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Research Article

An Energy-Efficient Broadcast MAC Protocol for Hybrid Vehicular Networks

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In vehicular networks, sparse roadside vehicular communication (RVC) systems on highways are difficult to provide full coverage of existing roadways because the distance between the roadside units (RSUs) is farther than the RSU's transmission range. In sparse RVC, collision-free communication is required because the time available for communication is very short. In addition, the collision-free communication has an energy-efficient feature. Therefore, we propose an energy-efficient broadcast MAC protocol in order to expand the service coverage in RVC systems and collision-free communication. The proposed protocol performs a hybrid vehicular communication (HVC). It has a rebroadcast mechanism using a vehicle's velocity, distance, and angle from nearby vehicle for collision-free communication. Then, we show our protocol's performance evaluation using ns-2.

1. Introduction

Vehicular communication is an integral part of intelligent transport systems (ITSs). GPS/DMB device has been already installed in many vehicles, and communication device will be also installed in most of vehicles in near future. The vehicular communication systems are divided into intervehicular communication (IVC) systems and roadside vehicular communication (RVC) systems [1]. IVC systems are completely infrastructure-free so that only onboard units (OBUs) are needed. In RVC systems, communication takes place between roadside units (RSUs) and OBUs. Hybrid-vehicular communication (HVC) systems are the hybrids of IVC and RVC systems. The studies on IVC systems have been conducted relatively more than the studies on RVC systems [2, 3].

This paper covers RVC systems with focus on information downloading service that provides information on road conditions or traffic. The information downloading service means seamless services such as multimedia streaming service [4]. RVC systems are divided to ubiquitous RVC (URVC) systems and sparse RVC (SRVC) systems. For URVC systems, RSUs are installed on all roads to ensure that communication with RVC systems, while a vehicle is moving, is not disconnected. Unfortunately, a URVC system may require a considerable investment to provide full coverage of existing roadways. On the contrary, for SRVC systems, RSUs are installed at a certain interval of distance, which is practical since it requires less investment cost than URVC systems. A weak point of SRVC system is that downloading service is unavailable if a vehicle is out of the RSU's transmission range because the distance between RSUs is large. Most of the studies on RVC systems had put focus on how to improve performance when a vehicle arrive within the RSU's transmission range [5–7]. However, if the RSU's transmission range is 1 km and a vehicle's speed is 100 km/h, the time available for communication is 72 seconds at the maximum, which is very short. Therefore, in order to provide an energy-efficient downloading service, the following study is necessary. First, the method expanding the service coverage is needed in order to extend the time available for communication. Second, collision-free communication is required in order to avoid the unnecessary delay occurred by the retransmission of the frame collisions. Minimizing the number of retransmissions means the energy-efficient features. From these motivations, this paper proposes an energy-efficient multihop relay broadcast MAC (MRB-MAC) protocol.

The remainder of this paper is organized as follows. In Section 2, a description of related research studies is provided. An application scenario is presented in Section 3. And an overview of our protocol is presented in Section 4.

The simulation validation is presented in Section 5. Finally, Section 6 concludes the paper.

2. Related Work

The routing protocols using the various metrics already have been studied for the multihop communication in the wireless networks [8, 9]. However, this paper focuses on the MAC layer protocol in order to reduce the routing overhead of the frequent topology changes according to a vehicle's movement characteristics.

Sloted-1 [10], which is a beaconless approach method, classifies the broadcast range locally and designates it as one "slot." And it allocates a shorter waiting time to the OBU in the farthest region based on the OBU that transmits data in order to avoid collision. The DDB [11] utilizes the distance of the OBU that an OBU will transmit after receiving data in order to calculate the cover additional area (AC) and the delay time for rebroadcasting. Unlike the case with the aforementioned study, the BCF [12] is a beacon-based approach method. This protocol periodically broadcasts the beacon message that includes the location, direction, and speed. And when a car accident happens, it selects a forwarder using the information of the beacon message.

RVC systems have the higher bit error rate (BER) than IVC systems because of the damage of wireless channel fading caused by the difference in high speed between an RSU and an OBU. Since communication in case of movement in the same direction is considered in IVC systems, the difference in speed is not greater than that of RVC systems. As a way to solve the problem, protocols that use cooperative communication (CC) were proposed. VC-MAC [5] proposed the mechanism to select relay node in order to avoid collision with other OBUs in consideration of the signal to noise (SNR) of the OBUs that received frame normally from the RSUs. ADC-MAC [6] uses CoopTable of CoopMAC [13] to select helper node and provides support for direct transmission (DT), cooperative relay (CR) transmission, and two-hop relay (TR) transmission based on the RTS-HRTS-CTS-HCTS-HACK mechanism. On the assumption that the location of the RSU is known to all vehicles, PVR [7], which does not use CC, proposed the method to select proxy node based on the information on neighbor nodes until it reached the RSU and to collect the information on nearby nodes in order to transmit data to the RSU. The authors of [14] presented the cluster-based mechanism employed for multimedia transmissions and the cluster head selection algorithm in HVC systems.

The problems found by the related works can be summarized as follows.

(i) There are insufficient studies on SRVC systems. In case of downloading service in SRVC systems, the RSU does not have enough time to provide service to the OBU because of having the limited transmission range.

(ii) Most of the studies did rarely take two-way street into consideration. In the two-way street, since the relative speed of a vehicle in the opposite direction is very high, there is a higher possibility of collision if the network topology changes more quickly in the contention mode.

(iii) The beacon-based mechanism to know the status of neighbor nodes such as BCF, VC-MAC, and ADC-MAC and the cluster-based mechanism causes wasting of bandwidth and frequent collisions.

3. Application Scenario

Before explaining the MAC protocol designed in this paper, this section explains an application scenario to which our protocol is applied. The application scenario presented in this paper is similar to information downloading scenario presented in VC-MAC [5]. The details, similar to those of VC-MAC, are as follows.

(i) In our scenario, we only consider the downlink, which means that an RSU sends data to an OBU.

(ii) In vehicular networks, every vehicle is equipped with a wireless device.

Their differences are as follows.

(i) Vehicles are equipped with the GPS, which is used for velocity/distance/direction calculation and time synchronization function. They are aware if the moving direction is on an upline or a downline.

(ii) Vehicle communication is assumed on the two-way highway as the system is SRVC system with RSUs installed at a certain interval of distance.

(iii) All RSUs are aware of the pre/post-RSU reaching distance, and intercommunication between them is possible.

In Figure 1, the upper road means a downline while the lower road means an up line. In this case, when the RSU in the left transmits data, almost every vehicle within the transmission range can receive the data. And a vehicle in the upline uses data forwarding mechanism to send data to other vehicle ahead. If vehicles in the upline/downline continue data forwarding onward, possibility of collision may increase due to data transmission by vehicles in the opposite direction. However, if the restricted region on the downline is designated as A and the one on the upline is designated as B, before vehicles in each direction within the restricted region stop data forwarding, almost all of the vehicles can be within the communication coverage without any collision as shown in Figure 1. In addition, even though the SNR is not used as the case with cooperative communication, it is possible to have the advantage of spatial reusability in case of having a relatively high BER.

4. MRB-MAC Protocol

This section presents the design details on the proposed MAC protocol. MRB-MAC is based on the time division multiple access (TDMA) and the IEEE 802.11 PHY. The reason why we select the TDMA instead of the IEEE 802.11p MAC is in order to prevent frame collisions among OBUs during

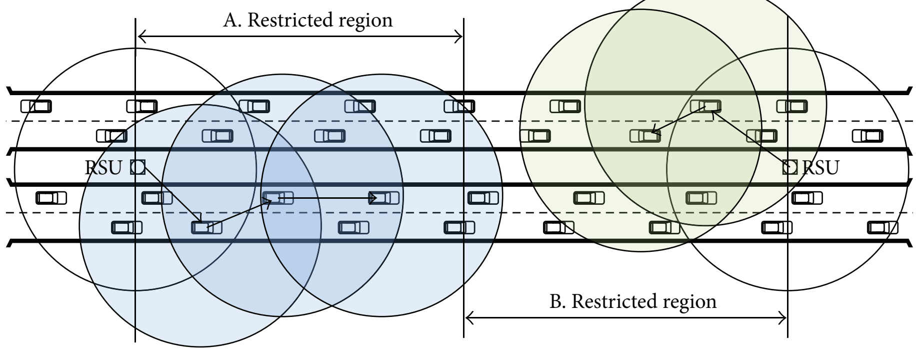

Figure 1: Application scenario.

multihop relay broadcast period. The protocol is composed of two components: RSU's broadcast period and OBU's relay broadcast period. In the RSU's broadcast period, the RSU broadcasts the frames to OBUs. In the OBU's relay broadcast period, the OBUs wait for the delay time calculated by the proposed algorithm for the rebroadcast delay time. Then, the OBU with the shortest delay time rebroadcasts the received data frame.

4.1. Restricted Region. In PVC, the restricted region is used in order to prevent frame collisions between the next RSU and the OBU approaching to the RSU. In addition, the restricted region improves in order to prevent frame collisions between the OBUs on the opposite lane.

Let $\mathrm{TR}_{\mathrm{RSU}}$ and $\mathrm{TR}_{\mathrm{OBU}}$ denote the transmission range of the RSU and OBU. The restricted region presented by PVR is the distance from the RSU location to $3 \times \mathrm{TR}_{\mathrm{RSU}}$ [7]. If the OBUs are in the restricted region, they do not transmit anything. As shown in Figure 2(a), if there is no vehicle in the opposite direction, consideration is taken only into collision-free RSU data frame (RDF) of the RSU. Therefore, the restricted region becomes the distance from the location of the RSU to $2 \times \mathrm{TR}_{\mathrm{RSU}}$. Figure 2(b) shows that a vehicle in the opposite direction leaves from the RSU later than vehicles that move to the right direction. In this case, in order to prevent collision of the OBU's data frame in the opposite direction, the restricted region is set as the distance from the location of the RSU to OBU's $2 \times \mathrm{TR}_{\mathrm{OBU}}$. Lastly, Figure 2(c) shows that vehicles move appropriately on both of the two directions of the road. In this study, the restricted region is designated as the distance from the next location of the RSU to $\mathrm{TR}_{\mathrm{RSU}}$ + half of the distance between the RSUs.

The distance from the point which a vehicle passes the RSU to the predicted point which the vehicle meets another vehicle on opposite side is computed as

$$D = \frac{v_1 \times D_{\mathrm{RSUs}} + \alpha \times v_1 \times v_2}{v_1 + v_2}, \quad \alpha = t_2 - t_1, \qquad (1)$$

where v_1 and v_2 are the velocities of vehicles, t_1 and t_2 are the departure time from RSUs, and D_{RSUs} is the distance between RSUs. Then the restricted region arrival distance (RAD) is computed as

$$\mathrm{RAD} = \begin{cases} D_{\mathrm{RSUs}} - 2 \times \mathrm{TR}_{\mathrm{RSU}}, & n = 0, \\ D - 2 \times \mathrm{TR}_{\mathrm{OBU}}, & D > \dfrac{D_{\mathrm{RSU}}}{2}, \\ \dfrac{D_{\mathrm{RSU}}}{2} - \mathrm{TR}_{\mathrm{OBU}}, & \text{otherwise}, \end{cases} \qquad (2)$$

where n is the number of the vehicles which depart in the opposite direction from the next RSU. Each RSU computes the RAD using (2) with the information of OBUs received from the next/previous RSUs. Then, this value is set to up/down RR *distance* field when broadcasting the RDF.

4.2. RSU's Broadcast Period. In this period, the RSU broadcasts the RDF periodically, and time slot begins from that point. Figure 3 shows the frame exchange mechanism that takes place after the RSU transmits the RDF. The time slot for the broadcasting of the RDF and the ODF is expressed as T_{RDF} and T_{ODF}, respectively. T_{RDF}, which is the time slot period of the RDF, is calculated as follows:

$$T_{\mathrm{RDF}} = T\,(\mathrm{RDF}) + \mathrm{Max\ \ prop.\ delay} + \mathrm{SIFS}, \qquad (3)$$

where $T(\mathrm{RDF})$ means the time that is taken for transmitting the RDF. And T_{ODF} is calculated as follows:

$$T_{\mathrm{ODF}} = T_{\mathrm{RDF}} + \mathrm{Maximum\ delay\ time}. \qquad (4)$$

Then, the RSU's broadcasting interval time is $T_{\mathrm{RDF}} + 3 \times T_{\mathrm{ODF}}$.

Figure 4 shows frame format of the RDF. In the figure, *lane count* field means the one-way maximum lane count of a highway where the RSU is installed. *Time stamp* field means the time when the RSU has broadcast, while the OBU uses the field to calculate the time slot period of the TDMA. RSU *location* field means the location of the RSU that transmits the RDF, while up/down *RR distances* field means the reaching distance up to the restricted region (RR) of up/downline, respectively. The OBU that receives the RDF uses a restricted region distance that is required according to the moving direction.

4.3. OBU's Relay Broadcast Period. The OBU that received the RDF uses GPS device to determine if the OBU is on an upline

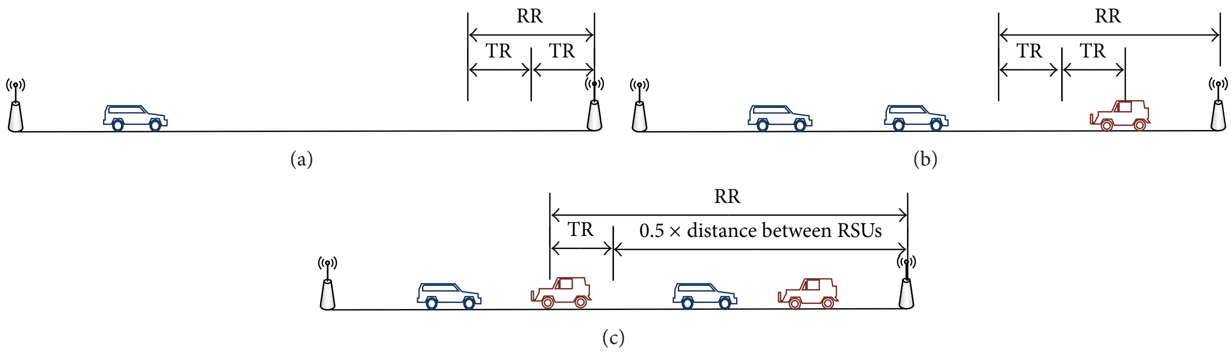

FIGURE 2: Restricted region examples.

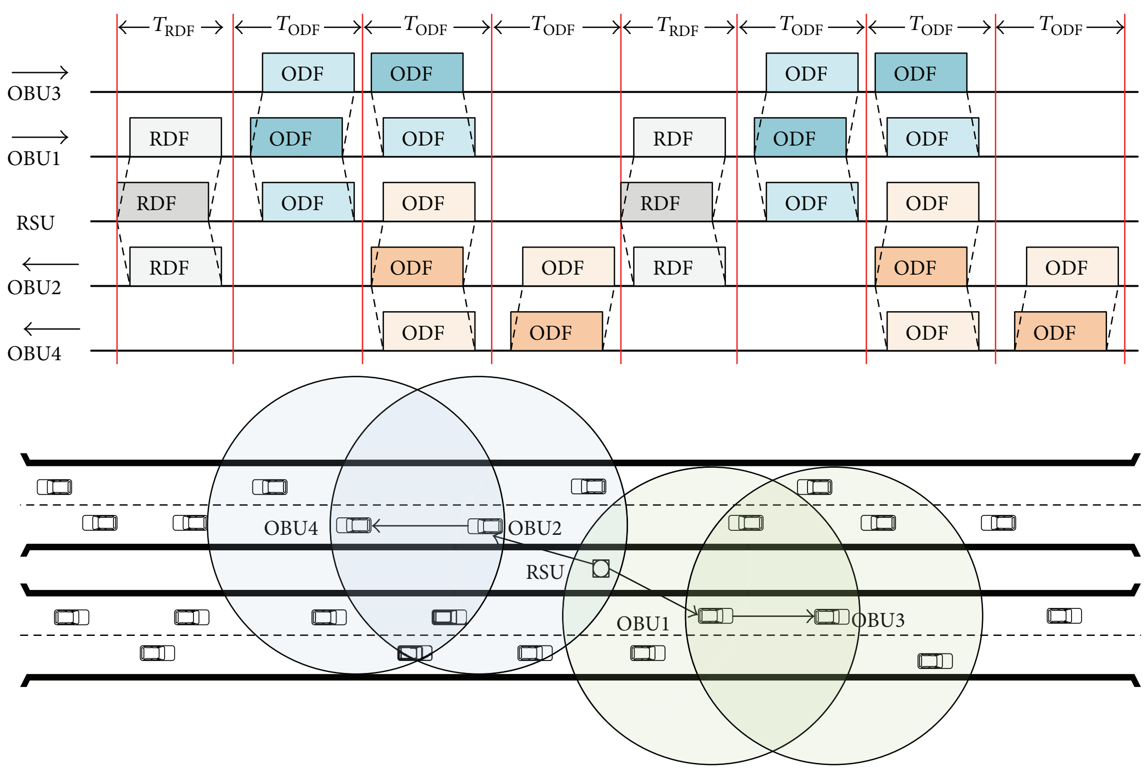

FIGURE 3: Frame exchange mechanism in the RSU/OBU's broadcast periods.

RSU data frame (RDF) (type: 1)

	Type	Lane count	Time stamp	RSU location	Up/down RR distances	Length	Data	CRC
Octets:	1(4 bits/4 bits)		8	8	4(2/2)	2	Variable	4

OBU data frame (ODF) (type: 2)

	Type	Lane count	Time stamp	OBU location	Direction	Velocity	RR distance	Length	Data	CRC
Octets:	1(4 bits/4 bits)		8	8	1	1	2	2	Variable	4

FIGURE 4: Frame format in the RSU/OBU's broadcast periods.

or a downline before performing the proposed rebroadcast mechanism. If the OBU is on an upline, it performs the rebroadcast mechanism immediately after the time of T_{RDF} has passed since the time point of RDF's *time stamp* field value just as the OBU1 in Figure 3. If the OBU is on a downline, it waits for the time of T_{ODF} before performing the mechanism. This prevents the ODFs that were broadcasted by the OBUs that receive RDF on the up/downline from colliding in the RSU. The RSU calculates the restricted region based on location and velocity of the ODF that it received.

The values of *time stamp* field and RR *distances* field of an ODF shown in Figure 4 are identical to the field values in the RDF that an OBU received. Based on this fact, if the OBU receives the ODF, procedures as below are taken.

(i) If the OBU receives the ODF that does not have the recent *time stamp* field value or the ODF of an OBU in the opposite direction, the OBU discards it.

(ii) If the OBU is within the restricted region, it does not perform the rebroadcast mechanism.

(iii) Otherwise, the OBU performs the rebroadcast mechanism.

(iv) If a carrier sensing occurs during the rebroadcast mechanism of the OBU, the mechanism stops.

4.4. Rebroadcast Mechanism. The key to the proposed rebroadcast mechanism is the RDF/ODF rebroadcast delay time algorithm (RDTA). The RDF RDTA is used by the OBU that received the RDF to calculate delay time. The direction and location of the OBU1 are used to induce a linear equation in the two variables while the location and transmission range of the RSU can be used to induce a circle's equation as shown in Figure 5(a). The RSU should be installed to ensure that the road traverses the transmission range of the RSU so that the two equations have the two solutions. And one of the two solutions becomes close according to the direction that the OBU moves, which becomes the RSU departure location that is the boundary that determines if it goes out of the transmission range of the RSU. For example, the departure distance between the OBU's current location and the RSU departure location is OBU1's D1 and OBU2's D2 in Figure 5(a). And the OBU calculates the RSU departure time (RDT) based on

$$\mathrm{RDT} = \frac{\text{OBU's departure distance}}{\text{OBU's velocity}}. \tag{5}$$

According to [15, 16], a safe headway is at least 2 seconds or more because it is impossible to follow a vehicle safely with a headway less than 2 seconds. For example, the safe headways of 100 km/h and 80 km/h are 54 m and 44 m, respectively. Let T_{safe} denotes the safe headway (second). Then, when the OBU receives the RDF, its delay time value (DTV) is computed as

$$\mathrm{DTV}_{\mathrm{RDF}} = \begin{cases} \mathrm{MDT} \times \dfrac{\mathrm{RDT}}{T_{\mathrm{safe}}}, & 0 \le \mathrm{RDT} \le T_{\mathrm{safe}}, \\ \infty, & \text{otherwise}, \end{cases} \tag{6}$$

where MDT is the maximum delay time. If the RDT of the OBU is smaller than T_{safe}, this means that the probability that there is no vehicle in front of it in the $\mathrm{TR}_{\mathrm{RSU}}$ area is very high. This reduces the number of competing OBUs, which results in reduction of collision probability.

The ODF RDTA is used to calculate the delay time of the OBU that received the ODF. While most of the related research works propose the algorithms based on the distance, the proposed RDTA uses the velocity and angle as well as the distance. Using the safe headways, the vehicles that received the ODF compute the number of vehicles in front of them in the same lane in the transmission range by

$$\mathrm{VC} = \left\lfloor \frac{\mathrm{TR}_{\mathrm{OBU}} - D_{\mathrm{OBUs}}}{\mathrm{Velocity}_{\mathrm{OBU}} \times s_{\mathrm{headway}}} \right\rfloor, \tag{7}$$

where the unit of $\mathrm{Velocity}_{\mathrm{OBU}}$ is "m/s", and D_{OBUs} is the distance between OBUs, as shown in Figure 5(b). And the OBU that received the ODF calculates the lane number (LN) of the received OBU in

$$\mathrm{LN} = \left\lfloor \frac{\left| D_{\mathrm{OBUs}} \times \sin\left(\theta_{\mathrm{OBUs}}\right)\right| - L_{\mathrm{width}}/2}{L_{\mathrm{width}}} \right\rfloor, \tag{8}$$

where D_{OBUs} is the distance between OBUs, L_{width} is the width of a lane, θ_{OBUs} is the angle between the direction of the transmitting OBU and the location of the OBU that received the ODF as shown in Figure 5(b). For example, if the value of LN is 0, this means that the OBU is in the same lane as that of the transmitting OBU. If the value of LN is 2, this means that the OBU is in the second lane above or below. In Figure 5(b), the OBU can tell if it is in the lane above or below the transmitting OBU because $\sin(\alpha)$ is larger than 0, and $\sin(\beta)$ is smaller than 0. However, even though a vehicle is equipped with a GPS device, it is difficult to find out which lane it is on. Therefore, in the proposed algorithm, the OBU that received the ODF based on the transmitting OBU uses the following to calculate its virtual lane number (VLN):

$$\mathrm{VLN} = \begin{cases} 2 \times \mathrm{LN}, & \sin(\theta) \le 0, \\ 2 \times \mathrm{LN} + 1, & \text{otherwise}. \end{cases} \tag{9}$$

For example, when D, E, and F in Figure 6(a) receive the ODF that A transmitted, H in Figure 6(b) becomes the transmitting OBU while the receiving OBUs are K, L, and M, respectively. As a result, the VLNs of K, L, and M are 0, 2, and 4, respectively. In the same way, when C in Figure 6(a) transmits the ODF, I, J, and K in Figure 6(b) receive the ODF while the *VLN*s are 3, 1, and 0, respectively.

The ODF delay time value (DTV) is computed using the results of (7) and (9) as

$$\mathrm{DTV}_{\mathrm{ODF}} = T_{\mathrm{tick}} \times \mathrm{VC} \times \mathrm{MLC} + T_{\mathrm{tick}} \times \mathrm{VLN}, \tag{10}$$

where MLC is the maximum virtual lane count, and T_{tick} means the minimum time unit. This provides that if a driver keeps the safe headway, then $\mathrm{DTV}_{\mathrm{ODF}}$ has a unique value and the collision-free communication becomes possible. If $\mathrm{DTV}_{\mathrm{ODF}}$ is larger than the maximum delay time, the OBU that received the ODF stops the rebroadcast mechanism.

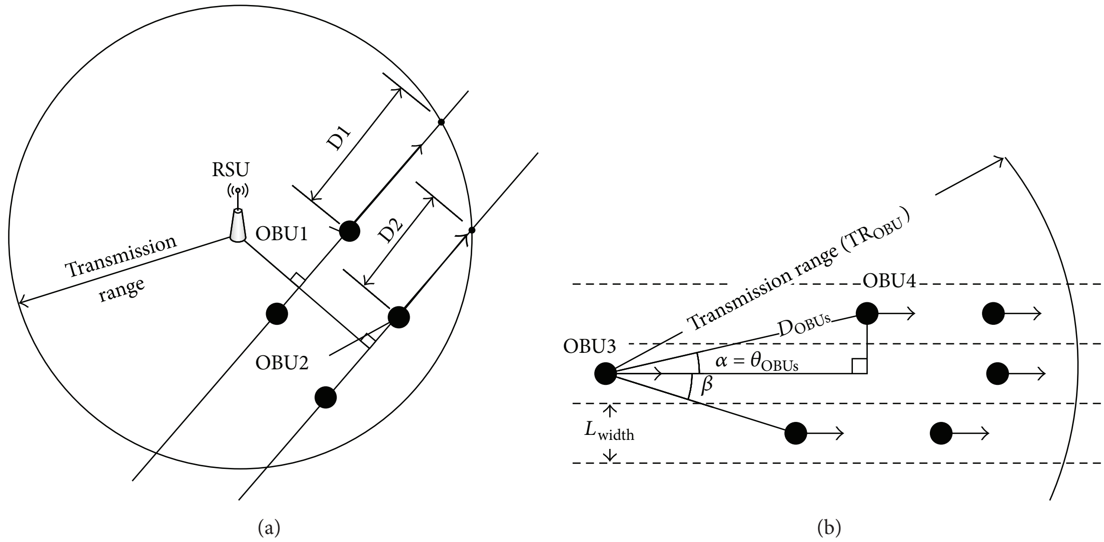

Figure 5: Examples for the rebroadcast delay time algorithm.

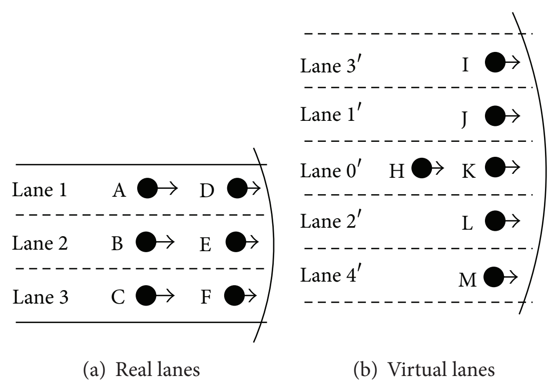

Figure 6: Example for the lane number calculation.

Table 1: Simulation parameters.

Parameter	Value
Maximum delay slot time count	15
Lane width (m)	4
Safe headway (second)	2
RSU count	2
Simulation time (second)	150

5. Simulation Results

In this section, we show the performance evaluation of the proposed MRB-MAC protocol. The simulation experiments are conducted by ns-2 with version 2.35-RC7 [17].

The main parameters of our simulations are shown in Table 1. The physical layer model is a two-ray ground inflection model, and the application is set to be a constant bit rate. In order to set up the other parameters, we refer to "tcl/ex/802.11/broadcast_validation.tcl" file in ns-2.

The deployment of the vehicles is assumed to be uniform because they move on highways. The number of the vehicles decreases as the distance between them increases when the speed of the vehicles becomes high with the safe headway being the same. The time available for communication with RSU increases as their speed becomes low.

Figure 8 shows the aggregated throughputs of MRB-MAC and the no-relay, which received only RSU frames, by the velocity with the distance between RSUs being 1 km (scenario: Figures 7(b) and 7(c)). From the result, as the velocity of a vehicle increases, the service time for downloading decreases, which leads to the decrement of the throughput.

Figure 9 shows the changes of the aggregated throughput of MRB-MAC as the distance between the RSUs changes at 4-lane roadway with 80 km/h velocity (scenario: Figure 7(c)). From the figure, it can be known that the throughput reduces sharply at the distance between the RSUs of 500 meters and 600 meters. This is because the interference occurs when moving vehicles in two-way directions relay the packets with the maximum sensing range being approximately 220 meters in the simulation configuration.

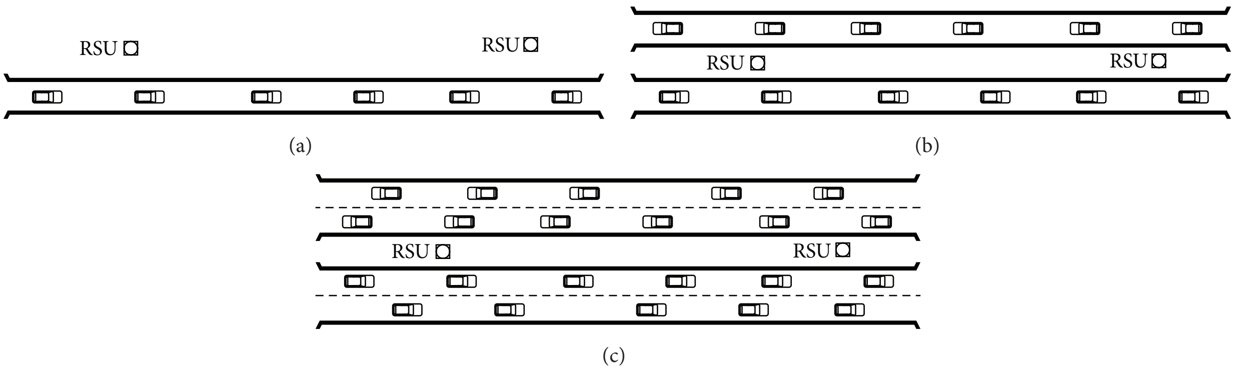

Figure 7: Simulation scenarios.

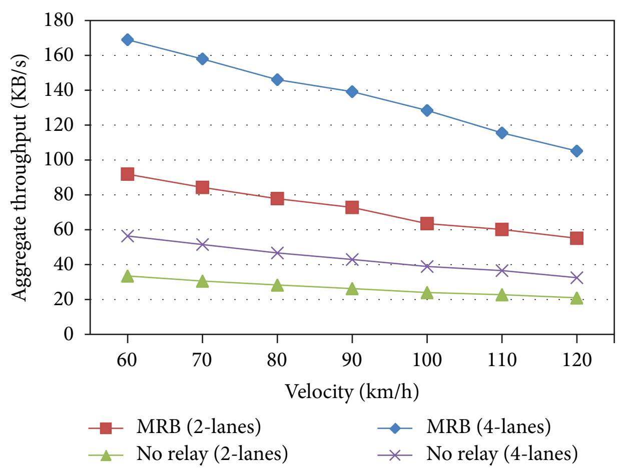

Figure 8: The aggregate throughput by the vehicle's velocity.

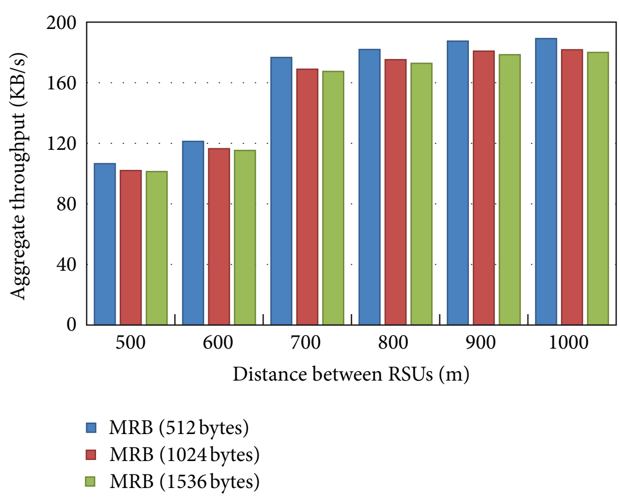

Figure 9: The aggregate throughput by the distance between RSUs (4 lanes, 80 km/h).

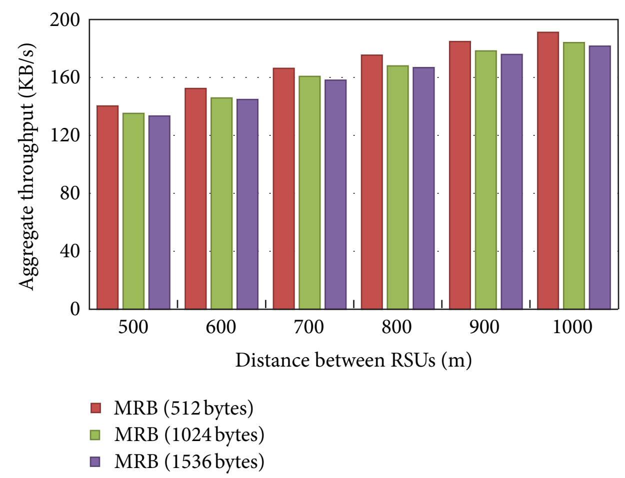

Figure 10: The Aggregate throughput by the distance between RSUs (1-lane, 80 km/h).

Figure 10 shows the results with the only change in 1-lane roadway from 4-lanes (scenario: Figure 7(a)). In the results, however, it is checked that the sharp reduction of the throughputs does not occur at the distance between the RSUs of 500 meters, because the vehicles move in one direction.

Figure 11 shows that the average delay increases as the packet length does (scenario: Figure 7(a)). It is known that as the increment of the data packet length makes both T_{RDF} and T_{ODF} longer, too big packet makes the interval of RSU receiving RDF take longer as well, which in turn leads to the performance degradation.

6. Conclusion

In this paper, we have proposed an energy-efficient multihop relay broadcast MAC protocol, which is designed for RSU downloading service in RVC systems. The RVC system has a disadvantage that its service coverage is small. In order to overcome it, we first present the restricted region for collision-free communication among RSUs and OBUs. Then, we design a protocol with a rebroadcast mechanism using a vehicle's velocity, distance, and angle from nearby vehicles. Simulation results show that the proposed protocol provides the expanded service coverage with energy-efficient collision-free communication.

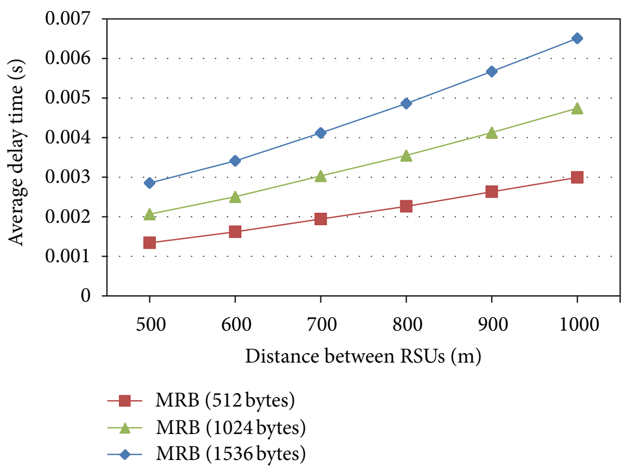

Figure 11: The average delay time by the distance between RSUs (1-lane, 80 km/h).

A disadvantage of our protocol is that network connectivity may not be guaranteed in a scenario with low vehicle density. However, by adjusting the distance between RSUs adequately depending on traffic volumes when an RSU is installed under a SRVC system, our protocol is expected to provide the good performance. In the future, we will focus on the cooperative communication in the urban scenario as well as the highway scenario.

Acknowledgment

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References

[1] M. Sichitiu and M. Kihl, "Inter-vehicle communication systems: a survey," *IEEE Communications Surveys and Tutorials*, vol. 10, no. 2, pp. 88–105, 2008.

[2] T. Willke, P. Tientrakool, and N. Maxemchuk, "A survey of inter-vehicle communication protocols and their applications," *IEEE Communications Surveys and Tutorials*, vol. 11, no. 2, pp. 3–20, 2009.

[3] S. Prahmkaew, "Performance evaluation of convergence Ad Hoc networks," *Journal of Convergence*, vol. 1, no. 1, pp. 101–106, 2010.

[4] N. Kryvinska, D. van Thanh, and C. Strauss, "Integrated management platform for seamless services provisioning in converged network," *International Journal of Information Technology, Communications and Convergence*, vol. 1, no. 1, pp. 77–91, 2010.

[5] J. Zhang, Q. Zhang, and W. Jia, "VC-MAC: a cooperative MAC protocol in vehicular networks," *IEEE Transactions on Vehicular Technology*, vol. 58, no. 3, pp. 1561–1571, 2009.

[6] T. Zhou, H. Sharif, M. Hempel, P. Mahasukhon, W. Wang, and T. Ma, "A novel adaptive distributed cooperative relaying MAC protocol for vehicular networks," *IEEE Journal on Selected Areas in Communications*, vol. 29, no. 1, pp. 72–82, 2011.

[7] M. F. Jhang and W. Liao, "On cooperative and opportunistic channel access for vehicle to roadside (V2R) communications," in *Proceedings of the IEEE Global Telecommunications Conference (GLOBECOM '08)*, pp. 5053–5057, December 2008.

[8] G. Zhao and A. Kumar, "Lifetime-aware geographic routing under a realistic link layer model in wireless," *International Journal of Information Technology, Communications and Convergence*, vol. 1, no. 3, pp. 297–317, 2011.

[9] B. Karp and H. T. Kung, "GPSR: greedy perimeter stateless routing for wireless networks," in *Proceedings of the 6th Annual International Conference on Mobile Computing and Networking (MOBICOM '00)*, pp. 243–254, August 2000.

[10] O. K. Tonguz, N. Wisitpongphan, J. S. Parikh, F. Bai, P. Mudalige, and V. K. Sadekar, "On the broadcast storm problem in ad hoc wireless networks," in *Proceedings of the 3rd International Conference on Broadband Communications, Networks and Systems (BROADNETS '06)*, pp. 1–11, October 2006.

[11] M. Heissenbüttel, T. Braun, M. Wälchli, and T. Bernoulli, "Optimized stateless broadcasting in wireless multi-hop networks," in *Proceedings of the IEEE 25th Conference on Computer Communications (INFOCOM '06)*, pp. 23–29, Barcelona, Spain, 2006.

[12] S. Bai, Z. Huang, and J. Jung, "Beacon-based cooperative forwarding scheme for safety-related inter-vehicle communications," in *Proceedings of the International conference on Computational Science and Its Applications (ICCSA '10)*, vol. 6019 of *Lecture Notes in Computer Science*, pp. 520–534, 2010.

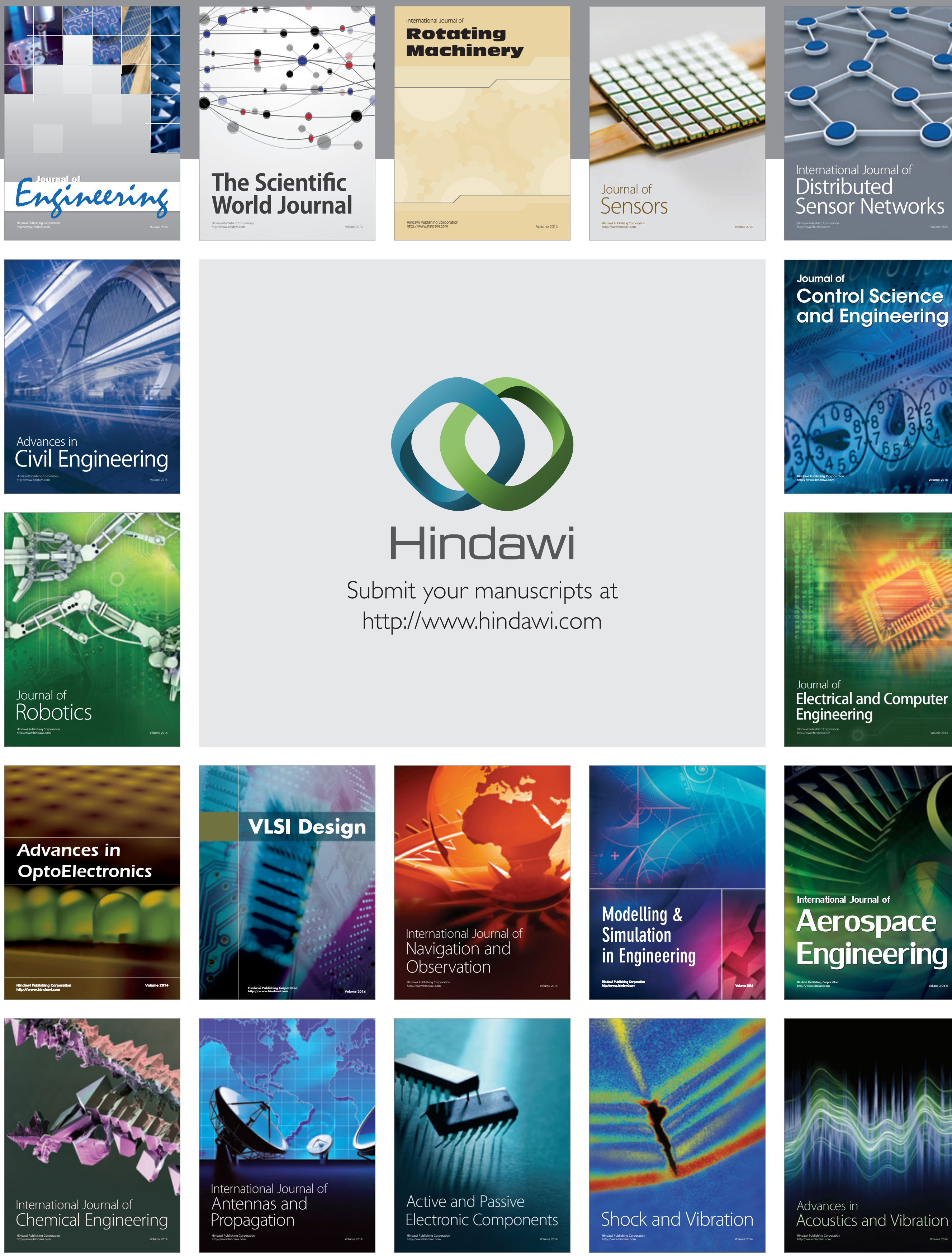
[13] P. Liu, Z. Tao, and S. Panwar, "A cooperative MAC protocol for wireless local area networks," in *Proceedings of the IEEE International Conference on Communications (ICC '05)*, pp. 2962–2968, May 2005.

[14] I. Tal and G.-M. Muntean, "User-oriented cluster-based solution for multimedia content delivery over VANETs," in *Proceedings of the IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB '12)*, June 2012.

[15] M. Fiorani, M. Mariani, F. Tango, and A. Saroldi, "SASPENCE—safe speed and safe distance," in *Proceedings of the 5th European Congress on ITS*, Hannover, Germany, 2005.

[16] C. J. Colbourn, I. D. Brown, and A. K. Copeman, "Drivers' judgments of safe distances in vehicle following," *Human Factors*, vol. 20, no. 1, pp. 1–11, 1978.

[17] NS-2, "Network simulator-2," http://www.isi.edu/nsnam/ns.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