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A Novel IEEE 802.11p Make Before Break Handover for Connected Car

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***Abstract:* -** In this paper, a novel IEEE 802.11p make before break handover scheme is proposed. IEEE 802.11 based Wireless Local Area Network (WLAN) does not provide handover mechanism because cellular like centralized control is not possible. In order for IEEE 802.11 Station (STA) to communication with Access Point (AP), association procedure is required. Similarly, in order to handover to a new AP, re-association with the new AP is required which causes some delay until the commencement of communication with the new AP. Since IEEE 802.11p STAs are normally vehicles and make connection with other vehicles and Road Side Units (RSUs), association procedure with a communication party can be skipped in IEEE 802.11p. By exploiting simple association procedure and multi-channel operation of IEEE 802.11p, a novel and seamless IEEE 802.11p Make Before Break (MBB) handover scheme is proposed. The proposed scheme utilizes two IEEE 802.11p communication channels for seamless handover. By exploiting the proposed scheme, seamless connected car control is possible.

***Keywords:* -** *Connected Car, IEEE 802.11p, Handover, Make before break, WAVE*

I. INTRODUCTION

With the emergence of data communication devices like smart phones and tablets, wireless data demand has increased exponentially. In order to provide broadband wireless services, various wireless access technologies such as 3GPP Long Term Evolution (LTE) [1], IEEE 802.16m based WiMAX [2], and IEEE 802.11 based Wireless Local Area Network (WLAN) [3] have been developed. WLAN has become one of very popular wireless access technologies due to its easy deployment and excellent data communication capability [4], [5]. Since WLAN uses license exempt wireless bands, it can be deployed without government regulations. The simple network architecture of WLAN also makes WLAN very popular. For such reasons, WLAN is used in various applications including Intelligent Transportation Services (ITS). However, in order for WLAN to use in ITS applications, vehicular specific requirements should be met. New IEEE 1609 series standards, named Wireless Access in Vehicular Environments (WAVE) [6], [7], [8], [9] have been developed to support vehicular communication with WLAN. WAVE is used in many vehicular communication services including automatic tolling system [11], [12], [13]. Also, IEEE 802.11 has developed a new amendment, IEEE 802.11p to support vehicular communication. One of major modifications is simple association procedure with a communication party. Since a vehicle can easily establish and break communication with other vehicles or Road Side Units (RSUs), simple communication commencement is indispensable. For this reason, association procedure can be skipped in case of the communication between IEEE 802.11p stations.

Since IEEE 802.11 based network cannot be controlled in a centralized manner like cellular networks, handover cannot provided. Lengthy association, re-association procedures also make handover procedure difficult. In order to provide seamless ITS services for connected cars, it is indispensable to provide seamless communication. In this paper, by utilizing simple communication commencement procedure of IEEE 802.11p and unique characteristics of ITS, a novel and seamless Make Before Break (MBB) handover scheme is proposed. It is very easy to estimate vehicles' movement since vehicles move along pre-constructed roads. The proposed scheme utilizes two wireless channels for seamless handover. By utilizing the proposed handover scheme, seamless connected car control is possible.

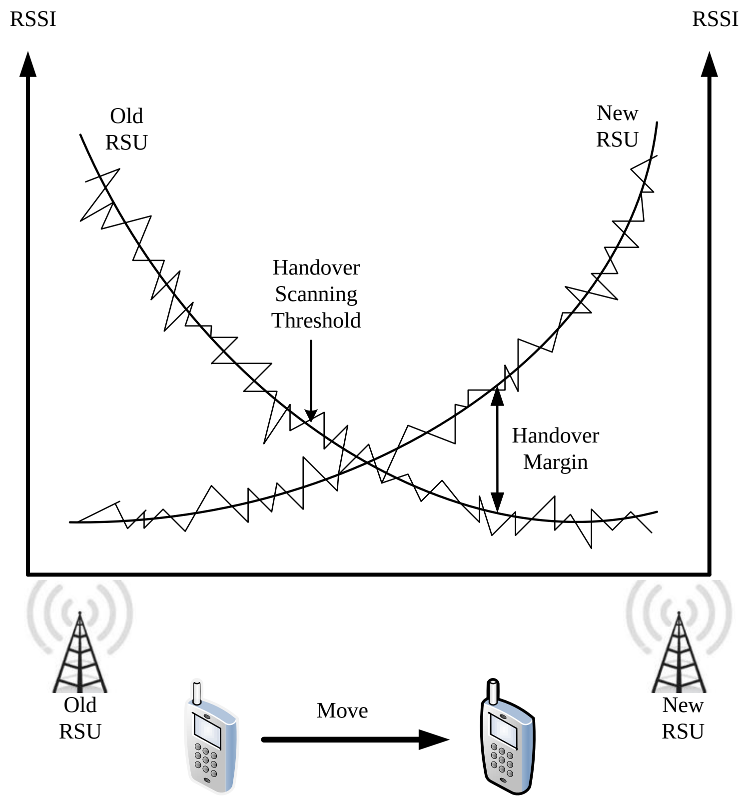

Fig. 1. Handover procedure

II. OVERVIEW ON HANDOVER

Fig. 1 shows wireless signal changes from RSUs as STA moves from one RSU to another RSU. In order to perform handover, STA performs a scanning procedure to measure signal quality from the serving RSU. Signal quality can be measured in various aspects and Received Signal Strength Indicator (RSSI) is widely used metric to measure signal quality. Typically handover is initiated when signal quality of the serving RSU gets worse than a handover scanning threshold. As we can see from the figure, the optimal handover point is when the RSSU of the current RSU and the RSSI of the target RSU are same. However, since signal quality fluctuates at the same position which is known as a short-term fading, frequent handover between the serving RSU and the target RSU might happen, which is known as Ping-Pong effect. Therefore, the recommended handover timing is when the signal quality of the target RSU is better than the signal quality of the serving RSU which is called as *handover margin*. When *handover margin* is used the Ping-Pong problem can be alleviated. *Handover margin* affects the handover performance. When *handover margin* is set to be small, STAs still suffer from the Ping-Pong effect and when *handover margin* is set to be large, handover interruption time is long. Optimal *handover margin* is a little larger value than the short-term fading. Handover procedure can be classified into three stages: handover preparation, handover execution, and handover completion.

- Handover Preparation: STAs monitor the serving RSU and make decision whether handover is required or not. Depending on the entity which makes handover decision, handover is classified into network controlled handover and mobile controlled handover
- Handover Execution: Handover target RSU is determined and performs handover procedure with the target RSU.
- Handover Completion: Handover procedure is completed and disconnect the connection with the previous RSU.

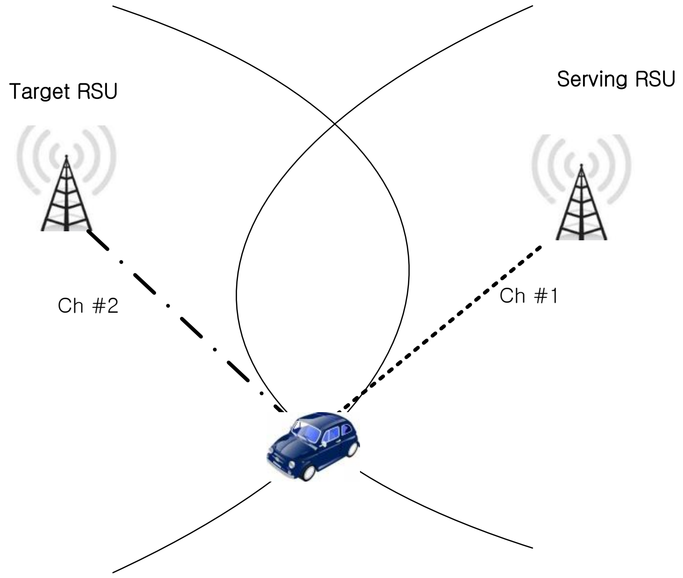

Fig. 2. WAVE Handover

III. PROPOSED MAKE BEFORE BREAK HANDOVER

As explained in the previous section, an efficient handover scheme should consider two important functions: link establishment/disconnection, and RSSI threshold setup. In this section, the proposed make before break handover scheme is described. Fig. 2 shows how two channels are used during handover. Since the OBU has two WAVE communication modules, it can establish connection with both the serving RSU and the target RSU simultaneously. As described in the previous section, a scanning threshold is set to initiate handover procedure. When the handover initiation condition is met (when the signal quality goes below the threshold), it starts scanning. As a result of the scanning, STA is able to find out a target RSU. Since IEEE 802.11p does not require for STA to associate with an AP to commence communication, the STA transmit any IEEE 802.11 packet to the target AP in order to register the STA to AP's Address Resolution Protocol (ARP) table. There are various schemes available how the packet to the STA is shared between the target RSU and the serving RSU. The exact scheme is outside the scope of this paper. Once STA is registered to the target ARP table, STA is able to receive the packet both from RSU1 and RSU2. When there is a packet to transmit from the OBU to the network, STA transmits it to both RSU1 and RSU2 simultaneously using two WAVE communication modules. For both uplink and downlink, duplicate packet elimination can be performed easily by using a certain timer. As the STA goes further away from the serving RSU, the RSSI of the RSU1 becomes very weak to disconnect the serving RSU. Disconnection is done by doing nothing because there is no disconnection procedure in IEEE 802.11. After some time, RSU will remove the STA from its ARP table.

The detailed handover procedure of the proposed make before handover scheme is shown in Fig. 3. The OBU can communicate with the serving RSU either with one WAVE communication module or two WAVE communication modules. In case of using two WAVE communication modules, RSUs should have two WAVE communication modules but this is not the requirement of the proposed scheme. The example in Fig. 3 is the case where both the OBU and the RSUs support two WAVE communication modules. While communication with the serving RSU, the signal quality from the serving RSU goes below the scanning threshold, *RSSI_s*, which is the handover initiation condition. Then, while communicating with the serving RSU using one WAVE communication module for data exchange, the OBU transmits a *Handover Request* control packet and starts scanning to initiate handover procedure using the other WAVE communication module. If a RSU with the signal quality better than the target RSSI, *RSSI_t*, is found as a result of scanning, the OBU transmits a Handover Command control packet to the found target RSU, which becomes a new serving RSU, and then

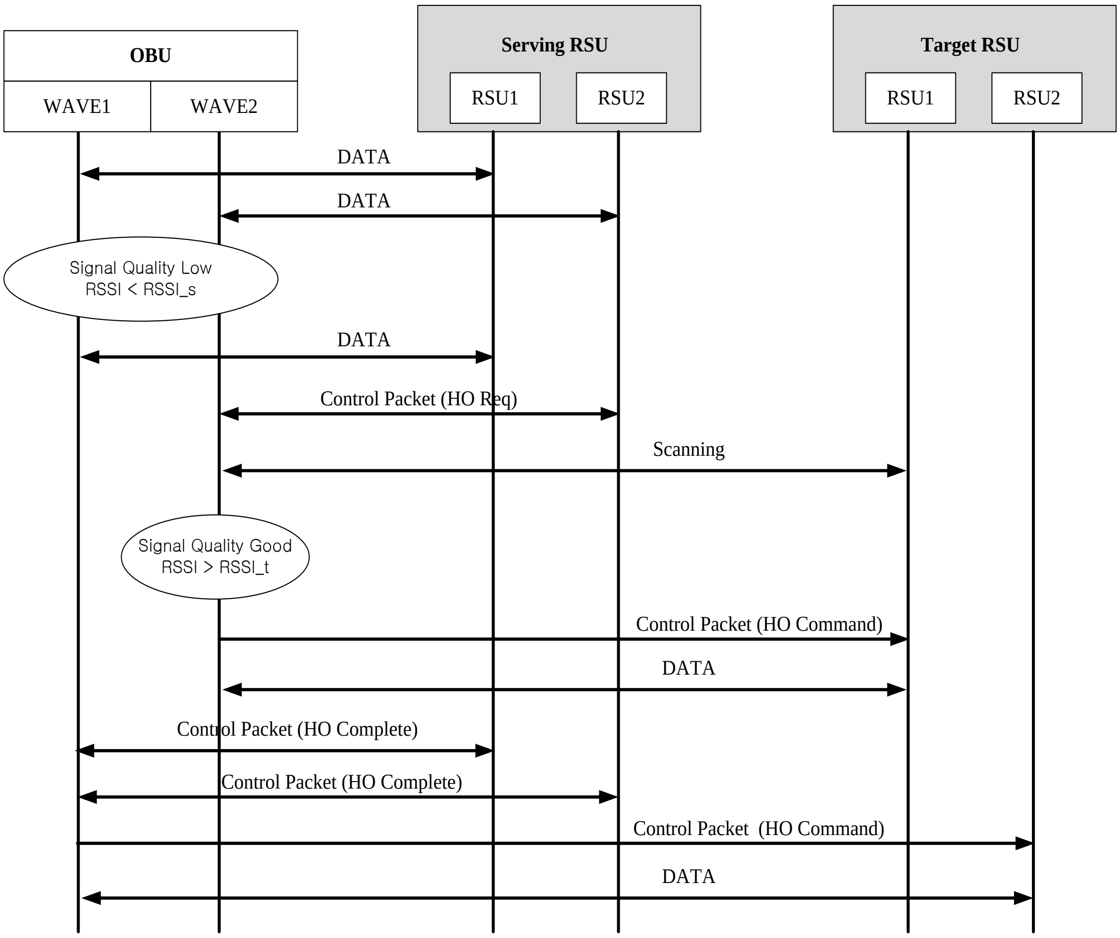

Fig. 3. WAVE handover procedure using two channels.

transmits data to the target RSU. After a successful data transmission with Acknowledgement (ACK), the OBU transmits a *Handover Complete* control packet to the serving RSU which becomes an old RSU. The OBU can transmit two *Handover Complete* control packets by using two WAVE communication modules for a reliable transmission because signal quality is bad at the timing of the handover. After the successful transmission of the *Handover Complete* control packet, the OBU transmits a *Handover Command* control packet in order to notify the target RSU of handover completion.

IV. CONCLUSION

In this paper, a novel IEEE 802.11p make before break handover scheme is proposed. The proposed scheme can be supported with two WAVE channels without minimum handover interruption time. The proposed scheme utilizes the IEEE 802.11p's simple association procedure and multi-channel operation to minimize the handover interruption time. Because the proposed handover scheme can provide minimum handover interruption time, by exploiting the proposed scheme, seamless connected car control is possible.

V. ACKNOWLEDGEMENTS

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