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Cluster-based data dissemination, cluster head formation under sparse, and dense traffic conditions for vehicular ad hoc networks

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Summary

Information and communication technologies have changed the way of operations in all fields. These technologies also have adopted for wireless communication and provide low cost and convenient solutions. Vehicular ad hoc networks are envisioned with their special and unique intercommunication systems to provide safety in intelligent transportation systems and support large-size networks. Due to dense and sparse traffic conditions, routing is always a challenging task to establish reliable and effective communication among vehicle nodes in the highly transportable environment. Several types of routing protocols have been proposed to handle high mobility and dynamic topologies including topology-based routing, position and geocast routing, and cluster-based routing protocols. Cluster-based routing is one of the feasible solutions for vehicular networks due to its manageable and more viable nature. In cluster-based protocols, the network is divided into many clusters and each cluster selects a cluster head for data dissemination. In this study, we investigate the current routing challenges and trend of cluster-based routing protocols. In addition, we also proposed a Cluster-based Routing for Sparse and Dense Networks to handle dynamic topologies, the high-mobility of vehicle nodes. Simulation results show a significant performance improvement of the proposed protocol.

KEYWORDS

cluster head, clustering, mobility, routing, scalability, VANET

1 | INTRODUCTION

Vehicular ad hoc networks (VANETs) have become an emerging field of research and provide communication services among vehicle nodes. In this filed, various different types of beneficial applications have been envisioned and greatly improve the safety and convenient in intelligent transportation systems.[1] Data communication among vehicle nodes is based on pure ad hoc and infrastructure-based networks. Pure ad hoc communication provides the low-cost solution with easy deployment in the network compared with full coverage infrastructure communication. These networks are likely based on large-scale communication networks and apparently different from other networks. The main differences between other networks and VANETs are its high mobility of vehicle nodes, unpredictable topologies, and dynamic networks environment. In addition, the vehicle nodes movement is limited to road topology and can afford significant

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computing and sensing capabilities. The high mobility of vehicle nodes and dynamic topologies of network make these networks more challenging and complicated.[2] Several researchers have tried to summarize and solve the network issues such as in Li and Wang, Nzouonta et al, Zhang et al, and Zhang and Chen.[3-6]

Various different types of routing protocols have been designed for VANETs such as topology, position or geographical, beaconless, geocast, and cluster-based routing (CBR) protocols. The topology-based routing protocols have adopted proactive and reactive approaches. In proactive protocols, vehicle nodes are relying on routing tables, which are constantly changing their position.[7] The exchange of routing tables utilizes more bandwidth and cause of validity issues in the network. The well-known proactive topology-based routing protocols are Destination Sequenced Distance Vector and Optimized Link State Routing.[8] On the other hand, reactive routing protocols detect a route only and cause of poor scaling system issues such as in Temporally Ordered Routing Algorithm, Dynamic Source Routing (DSR), and Ad hoc On Demand Distance Vector (AODV). Reactive protocols detect the route before data transmission and spend more time on it and when finding the route, so maybe the original departure point disappears due to high mobility of vehicle nodes. To handle these issues, geographical or position-based routing protocols have been designed, where nodes obtain their position by using Global Positioning Services (GPS) and pinpoint the source and destination position such as in Greedy Perimeter Stateless Routing and Geographical Source Routing.[9]

To address the scalability issues in geographical protocols, CBR protocols have been proposed. Cluster-based protocols utilize less bandwidth and scalable to improve the network data routing efficiency.[10] Basically, the vehicle nodes are divided into different clusters where each cluster has one cluster head (CH) and other vehicle nodes are cluster members (CMs). The CH is a coordinating agent of cluster and responsible to establish communication links between other clusters. The cluster-based protocols are utilizing less resources of network and have less overhead and efficient to redeploying the network capacity. In this paper, we discuss the formation, taxonomy, and advantages of CBR protocols and proposed Cluster-based Routing for Sparse and Dense Networks (CBRSDN) and critically compare the performance of CBRSDN with well-known existing CBR protocols. The main objectives of this paper are as follows:

- Discuss the routing challenges and trend of CBR protocols.
- Discuss the motivation to design CBR protocol and discuss the existing solutions for VANETs.
- Propose CBRSDN.
- Demonstrate the advantages of CBRSDN through simulation experiments.

The rest of the paper is organized as follows: Section 2 discusses the routing challenges. Section 3 illustrates the trend of CBR protocols. The well-known cluster-based protocols are discussed in Section 4. Section 5 presents the proposed cluster based routing protocol, cluster formation, cluster head election and management strategies. Section 6 presents experimental study, simulation settings and proposed protocol performance. The paper concludes with future direction in Section 7.

2 | ROUTING CHALLENGES IN VANETS

The vehicular networks have been suffered with various different challenges due to its unique features and characteristics. In these networks, vehicle nodes disseminate traffic information with each other by using wireless communication devices. The vehicle nodes stay in predefined roadway and have inconsistent and unpredictable relative velocity. Traditional routing protocols are not suitable for these networks due to frequent network partitioning and high mobility of nodes in the presence of different obstacles including buildings and interference, which makes the network more challenging.[11] On the other hand, in Mobile Ad hoc Networks (MANETs), the intermediate nodes always exist between sender and receiver nodes and connections between these nodes are always established.[12,13] Vehicular environment has frequent network partitioning, and no route exists between source and destination, to handle this issue carry and forward approach has used.[8] In this approach, if no direct route exists in the network, the data packet is carried by sending vehicle node until a node is being near with destination node. The carry and forward concept has further extended in 3 types of data forwarding routing protocols: opportunistic,[14] trajectory,[15] and perimeter forwarding.[16] In opportunistic forwarding, a message is stored until source node finds the optimal node in the network, but if target node is alone, it fails. In trajectory forwarding, the nodes follow road layout in the network. Opportunistic and trajectory approaches offer good scalability, but not suitable for dead-end roads. To solve scalability issue, perimeter routing approach was proposed in Lee et al,[17] where road infrastructure assists as an overlay and intersections serve as graph edges and nodes. However, the vehicular network is highly dynamic due to high-speed vehicle nodes and has radio propagation characteristics. The vehicle nodes are moving in opposite directions and quickly join or leave the network, leading to fast and frequently topology changes. The network also suffered with frequent disconnection issues due to high mobility and less life of link between two vehicle nodes.

To address these routing challenges, the CBR protocols have been proposed and the most popular and well-known protocols are discussed in the next section.

3 | TREND OF CLUSTER-BASED ROUTING PROTOCOLS

To make stable data communication, various different types of protocols have adopted for VANETs. Some routing protocols have adopted an entire route to establish data forwarding. Some protocols have adopted hop-by-hop data forwarding. Entire route establishment and hop-by-hop data forwarding have their own advantages and disadvantages. Clustering has also adopted for network management in which the vehicle nodes are divided into groups known as cluster. All clusters have their own CH, and other vehicle nodes are CMs. The CH is responsible in making the communication with other CHs direct or electing one of the CMs as a gateway. All communications among CMs are called intracluster communication, and intercluster refers to communication between different CMs. Therefore, clustering is a method to transform the network into different tiers. One of the significant advantages of clustering is to improve the scalability especially for ad hoc wireless communication.[18] The traditional protocols are not able to handle flat networks, especially in dense situations. Cluster-based protocols act as a central coordinator in Medium Access Control protocols to manage the access of its CMs for the wireless channels. Clustering method is helpful, especially for large-scale distributed networks due to its simple network segmentation strategy. The formations of cluster and classification of vehicle nodes are performed according to application requirement. The main reasons to adopt clustering in VANETs are as follows: increasing the network scalability by network segmentations,[19] less network overhead due to selection of CH for data aggregation,[20] decreasing communication channel congestion,[19] Better Quality of Services in data routing,[21] improving network quality by providing network connectivity and improve density variations,[22] addressing hidden terminal issues and decreasing contention,[23] and dealing with high mobility and dynamic topologies.[24]

The main aim of clustering is to select optimal vehicle nodes with similar mobility patterns to join the same cluster. Cluster-based routing protocols also help to reduce the channel contention and provide fair channel access to the nodes. These protocols are also effective to reduce the effect of handoff latency and minimize the packet dropping issues.[25]

4 | RELATED WORK

Clustering for Open IVC Network (COIN) was proposed in Blum et al[26] as a CBR protocol for VANETs. The COIN is an extended version of MANET protocol to address the scalability issue. This protocol enhances the cluster stability and also improves network scalability. Selection of cluster is based on driver behavior and the distance between vehicle nodes and their mobility instead of relative mobility and their IDs. The relative mobility of CMs and CHs should be low; because of this, they live long in radio range. The main function of COIN is offering the time to clusters for surviving with minimized control load. The author tested this protocol with three approaches: lowest ID clustering, Cluster head-Gateway Switch Routing Protocol, and relative mobility clustering.[27] The CH lowest ID is where protocol reruns if any changes happen in the network. The lowest ID is used for CH election, where 2 clusters contact with each other or when a node no longer exists in radio range with any CH. The last approach is relative mobility, where CH election is preserved and only nodes with the below definite threshold are clustered together. Finally, the COIN is more stable for vehicular networks, but it has extra overhead in the network.

Location Routing Algorithm with Cluster-Based Flooding was proposed by Santos et al.[28] In this protocol, every vehicle node is a member of the cluster or will be selected as a CH or gateway after the election. The network is divided into different clusters, and every cluster has a CH. If a node is covering two clusters, it is known as a gateway node. The CH is responsible for managing the communication between the gateway and member nodes. The protocol uses greedy forwarding for packet forwarding. The CH and gateway node send the location request in the form of location request packets and check the destination membership with the cluster. Whenever the destination vehicle node becomes a member of its cluster, then location reply packet returns to the sender with geographical location information because each node is aware of the position of source and neighbor node. This protocol has an optimal strategy to handle clustering in VANETs. However, the protocol has suffered from network overhead.

Cluster-based routing was proposed in Luo et al,[29] in which the geographical area is separated into series of logical grids where every node has exclusive ID that contains Medium Access Control and IP address. Every grid contains a CH, and through CH, the data will forward to the destination and the communication range must cover the neighbor cluster. This protocol has 4 steps for CH election: in the first step, the CH sends a LEAD message to its neighbor nodes; if any Road Side Unit (RSU) exists, it will be selected as a CH and LEAVE message will be sent directly. In next step, a node sends an APPLY (g, local) message to its neighbor nodes if it does not obtain a LEAD message in a specific interval of time T1 (g and local defines as coordinators of its grid and present location of node A). If CH receives an APPLY message and still in the grid, then a LEAD message will be replied to node A. In the meanwhile, there is another node B near the grid center and not a CH. It will receive the APPLY message and APPLY will be replied to A. If node A does not receive a LEAD message or APPLY message in a specific period of time T2, it will be a CH. In the third step, if the CH is out from its grid, it will send LEAVE message and other nodes of its grid send APPLY message according to step two and select a new CH after receiving LEAVE message. In the last step, there are many self-given CHs present and all other CHs cancel their position, whenever they receive a LEAD message from RSUs or the one that is near the grid center stops sending LEAD message anymore. After this election, the CH receives the packet from source node directly and then CH chooses best neighbor cluster and the data packets. If the sender node is CH, then it will select the best header directly. This forwarding process will start until finding the neighbor CH of the destination node. The author compared the proposed protocol with AODV, Destination-Sequenced Distance-Vector Routing, and DSR and showed better performance in network delay and packet delivery ratio. However, this protocol has computational complexities to initiate the process, which leads to network overhead.

Cluster based Directional Routing Protocol (CBDRP) was proposed by Song et al[30] to address link stability issue. The CBDRP is divided into several clusters based on the same direction vehicle nodes. Every cluster has one CH to forward the messages about its own existence to other CHs. Through this process, data will be forwarded to the required destination node. In this procedure, the link will maintain only when another intermediate header is present in the network. The data are routed through headers instead of vehicle nodes in cluster. Figure 1 shows two clusters with fixed center position after division. There are some assumptions for clusters in highway environment such as r is the radius of radio range, the length of cluster is d, the radius of transmission range is 1000 m, and cluster length is 500 m.

The CBDR protocol has two main functions; in the first function, the protocol selects the CH and in second function protocol initiates the routing. The CH selection is on the basis of vehicle node location and their velocity. Then, the CH forwards the route request (RREQ), route reply, and data packets to neighbor CHs. The REEQ checks the destination location and ensures that CH is located in the same cluster or not and then forwards the packet to other CHs by transmission direction setting. If the forwarder node does not find the destination node, then it waits until time to leave is equal to zero and adds forwarding route plus reverse route list in the routing table. The CBDRP selects the intermediate nodes and adopts store and forward strategy and sends RREQ to the destination node, and destination node replies route reply when receiving RREQ. The author compared CBDRS with AODV and Greedy Perimeter Stateless Routing protocols. The simulation results indicated that CBDRP has better packet delivery ratio, link stability, and small latency for safety applications in VANETs. However, the main issue in this protocol is processing overhead, which leads to network overhead and data delay issues in the network. In addition, this protocol is compared with AODV and GPRS, which are quite old, and AODV was designed for MANET and not feasible for high mobility nodes.

Traffic Infrastructure based Cluster Routing Protocol with Handoff was proposed in Wang and Wang.[31] This protocol adopts handoff cellular network idea due to the overlapping issue between clusters, which leads to inevitably in the network. This protocol improves the service of quality performance. The authors assumed some assumptions to design this

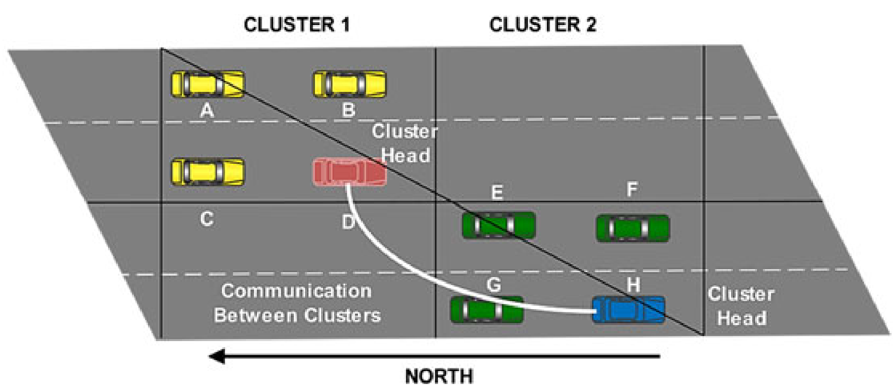

FIGURE 1 Cluster division of Cluster based Directional Routing Protocol

protocol: the vehicle nodes are deployed in two dimensions and equipped with location services (GPS) and links are bidirectional. This protocol utilizes the existing infrastructure where each cluster has one CH from backbone network and covers all the roads in urban environment. Figure 2 shows the clustering example where the shadow region between the clusters presents the overlap region.

In the above scenario, the more important thing is handoff idea, where vehicle node and its two neighbor CH dot product of velocity vector are calculated. The direction vector is based on the value of the dot product and approximates the cluster ID, and then vehicle node sends the message via selected CH. There are 2 possible scenarios in urban networks, first one is straight road driving and the second is turning vehicle into a new street. Inside the cluster, all vehicle nodes are interconnected and communicate with each other directly and through CH and disseminate data packets to other CMs. The author tested TIBSRPH protocol with six existing protocols and presented the best performance of TIBSRPH in average delivery ratio, average end-to-end delay in urban networks.

Stability based Clustering Algorithm (SBCA) was proposed in Ahizoune and Hafid[32] to address the network stability issue. Stability based Clustering Algorithm has two stages: setup and maintenance; in setup phase, vehicle nodes separated into clusters for CH selection, and in maintenance phase, a secondary CH is nominated for each cluster. In setup phase, CH is primary, and in maintenance phase, CH is secondary. If primary CH is no longer available in cluster, the secondary CH takes over. In the setup phase of SBCA, election represents an adaptive version of Cluster Configuration Protocol (CCP).[33] The author evaluated SBCA in average cluster lifetime, clustering overhead, and in packet delivery ratio. The average cluster lifetime of SBCA is higher than that of CCP. In CCP protocol, if the CH is absent, then new cluster selection will start and cause delay in network. On the other hand, the SBCA selects secondary CH and replaces with primary CH and lifetime of cluster will increase.

Passive clustering aided routing (PassCAR) was proposed by Wang and Lin[34] for suitable stable and reliable cluster structure during route discovery process. Passive clustering aided routing is based on passive clustering approach with passive behavior, which is low in control overhead in packet forwarding. The passive mechanism is working only when ongoing data packets maintain clusters as a substitute of plain control packets. The passive mechanism suffers from many issues in high mobile and dynamic nature of vehicular networks. The author selects this mechanism in PassCAR to expand the routing efficiency in VANETs. In PassCAR, each candidate node is self-determining and checks its own priorities with the help of multimetric election. Multimetric election has three metrics including link lifetime, transmission count, and node degree. The author tested PassCAR protocol with original PC mechanism and got successful probability in route discovery. It also selects suitable nodes as a member of clusters and better in packet delivery ratio, in throughput and stable and durable routing paths. However, this protocol has computational complexity issues, which lead to network overhead and data delay in the network.

Intelligent based Clustering Algorithm (IBCAV) was proposed by Mottahedi et al[35] based on interlayered methods, traffic flow information, cluster size, traffic density, velocity, and speed of vehicle nodes based on artificial neural

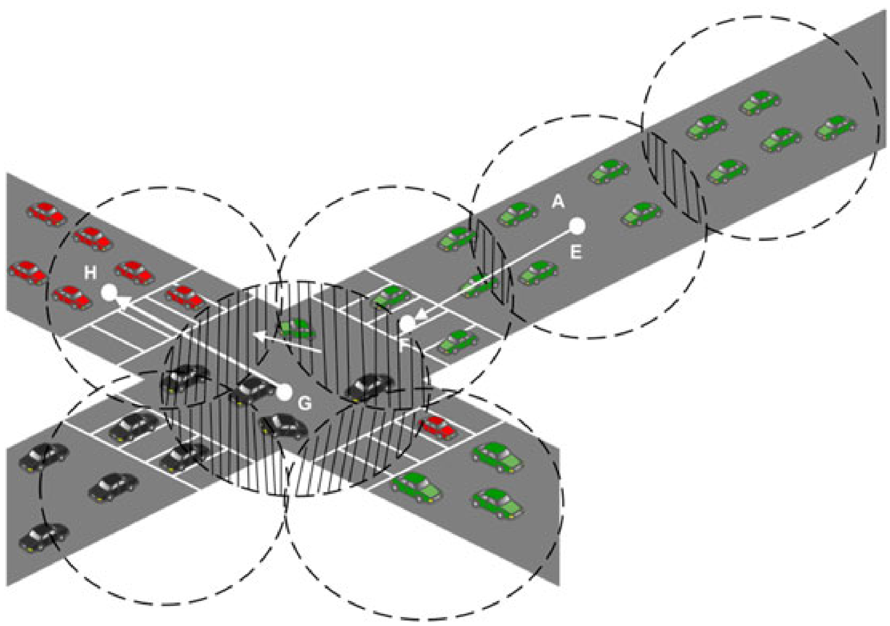

FIGURE 2 Clustering example of Traffic Infrastructure based Cluster Routing Protocol with Handoff

network. The moving vehicle nodes are divided into different groups or clusters and select a node as a CH. The CH election is based on a series of computations, time, and network resource consumption. In this protocol, the RSU is selected as a CH due to its strong processing capabilities, and if RSU does not exist in cluster, then the slow speed vehicle node will be CH. One of the reasons behind slow vehicle selection as a CH is its long stay in cluster compared with high-speed vehicle nodes. The CH utilizes Hello messages and store/carry forwarding approach for sending a message. Intelligent based Clustering Algorithm protocol uses artificial neural network for CH selection and combines all effective factors. One of the main advantages to adopt this technique is its technique to handle the defined physical environment of VANETs. The author tested this protocol with AODV and DSR, where the results indicated better results of IBCAV in throughput, packet delivery ratio, and end-to-end delay. However, with many advantages, this protocol always relies on RSU, which leads to disconnectivity issues due to various obstacles in the network. Table 1 compares all discussed protocols in term of their essential features, parameters, and performance metrics.

5 | PROPOSED CLUSTER-BASED ROUTING PROTOCOL

Cluster-based routing or clustering is a process in which vehicle nodes are divided into different groups where each cluster selects a CH for data transmission among network entities. Whenever, any node wants to send the data packets to the destination, the protocol is responsible to set up a route between source and destination nodes. Before describing the design model of the proposed CBR protocol, it is worthwhile to discuss some assumptions of the network. We assume the following assumptions:

- All sensor nodes have equal and large transmission range that covers the width of road range from 100 m to 300 m.
- All sensor nodes are aware of their location information through GPS.
- Road Side Units do not have any resource constraints.
- All vehicle nodes are homogeneous with same computing capabilities.
- The vehicle nodes are moving in the same direction.
- Every vehicle node is equipped with On Board Unit.
- Every vehicle node has a unique ID.
- Security and privacy are not considered.
- Computation complexity is not taken into account.

TABLE 1 Comparison of cluster-based routing protocols

S/No	Protocol	Essential Features	Parameters	Performance
1	COIN[26]	Based on MANET clustering and enhanced scalability in VANETs	Driver behavior, node mobility, and distance between vehicles	Better than CGSRP
2	LORA-CBF[28]	Used flooding approach and efficient in route discovery	Routing load, overhead, data delivery ratio	AODV, DSR
3	CBR[29]	Geographic area is separated into 4 square grids and decreases the packet delivery delay and control packets.	Data delivery ratio, packet delay	DSDV, AODV and DSR
4	CBDRP[30]	Efficient in link stability, header selection, and routing procedure used	Packet delivery ratio, link stability and small latency	CBDRP, AODV and GPSR
5	TIBCRPH[31]	Handoff idea of cellular networks used and improves the service of quality and quality of communication	Average end-to-end delay and delivery ratio	MFlood, DSDV, AODV, LAR, GPSR
6	SBCA[32]	Efficient in network stability	Average cluster lifetime, clustering overhead, packet delivery ratio	CCP
7	Pass CAR[34]	Passive clustering approach used for passive behavior and low in control overhead in packet forwarding	Packet delivery ratio, throughput and stable and durable routing paths	PC mechanism
8	IBCAV[35]	Artificial neural network used for header selection and combines effective factors	Packet delivery ratio, throughput and end-to-end delay	AODV, DSR

In the proposed CBR protocol, vehicle nodes are divided into clusters by vehicle node moving patterns in the network. A CH is elected for every cluster and responsible for exchange the information with other CM vehicle nodes. Basically, the road network represents a graph where vertexes represent intersections and edges represent roads. The proposed protocol is based on three main phases including cluster formation, CH election, and cluster management. Figure 3 shows the flow chart of CBRSDN.

5.1 | Cluster formation

The cluster formation is one of the significant parameters to formulate the network in different clusters. For cluster formation, CBRSDN formulates the network portions based on vehicle node distribution in the network. The main

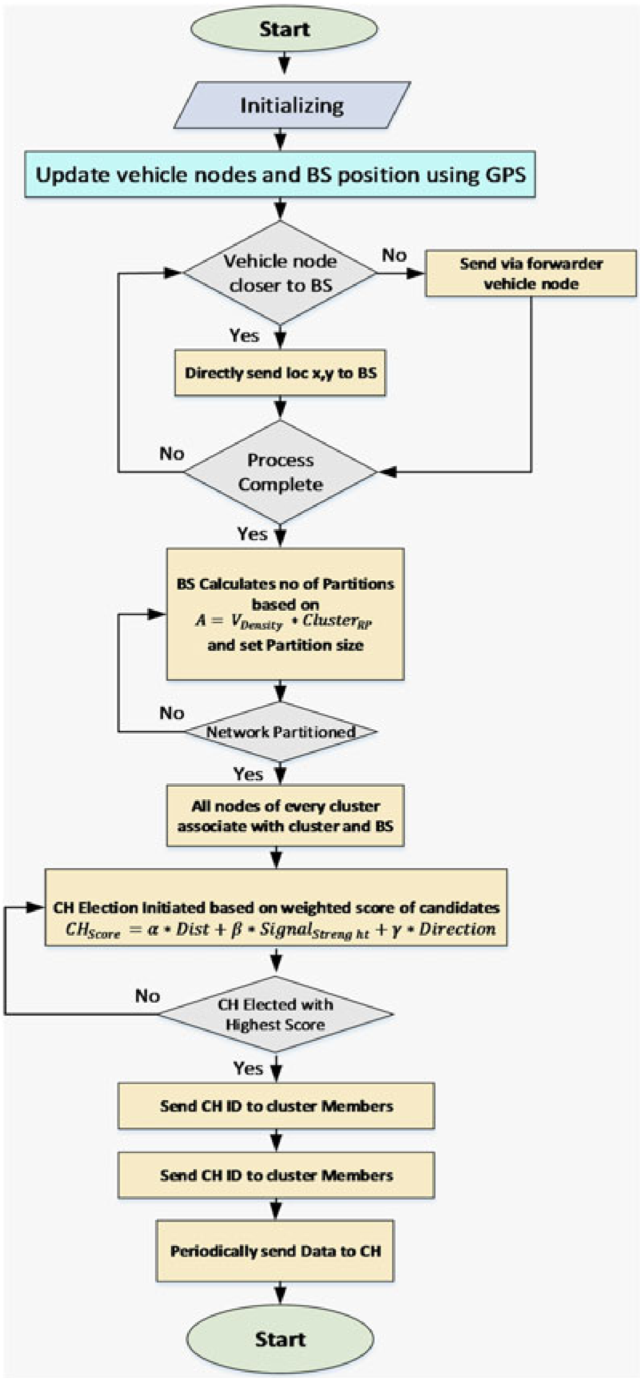

FIGURE 3 Flow chart of Cluster-based Routing for Sparse and Dense Networks

objective for cluster formation is to balance the network stability and improve the data routing. There are two main methods for cluster formation including single duty cycle and periodic reclustering methods. The periodic method has network overhead issues due to its temporary data suspension approach. In VANETs, all the vehicle nodes and base stations (BSs) are already aware about location of nodes through GPS by beacon (short/hello) messages. The BS plays a role to collect all vehicle node location information for consistent view of the entire network field. Equation 1 shows the dissection procedure where BS dissects the network into A square size partitions.

$$A = V_{\text{Density}} * \text{Cluster}_{\text{RP}} \tag{1}$$

where A denotes the number of square size partitions, V_{Density} denotes the vehicle node density, and $\text{Cluster}_{\text{RP}}$ is the required cluster percentage. After this calculation, the proposed protocol segments the vehicle nodes into geographical-based clusters. Afterward, the BS analyzes the center point ($\text{Centre}_{\text{point}}$) for each partition and distributes the information among vehicle nodes for every partition A_i based on location of vehicle nodes within partition. After receiving the complete information E_p, the BS generates a set of clusters based on a set of vehicle nodes that are close to its center point. In addition, BS also assigns a unique cluster ID to every cluster. This procedure will start until all entire networks are divided into clusters or groups. The main objective of this procedure is to initiate the load balancing among clusters. Algorithm 1 shows the cluster formation process.

Algorithm 1. *Cluster Formation*

```
Input
V_Density: Vehicle Node density
Cluster_RP: Required cluster percentage
Output
C_A: Cluster formation
Update the Vehicle node locations through GPS
Send information of entire network to BS
do
b = i. select upstream neighbor ()
i.sends toward Base Station (pos (xi,yi), j)
end for
12. A = V_Density * Cluster_RP/*A is number of required partitions*/
Procedure C_A (A)
for each partition
do
Compute Centre_point for i
Length Centre_point [i] = Centre_point;
end for
do
distance to Centre_point = compute distance (i x,y, Length Centre_point)
i. joins to nearest cluster (distance to Centre_point)
end for
end procedure
```

5.2 | Cluster head election and management

Cluster head election is one of the significant strategies to elect one vehicle node as a CH within each cluster region. Most of the existing CBR protocols generate extra computation complexities and overhead due to their complex CH election processes. The proposed CBRSDN protocol applies the CH election only on selected number of nodes that has less communication overhead in the network. Therefore, only limited numbers of vehicle nodes are participating in CH election by computing the load information and weightage. Cluster-based Routing for Sparse and Dense Networks adopts distributed manner where the vehicle nodes calculate their score for CH selection by using weighted metrics including distance, signal strength, and direction.

$$\mathrm{CH_{Score}} = \alpha * \mathrm{Dist} + \beta * \mathrm{Signal_{Strenght}} + \gamma * \mathrm{Direction} \tag{2}$$

In Equation 2, α, β, and γ denote the weighted factors for distance, signal strength, and direction, respectively. The weightage value of these three metrics sets to 1, whereas $0 \le \alpha \le 1$, $0 \le \beta \le 1$, and $0 \le \gamma \le 1$. The values of all metrics are customized based on applications in the network. The distance is one of the significant routing metric for CH election where most central vehicle node is selected as CH within each cluster. In Equation 3, the distance is calculated as follows.

$$\mathrm{Distance} = \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y\right)^2} \tag{3}$$

Afterward, the second parameter of CH selection is signal strength. Basically, the wireless communication channels have suffered with fading and attenuation issues due to unpredictable and obstacle-based road conditions. The signal strength is another significant metric to characterize the channel quality. Through this metric, the signal strength level has measured. The strong signal strength node within cluster has more chances to become a CH in the network. The third metric is vehicle direction toward destination. This metric is significant because of two-way traffic on roads. This metric is helpful to avoid the looping issues in the network. The high priority is given to that node which direction is toward the destination.

After CH selection, each CH broadcasts a presence message (PM) to its CMs to update its presence within cluster. The PM message contains elected CH identity and its position. Whenever member vehicle nodes receive the PM message, they further disseminate the message to other nodes inside the cluster. If cluster identification is different, vehicle nodes ignored that message. Algorithm 2 shows the CH election and its management process.

Algorithm 2. *Cluster Head Election and Management*

Input
C_A: Cluster formation
Output
ECH_i: Set of elected cluster heads
Procedure CH Election
for every cluster
do
Update cluster member position = get member position (i)
end for
for every cluster
for every cluster vehicle node
do
Highest weight based on //$\mathrm{CH_{Score}} = \alpha * \mathrm{Dist} + \beta * \mathrm{Signal_{Strenght}} + \gamma * \mathrm{Direction}$
end for
CH = Highest weight
do
Corresponding with BS and other CHs
end for
end procedure

6 | EXPERIMENTAL STUDY

In this section, we discuss the detail of experimental settings of the proposed protocol. We also compare CBRSDN with two existing protocols, SBCA[32] and PassCAR.[34] The proposed protocol varies with following parameters: distance between source and destination node, number of vehicle nodes, number of delivered messages, and network topology. These parameters will be evaluated in different performance metrics including message delivery time, packet delivery ratio, network overhead, and network delay.

6.1 | Simulation settings

The experiments were conducted by using well-known simulator NS-2.34 with the combination of mobility simulator SUMO under Ubuntu 15.04 operating system. The SUMO simulates the vehicle nodes in their mobility along the roads. Basically, the function of mobility model is providing a detail configuration of road network. In addition, the road editor is used to set the other road conditions such as number of roads, number of intersections, traffic signals, and obstacles. For the vehicle node setting, another module is used to set vehicle parameters such as vehicle speed, number of vehicle nodes, probability of right and left turn, and lane change probability. For this research, we set a road with 10 intersections, numbers of vehicles are around 50 to 500, and speed range is 30 to 50 km/h. The vehicle node starting positions are randomly distributed on the road map. Transmission ranges of all vehicle nodes are considered 300 m, and packet size is 512 Bytes. The traffic type is CBR, and shadowing propagation model and Omni directional antenna are other basic parameters. All simulation parameters are provided in Table 2. After configuration, simulations are performed and many source nodes are randomly selected from intersection points. For result preparation, an average of 10 simulations run and 95% confidence interval was used for all simulation results.

6.2 | Effect of message routing distance

In first experiments, the source nodes (sender) and destination nodes (receivers) are randomly selected in the network. The distance between source and destination nodes is between 300 m to 2500 m. For every simulation run, 100 messages are generated between source and destination nodes. This effect clearly shows the establishments of clusters of vehicle nodes in the network. Figure 4 clearly shows that the proposed protocol achieves highest delivery rate compared with state-of-the-art routing protocols. On the other hand, the SBCA protocol is slightly lower delivery rate, while PassCAR is the lowest. The delivery rate of SBCA drops quickly when the distance is increased to 1500 m because the clusters of vehicle nodes of CBRSDN are more stable than those of SBCA and PassCAR. On the other hand, the SBCA setup and maintenance phases consume more processing and time to establish the clusters of vehicle nodes. Moreover, PassCAR adopts passive clustering approach only when ongoing data packets maintain clusters as a substitute of plain control packets. The passive mechanism suffers from many issues in high mobile and dynamic nature of vehicular networks. Frequent changes of network topologies and cluster formation may not be valid for actual sent messages. Whenever the route distance becomes longer, the probability of route establishment is invalid and increases, which has serious effect on data delivery in the network. The average cluster lifetime of SBCA has higher than PassCAR due to its secondary CH selection and replaces with primary CH, which has more lifetimes of clusters in the network.

Figure 5 shows the delivery time with different message routing distance of CBRSDN and state-of-the-art protocols. Delivery time measures from source vehicle nodes till destination vehicle nodes in the network. The time taken by CBRSDN is lowest and stable even though the message routing distance increases. The SBCA and PassCAR perform well

TABLE 2 Simulation parameters

Parameters	Values	Parameters	Values
Total area of simulation	3500×3500 m^2	Total number of vehicle	50-500
Vehicle speed	15-50 km/h	Intersections	10
Transmission range	300 m	MAC protocol	IEEE802.11p
Traffic type	CBR	Data rate (MAC)	5 Mbps
Antenna model	Omnidirectional	Traffic signals	10
Beacon interval	3 s	Channel type	Wireless
Propagation model	Shadowing	Mobility simulator	SUMO
Message generation rate	100-512 Bytes	Distance between source and destination	2500 m

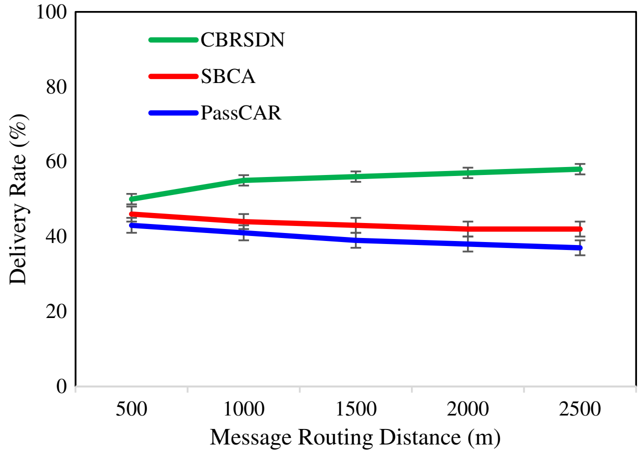

FIGURE 4 Data delivery ratio with message routing distance

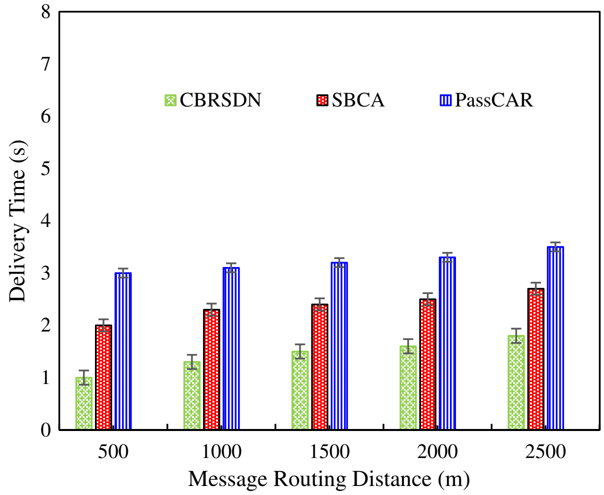

FIGURE 5 Delivery time with message routing distance

but take more time compared with CBRSDN, while PassCAR delivers messages slower than SBCA. This is because PassCAR has more complex processing compared with SBCA and CBRSDN in the network.

Finally, Figure 6 shows link failure with different message routing distance. In these experiments, CBRSDN has greter achievement compared with SBCA and PassCAR. We can see that the performance of SBCA is in between more

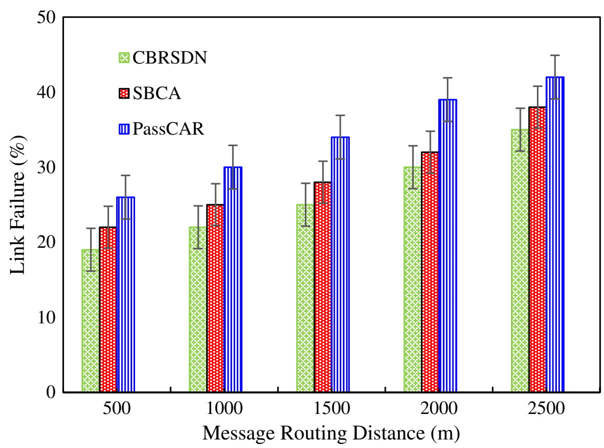

FIGURE 6 Link failure with message routing distance

failures than CBRSDN due to its maintenance process because it needs to maintain the route then send the actual message. On the other hand, the PassCAR has higher link failure because each candidate node is self-determined and checks its own priorities with the help of multimetric election. Another reason of link failure is high mobility of vehicle nodes in the network. Cluster-based Routing for Sparse and Dense Networks does not need to discover the entire route before sending the messages. Such low link failure by CBRSDN will be significant for scaling the applications in the real world.

6.3 | Effect with number of vehicle nodes

In these experiments, we set default road distance 1500 m between source vehicle nodes and destination vehicle nodes. Figure 7 shows the performance of CBRSDN with different numbers of vehicle nodes in the network. The main reason to set the vehicle node density between 100 and 500 is that this range is sufficient for urban areas for revealing the underlying performance. This range also covers the dense and sparse traffic density where around 100 vehicle nodes cover 0.30/100 m and 500 cover 1.30/100 m in the network. Experimental results indicated that CBRSDN achieves better delivery rate.

Figure 8 shows the delivery time with vehicle node density of CBRSDN and state-of-the-art protocols. Delivery time measures from source vehicle nodes till destination vehicle nodes in the network. The time taken by CBRSDN is lowest and stable even though the number of nodes is increasing up to 300,400, and 500, respectively. As for SBCA and PassCAR, they perform well but are taking more time compared with CBRSDN, while SBCA delivers messages slower than SassCAR. This is because PassCAR has more complex processing compared with SBCA and CBRSDN.

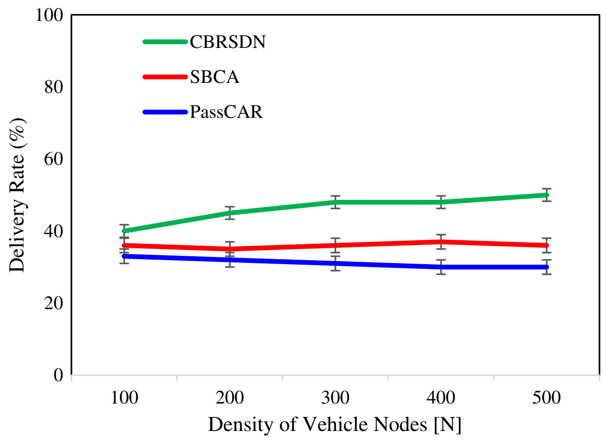

FIGURE 7 Deliver rate with node density

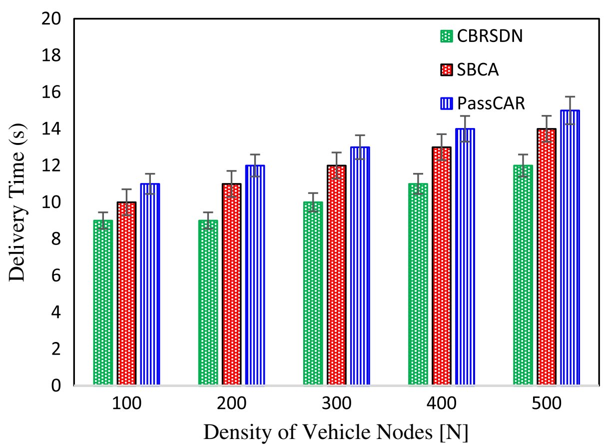

FIGURE 8 Delivery time with node density

Finally, Figure 9 shows link failure with vehicle node density. In these experiments, CBRSDN has greter achivement comapred to SBCA and PassCAR. We can see that the performance of SBCA is in between due to its maintenance process because it needs to maintain the route then send the actual messgae, which leads to more link failure. On the other hand, the PassCAR has higher link failure because each candidate node is self-determined and checks own priorities with the

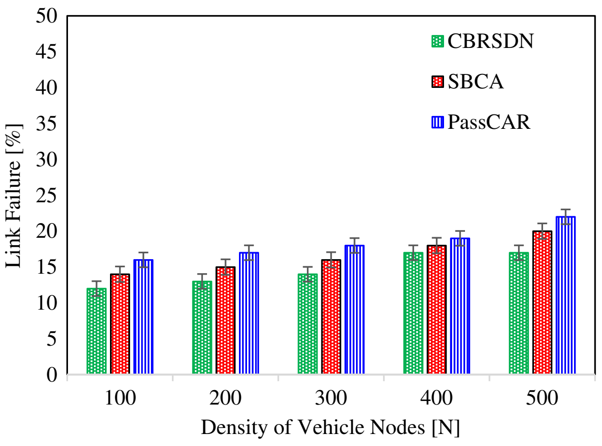

FIGURE 9 Link failure with node density

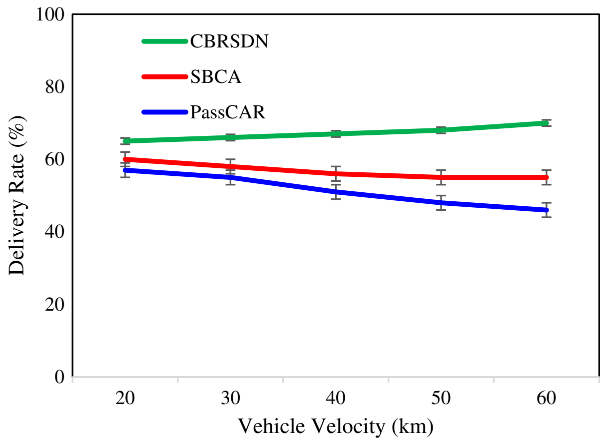

FIGURE 10 Data delivery ratio with vehicle velocity

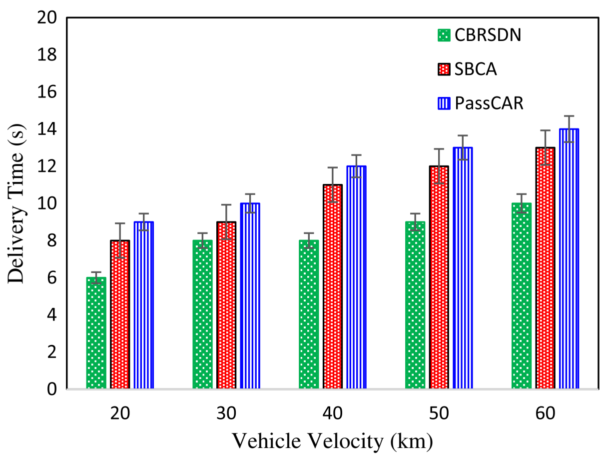

FIGURE 11 Delivery time with vehicle velocity

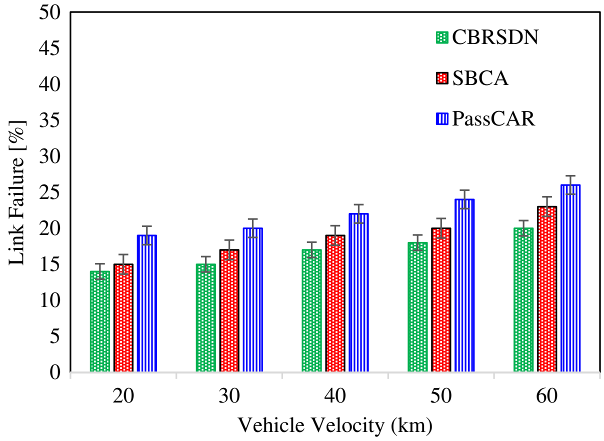

FIGURE 12 Link failure with vehicle velocity

help of multimetric election. Another reason of link failure is high traffic. Cluster-based Routing for Sparse and Dense Networks does not need to discover the entire route before sending the messages. Such low link failure by CBRSDN will be significant for scaling the applications in the real world even in the presence of high traffic density.

6.4 | Effect with vehicle velocity

In these experiments, we set vehicle node velocity 20 to 70 km/h. Figure 10 shows the performance of CBRSDN with different vehicle node velocity in the network. The main reason to set the vehicle velocity between 20 and 70 km/h is that this speed has significant impact on protocol performance to deal with vehicular networks. This speed also covers the dense and sparse traffic condition where vehicle nodes change their speed behavior based on traffic conditions. Experimental results indicated that CBRSDN achieves better delivery rate compared with SBCA and PassCAR.

Figure 11 shows the delivery time with vehicle node velocity and evaluates the performance of CBRSDN and state-of-the-art protocols. Delivery time measures from source vehicle nodes till destination vehicle nodes in the network. The time taken by CBRSDN is lowest and stable even though the vehicle node speed increases up to 40, 50, and 60, respectively. As for SBCA and PassCAR, they perform well but are taking more time compared with CBRSDN, while SBCA delivers messages faster than PassCAR. This is because PassCAR has more complex processing and designed to handle high mobility compared with SBCA.

Finally, Figure 12 shows link failure with vehicle node velocity. In these experiments, CBRSDN has greter achivement compared with SBCA and PassCAR. We can see that the performance of SBCA is in between due to its maintenance process because it needs to maintain the route then send the actual message, which leads to more link failure. On the other hand, the PassCAR has higher link failure because each candidate node is self-determined and checks its own priorities with the help of multimetric election. Another reason of link failure is high traffic. Cluster-based Routing for Sparse and Dense Networks does not need to discover the entire route before sending the messages. Such low link failure by CBRSDN will be significant for scaling the applications in the real world even in the presence of high traffic density.

All experiment results indicated the proposed CBRSDN higher performance compared with state-of-the-art cluster protocols and best option to deal traffic density, high mobility, and dynamic networks.

7 | CONCLUSION

This paper presents a CBRSDN appropriate for urban scenarios. Cluster-based Routing for Sparse and Dense Networks is basically based on clustering where protocol adopts well recognize routing metrics for CH election including vehicle density, signal strength, and direction. The network is divided into different clusters where each cluster has its own CH, which has higher weighting value. The BS is involved in network partition to reduce on demand routing in the network. For data communication outside the cluster, CH uses flooding approach toward other CMs. The simulation results indicated that CBRSDN has better results in data delivery, link failure, and delay time compared with existing state-of-the-art cluster protocols. In the future, we will test this protocol in highway scenarios where vehicle velocity is higher than urban scenarios.

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