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Wireless Vehicular Ad Hoc Networks: Performance Optimization

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Abstract: Intervehicle communication (IVC) is gaining attention of research community and Automotive industry as it enables intelligent Transportation systems (ITS). Intervehicle communication enables , real-time delivery of safety related messages to drivers and passengers of vehicles. Wireless Vehicular Ad hoc Network known as **VANET** is now emerging as a new class of wireless ad hoc networks. Wireless Vehicular Ad hoc Networks (VANET) are spontaneous networks formed by moving vehicles provisioned with wireless network interfaces, these vehicles could have similar or different radio access technologies, short-range or medium range wireless communication system. These moving vehicles can communicate among themselves and with roadside infrastructure communication networks. Delivering communication services with consistent QoS and high degree of reliability in a wireless vehicular heterogeneous and high-speed network is extremely critical and is an ongoing research.

Governmental and Standardization organizations are showing interest in VANET. Recent survey and statistics, indicated a significant reduction in deaths due to vehicular accidents, can be achieved by providing real-time safety messages to driver and passengers. Safety messages comprises of alerting drivers about road conditions ahead, proving real-time update through video images, real-time update on weather conditions on road ahead and early detection of traffic signals etc.

This study evaluated the optimum routing for VANET wireless ad hoc networks with AODV as routing protocol. AODV (Ad-hoc On-demand Distance Vector) routing parameters were evaluated for variations in key parameters, RREQ_RETRIES and MAX_RREQ_TIMEOUT. Key parameter values were studied for various vehicular node mobility to ascertain optimum configuration to enable better performance for VANET. The performance metrics used to determine the performance data were Packet Delivery ratio (PDR), Throughput, Packet Loss, and routing overhead. The result demonstrates that the key Parameters of AODV, RREQ_RETRIES and MAX_RREQ_TIMEOUT changes with the node speed and produced the best results for the wireless ad-hoc network with AODV as routing protocol. As the vehicle speed in VANETT are typically extremely high, above demonstration of enhancement in performance in network for the high-speed wireless nodes provides vital input for the design of VANET for optimum network performance.

Index Terms - AODV ,Optimization, VANET, Vehicular Ad-hoc networks.

1 Introduction

Wireless ad-hoc Vehicular Access Network (VANE), is a spontaneous network formed by moving Vehicles with onboard wireless interface devices . Moving vehicles integrated with wireless communication devices to communicate with other moving vehicles and with roadside infrastructures communication networks. VANET is a sub class of wireless ad-hoc network.

Wireless ad hoc networks are infrastructure-less multi-hop networks [1]. Vehicles with wireless devices behave as wireless mobile nodes/routers. Vehicular ad hoc networks are gaining momentum, researchers and academicians are enthusiastic about the technological developments and business opportunities that are being projected due to wireless Vehicular networks in near future. Wireless access integration with the vehicle would allow vehicle to exchange communication with roadside infrastructure and increases driver's knowledge about surrounding environment [2]. VANET services are provided by operators and service providers. Unique characteristics of VANET poses challenges to the network designers. VANET supports several network architectures to enable Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communications.

Three Core objectives of VANET are:

1. Delivery of safety messages to driver and passengers of high-speed moving vehicles to create safe driving experience.
2. Transportation of messages from sensors integrated in vehicles for performance monitoring to driver and vehicle manufacturers.
3. Reliable delivery of Infotainment.

Recent survey has shown that significant reduction in highway road accidents can be achieved by enabling delivery of safety messages to drivers and passengers. Many governments and organizations are showing interest to implement delivery of safety messages to high-speed moving vehicles. Car-to-Car Communication consortium (C2C-CC) formed by European car manufacturers and Original Equipment manufacturers (OEM). Intelligent Transport System (ITS) committee, responsible for standardization to support development and implementation of Intelligent Transport system has published specifications for various standards. IEEE Intelligent Transport System (ITS) is focusing on specifications for standardization of Information Technology aspect of transportation systems. IEEE 802.11p is an approved amendment to 802.11 [2] to enable wireless access to vehicular communications. 802.11p amendment has several changes to original Physical and MAC layer to support high speed vehicular environment.

Unique mobility characteristics of wireless Vehicular Ad-hoc Networks (VANET) creates challenges to researchers and implementors. Wireless VANET mobility management is one of the critical issues [3]. 802.11p enhancement has addressed some of these mobility management issues. Various networks architectures have been proposed over the years to resolve resource management issues. Cloud based vehicular architecture proposed [4] addresses resource management issues. Network routing is a critical issue, as it defines the performance of VANET as a network. Various routing algorithms have been proposed over the years to address routing issues in VANET. Here, we have made comprehensive study of AODV as a routing protocol for VANET wireless network to derive network's optimum performance.

2 VANET ARCHITECTURE

2.1 C2C-CC reference architecture [8]

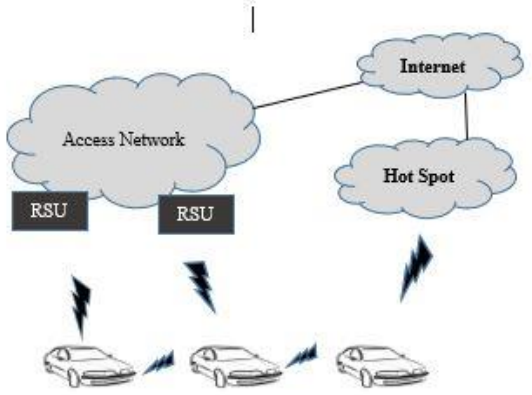


Figure 1.0 C2C-CC reference architecture

Car to car Communication Consortium reference architecture is shown in Fig 1.0. This architecture typically represents three distinctive domains. In-Vehicle domain represents communication within the vehicle. Ad-hoc domain. represents communication with RSU (road sided Infrastructure) and third represents communication with external network or Internet. In vehicle, comprises of OBU (On-board Unit) and AU (Application Unit) . OBU consisting of wireless communication capable interfaces .AU typically consisting of one or two application units. Both OBU and AU can be collocated as single unit. Roadside infrastructure comprising RSU (Road Ride Unit), stationed along roadside to establish and maintain communication with in-vehicle devices. RSU interacts with OBU and maintains communications with other RSU. Infrastructure domain responsible for communication with external network and Internet. Infrastructure domain may consist of RSU which establish communication with OBU and external networks or hotspots for interconnecting RSU and external network.
In Vehicle devices OBU can utilize existing mobile network access networks (GSM, GPRS, UMTS, LTE) or Wi-Fi networks provisioned for the VANET purpose.

2.2 VANET Deployment architecture

2.2.1 Heterogeneous network

Heterogeneous Vehicular network architecture, in which existing mobile network infrastructure co-exist with dedicated short range VANET. Soft-defined Heterogeneous Vehicular Networks [7] can address challenges of dynamic and rapidly changing VANET.

2.2.2 Homogeneous Network

Homogeneous network architecture , in which wireless devices integrated in the moving vehicles make use of either existing Mobile network infrastructure or Wi-Fi network infrastructure to enable V2V and V2I communications.

2.3 VANET features and challenges.

Vehicular ad hoc networks have following unique characteristics compared to other wireless ad-hoc networks [8].

1. Power availability for mobile devices in vehicles is not an issue. Vehicle onboard supply can provide sufficient power source for mobile devices.
2. High computing resources available onboard the vehicles can support higher processing and sensing applications.
3. Vehicular mobility path can be predicted to a greater accuracy than the traditional mobile mobility.
4. Very high-speed moving vehicles changes network topology at short intervals.
5. Large scale network of wireless devices.
6. Extremely high mobility.
7. Network performance impact due to routing

3 RELATED WORKS

3.1 IP Mobility optimization

IP Mobility management for Vehicular Communication Networks: Challenges and Solution [3] proposed by S. Cespedes, X. Shen and C. Lazo, elaborates IP Mobility solutions for Vehicular Communication networks. Proposed solutions considered the various unique characteristics of Mobile wireless ad-hoc networks [8].

This proposal has identified following IP mobility optimization techniques:

- Single hop connections between VCN and fixed networks. This strategy discusses on avoiding tunnel establishment between Mobile router (Vehicle) and Home Agent (HA)
    a. Tunnel establishment between Mobile Router (Vehicle OBU) and CN (Corresponding node)
    b. Tunnel establishment to closest or corresponding router
    c. Delegation to vising nodes optimizes the path between Visiting node (VN Mobility capable mobile network node) and corresponding node.
- Multi hop connection between VCN and Fixed Network
    a. IP routing is used to create a multi-hop path resulting in virtual connection between Vehicle and AR, without the need of processing of IP headers at intermediate nodes. This results in enhanced routing performance.
- Use of Geographic Information available in Vehicular Communication Networks to optimize IP mobility solutions.

3.2 Resource optimization

Towards Cloud-Based Vehicular networks with efficient Resource Management [4] proposed by R. Yu, Y. Zhang, S. Gjessing, W. Xia and K. Yang, this paper proposes resource optimization by integration Cloud computing into Vehicular Networks. The proposed solutions elaborate on cloud solutions for Vehicular networks, Roadside infrastructure, and centralized networks:

- Vehicular Cloud Networks: Vehicular cloud network is formed by group of vehicles sharing their Physical resources. Computing, storage, and radio resources of group of vehicles are shared to form vehicular cloud networks. Dynamic allocation of resources ensures efficient utilization. Vehicles use these cloud resources for their own requirements thus enhancing overall resource utilizations.
- Road-side infrastructure cloud: Road-side cloud networks are formed by dedicated local servers virtualizing physical resources. RSU extend radio resources to mobbing vehicles to access these road-side cloud infrastructures.
- Centralized cloud: Centralized cloud are dedicated high performance physical resources for computing and storage of large applications Centralized cloud are implemented in dedicated Vehicular network data centres or in standard open source or private cloud infrastructure.

3.3 Optimization of 802.11p protocol

Enhancement of 802.11p protocol for Access control on a VANET Control Channel [2] proposed by R. Stanica, E. Chaput and A. Beylot, this paper discuss on the enhancement to 802.11p protocol by having effective back off mechanism for control channel resulting in quality of communication on control channel.

- Solution proposes better back-off mechanism on VANET control channel. Researchers here have proposed decreased back-off mechanism resulting in improved performance and the scalability of MAC layer.

3.4 Optimization in Mobility and Handover management

Mobility and handover management in vehicular networks: A survey by Zhu, K., Niyato, D., Wang, P., Hossain, E. and In Kim, D [5] present comprehensive survey on mobility and Handover management for vehicular networks. Mobility management for VANET is different than typical wireless mobile network. VANET involves heterogeneous high speed mobile networks (Vehicular networks) with dynamic changes in network topology.

Survey highlights following points:

- Mobility management schemes for V2V and V2I communications
- Mobility management for VANET with heterogeneous access
- Host Mobility management for Vehicular networks
- Network Mobility for Vehicular networks
- Mobility management for Heterogeneous wireless access

3.5 Network optimization: LTE for vehicular networking

LTE and 802.11p for vehicular networking: Performance evaluation by Hameed Mir, Z., Filali, F. [6] illustrates the performance enhancement by integrating LTE networks for vehicular networks. Results demonstrate the Vehicular wireless Networks reliability, scalability, and mobility management provided by LTE networks and the results meets the Vehicular networks application demands.

3.6 Information Centric Network (ICN): Solution and Architectures for implementation of IoT designs

Recent Advances in Information-Centric Networking-Based Internet of Things (ICN-IoT) (ICN-IoT)," in IEEE Internet of Things Journal, vol. 6, no. 2, pp. 2128-2158, April 2019 [8] Proposed by S. Arshad, M. A. Azam, M. H. Rehmani and J. Loo.

This paper comprehensively discusses recent Advances in Information-Centric Networking-Based Internet of Things and reviews ICN simulation platforms and integration solutions for IoT implementation.

Proposed paper provides comprehensive design review on following points:

- IoT Architecture requirements and major ICN architecture for IoT
- ICN based architecture for IOT.
- Comprehensive survey on Caching techniques for ICN
- ICN based content naming approaches.
- ICN based security schemes for IOT.
- ICN based mobility schemes.
- Overview on ICN-IoT simulators

4 MATERIALS AND METHODS

The methodology used in this research was 3 stages. First stage involves, generating realistic road traffic map using OSM (Open Street Map) platform . Second stage , generating realistic vehicular road traffic mobility pattern using SUMO (Simulation for Urban Mobility) platform . Third stage involves , NS2 network simulator to simulate wireless ad-hoc network. The network simulation in NS2 was carried out to determine the optimum AODV routing protocol key parameters values to enable efficient packet delivery in VANET. Test was continued , with the test design to find AODV routing parameter values. Simulation was run with the designed configuration and the generated trace file was analyzed for PDR Throughout, Packet loss and Routing overhead .VANET simulation design steps is depicted in the fig 1.0.

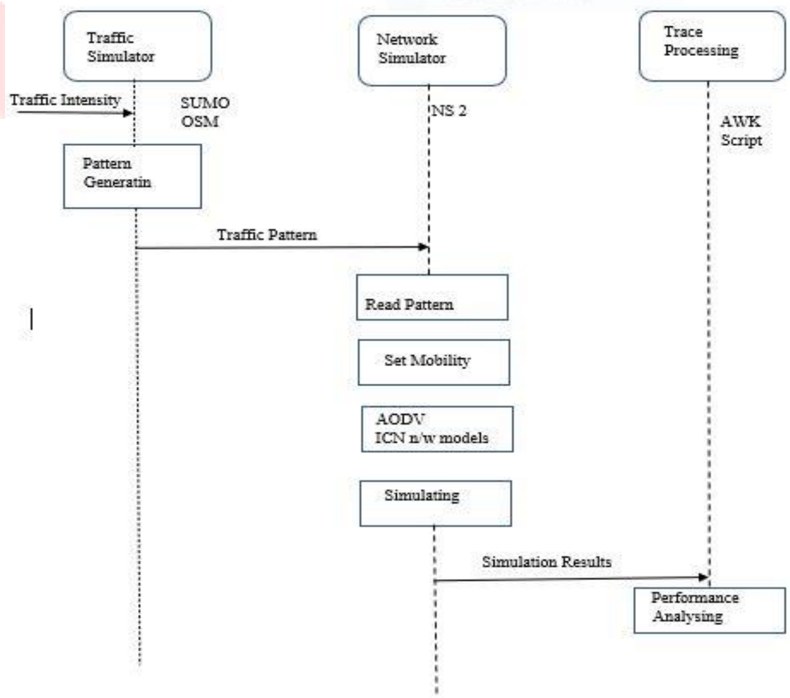


Figure 1.0 VANET Simulation

4.1 OSM (OpenStreetMap)

OSM provides free geospatial data , provides free access to map images and map data. OSM is used here to generate realistic road traffic images.

4.2 SUMO (Simulation of Urban MObility)

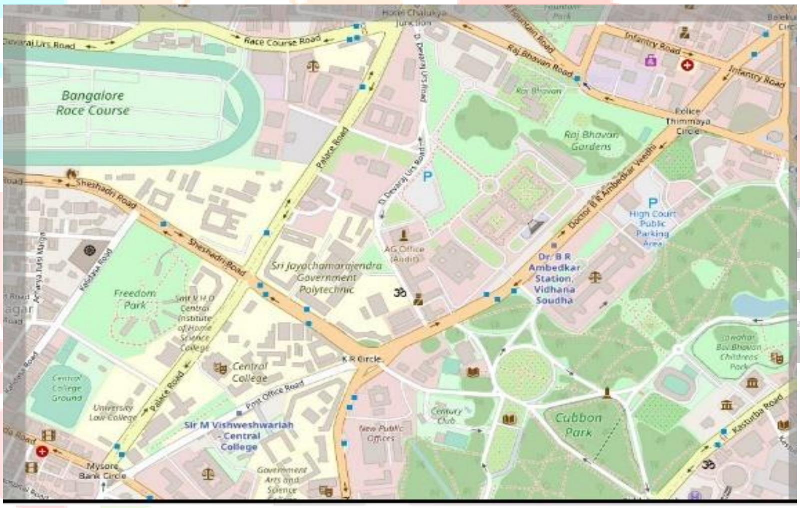
SUMO is an open source , portable, continuous traffic simulation package. It comes with lot of tools to generate traffic scenarios [19]. Raw vehicle positions dump is used here to generate realistic movement of vehicles with wireless interface devices. These files are compatible with the NS2 mobility traces.

4.3 Network Simulator – ns2

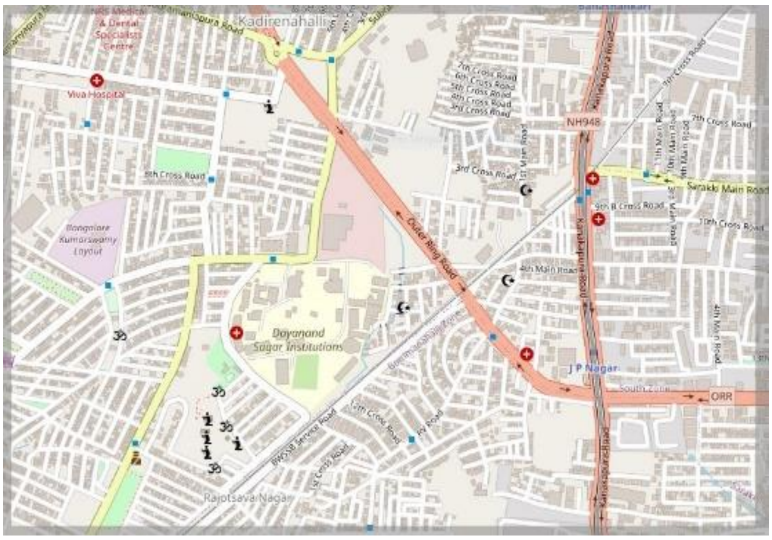
Ns2 is a discrete event simulator targeted at networking research. Ns provides support for simulating TCP,UDP , multicast routing protocol over wired and wireless networks. NS2 is used here to simulate vehicular wireless network with mobility traces generated from SUMO.

5 SIMULATION

The mobility selection is critical in this research, it is related to real traffic conditions .VANET vehicles integrated with wireless devices acts as wireless ad-hoc network and the mobility of real traffic is mostly along the straight road and across crossroads . SUMO simulation tools were chosen to generate realistic traffic mobility models. Along with SUMO , OSM platform provided realistic road traffic image required to generate SUMO models. NS2 provided perfect simulation platform to simulate VANET wireless ad-hoc network to analyze the VANET performance.
We have used simulation scenarios and setup to substantiate our findings.
Fig 2.0 and Fig 3.0 depicts the Open Street Map generated street image and Fig 4.0 depict the SUMO generated traffic mobility for the selected area.



©OpenStreetMap
Figure 2.0 OSM image of KR circle area, Bangalore



©OpenStreetMap
Figure 3.0 OSM image of street ner DCSE campus , Bangalore

Figure 4.0 SUMO generated mobility map of KR circle ,Bangalore traffic

6 TEST EXECUTION

The Simulation was carried out with the above-mentioned scenarios and settings to analyze the network performance with AODV as routing protocol. Multiple scenarios were used with different road traffic conditions and mobility patterns. Nodes created wireless ad-hoc network with multiple nodes moving in direction as simulated in SUMO , these movements created the necessary changes in routing path to observe routing parameters performance. These tests were carried out to test changes in AODV parameters, RREQ_RETRIES and MAX_RREQ_TIMEOUT values under different mobility conditions.

Table 1 NS2 Communication model parameters

parameter	Value
Channel	Wireless Channel
Propagation	Wireless Channel
Physical Interface	Wireless Phy
MAC	Mac/802_11
Queue	DropTail/PriQueue
Link Layer	LL
Antenna	Omni Antenna
X dimension of the topography	1602
Y dimension of the topography	1835
max packet in ifq	50
Routing Protocol	AODV

7 PERFORMANCE METRICSS

7.1 Packet Delivery ratio PDR

Packet delivery ratio defines the number of successfully received packets by the destination node (Rn) over total number of sending packets by source nodes (Sn) .PDR demonstrates the measure of successful delivery ratio, for better performance of the network, higher PDR is designed. PDR is one of the QoS parameter that defines the success ration of routing protocol.

PDR= sum of the packets received by nodes / sum of the packets sent by nodes

PDR result is shown in the fig 5.0. This result shows that reduction in RREQ_RETRIES increases the PDR performance and reduction in MAX_RREQ_TIMEOUT results in increased PDR performance. PDR performance remains consistent with increase in node speed and the result shows that PDR performance increases significantly for node speed a 20 m/s with the variation of RREQ_RETRIES and MAX_RREQ_TIMEOUT.

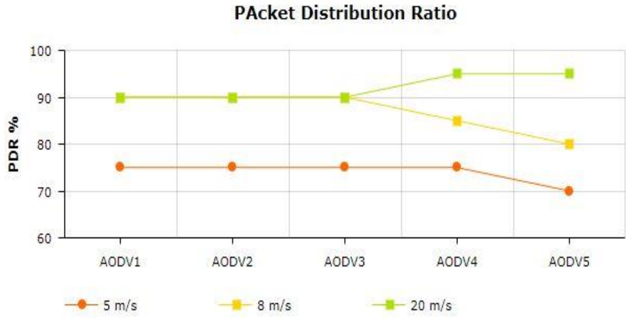


Figure 5.0 Packet Delivery ratio performance

7.2 Throughput (Bps)

Throughput determines the total number of data packets arrival on a device observed for a certain period divided by the total duration of the period of observation. Throughput determines the effective transfer rate of data packets and helps in determining the bandwidth available in the network.

Throughput = Total of the packets sent / Total packet sending time

Fig 6.0 shows the Throughput results observed in this experiment. Throughput here is defined in Bytes per second. Throughput remains constant for node speed of 5 m/s and for node speed of 8 m/s , throughput performance decreases with reduction in AODV key values and for node speed at 20 m/s , throughput performance increases with reduction in RREQ_RETRIES and MAX_RREQ_TIMEOUT values.

Figure 6.0 Throughput results

7.3 Packet Loss

Percentage of packet lost is the total number of packets sent over the network in proportion to the recorded time. In TCP, whenever the packet lost occurs , TCP protocol retransmits the packets. Retransmission causes the overload . UDP protocol does not attempt retransmission, resulting in packet lost. Packet loss could be due to several reasons including congestion, noise , error etc.

Packet loss = Total of packet sent – Total of packet received / Total of packets sent

Packet loss result is shown in the fig 7.0. Result shows that packet loss is less than 10% when node speed is greater than 8 m/s and AODV key parameters.

RREQ_RETRIES and MAX_TIMEOUT_TIMEOUT value is reduced.

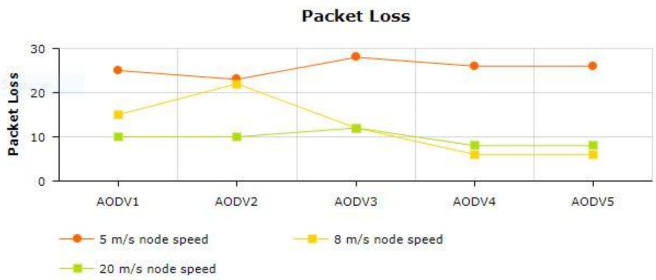


Figure 7.0 Packet Loss results

7.4 Routing Overhead

Routing overhead shows the number of routing messages transmitted over the network during the period. Routing messages in AODV are RREQ , RREP and RRER messages . Increase in routing messages may lead to network congestion, overload resulting in lower performance.

Routing overhead result is shown in the figure 8 . Result shows that routing overhead is significantly less when the node speed is higher than 20 m/s and key AODV key parameters value RREQ_RETRIES and MAX_RREQ_TIMEOUT is reduced .routing overhead is significantly higher when node speed less than 8 m/s and increases as key AODV parameters RREQ_RETRIES and MAX_RREQ_TIEMOUT is reduced.

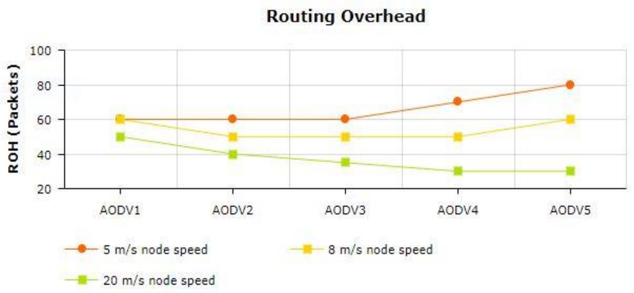


Figure 8.0 Routing overhead results

8 Result Analysis

The impact of change of AODV key parameters RREQ_RETRIES and MAX_RREQ_TIMEOUT on the AODV protocol shows that reducing the value of RREQ_RETRIES and MAX_RREQ_IMEOUT the percentage of packet delivery ration (PDR) improves with the increase in node speed .

Throughput result shows that , for the node speed of 5 m/s , it remains constant for variation in AODV parameter. Throughput performance increases as the AODV parameters are reduced for the node speed of 20 m/s. The result demonstrates the increase in performance of throughput as the node speed is increased when the AODV parameters values are reduced.

Packet loss result shows that the packet loss is less than 10% when node speed is greater than 8 m/s and AODV key parameters RREQ_RETRIES and MAX_TIMEOUT_TIMEOUT value is reduced.

Routing shows that the routing overhead is significantly less when the node speed is higher than 20 m/s and key AODV key parameters value RREQ_RETRIES and MAX_RREQ_TIMEOUT is reduced .Routing overhead is significantly higher when node speed less than 8 m/s and increases as key AODV parameters RREQ_RETRIES and MAX_RREQ_TIEMOUT is reduced.

Packet loss results shows that the packet loss is less than 10% when node speed is greater than 8 m/s and AODV key parameters RREQ_RETRIES and MAX_TIMEOUT_TIMEOUT value is reduced.

The result demonstrates that the key parameters of AODV RREQ_RETRIES and MAX_RREQ_TIMEOUT changes with the node speed produces the best results for the wireless ad-hoc network with AODV as routing protocol. As the vehicle speed in VANETT are typically extremely high, above demonstration of enhancement in performance in network for the high-speed wireless nodes provides vital input for the design of VANET for optimum network performance.

9 Conclusion

The result of this study demonstrates that AODV routing protocol provides robust and resilient protocol for wireless vehicular traffic under diverse conditions and AODV protocol can adapt to very high-speed moving vehicles .

AODV uses routing tables, one routing per destination. Unique destination sequence number prevents looping during routing in AODV.

In AODV routing algorithm , reduction in AODV key parameter values, RREQ_RETRIES and MAX_RREQ_TIMEOUT provides optimum network performance . As the node speed increases , reduction in AODV parameters results in increase in network performance .

The effect of high Mobility in VANET results in frequent link failures and reconfiguration of routes. Link failure triggers the new RREQ messages in AODV resulting in routing overhead. VANET due to its quick dynamic changes in network topology and very high-speed moving vehicles creates wireless network conditions that results in increased network changes ,this causes frequent retransmission of packets . AODV is highly effective in high mobility and heavy load networks.

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