

A Study for QoS support in the WAVE MAC

Jeong-Woo Lee, Hyun-Kyun Choi

SW Contents Research Laboratory, Electronics and Telecommunications Research Institute

Daejeon, Korea

jeow7@etri.re.kr, choihk@etri.re.kr

Abstract— WAVE(Wireless Access in Vehicular Environments) communication technology has been designed for short initial link, low latency and high mobility in the communication between vehicles or between a vehicle and an infrastructure. In order to provide high quality and reliable services using WAVE technology, it is required to guarantee QoS(Quality of Service) in the WAVE. However, there are limitations in guaranteeing QoS in current WAVE technology. In this paper, we present the features of the WAVE technology, the limitations in supporting QoS in the WAVE MAC(Media Access Control) and the enhanced technologies to overcome these limitations with considerations for the development of next-generation WAVE technology based on them.

Keywords—WAVE, MAC, QoS, EDCA, TDMA

I. INTRODUCTION

WAVE communication technology standardized by IEEE has been designed for short initial link, low latency and high mobility in the communication between vehicles or between a vehicle and an infrastructure. It allows to send and receive packets at a distance of up to 1km within 100msec delay time in the vehicle moving at speeds up to 200 km/h. WAVE technology can be utilized for various services based on these characteristics. Safety messages for the forward traffic accidents and hazards can be quickly delivered to the rear vehicles. The vehicle participating in the platooning or the autonomous driving vehicle[1-2] is able to go quickly after the lead vehicle by receiving its driving information. Like these, in order to provide high quality and reliable services using WAVE technology, it is required to guarantee QoS in the WAVE. However, there are limitations in guaranteeing QoS in current WAVE technology. Moreover, attempts to use the mobile communication technologies such as cellular, LTE and 5G for the vehicle communication[3] have been a big challenge to the WAVE technology. In order to overcome these challenges and problems, it is necessary to solve the technical limitations of the current WAVE technology and provide higher performance. In this paper, we present the features of the WAVE technology, the limitations in supporting QoS in WAVE MAC and the enhanced technologies to overcome these limitations with considerations for the development of next-generation WAVE technology based on them.

II. WAVE

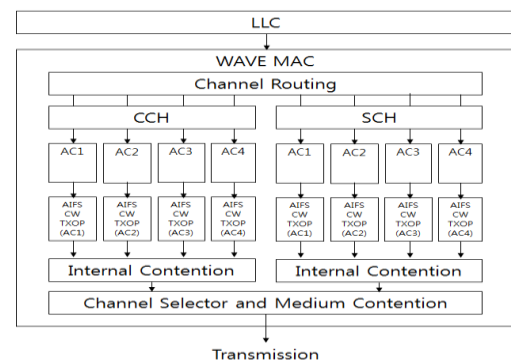


Figure 1. The transmit side of the WAVE MAC[4,5]

The WAVE communication standard consists of IEEE 802.11p and IEEE 1609[4,5]. As shown in Figure 1, the conceptual internal architecture of the transmit side of WAVE MAC model defined in IEEE 1609.4 assigns MSDU(MAC Service Data Unit) primitive information transmitted from the upper layer LLC in the queue of the appropriate channel and transmits it according to priority determined by IEEE 802.11 EDCA(Enhanced Distributed Channel Access). EDCA is designed to support QoS by providing different channel access probability depending on the priority of the transmission frame. It has four AC(Access Category)s having different value of AIFS(Arbitration Inter Frame Space) and CW(Contention Window) and makes the high priority AC have the high channel access probability. IEEE 1609.4 defines for a multi-channel operation and WAVE uses 7 channels divided into one CCH(Control Channel) and 6 SCHs(Service Channel) each having 10MHz bandwidth.

III. QoS SUPPORT ON THE WAVE MAC

In order to support QoS in the WAVE, the following requirements should be guaranteed [6].

- * Fair and efficient channel occupancy opportunity
- * Guarantees minimum collision and delay
- * Ensure maximum and reliable throughput
- * Ensure reliable transmission of urgent and safety message

WAVE requires low delay and fast processing time in order to send and receive services because the vehicle using WAVE service has dynamic and high mobility. In particular, the safety messages should ensure a high success rate of data transmission. In order to provide stable and reliable services

using the WAVE communication technology, differentiation QoS for each service should be guaranteed. In the WAVE standard, there is no specific mechanism for ensuring QoS of WAVE except EDCA. Therefore, most studies and researches have proposed the methods such as adaptive EDCA, variable channel interval and assignment, the TDMA(Time Division Multiple Access), etc. to improve QoS in the WAVE MAC. We will present the limitations of QoS support in current WAVE focused on the MAC layer and several proposed technologies to overcome them and discuss considerations for the development of next-generation WAVE technology based on them.

A. Adaptive EDCA

EDCA controls the order of transmission by given different AIFS and CW values for each AC which has different transmission queues according to the priority of each message to QoS in WAVE MAC. However, the probability of selecting same backoff parameter increases because CW of high priority AC has a small range. As a result, the probability of a packet collision also increases when several nodes transmit data of same AC[7]. Eventually, the range of CW value should be increased in order to reduce the probability of packet collision, but transmission delay may increase. In addition, because any node was also unable to transmit data during the AIFS period, it also causes another delay. Therefore, it needs to adjust backoff parameters dynamically with the change of network topology like following methods. In [7], they proposed the method that makes ACs of the same priority don't have the same CW or AIFS by adding a weight value calculated based on the collision rate to improve the overall network performance by reducing the collision probability. In [8], we can confirm that system throughput can be improved by only adjustment of CW value in V2I(Vehicle to Infrastructure) communication. When the density of the vehicle increases, the transmission efficiency is reduced in EDCA using the default parameter values because the packets collision increases. So, most studies like[9-11] propose algorithms to optimize and adjust the assigned priority or the CW size based on the density of the vehicle to ensure the throughput. In [9], the performance is improved by adjusting window size and priority level considering vehicle density, transmission range and network parameters.

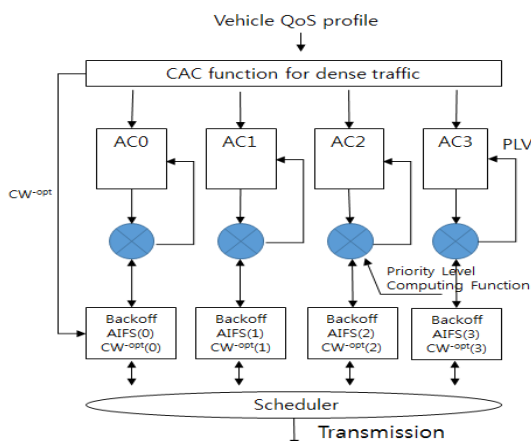


Figure 2. Adjusted packet scheduler in [9]

B. Variable channel interval and assignment

One of the WAVE features is that it provides a multi-channel operation. Because channel interval between CCH and SCH is fixed and it cannot use other channels even though there is no data to be sent during the allocated channel interval, the channel resources may be wasted[12]. And WAVE standard does not mention about efficient channel utilization and allocation method[13]. In [12], the optimal channel is assigned through negotiation and it makes the node send non-safety data in CCH interval using specific transmission mode. In [13], it configures variable CCH and SCH interval based on the optimal channel access probability. Several studies like [14-15] propose methods to increase the efficiency and capacity of the channel resources by setting the variable interval of the SCH and CCH or using a dedicated interval for a specific service or allocating optimal channel based on the packet collision probability, channel throughput, density and so on.

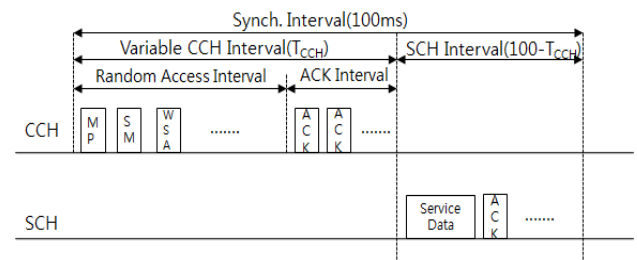


Figure 3. MP(Multi-priority supported p-persistent) MAC protocol in [13]

C. TDMA

CSMA/CA(Carrier Sense Multiple Access/Collision Avoidance) MAC protocol is used in WAVE has the disadvantage to increase the packet collision under high traffic loads due to the contention-based channel access scheme. TDMA MAC protocol, contention-free scheme, provides high reliability and quality for the service because it provides all the node with fair channel access opportunities without contention and allows the node assigned the time slot to continue to use it. However, problems like access collision and merging collision can occur when each node accesses the same time slot at the same time[16] and it may take a long time to allocate the time slot. Additionally, if there is no data to be transmitted, the channel resource is wasted because of the unused time slot and it may reduce the overall throughput. Because it uses the slot assigned based on the time information, all nodes should be the correct time synchronization. To overcome these problems, several enhanced algorithms based on TDMA MAC are proposed. Most algorithms of the TDMA scheme effectively allocates the time slot based on the node's location like [16]. In [17], they adjusted the size of time slot based on the number of nodes. STDMA of [18] is ETSI standard and is already used in other fields. It is time slot scheduling which the node determines the data transmission slot itself using the local frame interval.

D. Considerations for the next WAVE

For enhancing QoS on WAVE MAC, EDCA parameters should be adjusted variably in consideration of the factors affecting the performance like the density of the vehicle.

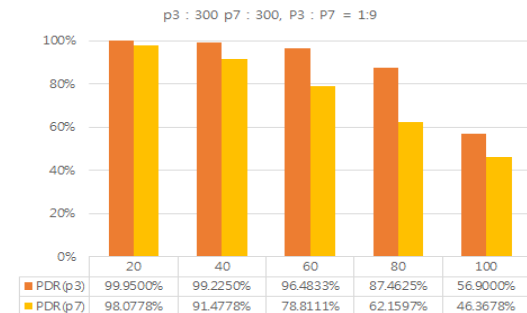
Current studies have each method for calculating density of vehicle. So, the accurate and proven method for calculating the density of the vehicle and for collecting information like position, distance and so on is needed. Because there is no RTS/CTS exchange or ACK for broadcasting, it cannot check whether collision of the packet. So, backoff mechanism does not work and the hidden terminal problem occurs[19]. These problems also need to be solved, and it may be required to adjust the transmission timing or to develop a flexible feedback algorithm as the degree that does not significantly interfere with the overall network performance. The adaptive EDCA method would be a good way of improving the overall performance and QoS while maintaining the existing EDCA protocol. A priority allocation method focused on the receiver that determine the sequence of packet transmission depend on the number of nodes which want to receive the service in order to provide first the service which many nodes want also may deserve consideration.

The use of variable channel interval needs additional information exchange protocol and data transmission and complexity of implementation increases because other nodes also have to know the changed channel information to apply the same channel interval. Because it can also be another cause of the performance degradation, these methods should be designed considering the protocol complexity. Especially, in the case of Multi-PHY devices, available network resource has doubled because it can be used by separating CCH and SCH. So, it is required to define additional channel exchange and allocation methods that can efficiently use each separate channel for these architecture devices according to the service characteristics while maintaining compatibility with the single-PHY device.

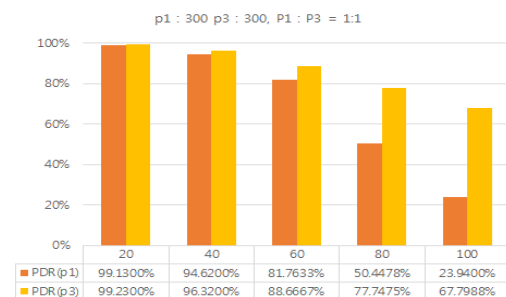
In TDMA, because the network topology is changed frequently, the owner of allocated time slot can also often change. Therefore, it is necessary to develop the algorithm that can assign a time slot fairly and quickly. It is also important to determine the optimized size of time slot to be assigned according to the density of the vehicle, service type and size and so on. Because CSMA/CA may have rather better performance in low density, it is a good solution to use the fusion algorithm which uses both CSMA/CA and TDMA to complement each pros and cons with variable channel interval like [20].

EDCA provides with a high-priority service among several services through the internal contention in a node. If we consider how often different types of multiple services on one node will provide at the same time, it may be better to consider a method for evenly allocating channels to multiple nodes to utilize efficiently on one CCH and six SCH than to control the service priority. Multiple nodes in a channel can transmit data of different sizes and priorities at the same time, and successful delivery of such data depends on the priority and size of the data currently being transmitted and how many nodes are transmitting by the EDCA mechanism. It is generally expected that high priority data will show higher PDR(Packet Delivery Ratio) than other priority data. However, in some cases like Figure 4 (a), when we tested that different rates of nodes would send data of the same size and different priority and compared the success rate of data transmission based on the received data

through the NS-3 simulator, it showed better PDR when sending low priority data. In most cases, nodes that sent high priority data showed high PDR like Figure 4 (b), but nodes that sent low priority data showed higher PDR when nodes sending low priority data were fewer than nodes sending high priority data. Therefore, it is important to efficiently allocate service resources to six service channels through a channel allocation algorithm which is not specified in the current standard.



(a) 300byte data transmission test(priority 3: priority 7(high) = 1:9)



(b) 300byte data transmission test(priority 1: priority 3(high) = 1:1)

Figure 4. NS-3 Simulation test in various conditions

The WAVE standard does not define the resource coordinate functions of the RSU(Road Side Unit) in V2I environment to monitor and allocate network resources efficiently. In several studies, algorithms that monitor and allocate the network resources to nodes around RSU are proposed. Some studies propose the clustering method which a cluster head like RSU manages other node's network resources. Because distributed or centralized approaches have the advantages and disadvantages, it shall apply the adaptive method according the network structure or the situation. It is also necessary to apply the specific handover method to guarantee a reliable QoS for the service provided through the RSU continuously because the vehicle quickly passes multiple RSU.

Most techniques or algorithms have been verified through analysis of mathematical model and simulations on specific testing environments with some constraint. However, since the network topology on the real traffic environment changes in various forms very quickly and unexpected situation can occur, it is difficult to predict to show similar result and performance as simulation in VANET(Vehicular Ad Hoc Network). Thus, enhanced algorithm for supporting QoS should be developed and tested in various VANET environments and all possible

traffic situations considering in each case of V2V or V2I, broadcast or unicast, urgency and importance of service and so on.

IV. CONCLUSIONS

So far, we presented the main limitations in supporting QoS in current WAVE MAC and current enhanced methods to overcome them and discussed considerations for the development of next-generation WAVE technology based on them. Currently, mobile communication technologies such as LTE and 5G are including the requirements for autonomous driving vehicle. Thus, WAVE will be required the performance level proposed in 5G mobile communication exceeding the performance suggested in the current WAVE specifications in order to have a competitive advantage to the trend of such mobile communication technologies. Therefore, the next-generation WAVE will need to be developed to guarantee the WAVE QoS while satisfying these requirements of performance based on considerations discussed in this paper.

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REFERENCES

- [1] Myungwook Park, et al. "Development of Steering Control System for Autonomous Vehicle Using Geometry-Based Path Tracking Algorithm," ETRI Journal, vol. 37, no. 3, 2015, pp. 617-625
- [2] Noh, Samyeul, et al. "Co-Pilot Agent for Vehicle/Driver Cooperative and Autonomous Driving," ETRI Journal 37.5 (2015): 1032-1043.
- [3] Oh, Sung-Min, et al. "Efficient Interference Control Technology for Vehicular Moving Networks," ETRI Journal 37.5 (2015): 867-876.
- [4] IEEE Standard for Wireless Access in Vehicular Environments (WAVE)-Multi-channel Operation, IEEE Std 1609.4-2010 (Revision of IEEE Std 1609.4-2006), vol., no., pp.1,89, Feb. 7 2011
- [5] IEEE Standard for Information technology- Local and metropolitan area networks- Specific requirements- Part 11: Wireless LAN Medium Access Control(MAC) and Physical Layer (PHY) Specifications Amendment 6: Wireless Access in Vehicular Environments, IEEE Std 802.11p-2010, vol., no., pp.1,51, July 15 2010
- [6] El Ajaltouni, Hikmat, Richard W. Pazzi, and Azzedine Boukerche. "An efficient QoS MAC for IEEE 802.11p over cognitive multichannel vehicular networks." 2012 IEEE International Conference on Communications (ICC). IEEE, 2012.
- [7] Huibin, Wang, et al. "A New Adaptive EDCA Approach to QoS of Wireless Communications." Wireless Engineering and Technology 2010 .
- [8] Kyunghwi Kim, Jeongbeen Lee, Wonjun Lee. "Performance Analysis of EDCA for Infrastructure-to-Vehicle Communications with Empirical Trajectory Data", Journal of KISS : Information Networking, 2013.8, 207-212 (6 pages)
- [9] Bejaoui, Tarek. "QoS-oriented high dynamic resource allocation in vehicular communication networks." The Scientific World Journal 2014.
- [10] Lim, Joanne Mun-Yee, et al. "Cognitive VANET with enhanced priority scheme." Telecommunications and Multimedia (TEMU), 2014 International Conference on. IEEE, 2014.
- [11] Chrysostomou, Chrysostomos, Constantinos Djouvas, and Lambros Lambrinos. "Applying adaptive QoS-aware medium access control in priority-based vehicular ad hoc networks." Computers and Communications (ISCC), 2011 IEEE Symposium on. IEEE, 2011.
- [12] Dang, Duc Ngoc Minh, et al. "An enhanced multi-channel mac for vehicular ad hoc networks." 2013 IEEE Wireless Communications and Networking Conference (WCNC). IEEE, 2013.
- [13] Shao, Caixing, et al. "A multi-priority supported medium access control in Vehicular Ad Hoc Networks." Computer Communications 39 (2014): 11-21.
- [14] Zang, Yunpeng, et al. "Towards broadband vehicular ad-hoc networks-the vehicular mesh network (vmesh) mac protocol." 2007 IEEE Wireless Communications and Networking Conference. IEEE, 2007.
- [15] Park, Sungjin, et al. "Dynamic Service-Channels Allocation (DSCA) in vehicular ad-hoc networks." 2013 IEEE 10th consumer communications and networking conference (CCNC). IEEE, 2013.
- [16] Omar, Hassan Aboubakr, Weihua Zhuang, and Li Li. "VeMAC: A TDMA-based MAC protocol for reliable broadcast in VANETs." IEEE Transactions on Mobile Computing 12.9 (2013): 1724-1736.
- [17] Jong Min Kim, Mingyu Lee, Tae-Jin Lee. "A TDMA-based MAC protocol for Enhancing QoS in Vehicular Ad Hoc Networks." Proceedings of Symposium of the Korean Institute of communications and Information Sciences , 2015.06, 1546-1547 (2 pages).
- [18] Khairnar, Vaishali D., and Srikhand N. Pradhan. "Simulation based evaluation of highway road scenario between DSRC/802.11 p MAC protocol and STDMA for vehicle-to-vehicle communication." (2013).
- [19] M. Hassan, H. Vu, and T. Sakurai, "Performance Analysis of the IEEE 802.11 MAC Protocol for DSRC Safety Applications," IEEE Trans. Vehicular Technology, vol. 60, no. 8, pp. 3882-3896, Oct. 2011.
- [20] Zhang, Yao, et al. "A channel coordination scheme for high density vehicular ad-hoc networks based on time division multiplexing." Journal of Communications 9.1 (2014)

Jeong-Woo Lee is a senior researcher of Autonomous Vehicle Infrastructure Research Section, Electronics and Telecommunications Research Institute, Daejeon, Rep. of Korea. He received his BS and MS degrees in computer engineering from Sungkyunkwan University, Suwon, Rep. of Korea, in 1999 and 2001, respectively. He joined ETRI in 2001. His research interests include intelligent vehicles, V2V, V2I, head-up displays, and augmented reality applications in vehicles.

Hyun-Kyun Choi is a principal researcher of the Autonomous Vehicle Infrastructure Research Section, Electronics and Telecommunications Research Institute, Daejeon, Rep. of Korea. He received his BS and MS degrees in electronic engineering from Kyungpook National University, Daegu, Rep. of Korea, in 1995 and 1997, respectively, and his PhD degree in electronic engineering from Chungnam National, Daejeon, Rep. of Korea, in 2015. He joined ETRI in 2000. His research interests include intelligent vehicles, V2V, V2I communication, ITS, and PON.