802.11p, ITS, Multi-channel, Railroad, WAVE*

I. INTRODUCTION

With the emergence of smart phones and tablets, Wireless Local Area Network (WLAN) [1] has become the most popular wireless access scheme. The reasons why WLAN is very popular are simple deployment due to using license exempt wireless bands, and high data transmission rate due to broadband channel access [2], [3]. Thanks to its advantages, WLAN has been used in various areas including Intelligent Transportation Services (ITS). In order for WLAN to be used in vehicular applications like ITS, service related protocols have to be newly defined and WLAN's Medium Access Control (MAC) and Physical (PHY) protocols should be modified. For such a reason, a set of new standards called Wireless Access in Vehicular Environments (WAVE), IEEE 1609 series [4], [5], [6], [7] have been newly developed and IEEE 802.11 amendment, IEEE 802.11p, has been made [8]. WAVE is used as a solution to Intelligent Transportation Services (ITS) in various areas including Dedicated Short Range Communication (DSRC) for tolling system [9], [10], [11].

There has not been any attempt to utilize WAVE for railroad applications. Since WAVE is originally designed for vehicular applications, its application to railroad is possible without much modification. However, in order to use WAVE in railroad applications, system and performance reliability need to be ensured because railroad applications are very closely related to passenger safety.

In this paper, reliable WAVE communication method is proposed for railroad applications. In order to provide reliable WAVE communication, network configuration, protocol architecture, and WAVE communication protocol for reliable communication are carefully designed. Since WAVE channel allocation is dependent on each nation's regulation, some countries may allocate redundant WAVE channel but some countries may not allocate redundant WAVE channel. Therefore, in this paper, both reliable WAVE communication protocol with one WAVE channel and with multiple WAVE channels are proposed. The proposed scheme can be utilized regardless of WAVE channel availability and the railroad WAVE system configuration can be very flexible due to the flexibility of the proposed protocol. The proposed architecture and protocol is not confined to railroad applications, typical Intelligent Transports System (ITS) is able to adopt the proposed scheme for reliability.



(a) Centralized Redundancy Configuration (b) Distributed Redundancy Configuration

Fig. 1. Railroad WAVE Redundancy Network Configuration

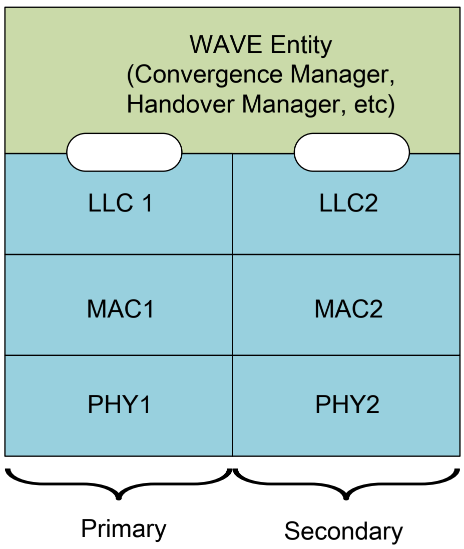


Fig. 2. WAVE Protocol Architecture for Redundancy Configuration with Two WAVE Channels

II. PROPOSED RELIABLE WAVE COMMUNICATION CONFIGURATION & PROTOCOL

Railroad WAVE redundancy can be both provided with one WAVE channel or multiple WAVE channels. For both cases, minimum two Road Side Unit (RSU) are required. Two RSUs are able to communication with On Board Unit (OBU) with one WAVE channel or OBU with two WAVE channels.

2.1 WAVE redundancy configuration

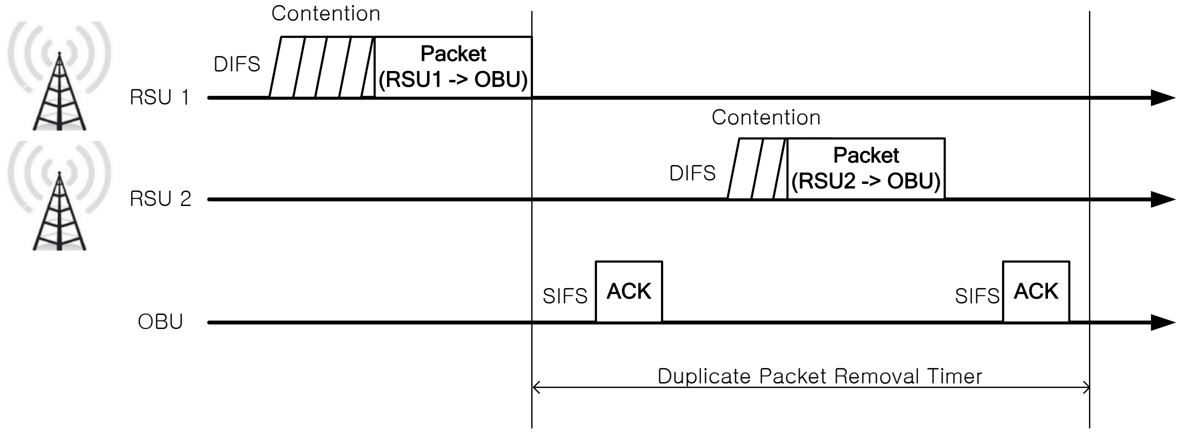
Fig. 1 shows WAVE redundancy network configuration and Fig. 2 shows WAVE protocol architecture for redundancy configuration. As shown in Fig. 1, there are two possible WAVE network configurations for reliable communication: centralized redundancy configuration and distributed redundancy configuration. In case of the centralized redundancy configuration, new control entity called RSU controller controls redundant packet transmission. The main role of RSU controller is making redundant packets to transmit to OBU and remove duplicate packets received from the OBU. In case of the distributed redundancy configuration, each RSU has a WAVE redundancy function which has similar functionality to RSU controller. RSUs should be able to communicate with other RSU in order to generate downlink redundant packets and remove uplink duplicate packets.

Fig. 2 shows WAVE protocol architecture of OBU for redundancy configuration in case of two WAVE channels. In order to operate with two WAVE channels without using multi-channel alternation operation, two WAVE communication modules are required. In order to provide reliable communication, a WAVE entity should be placed on top of two communication protocols. The WAVE entity provides the redundancy functionality of generating uplink redundant packets and removing downlink duplicate packets.

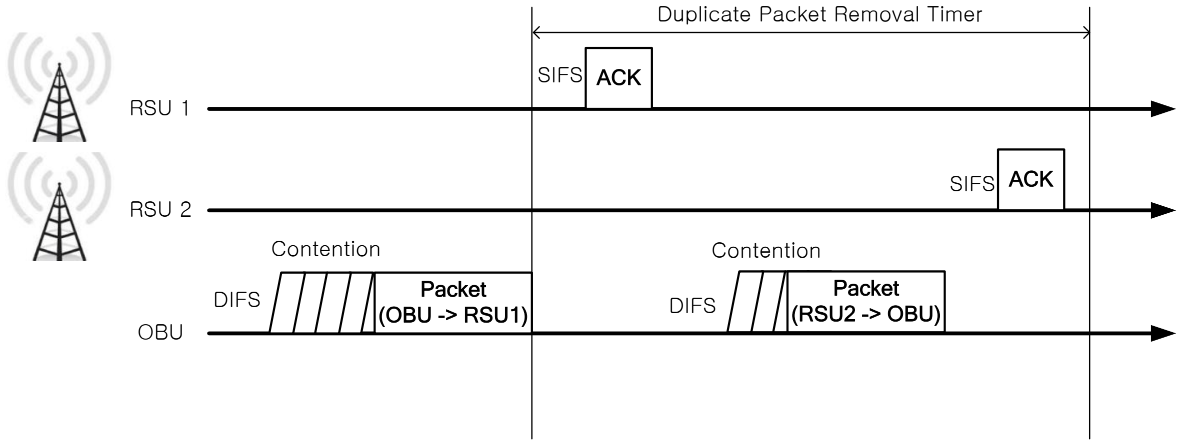
2.2 Reliable WAVE communication protocol using one WAVE channel

When redundancy system is configured using one WAVE channel, two RSUs cooperatively transmit downlink packets to OBUs using the same one WAVE channel. OBU is able to communicate with RSUs using one WAVE communication module. For better reliability, OBU may have two WAVE communication modules. Fig. 3 (a) shows reliable downlink WAVE communication using one WAVE channel. Two RSUs, RSU1 and RSU2 receives the same packet from the network at the same time. How RSUs receive the same packet is using the network configuration in section 2.1. Both RSU1 and RSU2 perform Carrier Sense Multiple Access / Collision Avoidance (CSMA/CA) on the same WAVE channel, i.e., wait for Distributed Coordination Function (DCF) InterFrame Spacing (DIFS) and then perform backoff with randomly chosen backoff values. In the example shown in the figure, because RSU1 has randomly selected smaller backoff value than RSU2, RSU1 is able to transmit a packet to the OBU. After transmission of ACK from the OBU to RSU1, RSU2 is able to transmit the packet to the OBU with proper backoff procedure. Upon receiving the first packet from a RSU, an OBU starts *Duplicate Packet Removal Timer* in order to remove duplicate packet transmission from the other RSU. During the time of *Duplicate Packet Removal Timer*, an OBU compares the received packet with the first packet to compare and discards if the received packet is a duplicate of the first packet. Packet duplication removal is performed in the WAVE entity described in section 2.1.

Fig. 3 (b) illustrates reliable uplink WAVE communication using one WAVE channel. In this case, the OBU has one physical module. When there is a packet to transmit from the OBU to the network, the OBU generates two packets with same payload but different destinations, one packet's destination is RSU1 and the other packet's destination is RSU2. The OBU transmits two packets using normal DCF. In the example shown in Fig. 3 (b), the OBU is able to transmit the packet to RSU1 first and then transmit the packet to RSU2. If minor modification on the standard is allowed, after the successful transmission of the first packet, the second packet can be discarded without transmission. Similar to Fig. 3 (a), duplicate packet removal procedure can be performed using *Duplicate Packet Removal Timer* in the network. Any duplicate packet received during this timer is discarded.



(a) Downlink communication



(b) Uplink communication

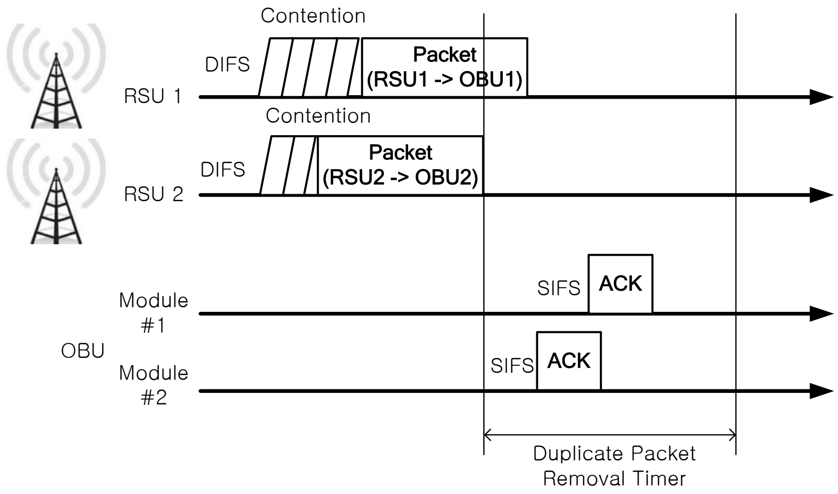
Fig. 3. WAVE Reliable Communication – one wireless channel

2.3 Reliable WAVE communication protocol using two WAVE channel

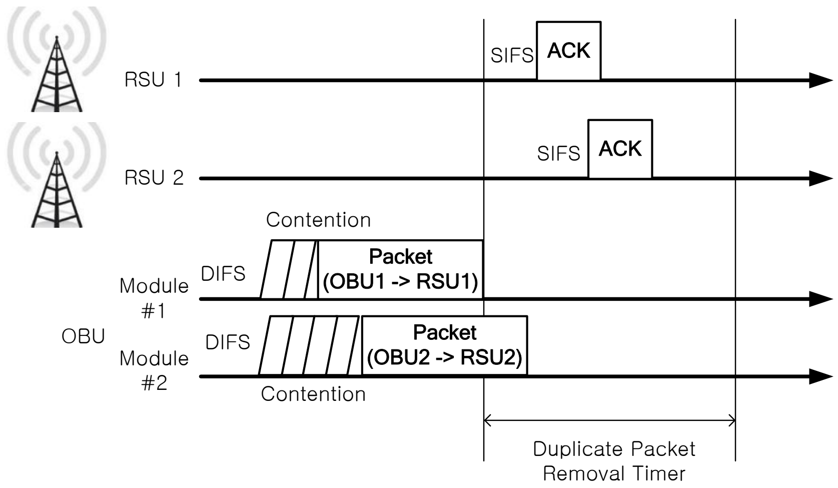
When redundancy system is configured using two WAVE channels, two RSUs cooperatively transmit downlink packets to OBUs using two WAVE channels. Since two RSUs simultaneously transmit using two WAVE channels, OBU needs to have two physical modules in order to communicate with two RSUs at the same time.

Fig. 4 shows how the proposed protocol works using the two WAVE channels. In case of downlink communication shown in Fig. 5 (a), RSU1 and RSU2 simultaneously transmit a packet using DCF independently. Receiving a packet and transmitting an ACK from an OBU to different RSUs can also be performed independently by using two physical modules. Upon receiving the first packet from a RSU, an OBU starts *Duplicate Packet Removal Timer* in order to remove duplicate packet transmission from the other RSU. During the time of *Duplicate Packet Removal Timer*, an OBU compares the received packet with the first packet to compare and discards if the received packet is a duplicate of the first packet. Packet duplication removal is performed in the WAVE entity described in section 2.1. The *Duplicate Packet Removal Timer* of this case (two WAVE channels) can be shorter than the *Duplicate Packet Removal Timer* in one WAVE channel case since contention time of one WAVE channel case would be much shorter than the two WAVE channel case.

Fig. 4 (b) shows reliable uplink WAVE communication using two WAVE channels. In this case, the OBU has two physical modules. When there is a packet to transmit from the OBU to the network, the OBU



(a) Downlink communication



(b) Uplink communication

Fig. 4. WAVE Reliable Communication – two wireless channels

generates two packets with same payload but different destinations, one packet's destination is RSU1 and the other packet's destination is RSU2. The OBU simultaneously transmits two packets using normal DCF. In the example shown in Fig. 4 (b), the OBU is able to start the transmission of the packet to RSU1 and then start transmission the packet to RSU2. Similar to Fig. 4 (a), duplicate packet removal procedure can be performed using *Duplicate Packet Removal Timer* in the network. Any duplicate packet received during this timer is discarded.

III. CONCLUSION

In this paper, reliable WAVE communication method is proposed for railroad applications. Because application for transporation, especially reailroad, requires high relibality, WAVE communication system needs to provide reliability with redundancy configuration. In order to provide WAVE communication reliability, network configuration, protocol architecture, and WAVE communication protocol are proposed in this paper. In order to remove the dependancy of various countries' different regulations, both reliable WAVE communication protocol with one WAVE channel and with multiple WAVE channels are proposed. Therefore, the proposed scheme can be utilized regardless of WAVE channel availability and the railroad WAVE system configuration can be very flexible due to the flexibility of the proposed protocol. The proposed architecture and protocol is not confined to railroad applications, typical Intelligent Transports System (ITS) is able to adopt the proposed scheme for reliability.

IV. ACKNOWLEDGEMENTS

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