A Network-Based Seamless Handover Scheme with an L2 Extension Mechanism in VANET

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Abstract. A smart vehicle becomes a communication device with the advance of VANETs. In the WAVE standards, which is the well-known VANET standards, RSUs interconnect a VANETs to the Internet, and they act as default routers for the vehicles. However, the WAVE standards have eliminated the L2 portal function, which was included in the previous WAVE standards. Due to the short communication range of RSUs and vehicles' high speed, a vehicle may have to change its point of attachment frequently. The change of the default router causes severe service interruption due to the standard IPv6 protocol's functions such as the address auto-configuration, DAD and NUD. We propose a new seamless handover scheme with an L2 extension mechanism without any modification of the WAVE standards. It increases the coverage of an access router to multiple RSU coverage, while the frequency of the default router changes can be decreased. It also supports seamless packet delivery during the change of the points of attachment. By decoupling the RSU and the access router, the deployment of the WAVE can be more flexible. The proposed mechanism is simulated with ns-3 and its results show the effectiveness of the proposed scheme.

Keywords: Vehicular communications · WAVE · Seamless handover

1 Introduction

Vehicular Ad hoc NETworks (VANETs) has attracted a lot of interest in the communication research area due to their potential to increase road safety. In addition, to meet users' demands in vehicles for new applications [5,6], it is necessary to connect VANETs to the Internet. The WAVE reference model [2] shows that the RSU acts as the default gateway for the vehicles. A vehicle must use the non-association MAC frame, which has only two addresses. The address 1 field must be the destination address of the MAC frame, and also be the target device address in the IEEE 802.11 link. Therefore, the RSU should be the final destination of the link layer.

Considering the high mobility of vehicles and short communication range between vehicles and RSUs (Road Side Unit), however, a vehicle usually passes

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an RSU quickly and meets another RSU frequently in its path. The vehicle receives different WRAs (Wave Routing Advertisement) from two RSUs. In the WAVE standards [2], the WRA replaces the RA (Router Advertisement) and NDP (Neighbor Discovery Protocol) [10]. When the vehicle receives a new WRA, it has to generate an IP address and to change its default router. To generate new IP address using address auto-configuration, the DAD (Duplicate Address Detection) [7] has to be executed. To change its default router, NUD (Neighbor Unreachability Detection) must be considered. The NUD requires at least three seconds delay [8]. In addition, the change of the current IP address requires an L3 handover mechanism to maintain the current IP session.

In this paper, we propose an L2 extension mechanism without any modification in the WAVE standards. The proposed scheme decouples the RSU functions and the default router. It does not change the WAVE interface and adds bridging and handover functions into the wired interface in the RSU. The Access Router (AR) connected to RSUs has a handover function to support the seamless handover among RSUs. As the access router can connect several RSUs, the coverage of the access router can be expanded to the coverage of its RSUs. It reduces the L3 handover frequency as the change of an RSU does not mean the change of the default router. The proposed network based handover scheme supports seamless packet delivery.

The rest of the paper is organized as follows. Section 2 introduces the related work in the area. Section 3 presents the proposed overall architecture to provide the handover process. Section 4 describes a simulation setup along with the simulation results. Finally, Sect. 5 concludes this paper.

2 Related Works

The WAVE standards consists of IEEE 1609 [2–4] series and IEEE 802.11p [1]. The WAVE defines two kinds of channels: CCH (Control CHannel) and SCH (Service CHannel). The CCH is used to send vehicle safety messages generated by several VANETs applications [9]. All vehicles and RSUs have to monitor the CCH(s) to detect surrounding traffic environment. An RSU can detect vehicles as they emit safety beacons. The SCHs are employed by IP to support non-safety applications. IEEE 802.11p defines non-association operation. The To DS/From DS bits in the MAC frame have to set to all zeros. The BSS ID field is filled with all ones. Only two addresses are used in the 802.11 MAC frame. The address 1 field must be used as the destination address as well as the target address of the wireless LAN. An RSU must be the destination and the target device for vehicles. The RSU must be a default router of the VANETs. The 1609.0 reference model shown in the Fig. 1 verifies that the RSU is a router connecting the VANETs and the Internet. A vehicle has to get an IP address and the default router information to use the Internet. IEEE 1609.0 specifies the WRA, which contains the network prefix and the MAC address of the default router, and the WRA may be included in the WSA (WAVE Service Announcement). When the vehicle receives a WSA with WRA, the vehicle can generate its IP address using address auto-configuration mechanism and get the MAC address of the default router.

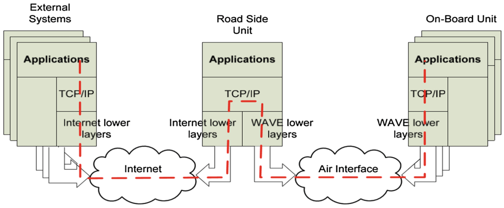


Fig. 1. 1609.0 reference model [2]

Several handover schemes [11–14] are proposed. They are the host-based handover schemes. Proactive caching and forwarding scheme [11] uses the old WAVE standards (2007) [15] as well as IEEE 802.11f which was withdrawn. WAVE point coordination function (WPCF) [12] uses the old WAVE standards, and it modifies the WSA to include the vehicles' MAC addresses sorted by the urgency of the vehicles. It focuses on minimization of the handover delay, and does not consider a seamless handover. VIP-WAVE [13] uses the current WAVE standards, and adopts the PMIPv6 to deal with mobility issues in VANETs. The PMIPv6 is an L3 handover solution and it does not support seamlessness. In [14], authors use the current WAVE standards and RSSIs (Receive Signal Strength Indicator) to decide the handover moment. It does not consider the seamlessness of packet delivery.

3 Proposed L2 Extension Mechanism

3.1 Our System Architecture

The L2 extension mechanism is proposed to extend the coverage of an AR by connecting RSUs with L2 switches. The overall system consists of 4 components: vehicles, RSUs, L2 switches and an AR. Figure 2 shows a simple configuration of the system.

Vehicles communicate with RSUs or other vehicle using the WAVE standards [1,3,4]. We assume that the vehicle executes at least one safety application specified in [9]. The safety beacon generated by the safety application includes the vehicle's current location and direction information.

L2 switches are ordinary Ethernet switches with the VLAN function. Each pair of an RSU and the AR consists of a VLAN in the link. The VLAN is used to decouple the RSU and the AR roles in the proposed system. Each VLAN acts as a WAVE interface, so it replaces the embedded WAVE interface of the AR required by the WAVE standards.

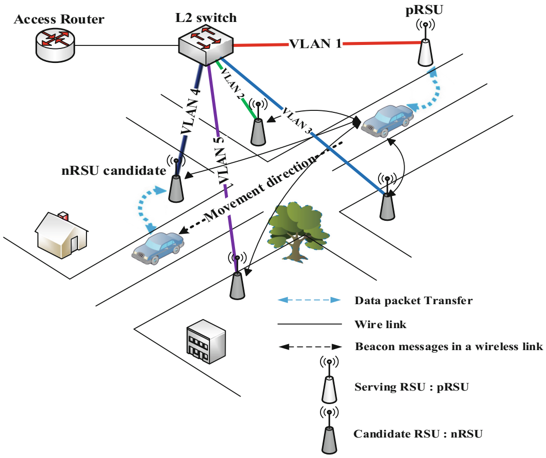


Fig. 2. Our system architecture

An RSU is an access point of the WAVE network for vehicles. It bridges the WAVE network with the Internet at the data link layer. An RSU has two interfaces: one for the WAVE networks and the other for the Internet.

An RSU has to monitor vehicles' safety beacon by tuning CCH. According to the CAMP (Crash Avoidance Metrics Partnership), almost all contain at least the position and the direction information of the vehicle [16]. The RSU can know a vehicle's position and direction passively. The RSU stores these information into its RCT (RSU Cache Table). Each entry of the RCT contains the MAC address, the latest receiving time and the position information.

To support a network based seamless handover, the RSU has to notify the AR about vehicle's movements but only the significant movements. To categorize the significance of a vehicle's movement, the RSU divides its coverage area into two zones. One is the normal zone and the other is the handover zone. The normal zone is defined within 370 m from the RSU. It is because the reliable communication range of VANETs without any obstructions is to be under 370 m [17]. The handover zone is the outside of the normal zone. An RSU processes all incoming safety beacons with its RCT, and sends a control message to the AR only for three cases. Firstly, it sends an AI (Attachment Indication) if a vehicle's information does not exist in the RCT and the vehicle is moving toward the RSU. Secondly, the RSU sends an HP (Handover Prepare) if the vehicle reaches the handover zone and it is moving away from the RSU. Finally it sends a DI (Detachment Indication), provided that no beacon is arrived from the vehicle for the predefined time or the RSU fails to deliver three consecutive frames to the vehicle. The serving RSU forwards packets to the vehicle even if the vehicle is in the handover zone as the comminution link between them is still alive. However, the communication link may down any time in the handover area. The RSU and the AR interacts to buffer undelivered packets exactly. The RSU knows a packet

Vehicle MAC	Rx. time	Position
MAC_A	10:15:38:19	30, 33
MAC_B	10:15:38:28	33, 33

(a) RSU Cache Table

Vehicle MAC	Serving RSU MAC	VLAN ID	Position
MAC_A	RSU_A	1	30, 33
MAC_B	RSU_B	2	33, 33

(b) AR Binding Table

Fig. 3. Data structure in network elements

delivery status using IEEE 802.11 ARQ mechanism, and it notifies it to the AR using an ARQ message.

According to the 802.11 MAC operations [18], the RSU does not process the MAC frame which has AR's MAC address in the address 1 field. To add bridging function in the RSU, it needs to process at least two MAC addresses in the address 1 field. First one is its MAC address, and second one is AR's MAC address.

An AR is a default router of the Internet for the WAVE network connecting several RSUs using L2 switches.

The AR makes the handover decision based on the control messages sent from RSUs and maintains an ABT (AR Binding Table) to store handover information in the control messages. Each entry of the ABT contains the vehicle MAC address, the RSU MAC address, VLAN ID (VID) and the position information. Figure 3(b) shows an example of the ABT.

By receiving AIs, the AR knows appearance of new vehicle or the entrance of a vehicle to a new coverage area of RSU. If the AR receives the AI and a vehicle is not registered in the ABT, it recognizes the vehicle as new one. It creates new entry for the vehicle and chooses the sending RSU as the serving RSU. If an AI is arrived for the vehicle which has its entry in the ABT or the AR has buffered packets for the vehicle in its buffer, it chooses the sending RSU as a new RSU. It updates its entry in the ABT and starts to send the buffered packets to the vehicle via the new RSU.

When the vehicle reaches the handover zone of the serving RSU, the AR detects this event by the HP. The AR starts packet buffering to prepare the handover, but it still forwards packets to the vehicle via the previous RSU (pRSU) until new RSU is selected or the pRSU cannot reach the vehicle anymore. The AR and the pRSU interact to track the exactly undelivered packet. The pRSU sends an ARQ-NACK for each unsuccessful delivery with a part of undelivered packet to the AR. The AR tries to match the packet in its buffer until it finds the matched packet, and removes the packet from the front of the buffer to the matched one. It mitigates redundant packet buffering. The pRSU may send the ARQ-ACK for each delivered packet to reduce the number of buffered packets. The AR does not retransmit the undelivered packet as recovering lost packet is not the role of the AR.

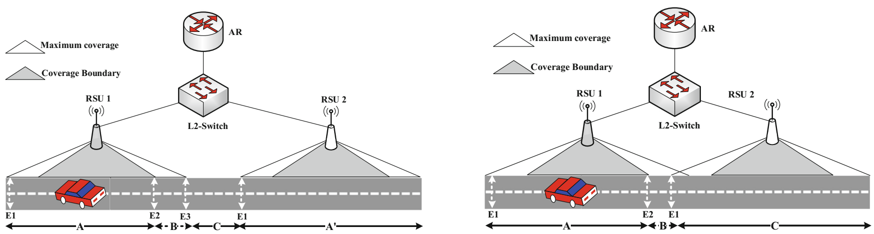
If the AR receives the DI, it stops packet forwarding and keeps buffering until it receives the AI from another RSU or the predefined timer expires.

3.2 Control Messages

For interaction between the AR and RSUs, new control message is defined. It uses the Ethernet frame with a new Ethertype. The message uses TLV (Type-Length-Value) format. The Type field defines the control message type. The first bit of the type field represent whether the message is for vehicle tracking or the ARQ. The Length field indicates the length of the following data. The first element of the data field is the vehicle MAC address. Vehicle tracking message contains additional position information. The ARQ message optionally contains the first 46 bytes of the original packet. The 46 bytes are chosen to include the Ethernet MAC header, the IP header and the TCP (UDP) header. As the Ethernet packet has to have at least 64 bytes, adding the part of original packet doesn't matter.

3.3 Handover Procedure

A handover occurs between two RSUs. The coverage areas of two RSU may be disjointed or overlapped. Figure 4(a) and (b) show two cases respectively. The handover procedure is almost same in the both cases, but the only difference is that the detachment event is occurred in the former case. The overall handover procedure is described in Fig. 5.



(a) Disjointed coverage (b) Overlapped coverage

Fig. 4. RSU deployment

Event 1: Detecting new vehicle (Section A): A RSU 1 detects an entrance of a vehicle from the vehicle's safety beacon. It generates an entry of the RCT and sends an AI to the AR. The AR creates new entry for the vehicle and chooses the sending RSU as the serving RSU. The vehicle starts a communication with a peer in the Internet. The AR relays data packets between them via RSU 1.

Event 2: Entering the handover zone in the RSU 1 (Section B): Whenever the RSU 1 receives the safety beacon from the vehicle, it checks the vehicle's current position to know whether the vehicle is located in its handover zone. If so, it sends the HP to the AR to inform that the handover may be happen soon. The AR starts packet buffering. It still forwards data packets via the RSU 1 to the vehicle. The AR and the RSU 1 start to interact with an ARQ mechanism. Whenever a packet is not delivered to the vehicle, the RSU 1 sends the NACK.

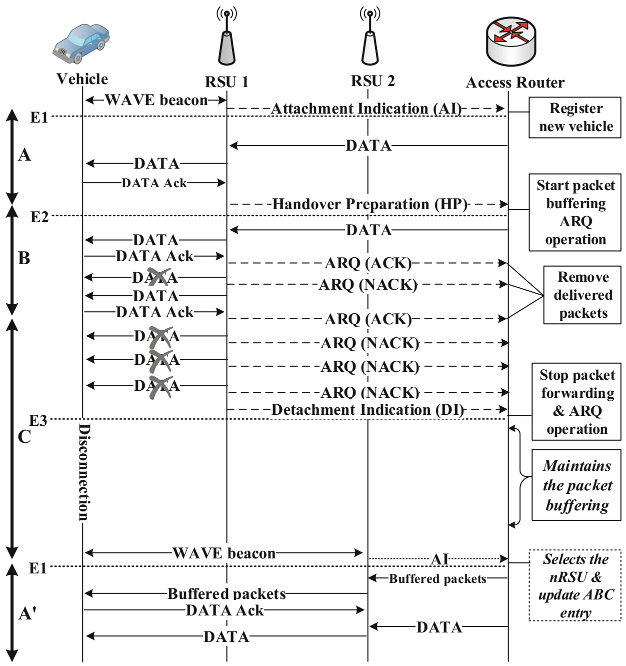


Fig. 5. Handover procedure

The AR eliminates packets from the it buffer. The RSU 1 optionally send the ACK for successfully delivered packet.

Event 3: Disconnection (Section C. The disjoint coverage case only): As the vehicle moves out of the scope of the RSU 1, the RSU 1 cannot receive the safety beacon anymore from the vehicle and/or fails to deliver packets to the vehicle consecutively. The RSU 1 sends the DI to the AR. The AR stops packet forwarding, but maintains buffering until it receives the AI from another RSU or the predefined timer expires. The disconnection occurs when the coverage areas of two RSU are disjoint.

Event 1: Entering coverage of RSU 2 (Section A'): The RSU 2 detects the vehicle from the safety beacon. As the vehicle is moving into the RSU 2's area, the RSU 2 creates a new RCT entry and sends the AI. The AR has an matching entry in the ABT and it knows that the vehicle moves to the RSU 2. The AR updates the RSU MAC address and the VID field. The AR forwards buffered packets to the vehicle via the RSU 2.

4 Simulation

To simulate the proposed scheme, ns-3 network simulator (version 3.23) and its WAVE model library are used. The network topology for the simulation is shown in Fig. 6.

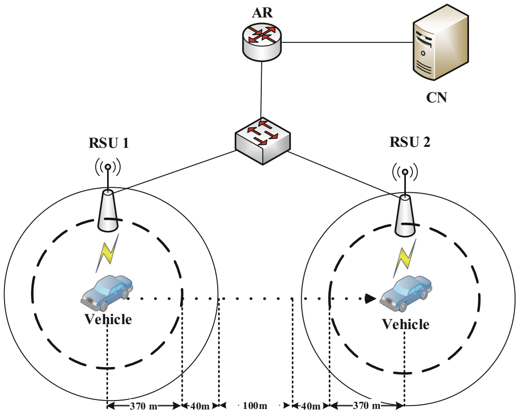
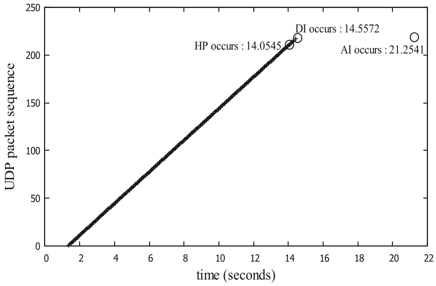


Fig. 6. Simulation topology

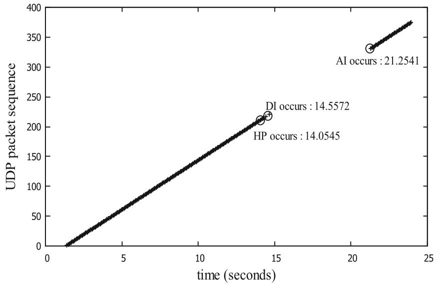
The vehicle has a WAVE interface and moves from RSU 1 to RSU 2 with the constant velocity (25 m/s). It communicates with the CN via the AR. The vehicle broadcasts a basic safety message per 100 ms. The RSU 1 and the RSU 2 broadcast a WSA with WRA per 100 ms. The RSUs stand 760 m apart for overlapped coverage case, and 880 m apart for the disjoint coverage case. The maximum coverage of each RSU is set for 410 m. The L2 switch connects RSUs with the AR via an Ethernet. The CN is connected to the AR. All wired link speeds are 100 Mbps. The link delay between the CN and the AR is 60 ms and all other link delays are 10 ms. The wireless link speeds are 6 Mbps. A 500 Kbps CBR traffic flows from the CN to the vehicle and the UDP is used to carry the traffic.

Simulations are performed under the four different scenarios. The RSUs sends control messages to the AR in all scenarios. In Scenario 1 (S1), simulation is performed without VLAN configuration and buffering scheme. In Scenario 2 (S2), simulation is performed only with the VLAN configuration. In Scenario 3 (S3) and Scenario 4 (S4) simulations are performed with buffering scheme and VLAN configuration. The S3 is performed under disjoint coverage, whereas S4 is performed under overlap coverage.

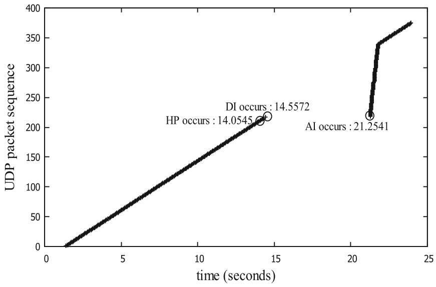
Figure 7 shows the received packet sequences at the vehicle. Before the handover occurs, all packets are successfully delivered to the vehicle. The S1 simulation result in Fig. 7(a) shows the need of the VLAN configuration. Even if the AR knows the vehicle is in the RSU 2, the vehicle cannot receive packets after the handover occurs. As the frame carrying an UDP packet does not contain RSU 2 MAC address, the L2-switch with the self-learning mechanism forwards the frame to the RSU 1 until the vehicle at RSU 2 generates any up-link packet to the AR. The S2 simulation result in Fig. 7(b) presents some packet loss due to the absence of buffering at the AR. The S3 and S4 simulation results show the effectiveness of packet buffering at the AR. In Fig. 7(c), all buffered packets are delivered to the vehicle rapidly after the RSU 2 detects the vehicle. The S4



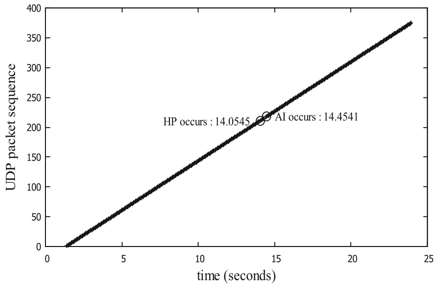
(a) The packet sequence in S1



(b) The packet sequence in S2



(c) The packet sequence in S3



(d) The packet sequence in S4

Fig. 7. The receive packet sequences in the vehicle

simulation result presented in Fig. 7(d) shows the consecutive packet delivery even if the handover occurs. The WAVE interface does not require the association procedure and the coverage of two RSUs are overlapped. Therefore, two connections, one for each RSU, are available during the handover period. It is the same as that of the soft handover. The vehicle can receive packets continuously.

5 Conclusion

We proposed an L2 extension mechanism with a network-based seamless handover scheme in VANETs. It reduces the L3 handover frequency by deploying several RSUs under an AR. In the proposed scheme, the RSU tracks the vehicle's movement using its safety beacon passively and it notifies the vehicle's significant movement events to the AR. The AR uses such notifications to start buffering for seamless packet delivery and to make handover decision. Simulation results show effectiveness of the proposed scheme. However, the proposed scheme only deals with the L2 handover. Eventually it needs some L3 handover schemes when a vehicle moves away from the AR's coverage.

As future work, we plan to adapt the existing L3 handover schemes incorporating the proposed L2 extension mechanism. PMIPv6 and LISP are good candidates of the VANETs-wide mobility management protocol. PMIPv6 is a network-based local mobility management protocol and it can be used a local mobility management protocol for the LISP which can handle inter-domain mobility.

References

1. Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment: Wireless Access in Vehicular Environments. IEEE Std, P802.11p (2010)
2. IEEE IEEE Guide for Wireless Access in Vehicular Environments (WAVE) - Architecture. IEEE Std, 1609.0-2013 (2014)
3. IEEE Standard for Wireless Access in Vehicular Environments (WAVE) Networking Services. IEEE Std, 1609.3-2010 (2010)
4. IEEE Standard for Wireless Access in Vehicular Environments (WAVE) Multichannel Operation. IEEE Std, 1609.4-2010 (2011)
5. Gerla, M., Kleinrock, L.: Vehicular networks and the future of the mobile internet. Comput. Netw. **55**, 457–469 (2011)
6. Park, J.T., Chun, S.M.: Fast mobility management for delay-sensitive applications in vehicular networks. Commun. Lett. IEEE **15**(1), 1689–1701 (2012)
7. Thomson, S., Narten, T.: IPv6 stateless address autoconguration. In: IETF RFC 2462 (1998)
8. Nordmark, E., Gashinsky, I.: Neighbor unreachability detection is too impatient. In: IETF, RFC 7048 (2014)
9. CAMP Vehicle Safety Communication Consortium: Vehicle safety communications project task 3 final report - identify intelligent vehicle safety applications enabled by DSRC. In: DOT HS, pp. 809–859 (2005)
10. Narten, T., Nordmark, E., Simpson, W., Soliman, H.: Neighbor discovery for IP version 6 (IPv6). In: IETF, RFC4861 (DraftStandard) (2007)
11. Chung, Y.-U., et al.: Proactive caching and forwarding schemes for seamless handover in IEEE WAVE networks. Int. J. Distrib. Sens. Netw. **9**, 627–691 (2013)
12. Chung, J.M., et al.: Time coordinated V2I communications and handover for WAVE networks. IEEE J. Sel. Areas Commun. **29**, 545–558 (2011)
13. Cespedes, S., et al.: VIP-WAVE: On the feasibility of IP communications in 802.11p vehicular networks. Intell. Transp. Syst. **14**, 82–97 (2013)
14. Cho, W., et al.: Implementation of handover under multi-channel operation in IEEE 802.11p based communication system. In: ICT Convergence (2011)
15. IEEE Trial-Use Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services. IEEE Std, 1609.3-2007 (2007)
16. Lee, J.-M., et al.: Performance analysis of WAVE control channels for public safety services in VANETs. Int. J. Comput. Commun. Eng. **2**, 563–570 (2013)
17. Meireles, R., et al.: Experimental study on the impact of vehicular obstructions in VANETs. In: Vehicular Networking Conference (VNC), pp. 338–345 (2010)
18. Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications. IEEE Std, 802.11-2012 (2012)