A SURVEY OF ROUTING PROTOCOLS FOR DELAY TOLERANT NETWORKS IN VANETS

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ABSTRACT*—Vehicular Ad-hoc Network (VANET) is the mix of Mobile ad-hoc network (MANET), wireless LAN (WLAN) and cellular technology aimed to improve safety and comfort through vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication. VANETs are different form MANETs due to their hybrid network architectures, node movement characteristics, and innovative application scenarios. Thus, VANETs carry out several unique research challenges. Beside other challenges, routing is the prime issue and the design of efficient routing protocols for VANETs is crucial. Current active research activity is taking place in intermittently connected ad-hoc networks and delay tolerant networks (DTN). These are sparse wireless networks where complete path from the source to the destination is mostly unavailable so routing in DTNs is greatly focused in contemporary research. In recent years, different routing protocols for various DTNs have been proposed. This article captures different routing protocols for DTNs in VANETs and categorizes them on the basis of neighbor selection methods used by these protocols. Various metrics used by these protocols are discussed. Finally, a qualitative comparison of DTN routing protocols on the basis of various metrics is presented.*

Keywords: DTN, Routing protocols, Vehicular networks, Vehicle-to-vehicle communication

I. INTRODUCTION

Vehicular Ad Hoc Networks (VANETs) [1-3] incorporates the latest wireless networks technology in automobiles. VANETs provide Vehicle-to-Vehicle (V2V) or Inter-vehicle Communications (IVC) and vehicle to infrastructure (V2I) communication [4]. By providing pervasive connectivity to passengers and effective V2V communications, it enables the Intelligent Transportation Systems (ITS) for cooperative traffic monitoring, traffic flows control, blind crossing, collisions prevention, and real-time alternative route computation applications. VANETs also provide Internet connectivity thus users can download, email, or play games [5 6].

Mobile vehicles in VANETs form a temporary and self-organize wireless connectivity to accomplish routing functions [7,9]. Contemporary research aims to develop a sophisticated vehicular communication system that ensures passengers' safety and comfort through quick and cost effective dissemination of data. However the existence of real life physical barriers and limited radio range etc. limit communication among vehicles thus results in network partitions. The high node mobility causes frequent changes in topology resulting intermittent and disrupted network [10]. In such intermittently connected networks, different links come up and down due to high node mobility. Message is sent to the destination over an existing link by buffering it at current vehicle until the next vehicle reaches to complete the broken link [11].

Intermittently connected mobile networks (ICMNs) are mobile wireless networks lacking a complete path to a destination. Issues in ICMNs are actively addressed in contemporary research [12] [13]. Sometime ICMNs are quite sparse and look like a set of disconnected, time-varying clusters of vehicles. ICMNs belong to the general category of Delay Tolerant Networks (DTN) which experienced very large and erratic delays [14]. Connections are established opportunistically with varying end to end delays [15]. Such networks play important role in harsh communication environments, like natural calamity, combat zone and road accidents etc. Despite high delay, the ability to communicate emergent information is of great value in such situations [10] [16].

DTN protocols provide routing with rare end-to-end connectivity [13]. Such protocols use a store-and-carry forwarding mechanism for message switching. Before reaching the destination, message is forwarded and stored from host to host opportunistically along a route. The host's mobility patterns and message carrier selection play important role for successful delivery [17].

Due to high mobility, variable network density, and unreliable channel conditions, VANETs faces challenging issues like data dissemination, data sharing, and security. To cope with these issues, efficient routing protocols for intermittently connected vehicles are mandatory. Such protocols are required to achieve high throughput, minimal communication time and minimum consumption of network resources. Many routing protocols developed for DTNs in Mobile Ad Hoc Networks (MANETs) are appropriate for VANETs as well [12]. Simulation results however, show the poor performances of such protocols due the different VANETs and MANETs environment [5]. Thus route discovery and maintenance in intermittently connected VANETs is a challenging job.

This article presents a survey of recent research progress of routing protocols for DTNs in VANETs. These protocols assume that each vehicle knows its location and location of target vehicle through Global Position System (GPS) unit installed on each vehicle. Most of these protocols use V2V communication strategy in urban regions.

II. CATEGORIZATION

One possible categorization of DTN routing protocols is shown in Fig.1. It is based on the following three forwarding neighbor selection techniques used by these protocols.

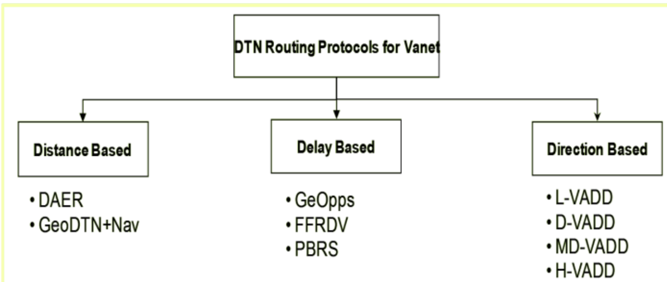

Fig.1: DTN Routing Protocols for VANET

A. Distance Based

Greedy routing strategy is the most common way of VANETs communication [18]. Here, a packet is forwarded by selecting a closest neighbor to the destination among all neighbors. Distance Aware Epidemic Routing (DAER) [19] and Hybrid Geographic & DTN Routing with Navigation Assistance in Urban Vehicular Networks (GeoDTN+Nav) exploit this scheme [20]. Distance based forwarding neighbor selection is shown in Fig. 2. Here, vehicle *A* receives a packet destined for destination *D*. The dotted circle around *A* denotes its communication range. As the distance between *B* and *D* is less than that between *D* and any of *A*'s other neighbors, so vehicle *A* forwards the packet to vehicle *B*. This process continues, until the packet reaches *D*.

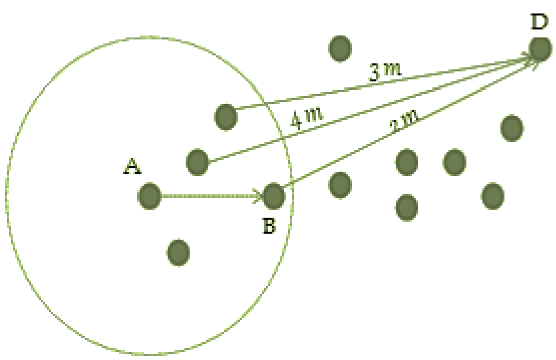

Fig.2: **Distance based forwarding**

B. Delay Based

Here, a packet is forwarded by selecting a neighbor that can send it in least possible time among the other nodes. Fastest-Ferry Routing in DTN-enabled VANET (FFRDV) [10], Geographical Opportunistic Routing for Vehicular Networks (GeOpps) [17] and Probabilistic Bundle Relaying Scheme (PBRS) [21] use this approach.

Delay based forwarding neighbor selection is shown in Fig. 3. Vehicle *A* forwards the packet to vehicle *B* as *B* can send the packet to the *D* in least time of 2 sec as compared to other neighbors. This process continues, until the packet reaches *D*.

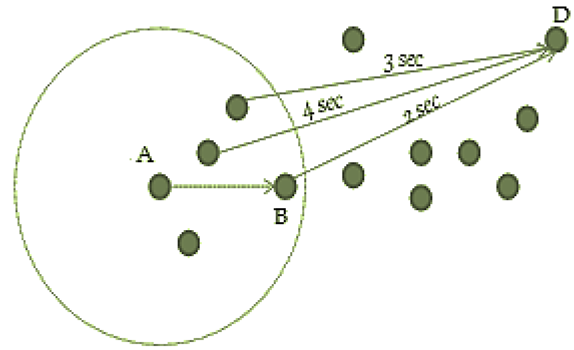

Fig.3: Delay based forwarding

C. Direction Based

Here, a packet is forwarded through a neighbor closest to the desired forwarding direction or a neighbor moving towards the desired direction. Location First Probe Vehicle-Assisted Data Delivery (L-VADD), Direction First Probe Vehicle-Assisted Data Delivery (D-VADD), Multi-Path Direction First Probe Vehicle-Assisted Data Delivery (MD-VADD) and Hybrid Probe Vehicle-Assisted Data Delivery (H-VADD) use this approach [22]. Direction based forwarding neighbor selection is shown in Fig. 4. Vehicle *A* has a packet to forward in north direction to destination *D*. *A* has two vehicles within its communication range i.e. *B* and *C*. *A* can either choose *B* or *C* as a next hop. Since *C* is closer to *D*, it can immediately pass the packet to *D*. Yet *B* can also be a choice as it is moving in the packet forwarding direction. These two choices lead to different direction based forwarding protocols.

The operations and features of these protocols and their qualitative comparison are discussed in the next section. Besides classification of routing protocols based on their neighbor selection techniques, another classification is based on the packet forwarding metrics used by these protocols.

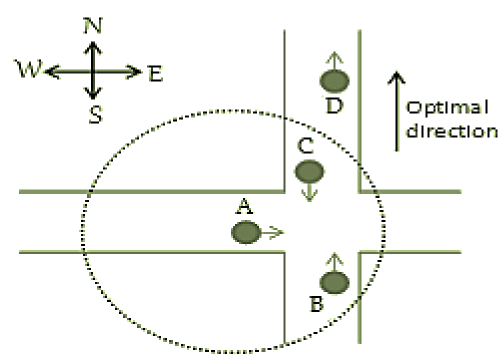

Fig.4: Direction based forwarding

III. PACKET FORWARDING METRICS

Routing protocols use different metrics for forwarding packets to their neighbors as shown in Fig. 5.

A. *Neighbor Distance:* Distance between sending vehicle's neighbor and destination of a packet

B. *Neighbor Velocity:* Velocity of sending vehicle's neighbor

C. *Neighbor Direction:* Movement direction of sending vehicle's neighbor
D. *Path Delay:* Time taken for a packet to be transmitted across a network from source to destination
E. *Path Distance:* Distance taken for a packet to be transmitted across a network from source to destination.

Next section presents the principles of DTN routing protocols.

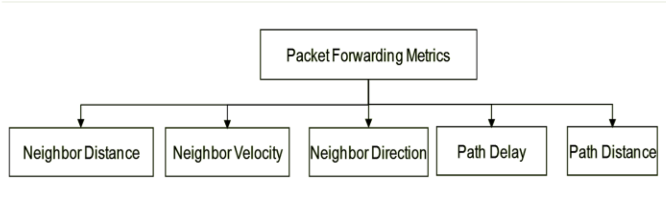

Fig.5: Packet Forwarding Metrics

IV. DTN ROUTING PROTOCOLS

This section discusses DTN routing protocols for VANETS. This discussion is mostly about the message delivery in DTN using these protocols. As shown in Figure 1, DAER and GeoDTN+Nav are distance based, FFRDV, GeoOpps, and PBRS are delay based, and VADD is direction based.

A. Distance Based

DAER [19] is a distance based routing protocol designed for intermittently connected MANETs and VDTN. DAER [19] addressed three problems that have not been considered in conventional epidemic routing. The first problem in epidemic routing is the absence of priority mechanism for forwarding the bundles. DAER [19] uses bundle priority assignment strategy to prioritize bundles that will get closer to their destination. DAER uses greedy distance forwarding where a bundle at source has high forwarding priority if the distance between neighbor and bundle's destination is less than the current distance (between source and bundle's destination). After forwarding bundle to its neighbor, it should stay on a source buffer among other bundles if it is moving toward its destination. This bundle can be forwarded several times thus increasing the duplication tree quickly.

The second problem of the epidemic protocol is the wastage of resources due to propagation of already delivered bundle copies. Bundle copies are set uniformly independent of their possibility to reach the destinations. DAER [19] also uses anti-diffusion pruning policy where a bundle is pruned off form the source buffer if it diffuses away from its destination with source e.g. its current distance with the destination is increasing from the previously recorded distance.

Lastly, in the buffer replacement policy, epidemic routing does not consider the geographical information. The buffer replacement policy used by DAER [19] is similar to pruning policy except that the old bundle has a higher priority to be replaced by a newly arrived bundle newly if it diffuses away from its destination e.g. bundle current distance is greater than the previously recorded distance.

GeoDTN+Nav [20] is a hybrid geographic routing approach that route packets using any of the three modes (greedy, perimeter, and DTN). GeoDTN+Nav use Virtual Navigation Interface and Network Partition Detection method to select the proper mode for a guaranteed packet delivery even in sparse or partitioned networks with a price of an increased delay.

First a packet is forwarded greedily by selecting a closest to destination neighbor among the others. Due to obstacles however, the local maxima may occur [23], where packet carrying node finds no neighbor closer to the destination than itself. The perimeter mode [24] is useful in such situation to extract packets from local maxima and then return to greedy mode. Greedy and perimeter mode however, are not sufficient as frequent disconnection or partitioning of network is common due to high mobility particularly in sparse networks. Thus DTN mode is beneficial for packets delivery in disconnected and partitioned networks as a result of high mobility factor in VANETs.

In GeoDTN+Nav [20], navigation information about the route and confidence value is announced by each vehicle periodically. A packet is first forwarded in greedy mode until it touches a local maxima where perimeter mode starts by calculating three factors which include the network disconnection probability $P(h)$, the delivery quality of node and its neighbors $Q(N_i)$, and neighbors direction quality $Dir(N_i)$. These factors help to calculate the Switch score of each neighbor. If the switch score of one or more vehicle's neighbors is beyond a certain threshold S_{thresh} then mode is switched to DTN and the packet would be sent to the neighbor with greater score among the others. The packet will be stored and carried by the node until it returns to greedy mode upon finding a relay with better progress than the one that caused the DTN mode. The packet is dropped if the hop count reaches the time-to-live (TTL) with no neighbor having switch score greater than S_{thresh}.

B. Delay Based

GeOpps [17] is a delay tolerant routing approach where vehicles are equipped with a navigation system capable of communication and computation of a route and estimated time required to a given destination. Vehicles broadcast the destinations of the stored packets to its one-hop neighbors. Neighbor following routes to the suggested destinations calculate the Nearest Point (NP) to the destination and expected time of arrival (ETA) of the vehicle to NP. The sum of both the NP and ETA values represents the Minimum Estimated Time of Delivery (METD) value. After getting the METD values from neighbors, the packet is sent to the neighbor only if it has lowest METD value among others including source node. Repeating this process, the packet either reaches the destination or expires.

FFRDV [10] is a unicast geographic routing scheme for VANET that provide improvement in DAER protocol by considering the vehicle's speed for fast forwarding of messages. Selecting of high speed relaying vehicle with long distance to destination can reach earlier in comparison to slow vehicle with short distance.

The bundles ferrying procedure employed in FFRDV chooses ferries on the basis of their velocities. On geographic information basis, roads are divided into logical blocks. The vehicle's state report about its current position and velocity is updated periodically. The vehicle that senses the occurred event first, becomes the initial ferry (IF). IF then compares the velocities of neighbor vehicles repeatedly block by block to choose the fastest vehicle as the next ferry until the bundles reached their destination.

FFRDV has two phases: the Ferry Selection Phase and the Message Forwarding Phase. In the first phase, once IF enters a new block, it broadcasts hello message and asks for state reports from neighbors. Vehicles in the block send back current location, a timer, and its current speed to IF. IF select and forwards the bundles to the fastest neighbor among others by comparing their speed values. The selected neighbor is known as dynamic ferry (DF). After receiving acknowledgement from DF, IF discards the bundle from its buffer. However, if there is no fastest vehicle in the block, then the IF carries the bundles to the next block and repeats the same selection procedure again. In the second phase, the message is forwarded on the current road till the next road intersection. Upon reaching the road crossing by DF, the direction of data transmission is measured to find the shortest path. The data transmission direction is changed for shortest path only if the next intersection along the same road is farther to the destination than the current one. In such case the current DF chooses the next DF in the new direction.

PBRS [21] is a two-hop communication approach for VDTN. In PBRS performs communication between Stationary Relay Stations (SRS) such as source *S* and destination *D* at distance d_{SD} along the highway. *S* and *D* are isolated and cannot directly communicate with each other. Vehicles with different speeds are passing by *S* and navigate towards *D*. These vehicles offer opportunistic store-carry-forward mechanism for connecting any arbitrary SRS like *S* and *D*. Using the vehicle's speed information, source *S* computes the bundle delivery time to destination *D* for each vehicle in its range. *S* selects vehicle with shortest delivery time to *D* and releases a single bundle *B* form its queue.

C. Direction Based

VADD [22] is a geographic routing protocol that provides the lowest data delivery delay to forward a packet to a road. Using delay computations performed by VADD delay model for each neighbor intersection, VADD forwards packet to a vehicle exist on a road with smallest delay among the available vehicles in communication range at the intersection. However, if the packet carrier vehicle finds no vehicle in communication range on the next traveling road, or available, but moving with longer delay than it, it passes the intersection, and looks for the next chance. On the basis of packet carrier location, VADD provides three packet modes: Intersection, Straight-Way, and Destination. Mode switching provides the best packet forwarding path to deliver a packet. Protocols used in Intersection mode are: L-VADD, D-VADD, MD-VADD and H-VADD.

L-VADD attempts to discover a closest vehicle in the desired road direction to carry packet with lowest data delivery delay. First, delay model is used to calculate delay for each outgoing road at intersection. Each road at intersection is assigned a priority on the basis of delay so road with smaller delay has higher priority. The packet carrier vehicle then chooses the highest priority outgoing direction and the next target intersection in that direction. The packet is forwarded to the vehicle moving to the target intersection using geographical greedy forwarding. If no vehicle is found, the same process is repeated for the next highest priority outgoing direction. The situation may occur when the selected direction has lower priority than the packet carrier's current moving direction. In such case the packet carrier will continue to carry the packet. L-VADD may possibly cause the routing loops during the delivery of packets [22].

D-VADD searches a vehicle in the preferred packet forwarding direction to carry the packet. The direction selection process in D-VADD is the same as L-VADD but instead of investigating direction by location, D-VADD picks the next hop vehicle closest to the selected direction among other the vehicles. D-VADD overcomes routing loops with cost of increased geographical forwarding distance [22].

Contrary to D-VADD, in MD-VADD, the packet carrier retains the packet until it is forwarded in the highest priority direction thus to increase the chance of finding vehicles moving towards the optimal direction. After selecting the next hop vehicle, the packet carrier delivers a copy of the packet to it and marks the packet as SENT in his buffer. It also notes the vehicle's direction d_{sent}. Later on, if another vehicle is found at same intersection having higher priority than d_{sent}, another copy is delivered to it and d_{sent} is modified subsequently. The packet carrier deletes the packet only after finding direction d_{sent} with highest priority. Once the vehicle leaves the Intersection, it discards all SENT marked packets form its buffer.

H-VADD combines the benefits of L-VADD, D-VADD, and MD-VADD by minimizing the forwarding distance and reducing routing loops. L-VADD reduces the forwarding distance but having low packet delivery ration due to routing loops. D-VADD and MD-VADD eliminate routing loops but having low packet delivery ratio due to long forwarding distance because of prioritizing the moving direction. H-VADD acts like L-VADD in Intersection Mode to achieve shortest forwarding path. If a routing loop is detected, it switches to D-VADD or MD-VADD until it departures the present intersection.

V. COMPARISONS OF PACKET FORWARDING METRICS

Table 1 presents a comparison of packet forwarding metrics used in various DTN routing protocols for VANETs.

DAER uses the neighbor distance as a packet forwarding metric which is obtained from the Global Positioning System (GPS) in the onboard navigation unit of vehicle. Hence, the complexity for calculating neighbor distance metric is low. In DAER, the source computation is high as the sending vehicle is responsible for calculating the distance between neighbor vehicles and packet's destination.

The performance of FFRDV depends on two metrics i.e. neighbor vehicle's velocities and path distance. As compared to neighbor distance metric, neighbor velocity metric is more useful to perform the fastest delivery of the packet by considering end-to-end delay. Velocity information is obtained easily from periodically exchanged state reports in FFRDV. Hence the complexity of measuring neighbor velocity is low. Additionally, the presence of path distance metric makes FFRDV more reliable by making intelligent direction selection decisions at intersections. Therefore, compared to the packet forwarding metric used in DAER, the metrics used by FFRDV is more accurate. In other words, both metrics are used to select shortest path and fastest vehicles in order to forward the packet in minimum possible amount of time. In case of FFRDV, source computation is high because it is the responsibility of sending vehicle to find a shortest path and maximum velocity of neighbor to forward a packet.

TABLE 1: PACKET FORWARDING METRICS FOR VANET

Parameters	DAER	GeoDTN+Nav	GeoOpps	FFRDV	PBRS	L-VADD	D-VADD	MD-VADD	H-VADD
Metrics Used	Neighbor Distance	Neighbor Distance	Path Delay	Neighbor Velocity, Path Distance	Path Delay	Path Delay, Neighbor Distance	Path Delay, Neighbor Direction	Path Delay, Neighbor Direction	Path Delay, Neighbor Distance, Neighbor Direction
No. of metrics	Single	Single	Single	Multiple	Single	Multiple	Multiple	Multiple	Multiple
Complexity of metric computation	Low	High	High	Low	Low	High	High	High	High
Source computation	High	High	Low	High	High	High	High	High	High
Neighbor computation	Low	Low	High	Low	Low	Low	Low	Low	Low

GeoDTN+Nav considers neighbor distance as packet forwarding metric. GeoDTN+Nav calculates the neighbor distance metric more accurately as it considers three different parameters i.e. neighbor route in case of buses, neighbor destination in case of taxis and neighbor direction in case of other vehicles [20]. Hence, the complexity for computing neighbor distance metrics is high in GeoDTN+Nav but it provides more reliable distance information as compared to the neighbor distance metric used in DAER. Since it is the responsibility of sending vehicle to calculate distance towards the destination of packets, the source computation is high in case of GeoDTN+Nav.

GeOpps considers path delay as a packet forwarding metric. GeOpps is different from above mentioned protocols since it considers neighbor routes to calculate METD to reach the packet's destination. The complexity for computing path delay metric is high because it requires GPS and map information to calculate NP. As compared to GeoDTN+Nav, GeoOpps can provide better delivery ratio as it considers the route information of neighbor vehicles to calculate the distance towards destination. However, it is always not possible that vehicles could provide information about their route [20], in such situation GeoDTN+Nav can provide better results. In case of GeOpps, it is the neighbor vehicle's responsibility to calculate NP and METD which is much time consuming process, so the neighbor computation is much higher as compared to the source computation.

PBRS considers the path delay as packet forwarding metric. The path delay metric in PBRS can be computed easily using hello message sent by vehicle moving to SRS. Hence, the complexity for calculating path delay metric is low. In case of PBRS, the source computation is high because it is responsible for finding suitable vehicle to deliver a bundle in minimum possible time. PBRS is much suitable for highway scenarios because it does not incorporate decision making at intersections which is a compulsory component of urban areas. Therefore FFRDV can perform better than PBRS when it comes to make decisions at intersections.

VADD protocols deliver packets with minimum data delivery delay to the roads. Hence path delay is a key packet forwarding metric for all VADD protocols but consider some additional metrics to make packet forwarding decision as well. L-VADD considers neighbor distance metric as it selects a neighbor vehicle which is closest to a road having lowest data delivery delay. D-VADD chooses a vehicle moving to the road having minimum data delivery delay. Therefore, D-VADD considers neighbor direction as a packet forwarding metric. If multiple vehicles are moving to desired road direction, then the vehicle closest to the preferred direction is nominated as next hop. MD-VADD is similar to D-VADD with the exception of selecting multiple vehicles (instead of a single vehicle) moving to the preferred packet direction. H-VADD is a hybrid protocol that combines the benefits of L-VADD and D-VADD or MD-VADD. The combination of these features in H-VADD protocol enables it to avoid routing loops and long message transmission delay. Hence, complexity of metrics computation in H-VADD is much higher than other VADD protocols. The source computation is high in all VADD protocols because it is the responsibility of sending vehicles to calculate the corresponding metrics.

VI. COMPARISONS OF DTN ROUTING PROTOCOLS

Table 2 presents the routing protocols in terms of forwarding neighbor selection method, number of neighbors selected, buffer pruning used, acknowledgement requirements, message scheduling policy, and the type of applicable VANET. The forwarding neighbor selection method is different in various routing protocols. Protocols such as DAER, GeoDTN+Nav use a distance-based forwarding neighbor selection approach. They select a single neighbor that is closer to destination. Once the selected neighbor receives a message, it again selects a next vehicle among its neighbors that is closer to destination. This process continues until a message is sent to destination. GeOpps, FFRDV and PBRS use delay-based forwarding neighbor selection approach. In this approach, vehicle selects a single neighbor that will deliver a message in minimum amount of time. Compared to the distance-based approach, delay-based approach incurs short message forwarding delay since it selects high speed vehicles to deliver the message. Two different approaches for forwarding neighbor selection are employed in the direction-based protocols. L-VADD selects a single neighbor closer to the direction of destination. It reduces message forwarding delay but it might result in routing loops. On the other hand, both D-VADD and MD-VADD select a neighbor which is moving in the direction of destination. The only difference between D-VADD and MD-VADD is that MD-VADD might select multiple neighbors (instead of a single) that are moving towards the optimal direction of destination. Compared to D-VADD, MD-VADD increases the chances of selecting a neighbor that has optimal direction towards the destination. D/MD-VADD increases message forwarding delay, but avoid routing loops. Finally, H-VADD switches between L-VADD and D/MD-VADD. Hence, compared to other VADD protocols, H-VADD reduces

Table 02: Summary of DTN Routing Protocols for VANET

Parameters	DAER	GeoDTN+Nav	GeOpps	FFRDV	PBRS	L-VADD	D-VADD	MD-VADD	H-VADD
Forwarding neighbor selection method	Distance-based	Distance-based	Delay-based	Delay-based	Delay-based	Direction-based	Direction-based	Direction-based	Direction-based
No. of neighbors selected	Single	Single	Single	Single	Single	Single	Single	Multiple	Single
Buffer pruning used	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes
Acknowledgement required	No	No	No	Yes	No	No	No	No	No
Message Scheduling Policy	MCD	FIFO	FIFO	FIFO	FIFO	FIFO	FIFO	FIFO	FIFO
Type of applicable Vanet	V2V	V2V	V2V	V2V	V2I	V2V	V2V	V2V	V2V

message forwarding delay while concurrently avoids routing loops.

All the protocols select a single neighbor as a message relay except MD-VADD as explained earlier. Buffer pruning policy is taken into account in DAER, FFRDV and the VADD protocols. All these protocols use different rules to delete message from a buffer. In case of DAER, message is deleted from a buffer if it is moving away from destination. In case of FFRDV, when an acknowledgement is received from a neighbor, only then a message is removed from a buffer. In case of VADD, when a message is forwarded to a direction of highest priority or a vehicle exits the intersection, all the messages that have been marked as SENT are removed from buffer. All the protocols use First-in-First-out (FIFO) message scheduling policy except DAER where a message that is closer to destination (defined as MCD) is selected first. Most of these protocols belong to V2V category except PBRS which belongs to V2I category. VADD, GeOpps and FFRDV has the shortest end-to-end delay, as both approaches consider a path that leads to destination and forward a packet to a vehicle moving towards a road with the lowest data delivery delay. In contrast, DAER, GeoDTN+Nav and PBRS do not consider a path that leads to destination. If a next vehicle is designated without considering a path that leads to destination, a message carrying vehicle may move in the direction away from the destination [25] which causes DAER, GeoDTN+Nav and PBRS to have longer end-to-end transmission delay.

VADD and FFRDV has the highest data delivery ratio, since they consider the path that leads to destination and also exchange only little information among neighbors which reduces the MAC layer collisions in the network. In contrast, DAER, GeoDTN+Nav, and GeOpps periodically exchange ID list of messages in buffer, Navigation information and destination of messages respectively. In a congested network, performance of these protocols decreases dramatically due to MAC layer collisions. PBRS exchange very little information that reduces the MAC layer collisions however, it does not consider path information of neighbors to whom messages are forwarded which may result in a situation where a message diffuses away from its target and ultimately discarded from the buffer. Hence, DAER, GeoDTN+Nav, GeOpps, and PBRS has smallest data delivery ratio as compared to VADD and FFRDV protocols.

To achieve scalability, a lightweight protocol having low network overhead is essential. VADD, FFRDV and PBRS outperform the others since they periodically exchange little information that produce little network overhead. The rest of the protocols i.e. DAER, GeOpps, and GeoDTN+Nav exchange heavy information as explained earlier. Thus for denser network, these protocols need a large data exchange causing a rise in network overhead and drop in network scalability.

VII. CONCLUSION

This article presented a survey of a number of proposed routing protocols for DTNs in VANETs. The major contributions of this article are the classification of different DTN routing protocols into three types based on their neighbor selection techniques and their evaluation on the basis of their characteristics. Most of these routing protocols are appropriate for metropolitan vehicular networks. These protocols use various packet-forwarding metrics to select next forwarding neighbor. Among all these protocols, VADD, GeOpps and FFRDV can provide better end-to-end delay, data delivery ratio and low network overhead in city environments because they include path information that leads to destination. PBRS can provide better results in highway scenario because it does not incorporate decision making at intersections.

The article will help the readers, who are new to VANETs, to improve their understanding of this contemporary area. It will support them to peruse their research in an efficient manner. Research in DTN for VANETs is passing from the infant phase with several open issues that must be fixed for achieving full benefits of the field. The main goal of this work is the assessment and comparison of the contemporary research activities and to inspire the researchers in developing efficient and better protocols for DTN in VANETs.

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