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Routing Protocol for Heterogeneous Networks in Vehicular Ad-hoc Network for Larger Coverage Area

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Abstract

Vehicles now come equipped with sensors, onboard units, and other processing as well as communication capabilities, thanks to significant advancements in the automobile sector. Intelligent transportation system (ITS) is one area to explore regarding vehicular ad-hoc networks (VANETs) in mobility management. Vehicle-to-vehicle communication is becoming more common thanks to VANETs, which eliminate the need for infrastructure, configuration effort, and significant expenses associated with a mobile communication network. Vehicle applications can be used to access internet services in addition to local data exchange. Internet gateways situated on the side of the road enable access. However, internet integration necessitates the vehicle Ad-hoc network's mobility support. The network mobility technique in vehicular Ad-hoc networks will be studied in this research. The pattern will represent the mobility of automobiles from one place to another. In this paper, an algorithm is purposed to reduce handover delay and reduce packet loss, and minimize signalling overhead by using the suggested handover strategy.

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1. Introduction

Network technology has progressed to the point that it can now be used in a wide range of applications. One of their more recent application programs is the establishment of vehicular ad-hoc networks (VANETs), a type of mobile ad-hoc network (MANETs), in which connections are shared with vehicles in this area. A vehicular ad-hoc network connection is now an ample scope of research work in wireless technology in these two sectors: education and the automobile. In essence, VANETs are based on intelligent transportation systems (ITS). The most commonly found mobility models are made from ordinary casual models, which are unable to reflect accurately automotive movement.

Vehicle–to–vehicle (V2V) communication is the most efficient for a variety of reasons, including its short range, low cost of connection, or higher capacity.[1] The VANET is a new type of MANET, which is made up of a wide array of vehicles that drive and communicate with one another without the use of established infrastructure. This is one of the major advantages of the ad-hoc network: any established infrastructure is not needed. VANET may as well be classified depending on different factors, such as the number of mobile nodes, the potential for a large-scale network, and the density of the network. VANET can also be used for a wide range of applications such as the safety of roads, making driving comfortable, internet connection, and multimedia-based (music, video). The majority of intelligent transportation systems apps are infrastructure-based connections and are applied to the accessing network in the vehicle. In this research, we provide a network mobility model for automotive Ad-hoc networks, which is a methodology that can be employed in both wired and wireless scenarios. We show that our approach delivers a more reliable and seamless handover than other schemes through a simulation study.

There have been several models introduced before the suggested handover strategy to reduce packet loss and latency. The development of a leader based on the device, which uses the network topology of VANETs as well as an automated setup method such as dynamic host control protocol (DHCP), ensures rapid and permanent address set up so as to serve actual time applications in VANETs.[2] However, because it is a proactive protocol, it expects by applying a DHCP server.

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When vehicles change their leader, it also requires Duplicate Address Detection (DAD), as described. In VANETs, the optimized existing protocol changeover approach utilizes the media independent handover (MIH) services.[3] They advocated using a custom cache kept by the transport or through the Access Router to shorten the expected time in an existing protocol, consequently enhancing the probability in the existing protocol's prognostic method. For the inter-VANET transfer of cars, global mobility management (GMM) was proposed.[4] The suggested method allows for a quick handover using L2 starting and packet transmission path optimization. In VANETs, the packet forwarding control (PFC) mechanism is developed for choosing a common ahead point (CAP) for packet forwarding. The mobility management internet protocol version 6 (MMIP6)[5] connects internet protocol version 6 (IPv6) based vehicle ad-hoc networks to the network in a multi-hop fashion. MMIP6 is following the concepts of mobile internet protocol version 4 (IPv4) and is aimed to be scalable and efficient. It does not support mobility methods such as IPv6, existing protocol, or hierarchical mobility internet protocol version 6 (HMIPv6). For VANETs, a NEMO protocol has been proposed.[6] Changeover latency, or the time a vehicular node (VN) is not able to address or receive packets through a handover, is the main issue with MIPv6.[7]

2. Experimental Setup

Assumptions made for the purposed routing algorithm as depicted in Fig. 1 include:

1. Each vehicle is moving at a speed between 50-120 km/hr.
2. RSU (Road Side Unit) has a transmission range of 5 km.
3. WiMAX (Worldwide Interoperability for Microwave Access) tower covers a range of 15 Km.
4. The vehicle is moving as per road safety topology and is under administrative control.
5. Vehicular nodes are moving as per the highway scenario.
6. Tile to live is assigned to all vehicles as the broadcasting limit.
7. The assumption is made that vehicles broadcast the packets up to a single hop only.
8. Time to live (TTL) is set to 1
9. The TTL value is incremented by one for each retransmission per node.

Information of all mobile nodes (vehicles) under RSU is stored at worldwide interoperability for microwave access (WiMAX). All RSUs maintain the updated information of all vehicles and register the authorized vehicles that come within the range of respective RSUs. The process of discovery and registration continues as the vehicles move in and out of their respective RSU range.[8]

The source node is represented as the source and the destination node is represented as the destination in Fig. 1. When a source vehicle wants to communicate with the destination vehicle, the source starts to send packets to the destination.

The proposed routing algorithm works in three different scenarios for registration on a newly discovered node.

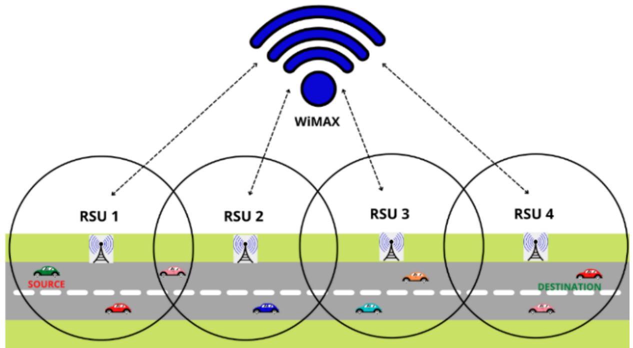

Fig. 1 Movement of the vehicles.

Case 1: In an ad hoc region, the source vehicle wants to transmit information to the destination vehicle. id1 is assigned to the source vehicle and id2 is assigned to the destination vehicle. Information about the neighboring nodes is maintained by the GPS of the respective vehicles.

The packet is delivered to the destination vehicle if it is found in the range of the source vehicle as represented in Fig. 2.

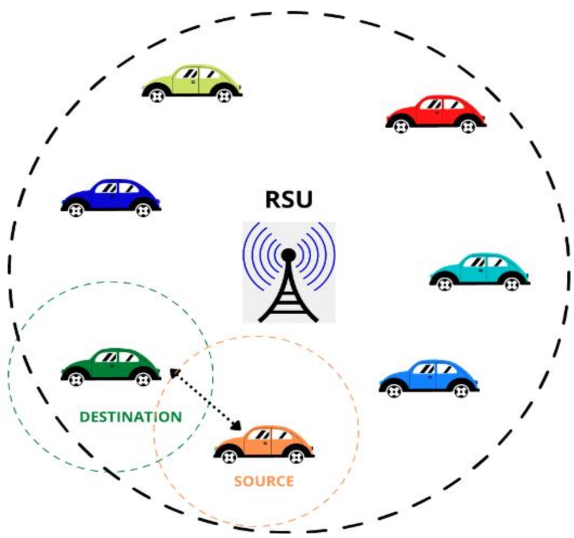

Fig. 2 Case 1 of the proposed routing algorithm.

Case 2: In case 2, both the source vehicle and destination vehicle are registered under the same RSU, then the data packet is delivered to the destination node via the same RSU. As per the scenario mentioned in Fig. 3, the source vehicle wants to send the data packet to the destination vehicle, but the destination vehicle and the source vehicle are registered under the same RSU as the destination vehicle, then the data packet will be delivered to the destination vehicle via the same RSU.

Case 3: If the destination vehicle and the source vehicle are not in the same ad hoc region and are registered under different RSUs, then communication will take place via WiMAX.

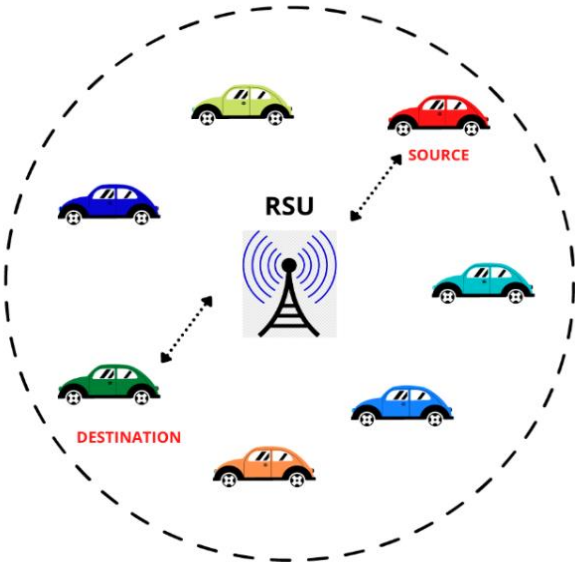

Fig. 3 Case 2 of the proposed routing algorithm.

As mentioned in Fig. 4, the source vehicle wants to send a data packet to the destination vehicle. The source vehicle is registered under RSU2 and the destination vehicle is registered under RSU1.

In this scenario, the source vehicle will deliver the data packet to RSU2, RSU2 will transmit the data packet to WiMAX, WIMAX will retransmit the data packet received from RSU2 to RSU1, and finally, RSU1 will transmit a data packet to the destination vehicle.[9]

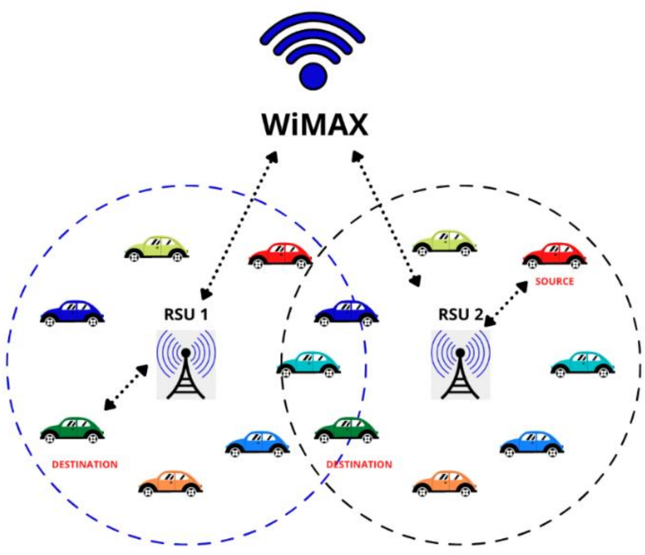

Fig. 4 Case 3 of the proposed routing algorithm.

As illustrated in Fig. 6, heterogeneous networks are included in the suggested design, where a cellular network is given with the activity by a few internet service providers (ISPs). The RSU of various accessibility of networks, such as wireless local area networks (WLAN) or mobile networks, is associated with vehicular nodes (VNs). To the vehicle equipped with routers, different ISPs have been referred to distinct addresses of the home. Each VN forms a worldwide IPv6 address via router advert from the RSU. As traffic is diverted in VNs in separate regulatory areas during the handover process, flow redirection may cause an issue. Because VNs belong to distinct HAs, ingress filtering prevents VNs from communicating with each other's home networks.[10] As a result, the VN is compelled to operate a different home address, which may result in the connection sessions being terminated. The routing algorithm purposed is represented in Fig. 5.

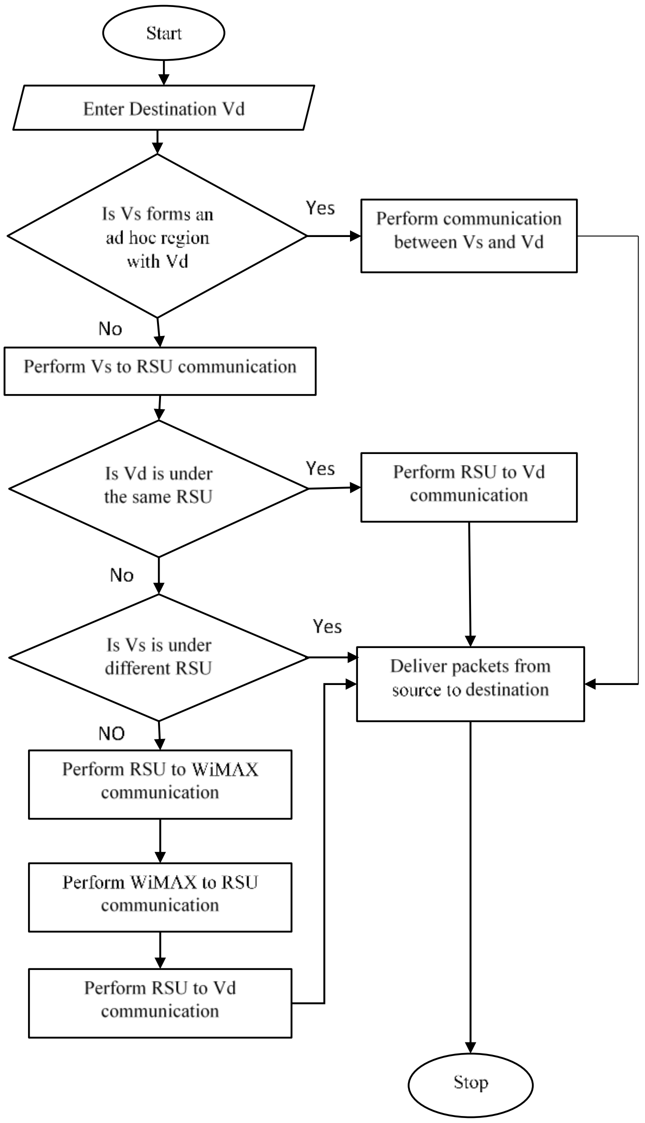

Fig. 5 Proposed routing algorithm.

The following are the parameters that are assumed in the proposed architecture:

(1) For better communication, several RSU is set (*i.e.* 5 km radius).

(2) The space between two RSUs is considered to be 1.5 km, resulting in a maximal recurrence area of 5 km on the road.

(3) The road topology and RSU placement on the roadside are likewise assumed to be fixed, with an overlapping region length of 1 km, for each. There is a strong case for the premise that highway road widths range between 4 and 5 km.

(4) Additionally, taking into account that there is enough

traffic on the road for communication between two vehicles equipped with VNs to be possible at all times with a set range of VNs; this also requires that the cars are traveling at about the same pace.[11]

The suggested architecture can accommodate any number of cars, but each one must be outfitted with a mobile router. We can suppose any number of vehicles in the vehicular scenario, but for the sake of alliteration, we've assumed two vehicles that are deployed on the way; each car has an Ad-hoc network communication. In Fig. 7, the source and destination vehicles are represented as source and destination, respectively. During the vehicle's travel from RSU1 to RSU2, cars set with destination depart RSU1 but source cars remain in RSU1's scope, ensuring that the source's internet connection is kept by the source until the destination completes the handover procedure. The traffic delivered to the destination is redirected to the source during the transition period. For a limited time, the car can connect to the internet via various RSUs (RSU1, RSU2..., RSUn) employing source and destination until the destination departs RSU1. Destination transports traffic addressed to the source during the source's handover period.[12]

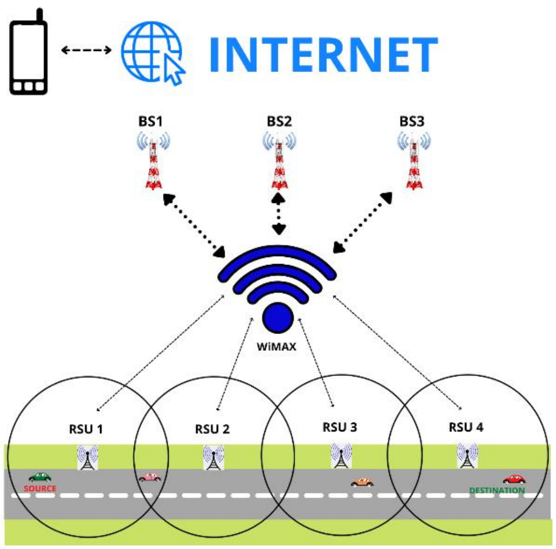

Fig. 6 Proposed architecture.

Once the destination enters the overlapping area, it receives a lesser wave, which may cause a poor internet connection. However, this issue may be solved by the fact that sufficient traffic is on the way for automobiles to communicate with one another. This means that the destination is still tied to RSU1 because the source is still within RSU1's scope and the destination and source are communicating ad hoc. At the same moment, the destination sends a registration message to RSU2. The destination receives the message from the source considering that the registering is not accomplished.[13] The time it takes for a destination to complete the handover process is calculated as follows:

Alternatively, 1.5 km is the area along the overlapping area at point RSU1 and the border region at point RSU2, and VS is the vehicle's speed, tv = distance traveled in the handover region/vehicle speed, once d = 1 km, tv is minimum, while d = 5 km, tv is maximum, supposing VS is unchanging in both situations.

3. Simulation

For the Handover scheme and tunneling establishment proposed, the strategy is redirecting the circulation of vehicles of the VNs (that are installed on the vehicles) to one another through various home agents (HAs) during the pass time to enable smooth handover of the vehicular network. While the cellular network travels with the vehicle, RSU2 is detected by the Router1 (installed on the initial vehicle source) via a Router advert message from RSU2. It loses its link to the global internet when it moves away from the subnetwork Access Router1. Until conversion to RSU2 is complete, the destination communication has to be routed via HA1-router2 (installed on vehicle destination) through the two-way tunnel. When the destination leaves RSU1's subnet and goes through the handover procedure, it establishes again the tunnel with HA1 and performs the tasks as follows:

i) Tunnelling with RSU1

The destination sends a binding update (BU) report to HA1 through the source instructing it to tunnel its packet to a destination, as still in RSU1's subnet working because both destination and source are in the Ad-hoc network area. The source tunnel that was built during the handover period is depicted in Fig. 7. The binding updates the message's home address, stopping place, and alternate address containing the destination's prior address (IP2) and source's previous address (IP1). HA1 produces a mapping between IP1 and IP2 when it receives a BU message. It is for tunnel packets routed to IP2 via RSU1. Each packet sent to the destination is caught by HA1 and encapsulated before being transmitted to IP1. Then, they were routed to the destination and then decapsulated to remove IP1 from the network. The correspondent node sends IP2 as the intended address (CN).

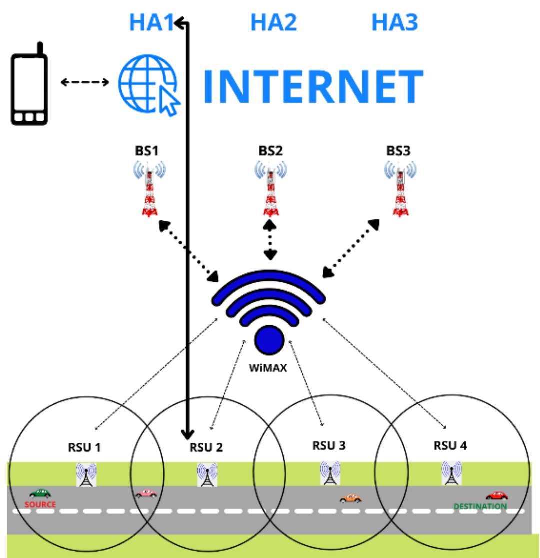

Fig. 7 Tunnelling with RSU1.

ii) HA2 registration and new care-of-address (CoA) configuration

Destination delivers RSU2 a route request communication to config a new CoA (IP3). RSU2 broadcasts a route advert communication, via which the destination receives and configures IP3. Destination checks IP3's rarity by delivering the NA message to RSU2, and accepting the acknowledgment message at the same time.[14]

Destination deletes the earlier home agent (HA1) record after IP3 configuration and registers a new home agent (HA2) by delivering a recent binding update (HA2-BU) communication to HA2. When HA2 receives a back note, it uses RSU2 for tunneling packets to IP3. Destination reaches the service area of a second service provider (ISP2) after completing the handover process, utilizing a distinct access technique from ISP1. ISP2 gives the destination a distinct home address with a different home agent. Source and destination are now linking the cellular network to separate home networks, *i.e.*, on their ingress interfaces, source and destination are advertising different prefixes. Source advertises a prefix that is registered to HA1, while destination advertises a prefix that is recorded to HA2. After the destination has finished the transfer procedure and begun accepting packets via RSU2, vehicles provided with the source will soon be required to undertake handover to RSU2. A source can begin creating a new tunnel via an alternate route, allowing the source to complete the handover with minimal disruption. The source then instructs HA1 to turn its packets to the destination in the RSU2 subnet through the HA2-destination bi-directional tunnel. In this situation, packets having a source address prefix may be dropped if HA2 acts the ingress filtering.[15]

iii) RSU2 tunneling

When the two tunnels come to a halt at different HAs, establish a tunnel with Home Agent 1 via Care-of-Address (CoA) received from the source irrespective of the destination location.

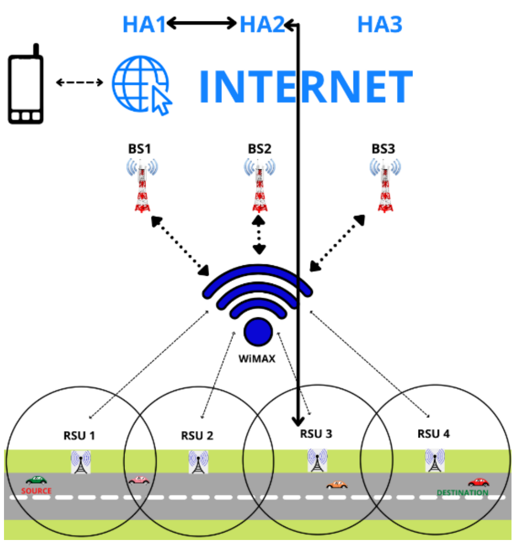

Fig. 8 Tunnelling with RSU1.

Figure 8 depicts the new binding's establishment of a bi-directional tunnel, for which the source performs the following functions:

1. Source gets its entrance and a recent CoA with the same prefix as the destination. It delivers a BU communication to HA1 with the help of the modified CoA. HA1 is able to encapsulate entering packets via the two-way tunnel via destination after receiving a BU message.
2. Packets transmitted to the destination are intercepted by HA1. The binding of CoA with HA1 will form a tunnel with HA1 so that packet can be delivered to a destination via the tunnel. As a result, the packets are encapsulated and sent to the source's new CoA via the HA2-destination two-way tunnel.

Entire traffic in CN and VN will be encapsulated at two layers following a successful BU between source and HA1, the initial level of tunneling is completed, and in destination and HA2, the next level of tunneling is completed. This method enables the destination to deliver and accept packets over the source's two-way tunnel, eliminating the requirement for the source to change HoA and ensuring that ongoing sessions are not interrupted within the handover.

The destination selects whether to stop in RSU1 or shift to RSU2 based on the availableness and intensity of the radio signal from RSU2. The source performs the same sequence of functions as the destination during the handover to RSU2. The same mode will take place in other means of transport that are on the way and attempt to connect to cyberspace globally via various RSUs (RSU1, RSU2..., RSUn).[16]

4. Results and discussion

Table 1 shows the results of simulations done at various parameters to assess the functioning of the proposed system and existing protocol. In model topology, we use abstract functions like HA, CN, the foreign agent (FA), RSU, as well as vehicular node (VN).

Table 1. Simulation parameters.

Parameters	Values
Area of Simulation	10,000*40 m
Time of Simulation	15 ms
ISP Coverage	0-10,000 m
The gap between ISP Range	15000 m
Required Interval	1 s
Number of Vehicles	30
Speed of Vehicles	50 Kmph to 120 Kmph
Ad-hoc Data T/R	4 Mbps
Packet Size	400 Bytes
Ad-hoc Coverage	5000 m

4.1 Latency in handover

The handover delay experienced during the simulation of the proposed method is shown in Fig. 9 and is compared to an existing protocol. For all protocols, handover reaction time in a cellular network is seen as the total duration taken to switch from one access router (RSU1) to another RSU2, and it is proportionate to the range in VN and HA. However, as the existing protocol requires a number of signaling communications to construct a tunnel in RSU1 and RSU2 before conducting HA-BU, the proposed approach has a lower latency than the existing protocol. Another reason for the reduced handover delay is that the second vehicle (source) is able to pre-con its new CoA by receiving router advertisement information from the destination before the present handover.

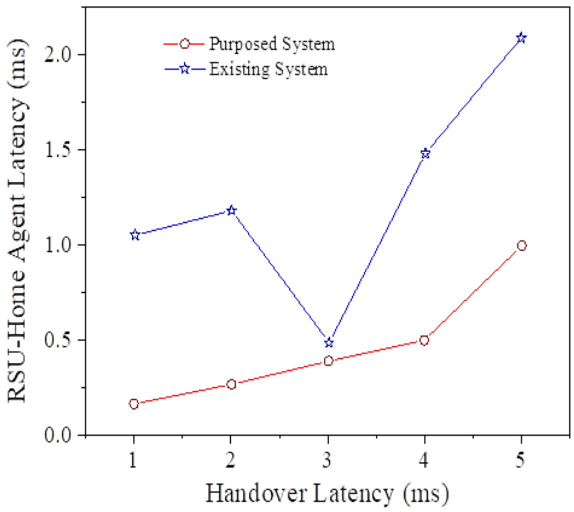

Fig. 9 Latency in handover.

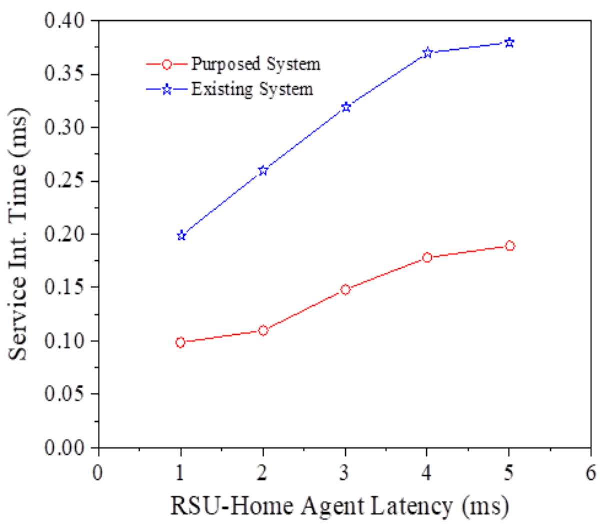

Fig. 10 Duration of service interruption.

4.2 Duration of service interruption

The period between the final packet from RSU1 and the initial packet from RSU2 can be characterized as the service disruption time during handover in an existing protocol. RSU1 and RSU2 have established a tunnel between them. The interval between receiving the final packet through the VN that is about to undergo handover and receiving the initial packet through another VN of the mobile network can be characterized as a service interruption period during handover in the proposed scheme. In terms of VN-HA delay, Fig. 10 vies the service disruption duration of the proposed method to an existing protocol. The existing protocol has a service interruption time of around 0.9 seconds (due to signaling and the time, it takes to construct a tunnel between RSU1 and RSU2), whereas the suggested system has a service disruption time of about 0.2 seconds (because solely, one signaling communication is required to establish again the two-way tunnel). This increases the likelihood that the proposed method will be able to provide smooth network mobility.

Packet Loss

The packet loss during the handover from RSU1 to RSU2 is depicted in Fig. 11. Because of the cooperative packet reception of VNs, the proposed method experiences the least number of packet losses, as seen in the graph. By re-establishing the bi-directional tunnel, packets addressed to the VN that is undergoing handover are received via another VN, and packet loss is independent of the distance between the VN and its HA. The packet loss is independent of VN-HA latency because the existing protocol creates a tunnel between RSU1 and RSU2. The number of lost packets is higher than that of the proposed approach due to the number of signaling messages needed in constructing the tunnel.

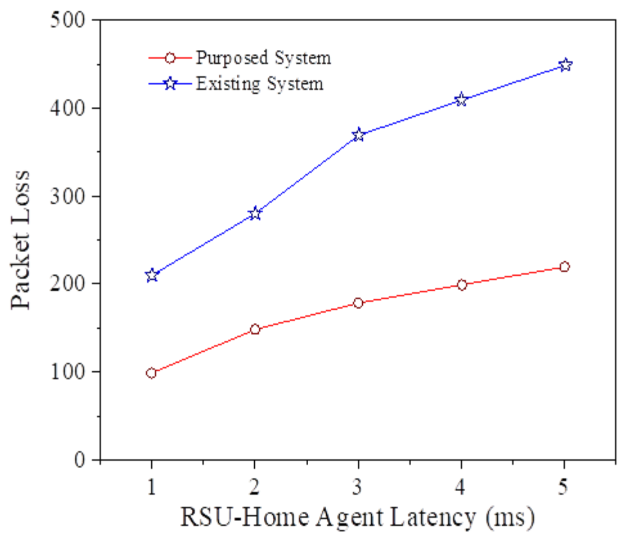

Fig. 11 Packet Loss.

Overhead signaling

In a multiple VNs-based mobile networks, Fig. 12 makes a comparison of the signaling overhead ratio in the existing protocol and the proposed system. The signal exchanging notes, to efficiently manage the handover, such as the communications required for establishing again the two-way tunnel to enable flow redirection of VNs via one another, is known as signaling overhead. Because the cast is involved in maintaining VN signaling messages, the suggested technique has some overhead. In comparison to the existing protocol, it has reduced overhead because FMIPv6 requires a large number of signaling messages to construct a tunnel between RSU1 and RSU2. The suggested technique rises the network's signaling overhead, and the signaling overhead of these protocols rises as VN-HA response time grows.[17]

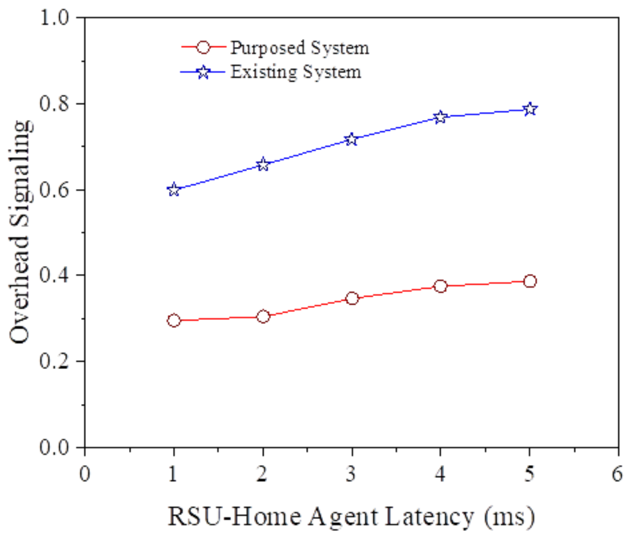

Fig. 12 Signal overhead.

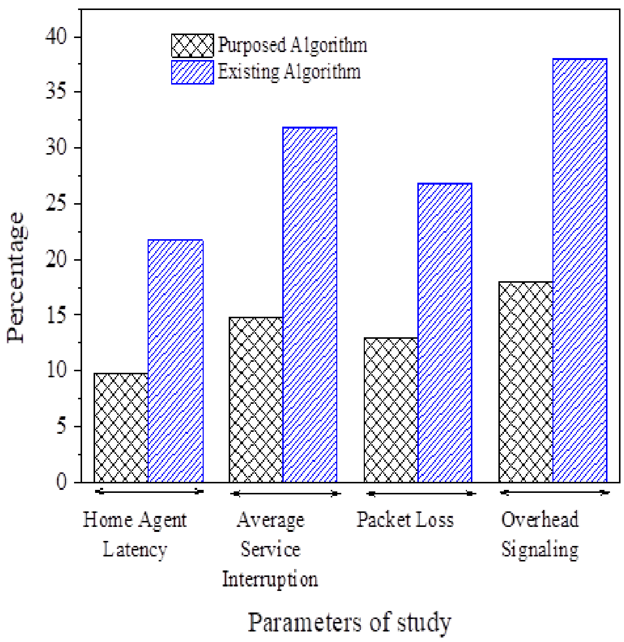

Fig. 13 Comparative study graph depicting the novelty of the work.

5. Conclusion

The suggested architecture allows mobile networks to move seamlessly across heterogeneous networks. A vehicular scenario is one, in which transport is given transportability via several Internet Service Providers (ISPs) and the goal is to employ several vehicular nodes (VN) according to the handover schema in the car. The handover schema based on multiple vehicular nodes (VNs), in which VNs cooperate to receive packets destined for each other, can provide no service disruption and greatly reduce packet loss during handover. It also eliminates the impact of handover latency on packet loss. Also, Fig 13 depicts the novelty of the work as compared to the existing algorithm. Furthermore, the design of multiple vehicular nodes (VNs) is extended to incorporate multiple home agents, each of which belongs to a distinct administrative domain. This enables the vehicle to perform seamless handovers across a heterogeneous network where mobility is offered by many internet service providers (ISPs). As shown in Fig. 13, a detailed simulation analysis is conducted to demonstrate the proposed handover architecture's comparative performance evolutions in terms of throughput, handover latency, service disruption time, packet loss, and signaling overhead. The model findings show that the proposed architecture allows for seamless mobility across heterogeneous networks in a mobile network. Even without improving handover latency, the overlapping reception of packets from separate access routers (RSUs) considerably reduces packet losses while handover.

Conflict of interest

There are no conflicts to declare.

Supporting information

Not Applicable.

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