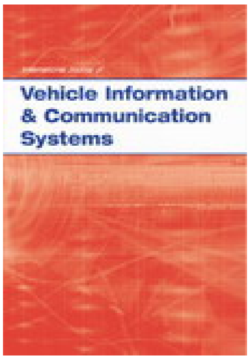

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Performance analysis of routing protocols for vehicular networks

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Abstract: With the advancement in the transportation system the need for faster data dissemination is the prime requirement of the network. VANET is a widely used network worldwide because of its specific characteristics. The high mobility and dynamic environment can be easily coped with using Ad-hoc On-demand Distance Vector (AODV) and Greedy Perimeter Stateless Routing (GPSR) routing protocols, which have been widely employed in various vehicular environments. Different metrics such as node density, node speed, bit rate, communication range and traffic pattern are not investigated properly. In this paper, we focus on multimeric approach to evaluate the performance of AODV and GPSR in five different scenarios in an urban environment using NS2 simulator. The in-depth impact of the metrics on the performance of routing protocols are investigated and the QoS parameters is measured which will help in the fast data dissemination, low latency and high throughput requirement fulfilment for the given vehicular environment.

Keywords: traffic pattern; vehicle routing; VANETs; AODV; GPSR; intelligent transportation systems.

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1 Introduction

With the increase in the number of vehicles on the roads, need for an intelligent transportation system has increased. The Vehicular Ad-hoc Network (VANET) is one of the important favourable candidates of emerging technology. The VANETs focus on reducing congestion on roads, and reduction in toxic emission and fuel consumption. The ITS also helps in the enhancement of traffic safety, providing more information about the surrounding environment. Dimitrakopoulos and Demestichas (2010) investigated that location-based services and traffic statistics can be obtained by the help of V2V and V2I mode of communication. Allouche and Segal (2015) analysed that the VANET provides different modes of communication between the vehicles (V2V), Vehicles and Persons (V2P), Vehicles to Infrastructure (V2I) or even vehicle to everything (V2X). Houssain et al. (2017) analysed the benefits such as low bandwidth, self-organisation, short range radio transmission ranges which make the VANET-based communication widely used in the vehicular environment. Schoch et al. (2006), Abbas et al. (2018) and Sivaraj et al. (2011) observed that the rapid growth in the vehicular communication, leads to many works findings which is covering at different aspects including security of data, latency improvement and performance analysis of various routing protocols to adapt in the fast-changing network topology in the vehicular environment. Multi-hop communication and better services can be possible due to the use of suitable routing protocols. There are some challenges with the VANET also such as intermittent network connection and highly dynamic topologies. The routing protocols of the VANET are mostly designed for different scenarios having constraints such as bandwidth limitation, interferences and mobility of nodes.

Li and Wang (2007) investigated the various classification of routing protocols which are based on the Quality-of-Services (QoS) improvement and efficient utilisation of the limited resources. Altayeb and Mahgoub (2013), Mezher and Igartua (2017) and Bernsen (2011) analysed the different approaches to obtain the reliable QoS based on end-to-end delay, throughput, latency and security. Stallings (2005) investigated the classification of routing protocols which is based on transmission strategies. The protocols are classified as unicast, multicast, broadcast or geocast. The topology and position information help to further classify the unicast protocol. Lee et al. (2009) and Gaikwad and Zaveri (2011) analysed that AODV is the routing protocols that can be used for unicasting, multicast and for broadcast application. The geographical routing protocol is one of the important sub-classification of unicast application. The local information is used by these protocols to make forward decisions of information. GPSR is one of the important protocols which uses the local surrounding information in routing and widely solves the problem of dynamic changing environment. Several works, e.g. Sharma (2013), Houssaini et al. (2017) and Aljabry and Al-Suhail (2021), proposed for the comparative analysis between the AODV and GPSR routing algorithms. Setiabudi et al. (2016) and Houssain et al. (2017) investigated the scenario where the comparison between DSR and ZRP protocols is done.

Most of the researchers have not considered the network metrics such as node speed, different traffic pattern and variation in transmission rate for the in-depth analysis and comparison of the routing protocol for fast data dissemination by reducing latency and reduction of congestion in different environment. Amaya et al. (2021) analysed the impact of hello message interval by variation caused due to node density and transmission rate. We employ the effect of the variation of vehicular node speed and communication range as a parameter to compute the QoS metrics and compare with the other work as given in the literature.

In the present paper we compare the AODV and GPSR routing protocols for vehicular environment where traffic load is varied by varying the density of vehicles per km^2, node mobility and transmission rate are also varied to different speed limits and

1 Mbps to 3 Mbps, respectively. The important parameter of traffic pattern is considered with above-mentioned network parameters which are helpful in the detailed analysis of the routing protocols.

The novelty of the paper is in depth analysis of the impacts of node density, node speed, transmission rate, bitrate and the Hello messages time intervals, along with the different traffic patterns combined in one work which has not been previously addressed. The abbreviation used in the given article is expressed in Table 1.

Table 1 Abbreviations

S. No	*Abbreviation*	*Explanation*
1	AODV	Ad-hoc On-demand Distance Vector
2	GPSR	Greedy Perimeter Stateless Routing
3	PDR	Packet Delivery Ratio
4	QOS	Quality of Research Spreading Factor
5	E2ED	End to End Delay
6	ZRP	Zone Routing Protocol
7	V2X	Vehicle to Everything
8	V2I	Vehicle to Infrastructure
9	V2V	Vehicle to Vehicle
10	V2P	Vehicle to Pedestrian
11	CSMA/CA	Carrier Sense Multiple Access/Collision Avoidance
12	VANET	Vehicular Ad Hoc Network
13	RREQ/RREP	Route Request/Route Reply
14	RERR	Route Error
15	CBR/VBR	Constant Bit Rate/Variable Bit Rate
16	TCP/UDP	Transmission Control Protocol/User datagram protocol
17	FTP	File Transmission Protocol
18	SUMO	Simulation of Urban Mobility
19	NS2	Network Simulator
20	DSDV	Destination Sequenced Distance Vector Protocol
21	OLSR	Optimum Link State Routing Protocol
22	DSR	Dynamic Source Routing Protocol

The contribution of this work is to provide five scenarios-based complete and in-depth performance analysis about AODV and GPSR protocol in VANETs which are missing previously in the literature. The rest of this paper is organised as follows: Section 2 presents the related work and comparison of the literature work. After that, Section 3 presents the systematic background description about the routing protocol Section 4 presents the insight of the simulation environment whereas Section 5 discusses findings and results. Section 6 concluded the work.

2 Related work

Most of the researchers, e.g. Brendha and Prakash (2017), Sharef et al. (2014) and Marzak et al. (2016), focused on the work related to implementation of different routing protocols for the VANETs. Various performance parameters such as PDR, delay and normalised load are considered for two different scenarios of city and highway. Bala and Ramakrishna (2014) suggested several routing protocols related to position and topology-based routing, and made performance examination of the AODV and GPSR. Sharma and Thakur (2015) analysed that AODV performs better in low density network as compared to GPSR which is suitable for the high density one. Ashtaiwi et al. (2014) compared the performance of the routing protocol at different scenario and environment. The authors only studied the effect of node density over the Quality-of-Service parameter. Bala and Ramakrishna (2014) investigated the scenario of different traffic patterns with variable node density in comparison of AODV and GPSR performance. The paper lacks the in-depth analysis of the impact of the network parameter of node speed and communication range. On routing protocol, Setiabudi et al. (2016) analysed the vehicular environment where the different protocols such as GPSR and ZRP are compared whereas Hu et al. (2016) in their work proposed the improved GPSR routing strategy in VANET. Houssaini et al. (2017) investigated the widely used VANET routing protocols. They have used four QoS metrics for the purpose of comparison between the protocol performances. The authors only take the effect of variation of node density as the parameter to compare the different routing protocols and other parameters are not considered.

An enhanced version of the GPSR is used in Houssain et al. (2017) work and the on-demand Hello message-based Kalman filters are used for better RSSI localisation in KFGPSR. The results show the GPSR outperforms various other routing protocols (ZRP, AODV and DSR). Upadhyaya and Shah (2019) proposed and examined the routing protocol based on position based and topology based on different simulation tools such as SUMO, MOVE and NS2 to obtain the results. The results are analysed under diverse parameters. Ghori et al. (2018) and Bengag et al. (2020) investigated and compared the application scenario of video transmission over VANET and presented a taxonomy and evaluation of routing protocols. Shrivastava and Vishwamitra (2021) compared the DSDV, OLSR and AODV using the network simulator NS3. Aljabry et al. (2021) investigated the performance of two well-known protocols GPSR and AODV in terms of QoS metrics. Different network parameters such as node density, node speed, variation of transmission range is considered in their investigation. The author takes some important network parameter variation, but they missed the traffic pattern, bit rate and the impact of hello message in the analysis of the given protocols. Amaya et al. (2021) investigated the scenario where three QoS metrics have been employed. The paper also investigated the effect of hello message interval by varying the node density. The in-depth analysis of the node speed and communication range impact on the routing protocol and on the Hello message interval is missing in the given paper. Hota et al. (2022) proposed the reliable route using comparative analysis of existing routing protocols with propagation models. Malik et al. (2020) investigated the detailed evaluation of three commonly used protocols, i.e., Ad-hoc On-demand Distance Vector Routing (AODV), Dynamic Source Routing (DSR) and Destination-Sequenced Distance-Vector Routing (DSDV) under three different traffic environments. Kumari and Yadav (2023) proposed a novel routing protocol that is high performance, energy efficient and extends from Cluster-Based Routing protocol. Rivero-Angeles et al. (2022) investigated simulation results considering the CSMA/CA random access scheme in the IEEE 802.11p communication protocol for V2V communications. Agrawal et al. (2022) provided the detailed study of mobile ad hoc networks, wireless sensor networks and wireless mesh networks in terms of their uses, limitations, issues, characteristics and advantages and disadvantages of routing protocols. Aljabry and Al-Suhail (2022) proposed the performance of a common reactive routing protocol named (AODV) ad-hoc on demand Distance Vector routing where two scenarios are considered. Kaushal et al. (2022) investigated protocols and compared based on different attributes such as recovery strategy, type of environment and traffic flow.

Table 2 gives the comparison of works on network by various researchers, e.g. Sharma (2013), Houssaini et al. (2017), Aljabry and Al-Suhail (2021), Amaya et al. (2021) and Bala and Krishna (2015), with our present work. It is clear from Table 2 that no single researcher has considered all the network conditions such as number of nodes, transmission rate, communication range, speed of the node, impact of hello message interval and traffic patterns in their work except in present work. In the present work we have performed in depth performance comparative analysis of the routing protocols considering all the network and traffic parameters at one place.

Table 2 Comparative study of variation of different network and traffic parameter on routing protocol

S No	*Research work*	*Speed of the nodes*	*Variation of bit rate*	*Node density*	*Transmission range*	*Traffic pattern*	*Interval of the hello message*
1	Sharma and Thakur (2013)	No	No	yes	No	No	No
2	Houssaini et al. (2017)	No	No	yes	No	No	No
3	Aljabry and Al-Suhail (2021)	yes	No	yes	yes	No	No
4	Amaya et al. (2021)	yes	No	yes	no	No	yes
5	Bala and Krishna (2015)	No	No	yes	No	yes	No
6	Our proposed approach	yes	yes	yes	yes	yes	yes

3 Background of the routing protocols

The routing protocols are the rules which define how moving routers exchange and communicate information about the network status and the route path in the VANETs. Important factors such as network density, scalability, mobility of nodes and transmission bandwidth play an important role in the performance of the dynamic network. Avoidance of the routing loops and the selection of the preferred routes to minimise the cost, time and network overhead are the main features of the routing protocols.

The design of the routing protocols is the most important aspect to route packets to the destination because the major challenges with VANETs include (a) High Dynamic Topology is caused due to high speed in different environmental scenarios (highways). (b) Different Communication Environment which causes different traffic conditions from city to rural environment. (c) Variable network density in VANET is not identical during the daytime and in all types of environments. (d) Mobility model needed because in

VANET the vehicles move according to a predefined trajectory, named as mobility model which is based on pre-existed roads, buildings, intersections and other traffic components. (e) Frequently disconnected network and delay constraint due to the high speed of vehicles. Now these different factors will motivate us to find the comparative selection between the two known routing algorithms that can best suit these factors and provide better performance. We have taken one of the protocols from Position-Based Routing (PBR) and Topology-Based Routing (TBR) protocols group to investigate in-depth performance comparison between them taking the effect of different network and traffic parameter scenarios.

Brendha and Prakash (2017), Sharef et al. (2014), Domingos et al. (2016) and Elgazzar and Alshareef (2020) investigated various routing protocols related to vehicular networks. These routing protocols as mentioned in the above work help in vehicular communication and help in defining in route discovery and creation process. Position-Based Routing (PBR) and Topology-Based Routing (TBR) are the two important categories of the classification of the protocols in VANET. We have taken one of the protocols from each of the above groups and investigated the in-depth performance comparison between them taking the effect of different network and traffic parameter scenarios. The background of the two protocols AODV and GPSR are given in this section.

AODV: out of different routing protocols used in MANET networks and the most common is the AODV routing protocol. In the work of Wang and Cui (2008) two techniques are used as destination sequence number and demand-based routing as the important part of the AODV routing protocol. Unnecessary route information is not maintained by nodes due to low overhead in the network. There are three kinds of route messages used in the AODV routing protocol. The two-phases used in the rote discovery mode are Route Request (RREQ), and Route Reply, (RREP). The disconnected route in the AODV route mechanism is defined by Route Error (RERR).

GPSR: is a geographic position-based routing protocol. Karp and Kung (2000) analysed that the information about the router next to immediate node helps to make decisions related to greedy forwarding. When a greedy forwarding is difficult the routing protocol will go to the perimeter forwarding state. Perimeter forwarding is used when the greedy forwarding route fails. Houmer and Hasnaoui (2019) proposed the enhanced version of GPSR that minimised the transfer delays of the control message. Mahmoud and Al-Khasawneh (2020) proposed the improved GPSR algorithm based on forwarding scheme in VANETs at the intersection points.

Fall and Veradhan (2011) and Issariyakul et al. (2009) described the NS2 tool for the simulation of routing protocols. The following steps have been adopted to carry out the experiment.

- *Step 1*: Running the TCL script the network model of the vehicular environment will be generated.
- *Step 2*: After running the simulation for the given amount of time using the different simulation parameter as mentioned in Table 1.
- *Step 3*: The Awk script is run over the trace file generated which helps to calculate the QoS metrices.
- *Step 4* Tuning of the appropriate network parameter of routing is done to enhance the QoS metrics.

The calculation functions for the performance metrics (Setiabudi et al., 2016) are given below:

Packet Delivery Ratio (PDR): PDR = Total number of received packets/Total number of sent packets

Throughput: Throughput = (Total number of received packets × Packet size)/Total simulation time

End-to-End delay: E2EDelay = (Packet arrival time − Packet departure time)/Total number of received packets

4 Simulation model

In the given simulation the routing protocols AODV and GPSR were considered for comparison with different node density, bit rate, node speed and transmission range under the effect of the traffic pattern CBR/UDP and FTP/TCP. The effect of the Hello message interval on AODV and GPSR is also studied under the varying node density and speed.

The five scenarios are considered as follows:

1. *Considering the scenario of CBR traffic pattern*: Comparative analysis of the two routing protocols at different node density and bit rate with constant transmission range, and node speed.
2. *Considering the scenario of CBR traffic pattern*: Comparative analysis of the two routing protocols at different node speed and bit rate with constant node density and transmission range.
3. *Considering the scenario of CBR traffic pattern*: Comparative analysis of the two routing protocols at different transmission range and bit rate with constant node density and node speed.
4. *Considering the scenario of different traffic patterns as UDP and TCP*: Comparative analysis of the two routing protocols at different node density and node speed with constant transmission range, and bit rate.
5. *Considering the scenario of variable Hello message time interval with CBR traffic pattern*: Comparative analysis of the two routing protocols at different node density and node speed, with constant bitrate and transmission range.

The scenarios mentioned above are simulated under the condition of the node buffer size of 64 data packets. Behrisch et al. (2011) analysed the SUMO simulator, which helps to generate the mobility pattern which results in variable node density in the simulated environment. The random source-destination pairs in the network are selected and packet sending rate is also varied in each pair, therefore, the offered load is changed in the network. The square network configuration of 1000 m × 1000 m field is used with 500 nodes (Zhang, 2020; Issariyakul and Hossain, 2009) as described in IEEE 802.11p standard for the NS2-based simulation of GPSR and AODV protocols. Table 4 gives the insight of the simulation network parameters which are widely used in the simulation (Prasad and Bhatia, 2017, 2018; Pereira and Leonardo, 2020; Prasad and Bhatia, 2014).

Two types of traffic pattern CBR/VBR/UDP and FTP/TCP traffic were used in the simulation scenario given in this work. The flowchart of the simulation methodology is as shown in Figure 1. Table 3 gives the advantages and limitations of the two routing protocols (GPSR and AODV) which are compared in different network conditions such as number of nodes, transmission rate, communication range, speed of the node, impact of hello message interval and traffic patterns in the research methodology of the present work. The improvement of the proposed protocol over existing group is also discussed in the Table 3 based on the observation obtained from the simulation results.

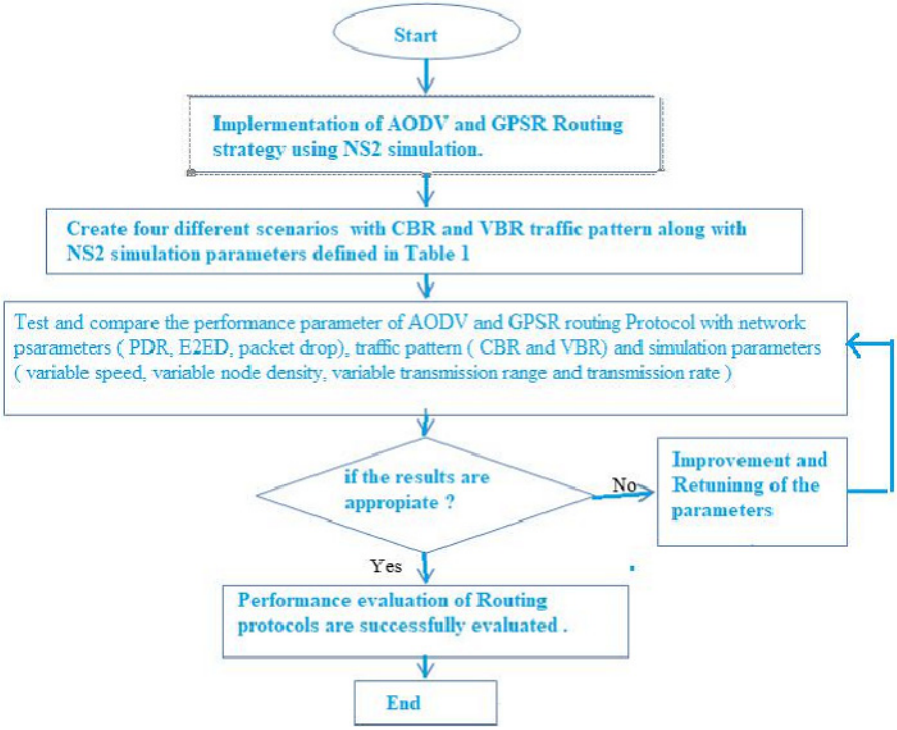
Table 3 Comparative analysis of the routing protocols (GPSR and AODV)

Routing algorithm	*Advantages*	*Limitation*
AODV	1. Requires less storage as compared to other reactive routing protocols.	1. Lacks efficient route maintenance and delay in information on demand during Route discovery mode.
	2. Handle highly dynamic VANETs.	2. large bandwidth and processing time
	3. Small routing table and Multicasting supported.	3. More number of overheads due to many routes reply message.
	4. Stored active route and Quick recovery only.	4. Large response time due to node densities and the size of network grows.
GPSR	1. No loop routing less processing overhead.	1. Large transmission power
	2. Less number of Hops	2. Frequent network disconnection due to mobility.
	3. Small hops of routing	3. End to end connection in low traffic density

Table 4 NS2 simulation parameters

S. No.	*Parameters*	*Value*
1	Physical layer	IEEE802.11p
2	Number of nodes	50,100,150 and 200
3	Simulation time	100 sec
4	Radio power	28 dBm
5	Routing protocol	GPSR and AODV
6	Packet traffic type	CBR and VBR under UDP, FTP/TCP
7	Node speed	20,40, 60 and 80 km/hour
8	Area	1000 m × 1000 m
9	Mobility model	Random way point
10	Propagation model	Two ray ground
11	Bit rate	(1–3) Mb/sec
12	Range	100, 200, 300 and 400

Figure 1 Flowchart of the comparison of routing protocol (AODV and GPSR) in vehicular environment



5 Results and observation

The performance parameters (E2ED, PDR) will help to judge which routing protocol between AODV and GPSR performs better in all the four scenarios. Different transmission speed, node density, transmission range and transmission rate are considered as different scenarios in this paper over which the performance parameters are measured. Different traffic patterns such as CBR/UDP and FTP/TCP are also considered during the experiment and lastly the different interval of Hello messages was also considered for the different value of node density in one of the scenarios.

5.1 Changing the number of vehicles

The given scenario, as shown in Figure 2, states the impact of the variation of node density from 50, 100, 150 and 200 vehicles/km^2 over the performance of AODV and GPSR. The speed is constant and set at the value of 40 km/h. In the given scenario we have considered the two cases of the transmission rate as 1 Mbps and 3 Mbps. Figure 2 shows that due to the smaller number of passes on node at lower density the PDR of AODV is less but as soon as the number of nodes increases from 100 to 200 nodes the value of PDR in the routing protocol GPSR is less than the AODV. Figure 3 shows that GPSR has better performance than AODV in terms of the value of latency in seconds as given in E2ED graph when the vehicle density increases. The route discovery phase in AODV leads to more latency. The hop-to-hop count-based mechanism helps to choose the shortest path which delivers packets in GPSR faster and with lower latency for both the transmission rates of 1 sec and 3 sec.

Figure 2 Network size variation on PDR (see online version for colours)

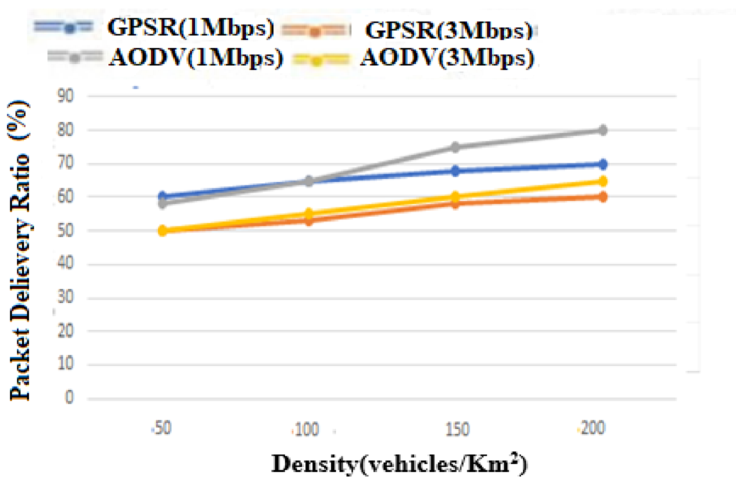
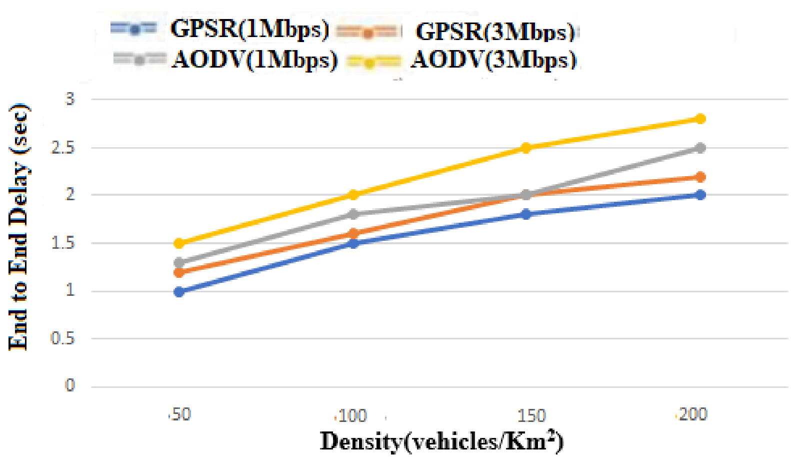


Figure 3 Network size variation on end-to-end delay (see online version for colours)



5.2 Changing the vehicles speed

Figure 4 shows the impact of the variation of node speed from 20, 40, 60 and 80 km/hour over the performance of AODV and GPSR. The node density is constant and set at the value of 100 vehicles/km^2. In the given scenario we consider the two cases of the transmission rate as 1 Mbps and 3 Mbps. Figure 4 shows that due to the increase in probability of failed connection with the increase in speed of the nodes the lost packets are more in AODV as compared to the GPSR. In GPSR due to frequent network disconnection due to the increase in speed of mobile nodes. Overall performance of GPSR is better than AODV when the speed of node is varied in the given stated scenario. Better performance of GPSR in terms of E2ED can be observed from Figure 5. Owing to the congestion at low speed and fixed node density the operation of AODV is affected. Owing to the long route selection in next hop perimeter forwarding mechanism used in GPSR, the routing protocol the End-to-End delay increases for both the transmission rates.

Figure 4 Node mobility variations on packet delivery ratio (see online version for colours)

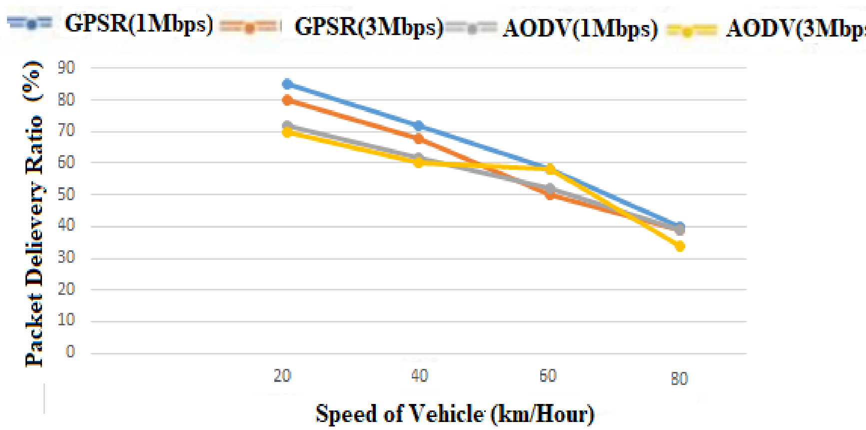
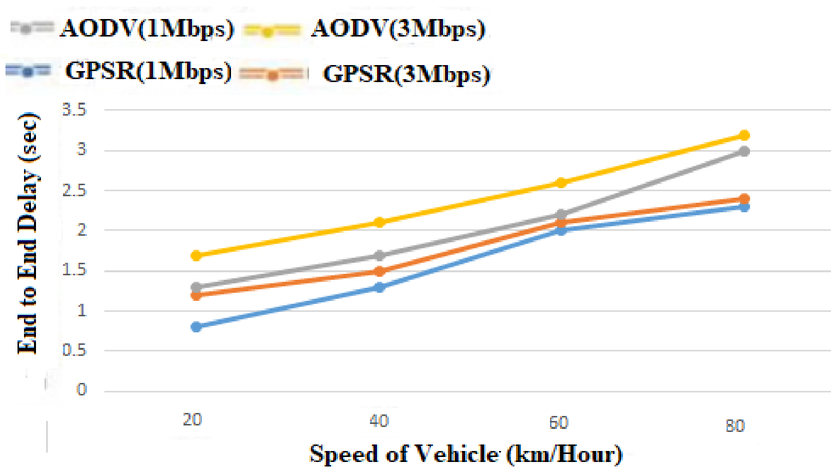


Figure 5 Node mobility variations on end-to-end delay (see online version for colours)



5.3 Changing the transmission range

Figures 6 and 7 show the impact of the variation of communication range values from 100, 200, 300 and 400 m over the performance of AODV and GPSR. The node density is constant and set at the value of 100 vehicles/km^2. In the given scenario we have taken the two cases of the transmission rate as 1 Mbps and 3 Mbps. Figure 6 shows that the AODV packet delivery ratio outperforms the GPSR one with increment of transmission range at both transmission rates. Figure 7 shows that the routing protocol GPSR has less delay than AODV in terms of End-to-End delay as the communication range increases. Owing to the congestion at low speed and fixed node density the operation of AODV is affected. On the other hand in GPSR and AODV the value of delay is more when the communication range is less than 200 metres. The high probability of nodes in the neighbours due to the increase in the transmission range makes data transmission faster and hence GPSR outperforms the AODV routing protocol.

Figure 6 Communication range variations on packet delivery ratio (see online version for colours)

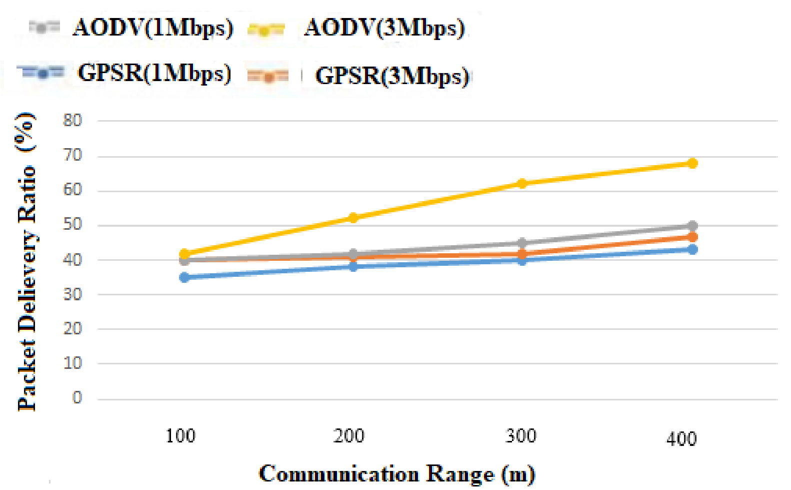
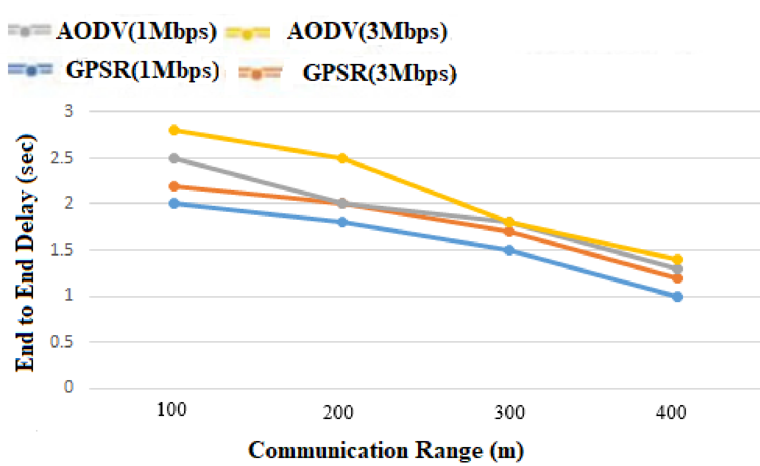


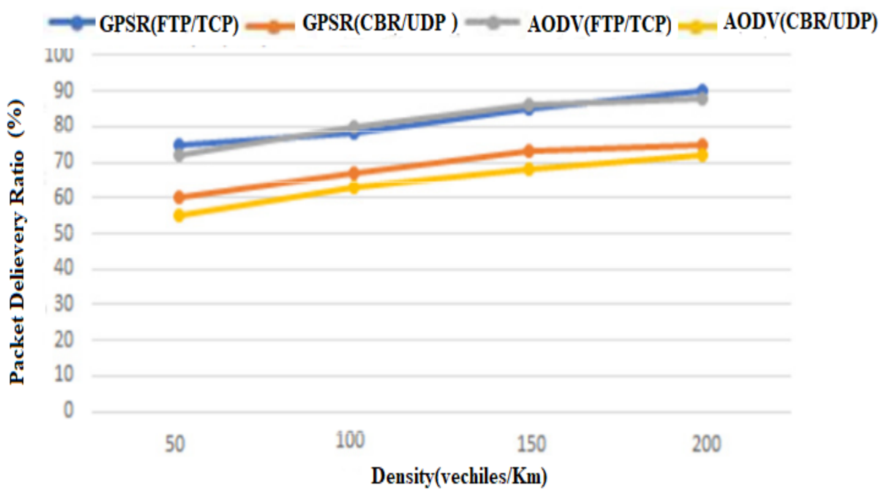
Figure 7 Communication range variations on end-to-end delay (see online version for colours)

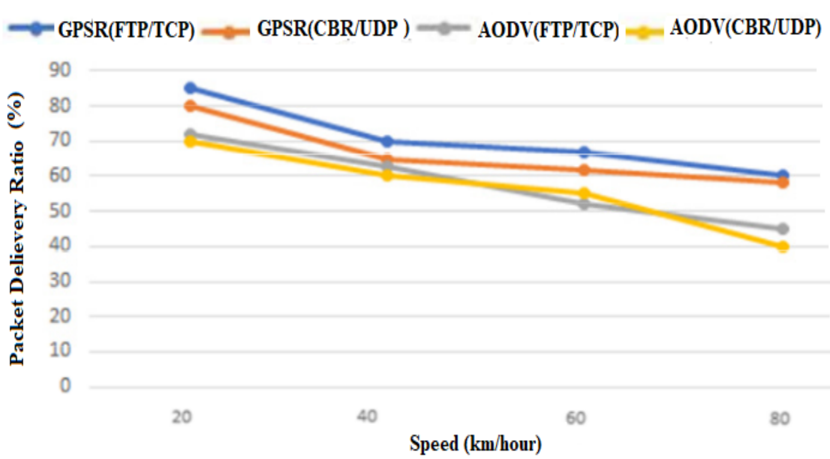


5.4 Changing the traffic pattern

The impact of the variation of node density from 50, 100, 150 and 200 vehicles/km^2 over the performance of AODV and GPSR is shown in Figures 8 and 9, respectively. The speed is constant and set at the value of 40 km/h. In the given scenario we have taken the two-traffic pattern of CBR/UDP and FTP/TCP respectively. Figure 8 shows the variation of PDR with respect to the variation of the node density under different traffic patterns, and it is observed that PDR is low at node density between 50 and 100 for both the protocols. The relaying nodes are fewer with low density that reduces number of packets to reach the destination and hence the packet drop ratio increases. Figure 8 also gave the indication that the value of PDR increases as the number of nodes increases in both the traffic patterns.

Figure 8 Traffic pattern variations on packet delivery ratio (see online version for colours)

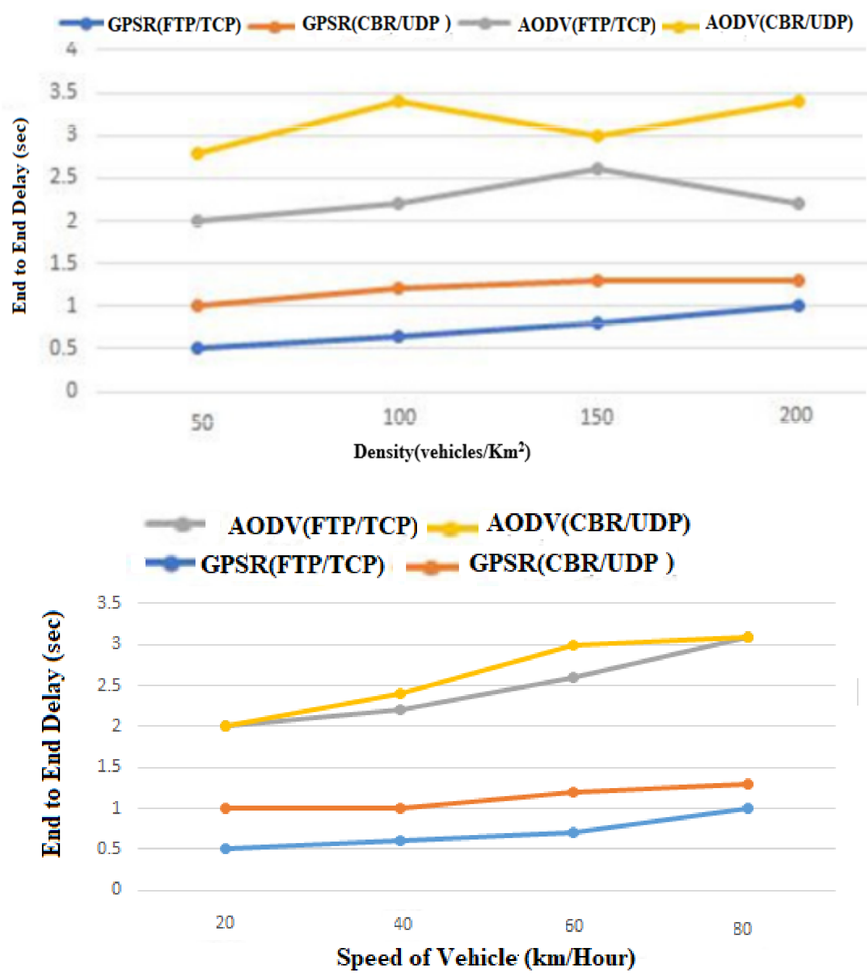




The increase in mobility will substantially decrease the PDR. In the case of GPSR the network portioning and the occurrence of void zones are higher at lower density. The increase in number of nodes helps to act as a greater number of intermediate nodes and results in the increase in value of the PDR. The important observation from the results stated that there is enhancement in the average value of the PDR of AODV by 24.05% and the average value of the GPSR by 15% in both the UDP and TCP 802.11p environment when node density increases.

In AODV the PDR value is 3% better than PDR value obtained in GPSR when implemented with FTP/TCP. GPSR is enhanced by 14% In UDP and TCP environment respectively. Figure 9 shows under the effect of two traffic patterns FTP/TCP and CBR/UDP, the E2ED parameter in AODV has lower performance than GPSR as the vehicle density and the node speed increases.

Figure 9 Traffic pattern variations on end-to-end delay (see online version for colours)



5.5 Changing the hello message interval

The given scenario, as shown in Figures 10 and 11, states the impact of the variation of node density from 50, 100, 150 and 200 vehicles/km^2 and the node speed from 20 to 80 km/hour over the performance of AODV and GPSR. In the given scenario we considered the traffic pattern as CBR/UDP. The interval of the hello message varies from 1 second to 3 second in the given routing protocols when implemented with 802. 11p. hello packets help to increase the awareness of mobility change of the routing protocols. The RREQ used in AODV helps to perform the hello function. The change in the interval of hello Packet message does not impact much on GPSR routing hence the PDR of GPSR for 1sec hello message interval is high as compared to the AODV. The impact of node mobility is also very less on PDR values. The GPSR routing protocol experienced less latency than the AODV when the node density increases as shown in the results of E2ED in Figure 11. The effect of hello packets duration with GPSR and AODV in VANETs is studied in the given section and the results show that the AODV is less beneficial than GPSR when the hello packet duration is low (1 second) which has significant high PDR in mobility and density scenario. The low value of hello packet duration 1 sec helps to provide low End to End delay with GPSR and it is not more beneficial to AODV due to large End to End delay in mobility and density scenario.

Figure 10 Interval of hello message variations on packet delivery ratio (see online version for colours)

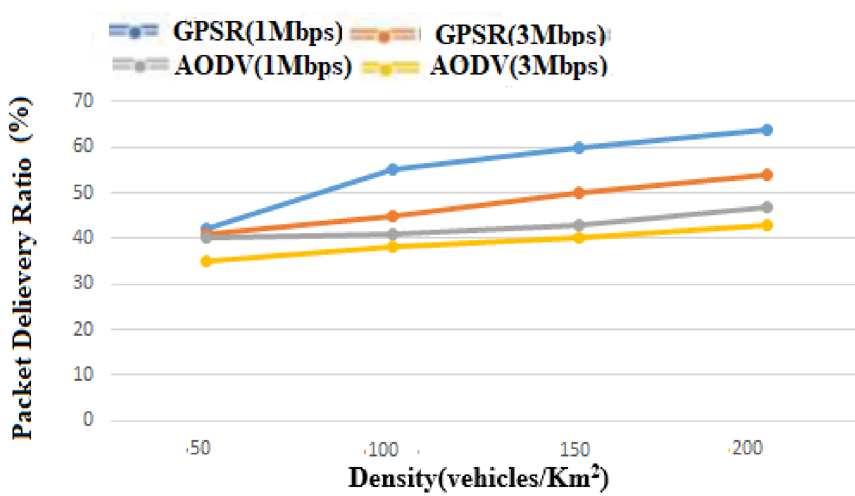
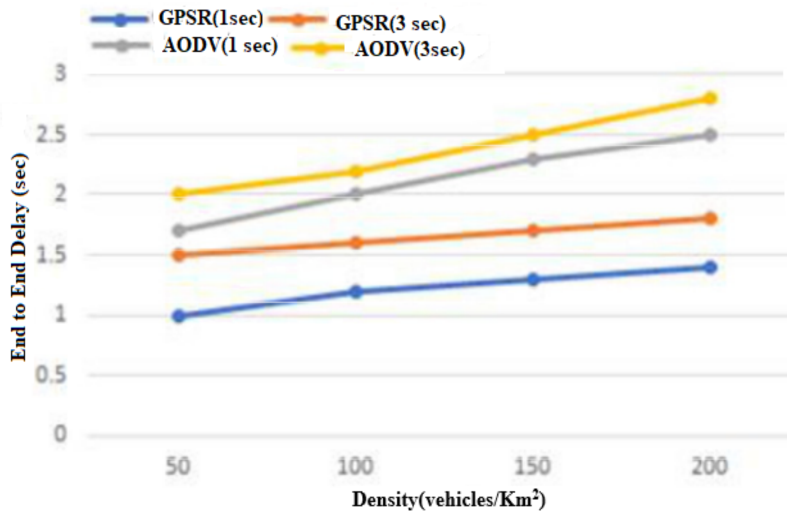
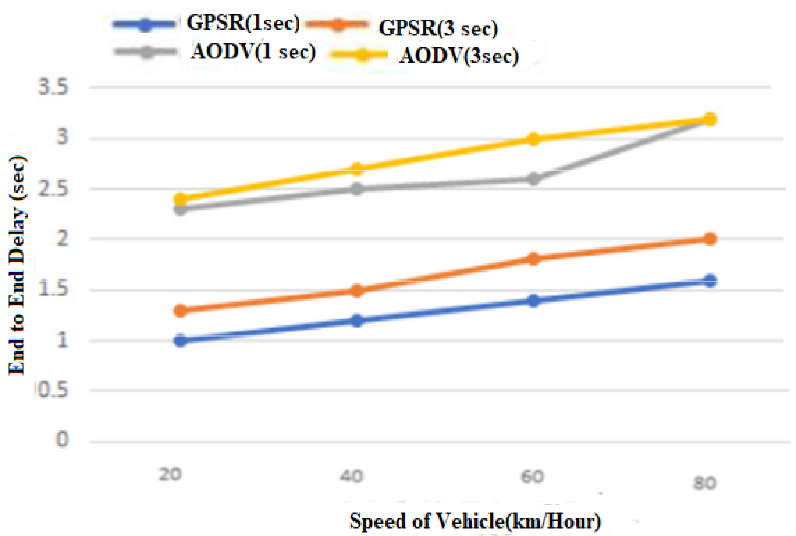


Figure 11 Interval of hello message variations on end-to-end delay (see online version for colours)





5.6 *Observation and findings*

Selection of the suitable routing algorithm is one of the major design challenges of VANET. There are many factors, discussed earlier, that motivate us to perform in-depth analysis of the impacts of node density, node speed, transmission rate, bitrate and the Hello messages time intervals on routing protocol with different traffic patterns which are combined in one work and the observation are shared in Table 5. Our scenario depends on varying the different parameters and observing the behaviour of two routing protocols in the Quality-of-Service (QoS) parameters such as End to End delay and Packet delivery Ratio.

Table 5 Observation of the comparative analysis of the routing protocols (GPSR and AODV)

Scenarios		*Observation*
1.	Variation in node density and bit rate with constant transmission range, and node speed.	1. Lower density values result in high PDR of GPSR but when the Number of nodes increase from 100 to 200 nodes the value of PDR for GPSR is lesser than the AODV. 2. The change of bitrate is not very significant on the PDR metric. 3. GPSR has better performance than AODV in terms of the value of latency and low E2ED value when the vehicle density increases. The route discovery phase in AODV leads to more latency.
2.	Variation in node speed and bit rate with constant node density and transmission range.	1. The increase in probability of failed connection with the increase in speed of the nodes the lost packets are more in AODV as compared to the GPSR so PDR metric of GPSR is better than AODV. 2. Better performance of GPSR in terms of E2ED value. The congestion at low speed and fixed node density affects the operation of AODV which enhances the delay.
3.	Variation in transmission range and bit rate with constant node density and node speed	1. AODV packet delivery ratio outperforms the GPSR one with increment of transmission range at different transmission rates. 2. GPSR has lesser value of delay than AODV in terms of End-to-End delay as the communication range increases. 3. High probability of nodes in the neighbours due to the increase in the transmission range which makes data transmission faster and hence GPSR outperforms the AODV routing protocol.
4.	Variation in traffic patterns as UDP and TCP with variation node density and node speed with constant transmission range, and bit rate.	1. The variation of PDR with respect to the variation of the node density under different traffic pattern (UDP and TCP), it is shown here that PDR is low at node density between 50 and 100 for both the protocols. The relaying nodes are less with low density that reduces number of packets to reach the destination and hence the packet drop ratio increases. 2. The value of PDR increases as the number of nodes increases in both the traffic patterns. The mobility increase will substantially decrease the PDR. 3. In the case of GPSR the network portioning and the occurrence of void zones are higher at lower density. The increase in number of nodes helps to act as a greater number of intermediate nodes and results in the increase in value of the PDR.
5.	Variation in HELLO message time interval with CBR traffic pattern: with different node density and node speed, with constant bitrate, and transmission range.	1. The AODV is less beneficial than GPSR when the hello Packet duration is low (1 second) which has significantly high PDR in mobility and density scenario. 2. The low value of hello packet duration 1 sec helps to provide low End to End delay with GPSR and it is not more beneficial to AODV due to large End to End delay in mobility and density scenario.

Improvements: The observation helps to provide the improvement in the data dissemination in VANETs scenario where the dynamic topology and the surrounding environment change very rapidly. The results and observation helped the researcher to select the best routing algorithm. The variable node density and the variable speed parameters are in depth analysed and the suitable algorithm is selected based on the analysis of QOS factors. The simulation results are helpful guidelines for researchers to improve and develop the protocol to the existing works. In future intelligent approaches such as Genetic Algorithm, fuzzy logic and Scenario Adaptable routing schemes can be applied in the VANET scenario for fast data dissemination.

6 Conclusion and future work

In this work, we have performed in depth performance comparative analysis of the routing protocols considering all the network and traffic parameters at one place first time because to our best knowledge, no single research has considered all the network and traffic parameters. These parameters are number of nodes, transmission rate, communication range, speed of the node, impact of hello message interval. Considering the five scenarios of vehicular environment scenarios a detailed comparison analysis between the performance of the two-routing protocol (GPSR and AODV) is done. The best choice between the two protocols is GPSR in the scenario of variable node speed, variable transmission range and in different traffic pattern. The choice is made based on throughput and End-to-End delay results. In the case of high density, the value of PDR for AODV is much better than that of GPSR. The results obtained in the present work were for the speed of nodes varied from 20 km/hour to 80 km/hour and the bit rate varied from 1 Mbps to 3 Mbps. The best routing protocol selection is taken based on QoS. These observations are not investigated by Sharma (2013), Houssaini et al. (2017) and Bala and Ramakrishna (2014).

In the first scenario, variation in number of nodes is considered and the simulation is performed by varying the bit rate from 1 Mbps to 3 Mbps at a constant speed. The results show that the routing protocol AODV gave better PDR value than the GPSR. The routing protocol GPSR shows less latency than AODV in terms of E2ED and hence faster data is disseminated in the given scenario. Varying the speed of the node between 20 to 80 km/h is taken in the second scenario and constant vehicle density is taken as initial condition. In this scenario the values of PDR and E2ED of GPSR are better than the values in AODV. The communication range varies between 100-400 m with a constant speed and constant node density in the third scenario. In this scenario because of high probability of the neighbourhood nodes, the PDR and E2Ed of GPSR outperforms the PDR and E2ED of AODV. Node density and node speed variation are considered in the fourth scenario where the simulation is performed by varying traffic pattern of CBR/UDP and FTP/TCP at a constant bit rate and transmission range. The results show that the routing protocol GPSR gave better PDR value and less delay in terms of E2ED than the AODV, and provided faster data dissemination and less congestion in the given scenario. Node density and node speed variation are considered in the fifth scenario where the simulation is performed by varying the interval time of the Hello message at a constant bit rate and transmission range. The results show that the routing protocol GPSR gave better PDR value and less delay in terms of E2ED than the AODV, when the interval is considered as 1 sec over the 3 sec of hello message interval.

In future, the performance of GPSR and AODV protocols in VANETs can be studied under the typical urban mobility scenario of different traffic flow by selecting different communication schemes and mobility pattern using the SUMO simulator. Variation of the different parameters such as traffic density and speed of the vehicles can be evaluated to select the best routing protocol. The performance of the routing protocol can be evaluated in the time critical real test bed implementation for fast data dissemination in the scenario of connected emergency vehicles.

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