Routing Protocol of Vehicular Ad hoc Networks: A Survey

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Abstract - A network that consists of several vehicular nodes which can enter or exit the network freely is known as Vehicular Ad hoc Network (VANET). The Intelligent Transport Systems are constructed on the basis of VANET (Vehicular Ad Hoc Network) for all applications. This latest research field attains the attention of a number of researchers all around the world. The vehicles travelled on road along with obtained safety and traffic efficiency and a level of comfort is offered to the individuals through Vehicular Ad Hoc Network. The various routing scheme of vehicular ad hoc network are reviewed in this paper in terms of certain parameters.

Keywords - VANET, Multi-hop routing, Broadcasting, Path Establishment

I. INTRODUCTION

Intelligent Transportation Systems (ITS) have received considerable attention from the research community due to the constantly evolving radio transmission technology and embedded systems. Being a specific MANET (Mobile Ad-hoc Network), Vehicle Ad-hoc Network (VANET) is a vital component for ITS. The VANET models have two main communication systems, which include vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) [1]. The adaptive nature of vehicle self-organization empowers the V2V system to share information and establish data communication between vehicles extremely easily. The V2I system, on the other hand, allows vehicles to get Internet accessibility to share information over long distances and accomplish the requirements of traffic and in-vehicle entertainment, among others. Since ITS is the main application domain of VANET, it needs VANET to deliver realistic and effective information to the driver, for example, information about the condition of roads and congestion, to increase the safety and efficiency of travel [2].

1.1 Internet of Vehicles

The Internet of Vehicles (IoV) is an inspiring application of the Internet of Things (IoT) and has attracted widespread attention from both the educational and industrial realms. Owing to the rapid advancement of vehicle-to-everything (V2X) transmission technologies, the nascent IoV platform can support many security-relevant services and infomercial applications [3]. The Roadside Unit (RSU) is of considerable importance on the internet of vehicles technology because of its higher communication capability and corresponding characteristics than automobiles. For example, it is possible to use roadside units as content dispatchers, sharing information across specific locales with neighboring vehicles. This is a core research area for the improvement of traditional VANETs and their performance. A universal system architecture for the IoV technology is illustrated in Figure 1. This architecture uses where both V2V as well as V2R communications to relay traffic information [4]. If there are few vehicles, Road Side Units (RSUs) help in reaching the vehicles. In case of a sufficient number of vehicles for V2V communication, they use using either single-hop or multi-hop communication to establish direct communication with each other. Also, when the density of vehicles is high, V2V is necessary to forward the information across IoV. Nevertheless, in the context of sparse vehicle networks, there may not be enough vehicles to transmit the information, thus requiring V2R (Vehicle to Road) and R2V (Road to Vehicle) communication [5].

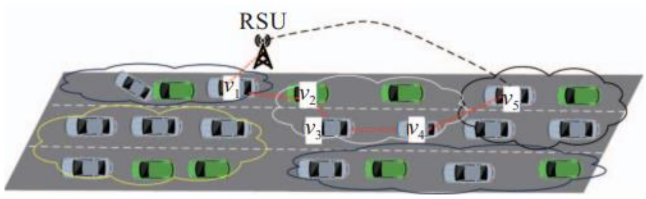

Fig. 1 Internet of Vehicles

In the above diagram, the Internet of Vehicles consists of a source vehicle (v1), relay nodes/vehicles (v2, v3, and v4), a roadside unit, and a destination v5 where vehicle v1 and vehicle v5 are unreachable through one-hop communication, and thus they depend on multi-hop communication [6]. In IoV, it is assumed that a source vehicle transmits information along with its hash value. Every vehicle receiving the information computes the hash value locally according to the message obtained. A comparison between this locally calculated hash value and the hash value relayed by the source vehicle is performed [7]. In one-hop or multi-hop communication for IoV, a vehicle post detecting a discrepancy in the hash values averts transmitting the colluded information to other vehicles. In such a situation, the source vehicle must broadcast the information again.

1.2 Clustering in VANET

In a vehicular ad-hoc network (VANET), vehicles taking part are mounted with wireless transmitters and receivers to enable them to share data with other nearby vehicles, and when require, transmit packets via nearby vehicles to destinations that are not directly within transmission range [8]. Single-hop connectivity to outdoor setup is dispensable, even though static RSUs (roadside units) can also take part in a vehicular network. This type of system has the potential to enable the formation of applications encompassing improved traffic security and collision avoidance to in-car information and entertainment systems. VANETs run in a complex communications scenario, which has a limited real-time implementation of the technology to date [9].

VANETs are mainly vulnerable to the hidden node issue; moreover, they have to struggle due to the restricted spectrum bandwidth and an ever-changing channel affected by both static and flexible impediments and interfering sources. In this setup, permanent networks are substantially advantageous over ad-hoc networks. For example, access points enable the best scheduling of channel access and allocation of network resources in a comparatively simplified way at the price of requiring to deploy multiple access points all over the projected range of coverage [10]. To leverage infrastructure-based networks without any physical setting, researchers have explored the concept of clustering in Vehicular networks, whereby a hierarchical network architecture is created in a distributed way all over the network by applying different types of clustering algorithms.

1.2.1 Applications of Clustering

The following section describe the typical applications of clustering in VANETs:

i. Routing: Clustering can act as a tool to actively build a hierarchical architecture-like overlay on top of a fundamental ad-hoc network, which is useful for the routing of packets. Typically, the cluster head accomplishes routing between its members and nearby clusters [11]. Consequently, VANET routing algorithms create hierarchical structures in one of three methods. First, a CH may can also become a member of another cluster, forming a treelike configuration. In the next crucial configuration type, an active backbone set-up is created, where all CHs share routing messages with or through each other; Finally, a hierarchy can be built on the basis of gateway nodes, who has membership of many clusters.

ii. Channel Access Management: One benefit of clustering is that it divides a VANET into an infrastructure network in a way similar to subnetworks. It enables the cluster head to build coordination events among its associates, specifically via scheduling channel entree. The algorithms targeted for this application generally employ a TDMA-based scheme whereby the CH assigns a particular time interval to its associates. Clustering algorithms adopting this approach provide a QoS guarantee and remove the requirement for RTS/CTS frames, which are not successful in VANET due to the hidden node issues [12].

iii. Security: The need to associate nodes to cluster heads in order to become member of their clusters offers a powerful mechanism to secure vehicular networks. Many of the algorithms studied use multi-state authentication solutions during the affiliation operation to be safe from malicious vehicles, and regularly involve trust level or historical consistency estimated in the calculation of cluster head selection metrics.

iv. Vehicular Network Topology Discovery: Multi-hop clustering infrastructures deliver an appropriate way [13] to analyse the topology of a network of moving vehicles. Cluster heads gather information from member nodes and nearby clusters to generate connectivity maps between network nodes. For a vehicular network, this information is vital for vehicle communication protocols, as well as delivers useful information to vehicle traffic controlling systems – for instance, recognizing location of traffic jam by studying movement patterns of vehicles. This information can be distributed either through routing protocol updates or through a devoted information distribution protocol [14].

v. Traffic Safety: VANETs may adopt a clustering mechanism to estimate vehicle collisions. Cluster-based risk-aware cooperative collision avoidance (C-RACCA) predicts a vehicle's estimated braking time and its equivalent collision-prevention capability in its CH selection method, guaranteeing that each node is sufficiently protected from the oncoming vehicle by applying brakes to prevent crash. During an emergency, an alert is broadcast via the cluster and the receiving vehicles take action accordingly either by automatically implementing vehicle controls or through some kind of emergency alert for the driver based on the incident provide in the alert message [15].

1.3 Need of Multi-hop Clustering in VANET

In contrast to MANETs, VANETs have promising features like faster vehicular speed, frequent change of network topology, and restricted driving directions; furthermore, it avoids energy issues. These specific characteristics are the reason behind the rare deployment of conventional clustering algorithms for MANET in vehicular networks [16]. Cluster steadiness is the main requisite in VANET. The fast-moving vehicles are responsible for the easy breaking of the cluster, affecting the routing efficacy. In addition, inconstant clusters tend to produce more control packets in the vehicular network and overload it. Comprehensive research has discovered clustering algorithms for the vehicular network to meet the necessitates of their new characteristics [17].

The majority of these studies rely on single-hop clustering, which only permits the exchange of information between a cluster member (CM) and its cluster head (CH) using a single-hop distance. In single-hop clustering, the range of the cluster is limited, leading to extra cluster heads and higher maintenance costs [18]. As a result, the research community has proposed many multi-hop clustering algorithms over the period. These algorithms can expand the range of clusters, mitigate the number of CHs, and make clusters more stable. However, multi-hop clustering for VANETs faces some issues. For example, cluster stability should be improved more, and maintenance overhead should be lesser. Thus, there is a need to design wide-ranging mechanisms [19].

1.3.1 A Typical Model of Multi-hop Clustering

The performance level of the classic single-hop clustering algorithm is not so high due to the dynamically changing VANET topology. In current years, some multi-hop distance-based clustering algorithms have been explored [20]. The multi-hop clustering algorithm makes the distance between the cluster members and the cluster head become n-hop, which can fruitfully prolong the cluster range. More cluster ranges can efficiently mitigate the number of cluster heads and make the clustering more stable to a certain level. The multi-hop cluster model dependent on the priority neighbor approach is depicted in Figure 2, where cluster A corresponds to the classic single-hop cluster configuration as it does not have many neighbors [21].

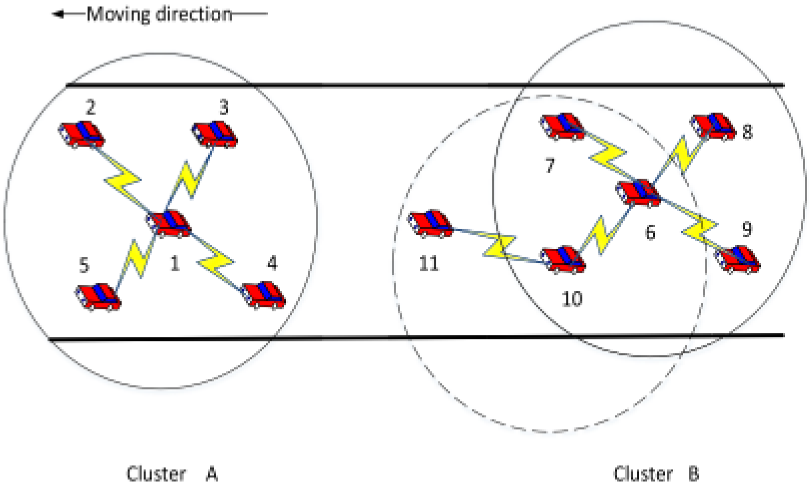

Fig 2. Multi-hop clustering model

In Cluster B, a multi-hop cluster structure is created in which the distance from Vehicle 11 to CH Vehicle 6 is 2 hops. Let each vehicle is mounted with an on-board unit with a maximal transmission radii R [22] and exchange information with other vehicles via the WAVE communication protocol. Vehicle nodes in the entire network, cluster member (CM) state, can only communicate with CM or cluster head (CH) nodes via the WAVE protocol and cannot have direct communication with the RSU. Vehicle node in CH state communicate with CM node by Wave as well as with roadside unit by 4G network [23]. This communication architecture permits the CM node to exchange information with the roadside unit only via the CH. An information table (INFO_TABLE) is stored in each vehicle, which includes the speed information of the vehicular nodes within an already defined maximum hop count (MAX_HOP).

II. LITERATURE REVIEW

2.1 Multi-hop Approaches to Improve the VANET performances

O. Senouci, et.al (2019) formulated a new MCA-V2I (Multi-hop Clustering Approach over Vehicle-to-Internet) for enhancing the performance of VANET (Vehicular ad hoc Network) [24]. This approach was planned on the basis of hypothesis that a vehicle was capable of connecting to Internet using RSU-G (Road Side Unit Gateway). A BFS (Breadth First Search) was implemented to traverse a graph depending upon a MR (Mobility Rate) whose computation was done with regard to the mobility parameters. SCH (Slave Cluster Head) as well as Master CH was selected to maximize the stability of clusters. NS-2 and the VanetMobiSim integrated environment was considered to quantify the formulated approach. The simulation outcomes depicted that the formulated approach performed more effectively as compared to other techniques concerning duration of cluster head, CN (Cluster Number), overhead, message delivery latency and message delivery ratio.

X. Zeng, et.al (2018) projected a novel probability-based multi-hop broadcast protocol for dealing with the issues related to reliability and latency [25]. Initially, the index number of node and other metrics were utilized for allocating a superior transmission probability to the nodes which were placed at distance from the source node. Subsequently, a clustering framework was put forward in order to mitigate the issues regarding redundancy and latency. Eventually, diverse parameters including transmission probability, average no. of copies and one-hop delay were considered for evaluating the projected protocol. The simulation outcomes confirmed that the projected protocol was efficient and led to enhance the performance of VANET (Vehicular ad hoc Network), make the network reliable and alleviate the latency.

F. Yang, et.al (2020) constructed a cross-layer optimization frame for multi-hop VANETs (Vehicular ad hoc Network) for enhancing the E2E (end-to-end) throughput of multiple simultaneous communication sessions [26]. The constructed approach was quantified by selecting a technique with no cooperative communication and IN as a benchmark. A comparative analysis was also conducted on this approach against other technique. The simulation outcomes indicated that the constructed approach was applicable for maximizing the throughput and the vehicle density in VANETs.

H. I. Abbasi, et.al (2020) investigated a multi-hop broadcasting protocol recognized as IFP (Intelligent Forwarding Protocol) having reliability and efficiency [27]. The handshake-less communication, ACK Decoupling, and a robust collision resolution technique were implemented in this protocol. An analysis was performed on the investigated protocol. This protocol was proved more efficient. The theoretical modeling was executed to optimize the investigated protocol in the experimentation. The results revealed that the investigated protocol had potential for mitigating the message propagation delay and PDR (packet delivery ratio).

Table 1: Multi-hop Approaches to Improve the VANET performances

Author	Year	Technique Used	Findings	Limitations
O. Senouci, et.al	2019	MCA-V2I (Multi-hop Clustering Approach over Vehicle-to-Internet)	The simulation outcomes depicted that the formulated approach performed more effectively as compared to other techniques concerning duration of cluster head, overhead, CN and message delivery ratio.	The scope of this work was constricted to this approach.
X. Zeng, et.al	2018	A new probability-based multi-hop broadcast protocol	The simulation outcomes confirmed that the projected protocol was efficient and led to enhance the performance of VANET (Vehicular ad hoc Network), make the network reliable and alleviate the latency.	The projected protocol was incapable of detecting the actual network density in case the transmission range was adjustable.
F. Yang, et.al	2020	A cross-layer optimization frame	The simulation outcomes indicated that the constructed approach was applicable for maximizing the throughput and the vehicle density in VANETs.	The constructed approach offered least throughput gains in case of maximization of subcarriers.
H. I. Abbasi, et.al	2020	IFP (Intelligent Forwarding Protocol)	The results revealed that the investigated protocol had potential for mitigating the message propagation delay and PDR (packet delivery ratio).	The PDR of this protocol was mitigated during the occurrence of more collisions and packet drops in the real-world conditions.

2.2 Clustering Approaches to Improve the VANET performances

M. Banikhalaf, et.al (2020) established a new clustering technique called ECHS (Efficient Cluster Head Selection) for large-scale and dynamic VANETs (Vehicular ad hoc Network) with the objective of selecting effective CHs (cluster head) [28]. Some conditions were applied on the techniques which were useful to develop clusters prior to select the CH. This technique ensured that the clustering was distributed properly in network in order to adjust 2 consecutive clusters. This kind of features provided superiority to the established technique over its traditional algorithms. The results depicted the effectiveness of the established technique concerning life span of cluster head, CML (Cluster Member Lifetime), PLR (Packet Loss Ratio), OC (Overhead for Clustering), APD (Average Packet Delay) and CN (Cluster Number).

H. Alabbas, et.al (2020) suggested a CAMVC (clustering algorithm for efficient multi-hop vehicular communication) in which the speed of cluster, acceleration, closeness centrality, and position metrics were utilized [29]. The finest CHs (cluster heads) were selected for prolonging the life span of cluster and the potential to compute the period of link connectivity was enhanced for discovering the gateways so that a link was established among clusters. The simulation was carried out to determine that whether the suggested algorithm was stable and efficient. The simulation results demonstrated that the suggested algorithm had generated optimal results concerning cluster stability and assisted in selecting the gateway.

W. Qi, et.al (2020) introduced a TDCR (Traffic Differentiated Clustering Routing) algorithm in a SDN (Software Defined Network)-enabled hybrid VANET (vehicular as hoc network) [30]. This algorithm made the deployment of centralized one-hop clustering approach and a technique of optimizing the data delivery. In particular, the optimization was executed for making a tradeoff amid cellular bandwidth cost and E2E (end-to-end) delay so that the CHs (Cluster Heads) attained power to deliver their aggregated data using multi-hop V2V (Vehicle-to-Vehicle) transmissions or the cellular networks. The simulation results validated that the introduced algorithm diminished the E2E delay and cellular bandwidth cost for high data-rate traffic.

A. Katiyar, et.al (2020) developed the clustering method known as DSCA (Dynamic Single-hop Clustering Algorithm) in the VANET (vehicular as hoc network) [31]. Diverse clustering techniques were present in the vehicular environment for selecting the finest CH (cluster head) on the basis of diverse parameters. Thus, the clustering efficacy was enhanced using an effective algorithm to select CH and cluster merging procedure. The simulation results exhibited that the developed method was more adaptable in comparison with others with respect to life span of CH and CN (Cluster Number).

Table 2: Clustering Approaches to Improve the VANET performances

Author	Year	Technique Used	Findings	Limitations
M. Banikhalaf, et.al	2020	ECHS (Efficient Cluster Head Selection)	The results depicted the effectiveness of the established technique concerning life span of cluster head, CML (Cluster Member Lifetime), PLR (Packet Loss Ratio), OC (Overhead for Clustering), APD (Average Packet Delay) and CN (Cluster Number).	The established technique performed poorly under complicated scenarios and dynamic environment.
H. Alabbas, et.al	2020	CAMVC (clustering algorithm for efficient multi-hop vehicular communication)	The simulation results demonstrated that the suggested algorithm had generated optimal results concerning cluster stability and selecting the gateway.	This algorithm attained lower efficiency in critical scenarios.
W. Qi, et.al	2020	TDCR (Traffic Differentiated Clustering Routing)	The simulation results validated that the introduced algorithm diminished the E2E delay and cellular bandwidth cost for high data-rate traffic.	Some flows were occurred when the cellular network transmitted the data which led to maximize the total bandwidth cost.
A. Katiyar, et.al	2020	(Dynamic Single-hop Clustering Algorithm)	The simulation results exhibited that the developed method was more adaptable in comparison with others with respect to life span of CH and CN (Cluster Number).	The developed method failed to perform well in case the metrics were maximized.

2.3 Clustering Approaches to Improve the VANET performances

G. Kaur, et.al (2019) constructed a new transmission approach in which the received SINR was considered via CVs (Connected Vehicles) for deciding the finest topology of the network [32]. The simulation results indicated that the constructed approach was capable of balancing the efficacy of single hop and the resource usage of dual hop transmission. This approach offered a CP (Coverage Probability) of 0.66 in comparison with others.

S. K. Gupta, et.al (2019) recommended a multicast communication model for distributing the WMs (warning messages) with the help of two communication protocols in AOR (Area of Relevance) [33]. The CMMP (Clustered Multi-hop Multicast Protocol) and the CMBMP (Clustered Multi-hop Broadcast and Multicast Protocol) were implemented in this model. OMNET++/SimuLTE/Veins/SUMO based simulation model was applied to evaluate both the protocols. The results proved the supremacy of these protocols over others. These protocols offered lower delay to deliver the WM and maintained higher WM (warning message) delivery ratio of 100%.

A. Abuashour, et.al (2018) designed a novel PCHEA (Passive Cluster Head Election Avoidance) protocol for optimizing the process of selecting number of CH (cluster head) [34]. This protocol utilized each CH to select another CH on the basis of precise information whose storage was done in its memory. Moreover, a CHR (Cluster Head Routing) protocol was presented for mitigating the number of relayed CHs among any pair of vehicles. The results exhibited the efficiency of both the protocols in diminishing the number of selected CH and maximizing the average throughput.

C. Wu, et.al (2018) presented a V2R (vehicle-to-roadside) communication protocol on the basis of distributed clustering which deployed a coalitional game technique for stimulating the vehicles so that a cluster was joined [35]. The stable clusters were produced using a FL (fuzzy logic) algorithm on the basis of different multiple metrics of vehicle velocity, moving pattern, and signal qualities among vehicles. Every vehicle was guided using a RL (reinforcement learning) algorithm for selecting the route which was capable of increasing the efficacy of the entire network. Moreover, a process of allocating the resource based on game theory was implemented for this. The presented protocol offered higher throughput and lower delay in multi-hop lossy vehicular environments. The simulation outcomes depicted that the presented protocol performed well in contrast to the other techniques.

Table 3: Clustering Approaches to Improve the VANET performances

Author	Year	Technique Used	Findings	Limitations
G. Kaur, et.al	2019	A novel transmission approach	This approach offered a CP (Coverage Probability) of 0.66 in comparison with others.	This approach was not performed well in dynamic environment.
S. K. Gupta, et.al	2019	CMMP (Clustered Multi-hop Multicast Protocol) and the CMBMP (Clustered Multi-hop Broadcast and Multicast Protocol)	The results proved the supremacy of these protocols over others. These protocols offered lower delay to deliver the WM and maintained higher WM delivery ratio of 100%.	The recommended model was unable to provide efficiency in different road and propagation conditions.
A. Abuashour, et.al	2018	PCHEA (Passive Cluster Head Election Avoidance) protocol	The results exhibited the efficiency of both the protocols in diminishing the number of selected CH and maximizing the average throughput.	The designed protocol was not provided good efficiency in different road terrains and transmission conditions.
C. Wu, et.al	2018	A vehicle-to-roadside communication protocol based on distributed clustering	The presented protocol offered higher throughput and lower delay in multi-hop lossy vehicular environments. The simulation outcomes depicted that the presented protocol performed well in contrast to the other techniques.	This protocol had not provided finer QoS (quality-of-service) in the presence of some fuzzy metrics.

III. CONCLUSION

The vehicular ad hoc network is the decentralized type of network in which vehicle nodes can join or leave the network when they want. The vehicle in the network has high mobility due to which it is difficult to establish path from source to destination. The various type of routing protocols is used for the path establishment which are broadly classified into reactive, proactive and hybrid protocols. The reactive routing protocols are the most popular protocols for the path establishment due to its high performance. The reactive routing protocols are improved in the past years to increase performance. In future multi cast model of reactive routing protocol will be designed for the path establishment in VANET.

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