Wireless Personal Communications (2022) 126:2841–2868
https://doi.org/10.1007/s11277-022-09669-z

Attack Resilient and Efficient Protocol based on Greedy Perimeter Coordinator Routing—Mobility Awareness for Preventing the Attack in the VANET

Naziya Hussain[1,2] · **Priti Maheshwary**[3] · **Piyush Kumar Shukla**[4] · **Anoop Singh**[5]

Accepted: 7 June 2021 / Published online: 1 September 2022
© The Author(s), under exclusive licence to Springer Science+Business Media, LLC, part of Springer Nature 2022, corrected publication 2022

Abstract

A Greedy Perimeter Coordinator Routing and Mobility Awareness (GPCR-MA) vehicular routing is a widely accepted routing protocol for VANET (Vehicular Ad hoc Network). The insufficiency of security measures in the operating design of GPCR-MA gives possible exposure to a Sybil attack. During a Sybil attack, the attacker (usually a vehicle) collects data packets by replicating multiple forged identities of numerous vehicles. The collected data packets are dropped instead of being forwarded. This paper presented a novel strategy to reduce Sybil attacks effect in the network through reduced storage and routing with computational overhead. The process integrates the phony route request to target or destination vehicles, the sequence number of destination vehicles and then further hop information to improve the restrictions of prevailing methods.

Keywords GPCR-MA · Greedy perimeter coordinator routing–attack resilient efficient (GPCR-ARE) · Quality of service (QoS) performance · Vehicular network · Sybil attack · Mobility models

---

✉ Naziya Hussain
naziyahussain@gmail.com

Priti Maheshwary
pritimaheshwary@gmail.com

Piyush Kumar Shukla
pphdwss@gmail.com

Anoop Singh
cmces.edu@gmail.com

[1] Department of CSE, Rabindranath Tagore University (Formerly AISECT University), Bhopal 464993, India

[2] School of Computers, IPS Academy, Indore 452012, India

[3] Rabindranath Tagore University (Formerly AISECT University), Bhopal 464993, India

[4] Department of CSE, UIT, Bhopal 462023, India

[5] CMCC, Mhow, Indore 453441, India

1 Introduction

Ad-hoc networking is the best solution for cooperative driving between cooperative cars on the road [1, 2]. Such networks, recognized as VANETs, communicate to a rapidly developing research field, being a particularly challenging set of Mobile Ad-hoc Networks (MANET). A VANET network has detailed highlights such as disseminated control and controlled networking administration, the expansive quantity of vehicles, high-speed vehicle, obliged however very inconsistent of network configuration. The transmission signals are hindered by buildings and high mobility leads to frequent partition. On the contrary, as different to MANET, no considerable power requires [2]. There is growing research as well as commercial importance in the development and configuration of VANETs [3]. VANET networks are an unusual example of MANETs (Mobile Ad-Hoc Networks) that are completed up of various vehicles moving through city streets and equipped to communicate with one another without the use of a fixed correspondence foundation.

The proposal for VANET's simulations is the wide assortment of models of mobility. The most usually model of mobility in the writing is the Random Waypoint (RWM) model [4]. Each vehicle chooses an arbitrary place of destination and random speed, proceeds to that target, stops, and then after that go-ahead to another indiscriminate goal. Random Walk, Random Direction, & Boundless Simulation Area are the additional open-field comparable models [5]. In which classified the mobility models in VANETs based on how they use existing information. In terms of geographical constraints, the mobility models used in VANETs differ slightly from the mobility models used in MANETs.

VANET technology can be used to communicate among vehicles, and with the improvement of intelligent transportation system applications, the various accidents and energy waste from fossil fuels is estimated to decrease. VANETs use short-range wireless communication (WC) within moving vehicles on the roads.

During a Sybil attack, a malicious vehicle delivers different messages to various other vehicles. Each message reveals separate created source individuality in a way that the original originator is not disclosed. The crucial purpose of the malicious vehicle (attacker) is to provide the false impression to different vehicles by sending incorrect messages & to wrongly encourage them to leave the street for the easy or free passage or other benefits of that malicious vehicle (attacker) as shown in (Fig. 1). Numerous messages revealing the

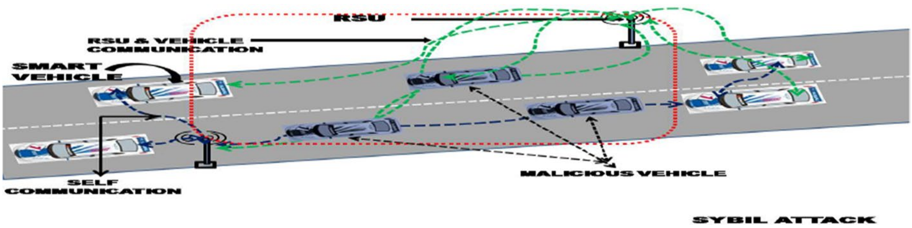

Fig. 1 Sybil Attack [6, 7]

diverse source of fictitious identities are sent by the attacker (malicious vehicle) to several other vehicles. Thus the attacker creates a fake notion of the presence of numerous vehicles on the street using these forged messages and an illusion of a traffic jam condition. Several vehicles fall in the trap and deliberately leave the street on a false notion of a traffic jam ahead providing an advantage to the attacker (malicious vehicle) [6, 7].

2 Related Review

In this section, present the mobility and VANET routing protocol concept related to the present research model. The QoS parameter performance can be increase and decrease of mobility model due to speed, direction variation as well as wireless connectivity with dynamic topologies. [3] Investigate three different mobility models as consider the vehicle movement behaviour and design a estimation method called route probability as well as to measure route setup achievement rate.

[4], investigated the control of a mobility model on the concert of a reactive and proactive vehicular ad-hoc routing protocol. With varying vehicle densities, the packet delivery ratio (PDR), throughput, and average delay are estimated. [5], investigated the effects of Random Walk, reflection, and wrapping, RWP and GPCR performance. The experimental result illustrates that the performance of the protocol such as PDR and delays varies across any various number of vehicles.

[6] Investigated PDR, throughput, and routing overhead in the Random Walk (RW) as well as the Random Waypoint (RWP) mobility model using sensitive routing protocols such as DSR, AODV, and one active routing protocol DSDV. The analysis revealed that the random Walk and RWP mobility models with AODV, DSR and DSDV routing protocols produce the similar performance for the inputs, when paused time is increased, then the performance of the network is also increased. Here demonstrated their movement direction, speed and angle direction for both the mobility models.

[8] Evaluating the Gauss-Markov model of mobility and its effect on network connectivity, hop count the lifetime routes. RWMM has utilized comparator evaluation of simulation results. Comprehensive simulations have been done for the distinctive number of the vehicle, and a different level to the randomness parameters α $(0 \leq \alpha \leq 1)$ to Gauss-Markov model. On networks with a little number of vehicles, network connectivity on Gauss-Markov models is basically lower than the Random Waypoint. In networks with a medium and large number of vehicles, network connectivity on both models practically equivalent. Gauss-Markov model of mobility, usual hop-count per lowest hop way impressively large then under Random Waypoint. The minimum hop path on Gauss-Markov mobility model has shorter route lifetime relate with the Random Waypoint.

There is always a trade-off between the delay and the network capacity at various mobility models. From the literature that has been studied, the characteristic of this trade-off is completely impacted by the optimal of the mobility model [9–11]. Investigate delay as well as capacity trade-off in MANET. System capacity is shared between a numbers of vehicles, hence as the network size grows bigger each vehicle gets smaller throughput, thereby indicate the static ad hoc networks are not accessible. It is important to systematically consider how much delay can be allowed because of vehicle mobility simultaneous as a result of an increase in the network capability.

The concept of average delay to observe several types of vehicle mobility analyzed in the literature from a general aspect and distinguish and compare them [12–16].

The RWP model of mobility was first designed by Johnson and Maltz1 in 1996 [17]. Not long after it turned into a most regularly utilized model of mobility for scientists for VANET networks. RWP Model of mobility is a model that uses the ideas of an interruption time between two cases of mobility. In begin mobile vehicles pick the random goal for movement. The speed of vehicles would be characterized appropriately and ought to be uniform before its movement. The term delay time alludes to the time when vehicle stop for a determined time in the wake of coming to at the goal. After the lapse of respite time, the vehicle again picks the arbitrary goal to move. In the event that the interruption time is set as ’0’ at that point, it implies that it is a nonstop model of mobility [18]. The model of mobility is incorporated into Network Simulator (NS-2) [19]. The RPW model is the most straightforward and simplest to utilize [20, 21].

3 Methodology and Algorithms

The methodology and procedure of the proposed algorithm are designed for securing the network. In which Max HopCount is adjusted the seed hashed of the top Hashfield. When a vehicle receives RREQ or RREP HopCount is verified by hashing Max HopCount by Hashfield. The achieved value of resultant is linked with the top Hashfield. However, if the verification is failed, then the packet is discarded. Prior to rebroadcasting an RREQ or forwarding RREP, a vehicle hashes is the field of Hash in the Signature Extension. Hashfunction field points out that is utilized for the computation of hash. The hashfunction is used by a forwarding vehicle, which is creator of the routing packet. The routing packets have selected due to the field that is already signed. If the vehicle does not support the hashfunction, the forwarding routing packet is dropped.

Algorithm I

```
Assumption: RREP header is improved with an extra field which is Speed of vehicle
in VANET network
Step 1: Source S broadcasts RREQ message to the network.
Step 2: If Destination D responses RREP then S will start transmission.
End
Step 3: If the intermediate vehicle (say Y) replies with RREP and when a packet
reaches to vehicle Y's preceding vehicle@ (say X), it checks the following:
if (Speed of Vehicle** > speed_threshold or SequenceNo** > seq_no_threshold)
Goto Step 4
Else
Goto Step 5
Step 4:   If (hopcount** >= 2)
Vehicle X will send a Modified Hello signal (MHELLO) with HopCount equal to 2
(in case hopcount** = 2)        or
HopCount equal to 3 (in case hopcount** > 2) to a Vehicle@@ (say Z) which is few
hops (equal to hopcount**) away from X.
If X receives acknowledgment from Z successfully then X forwards RREP to S and S
will transmit the data.
    Else
 Vehicle next to Y is SYBIL ATTACK and an alert signal will be transmitted by X to
 S.
     Else
 Vehicle Y is SYBIL ATTACK vehicle and an alert signal will be transmitted by X to
 S.
 Step 5:  X forwards RREP to S and S will transmit the data.
```

Note: - MHELLO is same as HELLO packet with hop count = hopcount**.
The threshold value is **updated every time** the intermediate vehicle receives an RREQ packet.
The threshold value of sequence no is calculated as

seq_no_threshold = seq_no (of RREQ packet) * hop count

Threshold value of vehicle speed is taken as

speed_threshold = 100 m/s

** All the values have to be taken from the RREP received from intermediate vehicle Y.
@Precedingvehicle X is in the direction in which RREP is traversing from Y towards S.
$^{@@}$ Z vehicle is in the path through which RREP packet has reached Y.

As per the routing protocol of GPCR-MA [21], a source vehicle needs to transmit the RREQ packet to locate a trail to arrive at the target or destination vehicle. The target vehicles, or some transitional vehicles along the path, can the reply back to that source vehicle. By default, then the source vehicle acknowledges the initial fresh RREP packet delivered to it. However, in routing protocol of GPCR-ARE [22, 23], the target or destination vehicle or any intermediate vehicle while generating the RREP packet also creates another packet of RREP. This is a sort of authentication of the primary packet attached with a sequential number increased by one count.

Hence, there are 2 (two) RREP packets from the destined or destination vehicle or any transitional vehicle that happen to along the route to final destination. One packet carries a normal sequence no. while the other packet bears an incremented value by one count (+ 1) of the previous sequence code. Both packets have the value ‘0’ set in the field ‘VERIFIED’. When an intermediate vehicle obtains an RREP packet, it preserves the data regarding the reply-packet. After that, it verifies our attached field ‘VERIFIED’ whether it is 0 or 1. If the field value is found as 0, it meant that the packet is yet to be verified or can be an invalid packet. The value as 1 proves the verification and validity of the packet. Hence, it should be forwarded to its destination or next vehicle. The flow chart of the proposed methodology mention in Fig. 2.

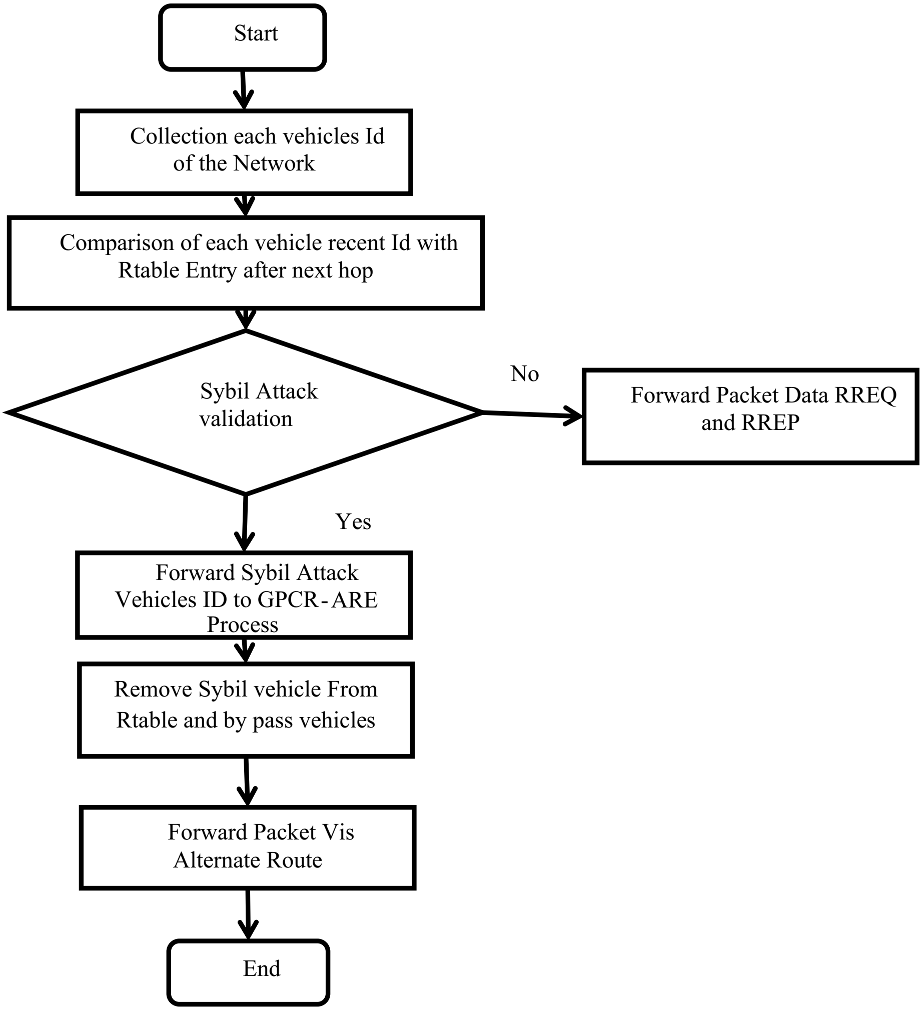

Fig. 2 Flow chart of GPCR-ARE for Sybil Attack

Table 1 Scenario Parameters for the current research in NS-2 [24]

Parameters	Values
MAC layer protocol (Wireless)	IEEE 802.11
Network Simulator	NS2.35
Application Layer	TCP
Routing protocols	GPCR-MA, & GPCR-ARE
Channel mode	Wireless channel
No. of Vehicles	20; 40; 60; 80; and 100
Simulation time	100; 200; 300; 400 & 500 Seconds
Traffic type	CBR
Mobility paradigm	Freeway, Manhattan, Gauss-Markov, RPGM & Random Way Point
Simulation district	900×900
Performance Metrics	Packet Delivery Ratio, Average network Throughput, Average Energy, and Average Delay
Interface queue type	Tail/Drop/PriQueue
Antenna type	Omni-directional
Network interface mode	Phy/WirelessPhy
Radio-propagation pattern	Two-ray ground

4 Experimental Analysis: Performance Metrics

A VANET topology consider with no. of vehicle for the simulation. The no. of vehicles are deployed with the help of different mobility inside the simulation area. The speed is fixed in all the mobility model but direction of the vehicle are depend on the mobility model structure. The simulation parameter which is used in this research are mention in (Table 1).

As per the simulation obtained data during simulation and extract the QoS parameter such as Average end-to-end delay, Average energy consumption, Average network throughput and PDR (packet deliver ratio) using the following formula.

1. Average end-to-end delay

Here, the Eq. (1) represents the formula of Average end-to-end delay, while the total number of successfully delivered packets.

$$Average\ end-to-end\ delay = \frac{\sum_{i=1}^{n} (Received\ Packet\ Time - Send\ Packet\ Time) \times 1000(ms)}{Total\ Number\ of\ Packets\ Delivery\ Successfully} \tag{1}$$

2. Average Energy Consumption

The consumption of entire energy is the sum total of use up the energy of overall vehicles in the network and spend energy of the vehicle is the summing up of energy used for communication.

2. Average network throughput

Here, the Eq. (2) represents the mathematical formula of throughput where PacketSize represents the size of the ith packet which reaches to the destination; the arrival time of the last packet is designated as PacketArrival while the arrival time of the first packet is marked as PacketStart

$$Throughput = \frac{Packet\ Size}{(Packet\ Arrival - Packet\ Start)} \tag{2}$$

4. Packet Delivery Ratio (PDR)

Mathematical formula to calculate PDR is stated as below.

$$\text{Packet delivery ratio} = \frac{\text{Received packets}}{\text{Generated packets}} \tag{3}$$

5 Simulation Results Analysis

Mobility extends, vehicle speed, and vehicle number are the requirements that should be established for mobility arrangement. In this paper, a road network based on the highway, Gauss Markov, Freeway, Manhattan, RPGM, and RWP mobility models is simulated for the standards 802.11p with the help GPCR-MA and GPCR-ARE protocols.

5.1 Relative Study of Mobility Models Based on GPCR-MA Vanet Protocol on the Simulation

Table 2 displayed the performance value of data transmission delay and energy consumption, which is consumed by data packet transmission based on network state change. According to the table, the maximum delay for Freeway, Gauss-Markov, Manhattan, RPGM, and RWP is 206.37, 203.67, 208.58, 127.14, and 130.39. When the entire mobility model is compared, the RPGM outperforms the other mobility models. Our research did not have a significant impact on the study.

In this Section GPCR-MA Vanet Routing performance presented in Tables 2, 3 with respect graphical representation in Figs. 3, 4. Here, Vanet mobility models examination at 100–500 s of simulation time through GPCR-MA. The Vanet mobility models (Freeway Gauss Markov, Manhattan, RPGM and RWP) performance demonstrates at various simulation time in respect of average delay, consumption of energy during the average network throughput, network, and PDR.

Table 3 displayed the throughput performance value, which indicates the number of packets delivered to the receiver side, and PDR, that indicates network performance as per rapidly changing network size. The maximum average throughput as well as PDR values for Freeway, Gauss Markov, Manhattan, RPGM, and RWP are 71.1, 64.79, 62.79, 72.21, 74.44, and 98.75, 98.76, 98.71, 98.75, 98.75, respectively. When compared to RPGM, these entire mobility models have significantly higher network performance. If the network changes quickly, RPGM has 98 percent network performance.

Table 2 Comparison study for mobility models in terms of average delay & energy consumption using GPCR-MA based on simulation time

Simulation time	Average delay					Average energy consumption				
	Freeway	Gauss-markov	Manhattan	RPGM	RWP	Freeway	Gauss-markov	Manhattan	RPGM	RWP
100	124.51	199.69	121.78	126.09	122.51	19.8	19.8	19.8	19.8	19.8
200	192.58	194.8	683.7	**127.14**	127.71	19.8	19.8	16.2	19.8	19.8
300	206.36	216.66	**208.58**	122.9	**130.39**	19.8	19.8	19.8	19.8	19.8
400	122.95	**203.67**	217.2	126.66	127.17	19.8	19.8	19.8	19.8	18
500	**206.37**	126.39	110.09	122.45	122.36	19.87	19.8	16.2	19.8	19.8

Bold values indicate the higher performance as compare to other protocols

Table 3 Comparative study of performance on the basis of the time of simulation applying protocol for GPCR-MA in respect of average throughput and PDR for models of mobility

Simulation time	Average throughput					Packet delivery ratio				
	Freeway	Gauss-markov	Manhattan	RPGM	RWP	Freeway	Gauss-markov	Manhattan	RPGM	RWP
100	69.47	61.66	60.53	59.58	66.08	**98.75**	48.38	**98.71**	**98.75**	**98.75**
200	70.02	63.53	15.45	56.87	70.3	48.78	48.86	16.66	98.63	98.63
300	64.47	**64.79**	60.56	**72.21**	71.35	48.86	48.78	48.88	98.71	98.59
400	**71.1**	64.46	**62.79**	57.65	**74.44**	98.71	48.86	32.22	98.61	98.64
500	66.22	52.09	17.74	71.24	64.71	48.86	**98.76**	16.66	**98.75**	98.64

Bold values indicate the higher performance as compare to other protocols

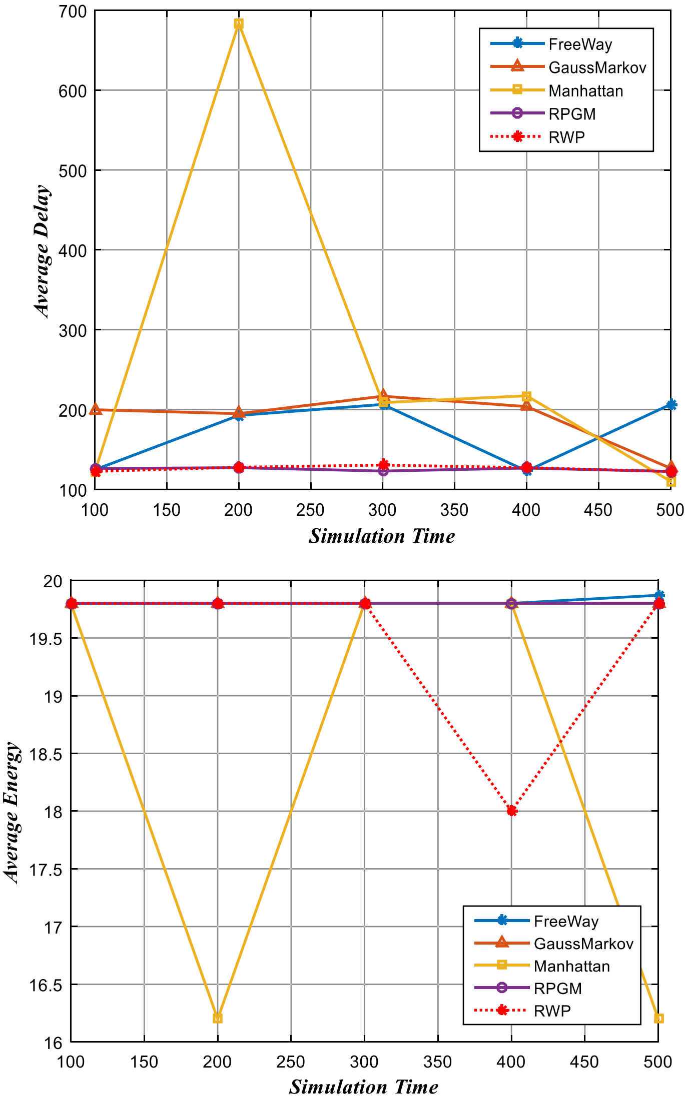

Fig. 3 Comparison of the average delay and energy consumption for mobility model on the basis of the time of simulation applying protocol for GPCR-MA

Figure 3 with their performance table shows the energy consumption. The energy consumption did not show much change over the routing and model of mobility, its value changed due to main 2 reasons (i) density of network traffic & (ii) network running time span. Each vehicle follows from source course to its destination within the network vicinity and the process of transmission for each data packet exhausts the energy unit, hence on that basis, the energy consumption has increased. This consumption can further increase with the increase of the traffic density or the network range. But all these models of mobility are not showing a large amount of difference, this network does not fully depend on the energy,

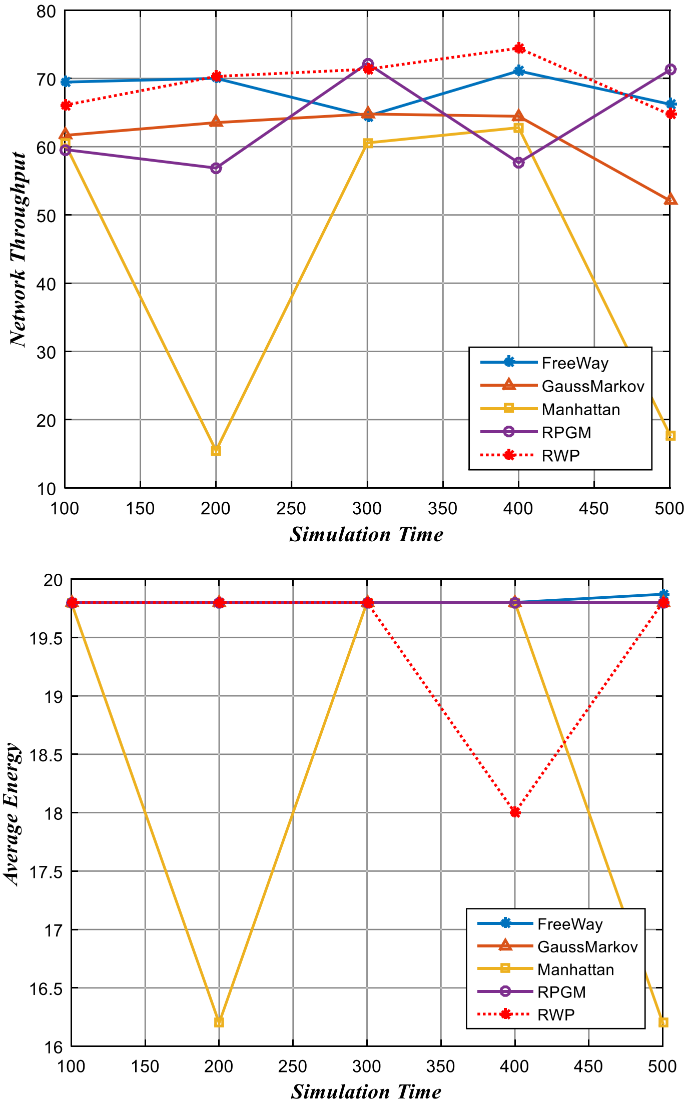

Fig. 4 Comparative study for mobility in terms of average throughput & PDR on the basis of the time of simulation applying protocol for GPCR-MA

it requires to start the network or network connection can communicate or we can say they manage their connection to other vehicles.

Figure 4 with respect to their performance in Table 3, indicating a better or higher packet delivery ratio when comparing these five mobility models, with RPGM having the highest PDR. Both scenarios of amplified network density & quickly transformed simulation time are compared. Network traffic is directly related to network, which implies enhanced PDR as every one vehicle has a better option in communication and gets more

Table 4 Comparative study of performance on the basis of the time of simulation applying protocol for GPCR-ARE in respect of average delay and energy consumption for models of mobility

Simulation time	Average delay					Average energy consumption				
	Freeway	Gauss-markov	Manhattan	RPGM	RWP	Freeway	Gauss-markov	Manhattan	RPGM	RWP
100	121	89.49	117.68	122.68	123	9	9	9	9	9
200	109	106.4	71.56	121.74	124.52	9	9	9	9	9
300	95.6	95.6	67.2	124.31	121	9	9	9	9	9
400	105.1	104.1	118.5	125.32	121	9	9	9	9	4.5
500	101.6	105.96	113.61	125.78	122	9	9	9	9	9

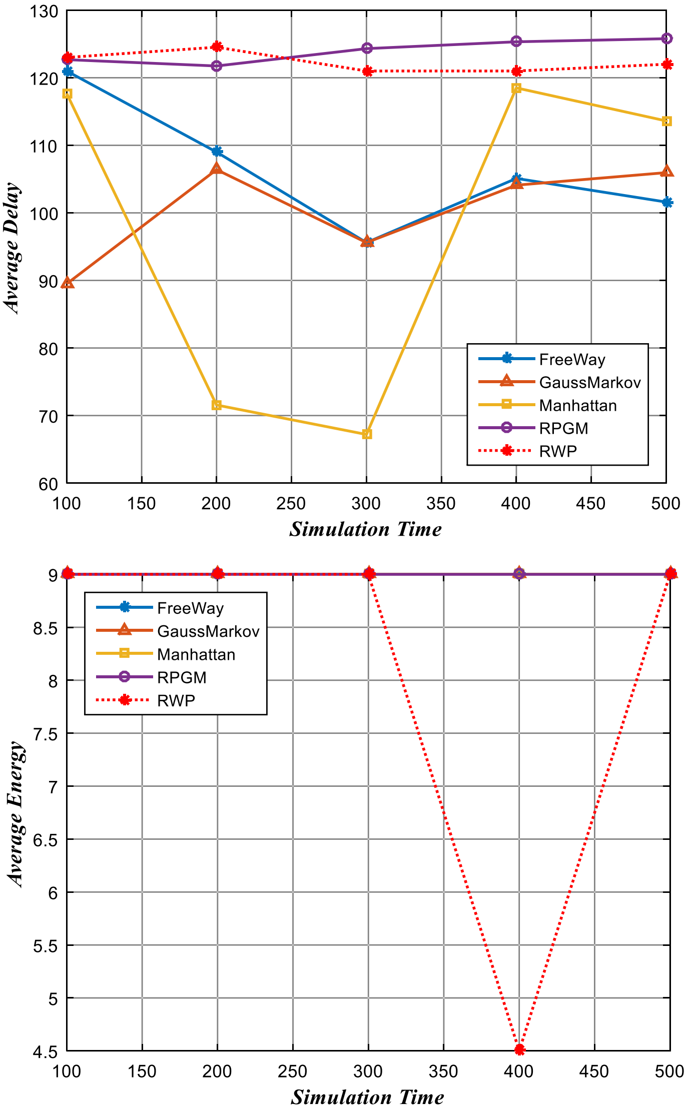

Fig. 5 Comparison of energy consumption and average delay for mobility model on the basis of the time of simulation applying protocol for GPCR-ARE

opportunity to locate a vehicle, which can be used to uncover an improved route from the sender to receiver vehicle.

5.2 Relative Study of Mobility Models of GPCR-ARE Vanet Protocol on the Basis of the Simulation Time Variation

Table 4 and Fig. 5, displayed the performance value of data transmission delay and energy consumption, which is consumed by data packet transmission based on network state

Table 5 Comparative study of performance on the basis of the time of simulation applying protocol for GPCR-ARE in respect of average throughput and PDR for models of mobility

Simulation Time	Average throughput					Packet delivery ratio				
	Freeway	Gauss-markov	Manhattan	RPGM	RWP	Freeway	Gauss-markov	Manhattan	RPGM	RWP
100	94.71	84.08	72.33	76.69	76.34	69.7	93.97	71	67.18	69.6
200	122.98	71.56	67.8	71.2	72.88	99.51	86.79	97.48	67.91	70
300	132.42	78.52	70.34	77.43	84.75	99.68	99.63	88.98	68.13	71
400	94.81	79.44	70.63	80.74	81.99	99.26	94.21	95.82	67.82	69.8
500	72.7	82.04	69.86	77.01	71.35	85	79.1	98.64	68.12	72

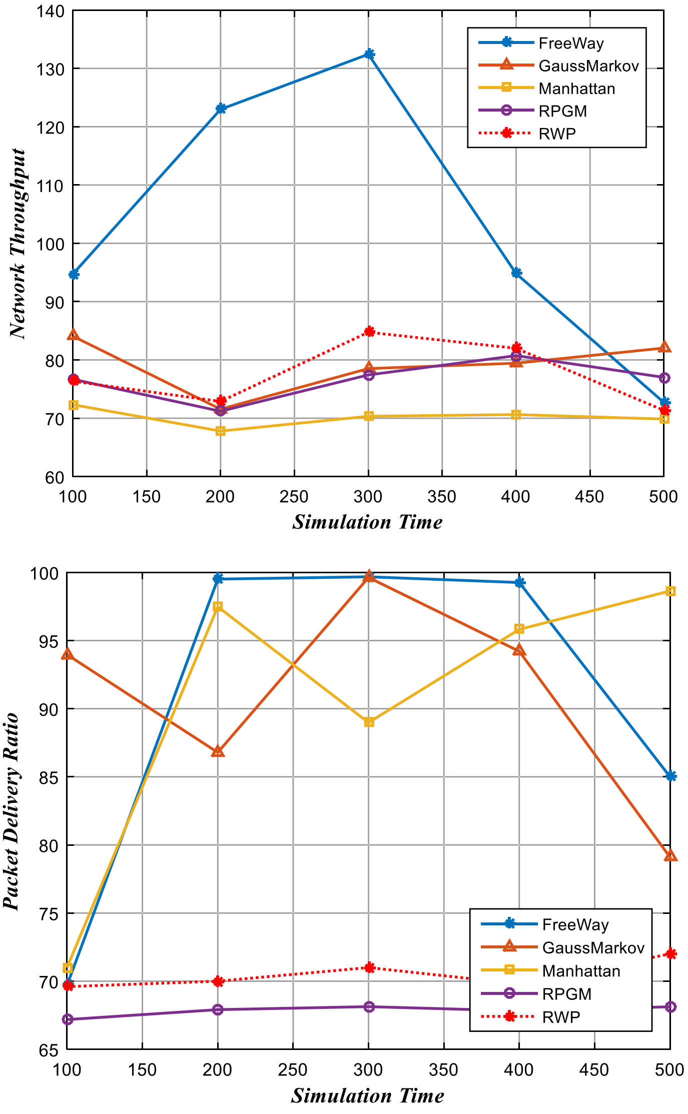

Fig. 6 Comparison of average throughput and PDR for mobility model on the basis of the time of simulation applying protocol for GPCR-ARE

change. According to the table, the maximum delay for Freeway, Gauss-Markov, Manhattan, RPGM, and RWP When the entire mobility model is compared, the RPGM outperforms the other mobility models. Our research did not have a significant impact on the study.

Table 5 and Fig. 6 displayed the throughput performance value, which indicates the number of packets delivered to the receiver side, and PDR, that indicates network performance based on quickly changing network state. The highest values of throughput and PDR are 70.02, 64.79, 65.85, 72.55, 76.30, and 58.65, 98.76, 98.71, 96.75, 95.63, for Freeway, Gauss-Markov, Manhattan, RPGM, and RWP, respectively. As per compare mobility model performance QoS values according to network simulation time. RPGM mobility model network performance for GPCR-ARE routing protocol consistently maintained 96%.

5.3 Relative Study of Mobility Models of GPCR- MA Vanet Protocol on the Basis of the Number of Vehicle Variation

Based on simulation, Table 6 and Fig. 7 presented the QoS performance value of average delay as well as energy consumption. In GPCR-MA, the maximum delay is 683.52, 258.54, 688.42, 129.94, and 130.34 all four-mobility model respectively.

Table 7 and Fig. 8, displayed the performance value of average throughput and PDR based on rapidly changing network traffic. The highest values of throughput and PDR are 224.97, 185.92, 202.37, 229.45, 178.51 and 98.66, 98.75, 98.66, 98.71, 98.75 for Freeway, Gauss-Markov, Manhattan, RPGM, and RWP, respectively. When we compare all mobility model values based on network traffic. RPGM and RWP mobility models network performance consistently maintained 98% in GPCR-MA routing routing.

5.4 Relative Study of Mobility Models of GPCR-ARE Vanet Protocol on the Basis of the Number of Vehicle Variation

Table 8 and Fig. 9, shows the performance value of average delay in packet transmission and energy consumption based on vehicle variation. The maximum value of average delay is 683.52, 334.52, 588.42, 290.04, and 333.20 for Freeway, Gauss-Markov, Manhattan, RPGM and RWP respectively in GPCR-ARE.

Table 9 and Fig. 10, displayed the network throughput and packet delivery ratio performance values based on rapidly changing network traffic. PDR values for Freeway, Gauss-Markov, Manhattan, RPGM, and RWP are 79, 78.76, 48.86, 97.75, and 96.15, respectively. When all mobility model values based on network traffic were compared, it appeared that this combination RPGM > RWP > Freeway > Gauss-Markov > Manhattan in GPCR-ARE Vanet routing.

6 Conclusion

We offer a proposal for a novel way out or solution to remove the attack effect from the vehicular network using fabricated request message as well as next hop information to mitigate Sybil attacks through a reduction in computational, storage overhead, & routing. Based on the proposed method, we have done practical and observed the above results, which reveal the reduction in delivery delay from end to end and increase in performance of throughput as well as in packet delivery ratio.

Table 6 Comparative study of performance on the basis of network traffic density applying protocol for GPCR- MA in respect of average delay and energy consumption for models of mobility

Number of Vehicles	Average delay					Average energy consumption				
	Freeway	Gauss-markov	Manhattan	RPGM	RWP	Freeway	Gauss-markov	Manhattan	RPGM	RWP
20	183.1	234.52	129.57	125.82	123.24	19.8	19.8	19.8	19.8	19.8
40	118.87	199.48	118.73	**129.94**	127.13	19.8	19.8	19.8	19.8	19.8
60	354.02	126.67	199.48	124.55	124.58	16.2	19.8	19.8	19.8	19.8
80	**683.52**	**258.54**	**688.42**	128.01	**130.34**	16.2	16.2	16.2	19.8	19.8
100	126.94	123.22	193.48	121.29	123.18	19.8	19.8	19.8	19.8	19.8

Bold values indicate the higher performance as compare to other protocols

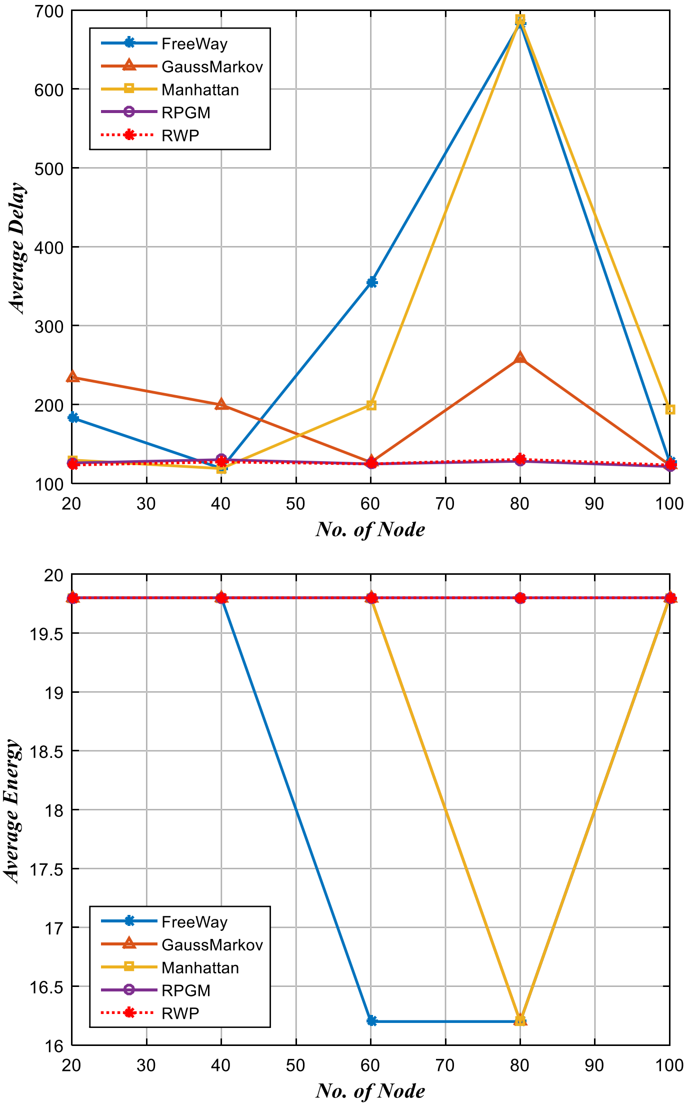

Fig. 7 Comparison of average delay and energy consumption for mobility model on the basis of network traffic density applying protocol for GPCR- MA

Table 7 Comparative study of performance on the basis of network traffic density applying protocol for GPCR-MA in respect of average throughput and PDR for models of mobility

Number of Vehicles	Average throughput					Packet delivery ratio				
	Freeway	Gauss-Markov	Manhattan	RPGM	RWP	Freeway	Gauss-Markov	Manhattan	RPGM	RWP
20	67.01	60.93	64.27	60.36	69.5	48.75	32.4	48.78	98.59	98.7
40	107.35	89	86.17	76.33	95.85	**98.66**	98.71	**98.66**	**98.71**	98.66
60	43.03	150.02	111.19	161.76	146.79	65.55	98.66	48.86	98.68	98.68
80	153.45	44.57	129.26	215.53	169.44	89.88	96.66	58.66	98.66	98.63
100	**224.97**	**185.92**	**202.37**	**229.45**	**178.51**	98.64	**98.75**	48.58	98.7	**98.75**

Bold values indicate the higher performance as compare to other protocols

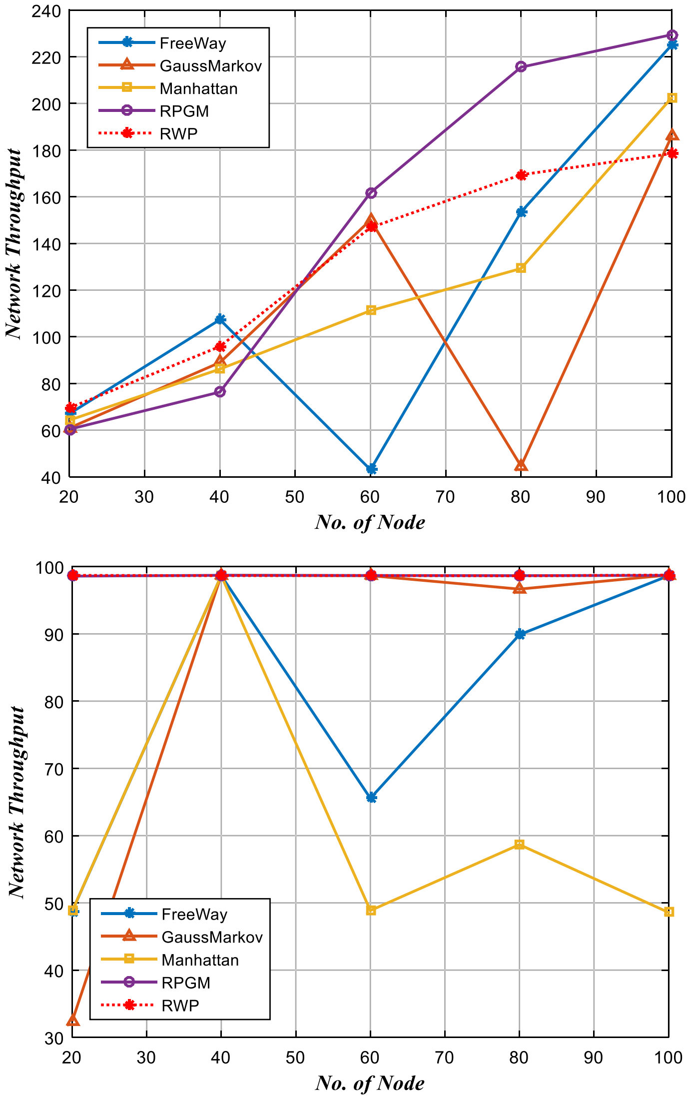

Fig. 8 Comparison of average throughput and PDR for mobility model on basis of on network traffic density applying protocol for GPCR-MA

Table 8 Comparative study of performance on the basis of network traffic density applying a protocol for GPCR-ARE in term of average delay and energy consumption for models of mobility

Number of vehicles	Average delay					Average energy consumption				
	Freeway	Gauss-markov	Manhattan	RPGM	RWP	Freeway	Gauss-markov	Manhattan	RPGM	RWP
20	69	95.4	79.34	120.59	124.58	9	9	9	9	9
40	111.3	119.2	114.51	123.3	123.71	4.5	4.5	4.5	4.5	4.5
60	94	121.67	85.63	119.69	123.61	3	3	3	3	3
80	107	124.9	104.69	123.71	122.56	2.25	2.25	2.25	2.25	2.25
100	106	124.58	113.9	122.67	122.48	1.8	1.8	1.8	1.8	1.8

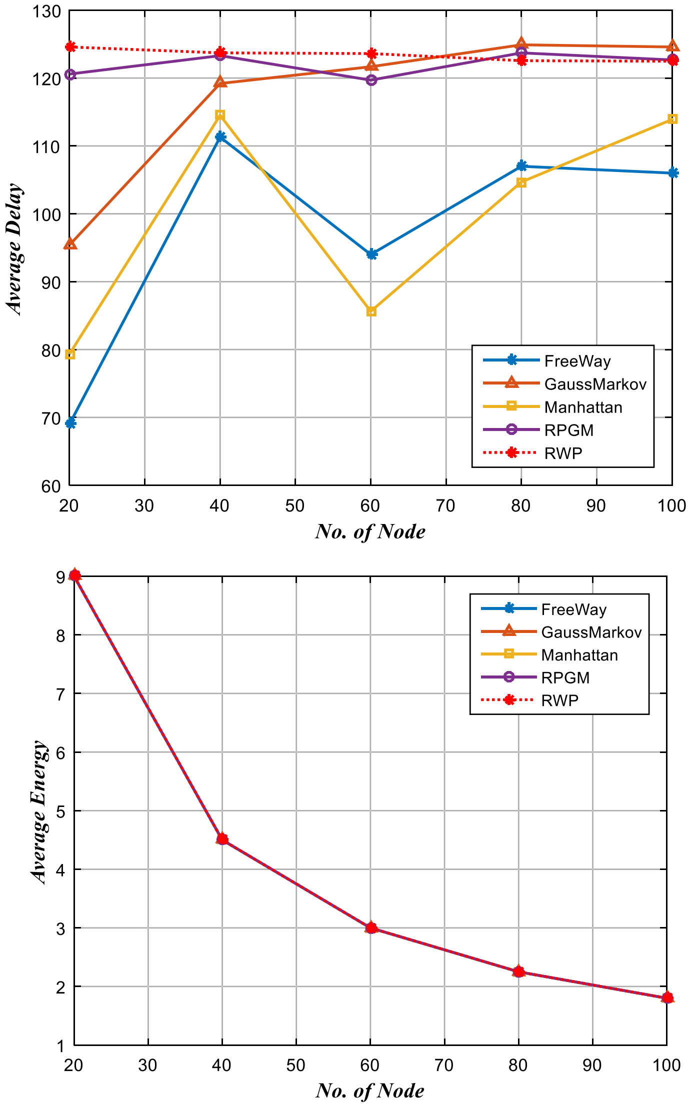

Fig. 9 Comparison of average delay and energy consumption for mobility model on basis of on network traffic density applying protocol for GPCR-ARE

Table 9 Comparative study of performance on the basis of network traffic density applying a protocol for GPCR-ARE in term of average throughput and PDR for models of mobility

Number of vehicles	Average throughput					Packet delivery ratio				
	Freeway	Gauss-markov	Manhattan	RPGM	RWP	Freeway	Gauss-markov	Manhattan	RPGM	RWP
20	67.7	83.06	71.18	72.33	75.16	45.25	75.48	48.18	96.59	95.5
40	84.26	88.17	74.03	93.6	80.52	33.66	78.71	48.66	96.7	95.66
60	80.13	96.74	80.75	98.96	84.84	67	**78.76**	**48.86**	97.08	95.88
80	104.92	88.39	89.09	102.96	98.23	**79**	76.76	48.85	97.16	96.11
100	95.96	84.23	81	86.12	100.7	68.64	78.25	48.84	**97.75**	**96.15**

Bold values indicate the higher performance as compare to other protocols

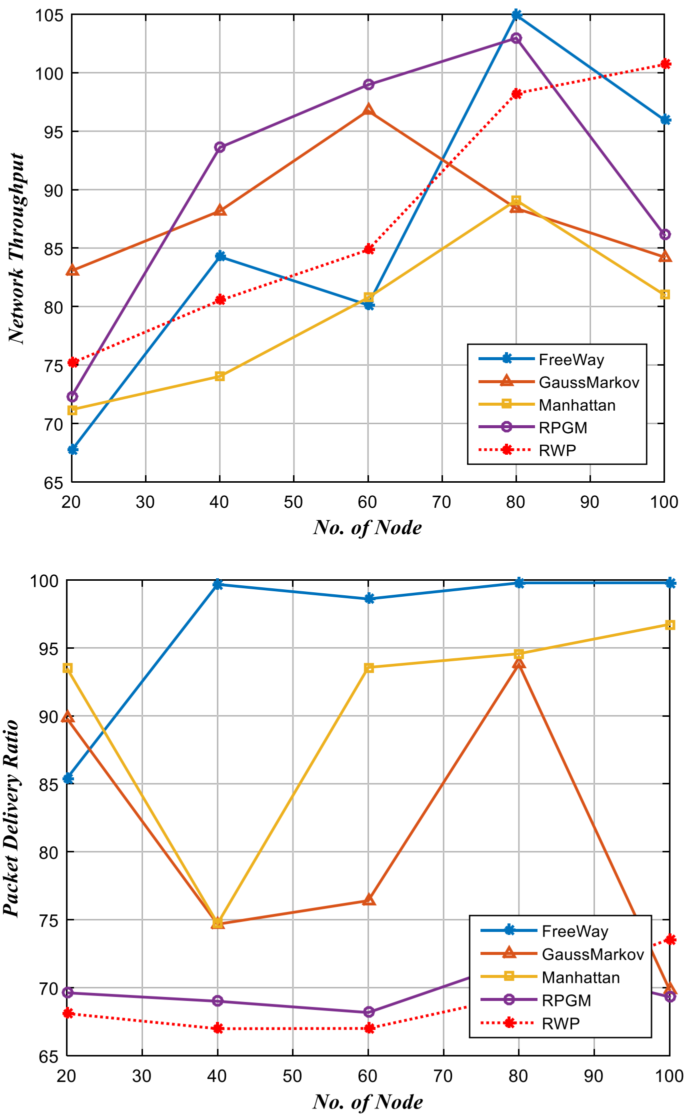

Fig. 10 Comparison of PDR and average throughput for mobility model on basis of on network traffic density applying protocol for GPCR-ARE

Funding The authors have no funding was received for this manuscript.

Data availability Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

Declarations

Conflict of interest The authors have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Fiore, M., Harri, J., Filali, F., & Bonnet, C. (2007, March). Vehicular mobility simulation for VANETs. In *40th Annual Simulation Symposium* (ANSS'07) (pp. 301-309). IEEE.
2. Lee, K. C., Lee, U., & Gerla, M. (2010). Survey of routing protocols in vehicular ad hoc networks. *Advances in vehicular ad-hoc networks: Developments and challenges*, 149–170.
3. Bai, F., Sadagopan, N., & Helmy, A. (2003). The IMPORTANT framework for analyzing the impact of mobility on performance of RouTing protocols for adhoc NeTworks. *Ad hoc networks, 1*(4), 383–403.
4. Bustamante, D. R. C. F. E. (2005). An integrated mobility and traffic model for vehicular wireless networks. In: *Second ACMinternational workshop on vehicular ad hoc networks* (VANET'05).
5. Camp, T., Boleng, J., & Davies, V. (2002). A survey of mobility models for ad hoc network research. *Wireless communications and mobile computing, 2*(5), 483–502.
6. Bai, F., Sadagopan, N., & Helmy, A. (2003, March). IMPORTANT: A framework to systematically analyze the Impact of Mobility on Performance of RouTing protocols for Adhoc NeTworks. In *IEEE INFOCOM 2003. Twenty-second Annual Joint Conference of the IEEE Computer and Communications Societies* (IEEE Cat. No. 03CH37428) (Vol. 2, pp. 825-835). IEEE.
7. Hussain, N., Singh, A., & Shukla, P. K. (2016). In depth analysis of attacks & countermeasures in vehicular ad hoc network. *International Journal of Software Engineering and Its Applications, 10*(12), 329–368.
8. Davies, V. A. (2000). *Evaluating mobility models within an ad hoc network* (Master's thesis, advisor: Tracy Camp, Department of mathematical and computer sciences. Colorado School of Mines).
9. Saha, A. K., & Johnson, D. B. (2004). Modeling mobility for vehicular ad-hoc networks. In: *Proceedings of the 1st ACM international workshop on Vehicular ad hoc networks* (pp. 91–92). ACM.
10. Choffnes, D. R., & Bustamante, F. E. (2005). An integrated mobility and traffic model for vehicular wireless networks. In *Proceedings of the 2nd ACM international workshop on Vehicular ad hoc networks* (pp. 69–78). ACM.
11. Zuhairi, M., Zafar, H., & Harle, D. (2012). The impact of mobility models on the performance of mobile Ad Hoc network routing protocol. *IETE Technical Review, 29*(5), 414–420.
12. Rai, A. P., Datia, S. R. I. T. S., Srivastava, V., Gwalior, I. T. M., & Khare, P. (2014). Effect of Mobility Models on the performance of Proactive and Reactive Routing Protocols. *International Journal of Engineering and Innovative Technology* (IJEIT), 3(12).
13. Rani, P., Sharma, N., & Singh, P. K. (2011, September). Performance comparison of VANET routing protocols. In: *Wireless communications, networking and mobile computing* (WiCOM), 2011 7th international conference on (pp. 1–4). IEEE.
14. Ahmad, N., & Hussain, S. Z. (2013). Performance analysis of adaptive routing protocol based on different mobility model with varying network size.
15. Meghanathan, N. (2010). Impact of the gauss-markov mobility model on network connectivity, lifetime and hop count of routes for mobile ad hoc networks. *JNW, 5*(5), 509–516.
16. Sharma, G., Mazumdar, R., & Shroff, N. B. (2007). Delay and capacity trade-offs in mobile ad hoc networks: a global perspective. *IEEE/ACM Transactions on Networking (ToN), 15*(5), 981–992.
17. Muhtadi, A., Perdana, D., & Munadi, R. (2015). Performance Evaluation of AODV, DSDV, and ZRP Using Vehicular Traffic Load Balancing Scheme on VANETs. *International journal of simulation system, science and technology*.
18. Perdana, D., & Sari, R. F. (2013). Mobility models performance analysis using random Dijkstra algorithm and Doppler Effect for IEEE 1609.4 standard. *International journal of simulation, systems, science, and technology, united kingdom simulation society*.
19. Liang, B., & Haas, Z. J. (2003). Predictive distance-based mobility management for multidimensional PCS networks. *IEEE/ACM Transactions on Networking, 11*(5), 718–732.
20. Ariyakhajorn, J., Wannawilai, P., & Sathitwiriyawong, C. (2006, October). A comparative study of random waypoint and gauss-markov mobility models in the performance evaluation of manet. In: *Communications and information technologies*, 2006. ISCIT'06. International symposium on (pp. 894–899). IEEE
21. Hussain, N., Maheshwary, P., Shukla, P. K., & Singh, A. (2017). *Simulation-based performance evaluation of GPSR and modified-GPCR routing protocols in vehicular Ad-hoc Network*. IJCSIS.
22. Hussain, N., Maheshwary, P., Shukla, P. K., & Singh, A. (2018). Attack resilient & efficient QoS based GPCR-ARE Protocol for VANET. *International Journal of Applied Engineering Research, 13*(3), 1613–1622.
23. Hussain, N., & Rani, P. (2020). Comparative studied based on attack resilient and efficient protocol with intrusion detection system based on deep neural network for vehicular system security. In: *Distributed Artificial Intelligence* (pp. 217–236). CRC Press.
24. https://www.isi.edu/nsnam/ns

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.

Dr. Naziya Hussain received her Bachelor's degree in Computer Science & Engineering, MITM, Indore in 2006, M. E. (Computer Science & Engineering) in 2010 from IES IPS Academy Indore, and PhD (Computer Science & Engineering) in 2020 from Department of CSE, Rabindranath Tagore University (Formerly AISECT University), Bhopal, M.P. India. She is working as a Assistant Professor in SOC, IPS Academy, Indore, India. She is Member of CSI (Life Member), ISTE, IAENG. Her research areas are Computer Network, Wireless Network, Ad-hoc Network and VANET. She has published more than 16 Research Papers in various International Journals & Conferences .

Dr. Priti Maheshwary is an Associate Professor in Computer Science and Engineering department and Director, Centre of Excellence for IoT & Advanced Computing (CIoTAC) at Rabindranath Tagore University (Formerly known as AISECT University), Bhopal. She had her Doctorate from MANIT, Bhopal in Remote Sensing Image Retrieval. She has completed research project on Climate Change detection and monitoring funded by SAC and Environment Monitoring using Sensor devices funded by AISECT University. Ongoing Project is on Crop Monitoring sponsored by SAC. She is the author of more than 20 publications in different journals of repute out of which two journal papers and two conference papers on IoT. She is the author of book chapter on Software Copyright. Her interests include Internet of Things, Cyber Physical Systems, Mobile Networks, WSN, Adhoc Networks, Data mining, and Image Processing. Her work experience includes 20 years in teaching computer science and engineering. She is guiding PhD in the field of image processing, IoT and Networks .

Dr. Piyush Kumar Shukla received his Bachelor's degree in Electronics & Communication Engineering, LNCT, Bhopal in 2001, M. Tech (Computer Science & Engineering) in 2005 from SATI, Vidisha and Ph.D. (Computer Science & Engineering) in 2013 from RGPV, Bhopal. M.P. India. He is Member of ISTE (Life Member),IEEE, IACSIT, IAENG. Currently he is working as an Assistant Prof. in Department of Computer Science & Engineering, UIT-RGPV Bhopal. He is also I/C of PG Programs in DoCSE, UIT, RGPV. He has published more than 60 Research Papers in various International & National Journals & Conferences .

Anoop Singh received his B. Sc. from DAVV Indore in 1987; PGDM from IMT Gaziyabad, Delhi in 1989; and MBA (Public System Management) from FMS, University of Delhi, India in 1991. His research areas are computer networks, ad-hoc networks, and VANET. He has published more than 15 research papers in various international journals and conferences. He is currently working as a Dean at IPS Academy Indore, looking after academic and administrative work. He is also nominated Director of CMCC as well as CMCES.