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Performance Analysis of various Routing Protocols with Preference to Border Nodes in VANET Environment

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ABSTRACT
Vehicular Ad-hoc Networks (VANETs) where vehicles are described as the moving nodes, is a subclass of Mobile Ad-hoc Networks (MANETs) in which moving nodes has the potential of self-organization without need of fixed infrastructures. VANET provides road safety, traffic control management and spreading the important information to drivers of the moving vehicles in highly mobile environments. Various safety and non-safety applications provided in time-critical situations, high node density and varying mobility distinguishes VANETs from other wireless networks. Routing protocols for MANETs are not suitable in VANETs but position based routing protocols are much suitable. In this paper, we describe the essentials of VANETs and elaborate various routing protocols mostly position based routing protocols with preference to border nodes and compare the existing protocols by considering some simulation criteria characterized by network size, number of nodes and time to simulate the network using the NS2 simulator and evaluated the performance of routing protocols and compute the results in terms of packet delivery ratio, end to end delay, throughput and describe which protocol gives the better results.

General Terms
BMFR, TB-MFR, BMAR, AMAR, GPSR, GPCR, DSR, MFR, PDR, End-to-End Delay.

Keywords
VANET, MANET, NS2, RSU, IVC, V2V, V2I, Routing Protocols, network simulation.

1. INTRODUCTION
At the present time with the sharp increase of transport vehicles and other private vehicles on the roads makes driving more challenging and dangerous. Nobody maintains the safety speed directions moreover roads are saturated and one important thing that matters is drivers behavior and lack of attention [1] which is liable for the increasing rate of road accidents and fatalities. Endless growing and advancing safety requirements and refinements in MANET (Mobile Ad Hoc Networks) technology as well as user's concern to access internet make VANETs (Vehicular Ad Hoc Networks) a hot research topic [2]. Many researchers are attracted by this field to develop simulation tools, applications, and various protocols for VANETs [3] and various issues are investigated by many researchers of different fields to remove several challenges face by developers [4]. V2I (Vehicle to Infrastructure) and V2V (Vehicle to Vehicle) communications are used to provide the safety messages to drivers, provided by vehicle safety communications. Which depend on the wireless self-organizing ad hoc networks through which vehicles are connected with each other and with road side fixed infrastructures (RSU's) [5]. Data transmitted by vehicles to other moving nodes or RSU's provides variety of applications like IVC (Inter Vehicle Communication), traffic control and circumferential monitoring [6]. Communication takes place through DSRC (Dedicated Short Range Communication) which is an IEEE 802.11p standard and WAVE which is a 1609 family of standards referred by IEEE [7]. Network characteristics gives methods of message diffusion, development of applications and security mechanics and communication patterns like beaconing, geo-broadcasting and information aggregation make VANETs a discrete subtype of ad hoc networks [8]. Various car manufacturing companies, academic organizations and government bodies recognize the prominence of VANETs and some of them launched valuable projects on VANETs such as ADASE (Advanced Driver Assistance Systems) [9], CarTALK2000 and CarNet, also VANET assigned a spectrum by FCC (Federal Communications Commission) [10]. Single path, Multi path, Carry and forward path routing is vividly described in routing protocols of VANETs. To develop an effective routing protocol for vehicular ad hoc networks is an ambitious task due to challenges like life time of the links prone to high mobility of nodes in a network [11], VANETs, as one of the categories of IVC networks, are described by repeated fragmentation and frequently changing network topologies [12]. Topology based routing is much suitable for MANETs but they are not stable in VANETs [13], in such cases position based routing is more suitable and gives better results than other conventional protocols. Position based routing protocols uses the position of the destination node to send the data packets without using the network address, source forwards the packet by placing the destination node's location in the header of the packet without requiring the route discovery, topology of the network and maintenance of the route [14]. Requirement of security protocols and privacy assurance in VANETs will be fulfilled to assure the acceptance by users and can be used in a successful manner [15].GPS or any other location service system is required to know the location of the moving nodes, moreover some of the techniques has an premise that while using the GPS positioning services there may not be recurrence in node trajectories [16]. The participative and dynamic nature of

VANETs does not contribute themselves for resource reservation, factors like vehicle's speed, position, link time-lag, reliability and link life all participate in the constancy of the route in VANET environments, QoS protocols provides assurance about the performance level given, which is obtained by resource reservation and adequate infrastructure which is a very hard job in wireless ad hoc networks [17].

Rest of the paper is organized as follows: section 2 depicts the communication technologies used in VANETs, section 3 describes the outline and essentials of various VANET routing protocols, section 4 describes the simulation criterion and setup parameters, section 5 evaluates the Performance and results obtained by implementing the existing routing protocols and a comparison is made between them, while we conclude the paper in section 6.

2. TECHNOLOGIES USED IN VANET

IEEE 802.11p standard DSRC is used for short range wireless communication in VANETs is derived from IEEE 802.11a standard protocol, than Wireless Access in Vehicular Environment (WAVE) is referred by IEEE and standardizes the whole communication stack by the 1609 family of standards. DSRC works on 5.9GHz Radio Signal Frequency and provides data rate more than 27mbps it is a 75MHz licensed spectrum, the range of transmission is about 300 to 1000 meters and supports an environment in which vehicles moving at varying speeds [18]. Some advance and growing technologies like LTE-Advanced, WiMAX rel 2 used by IEEE 802.21 Media Independent Handover Standard provides better services, continuous connections, supports high data rates, minimize delay, energy consumption and noise ratio in distinct high mobile networks [19].

3. ROUTING PROTOCOLS FOR VANET

The emphasis is on the position based routing protocols because they are more suitable and much stable in VANETs then conventional topology based routing protocols. We consider those protocols which preferred border nodes concept to forward the data to next hop. We discuss here GPSR which is the basis for various position based routing protocols, GPCR, MFR which is the origin of the BMFR protocol, AMAR and BMAR which club the properties of BMFR and AMAR additionally using Probability factor, to produce promising results.

3.1 GPSR: Greedy Perimeter Stateless Routing

GPSR works in two modes; first mode is Greedy forwarding in which GPSR [20] generally forward the packets by using the geographic location of the nodes in moving direction to its immediate neighbor farthest from the current node and nearest to the destination node and this selected node become the next-hop node or forwarding node. GPSR getting the information of the neighbor nodes from the location devices such as GPS [21], all it required that every node is capable of finding his current position through device receiver. GPS provides us the current position, speed and direction of the moving vehicle with current time.

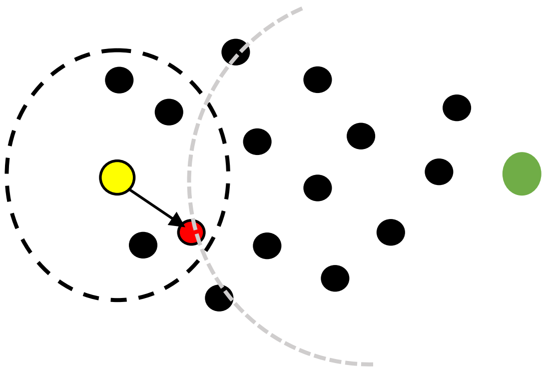

Fig 1: Greedy forwarding scheme

Figure.1 above depicts the greedy strategy in which the yellow forwarding node make a greedy choice in selecting the red node as next hop which is geographically closer to the destination of packet, doing so until the packet reaches its destination which is green node and all other are intermediate nodes, dotted circle represents the radio range of the node currently having the packet and arc with radius represents the distance between the selected next hop node and destination node. Advantage of Greedy forwarding is that its trust only on the information of the neighbor nodes of the forwarding node, the state requisite of the node is insignificant, and relies on the density of nodes in network, not the total no. of end point nodes in wireless network [20]. GPSR fails when it stuck in the Local Maximum problem; which means the forwarding node has no nearest or closest neighbor to forward the packet to the destination [22].

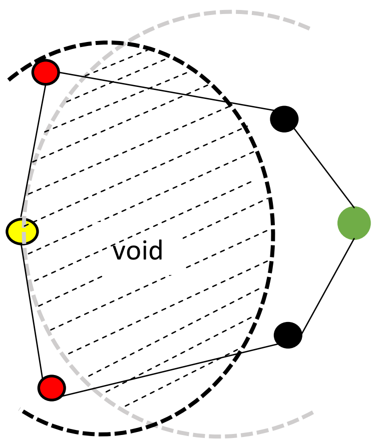

Fig 2: Greedy forwarding failure due to local maximum problem

Figure.2 shown above depicts the greedy forwarding failure due to local maximum problem, forwarding node (yellow) has no nodes in its radio range to forward the packets in the direction of the destination, which is shown void and forwarding node not choosing its neighbor nodes to forward the packet because itself more closer to destination (green) than its neighbor nodes(red). Then GPSR works in second mode by using an advanced recovery strategy called perimeter mode, in this mode it uses a planer graph traversal algorithm by using the famous Right hand rule to traverse a graph and find out the way to resolve the local maximum problem and forward the packet to next hop node to deliver it to destination node [22]. This strategy considers position information only, may lead data packets to be lost and transfer in wrong directions by losing some good candidates that are much reliable in sending the data to the end point [23]

3.2 DSR: Dynamic Source Routing protocol

DSR works on demand route formation as it a reactive routing protocol. It maintains the routing tables to stores the complete path from source to destination rather than next hop node differ than AODV [24]. The address of nodes includes in the packet header through which the data packet forwarded to reach the destination. This type of routing named as source routing that’s why the name given to the protocol DSR [25]. Route request RREQ and Route reply RREP messages are used to found the route like in AODV. The RREQ message is broadcast by source and the intermediate node which has the route to destination replies with the RREP message otherwise rebroadcast the message further after adding its own address, that’s why the size of the data packet increases as the number of nodes added and increases the length of the route. DSR discovers the new route only if it receives the RERR message causes by the link breakdown in the network and the source node aware other nodes by piggybacked the RERR with RREQ message, so that everyone knows about the link failure. No periodic packets are included by DSR to update the link status and list of neighbor node.

3.3 GPCR: Greedy Perimeter Coordinator Routing

GPCR is a Non-Delay Tolerant Network protocol, which is most suitable in highly mobile environments where node density is high like city scenarios, basically GPCR is based on the greedy strategy of forwarding the data packets. Beaconing should be periodically done by the current node to know its neighbors and location services should be used to know the position of the destination node [26]. Besides using the node planarization graphs in GPSR it uses the street maps and road layouts which will form the planar graph naturally, the packet forwarded by the current node will spread over the road until it reaches the next junction of the road [22]. In GPCR two parts will be covered in maintenance process: first is decision making; selection of the coordinator node, to which the packet will be forwarded on the intersection, and second is forwarding the data to next intermediate node which forward the packets in the direction of the destination node. It works on the principal that coordinator node will be responsible to decide the route through which the data will be forwarded, but the packets transferred to the furthest node from the current node, if no coordinator node is found in the route [27]. Global information is not needed by GPCR, however it depends upon the density of the next roads and connectivity with destination node through location services, it does not connect to the destination node if the density of mobile nodes is low, that results increment in transmission delay [28].

3.4 MFR: Most Forward with in Radius

Various GPS-based methods were developed earlier which uses the idea of progress, MFR defines the progress by transmitting the packets from transmitter node to destination node by projecting a straight line from source to destination node, in which data packets transmitted to the neighbor node which is in great progress towards the destination node [29]. MFR routing algorithm renowned for finding route in the network by using the location services to know the position information of the neighbor nodes [30]. The node with higher progress will be chosen as the next hop node on the straight line for sending packets, this process continues until the packet will reach the final destination [31]. This justify that selecting the neighbor node which is nearest to the destination make MFR protocol loop-free [32], MFR minimize the number of hops in the route, decreasing flooding rate and increasing success rate of packet delivery. Figure.3 shown below Depicts the working of MFR routing protocol in which circle represents the radio range of the source node (yellow), which selects the neighbor node (black) by using position information collected from interchanging beacon or hello packet messages [33], which has higher in progress and its projection on the straight line is closest to destination, this process repeats until the packet reaches its destination node (green). Nodes in color (red) are selected as border nodes when the process repeated further to send the packet to destination, rest are the intermediate nodes.

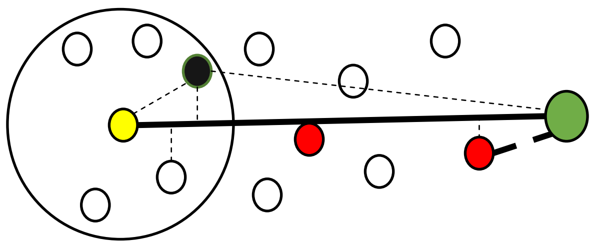

Fig 3: The selection of next node in MFR

3.5 BMFR: Border-node based Most Forward with in Radius

Greedy forwarding technique of finding the next hop for forwarding the packets to the final destination node is not much suitable in highly dense environments where mobility is very high such as Vehicular Ad Hoc Networks. Therefore MFR [30], GEDIR and etc. position based routing protocols have been used in VANET to increase its performance in highly dense mobile environment for non-linear networks. These routing protocols uses the concept of selecting the farthest next hop node closer to the destination in networks which are highly mobile for the further improvement. Then BMFR [33] has been developed, this protocol uses the concept of selecting the Border Nodes with in the transmission radio range of the source node, for transmitting the packets in the forwarding direction of the destination. BMFR leaving the intermediate nodes and utilizes the border nodes that lies on the periphery of the circle, which represents the transmission range of the source node. The data packets transmitted to that border node which has the greatest progress towards the destination, as the distance is calculated by projecting a straight line drawn from source and destination. The packet routes from border node to another border node until it reaches its destination. BMFR results in better packet delivery ratio and minimum end to end delay.

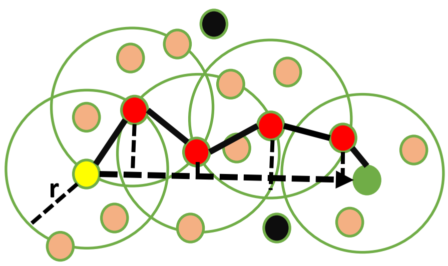

Fig 4: B-MFR forwarding technique

Figure.4 shown above represents the working of BMFR, where yellow and green are the source and destination nodes respectively, the nodes in color (red) are the selected border nodes and rest are interior (brown) or outer nodes (black), nodes inside the transmission range are interior nodes, **r** represents the radius of the circle, transmission distance of nodes. A straight dotted bold line is projected from source to destination and source node selects the border nodes to forward the packets, again selected node forwards the packet to its border node, this process runs until the packet reaches its final destination.

3.6 AMAR: Adaptive Movement Aware Routing protocol

Greedy Forwarding technique is not much suitable in highly mobile environments, it stuck in local maximum problem [34], the GPSR forwarding technique extended in Directional Greedy Forwarding (DGR) gives better decisions in routing, DGR works with direction of the moving nodes in addition to the position information of the nodes [35]. Further some improvements can be done in existing protocols which exploits the lifetime concept with mobility information in GPSR-LT [36, 37]. Further these techniques used in a new forwarding protocol, Movement Aware Greedy Forwarding (MAGF) which includes the speed parameter additionally with direction and position of the moving vehicle in order to give the optimal routing decisions in the highly dynamic networks. AMAR based on MAGF protocol, which selects the most appropriate next-hop node towards the direction of the destination. AMAR [38] protocol is suitable in highly mobile networks and performs well where greedy forwarding technique fails. In this scheme Vehicles calculate their position, direction and speed through GPS [21] or any other location services or navigation systems. Then AMAR plays a significant role in assigning priorities based on the attributes calculated among the neighbor nodes while choosing a next-hop node, which forwards the packet to destination. AMAR enumerates a weighted score Wi which depends upon the direction, speed and position parameters. The weighted score Wi can be calculated by current node to select a neighbor node i, to forward the packet, the weighted score can be calculated as follows:

$$\boldsymbol{Wi = \alpha Pm + \beta Dm + \gamma Sm}$$

Here α, β and γ are the weights of the three parameters Pm, Dm and Sm, representing the position, the direction and the speed factors respectively with:

$$\boldsymbol{\alpha + \beta + \gamma = 1}$$

The AMAR exploits the direction and the speed attributes other than position information of moving vehicles and provides the efficient data delivery by decreasing the local maximum problem cases and minimizing the end-to-end delay by avoiding the perimeter mode of GPSR protocol that increases the delay.

3.7 BMAR: Border node based Movement Aware Routing Protocol

BMAR adopts the BMFR [33] and AMAR [38] forwarding techniques together with an idea of selecting the border nodes as the next hop nodes that lies on the circumference of the transmission range of the source node and leaving the interior nodes which lies inside the fixed transmission range [2, 31] and know the position, direction and speed parameters from the well-known GPS services or navigation systems [21]. Current node which having the packet to deliver know the information of neighbor nodes by periodic beaconing [39] or exchanging the HELLO packets with the moving neighbor nodes, the format of HELLO packet described in Figure.5.

Information contained in HELLO packet				
ID	LOCATION	SPEED	CURRENT TIME	DIRECTION

Fig 5: Hello packet format

In BMFR Source node selects the border nodes as the best candidate nodes to deliver the packets as next forwarding node to destination [33] but there is a confliction in this protocol as more than two nodes on the projected line from source to destination having the same projection on line and having the same distance towards the destination, creates a conflict in selecting the next node among them. So the AMAR [38] protocol adopts which removes this conflict by giving the weighted score by using the three metrics: position, direction and speed of moving vehicles, the border node with the highest weighted score is selected as next hop node to forward the packet to destination with improved data delivery. Due to high traffic density AMAR also stuck in the situation where two border nodes having the same weighted score, this dilemma was resolved by BMAR protocol by using an attribute probability factor. It assumed that all the vehicles occupied with digital maps through which the Probability will be assigned to nodes that having change in direction at intersection and to those who don't change their direction. The current node examines the route of the conflicting border nodes and BMAR discards the nodes having intersection in their routes, thus preventing the packet not to be forwarded in the wrong direction. Finally the node will be selected as the next forwarder node that does not change its direction at intersection and successfully delivers the packet to destination and improves data delivery and minimizing the transmission delay. If BMAR does not suitable in the situation then the node which having the highest succeeding transmissions is chosen as the next forwarder node.

3.8 TB-MFR: Trusted border node based most forward with in radius routing protocol

TB-MFR adopt the benefits of BMFR [33] routing protocol by taking the border node as the next hop node to forward the packet in the forwarding direction. Mechanism is to calculate the trust value of mobile vehicles, trust value of the nodes is calculated and the more trusted node is selected, all the received, transmitted and dropped data packets are considered to evaluate the trust value of the node [40]. When two border nodes are at the same distance apart at every point then TB-MFR resolves this ambiguity problem from BMFR by using the concept of Trust value of node.

$$\boldsymbol{T_i = \frac{Trs - Trf}{Trs + Trf}}$$

Calculating Ti, represents the trust value of the node i, which is calculated by the total packets handled by each candidate node. Using terms Trs as the total number of data packets received successfully by the border node i, and Trf gives us the rate of failure, which means the total number of data packets drop by the node i, send by their neighbor nodes in the network.

4. SIMULATION SETUP AND PARAMETERS

To evaluate the performance of DSR [25], DSDV [41], GPSR [20], BMFR [33] and TB-MFR. we use NS2 simulator version 2.33 for the implementation of protocols and simulate the network in VANET environment. We compare all the stated routing protocols based on three research metrics: Packet Delivery Ratio (PDR), End-to-End Delay and Throughput with the simulation parameters given in such as: we simulate the network for 200 seconds and for wireless communications we consider 250-300 meter of transmission range with simulation area of 2400*800m², the size of the network depends upon the density of vehicles represents by the variation in no. of nodes we consider 21, 42 and 63 no. of nodes. IEEE 802.11 Distributed coordinated Function (DCF) is used as the MAC protocol, the packet size is of 1000 bytes with type of traffic is CBR (constant Bit Rate) which is responsible for the packet transmission density by making adjustments with different CBR rates using Radio Propagation Model for simulations. We have taken into account an average of 10 simulation runs.

5. RESULTS AND PERFORMANCE ANALYSIS

5.1 PDR V/S Varying Number of Nodes

By comparing the stated routing protocols with 21, 42 and 63 number of nodes in (Figure 6), we analyze that Packet delivery ratio (PDR) of TB-MFR routing protocol is better than others with each variation in nodes, while BMFR gives promising results and DSR performs worst among all, drops highest packets hence gives minimum packet delivery ratio but gives better results when no. of nodes are high than DSDV in case of 63 no. of nodes. Besides all, there is no long difference between the delay in delivering the packets and throughput between BMFR and TB-MFR but far better than GPSR, DSDV and DSR.

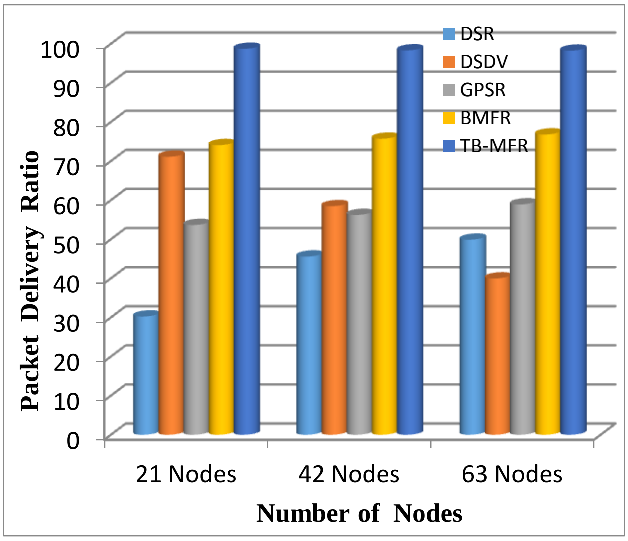

Figure 6: PDR (%) VS varying number of nodes

Table 1: Packet delivery ratio vs varying number of nodes

	DSR	DSDV	GPSR	BMFR	TB-MFR
21 nodes	30.2498	71.116	53.658	74.0865	98.7186
42 nodes	45.58	58.464	56.23	75.7286	98.316
63 nodes	49.8897	39.980	58.92	75.989	77.809

Table.1 represents the values of Packet Delivery Ratio with varying number of nodes, Table.2 shown below gives the values of End-to-End Delay of delivering the packets between nodes and Table.3 on next page represents the values of Throughput (Kbps) of each protocol with different number of nodes, these values are obtained after simulating the stated routing protocols in VANET environment using NS2 simulator for 200 seconds.

5.2 End-to-End Delay V/S Varying Number of nodes

Minimum the delay better is the performance of the routing protocol. Figure.7 shown below depicts the comparison of different routing protocols after getting the results from simulations in terms of end-to-end delay with varying number of nodes in vehicular environments.

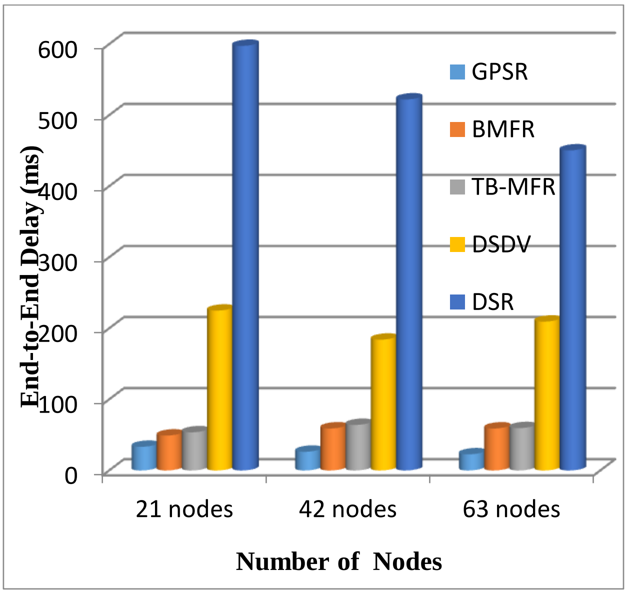

Fig 7: End-to-End Delay vs varying number of nodes

Table 2: End-to-End Delay V/S varying number of nodes

	DSR	DSDV	GPSR	BMFR	TB-MFR
21 Nodes	597.605	225.005	33.3	49.1119	53.6971
42 Nodes	522.24	184.103	26.3	59.1196	64.0898
63 Nodes	450.463	209.556	22.7	59.059	59.5928

5.3 Throughput V/S Varying Number of Nodes

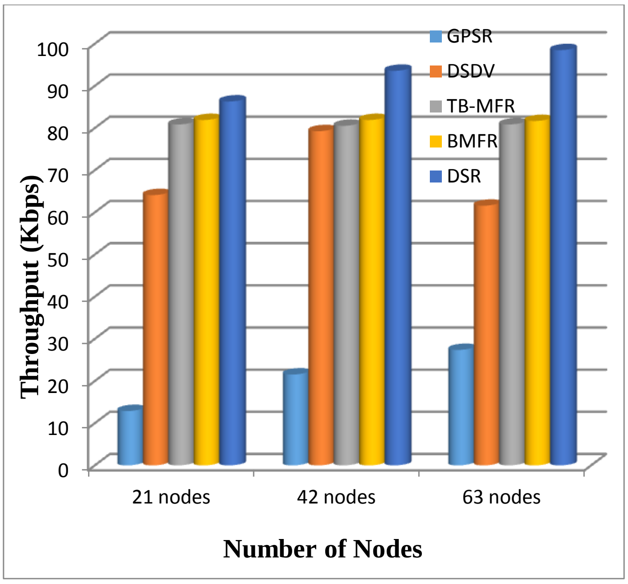

Figure 8: Throughput V/S varying number of nodes

Table 3: Throughput V/S varying number of nodes

	DSR	DSDV	GPSR	BMFR	TB-MFR
21 Nodes	86.31	64.11	12.89	81.92	80.87
42 Nodes	93.59	79.27	21.56	81.92	80.54
63 Nodes	98.49	61.59	27.39	81.68	80.86

In Figure.7 and Figure.8 shown above describes BMFR gives minimum delay and greater throughput than TB-MFR. DSR performs worst, takes highest delay in delivering the packets but gives maximum throughput in low and dense number of nodes among all others. Throughput of GPSR increases with each increment in nodes and throughput of DSDV increases with 42 nodes than decreases when number of nodes increases to 63.

By increasing the number of nodes to 42 and 63, we observe that the throughput and PDR of DSR and GPSR increasing with increment of nodes and there is a little downfall variation in throughput of BMFR also PDR of TB-MFR is continuously decreasing with high no. of nodes. While End-to-End Delay of DSR and GPSR is reduced, increases in case of BMFR and TB-MFR for 42 nodes and then decreases when node density is high that is 63 nodes. By analyzing the results obtained we conclude that overall performance of TB-MFR routing protocol is better than others. Table 4 shows above gives the comparison of various VANET routing protocols by taking into account the different parameters related to network, simulation criteria, delay, delivery, mobility etc., this table gives overview of various routing protocols with their essentials.

6. CONCLUSION

This paper provides anonymous information about VANETs, their working behavior, characteristics, suitable routing protocols and how communications takes place in VANETs. Various VANET routing protocols mostly border node preferred position based routing protocols are described and elaborated with their working and some existing routing protocols like DSR, GPSR, DSDV, BMFR and TB-MFR are implemented by considering different simulation criteria and research metrics like calculation of delay in terms of end-to-end delay, Packet Delivery Ratio (PDR %) and Throughput by considering the open scenario with varying number of nodes which elaborates the size of network, we simulating them using NS2 simulator and analyze their performance from their results. After simulating the routing protocols in the open vehicular network we conclude that TB-MFR gives better Packet Delivery Ratio (PDR), DSR gives better Throughput, GPSR gives minimum end-to-end delay in all scenario's and TB-MFR gives overall better results than all other protocols by increasing the PDR and Throughput, BMFR gives adequate results and surely better than DSR, DSDV and GPSR.

Table.4. Comparison of various VANET routing protocols by taking different parameters

PARAMATERS / PROTOCOLS	DSR	DSDV	GPSR	MFR	BMFR	AMAR	BMAR	TB-MFR
Bandwidth constraints	Low	Low	High	High	High	High	High	High
Power constraints	High	High	Low	Low	Low	Low	Low	Low
Packet delivery	Poor	Best effort	Best effort	Best effort	Best effort/ Guaranteed	Best effort	Best effort/ Guaranteed	Guaranteed
Packet delivery ratio	lowest	Low	Low	High	High	High	High	Highest
Packet overhead	High	High	Low	Low	Low	Low	Low	Low
Delay time	Highest	High	Lowest	Low	Low	Low	Low	Low

Network scalability	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Network topology	Fixed	Fixed	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic
Mobility factor	Low	Low	High	High	High	High	High	High
Mobility	Random	Random	Predictable	Predictable	Predictable	Predictable	Predictable	Predictable
Mobility model	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Simulation scenario	City	City	Open	City	City	City	City	Open
Resource utilization	Low	Low	High	High	High	High	High	High
Overall Performance	Lowest	Low	High	High	High	High	High	Highest
Traffic perception	No	No	No	No	No	No	No	No

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