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A Novel WAVE Multi-Channel Alternating Scheme for Railroad Applications

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Abstract: - In this paper, a novel Wireless Access in Vehicular Environments (WAVE) multi-channel alternating scheme is proposed. WAVE is exploited in various applications including Intelligent Transportation Service (ITS). For efficient operation of WAVE, multiple channels for various traffic types should be used. WAVE can also be applied for various railroad applications such as railroad wireless multimedia communication, passenger information services, and Communication Based Train Control (CBTC). In order for WAVE to be used for railroad applications, WAVE needs to meet the Quality of Service (QoS) requirements which some railroad applications require. Since only a basic multi-channel operation is defined in the WAVE standards, an efficient multi-channel operation scheme is required to meet the QoS requirements of railroad applications. In this paper, a novel and efficient WAVE multi-channel alternating scheme is proposed. Since the proposed scheme reuses the existing primitives, the WAVE standard does not need to be changed and only simple WAVE modem implementation per the proposed scheme is required. The proposed scheme can be used not only for the railroad applications but also ITS applications which require strict QoS requirements.

Keywords: - *OFDMA, Uplink, Random Access, IEEE 802.11ax*

I. INTRODUCTION

Because Wireless Local Area Network (WLAN) [1] can be very easily deployed and has excellent performance, WLAN has made a big progress since its emergence [2], [3]. WLAN is exploited in various applications including Intelligent Transportation Services (ITS). In order for WLAN to apply to ITS, a set of standards, Wireless Access in Vehicular Environments (WAVE) [4], [5], [6], [7] and IEEE 802.11p [8] had been developed. WAVE consists of IEEE 1609 series standards and IEEE 802.11p standard. WAVE is designed to be appropriate for vehicular wireless communication. Two kinds of communication methods are supported in WAVE: Vehicle to Vehicle (V2V) communication and Vehicle to Infrastructure (V2I) communication. IEEE 802.11p standard is an amendment for V2V and V2I vehicular communication based on IEEE 802.11 standard. WAVE was developed for Dedicated Short Range Communication (DSRC) [9], [10] and is being used as a highway tolling system [11]. As a solution to Intelligent Transportation Services (ITS), various methods using WAVE have been studied.

The Federal Communications Commission (FCC) in the United States allocated 7 channels of 10MHz for WAVE as shown in Fig 1. As FCC allocated, Ch. 172 and Ch. 184 are used for safety channels: Ch 172 for critical safety of life and Ch 184 for high power public safety. Ch. 178 is designated to be used as a Control Channel (CCH) and Ch. 174, Ch. 176 (20MHz Ch. 175) and Ch. 180, Ch. 182 (20MHz Ch. 181) are designated to be used as Service Channels (SCH). As an aggregation of two 10MHz channels, 20MH channels can be used.

Depending on the capability of WAVE devices, multi-channel operation of Medium Access Control (MAC) layer and Physical (PHY) layer is required [7]. When there are more number of channels to access than the number of physical modules, alternating operation needs to be used. Such alternating multi-channel operation is defined in [7] and there are four possible channel usage models:

- Operation only on the CCH (e.g., by a single-PHY device).
- Operation only on an SCH (e.g., by a single-PHY device).

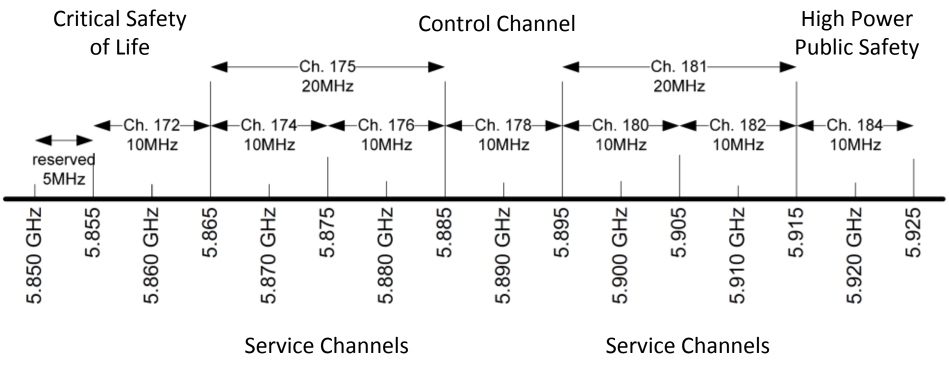


Fig. 1. FCC WAVE Channel Allocation

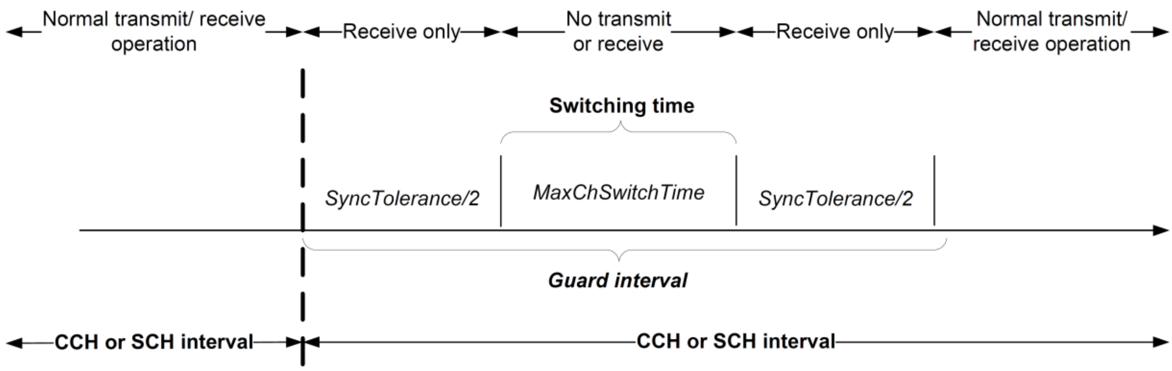


Fig. 2. WLAN uplink OFDMA & uplink OFDMA random access in IEEE 802.11ax

- Alternating operation on CCH and SCH, in CCH intervals and SCH intervals, respectively (a switching device).
- Simultaneous operation on CCH and one or more SCHs (by a multi-PHY device).

In order to efficiently access wireless channels by combining the 4 channel usage models, the number of multi-PHY need to be decided. In this paper, a novel and efficient channel alternating scheme is proposed for railroad applications. The proposed channel allocation considers possible number of multi-PHYs. Since stability is very important in railroad applications, Quality of Service has to be fully considered.

II. PROPOSED MULT-CHANNEL ALTERNATING SCHEME

Fig. 2 shows the components of the guard interval: *SyncTolerance* and *MaxChSwitchTime*. *MaxChSwitchTime* is the time duration that the radio of communication device is not able to transmit and receive signals. *SyncTolerance* is required time duration for the radio of communication device to synchronize. Since many railroad applications require time critical services, CCH interval and SCH interval need to be designed to meet the requirements of railroad applications considering the aforementioned device dependent guard intervals.

According to the channel usage models, there is no usage model for alternating operation between SCHs. However, by using the primitives defined in the standard, alternating operation between SCHs is possible. Fig. 3 shows the alternating operation between CCHs and SCHs. When MAC Layer Management Entity (MLME) receives MLMEX_SCHSTART.req, MLME automatically transmits PLME-SET.req in every 50ms to PHY layer to alternate between CCH and SCH. As mentioned before, alternating operation between SCHs is possible by using the primitives, MLMEX-SCHSTART.req with ExtendedAccess parameter, and MLMEX-SCHEND.req. When MLMEX-SCHSTART.req with ExtendedAccess parameter is received, MLME does not transmit PLME-SET.req during the time indicated with ExtendedAccess parameter. When another MLMEX-

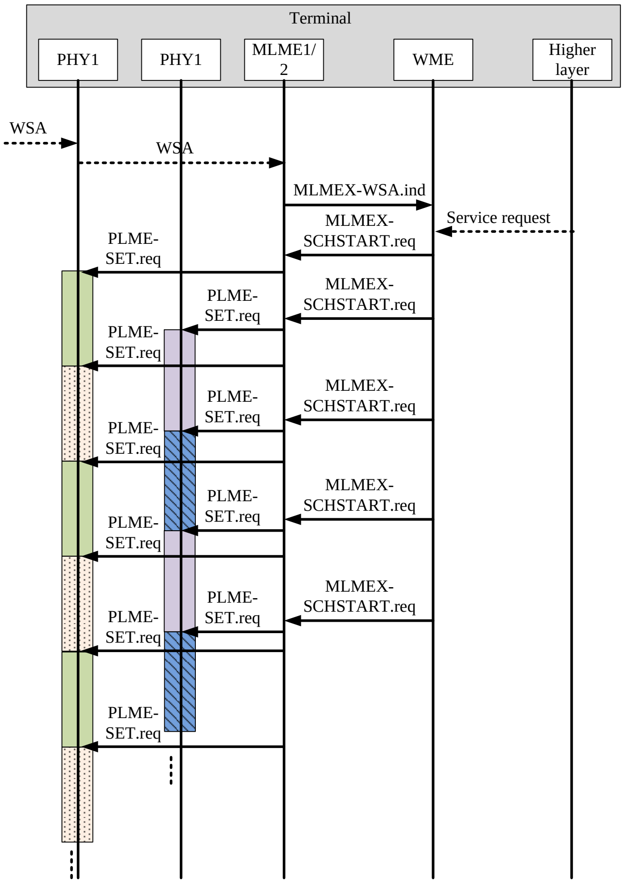
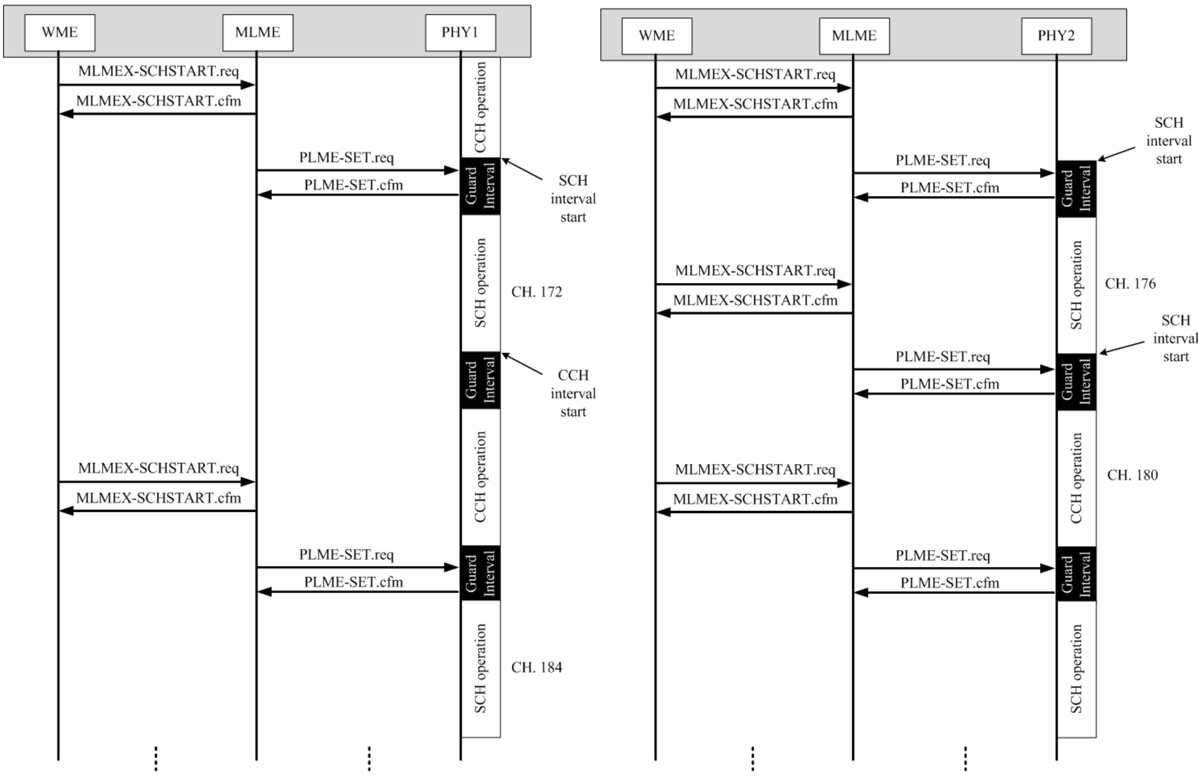


Fig. 3. Alternating operation between CCHs and SSHs

SCHSTART.req or MLMEX-SCHEND.req is received during the time indicated ExtendedAcces parameter, MLME transmits new PLME-SET.req primitive to PHY layer to switch to another SCH. In Fig. 3, start point of PHY1 and PHY2 is not synchronized to show the operation clearly, it is recommended to synchronize PHY2 SCH's starting point with PHY1' starting point.

In multi-channel alternating operation, the number of sync intervals, which is the time duration of CCH interval plus SCH interval, must be an integer number within 1s. Therefore, 50ms interval of CCH interval and SCH interval is used in the standard as an example. The short interval of 25ms is also possible since 2 sync intervals (2 CCH intervals and 2 SCH intervals) can be allocated within 1s. When sync interval is short, some devices are not able to be supported depending on the devices' channel switching time and synchronization time. Devices' capability should be fully considered when sync interval is determined. In this paper, even though 50ms CCH interval and 50ms SCH interval is used for simplicity, 25ms intervals can be easily used.
Fig 3. shows the alternating operating using the proposed alternating scheme. Fig. 3 (a) is the case where one PHY accesses one CCH and two SCHs. Ch. 178 is used for CCH channel and Ch. 172 and Ch. 184 are used for SCHs. When MLMEX_SCHSTART.req is transmitted from Wave Management Entity (WME) to MLME, MLME transmits PLME-SET.req and receives PLME-SET.cfm during the guard interval. Since channel information such as center frequency is included in the MLMEX_SCHSTART.req, MLME can inform the PHY to change to the proper wireless channel using the copied information in the PLME-SET.req. Since PLME-SET.req primitive makes PHY alternate between CCH and SCH, no further primitive transmission is required for CCH and SCH alternation. When PHY should access another SCH after CCH interval, WME transmits another MLMEX_SCHSTART.req to MLME. Upon reception of MLMEX_SCHSTART.req, MLME transmits PLME-SET.req primitive during the guard interval to PHY to tune to another SCH. Then alternation between newly indicated SCH and CCH is performed.
Fig. 3 (b) is the case where on PHY access two SCHs in every 50ms. CH. 176 and Ch.180 are used for SCHs. Since PHY alternates SCHS in every 50ms, MLMEX_SCHSTART.req with SCH channel information during the guard interval, which is the beginning of SCH interval, should be transmitted from WME to MLME.



(a) One CCH and two SCHs alternating (b) two SCHs alternating

Fig. 3. Alternating operation between CCHs and SSHs

Since this operation is the internal operation in WAVE modem, if alternating SCHs are fixed for railroad applications, this operation can be fixed without transmitting MLMEX_SCHSTART.req in every 50ms.

III. CONCLUSION

In this paper, a novel WAVE multi-channel alternating scheme for railroad applications is proposed. Since there are various railroad applications such as railroad wireless multimedia communication, passenger information services, and CBTC and some railroad applications require strict QoS requirements, WAVE needs to provide an efficient and flexible multi-channel operation scheme. Since only a basic multi-channel operation is defined in the WAVE standards, such an efficient and flexible multi-channel operation is not possible. In this paper, by exploiting existing WME and MLME primitives, a novel and efficient multi-channel alternating scheme is proposed. Since the proposed scheme reuses the existing primitives, the WAVE standard does not need to be changed and only WAVE modem implementation per the proposed scheme is required. The proposed scheme can be used not only for the railroad applications but also ITS applications which require strict QoS requirements.

IV. ACKNOWLEDGEMENTS

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