

Performance Enhancement of NEMO based VANET using Localization Router (LR) to reduce Handoff Delays

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Abstract

Vehicular Ad hoc networks (VANETs) combined with vehicle-to-vehicle and vehicle-to-infrastructure communications can be considered as the most suitable technology to enable ITS (Intelligent Transport System) application bestowed upon travellers with mobility, safety and productivity with human comfort. As a delay sensitive ITS application, handoff delays and packet losses are critical parameters for maintaining seamless connectivity in VANET solution. During handoff, when mobile node (vehicle) is acquiring new CoA (care of address), packets directed towards that node are lost; because it's old identity is no more valid. So in high speed dynamic vehicular environment the number of frequent handoffs would produce delay beyond the normal limit. Therefore, it is very important to resolve the issues of handoff delay and packet losses in VANET environment. As a solution, a domain based RHD-NV (Reducing Handoff Delay in NEMO based VANET) scheme is proposed in this paper. Number of vehicles moving towards the road constructs a domain where network mobility NEMO-BS protocol is applied. A vehicle is selected as MR (master router) and connected to the RSU (road side unit) to the internet and other vehicles in the domain work as LRs (localization router) and communicate through MR. Simulation tests performed in NS3 (network simulator) and MATLAB SIMULINK demonstrate that using LRs (localization router) in the domain, the number of handoffs and handoff delay are significantly reduced.

Keywords: VANET, NEMO, V2V, V2I, VANEMO, Intelligent Transport System.

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1. Introduction

Vehicular Ad hoc networks (VANETs) combined with vehicle-to-vehicle and vehicle-to-infrastructure communications can be considered as the most suitable technology to enable ITS (Intelligent Transport System) application bestowed upon travellers with mobility, safety and productivity with human comfort. As a delay sensitive ITS application, handoff delays and packet losses are critical parameters for maintaining seamless connectivity in VANET solution [1]. During handoff, when mobile node (vehicle) is acquiring new CoA (care of address), packets directed towards that node are lost; because it's old identity is no more valid [2]. Increasing attention and advancement in the arena of intelligent transport system (ITS) have brought significant demand in academic research and in relevant industry [3]. An ITS system, consists of VANET systems such as; vehicle to vehicle and vehicle to infrastructure communication. Here each vehicle comes up as a mobile node with two important parts i.e. OBU (on board unit) and AU (application unit); OBU is used for network communication and AU is used for executing the program located on OBU. And attached infrastructure network beside the roads which can be called as Road Side Unit (RSU) is connected to the internet [4, 5]. Wireless Access in Vehicular Environment (WAVE) is one of the most popular architecture which uses 802.11p protocol and it is an enhanced version of 802.11. This protocol is adapted to the high speed of vehicles because it minimizes the overhead required for establishing connection (no association, a lightweight authentication scheme) and it allows the exchange of data in short durations [6, 7, 8].

A key difference of VANETs – when contrasted with different flavors of ad-hoc networks, is that their abnormal state of node portability (because of vehicles' fast movement) creating frequent break down of connections among nodes. Nodes' mobility in VANET is

commonly confined as Vehicles move based on given topology of the streets. Furthermore, VANET nodes have limited memory and processing abilities [9]. All these mentioned properties of VANETs protocol can have significant impact on the deployment of ITS application. The concept of NEMO BS protocol can be considered to reduce the effect of frequent changes of point-of-attachments encountered in VANET thus enabling easy deployments of ITS applications.

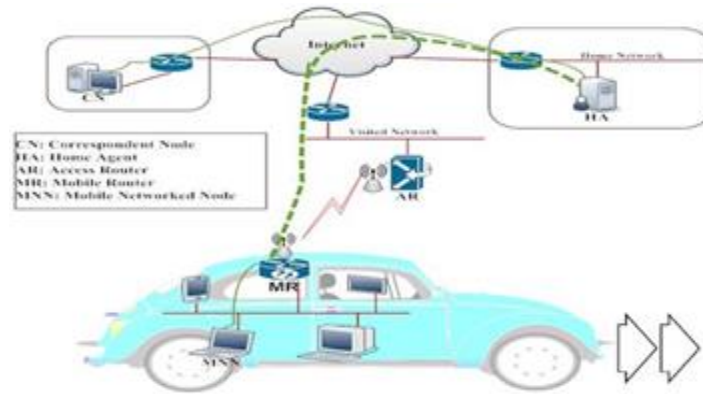


Figure 1. Basic diagram of NEMO-BSP

Support for network mobility in MIPv6 with NEMO Basic Support protocol has been elaborated in RFC 3963 [7] as depicted in Figure 1. This protocol maintains the session continuity for all the mobile network nodes (MNNs). Two key components in NEMO: mobile routers (MR) and mobile network nodes (MNNs) are used to deliver continuous end to end connectivity and network mobility [10]. While mobile router's change its point-of-attachments with access point to the internet, it keeps communication with all of the relevant MNNs.

To exploit the features of NEMO BS protocol in VANET we need to form a domain of multiple mobile nodes (vehicles) each of them are equivalent to an MNN that also acts as a localization router (LR) for the group. Therefore a domain based efficient scheme for reducing handoff delay in NEMO based VANET (RHD-NV) is proposed to minimize the number of handoffs significantly.

The paper is organized as the following: after introduction in section 1, Section 2 present related research articles published in recent years. In section 3 design of RHD-NV scheme is explained. Simulation results and performance evaluation are illustrated in Section 4. And finally conclusion is drawn in Section 5.

2. Related Handoff Studies

Due to antenna's limited transmission range, the mobile nodes have to connect with different access points to keep the wireless networks connected while they are moving [8]. Handoff related solution and schemes are most important as it has great impact on ITS based solution where many researchers are trying to give diverse solutions and algorithms to overcome the issues.

In Park, et. al. [12], a new IP mobility management scheme is proposed. Multiple concurrent tunnels connecting HMIPv6 MAP and the mobile gateway are created dynamically in which extended IETF standard HMIPv6 used. Designing the multiple channel supported architecture and mathematical examination and simulation have made for evaluation of its performance. During handover process, packets are travelling parallel through these multiple tunnels constructed between the HMIPv6 MAP and MG to minimizing both handover latency and losses of packets. However to establish multiple channel and keep it up until next handoff involves huge process cost in which vehicle nodes need to be aware of multiple channels for communications. This may subsequently delay the data packets.

In Okabe, et. al. [13], vehicles with dual antenna is proposed here. Each antenna comes with one interface card. Interface card with one antenna is used to receive and transmit data while interface card with other antenna scans for new base station through different channels. Both antennas collaborate with each other. When radio signal strength (RSS) of base station measured by one antenna of the vehicle reaches the minimum threshold limit, it decides to switch to new point of attachment and tries to register and authenticate the network. And when registered, the other antenna of the vehicle starts to transmit and receive data. As the vehicles are equipped with on board unit which is a low memory processed device, during communication both v2v and v2i's processing time of handoff will be very high due to having RSU's limited transmission range.

In the paper Almulla, M., et. al. [14], author proposed a scheme of AP selection in which Global Positioning System (GPS) technology is used to collect vehicles geographic location and movement direction. Their scheme works on turn detection and AP selection process. AP selection scheme which works in combination with other schemes e.g. prioritized scanning scheme and blacklist scheme. In view of his research, AP placement had made with very short distance because of limited transmission range of AP. So corresponded road direction will need increased number of APs. Therefore handoff will increase in number during vehicle's movement towards the road which ultimately leads to packet losses. Because in high dynamic vehicular environment repeated attempts of handoff, after a short while will increase the long latency of packet and starts dropping the packets as a consequence.

In Wang, et. al. [15] author presented an architecture based road domain vehicular network environment. An algorithm with intra-RD and inter-RD mobility handover introduced here. In the infrastructure oriented vehicular environment vehicles care of address remain unchanged during the intra-RD handover process. So the intra-RD mobility handover does not carry the configuration of care of address. And handover cost and delay minimized as a consequence. But in dynamic vehicular environment both v2v and v2i communications are the key concerns. In high vehicular traffic environment some vehicles become v2v centric due to limited channel capacity of RSU. So the vehicle may face the limited channel capacity for association.

The policy of the minimization of IP obtaining overhead is introduced in IP passing protocol scheme by Arnold, et. al. [16]. In this concept handover takes place through three main steps as following: First, collecting IP configuration with data; second, passing it from preceding vehicle to following vehicle and third setting up the IP configuration to the following vehicle. According to this scenario of vehicular architecture, the nodes need to maintain constant vehicular speed and moving direction.

In Chiu, et. al [17] NEMO and multi-hop relay mechanism is used together in this scheme. Two Mobile routers (MR) as front and rear are used to use internet through WiMAX and WiFi. Rear MR connects all mobile host devices using Wi-Fi. WiMAX uses the method for authentication which brings long postponement in handoff. Usages of IEEE 802.1X in v2v communication environment it is not suitable with others wireless technologies.

Chaurasia, B. K. et. al. [2] present a method of using an IP pool between two subsequent access routers. A subnet of IP address will be shared to maintain the connection through making an overlap area to increase the communication range of access points. Entering to that overlapped area the vehicle node can initiate a soft threshold while there are front and rear vehicle exist. VANET connection will be continued or needs to start handover process because node requires new IP address, node still sticks to previous IP address and after making handshaking, it gets new care of address. But in high way vehicular environment presence of front and rear vehicles will not be in parallel distance always. And if there is a need of handoff, it experiences delay time and gets packet drops which will create the consequence of adaptation delay.

3. Domain Based RHD-NV Scheme

In general, vehicles construct different domains and each domain works as a mobile network to forward data packets. In each domain one vehicle becomes domain head (DH) and works as a master router (MR) and others vehicle are assigned to work as localization router (LR) to assist master router to reduce handoff latency for the whole domain and they are considered as active nodes. A scenario is illustrated in Figure 2.

In our proposed scenario a domain consists of vehicles moving towards the road and keeps communication to the RSU to the internet. Vehicles are embedded OU (onboard Unit) with wireless antennas and road side units are access points. Positions, relative speed and moving direction are the metrics on which vehicles are grouped together in different domains. Each of the domain works as a mobile network and NEMO is applied to the domain for network mobility which forwards packets towards internet. All others vehicles in the domain work as mobile nodes which are called LR and communicate through the master router to the internet. Post Enhancement.

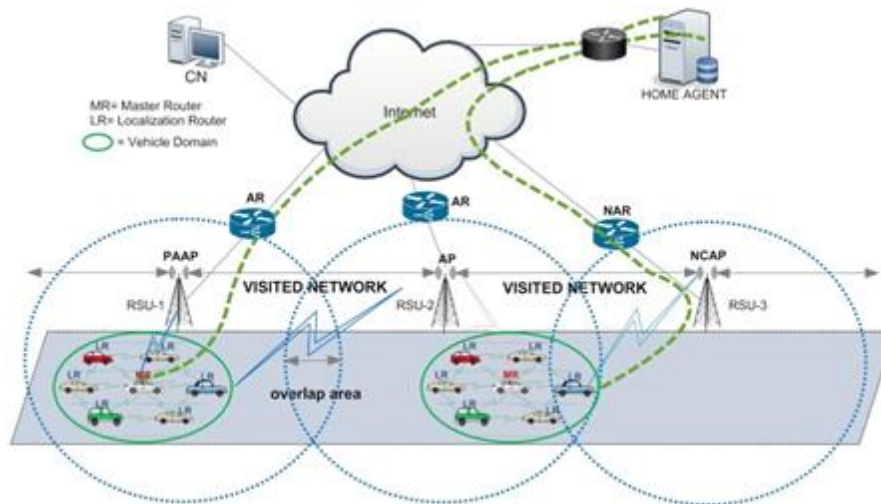


Figure 2. Diagram of RHD-NV scheme

In the domain MR maintain updated topological information with other vehicles. LRs also keep same topological updates as MR, but does not forward data to access points and keep scanning the new candidate access point (NCAP) for MR. When actual hand off takes place, ongoing traffic or data can be redirected to other alternative forwarding gateway through LR if MR fails to make association with (NCAP). All the LRs broadcast live hello packet to keep the topological information to communicate with MR. Any changes inside this vehicles domain like leaving the domain, became inactive or LR vehicle or assign new AP with strong and quality signals priority, MR updates their topological database. In this regards all the active vehicles. During mobile vehicle's movement, the connection between the master router and the connected access point will be interrupted because of limited transmission coverage. To continue the wireless connection with the RSU backbone, the MR needs to find the new candidate access point and establishes the connection with NCAP. So, when the MR senses that the signal condition of the Present Associated Access Point (PAAP) is deteriorating below the minimum acceptable threshold, and can't make binding with NCAP it should sends to LRs the notification to start handoff process.

When the LR receives the new care of address (NCoA) for the next handoff of the whole domain, it sends a handoff notification message to the MR. MR then redirects its current forwarding data towards LR. LR forwards the data to the internet through its new associated access point and broadcast to all others vehicles in the domain as a MR. And old MR switches to a LR mode inside the domain or can left the domain. Thus a number of handoff may reduce and minimize the losses of packets which would trigger enhancement of NEMO based VANETs. Due to presence of MR and LR, the reduction of adaptation delay came to a noticing level.

The Figure 3 is illustrating the signaling flow during handoff among MR, LR & new RSU and HA (Home Agent).

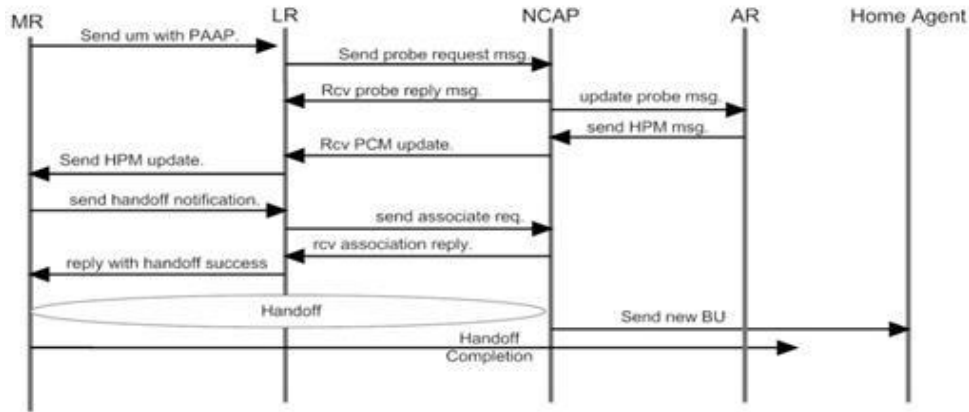


Figure 3. Signaling message flow

3.1 Handover Analysis

In this section, handover is defined as the time taken for the packets being created at the source to the being received at the destination. It is assumed that, the communication area as well as domain for any vehicle is A and D (i.e. d_1, d_2) respectively where D is surrounded by the wireless access points are mainly AP1 and AP2. According to the proposed scheme, the length of current domain (D1) is $L \cdot A$ ($L \geq 2$), AP2 belongs to both domains, and the access router in new domain (d_2) is expressed as AR2, as depicted in Fig. 2.

Therefore, the delay (∂_{total_intra}) of a vehicle during intra movement can be expressed in Equation (1) as:

$$\partial_{total_intra} = \partial_{intra} + \partial_{Layer2} \tag{1}$$

Where,

$$\partial_{intra} = \partial_{HPM} \times [L/2] + \partial_{PCM} \times [L/2] + (\partial_{HPM} + \partial_{PCM}) \times \frac{(H_{AR-NCAP} + H_{NCAP-MR}) \times P}{(1-P)} \tag{2}$$

In Equation 1 and 2, the delay time for exchanging binding update and binding acknowledgement among neighbor vehicles can be expressed as ∂_{BU} and ∂_{BA} respectively. (H_{AP-AR}) is the hop distance between access points and access routers whereas ∂_{Layer2} indicates the delay occurred during layer 2 handoff. Wireless link failure probability can be symbolized as P.

According to the proposed scenario, once a vehicle changes from current domain to the new domain, the inter movement can be expressed in Equation 3:

$$\partial_{total_inter} = \partial_{inter} + \partial_{Layer2} \tag{3}$$

Where,

$$\partial_{inter} = 2 \times \partial_{HPM} + \partial_{PCM} + \frac{P}{(1-P)} \times \max\{(\partial_{HPM} + \partial_{PCM}) \times H_{NCAP-AR}, (\partial_{HPM} + \partial_{PCM}) \times H_{NCAP-LR}, (\partial_{HPM} + \partial_{PCM}) \times H_{MR-HA}\} \tag{4}$$

The distance between Home Agent (HA) and Access Routers (AR) is greater that the distance between access points and Access Routers (AR) since each and every access points attains the communication with its Home Agent (HA) through access routers. Therefore, the inter movement can be expressed into Equation (5) as:

$$\partial_{inter} = 2 \times \partial_{HPM} + \partial_{PCM} + \frac{P}{(1-P)} \times (\partial_{HPM} + \partial_{PCM}) \times H_{CAP-HA} \quad (5)$$

Therefore, if the road size is assumed as λ , the total handover delay (ψ_{total_delay}) is formulized as:

$$\psi_{total_delay} = \frac{\lambda}{L.A} \times (\partial_{total_intra} + \partial_{total_inter}) \quad (6)$$

Where, $\partial_{total_intra} \leq \partial_{total_inter}$

3.2 Signaling Cost

In the proposed scheme, the signaling overhead for the moving vehicle is managed among the entities are mainly MR and LR. Two signaling messages are mainly HPM as well as PCM are proposed to minimize handover delay in the proposed scenario. Therefore, the signaling cost for the proposed scenario is calculated as:

$$\mathcal{E}_{total_cost} = \frac{1}{\psi_{CRT}} \times N_{vehicle} \times (\mathcal{E}_{PC} + \mathcal{E}_{Total_Sig}) \quad (7)$$

In equation 7, average cell residence time is denoted as ψ_{CRT} whereas number of vehicle can be symbolized as $N_{vehicle}$. Similarly, \mathcal{E}_{PC} and \mathcal{E}_{Total_Sig} is referred as the cost for processing as well exchanging total signaling message to reduce handover delay in the proposed scheme. Thus, \mathcal{E}_{Total_Sig} is calculated as:

$$\mathcal{E}_{Total_Sig} = \frac{\lambda}{L.A} \times (\mathcal{E}_{total_intra} + \mathcal{E}_{total_inter}) \quad (8)$$

Where,

$$\mathcal{E}_{total_intra} = S_{HPM} \times [L/2] + S_{PCM} \times [L/2] + (S_{HPM} + S_{PCM}) \times \frac{(H_{AR-NCAP} \times H_{NCAP-MR}) \times P}{(1-P)} \quad (9)$$

$$\mathcal{E}_{total_inter} = 2 \times S_{HPM} + S_{PCM} + \frac{P}{(1-P)} \times (S_{HPM} + S_{PCM}) \times H_{CAP-HA} \quad (10)$$

Here, S indicates the size of message length. Notation and values used in numerical analysis as depicted [18, 19, 20].

Table 1. Illustrates numerical notation with values

Symbols	Explanation	Value
∂_{HPM}	Delay of handoff preparation message	50ms
∂_{PCM}	Delay of preparation confirmation message	60ms
$H_{AR-NCAP}$	Hop distance access router to new candidate access point	1
$H_{NCAP-MR}$	Hop distance between new candidate access point & master router	2
$H_{NCAP-AR}$	Hop distance between new candidate access point and access router	1
$H_{NCAP-LR}$	Hop distance between new candidate access point and localization router	1
H_{MR-HA}	Hop distance between master router and home agent	2
H_{CAP-HA}	Hope distance between candidate access point and home agent	1
$L.A$	Length of Domain	50 m
P	Probable link failure of wireless	5%
∂_{Layer2}	Layer 2 delay	50ms
$N_{vehicle}$	Number of vehicles	30
ψ_{CRT}	Average cell residence time	10ms
\mathcal{E}_{PC}	Processing cost	2ms
S	Size of message length	512

4. Simulation Results

The performance of proposed RHD-NV scheme is evaluated by Network Simulator 3 (Release 3.26) [21]. Manhattan mobility model [22] is used for vehicle's movement. Moving probability is set to straight at 0.5, left-right turning probabilities are set to 0.25 individually. To

test the scheme with different vehicle speeds and relevant traffic, various simulation scenarios are used.

Table 2. Simulation parameters are illustrated

Parameters	Value
Total Time	600 s
Limit of Transmission area	2000 m * 2000 m
Vehicles speed	5 - 30 m/s
Access Points	10
Vehicle's Quantity	9 * 2
Area range Average	130 m
Transmission rate	6 Mbps
Relevant data rate	0 - 512 Kbps

During the handoff process the interruption time of transmission is mentioned as handoff latency. Due to handoff latency packet loss increases with the increase of data rate [24]. During the handover process master router disconnects from PAAP and connects with NCAP. This interruption interval is an important parameter to evaluate the efficiency of a handoff scheme. The impact of vehicular speed and data rate on handoff latency is shown in Figure. 4. Four relevant data traffic ranges from 64 Kbps to 512Kbps is considered for the simulation. Also we used various vehicle speeds ranging from 5 m/s up to 30 m/s. It can be seen that the handoff latency increased slightly while vehicle speed grows. Higher seed introduces more handoffs leading to higher handoff latency.

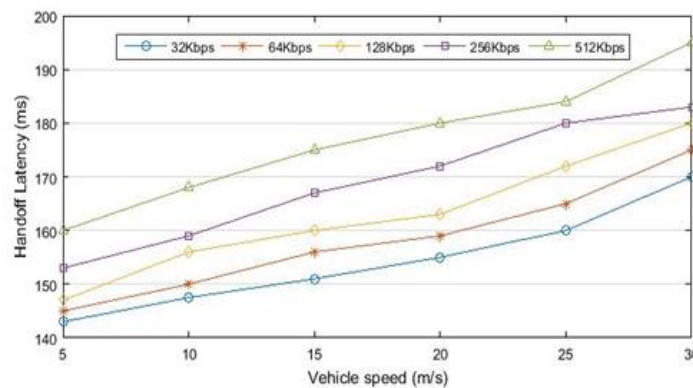


Figure. 4. Handoff latency with relevant traffic

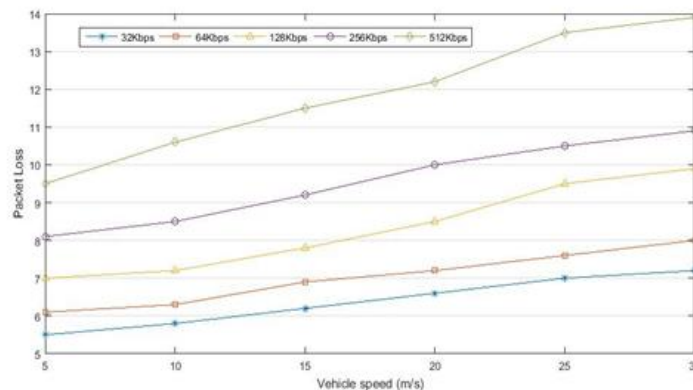


Figure 5. Packet losses on vehicles speed and relevant traffic

The impact of various vehicular speeds for a range of data traffic rate on packet loss is presented in Figure 5. CBR data flow is established through UDP to test the packet loss. As VoIP applications are run through UDP packet, we set packet size, packet interval and traffic moving duration as 160 byte, 20 ms and 100 s to 500 s. The result indicates that Packet loss increases as the vehicle speed grows from 5 m/s to 30 m/s.

Similar CBR flow is used for latency and delay calculation. Two important metrics to evaluate handoff scheme packet latency and inter-frame delay are used. Figure 6 is illustrated to present the packet latency. Here latency is defined as the interval time between the time of data packet send and time of data packet received which is 110 second to 120 second and mobile router complete the hand of process time is changes to 113 second including the latency time. A CBR flow of 20000 UDP packet is represent here. After switching its access point from PAAP to NCAP the packet latency increases from 40 ms to 110ms, as it moves home agent's existing domain to a domain of foreign network. All the data packets towards to master router redirect to new master router. Therefore here also increase the packet latency.

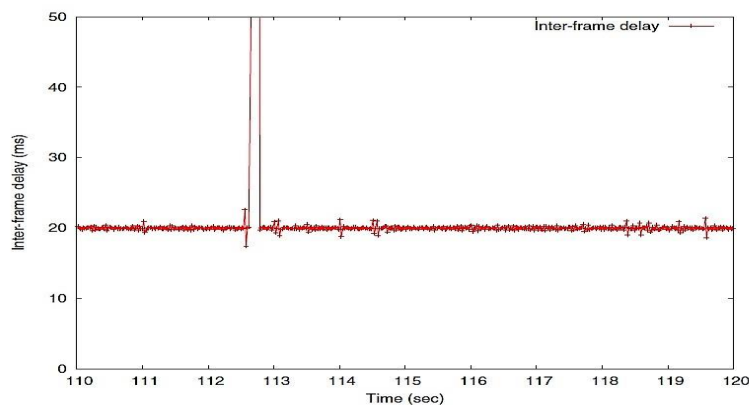


Figure 6. Inter-frame delay

A key attribute of the quality of wireless data communication is the level of inter-frame delay. The inter-frame delay is the time gap between two consecutive data packets received by the recipient. Handoff delay can adversely affect the inter-frame delay. Figure 6 demonstrates the inter-frame delay before, during, and after a handoff during a simulation run. Here the time from 110 to 120 second denotes the simulation time. The average inter-frame delay found to be 20 ms before and after handoff. However during handoff it increased to about 50 ms (around 12.8 sec simulation time). This is because handoff process involves disconnection from the old access point to the connection to the new access point and the interruption between mobile router and its correspondent node.

4.2 Benchmarking

The performance of the proposed RHD-NV is compared with the result of Chaurasia's paper [2] which reported an optimized enhancement handoff process. The performance of RHD-NV has been optimized through the reduction of handoff delay.

Figure 7 depicts benchmarking for NEMO-BSP, RHD-NV and VANET Optimization scheme. At the beginning when the vehicles are stationary or moving with low speed, all of the schemes show small delay in handoff process however it increases with vehicle speed. At speed of 5 m/s the delay time of NEMO-BSP is about 150 ms, VANET Optimization is around 110 ms and RHD-NV is almost 90 ms. With the increase of vehicles speed, the handoff delay grows as well. Beyond the speed of 15 m/s, the delay of VANET Optimization grows rapidly while both NEMO-BSP and RHD-NV have linear growth. From vehicle speed 25 m/s to 30 m/s the RHD-NV delay becomes stable at around 220 ms, NEMO-BSP exhibit delay of around 440 ms, however, VANET Optimization shows very high delay of about 480 ms at 25 m/s and around 750 ms at 30 m/s. So, in comparison with both NEMO-BSP and VANET optimization scheme, RHD-NV demonstrations significantly improved performance by reducing handoff delay drastically compared to the other two.

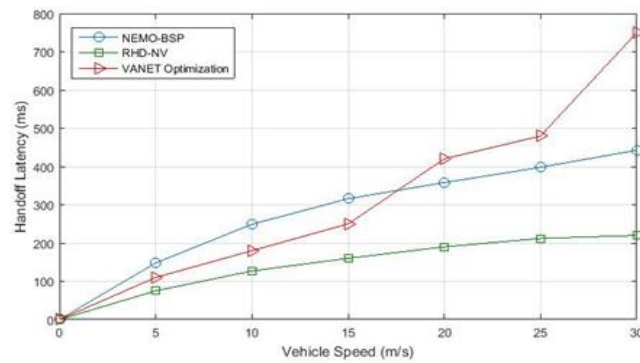


Figure 7. Handoff delay benchmarking based on vehicles speed

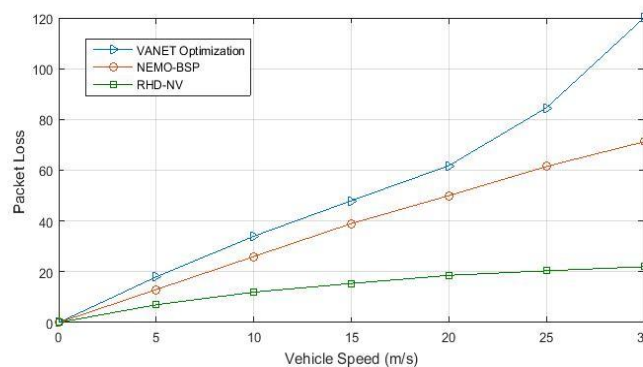


Figure 8. Packet losses benchmarking on vehicles speed

Packet losses versus vehicle speed under VANET Optimization, NEMO-BSP and RHD-NV schemes are illustrated in Figure 8. VANET Optimization shows highest rate of packet losses. As it can be seen, both VANET Optimization and NEMO-BSP have similar trends of packet losses until the speed is 20 m/s while RHD-NV experiences much lower rate of packet loss. At vehicle speed increases from 25 m/s to 30 m/s, VANET Optimization scheme starts to exhibit very high packet losses reaching 120 packets thus performing worst. The second best result has been shown by NEMO-BSP giving about 70 packets loss. RHD-NV, on the other hand, demonstrates an overall very impressive low packet loss with minimum increase rate throughout the range of vehicular speed considered. At the peak RHD-NV shows loss of 22 packets.

In VANET Optimization Scheme, during handoff, acquiring the care-of address from the front or the rear vehicle introduces a factor of multiphop delay in process. Failing to acquire care-of address from these vehicles creates additional request for care-of address from the next AP. As a result, delay and cost of handover are increased extensively. In RHD-NV, LR does not need to request for care-of address as it has to be done before actual handoff operation. So the process time for new care-of address is waived and the handoff delay is reduced. Packet loss is decreased consequently.

5. Conclusion

In this paper, we have reviewed different type of proposed handoff schemes and solutions in VANET and NEMO based VANET. Our proposed domain based RHD-NV is to improve their handoff process to minimize the number of handoff, handoff latency and losses packet. Simulated results have been analyzed to justify the proposed RHD-NV scheme and also the proposed design has been compared. In view of the above papers we are trying to enhance

the performance of VANET solution for benefit of ITS (intelligent transport system) that applies advancement in technology of transportation section to improve user mobility, safety, productivity and minimize the adverse impact on the environment. But there are still huge demands in ITS applications to improve its performance which are affected by handoff management [25]. Therefore in future various mobility models will be considered to test further for enhancing its performance

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