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A Proxy MIPv6 Handover Scheme for Vehicular Ad-hoc Networks

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Abstract With the rapid growth in the number of mobile devices, such as cellular phones, PDAs and laptops, the need for seamless and ubiquitous Internet connectivity is tangible. Vehicular ad-hoc network (VANET) is a rapidly developing technology, which makes vehicle-to-vehicle and vehicle-to-infrastructure communication feasible. However, when a vehicle travels from one point of attachment to another, handoff delays and provision of seamless connectivity are considered as important issues. Ubiquitous and integrated Internet connectivity can be achieved if on road moving vehicles are connected. However, when vehicle density is small and/or vehicle velocities are different, end users may suffer from a high level of connection failure. IP mobility protocols are designed by Internet Engineering Task Force to provide acceptable levels of continuous Internet connectivity, maintaining mobile node communications as they travel amongst points of attachments. However, the current IP mobility approaches applied on VANET did not resolve the connection failure issues efficiently. Therefore, in this paper a new effective solution is proposed in order to eliminate the large amount of handover latency and eventually high packet loss ratio.

Keywords IP mobility in VANET · Proxy MIPv6 · Seamless connectivity · Ad hoc

1 Introduction

Thanks to the wireless communication technology advancements and improvements, mobile end-users may access the Internet ubiquitously. Many applications such as VoIP calls, weather forecasting and road traffic information can be more easily utilized as usage rate of wireless

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communication increases. Throughout the past decade, many research communities have been focusing on Mobile Ad-hoc Networks (MANET) in which nodes communicate with each other through one-hop or multi-hop communication without the need for network infrastructure [1]. Due to the dynamically and fast changing topology of VANET, applying MANET communication protocols in VANET is not advised. Unlike mobile nodes in MANET, communication devices attached on vehicles have plenty of power available, provided by the vehicle. Broadcasting messages [2] instead of unicasting and highly predictable movement [3] can be considered as other VANET specifications over MANETs. In VANET, vehicles are equipped with short or medium range wireless transceivers that enable vehicles to acquire information and services through vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) communications. V2V communication is based on dedicated short range communication (DSRC) technology, while V2I communication is based on WiMAX, WiFi or GPRS/3G.

VANET is designed to provide low-cost communication networks for vehicles. Infotainment applications are designed to be utilized in VANET such as emergency warnings, collision and car crash information, heavy traffic locations and alternative routes, VoIP calls, Video conferences and other entertainment applications. Real-time applications such as VoIP and video conferencing require seamless and continuous connectivity.

Considering VANET technology, when a vehicle is traveling from one point of attachment (PoA) to another, in order to maintain its Internet connectivity, it needs to perform a handoff procedure which includes acquiring a new channel address (layer 2 handoff) and a new IP address (layer 3 handoff). Due to the high velocity of vehicles in VANET and time consuming handoff procedures, seamless connectivity to the Internet is a difficult task to achieve.

IP mobility management strategies are proposed and designed to assign and reassign IP to the mobile node efficiently. Mobile Internet Protocol version 4 (MIPv4) [4], designed by the IETF, was proposed to provide such IP mobility, but due to its short IP range and high burden on network entities, Mobile Internet Protocol version 6 (MIPv6) [5] was instead proposed to alleviate the above-mentioned shortcomings of IPv4. However, due to the high handoff latency of the MIPv6 protocol, some other host-based mobile IP protocols were proposed by the IETF, such as Fast Handover for MIPv6 (FMIPv6) [6], Hierarchical MIPv6 (HMIPv6) [7] and Fast Handover for Hierarchical MIPv6 (FHMIPv6). In order to put all the burden of the handoff procedure onto network entities, such as access points (AP) and access routers (AR), some network-based protocols were proposed such as Proxy MIPv6 (PMIPv6) [8] and Network Mobility (NEMO) [9]. GPS (Global Positioning System) approaches are proposed to mitigate the total amount of handoff latency as well as reduction in resource consumption and bandwidth usage [10–13]. Although the aforementioned IP mobility protocols were designed to provide continuous Internet connection, VANET still encounters some challenging difficulties; the high velocity of vehicles results in performing handoff procedures more frequently and the handoff procedure itself is a time consuming procedure which may cause significant handoff latency that eventually lead to packet loss. Addressing in VANET could be achieved by applying a DHCP (stateful auto-configuration) mechanism which has been widely and extensively deployed in computer networks. However, Due to requiring too much time to complete the association process and consuming a significant amount of time to achieve seamless handoff, hence alleviating the acquiring IP address time still remains an important issue.

The rest of the paper is organized as follows; Sect. 2 explores the review of literatures related to merging the IP mobility protocols with VANETs and substantial steps required to complete handoff procedures in VANET while utilizing IP mobility protocol specifications such as IP acquisition procedure. Section 3 proposes the Early Binding update Registration in PMIPv6 (EBR-PMIPv6) applied on VANET. Performance evaluation of the proposed scheme is discussed in Sect. 4 and eventually Sect. 6 concludes the paper.

2 Related Work

Handoff delay involves two layers of handoff; (1) Layer 2 handoff procedures in which the vehicle (mobile node) spends time to scan the link in order to retrieve the received signal strength (RSS) disseminated by PoA. (2) Layer 3 handoff procedures in which either by stateful or stateless addresses auto-configuration, the vehicle acquires an IPv6 address. Layer 3 handoff procedures also takes a significant amount of time, which compels the IP mobility research communities to address issues brought up by layer 3 handoff procedure and consequently propose some mobility management schemes and strategies to resolve the most likely deficiencies occurred layer 3 handoff procedure [14–17].

Literature [14] has proposed a solution in which, by applying IP passing strategies from VANET, vehicles are able to reuse IP addresses assigned to other vehicles that are leaving the APs coverage area. In order to pass the IP address to a newly entered vehicle, the leaving vehicle deploys a Signal to Noise Ratio (SNR) value in order to detect its movement. When the SNR value exceeds the threshold, the leaving vehicle passes its IP to the newly entered vehicle. This procedure reduces the average latency of IP assignment procedure without AP modification. If the IP acquisition takes time longer than an anticipated value, the vehicle may acquire an IP address by sending a request message to the DHCP server [18]. Figure 1 indicates the message signaling sequence diagram in both scenarios. However, in this paper the comparison is made between our proposed scheme and the IP passing approach without the DHCP requesting feature being enabled, as we will see in the next section.

The negative effect of network fragmentation on handover latency is reduced by utilizing the scheme proposed in [19]. The proposed approach delays the release time of the IP addresses on DHCP server which infers the extension in IP lifetime. This could provide the opportunity for the vehicle to acquire new IP address in a faster way through multi-hop relays from other vehicles either on the same lane or the opposite one. Although the proposed approach outperforms the conventional IP passing approaches in terms of handover latency and packet loss rate, but the effect of prolonged binding update registration still makes a huge difference in comparison with EBR-PMIPv6. Furthermore, the packet loss rate worsens as the velocity and density of vehicle increase.

Vehicular address configuration (VAC) is another scheme proposed in vehicular networks [16], in which IP addresses are assigned to vehicles using a distributed DHCP service. In this approach a leader will be elected to take over the responsibility of running the DHCP service. Each node within range of the leader will be assigned an IP address. VAC contains two main steps; (1) building and maintaining the leader‘s chain, where in leaders are elected and changed when the mobility management makes it necessary; (2) to configure and maintain addresses that are possible to be assigned within the network.

Utilizing DHCP service as a centralized addressing scheme is an effective solution in dealing with current addressing issues in VANET [17]. Having vehicles equipped with two interfaces makes V2I and V2V communication simultaneously feasible. However this scheme requires a received packet management strategy to put packets in the right order to be interpreted accurately. In the proposed approach, the vehicle disseminates an address request message, which is termed as a DHCP DISCOVER message to the nearest Road Side Unit (RSU). Thereafter, the first RSU that receives the address request message acts as a relay and forwards the message to a centralized DHCP server. Upon receiving this message, the DHCP

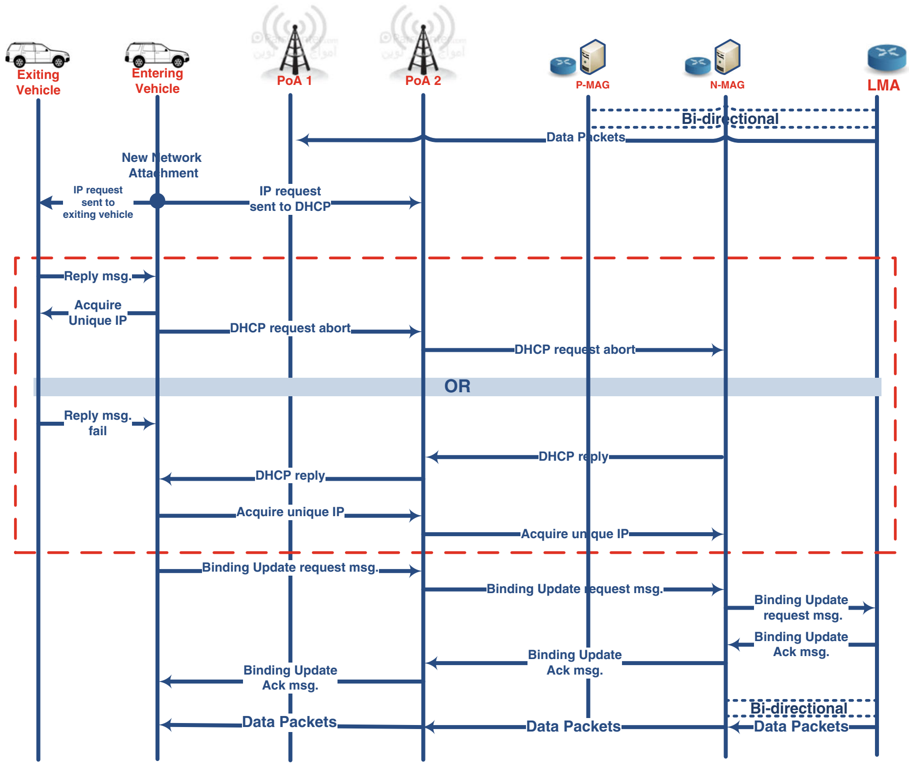


Fig. 1 IP passing with and without the DHCP request feature

sever responds with a DHCP OFFER message accompanied with an available IP address to vehicle that is relayed by AP.

Network mobility (NEMO) protocol has been proposed to be applied in VANET [20]. The proposed scheme includes two algorithms, (1) *NEMO scheme for the real bus* in which the bus is equipped with two mobile routers. One to perform the pre-handoff procedure and the other to maintain the MN‘s Internet connectivity; (2) *NEMO for virtual bus* in which the vehicle is equipped with a mobile router and has WiMAX and Wi-Fi interfaces. Two or more vehicle in the lane of the same and/or the opposite direction may be grouping as virtual bus. In the worst scenarios, if the vehicle density is low and grouping might not seem to be feasible, the vehicle could acquire an IP from the DHCP server. In addition to the above protocols mentioned, when a vehicle or a group of vehicles is about to leave the current associated PoA, the IP passing strategy may serve the newly entered vehicles either passing the IP to the vehicles moving at the same or in the opposite direction. IP address passing among vehicles results in improved handoff latency.

Global mobility management (GMM) is proposed to overcome inter-VANET handoff for vehicles [21]. In the network configuration of the proposed scheme MAC address, Permanent address, Care of Address (CoA) Identification of Local VANET (VID), IP address of local vehicle mobility manager (LVMM) and Identification of V2V Group (GID) are managed by an entity termed as global vehicle mobility manager (GVMM). Additionally, GVMM manages the binding information related to communication between vehicles and their correspondents. The proposed scheme tends to provide a fast handoff process utilizing L2 triggering and a route optimization mechanism for packet transmission.

The cross-layer design vehicle-aided handover scheme proposed in [22] provides a new communication framework for VANET formed by high speed vehicles. This newly developed wireless technique is termed WiMAX mobile multi-hop relay (MMR) makes some specific vehicles able to act as relay vehicles to provide Internet access for other vehicles. However, applying standard WiMAX MMR techniques to perform seamless handover procedures may result in huge numbers of packet loss due to the long delay caused by a lack of information about the next vehicles in the relay. In order to overcome the long delay, Vehicular Fast Handover Scheme (VFHS) is proposed, in which the physical information is shared with the MAC layer to reduce the handover delay. The proposed VFHS approach aims to utilize oncoming vehicles to gather and accumulate information of relay vehicles such as physical and MAC layer information and then to disseminate this information to other vehicles.

Many research communities have been utilizing mobility prediction features in order to be able to reduce the handover latency. A new mobility prediction scheme is proposed in [23], called Reliable Broadcast routing, which is based on Mobility Prediction (RB-MP). This scheme utilizes the position and relative velocity of the vehicle in order to Predict the Holding Time (PHT) and selects a reliable and efficient rebroadcasting node according to the PHT value of different vehicles. Results have shown that prediction can play a pivotal role in providing better performance in terms of having fast handover procedures.

A fast handover method was proposed in [24] based on the 802.11 networks for the PMIPv6. Context information, such as the mobile node's authentication information and HNP, is transferred using the Inter-AP Protocol (IAPP) scheme. It suggested adapting IAPP (Inter-AP Protocol) to reduce the "access authentication/obtaining MN's profile" time of the total handover delay. Nonetheless, the on-the-fly packets will still be lost during a handover.

The Social cluster-based structure and life-time aware flooding scheme and the connectivity-aware retrieval scheme are two major factors which enable vehicles to estimate similarity and connection conditions among vehicle peers to provide efficient resource discovery and retrieval in a social cluster-based P2P framework. The first scheme enables vehicles to discover resources through the Internet and VANET and the second scheme concentrates on lifetime and bandwidth allocation schedule, and determines the ways to retrieve resources from the existing available vehicle peers [25].

IP address acquisition is one of the major processes that may result in significant handover latency due to being a huge time consuming procedure. Authors in [26] present a new IP address assignment scheme in which a newly joined node could acquire an IP address by broadcasting a "hello message" to vehicles that were selected as coordinators. The coordinator chooses an available IP address from a pool of IP addresses, merges it with the reply "hello message" and sends it back to the requesting vehicle. Simulation results have shown a significant save in IP acquisition time.

Real-time applications such as video conferencing and VoIP are known as non-delay tolerant applications. There are some specific requirements needed for these applications to keep mobile end-users satisfied while using these applications and traveling among PoAs simultaneously, such as providing available bandwidth and elimination handover delay approaches. The agent-based context transfer approach proposed in [27] has improved handoff performance by 54.8 % compared to traditional client-server context transfer structure.

Fast Handover for PMIPv6 (PFMIPv6) is another effective scheme which is standardized by IETF to reduce the handover latency caused by PMIPv6. The performance of PFMIPv6 is elaborated in Sect. 3.

In this paper, a new scheme of handover procedure in PMIPv6 is proposed which can be applied on VANET with a much lower handover latency and, eventually, packet loss rate.

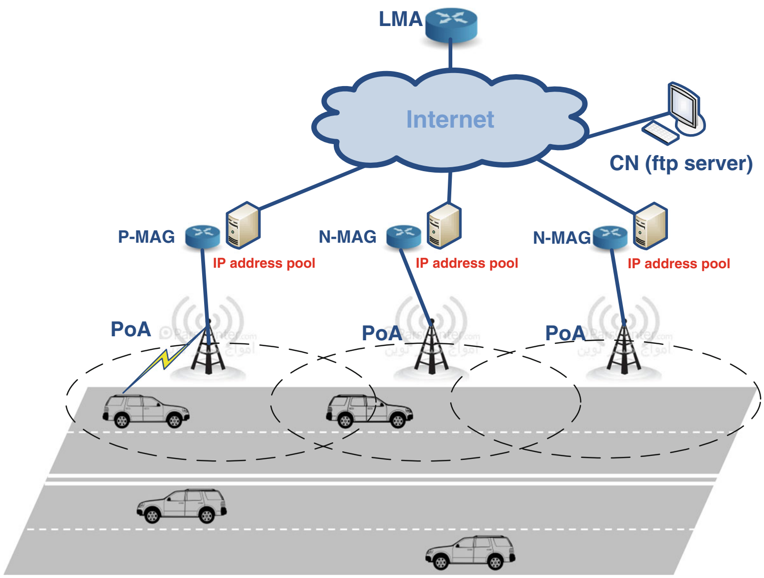


Fig. 2 PMIPv6 structure applied on VANET

As mentioned earlier, many researches are concentrated on IP mobility protocols such as MIPv6 and specifically its improved technologies; e.g. FMIPv6, HMIPv6, FH-MIPv6 and PMIPv6 [28–31]. As VANET structures become more and more popular in our societies, VANET mobility management becomes more and more important as well. Although the existing IP mobility protocols, IP passing schemes and mobility solutions may reduce the handoff latency, there is still a tangible need due to being incompletely compatible with VANET and suffering from high handover latency and packet loss issues.

3 System Architecture

The system architecture of our proposed approach is depicted in Fig. 2. Our proposed approach contains a fragmentation structure on the highway, with two lanes in each direction, equipped with PoAs such as WiMAX, 3G or 4G being distributed along the roadsides. The LMA maintains the vehicle‘s new location and the Correspondent Node (CN) acts as an FTP server. Unlike many other researches, vehicles in our proposed scheme are not equipped with multiple interfaces not being as cost effective and requiring some complex algorithms to sort packets in accurate orders. IP passing and virtual bus approaches are not utilized in our proposed scheme either, as they require a high level of vehicle density.

3.1 Fundamental PMIPv6 Handover Procedure

In wireless communication networks, multimedia streaming services are considered primary applications, as shown in IPTV applications. To provide seamless mobility as well as ubiquitous connectivity, we may consider MobileIPv6 (MIPv6), Fast Handover MIPv6 (FMIPv6) and Hierarchical MIPv6 (HMIPv6), as Host-based mobility protocols, whereas Network-based Localized Mobility Management (NETLMM) working group of IETF has been working on a Network-based mobility solution called Proxy- MIPv6 (PMIPv6). PMIPv6 provides

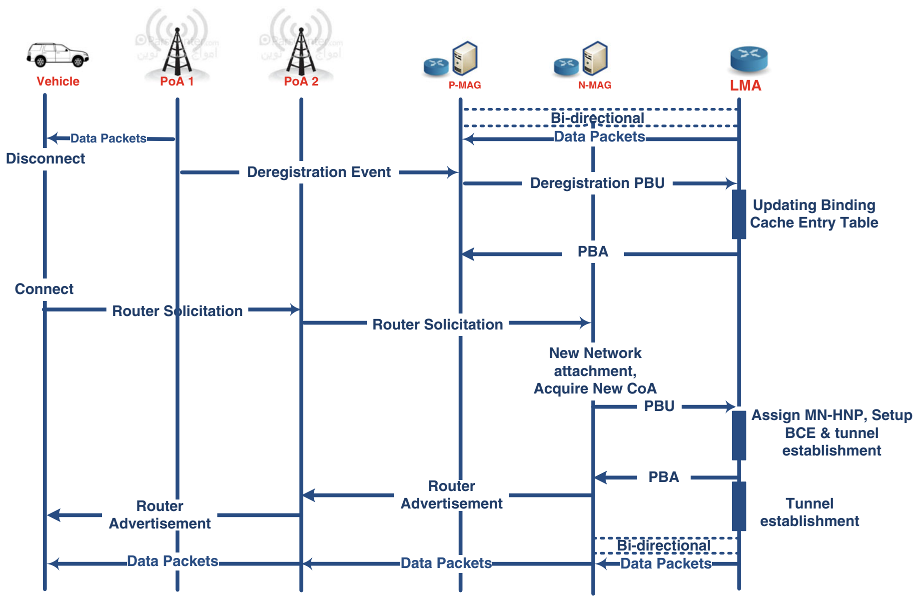


Fig. 3 Fundamental PMIPv6 handover procedure applied on VANET

the local mobility management to a mobile node without any modification in the same PMIPv6 domain. There are two new entities here called Mobile Access Gateway (MAG), which creates tunnels with Home Agent (HA) [32]. It does the mobility management signaling with HA on behalf of the MN attached to network. The other one is local mobility anchor (LMA), which maintains the reachability state of the MN in addition to being the anchor point for MN topologically in order to provide a home network prefix when the MN is not in home network. It is noted that PMIPv6 is used mainly for the binding update of the location of MNs. However, PMIPv6 was also developed for supporting seamless and robust IP handover. Although thePMIPv6 protocol reduces handover latency due to decreasing the number of message exchanged among network entities, but still handover latency and packet loss rates make the PMIPv6 protocol unable to be fully adopted by scientists to be merged with VANET.

Figure 3 describes the fundamental handover procedure in PMIPv6 network. By departing from the current network to the new one, vehicle is referred as MN changes its Point of Attachment (PoA) and consequently the MN will be compelled to acquire a new Care of Address (CoA). At the same time, the P-MAG that detected the MN‘s detachment, exchanges the proxy binding update (PBU) and its reply proxy binding acknowledgment (PBA) with the LMA in order to update the binding cache entry (BCE) table and remove the old binding state related to the MN. When the MN receives the specific Link-Up trigger broadcasted by the N-MAG, it sends a Router Solicitation message (RS) in order to start the association process and eventually to establish a new connection with N-MAG. Thereafter N-MAG sends the PBU message to LMA requesting to establish a new proxy mobile-IP tunnel between them. Upon receiving the PBU request sent by N-MAG, the LMA updates the binding table associated with the MN and inserts the new assigned MN‘s CoA and sends the PBA to N-MAG containing the Home Network Prefix (HNP) of the MN. At this time a bi-directional tunnel is established and the LMA is able to deliver data flows to MN through N-MAG. Upon receiving the HNP, the N-MAG replies to the Router Advertisement (RA) message containing the MN‘s HNP to the MN. It can be observed that during the time of disconnection a considerable amount of packet loss may occur due to the prolonged handover latency period. In order to overcome this handover latency, several schemes and approaches have been proposed. In [33] the handover procedure is performed by having the data flow bicasting from the LMA to both P-MAG and N-MAG which is not only a waste of resources, but also still suffers a considerable amount of packet loss. Partial bicasting [34] is another proposed scheme in which the N- MAG deploys a buffering mechanism to buffer the data flow sent by the LMA whilst the MN is disconnected from P-MAG and is not yet connected to N-MAG. Clearly the proposed scheme requires huge amount of resources in order to buffer the data packets related to thousands of MNs (vehicles) that change their PoAs frequently, when the number of MN is being increased every day.

3.2 Fast Handover for Proxy Mobile IPv6 (PFMIPv6)

During the handover procedure, mobile nodes may encounter packet losses due to link switching delay and prolonged handover latency caused by PMIPv6 procedure. Therefore, in order to alleviate the handover latency and packet loss, fast handover scheme for PMIPv6 is standardized by IETF. In PFMIPv6, the Handover Initiation (HO-ini) process will be started before the execution of handover procedure by MN in order to forward data from P-MAG to N-MAG. The HO-ini procedure will be triggered if the Received Signal Strength captured by MN degrades from the pre-defined threshold value. Thereafter, MN proceeds to scan the neighboring networks searching for a PoA from which the MN received the strongest signal. A layer 2 report message will be send to the currently associated PoA which contains MN‘s ID and the neighboring selected PoA. Upon reception of this message by current PoA, the serving MAG (P-MAG) will be informed of MN‘s handover to N-MAG. Thus, a bi-directional tunnel will be established between P-MAG and N-MAG through sending the handover initiation message. The set flags included in this message, impel N-MAG to buffer the received packets. The procedure is depicted in Fig. 4.

Upon receiving the handover initiation message at N-MAG, a Handover Acknowledge (Hack) message will be replied to P-MAG indicating the readiness of receiving data packets. The forwarded buffered the data packets through bi-directional IP-in-IP tunnel, will be delivered to MN after the association procedure is completed. The last step is the exchanging the PBU and PBA with LMA accordingly. The mentioned procedure is called Predictive PFMIPv6.

Furthermore, an MN is also capable of performing the handover procedure and moving to N-MAG coverage area, before sending the report message to currently associated PoA. This procedure is called Reactive PFMIPv6. In this case, N-MAG sends the HO-ini message containing the Context Request option to the P-MAG. By the time that MN has moved to new link, the MN‘s context information can be obtained by N-MAG in order to establish the bi-directional tunnel with P-MAG. After sending the handover initiation message by N-MAG and receiving the corresponding Hack from P-MAG, data packets will be forwarded and buffered to N-MAG. Please note that predictive PFMIPv6 in considered in this study.

3.3 Early Binding Update Registration in PMIPv6 (EBR-PMIPv6)

In our proposed scheme (EBR-PMIPv6), vehicles are equipped with a GPS device to send their current coordinates to PoAs. This helps the PoAs to detect whether the vehicle is about to leave the coverage area by comparing the vehicle‘s current position with a preconfigured

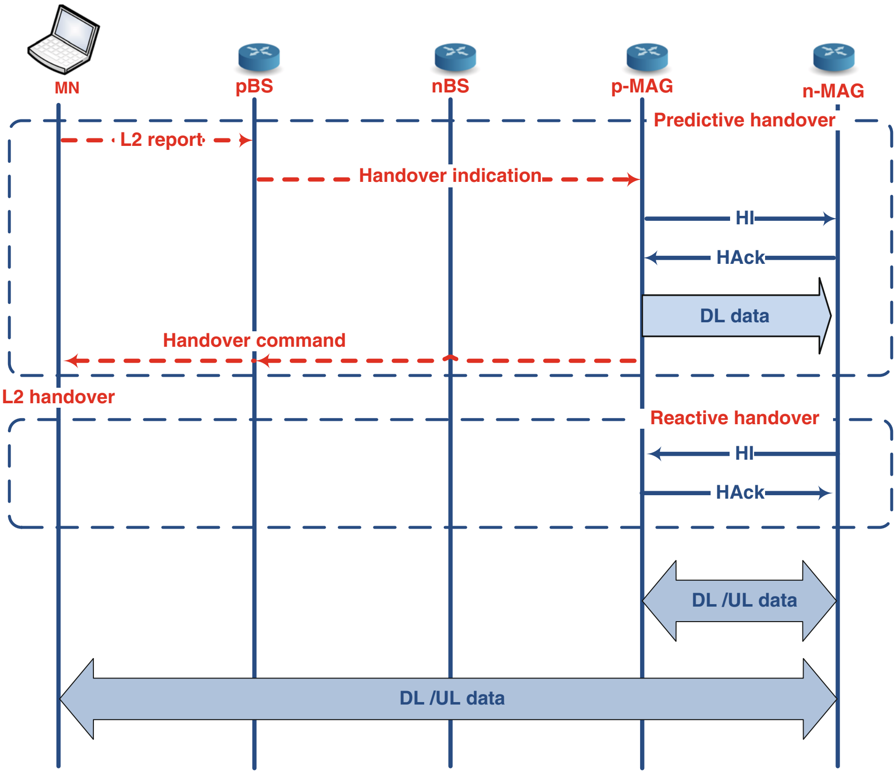


Fig. 4 PFMIPv6 handover procedure

threshold. The threshold value varies based on each vehicle's velocity. As the velocity of the vehicle increases the threshold value will be set to a lower value [13]. By utilizing the GPS coordinate information sent to PoAs, the direction of movement can be measured as well, thus the PoA is able to determine the next PoA. The currently associated PoA sends the information request (IR) message to its associated P-MAG which contains information regarding the next PoA of the vehicle, and the vehicle's Home Address (HoA). In our proposed scheme, MAGs maintain specific information about their neighboring MAGs in a predefined table, and maintain a pool IP addresses in a specific range, which is administratively assigned to each MAG. This event helps the MAG to send the IR message directly to the exact N-MAG and, upon receiving the IR message, the N-MAG selects an available IP address from the pool of IP addresses then sending an IR Acknowledgement (IRA) message containing a new CoA for the vehicle back to the N-MAG and sends a request for an update of the binding cache entry (RBCE) message to the LMA at the same time. Upon receiving the RBCE message from the LMA, it updates the binding cache entry (BCE) table, replying with the proxy binding acknowledgement (PBA), which contains the home network prefix (HNP) of the vehicle, to the N-MAG and starts to establish a bi-directional tunnel with the N-MAG. Meanwhile; the IRA message is delivered to the vehicle through the currently associated PoA. Therefore the required information to perform the handover procedure could be preconfigured by the vehicle while still connecting to the current associated PoA. Figure 5 demonstrates the sequence of message signaling during the handover procedure in the EBR-PMIPv6 approach. In the EBR-PMIPv6 scheme, each vehicle is able to perform handover

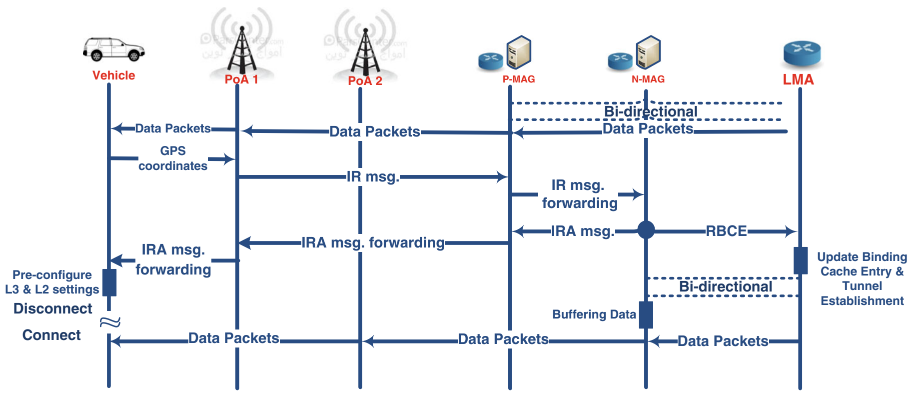
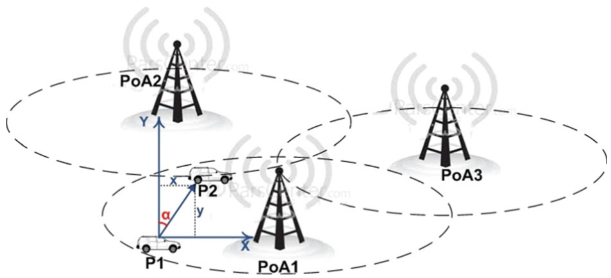


Fig. 5 EBR-PMIPv6 handover procedure applied on VANET

Fig. 6 Movement direction calculation



procedures individually without the aid or presence of other vehicles. Registration signaling messages are less than the traditional standard PMIPv6 applied on VANET. Multiple network interfaces and a high vehicular density are not required. Neither the virtual bus approach nor the IP passing technique is necessary.

EBR-PMIPv6 contains 3 stages; (1) Handover Detection based on Exceeding Threshold, (2) Connection Establishment between N-MAG and LMA, (3) Connection Establishment between MN and N-MAG.

Stage 1: This phase starts with movement detection performed by PoA based on the GPS coordinates of a vehicle's position. In our simulated scenario it is assumed that the vehicle is moving in linear motion with constant velocity. This assumption helps to calculate the exact distance moved by MN as well as direction of movement without applying complicated and heavy mathematical calculations. The following equation is applied to calculate the exact distance moved by MN at any specific time:

$$D = VT \tag{1}$$

$$\alpha = \arcsin\left(|x|/(x^2 + y^2)^{1/2}\right) \tag{2}$$

where parameter D is the total amount of distance moved by MN since movement starts, T represents time and V represents the velocity of the MN. Figure 6 illustrates the calculation of movement direction.

Where P1 and P2 are the very last coordinates retrieved by the PoA, applying equations (1) and (2), the exact N-MAG can be determined.

Stage 2: At this point the MN is located in a handover zone, or Ping-Pong area, which may result in having a Ping-Pong effect. The direction movement calculation mechanism described in phase 1 prevents the Ping-Pong effect, as the MN determines the exact N-MAG. Stage 2 starts by sending an IR message from PoA to its associated P-MAG. The IR message contains information regarding the next PoA into which the vehicle is moving, as well as the vehicle‘s Home Address (HoA). It is noted that, MAGs maintain information about their MAGs as well as a pool of IP addresses which are administratively set for each MAG individually. This event helps the MAG to send the IR message directly to the exact N-MAG and upon receiving the IR message; the N-MAG selects an available IP address from the pool of IP addresses, then sends an IR Acknowledgement (IRA) message which contains a new CoA for the vehicle back to N-MAG and send Request to update the Binding Cache Entry (RBCE) message to the LMA at the same time.

Stage 3: Upon receiving the RBCE message from the LMA, it updates the binding cache entry (BCE) table, replies with a proxy binding acknowledgement (PBA) which contains the home network prefix (HNP) of the vehicle to the N-MAG and starts to establish a bi-directional tunnel with the N-MAG. Meanwhile the IRA message is delivered to the vehicle through the currently associated PoA. Therefore the required information to perform the handover procedure could be preconfigured by the vehicle while still connecting to the current associated PoA. Thereafter, the vehicle starts to establish a connection with the N-MAG as soon as it receives the router advertisement (RA) broadcasted by the N-MAG within its coverage area. At this point the vehicle is located inside the Ping-Pong area and is getting ready to perform the L3 and L2 handover procedures using preconfigured settings. The L3 handover procedure takes a very negligible amount of time due to its utilization of preconfigured settings. Therefore the only time consumed by the vehicle in order to finalize the handover procedure is the time taken to perform the L2 handover procedure by switching the link and connecting to the new PoA. Eventually, after the authentication process, the N-MAG forwards the buffered data flows to the vehicle.

4 Performance Evaluation

This section reveals the performance analysis of the handover procedure performed by EBR-PMIPv6, standard PMIPv6 and IP passing approach [14]. IP passing protocol is selected due to its better performance in terms of IP acquisition time in comparison with other approaches. In order to simulate the aforementioned schemes, NS-2 networks simulation framework and Mobility model generator for Vehicular Network (MOVE) are utilized in order to simulate the movement of vehicles [35]. Figure 7 indicates the PMIPv6 domain including P-MAG, N-MAG, LMA, CN, PoAs and vehicle. In this scenario, the vehicle starts its movement from P-MAG destined to N-MAG while trying to keep its connection with CN. Referring to literature [34], The wired link between LMA and CN is configured to have 100 Mbps of bandwidth and 50 ms of link delay while the connection between LMA and MAGs are set to 100 Mbps of bandwidth and a transmission delay of 10 ms. The amount of bandwidth dedicated to the wireless connection is set to 11 Mbps in addition to 10 ms link delay. The link switching latency is configured to 100 ms, which is the default setting. Table 1 indicates the other parameters and settings of our simulated scenario. In order to achieve the accurate results, 50 simulation run is performed for each “IP aqcuisition time”, “handoff latency” and “packet loss ratio”. The values indicated in diagrams are the average values of 50 rounds of simulation run for each and every above-mentioned parameters.

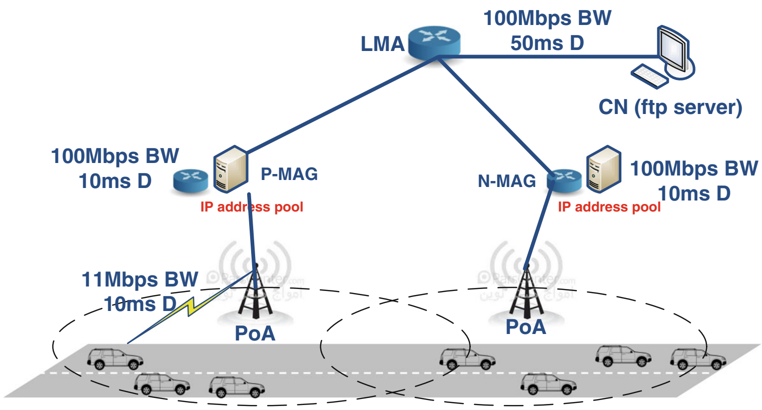


Fig. 7 Implemented scenario

Table 1 Simulation parameters

Parameters	Values
Network size	1 km × 6 km
Wireless transmission range	1 km
Number of vehicles	5–100
Length of IP passing (hops)	1–20
Packet size	320 byte
DAD	On
MAC protocol	802.11 b
Transmission power	5 dBm
Simulation time	300 s

The IP acquisition time is one of the functions that consumes a lot of time during the handover procedure. Therefore, a comparison is made based on the IP acquisition time occurring in the aforementioned protocol and schemes. In PMIPv6, the IP acquisition time is defined as the time of movement detection, request for new CoA, performing DAD process and eventually assigning the new CoA (IP address) to vehicle. The same measurement is also considered for PFMIPv6. While in the IP passing approach is defined as the interval from the time when the newly entered vehicle disseminates the IP address request, receives the IP address from the exiting vehicle, IP address registration with the LMA and eventually the vehicle IP address assignment. Figure 8a, b reveal the impact of vehicle speed and vehicle density on IP acquisition time, respectively. As the speed increases, the IP acquisition time increases as well due to tolerance of a shorter handoff delay.

In the IP passing approach, higher vehicle densities require higher contentions and collisions. While in standard PMIPv6, the large number of messages exchange and time consumed in binding the update registration causes the MIPv6 diagram to have an upward trend. Although PFMIPv6 represents the better performance amongst the above-mentioned schemes, EBR-PMIPv6 performs the best on the IP acquisition process due to the utilization of an IP address pooling strategy, with which the vehicle has the opportunity to have the final version of an IP address without performing DAD procedure. Additionally, having message exchange alleviated while performing the binding update registration results in better performance in terms of IP acquisition time.

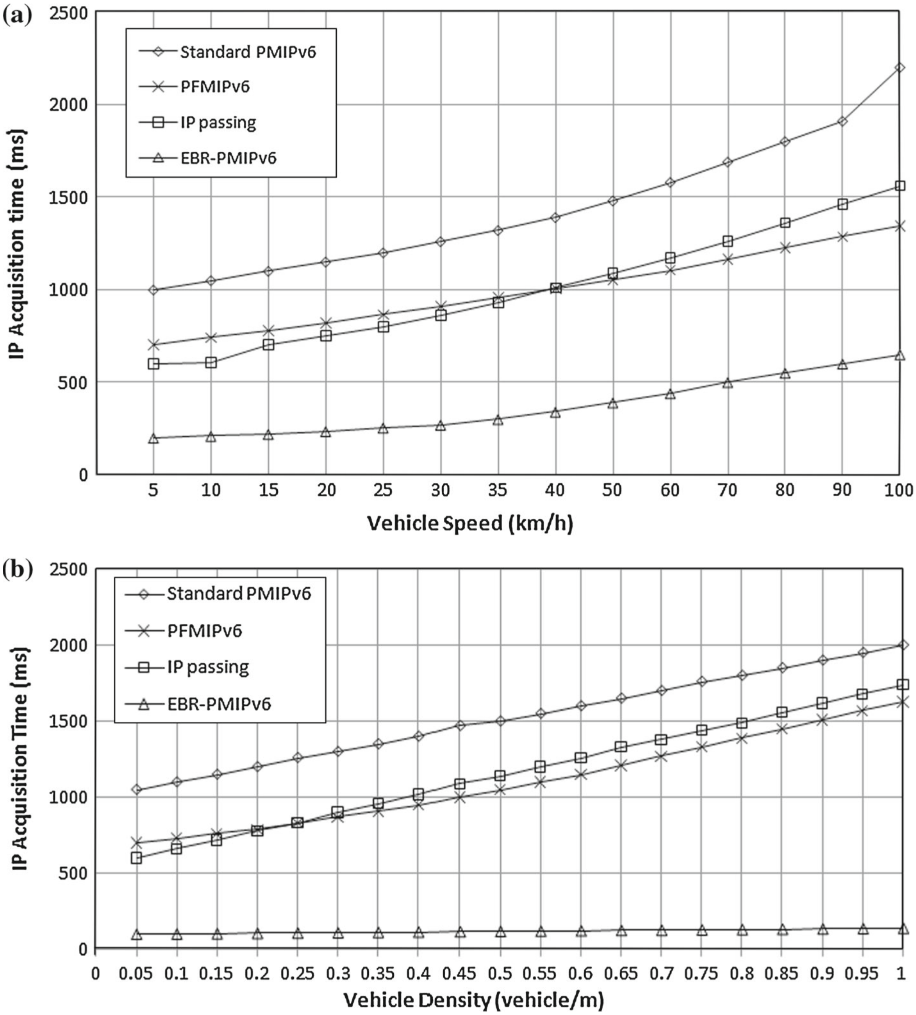


Fig. 8 **a** IP acquisition time as the speed increases. **b** IP acquisition time as the vehicle density varies

Figure 9a, b illustrate the impact of vehicle speed and vehicle density on the handoff latency in the mentioned protocol and schemes, respectively. The handoff latency is defined as the interval from the time when the last packet is received from the P-MAG to the time when the first packet is received from the N-MAG. As the vehicle speed and vehicle density increase, the handoff latency increases. Considering the IP passing approach, moving with high velocity eliminates the chance of the IP address passing at the proper time. In standard PMIPv6, the binding update registration and DAD processes are the most time consuming processes, requiring a considerable amount of time to be performed completely. Therefore, as the velocity increases and the amount of time required to completely perform those aforementioned time consuming processes remains constant, the handoff latency increases. PFMIPv6 scheme depicts the upward trend as the velocity and density of the vehicles increase. This is mainly due to prolonged DAD and binding update registration time. However, in EBR-PMIPv6, due to the omission of the DAD procedure and having less binding update registration signaling,

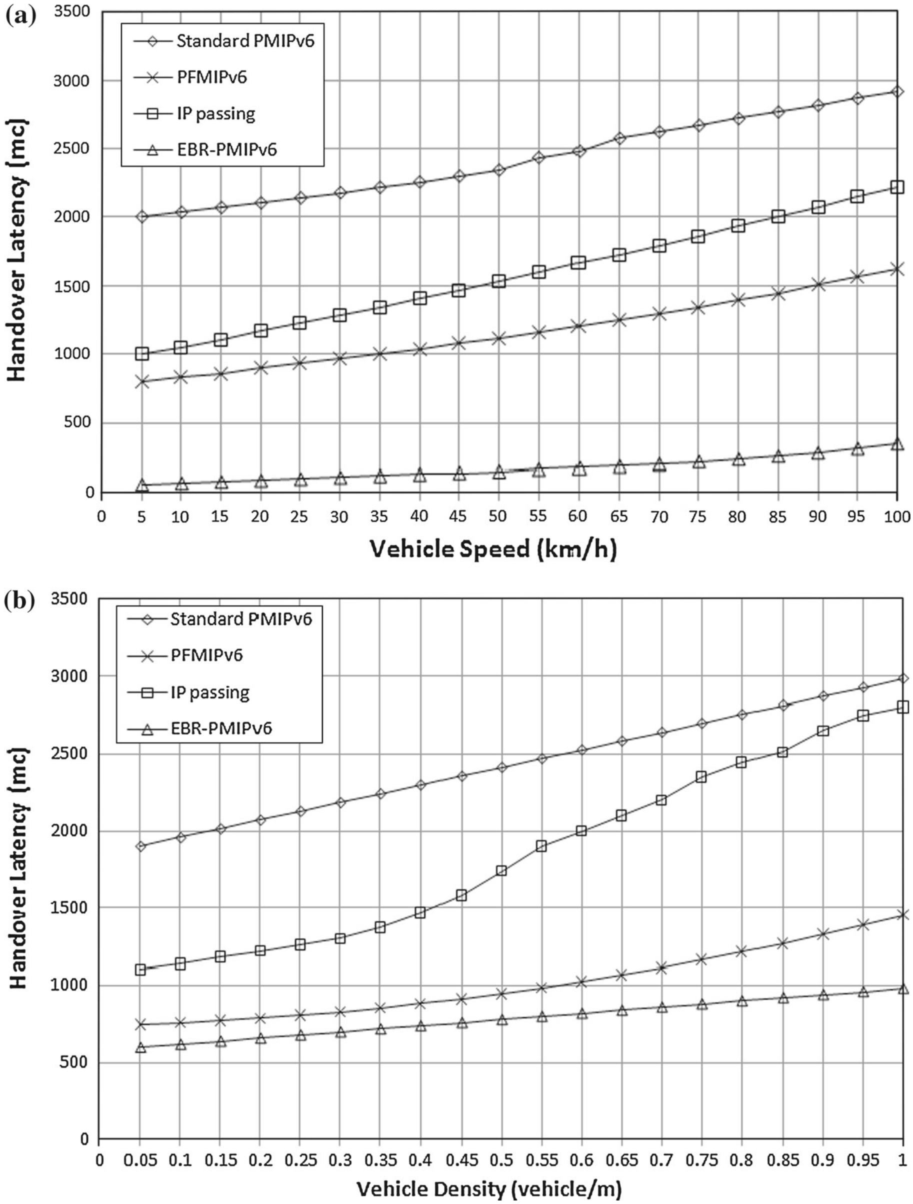


Fig. 9 **a** Handoff latency as the vehicle speed increases. **b** Handoff latency as the vehicle density varies

a significant disparity can be observed in comparison with the other two approaches. Higher vehicle density leads to enqueueing of more requests, processing each request in its specific time order takes a considerable amount of time, which consequently results in experiencing higher handoff latency.

Since packet loss rate and handoff latency follow the same trends; as a vehicle's velocity increases, handoff latency increases and, consequently, packet loss rate increases. However,

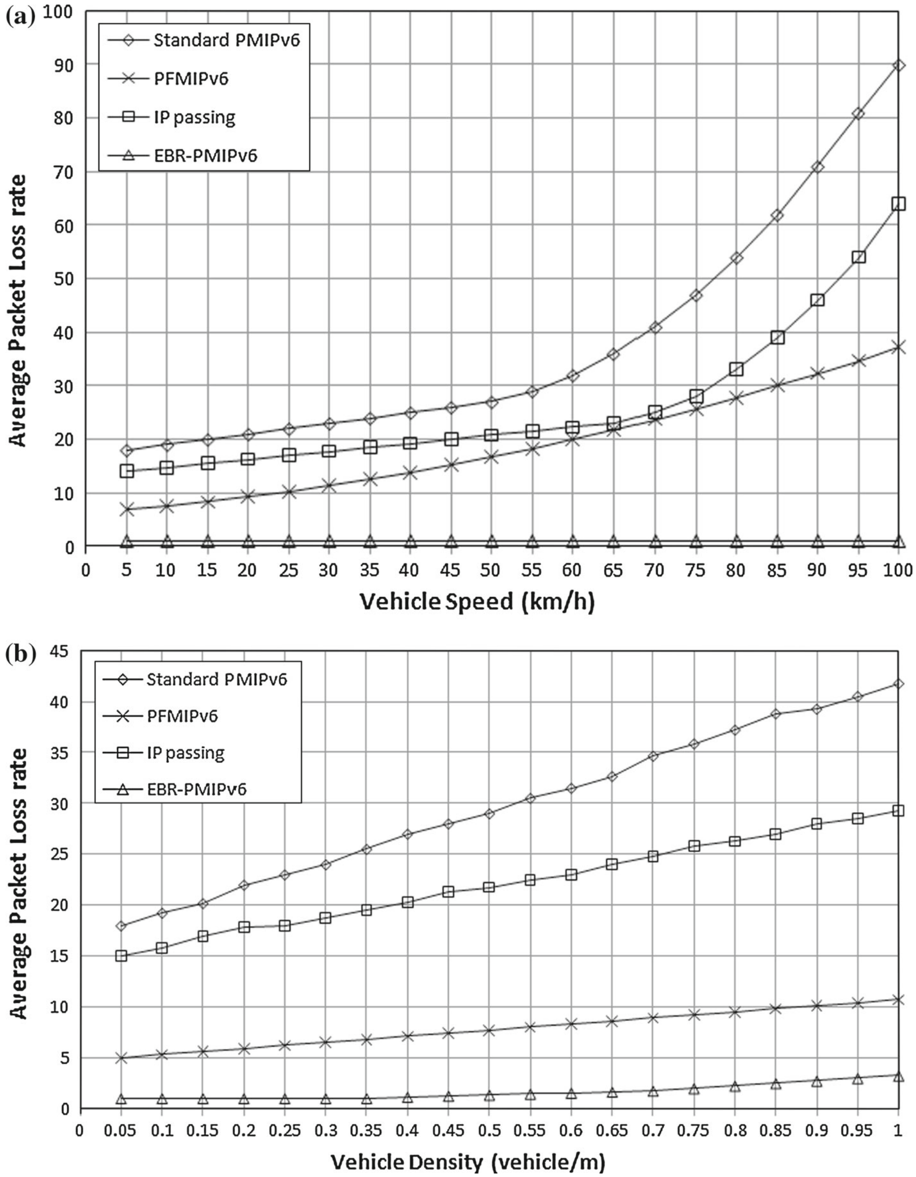


Fig. 10 **a** Packet loss rate as the vehicle speed increases. **b** Packet loss rate as the vehicle density varies

in the EBR-PMIPv6 scheme, packet loss rate still owns the lowest packet loss rate among the other two compared approaches due to the buffering of the data flow and forwarding it as the vehicle enters to the new PoA. Figure 10a, b illustrate the packet loss rate as the vehicle velocity and vehicle densities vary.

As the vehicle density increases, the number of vehicles intending to leave the associated PoA increases and that result in having a slightly upward trend of packet loss rate due to buffer size limitations.

5 Analysis and Discussion

Simulation results reveal the fact that EBR-PMIPv6 has the best performance when compared with standard the PMIPv6 protocol and the IP passing approach. The reasons are analyzed as follow:

A. Considering the IP acquisition time, in aforementioned schemes; the standard PMIPv6 protocol, PFMIPv6 and the IP passing scheme, a vehicle is assigned the IP after leaving its associated PoA. While in EBR-PMIPv6 the required information is provided before leaving the current connected PoA. Thus, the vehicle has the opportunity for the pre-configuration of specific settings (L3 handover) and performing only the L2 handover in a very negligible amount of time. Although in PFMIPv6 scheme, vehicles attempt to acquire IP addresses before leaving the coverage area, but the prolonged DAD and binding update registration processes make them to be not efficient enough in comparison with EBR-PMIPv6 approach.
B. Handoff latency is caused by some important parameters. In this paper, handoff latency has been measured as the vehicle speed and vehicle density values varied. In standard PMIPv6, as the vehicle speed increases, the handoff latency increases due to the time consuming binding update registration and DAD procedures. However, in the IP passing approach, in addition to the impact of time consumed in the binding update registration, the handoff latency increases due to a large number of messages signaling as well. Handover latency in PFMIPv6 is also influenced by the time taken to perform DAD and binding update registration procedures. Although a vehicle is provided necessary information to perform the handover procedure in lesser amount of time, but as the speed increases, the number of retransmission of message report to currently associated PoA increases as well. This is mainly due to occurrence of experiencing high packet losses (both report message and its corresponding Ack message). Whereas in EBR-PMIPv6, the handoff latency parameter has its lowest values in both the vehicle speed and vehicle density diagrams due to being independent of running the DAD procedure and having the L3 handover information preconfigured before leaving its connected PoA.
C. Taking EBR-PMIPv6 into consideration, packet loss simulation results reveal a significant disparity in both vehicle speed and vehicle density diagrams due to the buffering of the data flow and forwarding it at the appropriate time. Therefore the packet loss rate is at a minimum level when compared to the standard PMIPv6 protocol, PFMIPv6 and the IP passing approach. Running the DAD procedure in the PMIPv6 and PFMIPv6 protocols and a large number of message signaling is related to the binding update registration, in PFMIPv6, standard PMIPv6 and IP passing schemes cause a considerable amount of packet loss.

6 Conclusion

In this paper, IP mobility approaches and some other schemes have been investigated. Handoff latency and packet loss are the main issues in VANET structure. Therefore many research communities have been putting efforts into proposed solutions to overcome such defects by merging and applying IP mobility protocols and approaches on VANETs. Vehicle speed and vehicle density parameters were measured to reveal their impact on IP acquisition time, handoff latency and packet loss. The simulation results depicted in Figs. 8, 9 and 10 reveal the fact that our proposed scheme (EBR-PMIPv6) has the best performance in comparison with the standard PMIPv6 protocol, PFMIPv6 and the IP passing approaches due to its early binding registration procedure and leaving the DAD procedure out, which saves significant amount of time.

References

1. Macker, J. (1999). *Mobile ad hoc networking (MANET): Routing protocol performance issues and evaluation considerations*. RFC 2501, Network Working Group. http://www.ietf.org/rfc/rfc2501.txt.
2. Martinez, F. J., et al. (2011). A street broadcast reduction scheme (SBR) to mitigate the broadcast storm problem in VANETs. *Wireless personal communications*, *56*(3), 559–572.
3. Bohlooli, A., & Jamshidi, K. (2012). A GPS-free method for vehicle future movement directions prediction using SOM for VANET. *Applied Intelligence*, *36*(3), 685–697.
4. Perkins, C. (2002). *IP mobility support for IPv4*. RFC 3344, Internet Engineering Task Force (IETF). http://www.ietf.org/rfc/rfc3344.txt.
5. Johnson, D., Perkins, C., & Arkko, J. (2004). *RFC 3775: Mobility support in IPv6*. IETF.
6. Koodli, R. (2005). *Fast handovers for mobile IPv6*. RFC 4068, Internet Engineering Task Force (IETF). http://www.ietf.org/rfc/rfc4068.txt.
7. Soliman, H., Bellier, L., & Malki, K. E. (2005). *Hierarchical mobile IPv6 mobility management (HMIPv6)*. RFC 5380, Internet Engineering Task Force (IETF). http://tools.ietf.org/html/rfc5380.
8. Gundavelli, S., et al. (2008). *Proxy mobile ipv6*. RFC 5213, Internet Engineering Task Force (IETF). http://tools.ietf.org/html/rfc5213.
9. Devarapalli, V., et al. (2005). *Network mobility (NEMO) basic support protocol*. RFC 3963.
10. Moravejosharieh, A., Salleh, R., & Modares, H. (2011). *A novel approach for efficient resource consumption in GPS-based mobile IPv6 wireless LAN*. IEEE.
11. Moravejosharieh, A., Salleh, R., & Modares, H. (2011). *Overview of latest approaches in heterogeneous and mobile IPv6 homogeneous wireless networks based on location-assisted information*. IEEE.
12. Moravejosharieh, A., Salleh, R., & Modares, H. (2012). *Overview of handover latency and resource consumption in hierarchical mobile IPv6 protocol and GPS approaches*. IEEE.
13. Amirhossein Moravejosharieh, R. S. (2012). Geometrical GPS optimization for bandwidth consumption and resource usage in MIPv6 wireless LAN. *International Journal of Scientific and Engineering Research (IJSER)*, *3*(6), 1–12.
14. Arnold, T., et al. (2008). *IP address passing for VANETs*. IEEE.
15. Fazio, M., et al. (2007). *Facilitating real-time applications in VANETs through fast address auto-configuration*. In *Proceedings of IEEE CCNC/NIME*.
16. Fazio, M., et al. (2006). *Automatic IP address configuration in VANETs*. ACM.
17. Mohandas, B. K., & Liscano, R. (2008). *IP address configuration in VANET using centralized DHCP*. IEEE.
18. Chen, Y. S., Hsu, C. S., & Yi, W. H. (2012). An IP passing protocol for vehicular ad hoc networks with network fragmentation. *Computers & Mathematics with Applications*, *63*(2), 407–426.
19. Chen, Y.-S., Hsu, C.-S., & Yi, W.-H. (2012). An IP passing protocol for vehicular ad hoc networks with network fragmentation. *Computers & Mathematics with Applications*, *63*(2), 407–426.
20. Chen, Y. S., et al. (2009). *Network mobility protocol for vehicular ad hoc networks*. IEEE.
21. Lee, J. M., et al. (2008). *A new scheme of global mobility management for inter-vanets handover of vehicles in v2v/v2i network environments*. IEEE.
22. Chiu, K. L., Hwang, R. H., & Chen, Y. S. (2009). Cross layer design vehicle aided handover scheme in VANETs. *Wireless Communications and Mobile Computing*, *11*(7), 916–928.
23. Lai, P., et al. (2009). A reliable broadcast routing scheme based on mobility prediction for VANET. In *Intelligent vehicles symposium, IEEE2009* (pp. 1083–1087). IEEE.
24. Lee, J.-C., & Kaspar, D. (2007). *PMIPv6 fast handover for PMIPv6 based on 802.11 networks*. IETF draft-lee-netlmm-fmip-00 (July 2007).
25. Lin, S. H., et al. (2009). *A novel social cluster-based P2P framework for integrating VANETs with the Internet*. IEEE.
26. Sheu, J. P., Tu, S. C., & Chan, L. H. (2008). A distributed IP address assignment scheme in ad hoc networks. *International Journal of Ad Hoc and Ubiquitous Computing*, *3*(1), 10–20.
27. Siddiqui, F., & Zeadally, S. (2008). An agent-based architecture for fast context transfers during handoffs. *International Journal of Ad Hoc and Ubiquitous Computing*, *3*(4), 236–244.
28. Li, R., et al. (2008). An enhanced fast handover with low latency for mobile IPv6. *IEEE Transactions on Wireless Communications*, *7*(1), 334–342.

29. Shin, D., & Min, S. (2008). *Fast handover solution using multi-tunnel in HMIPv6 (FM-HMIPv6)*. IEEE.
30. Obele, B. O., Rhee, J. K., & Kang, M. (2008). *A proposal for reducing handover latency and improving route optimization in proxy mobile ipv6*. IEEE.
31. Lee, J. C., & Park, J. S. (2008). *Fast handover for proxy mobile IPv6 based on 802.11 networks*. IEEE.
32. Hwang, H., et al. (2010). *Fast handoff scheme using multicast group for intra-domain in PMIPv6 networks*. IEEE.
33. Moon, S. D., et al. (2011). *Fast handover with low latency for proxy MIPv6 in vehicular networks*. ACM.
34. Kim, J. I., & Koh, S. J. (2011). *Proxy Mobile IPv6 with partial bicasting for seamless handover in wireless networks*. IEEE.
35. Cristea, V., et al. (2009). Simulation of VANET applications. *Automotive Informatics and Communicative Systems*. doi:10.4018/978-1-60566-338-8.ch014.

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