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Determination of Most Efficient Routing Protocol in Vehicular Ad-hoc Network (VANET) for Highway Scenario Using the Simulation Approach

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Abstract: *Wireless transmission is becoming extremely challenging in VANET environment. Cars are moving in a high speed which brings in-deterministic fashion in topology change and thus become greatest challenges facing in VANET technology. This frequent topology changes occurred as a result of high speed movenment of vehicles in highway causing disconnection of information when message is being relayed between vehicles. To practically and effectively deploy wireless technology in highway for maximum efficiency, problem of frequent topology changes and many other challenges need to be tackled. To deal with some of these challenges, a siimulation environment was set-up to determine efficient routing protocol to handle these specific characteristics in Vehicular Ad-hoc Network (VANET) for highway scenario using Simulation of Urban Mobility (SUMO) and Network Simulator (OMNet++) by considering Contention-Based Forwarding (CBF), Anchor –based Street and Traffic Awareness Routing (A-STAR), and Greedy Perimeter Coordinator Routing (GPCR) of position-based routing protocol for comparison based on selected network parameters such as End-to-End delay, Routing Overhead and Packet Deliver Ratio. Transmission range and the speed of the vehicle were varied at constant node density. Results obtained from the simulation show that with varying speed, highest packet delivery ration and lowest end-to-end delay was observed in CBF, while A-STAR has lowest routing overhead. Also with varying transmission range, CBF still considered best with highest packet delivery ratio. GPCR has lowest end-to-end delay with relative transmission range and A-STAR has better routing overhead with relative transmission range.*

Keywords: *OMNet++; Routing Protocols; SUMO; Transmission Range; Varying Speed.*

1. INTRODUCTION

Many researchers have proposed different routing protocols which are grouped into five. These are: position based, topology based, Broadcast, Geo cast and Cluster based routing protocols [1], [2]. Position based Routing protocol is considered most important routing protocol in VANET technology and some examples of position based routing protocol were considered for this research work for efficiency due to the fact that position based routing protocols decides on the next forwarding hops based on the geographical positioning information [1], [2].

However, deploying routing protocols in real world in VANET environment is complex, laborious and expensive [3], [4], and as a result, simulation tools are being considered because of its simplicity, flexibility and availability to generate and evaluate required components for VANET work. The simulation tools used in VANET are classified into mobility generators to generate realistic traces of vehicle in motion that could be exported to another simulator for further analysis which includes SUMO, VanetMobiSim, STRAW, FreeSim. Network simulator allows the needed components such as channels, node structure (cars), transmission, data traffic and so on to be created and calculated in wireless network and these in-

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clude OMNET++, NS-2, OPNET, Ns-3, GloMoSim, QualNet [3], [5], [6], [7]. Also these two simulators can be available as hybrid VANET simulator that combined both mobility generator and network simulator features into one which include NCTUns, TraNS, GrooveNet, Veins, MOVE [6], [3]. SUMO (Simulation of Urban Mobility) and OMNET++ (Objective Modular Network Testbed) were the two simulators considered for the development of this research work because they are users friendly in that; they are simpler in use, freely sourced (open source), allow realistic traffic and map to be supported [3], [7].

More also, many performance metrics are suggested by different reaserchers to determine the best path in sending data traffic in network communication such as hop count, maximum transmission unit, path speed, path reliability, throughput, load [8] [9], delay, packet loss, capacity, jitter, quality of service [10], routing control over head, link failure, end-to-end delay and packet delivery ratio [11]. Three of these performance metrics were considered for this research work which include packet delivery ratio to determine the ratio of number of data packet successfully received at the receiving end node to the number of data packet expected to be sent by the sending end node [11], end-to-end delay to determine overall delay of data packet received from source node's application agent when it is being transmitted to the destination node's application agent [6] and also routing overhead to determine the proportion of routing control message generated to total expected number of data messages received [11].

Further more, VANET technology architecture is devided into three modes which include ad hoc mode where the vehicle communicate and exchange information with other vehicle wirelessly using On-Board Unit. In this regard, the vehicle (that is, node in the wireless communication) which act as a router allow messages to be transmitted from source to destination. The Infrastructure mode allow vehicle to obtained routing data or traffic information using fixed access point to link internet, and hybrid achitecture mode allow combination of both ad hoc and infrastrured architecture which include using both On-Board Unit to communicate between consecutive vehicles using fixed access point to link the internet for information exchange [12]. Applications derived from VANETs can be categorized into safety and non- safety applications .The safety applications enable general safety improvements by reducing road accident and this further classified into safety-critical, where situation is hazardous (such as collision, high danger) and safety- related associated with either low danger (curve speed warning) or eminent (work zone warning). These two safety applications involved vehicle to infrastructure (V2I)/ (I2V) or vehicle to vehicle (V2V) communication. Also non-safety applications improve traffic comfort by providing information about traffic [6], and further classified into comfort-oriented and convenience-oriented applications, which make the comfort of passenger and efficiency of traffic to get better [6], [13]. These include payment service such as (electronic toll collection, parking management), infotainment service such as (internet access, instant messaging, and media downloading), road service finder such as *(*restaurant, nearest fuel station), and traffic optimization such as (enhanced route guidance, traffic information and recommendation) [6].

The remaining part of this paper is structure as follows: Section II reviewed similar work done on position based routing protocols by different researchers using different network parameters, investigated with different mobility and network software. Section III presents simulation environment and routing protocols considered for the analysis. In Section IV, the results for the analysis are represent and presented in tables and figures using Microsoft excel. Conclusion and future direction on further investigation on routing protocols using different network parameters are presented in section V.

2. LITERATURE REVIEW/ RELATED WORK

It is hard to choose appropriate mobility model and routing protocols as a result of repeated disconnection and speedy topology changes. Therefore carry out performance evaluation and analysis of the two on-demand routing protocols that are DSR and AODV; two simulators are required and these are Random Waypoint mobility model and Network Simulator (NS-2.34) and these are based on three selected performance metrics end-to-end delay, loss packet ratio and packet delivery ratio by varying speed limit/pause time and node density and concluded that these two routing protocols show a few variations in performance at low and high density [14], [15].

Also NS-2 simulator was used to compared DSR, AODV and TORA routing protocols in a various highway set-up having characterized with load, mobility and range of networks. These are equally based on routing load, packet delivery ratio and end-to-end delay and it was concluded that DSR showed excellent performance in the simulation with TORA which has a better performance at high speed and highest node density [16].

Assessment and analysis of VANET performance in a realistic environments were carried out with simulation due to complexity of implementing and high cost of deployment. In this, existing GIS tools and Google Earth was used to create a real world road Map of JNU by obtaining limited region of road Map to capture the realistic mobility based on router drop, packet loss and packet delivery ratio as statistical measures using NS2 simulator on AODV routing

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International Journal of Advances in Computer and Electronics Engineering
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protocol and IEEE 802.11 standard with varying node density, constant transmission range of 250m and frequency of 2.4GHz and therefore, concluded that RSU can be used to reduce packet drops which can forward the packets even the packets had been dropped at the intersections by intermediate vehicles [4].

Vein framework that combined Simulation of Urban Mobility (SUMO) and Objective Modular Network Testbed (OMNET++) were used to simulate selected city of Cologne, German for realistic traffics simulation to establish Probability of Beacon Delivery for each car sampled and established that as the number of cars increase or received beacons increase or decrease in each time, and every car has different Probability of Beacon released that can be varied [7]. [17]. Also, it is important and accurate to use realistic road Map to analyze routing protocols performance and therefore use Simulation of Urban Mobility (SUMO) and NS-2.33 to analyzed performance of three routing protocols: GPSR, DSR and AODV on packet loss, packet delivery ratio and throughput and considered GPSR performance better in packet delivery ratio, throughput with lesser packet loss

3. METHODOLOGY AND PROCEDURES

The approach is fully a simulation method, and this involved the use of simulation of Urban Mobility (SUMO-0.19.0) and OMNet++ 4.4.1 simulators. These are equally the two open source simulation softwares, used to achieve the aim and objectives of this research work.

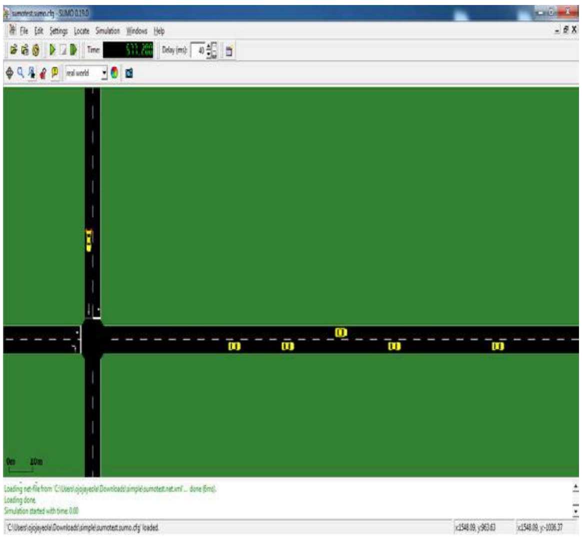

Figure 1 Highway scenario vehicle traffic generated during simulation in SUMO-0.19.0

SUMO was used to generate the mobility of vehicle on highway as indicated in Figure 1 and the outputs, that is, the resultant generated parameters were then used as input parameters for further simulation using the OMNet++, the three selected position-based routing protocols: GPCR, A-STAR, and CBF with another three selected network parameters: routing overhead, end-to-end delay, and packet delivery ratio were used. The carrier frequency of 5.89GHz with maximum transmission power of 2mW was also considered for high speed and almost error free propagation of signal, as the signal delivery efficiency and integrity are required. Speed, transmission range and node density are the three important elements used in this simulation approach. Speed and transmission ranges were varied at regular interval of span while the node density was kept constant for the simulation period. Simulation area of 2500m x 2000m was used for the highway scenario. The total simulation period for each process was 600seconds and all other parameters, which were used for this simulation, are numerically indicated in Table 1

TABLE 1 PARAMETERS CONFIGURATION USED FOR THE SIMULATION

Parameters	**Value**
Simulation Scenario	Highway Scenario
Network Simulator	OMNet++ 4.4.1
Vehicle Mobility Generator Simulator	SUMO-0.19.0
Simulation Area	2500m x 2000m
Routing Protocols	CBF, ASTAR, GPCR
Simulation Time Limit	600s
Node Density	10
Transmission Range	150m, 250m,350m
Speed	80m/s, 120m/s, 160m/s
Mobility Type	TraCIMobility
Carrier Frequency	5.89GHz
Maximum Transmission Power	2mW
Mac	IEEE802.11p
Traffic Type	UDP
Channel Bitrate	2Mbps

4. RESULTS AND DISCUSSIONS

The results were generated using OMNet++ 4.4.1. The first condition according to Table II have speed variations of 80m/s, 120m/s, and 160m/s while the transmission range and node density are kept constant at 150m and 10m of span respectively. The results for GPCR, A-STAR, and CBF were studied based on packet delivery ration (%), end-to-end delay (second), and routing overhead (%) and technically, the efficient routing protocols must possess certain qualities to make them more suitable for VANET operation such that packet delivery ratio must be higher, end-to-end delay and routing overhead must be lower.

Table II represents results obtained for each processes as the speed changes. These results were tactically and technically analyzed using Microsoft excel as a tool and the appropriate graphical illustration are well represented in Figures 2. Different speeds at 80m/s, 120m/s, and 180m/s were used to determine

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Volume 3, Issue 12, December 2018, pp. 7–13

the packet delivery ratio for the three routing protocols, these at constant node density of 10 and transmission ratio of 150m. Observation from Table III indicates that packet delivery ratio is constant for both A-STAR and GPCR and all through the speeds and it was kept constant for CBF for specific period of speed before decreasing.

TABLE II SIMULATION BY VARYING THE SPEEDS WITH FIXED TRANSMISSION RANGE, AND FIXED NODE DENSITY

Speed (m/s)	Routing Protocols	Packet Delivery Ratio (PDR)	End-to-End Delay (sec)	Routing Over-head
80	A-STAR	0.64	10.71	17.78
	GPCR	0.60	5.70	43.92
	CBF	1.12	3.80	109.55
120	A-STAR	0.64	7.70	18.11
	GPCR	0.60	8.89	81.58
	CBF	1.12	6.75	111.61
160	A-STAR	0.64	6.83	64.10
	GPCR	0.60	9.84	61.63
	CBF	0.74	4.87	59.70

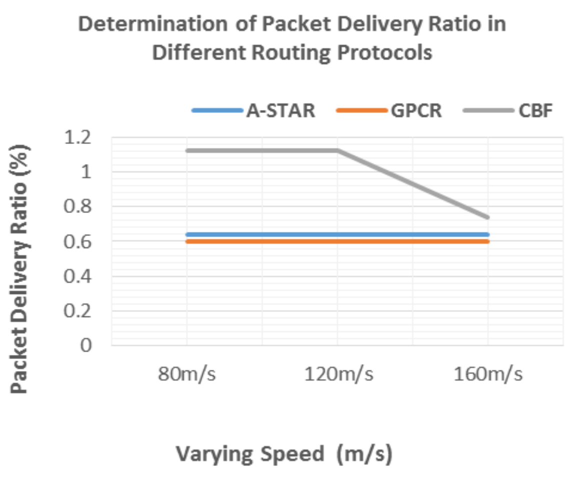

Figure 2 Packet delivery ratio determination with varying speeds, fixed node density, and fixed transmission range

The observation indicated there were a lowest packet delivery ratio in GPCR and consequently, a highest packet delivery ratio in CBF. Figure 2 below therefore do pictorial illustrated technical justice by direct interpretation of numerical illustrated depicted data of Table III

The result for end-to-end delay at different speeds of: 80m/s, 120m/s, and 180m/s for the three routing protocols are indicated in Table IV and the graphical illustration is shown in Figure 3 below. It was therefore observed from both Table IV and Figure 3 that, the Contention Based Forwarding (CBF) has lowest end-to-end delay in sending packet across the node irrespective of the magnitude of speeds.

TABLE III VARYING SPEED TO DETERMINE PACKET DELIVERY RATIO IN DIFFERENT ROUTING PROTOCOLS

Speed (m/s)	A-STAR	GPCR	CBF
80m/s	0.64	0.6	1.12
120m/s	0.64	0.6	1.12
160m/s	0.64	0.6	0.74

TABLE IV VARYING SPEED TO DETERMINE END-TO-END DELAY IN DIFFERENT ROUTING PROTOCOLS

Speed (m/s)	A-STAR	GPCR	CBF
80m/s	10.71	5.7	3.8
120m/s	7.7	8.89	6.75
160m/s	6.83	9.84	4.87

TABLE V VARYING SPEED TO DETERMINE ROUTING OVERHEAD IN DIFFERENT ROUTING PROTOCOLS

Speed (m/s)	A-STAR	GPCR	CBF
80m/s	17.78	43.92	109.55
120m/s	18.11	81.58	111.61
160m/s	64.1	61.63	59.7

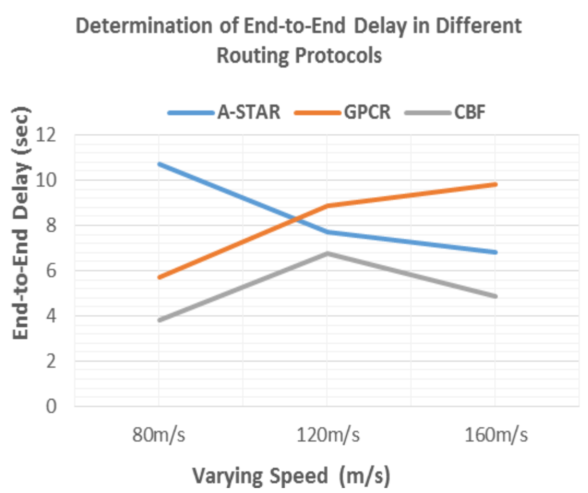

Figure 3 End-to-End Delay determination with varying speeds, fixed node density, and fixed transmission range

The routing overhead was at different speeds of 80m/s, 120m/s, and 180m/s for the three routing protocols are indicated in Table V; also, the graphical illustration is shown in Figure 4 below. The results

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Volume 3, Issue 12, December 2018, pp. 7–13

show that, the routing overhead increases with increased speed with Anchor-Based Street and Traffic Routing (A-STAR), increases at specific period of speeds for both Greedy Perimeter Coordinator Routing (GPCR) and Contention Based Forwarding (CBF), before it is finally decreased. Therefore, routing overhead is considered preferable in A-STAR at relative speed of 80m/s to 120m/s.

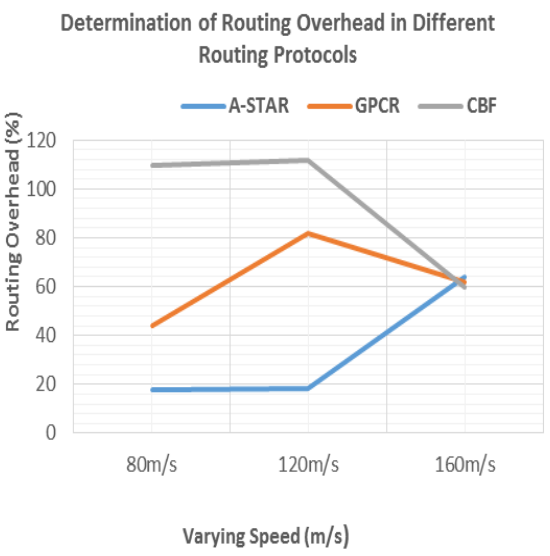

Figure 4 Routing overhead determination with varying speeds, fixed node density, and fixed transmission range

TABLE VI SIMULATION BY VARYING THE TRANSMISSION RANGE WITH FIXED SPEED, AND FIXED NODE DENSITY

Trans mission Range (m)	Routing Protocols	Packet De-livery Ratio	End-to-End Delay	Routing Over head
150	A-STAR	0.64	10.71	17.78
	GPCR	0.6	5.7	43.92
	CBF	1.12	3.8	109.55
250	A-STAR	0.64	6.83	80.31
	GPCR	0.6	2.77	18.49
	CBF	0.74	10.83	78.96
350	A-STAR	0.64	4.81	12.84
	GPCR	0.6	8.79	43.54
	CBF	0.74	6.83	68.96

For the second condition, different transmission ranges of 150m, 250m, and 350m are indicated in Table 6.0. These data were respectively studied at constant node density of 10 and at constant speed of 80m/s for the three position based routing protocols: GPCR, A-STAR, and CBF and these were fully based on, end-to-end delay (in seconds), packet delivery ratio (in %) and routing overhead (also, in %). The results that were obtained from OMNet ++ simulation were analyzed and pictorially represented in Figure 5, 6 and Figure 7 using Microsoft excel.

The Packet delivery ratio at various transmission ranges of: 150m, 250m and 350m from Table VI above for the three routing protocols are shown in Table VII. Observation from this table indicates that packet delivery ratio is constant for both A-STAR and GPCR at any transmission range and also constant for CBF when the transmission range increases from 150m through 250m to 350m after decreasing. In this regard, packet delivery ratio can be said to be the greatest in CBF and the tabular parameters of Table VII are pictorially represented in Figure 5 below.

TABLE VII VARYING TRANSMISSION RANGE TO DETERMINE PACKET DELIVERY RATIO IN DIFFERENT ROUTING PROTOCOLS

Transmission Range (m)	A-STAR	GPCR	CBF
150	0.64	0.6	1.12
250	0.64	0.6	0.74
350	0.64	0.6	0.74

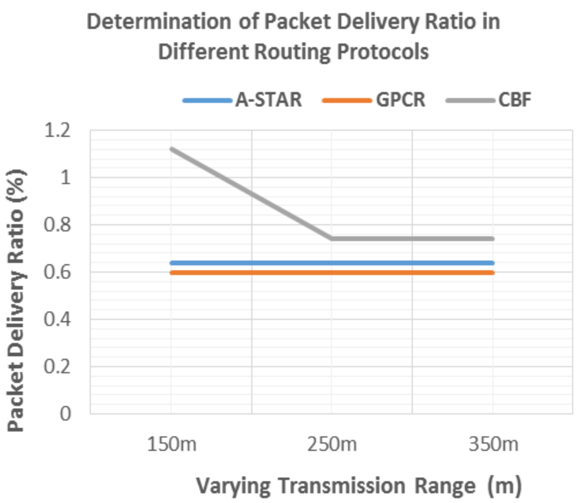

Figure 5 Packet delivery ratio determination with varying transmission range, fixed node density, fixed speed.

End-to-end delay is indicated in Table VIII below for A-STAR, GPCR, and CBF routing protocols at various transmission ranges of: 150m, 250m and 350m. From the table, CBF has the lowest end-to-end delay at 150m, GPCR has the lowest end-to-end delay at 250m, and A-STAR has the lowest end-to-end delay at 350m. Therefore GPCR can be considered to have delivered the best data packet transmission be-

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Volume 3, Issue 12, December 2018, pp. 7–13

tween the nodes at lowest end-to-end delay of 2.77(second) and at 250m transmission range. The tabular parameters of Table VIII are pictorially represented in Figure 6 below.

TABLE VIII VARYING TRANSMISSION RANGE BY DETERMINING END-TO-END DELAY IN DIFFERENT ROUTING PROTOCOLS

Transmission Range (m)	A-STAR	GPCR	CBF
150	10.71	5.7	3.8
250	6.83	2.77	10.83
350	4.81	8.79	6.83

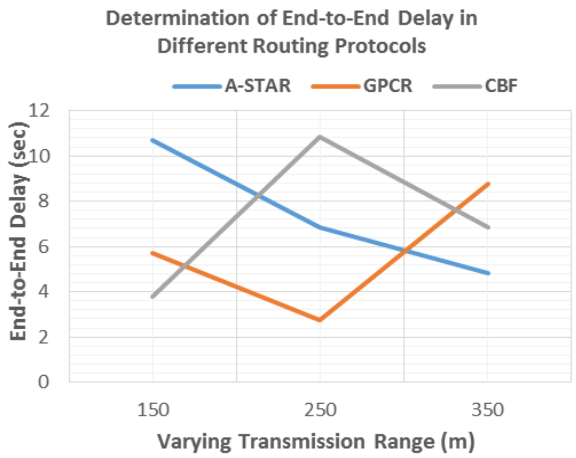

Figure 6 End-to-End delay determination with varying transmission range, fixed node density and fixed speed

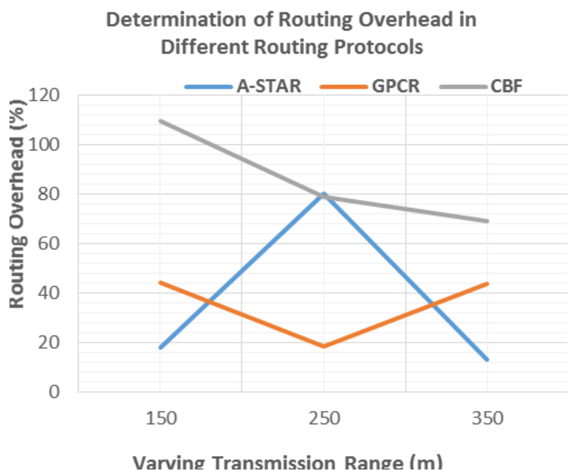

Figure 7 Routing overhead determination with varying transmission range, fixed node density, and fixed speed

The routing overhead at various transmission range is illustrated in Table IX for the three routing protocols. A-STAR was considered the best for routing overhead at span of 150m and 350m with 17.78% and 12.84% respectively while GPCR considered the best at 250m with 18.49%. In all, A-STAR could be considered protocol of choice at 350m with 12.84% of routing overhead when best transmission range for data packet between nodes in highway scenario is of higher interest. Figure 7 represents the graphical illustration of Table IX, and this is as shown in the Figure 7.

TABLE IX VARYING TRANSMISSION RANGE BY DETERMINING ROUTING OVERHEAD IN DIFFERENT ROUTING PROTOCOLS.

Transmission Range (m)	A-STAR	GPCR	CBF
150	17.78	43.92	109.55
250	80.31	18.49	78.96
350	12.84	43.54	68.96

5. CONCLUSION

Many position-based routing protocols have been developed by different researchers for highway scenario, but the results obtained from their analysis, using various simulation techniques proved that, there is no single or specific routing protocol that had been able to achieve all the network performances in all situation as far as VANET environment is concerned. Therefore, this research work clearly proved beyond doubt that the use of simulation of urban mobility (SUMO) and OMNet++, if not the best, it is still a remedy as it has a crystal evidence, and it is clear that the Contention Based Forwarding (CBF) performed excellently well, using some network parameters, so also are the Anchor-Based Street and Traffic Routing (A-STAR) when their speed are varied. Likewise, when the transmission ranges between vehicles are equally varied, each routing protocol will have performed well at different network parameters. In conclusion, the results obtained emphatically proved that no single or specific routing protocol has been able to achieve all the network performances in all situations in highway scenario and this fact actually make it difficult to determine the most efficient routing protocols in this scenario.

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