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Adaptive and Efficient Rate Control Algorithm with Different Routing Protocols in VANET

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Abstract: The objective of the work is to find the best combination of rate control algorithm with routing protocol and implement them to improve the performance of the Vehicular Ad Hoc Network (VANET). In this paper, the performance of rate control algorithm with different routing protocols is evaluated for the real-time scenario in vehicular networks. Real-time map and the traffic are generated using Simulation of Urban Mobility (SUMO). Control algorithms and routing protocols are taken into consideration and simulated using Network Simulator version 3 (NS3). Goodput, Packet delivery ratio and routing overhead are parameters used for the analysis. The simulation results in low densities of vehicles show that Minstrel rate control algorithm with DSDV routing protocol performs best, whereas in high densities of vehicles AARF algorithm with DSDV routing protocol performs best in terms of average goodput when compared with other approaches.

Keywords: VANET, SUMO, Rate Control Algorithm, Routing Protocol.

1 Introduction

Vehicular Ad Hoc Network (VANET) is a wireless network designed to provide safety, comfort and other information needed by the drivers. Rate control algorithm plays an important role in IEEE 802.11 wireless network. The rate control algorithm is widely used for static residential and enterprise network scenarios. The rate control algorithm assesses the channel condition to adjust the data transmission rate.

Vehicular Ad Hoc Networks (VANET) is an emerging technology with many innovative ideas concerning traffic efficiency and road safety. Some of the key components governing VANET are smart infotainment devices, Global Positioning Systems (GPS) sensors, transceivers, etc are used to better facilitate the transportation of people by saving time and by providing safety. IEEE 802.11P is the specific standard administering the vehicular communication systems in an intelligent manner. Also coined as Wireless Access in Vehicular Environment (WAVE), it potentially covers two modes of communication: Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I).

One of the major issues with the VANET technology is the Control of the transmission data rate in the highly mobile and dynamic vehicular communication systems [1]. Rate control or rate adaptation is the technique that provides adequate transmission data rate by assessing the channel conditions [2]. These are widely studied and right now research is on determining the cause for packet loss and then fine-tuning the data rate. Saad Biaz and Shaoen Wu in their paper [3] presented a detailed survey on the state-of-the-art rate control schemes for IEEE 802.11 networks. In general, rate control algorithms can be broadly classified into two types: Signal to noise ratio (SNR)-based or statistical count-based system. In the proposed work, statistical-based rate control algorithms are preferred because the SNR values are infeasible in highly changing VANET environment [4]. The rate control algorithms implemented and evaluated are Auto Rate Fallback (ARF), Adaptive Auto Rate Fallback (AARF), Onoe and Minstrel.

The earliest rate adaption method for IEEE 802.11 wireless network is Auto Rate Fallback (ARF). It was developed by [5] for the Lucent Wave-II wireless LAN adapters. The ARF algorithm is very simple and intuitive

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rate adaptation algorithm. The ARF algorithm starts its transmission by lowest data rate through sender and triggers a timer. The sender increases its old data rate to new data rate once the sender succeeds in a consecutive transmission of data for a constant threshold. If the new rate transmission fails due to loss of data or the timer gets expired suddenly after the increase in data rate then the sender returns or falls back to the old data rate. If the sender fails twice then the data rate is decreased in ARF algorithm. The channel condition in ARF algorithm is considered by their frame loss ratio.

Adaptive Auto Rate fallback is developed by [6] to enhance the performance in stable environment. In ARF the threshold constant is increased by the rate but in AARF the threshold is adjusted. The old data rate increases into new data rate by a sender after *N* consecutive successful transmission. The threshold increases or doubles into 2N, once the new rate is failed and the sender falls back into old rate [7]. The AARF increases the time interval between rate increases over a stable channel and gives fewer fluctuations in rate compared to ARF algorithm.

Onoe is the variation of Adaptive Multi-Rate Retry (AMRR) [3]. It is introduced by Madwifi organization for the wireless adaptor with Atheors chip. Basically, it associates the number of credits to the current transmission rate. It also finds best data rate with a loss ratio of not up to 50%. The data rate is adjusted by Onoe rate adaption algorithm at the end of each 1000 ms cycle depending on collected transmission statistics.

Minstrel algorithm adapts the data rate based on the statistical table results of the sampling rate. Sampling rate that produced the best throughput and successful packet transmission rate are used as a data transmission for next packet transmission [8]. The Minstrel algorithm consists of retry chain mechanism, the rate decision process and statistic calculation. The short-term variation in the channel quality is enabled by multi-rate retry chain mechanism. The final step in the minstrel algorithm is to calculate the probability of success along with throughput for each data rate. It maintains the successful data rate transmission as an Exponentially Weighted Moving Average (EWMA). It spends a little time trying other rates [9].

$$Pnew = \frac{Psti \times (100 - ael) + (Pold \times ael)}{100} \quad (1)$$

$$Pstt = \frac{npss}{nps} \quad (2)$$

where sti is success_this_time_interval,
ael is ath_ewma_level,
stt is success_this_time_interval,
$npss$ is number_packets_sent_successfully _this_rate_time_interval and
nps is number_packets_sent_this_rate_time_interval

Routing protocols use algorithms to determine optimal network data transfer and communication paths between network nodes. Due to highly dynamic topology, the design of efficient routing protocols for VANET is very challenging [10, 11]. In the proposed work, three best performing routing protocols are implemented and evaluated with the above discussed Rate Control Algorithms Adhoc On-Demand Distance (AODV), Destination Sequence Distance Vector (DSDV) and Optimized Link State Routing (OLSR).

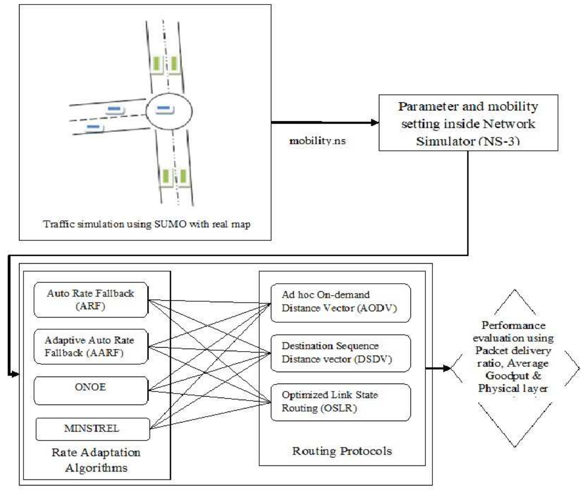


Fig. 1: Proposed Framework

Adhoc On-Demand Distance (AODV) is a reactive routing protocol. Destination Sequence Distance Vector (DSDV) and Optimized Link State Routing (OLSR) are proactive routing protocols. In this paper, both reactive- and proactive-type routing protocols are used for analysis.

AODV protocol creates routes to a destination on-demand basis and facilities both unicast and multicast routing. The main feature of AODV is that it does not provide additional space for unwanted traffic as the route is optimized based on the requirements of the nodes. This could further enhance the flexibility of the nodes as they can enter or leave the network based on their obligation. AODV also provides optimized network bandwidth and reduces excessive memory requirements and route redundancy [12].

Destination-Sequenced Distance Vector is a table-driven or proactive algorithm and it requires each node to periodically broadcast routing updates. Each node in the network will have entries such as destination node, number of hops required to reach them and sequence number. The route used is the one with the highest sequence number. Each DSDV node maintains two routing tables: one for forwarding packets and another one for broadcasting incrementing routing packets [13].

Optimized link state routing is the proactive link state algorithm and the main concept used is Multipoint Relays (MPR). MPRs are selected nodes that forward broadcast messages during network flooding. Also, link state information is generated only by the selected MPR. OLSR considerably reduces the message overhead and it is specifically applicable to large and dense networks [14].

2 Methodology

The major contributions are summarized as follows: first vehicular traffic in a real map scenario is simulated using SUMO. Then, rate control algorithms with different routing protocols using the input generated by SUMO is implemented and their performance is evaluated. Finally, performance comparison of each rate control algorithms with different routing protocols to determine the best combination for selected parameters is done.

2.1 Traffic Simulation using SUMO with Real Map

Simulation of Urban Mobility (SUMO) is an open source simulation suite used to generate traffic for any type of vehicles and people on a selected route [15]. As shown in Fig. 2, a real map is taken (a college campus is considered in our scenario), vehicles are generated, trips are defined and a file is created based on this data in NS3 format. The following steps are used to generate a mobility file which is the input to NS3.

1. Initially, a particular area (shown in Fig. 2) is chosen using an open street map on Google maps and map.osm file is created.
2. NETCONVERT is used to import the digital road network and converts it into a road network format that can be used by the SUMO.
3. POLYCONVERT is used to import geometrical shapes and converts it into representation (using a reference file type.xml) that can be visualized in SUMO Graphical User Interface (GUI).
4. RandomTrips.py command is used to generate random *n* number of trips for the vehicle nodes.
5. The routes for the vehicles are given by the file map.rou.xml
6. Now the configuration file is generated that can be run and visualized through the SUMO-GUI.
7. The configuration is converted to trace file and finally to mobility file (mobility.ns) that acts as input to NS3.

2.2 Parameter and Mobility Setting Inside Network Simulator (NS-3)

NS-3 is an open source network simulator built with C++ and primarily runs on Linux systems (Ubuntu 16.04 is used in this work) [16]. It contains many models of networking technologies that can be used into both wired and wireless networks. An NS3 program is written for the proposed concept which works basically on the scenario

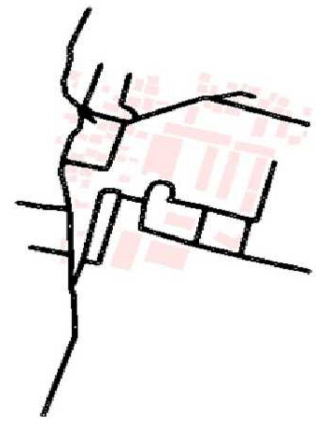


Fig. 2: Real Map Scenario using SUMO-GUI

created by SUMO. The input to the program is the trace file from SUMO. The number of vehicles are varied between 20 to 100 and maintained for 100 simulation seconds. The speed of the vehicle is maintained at 20 m/s. Each vehicle transmits 200 byte basic safety messages at the rate of 10 Hz with the transmission power of 20 dbm. Two-ray ground propagation loss model is used. Vehicles move according to random waypoint mobility model. The parameters determined are goodput, packet delivery ratio and Mac/physical layer overhead.

Average routing goodput is calculated in this work using the following formula [17].

$$\mathrm{AvgRoutingGoodput(Kbps)} = \left(\frac{\frac{\text{Total Rx bytes}\times 8.0}{\text{Total Simulation time}}}{1000} \right) \quad (3)$$

Packet Delivery Ratio (PDR) [17] is the ratio between packet received and packet sent

$$PDR = \frac{\text{Packets received}}{\text{Packets sent}} \quad (4)$$

MacPhyOverhead is calculated using the formula [17, 18]

$$\mathrm{MacPhyOverhead} = \frac{(\text{Total Phy bytes} - \text{Total App bytes})}{\text{Total Physical bytes}} \quad (5)$$

These are the core settings in the NS3 code for extracting the desired output.

2.3 Rate Control Algorithms with Routing Protocols

This is the main part of the methodology as all the possible combination of the rate control algorithms and routing protocols are implemented into the VANET scenario as shown in Fig. 1. The rate control settings are assigned to Auto Rate Fall (ARF), Adaptive Auto Rate Fall (AARF), Onoe, Minstrel rate control algorithm one by one with their respective class that is available in NS3 and simulation is run by changing the routing protocols AODV, DSDV and OLSR for each rate control algorithm.

2.4 Performance Evaluation

Performance evaluation is done based on the results taken from the different combination in terms of Goodput, packet delivery ratio and overhead. Each parameter is analysed with different densities of the vehicles and the best performing combination of rate control algorithm and routing protocol is found and which can be implemented in real vehicle devices for the efficient communication in VANET.

3 Results and Discussion

3.1 Experimental Results

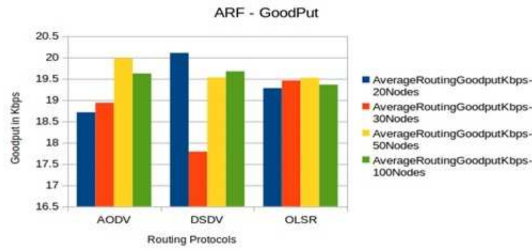
ARF, AARF, Onoe, Minstrel rate control algorithms are implemented with AODV, DSDV and OLSR routing protocols for the vehicle densities 20, 30, 50 and 100 and the performances are evaluated in terms of an average goodput, packet delivery ratio, and Mac/physical layer overhead.

3.1.1 Simulation of ARF Rate Control Algorithm with Different Routing Protocols

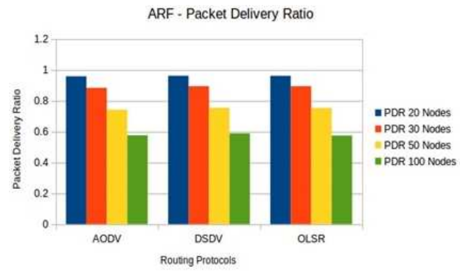
Fig. 3(a) shows the average routing goodput of ARF rate control for different routing protocols. Clearly, DSDV routing protocol outperforms AODV and OLSR routing protocol for the lower and higher density of the vehicle, OLSR routing protocol performs well when the number of the vehicle nodes is set to 30 and AODV routing protocol performs well when the number of vehicle nodes is set to 50. In Fig. 3(b) ARF rate control protocol with DSDV routing protocol performs well in terms of packet delivery ratio when compared with other routing protocols in higher and lower densities of the vehicles whereas OLSR routing protocol performs well when the number of vehicles is set to 30 and 50. PDR is the ratio between the number of packets received by the destination vehicle node to the number of packets sent by the source vehicle node. Fig. 3(c) shows that in terms of Mac/physical overhead OLSR routing protocol performs well with ARF rate control algorithm for the vehicle densities of 20, 30, 50 and DSDV protocol performs well for the vehicle density of 100 nodes. MAC/physical layer overhead is the overhead caused due to Mac layer and the physical layer which is same when the data is transmitted in short time and with higher data rates.

3.1.2 Simulation of AARF Rate Control Algorithm with Different Routing Protocols

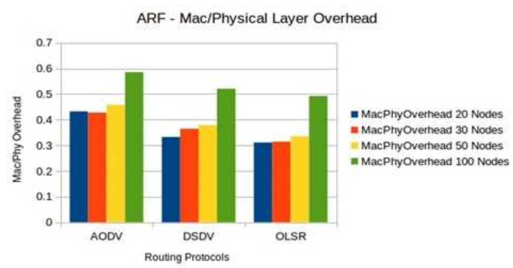
Fig. 4(a) shows that AARF rate control algorithm with DSDV protocols outperforms AODV and OLSR in terms of Average Routing goodput for the densities of 20, 30 and 100 vehicles. AODV protocol performs well with the density of 50 vehicles. AARF rate control algorithm with DSDV routing protocol gives the best performance in higher densities of the vehicles so this combination can be used in the areas where the vehicle traffic is high. Goodput is the measure of useful information delivered by the source vehicle to the destination vehicle in particular time period. Fig. 4(b) shows that in terms of packet delivery ratio DSDV performs well for the vehicle densities of 20 and 100, OLSR performs well for the vehicle densities of 30 and 50. PDR is the ratio between the number of packets received by the destination vehicle node to the number of packets sent by the source vehicle node. Fig. 4(c) shows that OLSR protocol performs well in terms of Mac/physical overhead for the vehicle densities of 20, 30, 50 and DSDV protocol performs well for the vehicle density of 100. MAC/physical layer overhead is the overhead caused due to Mac layer and the



(a) Routing goodput of ARF rate control algorithm with different routing protocols

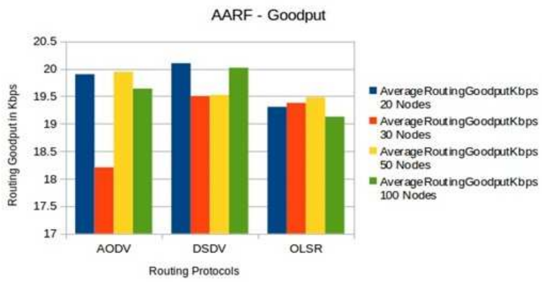


(b) Packet delivery ratio of ARF rate control algorithm with different routing protocols

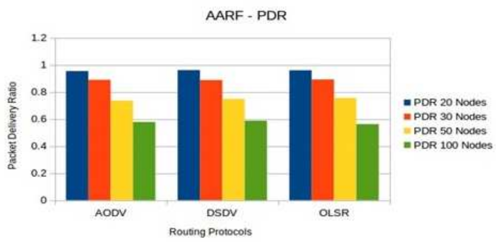


(c) Mac/physical overhead of ARF rate control algorithm with different routing protocols

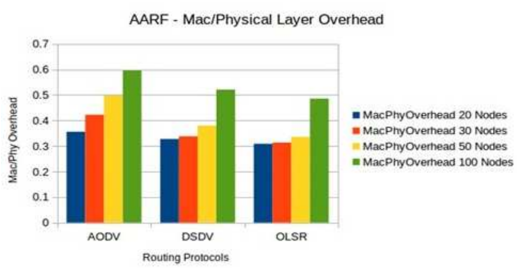
Fig. 3: Performance analysis of ARF rate control algorithm with different routing protocols



(a) Routing goodput of AARF rate control algorithm with different routing protocols

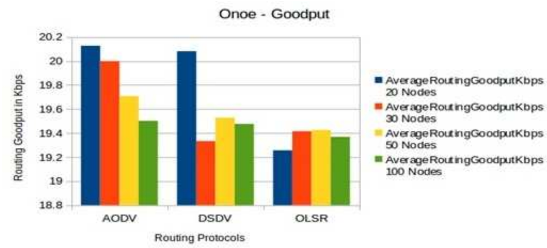


(b) Packet delivery ratio of AARF rate control algorithm with different routing protocols



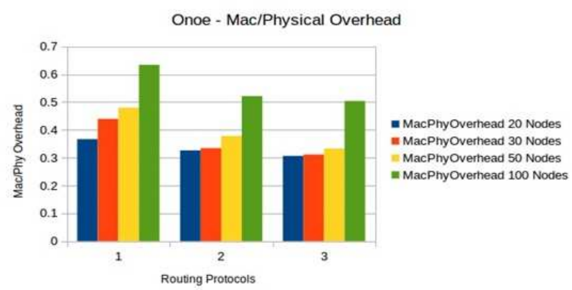
(c) Mac/physical of AARF rate control algorithm with different routing protocols

Fig. 4: Performance analysis of AARF rate control algorithm with different routing protocols



(a) Routing goodput of Onoe rate control algorithm with different routing protocols

(b) Packet delivery ratio of Onoe rate control algorithm with different routing protocols



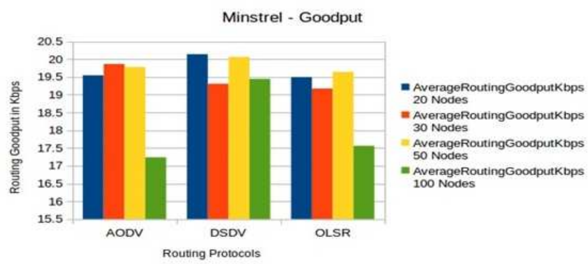
(c) Mac/physical overhead of Onoe rate control algorithm with different routing protocols

Fig. 5: Performance analysis of Onoe rate control algorithm with different routing protocols

physical layer which is same when the data is transmitted in short time and with higher data rates.

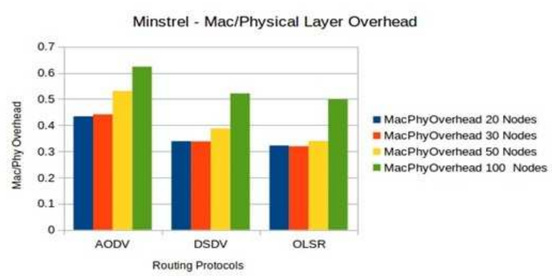
3.1.3 Simulation of Onoe Rate Control Algorithm with Different Routing Protocols

Fig. 5(a) shows that the Onoe rate control algorithm with AODV routing protocol outperforms DSDV and OLSR routing in all densities of the vehicles. Goodput is the measure of useful information delivered by the source vehicle to the destination vehicle in particular time period. Fig. 5(b) shows that Onoe rate control algorithm with AODV routing protocol in terms of packet delivery ratio DSDV performs well for the vehicle densities of 20 and 100 whereas OLSR performs well for vehicle densities of 30 and 50. In terms of packet delivery ratio, Onoe rate control algorithm with DSDV routing protocol performs well compared to other approaches when the vehicle density is high and low. PDR is the ratio between the number of packets received by the destination vehicle node to the number of packets sent by the source vehicle node. Fig. 5(c) shows that Onoe rate control algorithm with AODV routing protocol in terms of Mac/physical overhead OLSR performs well when compared to other protocols. In this figure routing protocol 1 is AODV, routing protocol 2 is DSDV, routing protocol 3 is OLSR. In terms of Mac/physical overhead, Onoe rate control algorithm with OLSR routing protocol performs well compared to other approaches in all densities of the vehicles. MAC/physical layer overhead is the overhead caused due to Mac layer and the physical layer which is same when the data is transmitted in short time and with higher data rates.



(a) Routing Good Put of Minsrel rate control algorithm with different routing protocols

(b) PDR of Minsrel rate control algorithm with different routing protocols



(c) Mac/physical Overhead of Minsrel rate control algorithm with different routing protocols

Fig. 6: Performance analysis of Minstrel rate control algorithm with different routing protocols

3.1.4 Simulation of Minstrel Rate Control Algorithm with Different Routing Protocols

Fig. 6(a) shows that Minstrel rate control algorithm with DSDV routing protocol performs well for the vehicle densities of 20, 50 and 100. AODV performs well for the vehicle density of 30 in terms of average routing goodput. Goodput is the measure of useful information delivered by the source vehicle to the destination vehicle in particular time period. Fig. 6(b) shows that for the vehicle densities of 20 and 100 AODV performs better and for vehicle densities of 30 and 50 DSDV performs better in terms of packet delivery ratio. Minstrel rate control algorithm and AARF control algorithm with OLSR routing protocol perform well for the vehicle densities of 50 and 30 respectively. PDR is the ratio between the number of packets received by the destination vehicle node to the number of packets sent by the source vehicle node. Fig. 6(c) shows that in terms of Mac/physical overhead OLSR performs well when compared to other protocols. The outcome of this extensive research has shown some interesting results. In terms of average routing goodput Minstrel rate control algorithm with DSDV routing protocol gives the best performance in low densities of the vehicles so this combination can be used for the sparse networks where the vehicles are less in numbers. MAC/physical layer overhead is the overhead caused due to Mac layer and the physical layer which is same when the data is transmitted in short time and with higher data rates.

4 Conclusion and Future Work

In this work ARF, AARF, Onoe, Minstrel rate control algorithm with AODV, DSDV, and OLSR routing protocol are implemented in real-time VANET scenario. Based on the input from the SUMO and NS3, simulations are run for all possible combinations and found that Minstrel rate control and AARF rate control algorithms performs better in low densities and high densities respectively with DSDV routing protocol in terms of average routing goodput which is the important parameter as far as the rate control is concerned. Packet delivery ratio and Mac/physical overhead are also considered in this work and their results are also discussed. In future, various other rate control algorithms and routing protocols can be implemented and compared with different parameters which are closely related to rate control methodology.

References

[1] Ayoade Ilori, Zuoyin Tang1, Jianhua He and Yue Li2, Throughput-based rate adaptation algorithm for IEEE 802.11 vehicle networks, IET Netw., **4(2)**, 111–118, 2015.
[2] Makhlouf, A. B and Hamdi. M, Design and experimentation of rate adaptation for IEEE 802.11n WLANs, IEEE Trans. Wirel. Commun., 908–916, 2011.
[3] Saiid Biaz and Shaoen Wu, Rate adaptation algorithms for IEEE 802.11 networks: A survey and comparison, IEEE Symp. Computers and Communications, 130–136, 2008.
[4] Zhang, J, Tan, K, Zhao, J, and Wu, H., Zhang. Y, A practical SNR-guided rate adaptation, 2008 IEEE INFOCOM–The 27th Conf. Computer Communications, 2083–2091, 2008.
[5] A. Kamerman and L. Monteban, ”WaveLAN II: A high-performance wireless LAN for the unlicensed band,” Bell Labs Technical Journal, **2(3)**, 118–133, 1997.
[6] M. Lacage, M. Manshaei, and T. Turletti, ”IEEE 802.11 Rate Adaptation: A Practical Approach”, in MSWiM04, 126–134, 2004.
[7] Song, Y, Zhu. X, Fang. Y and Zhang. H, Threshold optimization for rate adaptation, IEEE Trans. Wirel. Commun., **9(1))**, 318–327, 2010.
[8] Igor Kim, Young-Tak Kim, Realistic modeling of IEEE 802.11 WLAN considering rate adaptation and multi-rate retry, IEEE Transactions on Consumer Electronics, **57(4)**, 2011.

[9] Jian Xiong, Cailian Chen and Xinping Guan, LRRA: Location-Related Rate Adaptation Algorithm in IEEE 802.11p for DSRC Technology in VANET, IEEE 84th Vehicular Technology Conference (VTC-Fall), 2016, pp: 1–5.
[10] M. Nekovee, Sensor networks on the road: the promises and challenges of vehicular ad hoc networks and vehicular grids, In Proc. of the Workshop on Ubiquitous Computing and e-Research, Edinburgh, U.K., May 2005.
[11] J. Blum, A. Eskandarian, and L. Hoffmman, Challenges of intervehicle ad hoc networks, IEEE Trans. Intelligent Transportation Systems, **5(4)**, 347–351, 2004.
[12] Jack Fernando Bravo-Torres, Martí n Lopez-Nores, Yolanda Blanco-Ferná ndez, Jose Juan Pazos-Arias, Manuel Ramos-Cabrer, Alberto Gil-Solla, Optimizing Reactive Routing Over Virtual Nodes in VANETs, IEEE Transactions on Vehicular Technology, **65(4)**, 2016.
[13] Hemanth Narra, Yufei Cheng, Egemen K. Ç etinkaya, Justin P. Rohrer, and James P. G. Sterbenz, Destination-Sequenced Distance Vector (DSDV) Routing Protocol Implementation in ns-3, ICST SIMUTools Workshop on ns-3 (WNS3), Barcelona, Spain, March 2011, 439–446.
[14] Jamal Toutouh, Jose Garcia-Nieto, Enrique Alba, Intelligent OLSR Routing Protocol Optimization for VANETs, IEEE Transactions on Vehicular Technology, **61(4)**, 2012.
[15] Seung-Seok Kang; Ye-Eun Chae; Seunguk Yeon, VANET routing algorithm performance comparison using ns-3 and SUMO, 2017 4th International Conference on Computer Applications and Information Processing Technology (CAIPT), pp: 1–5
[16] M. Xing, J. He, and L. Cai, Maximum-Utility Scheduling for Multimedia Transmission in Drive-Thru Internet, IEEE Transactions on Vehicular Technology, **65(4)**, 2649–2658, 2016.
[17] P. Fazio, D. F. Rango, and C. Sottile, A Predictive Cross-Layered Interference Management in a Multichannel MAC with Reactive Routing in VANET, IEEE Transactions on Mobile Computing, **15(8)**, 1850–1862, 2016.
[18] Soon-Hyeok Choi and S. M. Nettles, An overhead controlled MAC protocol for high data-rate wireless networks, VTC-2005-Fall. 2005 IEEE 62nd Vehicular Technology Conference, 2005.

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