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WAVE Multi-Channel Allocation for Railroad Applications

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Abstract: - In this paper, WAVE multi-channel allocation is proposed for railroad applications. In order to utilize WAVE in railroad applications, various Quality of Services (QoSs) of railroad traffics should be guaranteed. In order to provide QoS in WAVE, channel alternating operation is defined in the specification for single physical module WAVE device. In order to meet the QoS requirements of railroad traffics, multiple physical modules WAVE device should be used. However, in the standard WAVE, multi-channel allocation is not defined since channel allocation is dependent on countries' regulation and applications. In this paper, possible WAVE multi-channel allocation for railroad applications is proposed under the assumption of 7 WAVE channels. Since, depending on the number of physical modules, multi-channel allocation and channel usage should be designed properly, the proposed WAVE multi-channel allocation is per the number of physical modules. By using the proposed WAVE multi-channel allocation, proper WAVE multi-channel allocation depending on the number of physical modules can be selected.

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

I. INTRODUCTION

Wireless Local Area Network (WLAN) [1] has become one of popular wireless access schemes because it can be simply deployed and easily used. Despite it simple deployment and easy usage, it shows excellent performance [2], [3]. Since WLAN utilizes license exempt wireless bands, it is used in various areas including Intelligent Transportation Services (ITS). In order to meet the unique requirements of ITS, a set of new standards, Wireless Access in Vehicular Environments (WAVE) [4], [5], [6], [7] have been developed and IEEE 802.11 standard had to be amended [8]. An IEEE 802.11 amendment for vehicular wireless communication is IEEE 802.11p. In order to deploy WAVE, IEEE 1609 series standards and IEEE 802.11p standard should be used. 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].

In the United States, Federal Communications Commission (FCC) defined 7 channels of 10MHz for WAVE. Among 7 channels, there is one Control Channel (CCH) and 6 Service Channels (SCHs). Two 20MHz channels can be used by channel bonding of two 10MHz bands for broadband wireless access. Depending on the capability of WAVE devices, multi-channel operation of Medium Access Control (MAC) layer and Physical (PHY) layer is required [7]. Since multi-channels should be utilized with one or more number of physical modules, alternating multi-channel operation is defined in [7]. In the specification, four possible channel usage models are defined: operation only on the CCH (e.g., by a single-PHY device), operation only on an SCH (e.g., by a single-PHY device), 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).

Depending on the number of physical modules, multi-channel allocation and channel usage should be designed properly. In this paper, possible WAVE multi-channel allocation for railroad applications is proposed under the assumption of 7 WAVE channels. In the proposed WAVE multi-channel allocation is per the number of physical modules. By using the proposed WAVE multi-channel allocation, proper WAVE multi-channel allocation depending on the number of physical modules can be selected.

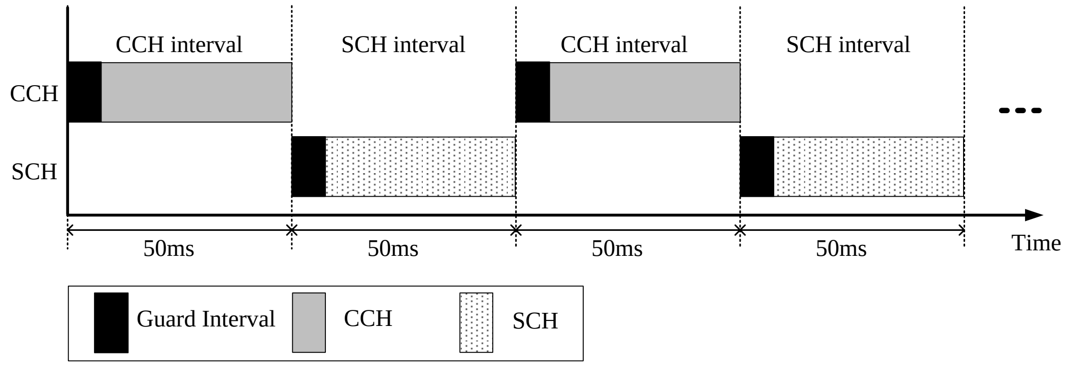

Fig. 1. WAVE Multi-channel alternation – One physical module case

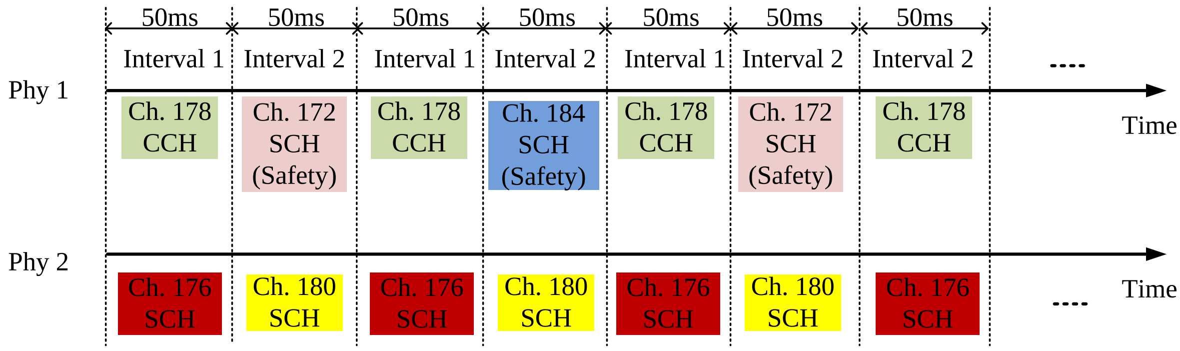

Fig. 2. WAVE multi-channel allocation for two physical modules

II. PROPOSED WAVE MULTI-CHANNEL ALLOCATION FOR RAILROAD APPLICATIONS

Fig. 1 shows the WAVE multi-channel alternation operation in case of one physical module. In order to access both CCH and SCH, Time Division Multiple Access (TDMA) is utilized. Since, in the specification, integer number of CCHs and SCHs should be accommodated in 1 second duration, 50ms duration is used as an example in the specification and in this paper. However, different time duration can be used as long as the integer number of channels can be allocated within 1 second. At the beginning of CCH or SCH, there is a guard interval in order for devices to synchronize. In the following subsections, multi-channel allocation for two, three, four, five, six, and seven physical modules.

2.1 Two-PHY Channel Access

When the number of physical modules are two, the first physical module can perform alternation between CCH and SCH and the second physical module can perform alternation between two SCHs. In this case, the first physical module and the second physical module should be synchronized. In case of railroad WAVE, safety is a top priority, safety channels, Ch. 172 and Ch. 178 should be both monitored. Therefore, the first physical channel accesses CCH and SCHs of Ch. 172 and Ch. 178 as proposed in the Fig. 2. The same alternation interval of 50ms as in the standard is used in the proposed scheme. By using the proposed channel allocation, the periodicity of safety channel access is 200ms. If 200ms time period of safety channel access meets the requirement of safety regulation should be carefully examined. The second physical channel performs alternation between two SCHs, Ch. 176 and Ch. 180 are selected as SCHs in this paper. The periodicity of the SCH channel access if 100ms. The performance should be carefully verified whether 100ms periodicity meets the requirements of realtime application.

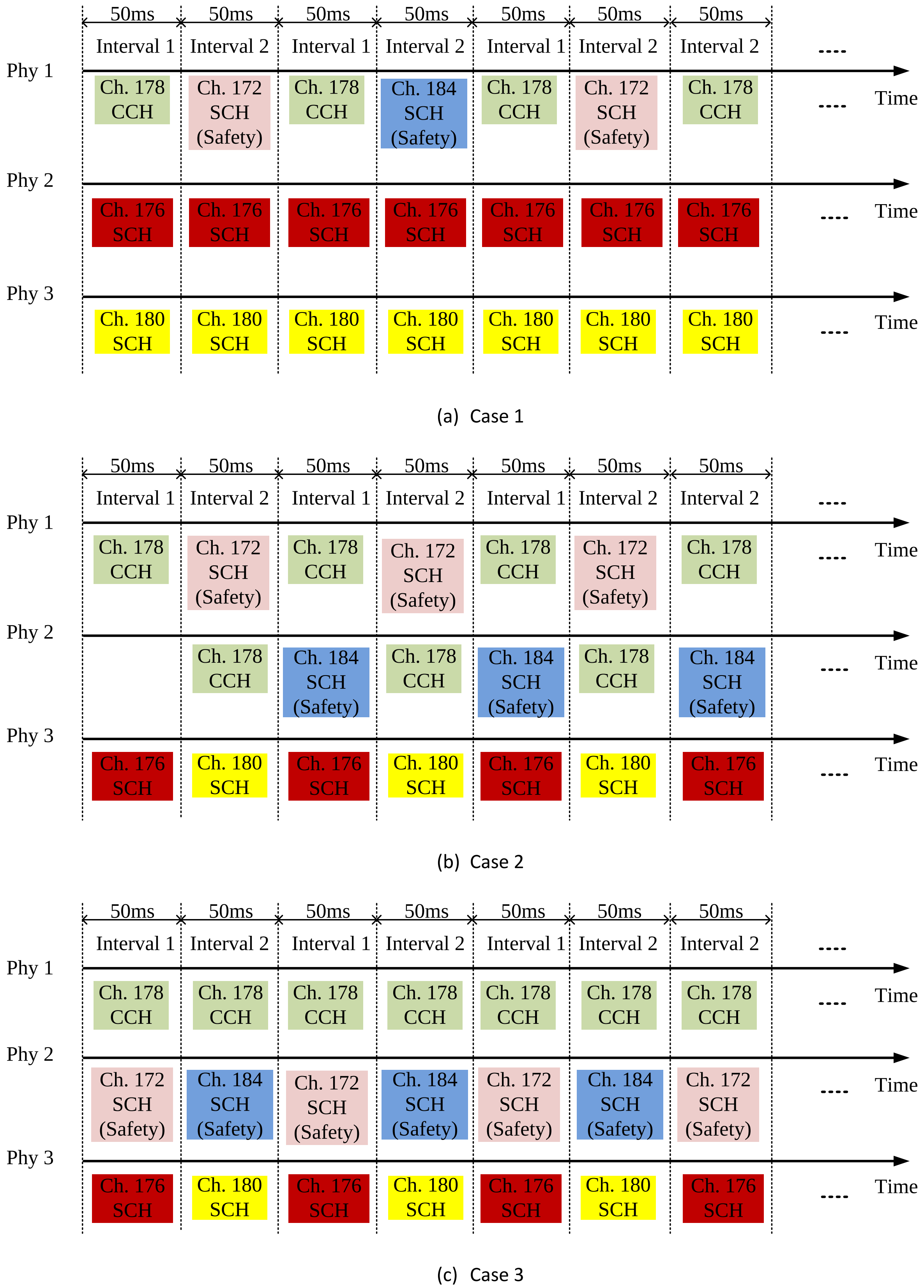

Fig. 3. WAVE multi-channel allocation for three physical modules

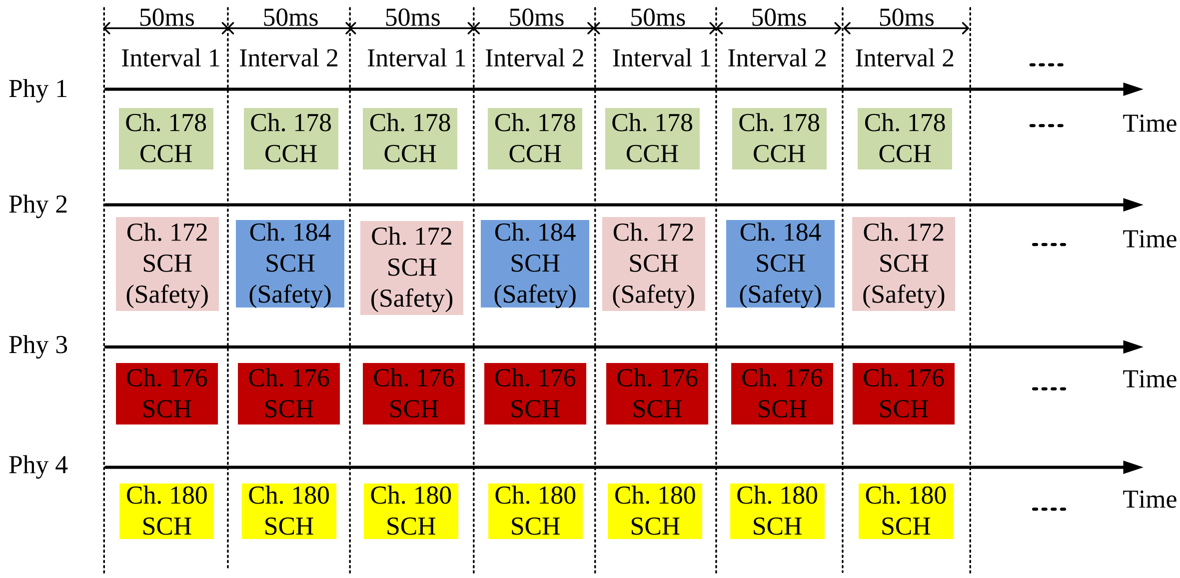

Fig. 4. WAVE multi-channel allocation for four physical modules

2.2 Three-PHY Chanel Access

When the number of physical modules are three, there are three possible variations of channel allocation. The first variation is shown in Fig. 2 (a). The first physical module can perform alternation between CCH (Ch. 178) and SCH (Ch 180) as in the two physical module case and the second module accesses one SCH (Ch. 176) and the third physical modules accesses one SCH (Ch 180). The first variation has the advantage of stable SCH access since two physical modules access their dedicated SCHs. As mentioned in 2.1, careful examination whether 200ms time period of safety channel access meets the requirement of safety regulation should be taken.

The second variation shown in Fig. 2 (b) is that the first physical module performs alternation operation between CCH (Ch. 178) and one safety SCH (Ch. 172), the second physical module performs alternation operation between CCH (Ch. 178) and the other safety SCH (Ch. 184), and the third physical module performs alternation operation between two SCHs (Ch. 176 and Ch. 180). In this variation, the periodicity of safety channel is shortened to be 100ms and the utilization of CCH can become high. However, if 100ms time period of the SCH channel access meets the requirement of realtime traffic should be carefully examined.

The third variation is shown in Fig. 2 (c). In the third variation, the first physical module dedicatedly accesses CCH (Ch. 178) and the second and the third physical modules perform alternation operation between two SCH channels respectively. The second physical channel alternates between two safety SCHs (Ch. 172 and Ch. 184), and the third physical channel alternates two railroad WAVE application SCHs (Ch. 176 and Ch. 180). In this variation, the periodicity of safety channel becomes 100ms, and the CCH access becomes simple and its utility is maximized due to dedicated CCH access. As previously mentioned, if 100ms time period of the SCH channel access meets the requirement of realtime traffic should be carefully examined.

2.3 Four-PHY Channel Access

When there are four physical modules, as shown in Fig. 4, the first physical module dedicatedly accesses CCH (Ch. 178) and the second physical module performs alternation operation between two safety SCH channels (Ch. 172 and Ch. 184). The third and the fourth physical modules accesses its own SCH. The third physical module accesses Ch. 176 and the fourth physical module accesses Ch. 180. In this variation, since three physical modules provide dedicated physical channel access, channel utility becomes high and operation

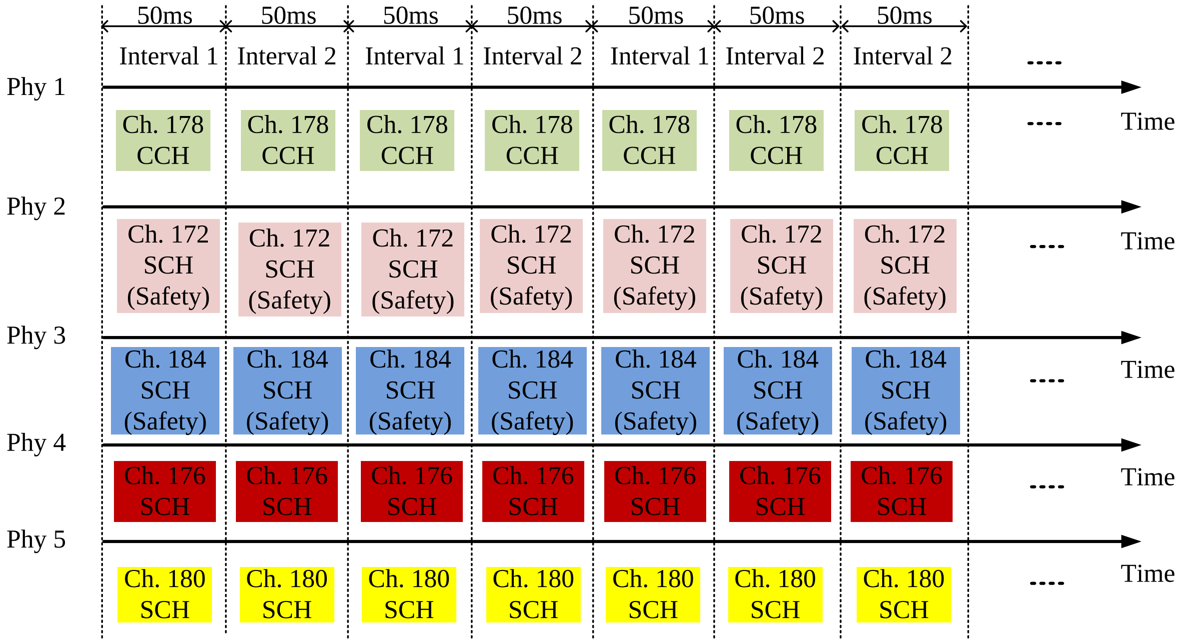

Fig. 5. WAVE multi-channel allocation for five physical modules

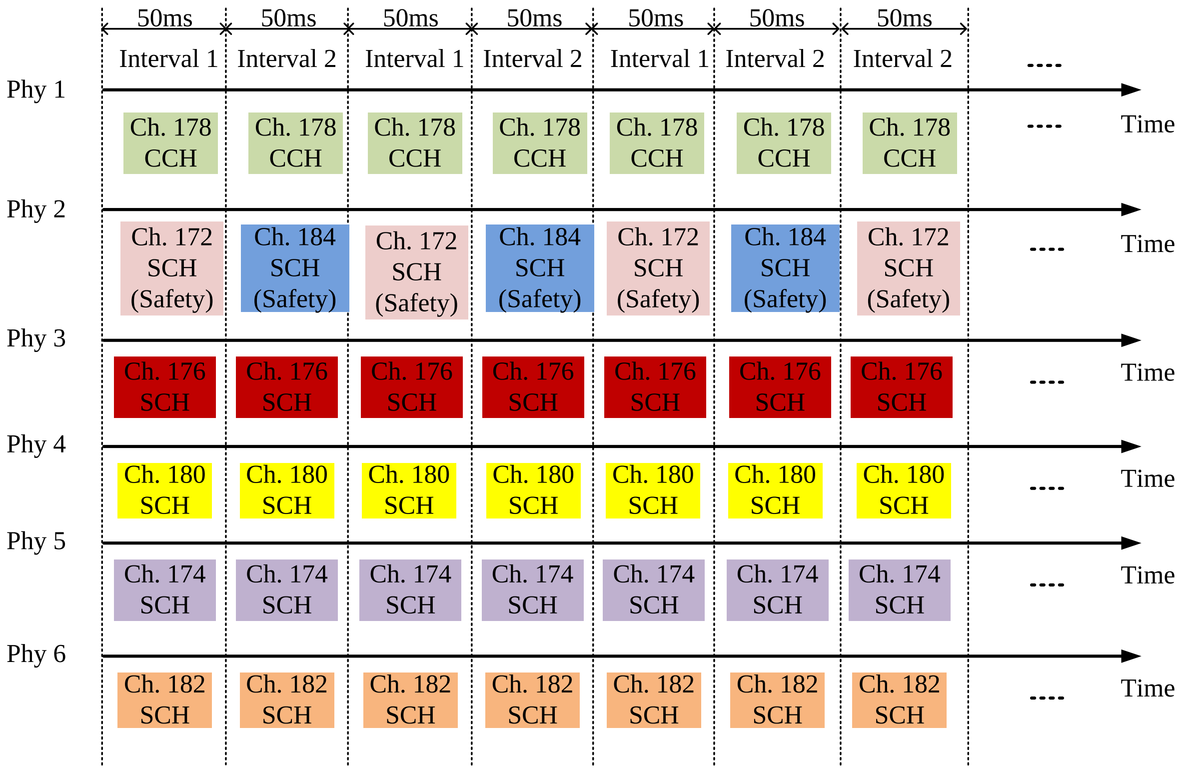

Fig. 6. WAVE multi-channel allocation for six physical modules

becomes simple. Since the second physical module is assigned for safety channels, the safety requirements of railroad can be met.

Fig. 7. WAVE multi-channel allocation for seven physical modules

2.4 Five-PHY Channel Access

When there are five physical modules, one CCH (Ch. 178) and four SCHs (Ch. 172, Ch. 184, Ch. 176, and Ch. 180) can be dedicatedly used by each physical module as shown in Fig. 5. In this operation, since alternation operation is not required, device operation becomes very simple without synchronization.

2.5 Six-PHY Channel Access

When there are six physical modules, as shown in Fig. 6, two safety SCHs are alternatively accessed by one physical module and other SCH and CCH are dedicatedly accessed by each physical module.

2.6 Seven-PHY Channel Access

When there are seven physical modules, all SCHs and CCH channel can be dedicatedly allocated to own physical modules. Due to dedicated access of the channels, operation becomes very simple.

III. CONCLUSION

In this paper, WAVE multi-channel allocation is proposed for railroad applications under assumption of 7 WAVE channels. Depending on the number of physical modules, multi-channel allocation and channel usage should be designed properly, the proposed WAVE multi-channel allocation is per the number of physical modules. Since the proposed channel allocation provides various alternatives, proper option, which can meet the various Quality of Services (QoSs) of railroad traffics can be selected.

IV. ACKNOWLEDGEMENTS

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