Abstract

Objective: The main objective of this paper is to design a highway road accident prevention system to proactively alert vehicles about a possible accident with an Emergency Warning Message (EWM). Methods/Analysis: A Bandwidth Efficient Acknowledgement based Multicast protocol for High-Way (BEAM-HW) scenario is proposed in this paper. The BEAM-HW protocol attempts to multicast EWM only to the vehicles that are endangered or intended to receive and it has an acknowledgement mechanism to ensure reception. Network Simulator-2 is used to compare and validate the performance of BEAM-HW protocol with Bandwidth Efficient Acknowledgement based Multicast (BEAM) protocol, which is developed for sub-urban scenario in Vehicular Adhoc Network (VANET). Findings: In BEAM-HW, once an emergency situation is predicted, the Road Side Unit (RSU) performs the following tasks, 1. Forms a multicast group, 2. Generates a EWM, 3. Multicasts the EWM to the vehicles in the multicast group and 4. Ensures the EWM reception using acknowledgement mechanism. It is evident from the simulation experiment that BEAM-HW protocol outperforms BEAM in EWM notification and end-to-end delay. During simulation the following observations are made: BEAM-HW notifies EWM to 95.625 percent of vehicles and this is 8.25 percent higher than BEAM. The end-to-end delay in BEAM-HW for a vehicle density of 160 vehicles is 47 ms, which is comparatively better than BEAM. The performance of BEAM-HW and BEAM are closer in in-network message transaction, reception rate and network processing overhead. Novelty/Improvement: The BEAM-HW helps to reduce: 1. Number of highway road traffic accidents, 2. Death and injury rate, 3. In-network message transactions. It also assures EWM delivery and uses the bandwidth efficiently.

Keywords: Bandwidth, End-to-End Delay, Emergency Warning Message, Multicast, Notification, Vehicular Adhoc Network

1. Introduction

A part of the Gross Domestic Product (GDP) of a country is decided based on the road transportation system it has\(^1\). On the other side, due to the increase in the vehicle population, most of the roads are filled with vehicles. During the past two decades, the vehicle population in India has raised due to the Information Technology and economical boom\(^2\). This results in an increased traffic in the Indian express highway roads. But the highway road infrastructure is not sufficient to support or serve this vehicle population. Due to this reason, the road traffic accidents frequently occur in Indian express highway roads.

This paper is highly motivated by the road traffic accidents\(^3\) that happen all over the world and especially in Indian express highway roads. The road traffic accidents might be caused because of vehicle’s major mechanical problem, driver’s illness, driver’s miss obey of rules and improper driving\(^4\). One solution to this problem is to gradually implement Intelligent Transportation System (ITS) in Indian express highway roads. In this connection,
a Bandwidth Efficient Acknowledgement based Multicast protocol for High Way (BEAM-HW) scenario is proposed in this paper.

The main objective of this paper is to alert the vehicles with Emergency Warning Message (EWM) to prevent the vehicles from road accidents. This will definitely reduce the number of road accidents and the death and injury rates as well. In addition to the main objective, it is also proposed to reduce the total number of in-network message transactions and to provide assurance of timely EWM delivery assurance. The protocol like BEAM can be used for comparing the performance of BEAM-HW. The VANET is an infrastructure independent ad-hoc network and this can be viewed as a subset of Mobile Ad-hoc Network (MANET). VANET uses moving vehicles as mobile nodes and forms a mobile network as shown in Figure 1. The communication between vehicles is performed by using Vehicle to Vehicle (V2V) communication. The communication between the vehicles and the RSU is performed using Vehicle to Infrastructure (V2I) communication. Sometimes there exists a third type of communication called Infrastructure to Infrastructure (I2I) communication. These communications are supported by the standards called,

- Dedicated Short Range Communication (DSRC),
- Wireless Access to Vehicular Environment (WAVE) and
- Variants of Ethernet.

Once the possibility of occurrence of a road accident is predicted in advance, the BEAM-HW works as follows:

- The RSU forms a multicast group.
- The RSU generates an EWM.
- The RSU multicasts the EWM to the vehicles in the group and finally.
- The RSU ensures the EWM delivery to the vehicles in the group. To accomplish the above tasks the following questions has to be answered.
  - How the road traffic accident is predicted? Who will predict the road traffic accident?
  - Who will generate the EWM?
  - How the multicast group is formed and maintained?
  - How to multicast the EWM to the vehicles?

The BEAM-HW protocol provides the following contribution to address the above questions. First, the road accidents are predicted by the RSU based on the Status Report (SR) and Traffic Data (TD) send by the moving vehicles and the sensors embedded in the roads. Second, upon successful prediction of road accident: A subsystem in RSU generates a EWM. Third, a subsystem in RSU is designed to form and maintain the multicast group. Finally, the subsystem in RSU is designed to multicast the EWM to the vehicles in the highway roads.

If the vehicles receive the EWM in advance to the occurrence of a road traffic accident then the vehicles has a high possibility to prevent themselves from these accidents. The vehicles can also change their route of travel, they can stop travel and they can perform lane change. By doing the above possible actions, an efficient and safe travel with comfort can be achieved.

The remaining of the paper is organized as follows: Section 2 explains the related system, section 3 presents the design and methodology of BEAM-HW, section 4 discusses about the simulation setup, the results are analyzed in section 5 and finally section 6 concludes.

If an accident occurs at a particular site, only the vehicles closer to the site alone need to be warned about the situation and all other vehicles travelling in the highway need not be warned immediately. The far away vehicles might be informed about the accident at later stage. In this case, a multicast approach would be well suited rather than a broadcasting approach, which disseminates the message to all the vehicles in the highway. Below, the works related to BEAM-HW protocol are analyzed and discussed.

Niyoti Pathak and Jayant Rohankar developed a system for finding relative position based on travel direction among moving vehicles using Global Positioning System (GPS). This system is developed for multicast of alert packets in emergency situation. Multicast approach
is used in this system to avoid traffic congestion during excess alert message transmission in highway scenario. This system is used for finding the relative position among moving vehicles.

Yogita Raut and Vaishali Katkar\textsuperscript{15} proposed a system for multicasting the warning message to a group of vehicles that are expected to be affected in case an accident in the highway roads. The authors have also investigated the impact of deployment of RSU and multicasting of warning message in highway scenario. They have insisted the importance of multicast of emergency message instead of broadcast.

Soudeh Shadravan et al.\textsuperscript{16} proposed an alert message propagation scheme for VANET considering various vehicle densities. The authors designed an opportunistic position based approach for forwarding data packets in optimal paths. The scheme is simulated in both the sparse and dense traffic scenarios with varying vehicle densities. The parameters such as end to end delay and protocol overhead are considered for simulation in sparse and dense traffic scenarios.

Alwin Sebastian et al.\textsuperscript{17} developed a Cooperative Collision Warning System (CCWS) for event safety or warning message dissemination to the travelling vehicles using a multicast scheme. This multicast scheme designed to deliver the warning message on time with cooperative communication. This scheme is used to find the abnormal vehicles, the vehicles that might be affected by the abnormal vehicles and expected time of reception of warning message by the possible surrounding vehicles. The authors have mapped a multicast routing problem into a delay constrained minimum Steiner tree problem. They have developed an analytical model for the delay constrained minimum Steiner tree problem. This scheme is yet to be simulated.

Alwin Sebastian et al.\textsuperscript{18} proposes a context aware multicast protocol for EWM dissemination (CMED) that is used to disseminate the warning message only to the vehicles that are expected to be the victim for an accident. This protocol has been developed for a highway scenario in VANET. The authors express that this protocol provides reliable, efficient and fast delivery of the warning message. The protocol has been simulated using network simulator (NS-3). They also state that the protocol is capable to deliver the warning message to the vehicles in different traffic scenarios. In CMED protocol, when comparing to other protocols the computational overhead is more because of the context information computation. The execution time of this protocol is also more because of the multicast tree generations.

Paolo Bucciol et al.\textsuperscript{19} performed an analysis about the performance of multicast of audio communication for safety application in VANET. The authors have examined the effectiveness of vehicle to RSU communication for the multicast of the above messages. For simulation they have used the client server software suite of LS cube project. This scheme have been designed and simulated for the urban scenario of VANET and proposed to be simulated for the highway scenario. The results show that the plain 802.11b standard can be used for multicast of safety messages such as weather forecasting.

Maria Kihl et al.\textsuperscript{20} developed a Robust Vehicular Routing (ROVER) protocol for VANET to perform reliable geographical multicast. This protocol performs multicast of traffic information to the vehicles in the zone of relevance. The authors have simulated the protocol using Jist/SWANS considering a highway road of 10 kilometers length with 6 lanes (3 in each direction). The simulation has been done to assess the packet delivery ratio and Packet delivery time in respect to various vehicle densities and zone of relevance. The ROVER is a reactive protocol that performs multicast on-demand.

It is studied from the above works that the multicast approach is most suitable for EWM delivery rather than the broadcast approach. By going with the multicast approach only the intended vehicles alone are alerted with EWM and the far away vehicles are not disturbed. This conserves the bandwidth and reduces the number of in-network message transactions.

2. Design and Methodology

A task of transmitting and delivering the message to all nodes in the present network other than the source node is termed as broadcasting\textsuperscript{5}. Once a message is delivered to the desired destinations in turn the destinations reply with an acknowledgement.

This ensures the prompt delivery of the message. This bidirectional communication assures reliable delivery of emergency messages. But this utilizes excess bandwidth by performing more number of in-network message transactions in the network. The existing broadcast protocols does not bather about whether the surrounding vehicles need the EWM or not, the broadcasting approach will send the EWM to these vehicles and expects acknowledgement from them.
The BEAM-HW differs from the broadcasting process; it permits the vehicles travelling in the highway roads to choose for the reception of the EWM. The BEAM-HW gives an option to the vehicles whether they wish to receive the EWM or not. By this approach, only the intended vehicles alone will be delivered with the EWM and others will not be disturbed. The intended vehicles are the one that are closer to the possible accident area. In this way BEAM-HW forms a multicast group and performs multicast of EWM to the vehicles and assures the EWM delivery by receiving acknowledgement. Figure 2 shows the architecture of the BEAM-HW protocol.

2.1 Design of BEAM-HW

In BEAM-HW, the RSU performs prediction of road traffic accident based on the Status Report (SR) send by the vehicles. The SR consists of the speed and yaw-rate of the vehicle. The SR is set to be abnormal if any of the following case arises:

Case 1: If the speed of the vehicle suddenly increases or decreases beyond 30 km/h in two continuous time slots.
Case 2: If the chance in yaw-rate varies by 30 degrees in two continuous time slots.

If the SR is abnormal then it is concluded that an abnormal situation is predicted, i.e., the possibility of occurrence of an accident is noticed.

In this case, the RSU generates an Emergency Warning Message (EWM) and multicast this to the vehicles present in the Multicast Group (MG). Upon reception of the EWM, the vehicles are expected to do two operations:

- The vehicles need to respond with an acknowledgement and,
- The vehicles take steps to prevent themselves from road traffic accidents by stopping, detouring, changing the lane, etc.

Since the BEAM-HW is a highway variant of BEAM, the structure and the working the BEAM-HW is almost similar to BEAM. The structure of BEAM-HW is organized into two protocols. The former works in the RSU and the later works in the vehicles. The RSU part of the protocol is divided into four sub modules such as:

- Multicast Group Establishment Module.
- Road Accident Prevention Module.
- Membership Verification Module, and
- Acknowledgement Module for EWM.

Similar to the RSU part, the vehicle part of the protocol is also divided into two sub modules such as:

- Response module.
- Report Module.

The working of the modules of BEAM-HW is discussed below. The Figure 3 gives the definition and initialization part of the pseudo-code of BEAM-HW.

2.1.1 Multicast Group Establishment Module

This module is instrumental in establishing the multicast group dynamically by the RSU. Further this module is categorized into two sub modules as shown in Figure 4. Periodically (periodic_timer is set as 1 second), the
sub-module 1 broadcast join control packet to the vehicles and the sub-module 2 finds the Vehicle ID (VID) from the reply control packet send by the vehicles. If this VID of the vehicle is new then it is added to the Multicast Group (MG). The MG is updated whenever a vehicle enters or leaves the group.

The liveliness of a vehicle needs to be checked in the MG. Hence to each member (i.e. vehicle) a life_timer (60 seconds) is set. The life_timer is set so because the vehicle travels within the RSU coverage area (1000 meters) for the maximum of 60 seconds at an average travel speed of 60 km/h.

2.1.2 Road Accident Prevention Module
The RSU performs road accident prevention as discussed in this module. Once the SR is abnormal, the RSU generates a EWM and multicasts the same to the vehicles in MG. After receiving the EWM, the vehicles respond immediately by taking actions to prevent from the road traffic accidents. The actions might be: Stopping of the vehicle, performing lane change, taking alternate routes for travel, etc. In addition to this, the vehicles also send back an acknowledgement to the RSU. The pseudo-code of this module is presented in Figure 5.

To ensure the timely reception of the acknowledgement, the RSU maintains an acknowledgement timer (Ack_timer) for each vehicle in MG. This Ack_timer is set as 1 second.

2.1.3 Membership Verification Module
This module works in the RSU side of the protocol and the pseudo-code of this module is displayed in Figure 6. In order to ensure the presence of the vehicle in the MG, the liveliness or the membership of the vehicle in the MG need to be verified. Before the expiry of both the status and life timers (say status_timer and life_timer), if the vehicle is not updating its status then it is decided that the vehicle has left the MG (i.e. the coverage of the RSU).

2.1.4 Acknowledgement Module for EWM
The reliable delivery of the EWM is ensured by the acknowledgement mechanism adopted. The pseudo-code of this module is shown in Figure 7. Once the vehicle receives a EWM, it is expected to send an acknowledgement to the RSU. The acknowledgement module performs this task. In order to accomplish this, an acknowledgement timer (Ack_timer) is constituted. This Ack_timer is set as 1 second as the acknowledgement has to reach the RSU within 1 second. If the acknowledgement for the EWM is received then the Ack_timer for the respective vehicle is stopped. If the RSU does not receive the acknowledgement before the expiry of the Ack_timer then it is decided that the EWM has not been delivered to that vehicle.

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**Figure 4.** Pseudo-code of the multicast group establishment module.

**Figure 5.** Pseudo-code of the road accident prevention module.

**Figure 6.** Pseudo-code of the membership verification module.
such case, retransmission of the EWM is made for another time or attempt. The total number of attempts is set as two and the same is monitored by this module.

2.1.5 Response Module

This module works in the vehicle side of the protocol and the pseudo-code of this module is shown in Figure 8. If a vehicle enters into the coverage of the RSU instantly it receives a join control packet. In case if the vehicle wishes to receive the EWM from the RSU then it has to associate itself in the MG. In such case, the vehicle responds with a reply control packet and joins into the MG. During the validity of the life_timer, if the vehicle receives a EWM then it has to respond with an acknowledgement as explained in section 3.1.4.

2.1.6 Report Module

The report module works in the vehicle and this module is used to sense and report the Status Report (SR) of the vehicle. The SR has the parameters such as speed and yaw-rate of the vehicle. This module is expected to send or report the status of the vehicle with respect to the status_timer (set as 1 second). The pseudo-code of the report module is shown in Figure 9.

2.2 Working of BEAM-HW

To ensure a reliable exchange of the EWM and acknowledgement, two lists namely Rc and NRc are used. Initially the vehicle ID (VID) of all the vehicles is entered in the NRc list and the list Rc is made as an empty list. In emergency situations, if the RSU sends a EWM to the members (vehicles) and in response if the vehicle sends an acknowledgement to the RSU within the time mentioned in the Ack_timer then the VID of the vehicle is moved from NRc list to Rc list. This process is repeated for all the vehicles in the MG. Finally, if the Rc list consist the VIDs of all members of MG or if the NRc list is empty then it is concluded that the EWM has been multicast or delivered to all the vehicles in the MG. Otherwise, it states that a particular vehicle has left the group during the exchange of the EWM and acknowledgement.

3. Simulation Setup

In order to assess the performance of BEAM-HW, extensive simulation is conducted using the Network Simulator-2 (version 2.34). The highway scenario is simulated using the Freeway Mobility (FM) model. The highway scenario is designed with four lanes, where the travel and behavior of the two lanes are symmetric to the other two lanes in the other direction of travel. The vehicular nodes are made to move or travel in these lanes at random speeds and they are injected into the lanes at different intervals so that the inter-vehicle distance between the nodes is different for all pair of vehicular nodes. The main simulation parameters used for this simulation are shown in Table 1.

IV. ACKNOWLEDGEMENT MODULE FOR EWM:

1. Sleep until the periodic_timer matures.
2. For every member in the current dynamic multicast group.
   1. If (ACK is received for this particular E-Msg.)
      1. Stop the Ack_timer.
      2. Move the respective VID from NRc to Rc.
   2. Else
      1. Check the VID in multicast group.
         1. If (Found)
            1. Increment attempt value by 1.
            2. If (Attempt greater than maximum)
               1. Discard the VID from the current multicast group.
               2. Return.
            3. Else
               1. Send EWM to the vehicle.
               2. Return.

Figure 7. Pseudo-code of the Acknowledgement module.

I. RESPONSE CONTROLLER MODULE:

1. If (Join control packet is received.)
   1. If (vehicle wishes to receive an EWM during an emergency situation.)
      1. Send reply control packet.
      2. Return.
   2. If (an EWM is received.)
      1. Send ACK.
      2. Report the emergency situation to take preventive actions.
      3. Return.

Figure 8. Pseudo-code of the response controller module.

II. REPORT MODULE:

1. Sleep until the status_timer matures.
   1. If (True)
      1. Read speed and yaw-rate from in-vehicle sensors.
      2. Send status report.
      3. Return.

Figure 9. Pseudo-code of the report module.
setup to behave abnormally. These abnormal vehicular nodes are made to misbehave by performing sudden stoppage, abnormal lane change, sudden acceleration and deceleration. By this way, the FM model is used to setup the real four lane highway road scenario. The source RSU is setup in such a way that it monitors the vehicular traffic and reacts in case an abnormality arises. The behavior of both the RSU and moving vehicles are clearly configured in the simulation setup. The vehicle density is made to change from 20 to 160 vehicles and they are injected into each lane at different injection rates as 10 per second through 75 per second. The simulation for different vehicle densities, different behavior of vehicular nodes have been made in different runs and the reaction is recorded for further analysis.

4. Results

The results of simulation show that the performance of BEAM-HW protocol is promising towards the prevention of the highway road traffic accidents. To assess and demonstrate the effectiveness of BEAM-HW, the following performance metrics are used:

- **Number of In-network message transactions**: The total number of EWM and acknowledgement messages transmitted in the present network.
- **Notification**: The number of successful EWM notifications by the source RSU to the vehicular nodes in the Multicast Group (MG).
- **End to End Delay**: The time consumed for the EWM delivery by the source RSU to the desired vehicles in MG.
- **Reception Rate**: Percentage of the vehicles that is ready for successful EWM reception.
- **Network processing overhead**: The excess number of message transaction due to the maintenance of the MG.

### 4.1 Number of In-network Message Transaction

During simulation, once the possibility of a road accident is predicted by the RSU, then it initiates the prevention process. Initially, the vehicle density was set to 20 vehicles in different injection intervals and gradually it has been increased to 160 vehicles. The total number of message transaction is found to be approximately equal for both BEAM and BEAM-HW protocols.

Figure 10 show that the BEAM-HW consumes 14 messages for a group size of 7 vehicles among the vehicle density of 20 vehicles and consumes 102 messages for a group size of 51 vehicles among the vehicle density of 160 vehicles. The broadcasting approach might consume 40 messages for a vehicle density of 20 and 320 messages for a vehicle density of 160 vehicles. In this way, BEAM-HW protocol has reduced the in-network message transactions.

<table>
<thead>
<tr>
<th>Table 1. Simulation parameters</th>
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<tr>
<td><strong>PARAMETER</strong></td>
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<td>High Way Road</td>
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<td>Segment Size</td>
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<td>Number of Lanes</td>
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<td>Travel Speed Limit</td>
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<td>Vehicle Density</td>
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<td>Speed – Abnormal</td>
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<td>Number of Vehicles</td>
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<td>Coverage</td>
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<td>MAC Protocol</td>
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<td>Coverage</td>
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<td>Traffic Injection Rate</td>
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<td>EWM</td>
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<td>Size</td>
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<td>Notification Range</td>
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<td>Acknowledgement Packet Size</td>
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<td>Simulation Time</td>
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Figure 10. Number of message transactions for different vehicle densities.
4.2 Notification
This parameter mainly focuses on the total number of vehicles successfully notified (in percentage) with the EWM. For a group size of 20 vehicles, 18 vehicles has been notified with the EWM and for a group size of 102 vehicles, 97 vehicles has been notified with the EWM successfully as shown in Figure 11. The average performance of the BEAM-HW protocol in terms of notification is found to be 8.25% more when comparing to BEAM. This shows that the BEAM-HW is performing well in the highway scenario than the performance of BEAM in the sub-urban scenario.

4.3 End to End Delay
Initially the end to end delay is high for a vehicle density of 20 vehicles and the end to end delay decreases for the vehicle density of 160 vehicles as shown in Figure 12. This proves the common phenomena in computer network that the end to end delay is high for a lesser vehicle density and the end to end delay is low for a larger vehicle density.

The BEAM-HW protocol has performed well in the case of end to end delay; it consumes only 47 milliseconds for the larger vehicle density of 160 vehicles. Whereas the end to end delay of BEAM is found to be 70 milliseconds for a vehicle density of 160 vehicles. The end to end delay in a sparse network is higher than a dense network.

4.4 Reception Rate
The reception rate is directly affected by the vehicle density. The simulation result shows that the increase in the vehicle density makes the reception rate of the vehicles to decrease. Figure 13 Shows that the EWM reception rate is found to be 100 percent for a vehicle density of 20 vehicles and the same falls to 81 percent for a vehicle density of 160 vehicles.

The reason for the decrease in reception rate might be collision and inference in the dense network. This slightly affects the performance of the BEAM-HW protocol.

4.5 Network Processing Overhead
Since BEAM-HW is a multicasting protocol, it has to perform additional activities such as establishment and maintenance of multicast group that involves additional message transactions in the network. Due to the additional message transactions in the present network, the network processing overhead of the BEAM-HW protocol has been increased. With reference to Figure 14, if the vehicle density is found to be 160 vehicles then the network processing overhead is found to be 74 messages. This has an impact on the performance of the BEAM-HW protocol.

Figure 11. EWM Notification for different vehicle densities.

Figure 12. End to end delay for different vehicle densities.

Figure 13. EWM reception rate at different vehicle densities.
5. Conclusion

In this paper, a Bandwidth Efficient Acknowledgement based Multicast protocol for High Way (BEAM-HW) scenario has been proposed. This protocol can be considered as a highway scenario variant of our previous work named the BEAM protocol. The BEAM-HW multicast the EWM to the intended or endangered vehicles that are closer to the possible accident site and do not disturb all other vehicles in the highway road. This result in:

- Reduction of number of highway road traffic accidents.
- Reduction of death and injury rate.
- Reduction of number of in-network message transactions and efficiently uses the bandwidth and
- Provision of EWM delivery assurance with an acknowledgement mechanism. The performance of this protocol is thoroughly analyzed based on the EWM and acknowledgement exchanges. During the simulation, two abnormal behaviors are made and the reactions are analyzed. The transmission of EWM to the neighboring RSUs and the coverage extension are set to be the future scope of the BEAM-HW protocol.

6. Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

7. References