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Design and Analysis of An Improved AODV Protocol Based on Clustering Approach for Internet of Vehicles (AODV-CD)

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***Abstract*—The Internet of Vehicles (IoVs) has become a vital research area in order to enhance passenger and road safety, increasing traffic efficiency and enhanced reliable connectivity. In this regard, for monitoring and controlling the communication between IoVs, routing protocols are deployed. Frequent changes that occur in the topology often leads to major challenges in IoVs, such as dynamic topology changes, shortest routing paths and also scalability. One of the best solutions for such challenges is "clustering". This study focuses on IoVs' stability and to create an efficient routing protocol in dynamic environment. In this context, we proposed a novel algorithm called Cluster-based enhanced AODV for IoVs (AODV-CD) to achieve stable and efficient clustering for simplifying routing and ensuring quality of service (QoS). Our proposed protocol enhances the overall network throughput and delivery ratio, with less routing load and less delay compared to AODV. Thus, extensive simulations are carried out in SUMO and NS2 for evaluating the efficiency of the AODV-CD that is superior to the classic AODV and other recent modified AODV algorithms.**

***Keywords*—Ad hoc On-Demand Distance Vector Routing, Clustering, Internet of vehicles, Vehicular ad hoc networks, Quality of service, 5G wireless networks**

I. INTRODUCTION

PREDICTIONS show that by 2020 about 1.25 billion "things" will all be linked up to the Internet and a major constituent of that number will be from vehicles. Existing areas such as smart transport, smart industry, smart health, smart home and smart energy are already experiencing the integration 5 of smartness by Internet of Things (IoTs). One of IoT's big revolutions is IoV which is an emerging Technologies for connecting all smart devices such as vehicles and Vehicles-to-Everything (V2X), intelligent traffic light systems, office-and-home smart appliances. Therefore, in order to fulfill IoVs' requirements cloud computing is contemplated. Moreover, deploying resources at the edge of wireless network has been considered by the industry and academia in order to overcoming issues such as the restricted capabilities of storage, onboard computing, energy and communication. This deployment in cloud computing prevents unnecessary latency.

Currently with the traditional Vehicular ad hoc networks (VANET) changes are being made into the IoVs because of the increase in the quantity of vehicles that are connected to the IoT [1]. Figure 1 shows the impact of IoT. VANET makes all vehicles that are participating to become a wireless router or mobile node, which enables the vehicles to connect to each other and for them to establish a wide range network [2]. Furthermore, other vehicles are able to join in as other vehicles leave the signal range or leave the network which connects the network to one another to enable the creation of a mobile network. It was observed that just a small mobile network is covered by VANET which actually is being subjected to mobility constraints and also the number of vehicles connected.

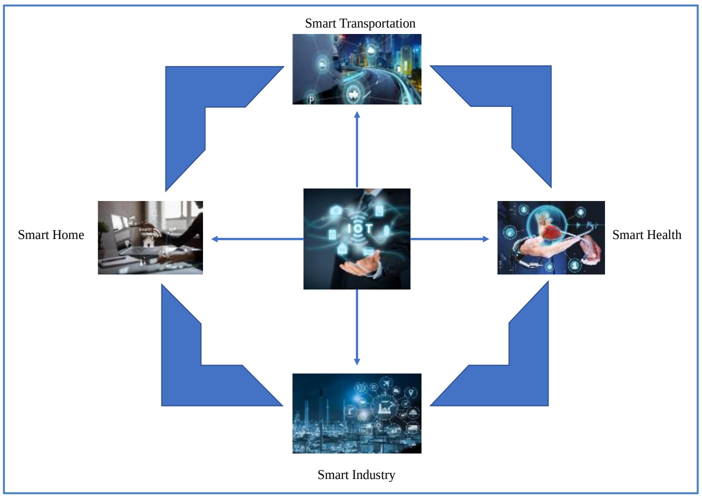

Fig. 1. Impact of IoT

IoVs' routing protocol is an important research area. There are various routing protocols which come from Mobile Adhoc Network (MANET) studies like Destination-Sequenced Distance-Vector (DSD-V) [3], Dynamic Source Routing (DSR) [4] and AODV [5]. Protocols such as Greedy Perimeter Coordinator Routing (GPCR) [6] and Greedy Perimeter Stateless Routing (GPSR) [7] are some of the geographic protocols proposed by researchers when taking vehicle properties into consideration. It is important to mention that the majority of routing algorithms are only appropriate for solo wireless access technology and limited scale.

Reduction of communication issues between vehicles is a major challenge for industries and automobile companies such

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as Car TALK 2000, COMCAR projects, DRIVE, Car Net and Fleet Net [8-13]. Some important parameters that affect the performance reduction of routing protocols are network size and vehicles' speed. The IoVs network is a dynamic network, being that there are nodes having inconsistent/random motion leading to nodes frequently experiencing structural deviations. Eventually, this leads to network expiration resulting from the network separation. In order to increase its lifetime, the mobility pattern or forecasting pattern can be forecasted, which will result in the extensive usage of application in multimedia, commercial, emergency, safety and managing of traffic applications. Moreover, for data to be transmitted efficiently, it is mandatory for efficient Quality of Service (QoS). Therefore, designing an appropriate routing protocol for vehicles in large-scale is a challenging issue.

Lack of network scalability is a problem that leads to a lot of damage in the network sustainability. Also, in cases of surveillance and safety applications, delay can be dangerous. In this regard, optimizing vehicular network for equal distribution of network load and scalability can be created by intelligent clustering algorithms that contribute to key aspects. The contribution of this study can be explicated as follows:

- Analyzing and measuring the performance of AODV-CD for Internet of Vehicles (IoVs).
- Proposing a realistic communication model by hybridization of DA-TRLD and AODV based-clustering that can be suitable for IoVs environment for supporting V2I and V2V communication.
- Avoiding network dissemination problems, by enhancing PDR and reducing link failure that is achieved by selecting reliable nodes as *CH* with low mobility.
- Minimizing the routing cost by adapting clustering approach leads to reduction of both bandwidth resource and computing resource consumption for routing data traffic.
- Increasing efficiency of AODV in terms of reliability and scalability by discovering the shortest route and selecting the appropriate node as *CH*.

In this paper cluster-based routing methodology for AODV protocol is proposed in the heterogeneous network. In the next section there will be a brief explanation of AODV algorithm structure, improvements that are applied on AODV and clustering techniques in IoVs. Section 3 depicts our proposed methodology step by step. In section 4 there will be an illustration of the simulation setup and outcomes. The final section includes the conclusion and suggestions for future work on this topic.

II. Literature Review

A. Related Work on AODV

AODV is a reactive routing protocol with the functionality of DSR and DSDV protocols. These functionalities are AODV's routing table which works in the same manner of DSDV [14]; and AODV's route discovery structure which is analogous to DSR. The application of the routing table in AODV is for retaining information of routes. For resolving the route between source and destination these saved information are a great aid. AODV consists of four control message types, such as Route Error (RERR), Route Reply (RREP), Route Request (RREQ), Route Reply Acknowledgment (RREP-ACK). The AODV using route detection algorithm for data communication among nodes. This reactive algorithm broadcasts a path failure message as RERR to each node in the entire network to obtain better Packet Delivery Ratio (PDR) in network. As the advantages of AODV we can name low network utilization and reliability in wireless mesh network. These basic operations of AODV is shown in detail in [15].

AODV_BD is proposed for packet delay reduction in VANETs [16]. This algorithm uses packet broadcasting with implementing the process of local route repair. Therefore, data packets and requested packets are transferred to the destination for decreasing delay of routing. For resolving the realistic model issues and increasing efficiency of AODV, other modification on AODV protocol is introduced [17]. If static node exists in the current path then this approach uses static node instead of source node for broadcasting RREQ message during link failure. In [18] author proposed a new improvement on AODV based-clustering that takes distance of nodes into consideration. However, this protocol was not suitable for VANET environment which has dynamic nature.

Reliable AODV protocol which is the Link expiration time-based, is proposed, namely AODV-L [19]. This algorithm is combined with new designed MAC protocol for VANET that uses multiple channels which named AODV-AD. The outcome of these protocol illustrates better performance in terms of higher PDR, lower packet drops and better route stability. For reducing the negative impact of large vehicle on highways during broadcasting RREQ message, a new algorithm is proposed named AODV-LV [20]. This algorithm selects the large vehicles which have higher antenna position for broadcasting RREQ messages and that allows longer transmission distance. The SODV [21] protocol is introduced as a speed-based algorithm which calculates the average speed of nodes to destinations in order to choose better route with lesser delay. The AAODV algorithm [22] is introduced to decrease the routing time and memory overhead by increasing PDR. The basis of this improvement is using Adaptive Network-based Fuzzy Interference System (ANFIS). The mechanism of this algorithm is extracting the nodes' value from RREQ packets and utilize them in the fuzzy system as input. Also, this protocol is designed for MANET.

Combination of trust mechanism and AODV is introduced by Mukherjee et al as stated in [23]. This mechanism uses the modification theory of Dempster-Shafer for building trust on multiple pieces of trust evidence. This approach consists of Trusted Route Selection and Route Discovery stages. By using these stages, only reliable nodes will be selected as a next hop in routing process. The mobility of these reliable nodes is low which leads to less packet drop. Enhanced route discovery algorithm is introduced by Venkatesh and Murali [24] to increase security and efficiency of data routing. This approach utilizes Multi-Swarm Optimization for defining the probability of link failure and optimizing the route discovery. The other new research is proposed by Li et al [25] based on combination of AODV and ACO algorithm in VANETs. This work was aimed to obtain better network stability and reducing the packet loss ratio. Kumar and Sinha [26] improved AODV and analyzed the AODV vulnerability and the performance of that by applying black hole and flooding attack. The other variation of AODV is Blackhole Protected AODV (BP-AODV) which is proposed for the MANET environment. This protocol is implemented on the basis of Chaotic Map and concentrates on the vulnerability of blackhole which is related to AODV. The outcome of this experiment showed effectiveness of BP-AODV against attack of blackhole. The double-ended queue (dqAODV) in a request packet header is introduced to achieve a good outcome in terms of throughput [27]. The aim of introducing the multiple AODV (MAODV) algorithm is to obtain better performance than AODV for VANET scenarios on multi-cast transmission technology. This algorithm succeeds to outperform the AODV in terms of packet delivery [28]. Specifying silent or relaying node in a network for sending packet was the main concern of this study. In this regard, EMAODV algorithm is proposed for overhead reduction during route discovery [29]. Authors in [30] proposed a Dual-Phase AODV algorithm (MDRMA) on the basis of Adaptive Hello Messages that applied on Flying Ad hoc Network (FANET). This algorithm guarantees the solidification of routes establishment by utilizing wireless links for forwarding data rapidly.

More studies on the AODV extensions are analyzed in detail in reference to reliability, security, energy, routing strategies and quality by Saini and Sharma [15]. Moreover, several systematic studies have been conducted on the basis of AODV protocols and various existing mechanism of routing over a few decades [31-33]. These studies are assessed with various routing techniques in VANET and MANET. All these extensions on AODV algorithm are applied in order to enhance the QoS in MANET and VANET scenarios. The performance and improvement of these algorithms are analyzed and experimented by many literatures from many perspectives such as routing overhead, delay, throughput, signal strength, mobility, etc. As it is clear in Figure 2, route discovery of AODV is based on the highest QoS in terms of bandwidth that is shown.

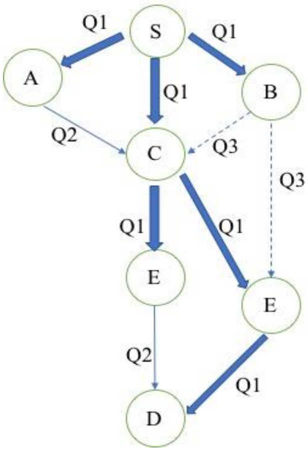

Fig. 2. QoS Routing of AODV based on the highest bandwidth path. (bandwidth Q1>Q2>Q3, path S-C-E-D)

AODV algorithm has attracted lots of interest from researches. In this context, enormous number of articles have been proposed the enhancement of this algorithm from different perspectives [27, 34-42]. Figure 3 illustrates these enhancements in different categories such as QoS, scalability, interface aware and optimization.

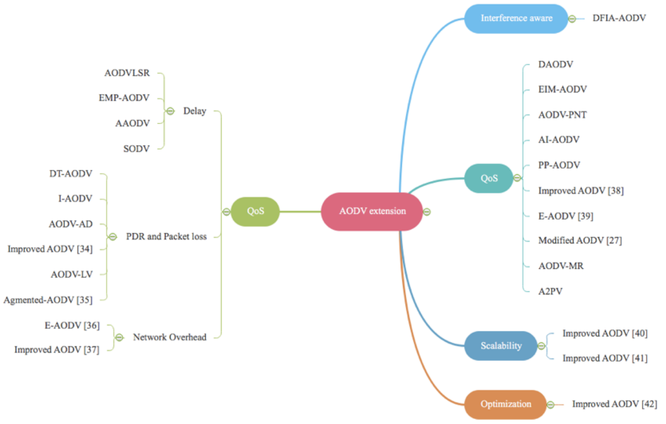

Fig. 3. Variation of AODV algorithm over recent decades

B. *Clustering in IoVs*

Designing a proper routing algorithm for IoVs environment which in this network nodes have inconsistent movement is a challenging task. Structural deviations happen as a result of these frequently moving which creates network of separation which leads to expiration of network. Therefore, the design protocol should fulfill most of the requirements of Intelligent Transportation System (ITS) applications in terms of Quality of Service (QoS) like delay which may become very critical in circumstances like surveillance and safety applications. Thus, in order to increase the network lifetime, prognostication of vehicular mobility pattern can be a great aid. The principal framework of ITS is IoVs. The ITS proposition is attempting to aid drivers for gathering essential information in order to enhance road safety and positive effectiveness of traffic management like flow of traffic, collision avoidance, etc. Thus, establishing sustainable and safe mobility requires several challenges to be determined, resolved (such as connectivity and security) and scrutinized for presenting an effective V2X mechanism to the market that incorporate technical challenges, deployment plans, standardizations, etc [43]. Scalability is a challenging task that has direct impact on the network sustainability. Therefore, load balance management should be considered for enhancing the network lifetime. In this context, designing intelligent clustering algorithms for network optimization are significantly necessary [44].

The word clustering means bringing nodes together or grouping nodes on the basis of their attributes in order to achieve a certain objective in the network. The similarity or dissimilarity can be taken into consideration by the diverse parameters which includes bandwidth availability, distance among nodes, etc. When various nodes are collected together a cluster is formed. After the cluster is formed, one of the nodes within this cluster is chosen as the Cluster Head (*CH*). The Figure 4 [45] shows interaction of Cluster Members (CMs) with a *CH* the on a highway. The cluster size is directly in proportion to the transmission coverage area (radio range). The transmission coverage determines the size of the cluster. Thus, wider coverage range leads to have a better cluster size, invariably meaning that there will be more cluster members in one large cluster. Considering that lesser amounts of clusters in the entire network is preferred for overcoming the mentioned problem which is network scalability. Intelligent grouping of vehicles in the IoVs leads to long lifetime of cluster, forming optimal or a smaller number of cluster and *CHs*.

Adapting clustering technique for our proposed method restricts direct communication of nodes with their neighbors and Road side Unite (RSU) while using GW and CH for each cluster. Consequently, transmission energy and link failures will be minimized. Thus, the less communication distance in proposed AODV-CD protocol, automatically draws to less end-to-end delays.

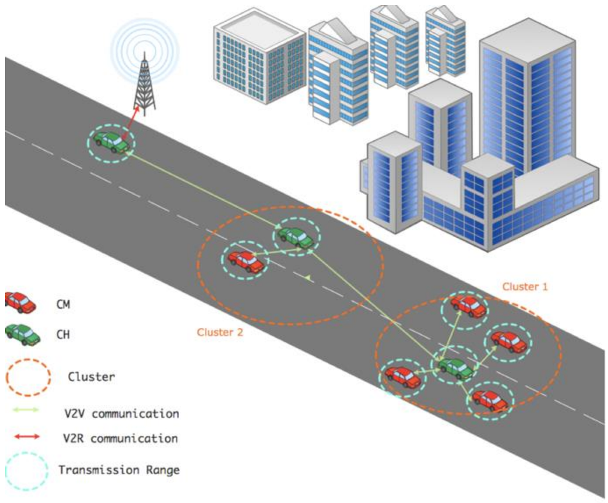

Fig. 4. Clustering in IoVs

In IoV, mobile nodes move very quickly thereby leading to frequent topological changes. As this topological change occur, instability is created which leads to issues with scalability. Clustering can be done so as to be able to overcome this problem. Large number of cluster-heads is generated using existing clustering approaches in VANETs which use the wireless resources that are scarce and results in degraded performance.

In a large-scale heterogeneous network, clustering is a strategy to routing. After the successful clustering of nodes and the election of *CH*, figuring out how to decide which vehicle plays a proxy role is an important task. Moreover, lack of designing a proper routing algorithm for IoVs environment with inconsistent node's movement is a challenging gap in existing literature.

In this context, the contribution of our study is to emerging technologies in learning contexts is enhancing QoS for satisfying user's requirement and enhancing the road safety. This objective is fulfilled by proposing a novel efficient routing protocol in IoVs due to lack of robust algorithm for overcoming the existing issues in VANET and IoVs while, IoVs' nature is dynamic and is multi-objective problems.

III. Proposed AODV-CD Architecture

The AODV-CD algorithm is a novel clustering approach on the basis of AODV. Having dynamic transmission range instead of a static one is one solution in this type of challenge. In this regard, firstly Dynamic Aware Transmission Range (DA-TRLD) algorithm is applied based on our previous research [43] on the basis of local traffic density. Secondly, new modification for AODV is proposed (AODV-CD) which consists of three main stages such as Cluster Formation, Cluster Maintenance and Clustered Routing. The AODV-CD protocol starts with assigning transmission coverage dynamically to all existing nodes/vehicles in a network on the basis of their local traffic density. By applying clustering approach to AODV algorithm, RREQ message will be sent to *CHs* instead of be broadcasted among all vehicles. Therefore, routing information among CMs will be distributed by *CH*. In case of route availability, RREP packet will send to vehicles otherwise *CHs* receives RREQ message. In this regard, amount of control message (RREQ) to discover route will be decreased considerably which leads to reduction of congestion and network overhead in the entire network. In this context, the performance improvement of AODV can be achieved.

A. Solution Evaluation

Solution evaluation can be obtained by Eq. (1). According to IoV nature that is multi-objective, the following Equation is used to evaluate AODV-CD route by normalizing the objective function:

$$f_t = f_1 . W1 + f_2 . W2 + f_3 . W3 \quad (1)$$

where $W1 = W2 = W3 = 0.5$ show the assigned weights to three objective functions such as f_1, f_2 and f_3, respectively. For AODV-CD, the first parameter is delta difference value of the clusters (f_1, based on Eq. (2)); and f_2 is obtained from summation distance of *CMs* from their *CHs* that applies for all clusters. The f_3 is the speed function that selects the nodes with lowest speed as a candidate for becoming *CH* or *GW*.

$$f_1(\Delta\ difference) = \sum_{i=1}^{|t|} ABS(D - |CN_i|) \quad (2)$$

where $|t|$ is the entire number of clusters that was formed. The entire existing vehicles in the network that present in a cluster i is $|CNi|$, however this is excluding *CH*. The given value's absolute value is returned by the ABS function. The clusters formation is represented by the lowest value of D which is almost equivalent to the ideal degree specified by the user. In regards to the user's ideal degree requirements, the clustering is optimal if D's value is zero. By the use of Eq. (3), the calculation of the distance can be done between the CNi and *CH*:

$$dist_{CH\text{-}i} = \sum_{J=1}^{|CN_i|} ED(CH_i, CN_{j,i}) \quad (3)$$

The CH_i is the coordinate position of the i^{th} *CH*. Accordingly, $CN_{j,i}$ is the coordinate position of the j^{th} *CN* which actually is cluster i member. The Eq. (4) is similarly used to calculate the f_2 objective value:

$$f_2\ (Dist\text{-}sum) = \sum_{i=1}^{|t|} dist_{CH\_i} \quad (4)$$

Just like f_1 lowest value of f_2 is desirable. Lesser energy is needed to shift the data when the distance between the *CH* and its cluster members are shorter. Normalized of comparative speed (f_3) is obtained by using following equation which regulates the vehicles' speed as it shown in Figure 5.

$$f_3 = {S_{ij}}/{S_{max}} \quad (5)$$

In this calculation S_{max} is the predefined of maximum speed and S_{ij} is the comparative speed between vehicle i and j with the specific angle (φ) from CH_i 's direction of travel and it's adjacent vehicles ($CN_{j,i}$) that is computed by utilizing Eq. (6).

$$S_{ij} = \begin{cases} S_i + S_j & If\ \varphi = 180°; \\ S_i - S_j & If\ \varphi = 0°; \\ \cos\ \varphi * ED(CH_i, CN_{j,i}) & Otherwise \end{cases} \quad (6)$$

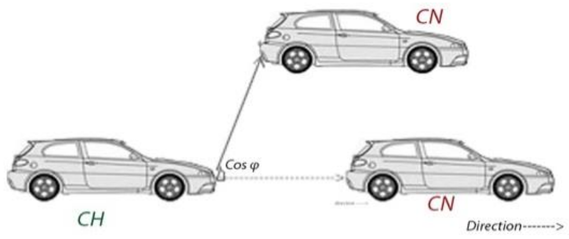

Fig. 5. Normalized of comparative speed

B. Cluster Formation

For minimizing the network overhead, cluster size in the AODV-CD is limited to dynamic radio range of *CH*. In our protocol, ID is assigned to each vehicle. Each vehicle keeps the routing table in their memory according to their status. If the status be *CH* then it has *CMs_TABLE* and if the vehicle status be CM then it keeps the *CH_TABLE.* Also, the cluster size is called Degree which determine by the Neighbours List (NL) field in the *HELLO-packet*. The process starts with exchanging *HELLO-packet* among all vehicles to announce their existence in the network. Then vehicles will be clustered based on Algorithm 1.

Algorithm 1. AODV-CD protocol

1. *Forming vehicle traffic on highway with using of SUMO;*
2. *Forming mesh topology between vehicles/nodes by using DA-TRLD;*
3. *Analyzing objective function (Eq. (1)) for corresponding edges (by using the output of DA-TRLD);*
4. ***IF** Neighbour List (NL) = Empty **THEN***
5. *Change the node's status to CH (status = CH)*
6. ***Else IF** node's status = CH **THEN***
7. *Call **CH-election** algorithm (Algorithm 2)*
8. ***Else IF** Neighbour List (NL) has any CH **THEN***
9. *Call **GW-election** algorithm (Algorithm 3)*
10. ***Else***
11. *Compute objective function Eq. (1)*
12. *Call **CH-election** algorithm (Algorithm 2)*
13. ***ENDIF***
14. ***IF** node elected as CH **THEN***
15. *Change the node's status to CH (status = CH)*
16. *Broadcast CH-packet to its NL*
17. ***Else***
18. *Change the node's status to CM (status = CM)*
19. ***ENDIF***
20. *Update CH-packet*
21. *Update HELLO-packet*

As it shown in Figure 6, the packet of *HELLO* message consists of five parameters such as status, ID, NL, delta-difference (f_1), dist-sum (f_2) and nodes' speed (f_3) fields. In order to prevent control overhead and restrict number of CMs in a cluster, every *CHs* permits vehicles to join to the cluster based on the cluster degree (which determines by *DA-TRLD* algorithm).

status	*ID*	*NL*	f_1	f_2	f_3

Fig. 6. Structure of HELLO packet.

CH-packet, consist of four different fields such as Source ID, CH-ID, destination ID and message ID, as it can see in Figure 7.

source$_{ID}$	***Msg$_{ID}$***	***destination$_{ID}$***	***CH$_{ID}$***

Fig. 7. Structure of CH-packet.

The GateWay (GW)-packet in this study consists of four fields such as *Source-ID*, List of *CH-ID* (*LCH-ID*) in the radio range of GW node, *destination-ID* and *message-ID*, as it can see in Figure 8.

Source$_{ID}$	***Msg$_{ID}$***	***Destination$_{ID}$***	***LCH$_{ID}$***

Fig. 8. Structure of GW-packet

In our proposed algorithm, all nodes in the same direction on the highway send *HELLO* messages to their neighbors based on their transmission range which is dynamic (obtained from Algorithm 3). The status of any nodes that do not receive *HELLO* message will be *CH*. Otherwise, their status remains *CM*. This process will be continued for all incoming nodes to the network. Afterwards, the *CH* election progress will start by vehicles with having *CM* status. In case of existence of more than one *CH* in any vehicle's routing table, GW status will be assigned to the vehicle. The GW node advertises its packet to the *CHs* which are in radio range of this node. This progress is done based on three important objective functions. First parameter is delta difference value of the clusters or Delta-difference (f_1) (see Eq. (2)). The second one is summation distance of *CMs* from their *CHs* or (f_2) (see Eq. (4)). The last one is f_3, vehicle's speed which is preferred to be low for increasing the lifetime of cluster (see Eq. (5)). This parameter is determined randomly in the initiation phase of simulation. The total value of these objective functions will be utilized in *CH* election process. When *CH* is elected, *CH-packet* will be sent to all *Neighbour List* of *CH* and they will be become as its *CMs*. Therefore, all *CMs* should update their routing table every time that receive a *HELLO* message. In this regard, each node belongs only to one cluster. At the end all *CHs* communicate with the 5G backbone which is gNodeB (5G network Node Base station). Moreover, the size of clusters varies based on their transmission range which are dynamic and are obtained from Algorithm 4. Note that all vehicles have different radio range in regards to their local traffic density. Algorithm 2 and Algorithm 3 show *CH-election* and *GW-election* process respectively.

Algorithm 2. Proposed *CH-election* Algorithm

1. ***IF** Neighbour List (NL) doesn't have any CH **THEN***
2. *Start CH-election process based on objective function (Eq. (1))*
3. ***IF** node advertises itself as CH **THEN***
4. *Change the node's status to CH (status = CH)*
5. *Broadcast CH-packet to it's NL*
6. ***Else***
7. *Change the node's status to CM (status = CM)*
8. ***ENDIF***
9. *Update CH-packet*
10. *Update HELLO-packet*

Algorithm 3. Proposed *GW-election* Algorithm

Check the vehicle's Neighbour List (NL);
IF** Vehicle has one CH in its NL **THEN
  Change the vehicle's status to CM (status = CM)
ElseIF** Vehicle has two CH in its NL **THEN
  Change the node's status to GW (status = GW)
ENDIF
Broadcasting GW-packet to the vehicle's NL

IV. PERFORMANCE EVALUATION OF THE AODV-CD ALGORITHM

A. *Simulation Setup*

This division of the experimental research reveals factors that are used for implementing this idea. The network topology is employed on two parallel highways with 4 lanes on each direction and gNodeB, which is positioned in the middle of the highway. The vehicles' locality is specified by the location server and each vehicle is equipped with the DSRC. All vehicles in the same directions are contemplated as neighbor. Also, a V2R communication scenario is considered for simulating our idea. Cloud computing framework and Software Define Network (SDN) are utilized in 5G structure for preventing regular handovers among RSUs and vehicles [46]. The first phase of simulation belongs to scenario initialization and defining the environment details and mobility pattern of vehicles on the highway by SUMO [47]. In the second phase, the Network Simulator (NS-2) takes the input of the generated file of SUMO. The WAVE-IEE 802.11p which is a MAC layer protocol enables communication among vehicles and road-side infrastructure network to be utilized in our topology. In order to analyze and evaluate our proposed algorithm, conventional AODV is predefined and is supported in NS2 (existing NS2 libraries is used) and is chosen for comparison. Figure 9 illustrates the framework of simulation process that applied in this research.

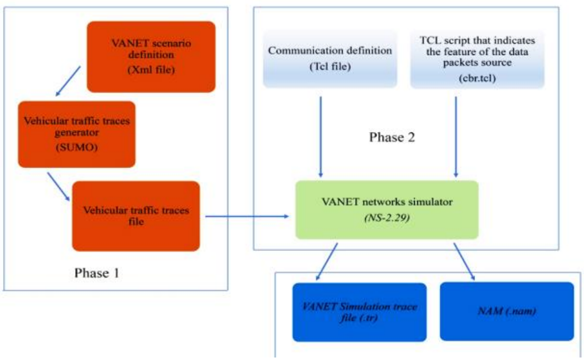

Fig. 9. The framework of simulation process.

Comparison of more recent algorithms with the proposed one is presented for this experiment. In this aim, the current research is divided the experimental work in 2 different phases in order to compare AODV-CD performance.

In first phase, comparison results of the proposed algorithm (AODV-CD) and conventional AODV are presented by modifying and testing. Our scenario includes different number of nodes in range of 40 to 500. The scenario that is considered here involves evaluation of the performance metrics respect to vehicular density in the network (which leads to increasing number of vehicles per cluster and increasing overall number of clusters in network). Table I illustrates experimental parameters of simulation. The pure AODV algorithm has constant transmission range value at 300m, and AODV-CD has dynamic transmission range. The performance metrics used for the results evaluation were throughput, packet delivery, routing overhead and E2E delay versus the increasing number of vehicles in networks size of 4Km while the simulation times is 500 seconds. The simulation is performed 20 times and the average is used in the result. The node clustering and scenario that is applied for both AODV-CD and conventional AODV is demonstrated in Figure 10.

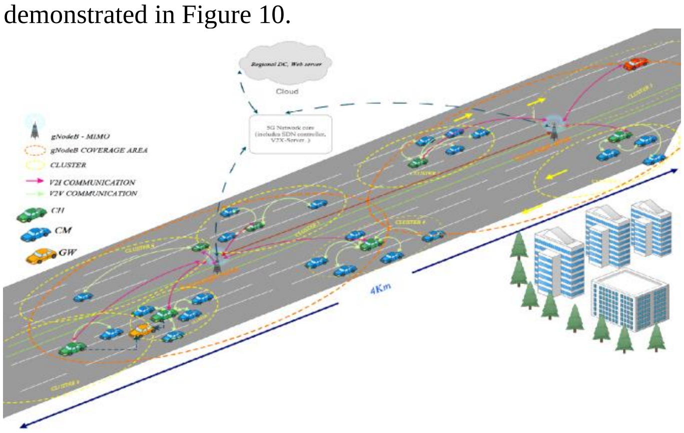

Fig. 10. AODV-CD Scenario.

The second phase of this research, focuses on performance comparison between the proposed algorithm (AODV-CD) and other 4 recent algorithms such as AODV+ACO [25], AOMDV [48], Improved-AODV [49] and Pro-AODV [50]. The simulation parameters of each algorithm can be found in Table I. For this experiment AODV-CD compared separately with each algorithm due to different network parameters. Therefore, simulation parameters of AODV-CD are configured as same as the target algorithm for each experiment to obtain a fair outcome. Comparison of these methods are done on the light of throughput, delay, network overhead, packet delivery and drop ratio.

B. *Analysis and Simulation Results*

The performance of the AODV without the DA-TRLD mechanism is worst and the proposed mechanism (AODV-CD) outperforms the AODV for all cases. Applying dynamic transmission range for vehicles instead of constant value and using clustering technique for AODV algorithm are strong reasons for the huge difference between the obtained results from these two algorithms. The obtained results from the first stage is illustrated in Figures 11 to 14. Moreover, Figures 15 to 20 demonstrate the experimental outcome of the second stage.

- *Result Analysis of stage 1*

Throughput: Increasing vehicle density leads to more packet transmission in the network. Thus, this metric increases proportionally to the node density. Also, our protocol reduces the resource requirement in the vehicular network and less communication overhead between *CHs* and RSUs. In this experiment all vehicles are placed randomly in the highway so if geographical positioning of vehicles be close to each other, the number of successfully transmitted packet to the destination will increase and vice versa. Figure 11 shows that AODV uses hop-by-hop routing mechanism while constantly updating the shortest possible source destination path. Also, the amount of information that may add up to network overhead is very less. Also, it illustrates that by increasing node density from 40 t0 500, AODV-CD performs better than conventional AODV, due to quicker route discovery of our proposed algorithm. This metric can be calculated by Eq. (7).

$$T = \frac{Recieved_{data}\ (bits)}{DataTranmissionPeriod\ (second)} \quad (7)$$

Routing Overhead: The ratio of control packets (routing packets) that required for network communication per number of received data packet defines the routing overhead. Figure 12 illustrates the average routing overhead versus node density and shows lower routing overhead belongs to our proposed protocol due to clustering and applying DA-TRLD algorithm. Generally, due to increasing the number of neighboring nodes which causes higher contention, routing overhead increases proportionally to the vehicle density. Moreover, in the dense traffic, increasing the broadcasted RREQ packet leads to higher nodes' reachability. However, co-channel interference will increase due to increasing broadcasted RREQ packet and might be necessary for restarting the progress of route discovery and restricting the nodes' reachability. This phenomenon explicitly describes the issue of higher overhead of conventional AODV algorithm.

Packet Delivery Ratio (PDR): Pure/ conventional *AODV* protocol uses limited time for Hello-message to the neighbors which has a low overhead to network. This message can expire if the next hop is far from the current node. Therefore, in case of having vehicles with close geographical position to each other, breakage of link to next hop reduces and causes increment in *PDR*. This is because the established route by this protocol stays alive a longer time. Therefore, ratio of packet drop is less. But after increasing the number of nodes, packet drop increases due to link failure which occurs based on mobility of nodes and instability of the wireless environment in an established route. We conclude that increasing vehicle density leads to more packet transmission in the network. Thus, this metric increases proportionally to the node density as it's clear in Figure 13.

Average E2E Delay: E2E-delay directly be contingent on the PDR. Moreover, this metric is encompassed of other network delays, like, queueing, propagation, latency, buffering, packet sending and transfer time at the MAC layer.

TABLE I
SIMULATION PARAMETERS

Parameter	**Values**				
	Proposed (AODV-CD)	**AODV+ACO[25]**	**AOMDV[48]**	**Improved-AODV[49]**	**Pro-AODV[50]**
Antenna model	Omni-directional MIMO	-	Omni Antenna	-	-
Beam-forming Technology	MmWave	-	-	-	-
Grid size	4000 m × 450 m	1000m × 1000m	500m ×500m	1200m × 1200m	1000m × 500m
Lane width	50 m	-	-	-	-
MAC layer	WAVE_IEEE 802.11p	IEEE 802.11p	IEEE 802.11	IEEE 802.11p	-
Mobility model	Freeway mobility	Urban	Urban	Urban	Random waypoint
Node movement	Bidirectional	IDM_IM	IDM-LC	-	-
Number of lane	8	2, 3, 4	-	-	-
Number of network nodes	40, 100, 200, 300, 400, 500	10 – 500	20, 25, 30, 40, 50, 60, 80	15-50	25, 50, 75, 100, 125, 150, 200, 250
Number of RSUs	4	-	-	-	-
Packet Size	512 bytes	512 bytes	512 bytes	512 bytes	512 bytes
Queue type	Drop-tail (50 packets)	-	Drop-tail	-	Drop-tail (40 packets)
Radio propagation model	TwoRay ground	TwoRay Ground	TwoRay ground	-	TwoRay ground
RSU transmission	1000 m	-	-	-	-
Simulation run	20	-	-	-	30
Simulation time	500 s	500 s	900 s	100 s	200 s
Simulations tool	NS2, SUMO	NS2, VanetMobiSim	NS2	SUMO, NS2	NS2
Transmission Range	Dynamic	250m	100m	250m	250m
Transport layer protocols	UDP/ CBR	FTP/TCP	CBR	UDP/ CBR	CBR
Velocity	22–30 m/s uninform	[40, 120] km/h	[10-90] m/S	0-30 m/s	40 m/s

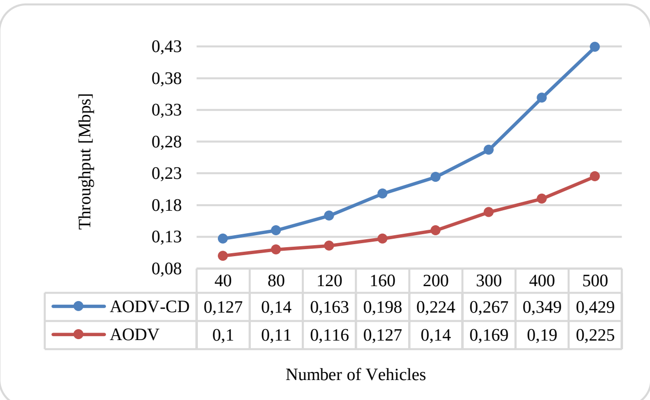

Fig.11. Throughput of AODV and AODV-CD respect to vehicular density.

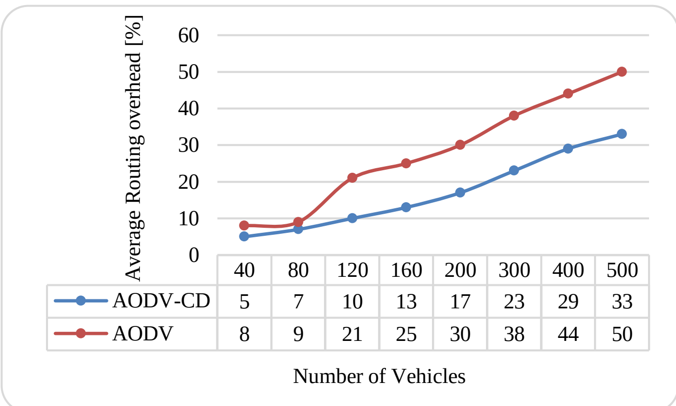

Fig.12. Average Routing overhead of AODV and AODV-CD respect to ehicular density.

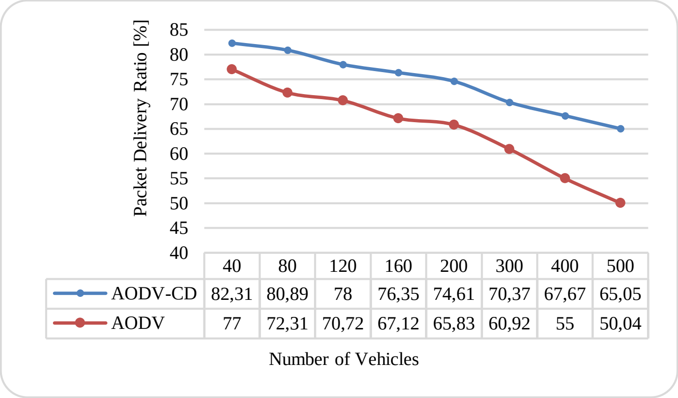

Fig. 13. PDR comparison of AODV and AODV-CD respect to vehicular density.

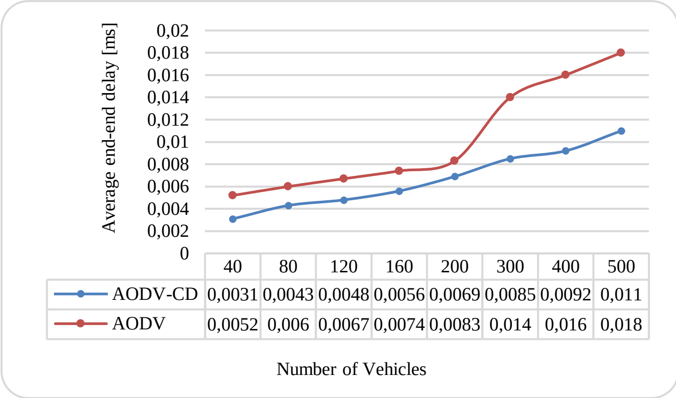

Fig. 14. Average E2E delay comparison of AODV and AODV-CD respect to vehicular density

The AODV-CD algorithm illustrates considerable performance enhancement against other algorithms in terms of *E2E-delay*. It is clear that by expanding the vehicle number in the interval of 40 to 500 in the network, this metric grows for both algorithms as shown in Figure 14. The high *E2E-delay* of pure AODV occurs due to higher route discovery time. With this way of cluster architecture and limited forwarding domain that is applied in AODV-CD, number of the nodes associated with discovery and maintenance of route are reduced dramatically, which results in less *E2E*-delay and routing overhead. Theoretically, the analysis and simulation outcomes show that the proposed clustering algorithm is highly efficient, scalable, and suited for heterogenous networks. The average *E2E-delay* results depends on many factors such as cluster density, vehicular position in the network, nodes' speed, etc.

AODV-CD protocol shows insignificant delay growth when scaling up the number of vehicles. The reason behind this is AODV-CD creates stable clusters which can assure reliable linking and sufficient connectivity. Consequently, we can claim that the proposed system has a significant impact on minimizing the E2E delay which leads to satisfaction of real-time applications requirements.

Equation (8) illustrates the calculation formula of this metric. In this regard, packet index is shown by i, the exact time that the packet is sent from source and recieved by destination are shown by ts_i and tr_i respectively. Also, n represents the recieved total of data packets.

$$E2E_{delay} = \frac{1}{n}\sum_{i=1}^{n}(tr_i - ts_i) \tag{8}$$

- *Result Analysis of stage 2*

The avg. Throughput of AODV-CD is higher than other recent algorithms which shown in Figures 15 to 17 under various vehicle densities. Enhancement of the network connectivity in the proposed algorithm (AODV-CD) cause the increase in throughput. Moreover, this algorithm has better throughput among others due to superlative packet transmission.

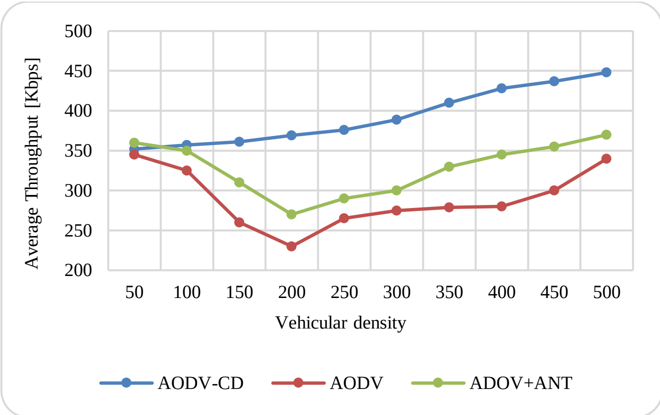

Fig.15. Throughput comparison of AODV-CD versus AODV+ANT

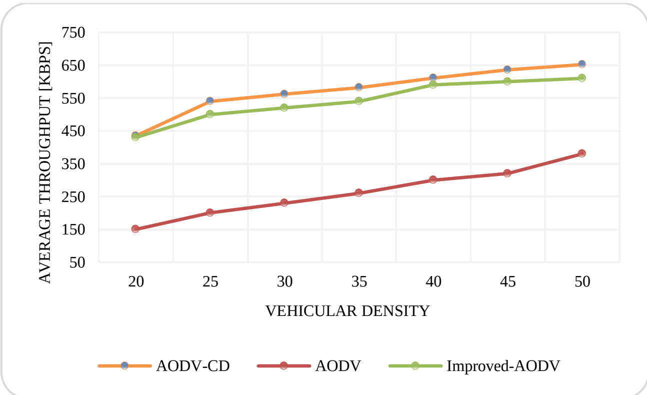

Fig. 16. Throughput comparison of AODV-CD versus Improved-AODV

The frequency of the successive packet loss is illustrated in Figure 18 under the vehicular density of 100 and 300. the worse performance in this graph belongs to AODV. The AODV-CD obtains the best performance due to enhancement of packet retransmissions. Drop ratio impact versus the different vehicle density is shown in Figure 19 which present the superiority of our algorithm in the large-scale network. The lower routing overhead for AODV-CD protocol against improved-AODV is obtained due to clustering and applying DA-TRLD algorithm. This claim is demonstrated in Figure 20.

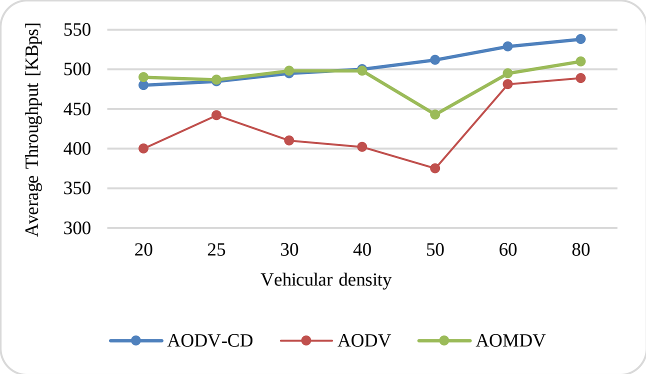

Fig. 17. Throughput comparison of AODV-CD versus AOMDV

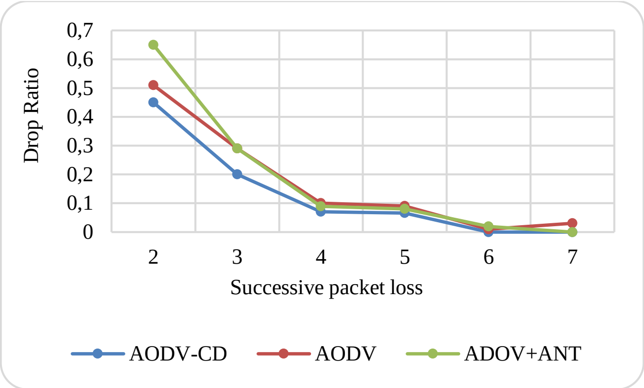

Fig.18. Drop ratio comparison of AODV-CD versus AODV+ANT

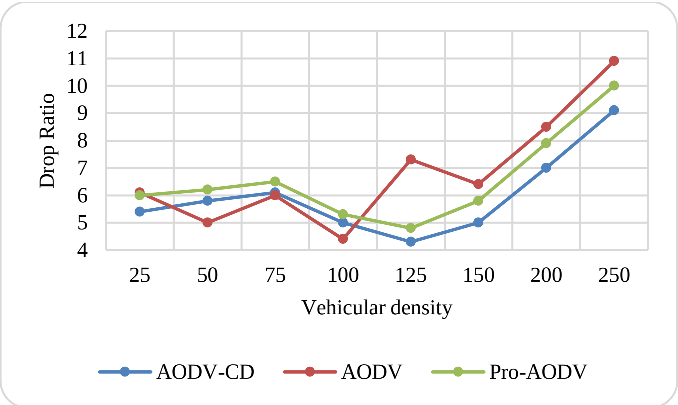

Fig.19. Drop ratio comparison of AODV-CD versus Pro-AODV

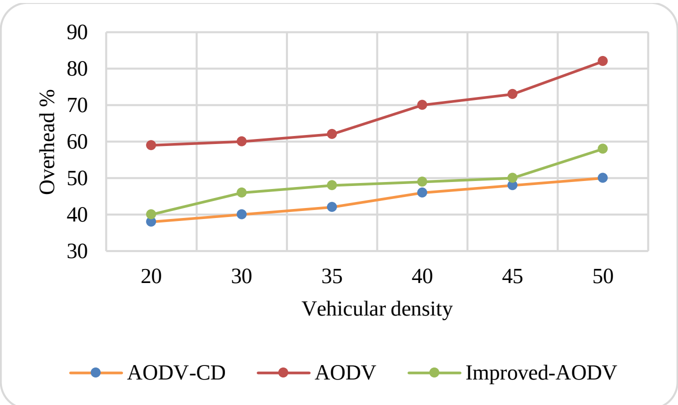

Fig.20. Overhead comparison of AODV-CD versus Improved-AODV

Conclusion

Network stability and scalability are vital issues in heterogeneous environment of vehicles. Therefore, efficacious network management and effective communication are essential challenges in IoVs due to high motion of vehicles that have effect on the data delivery in the formed network. Variations in traffic dynamics and travel behavior which cause vehicle mobility patterns can lead to substantial difficulty on how efficient and reliable the communication networks of vehicles can be. A novel methodology which is efficient and systematic for adjusting the factors of clustering and routing protocols is explicated through this study. This research proposed a unique protocol to elevate the AODV from view of throughput, routing load, PDR and E2E-delay. The AODV-CD is hybridization of the dynamic transmission range algorithm and modified AODV based-clustering in IoV. Our proposed approach applies two unique messages as HELLO-packet and CH-packet during route/path detection and route preservation process in the clustering technique for AODV protocol. The experiments in which we carried out on NS-2 and SUMO, proved significant enhancements and superiority of AODV-CD over conventional AODV. Combining AODV-CD with an artificial intelligence algorithm which is a sub category of emerging technologies is our future direction in order to enhance QoS in IoV and have greener and smarter cities.

References

[1] Feki, Mohamed Ali, Fahim Kawsar, Mathieu Boussard, and Lieven Trappeniers. "The internet of things: the next technological revolution." *Computer* 46, no. 2, 2013, pp. 24-25.

[2] Sun, Yunchuan, Houbing Song, Antonio J. Jara, and Rongfang Bie. "Internet of things and big data analytics for smart and connected communities." *IEEE access* 4, 2016, pp. 766-773.

[3] Perkins, Charles E., and Pravin Bhagwat. "Highly dynamic destination-sequenced distance-vector routing (DSDV) for mobile computers." *ACM SIGCOMM computer communication review* 24, no. 4, 1994, pp. 234-244.

[4] Johnson, David B., and David A. Maltz. "Dynamic source routing in ad hoc wireless networks." In *Mobile computing*, pp. 153-181. Springer, Boston, MA, 1996.

[5] Perkins, Charles E., and Elizabeth M. Royer. "Ad-hoc on-demand distance vector routing." In *Proceedings WMCSA'99. Second IEEE Workshop on Mobile Computing Systems and Applications*, pp. 90-100. IEEE, 1999.

[6] Lochert, Christian, Martin Mauve, Holger Füßler, and Hannes Hartenstein. "Geographic routing in city scenarios." *ACM SIGMOBILE mobile computing and communications review* 9, no. 1, 2005, pp. 69-72.

[7] Karp, Brad, and Hsiang-Tsung Kung. "GPSR: Greedy perimeter stateless routing for wireless networks." In *Proceedings of the 6th annual international conference on Mobile computing and networking*, pp. 243-254. 2000.

[8] Shastri, A., R. Dadhich, and Ramesh C. Poonia. "Performance analysis of on-demand Routing protocols for vehicular ad-hoc Networks." *International Journal of Wireless & Mobile Networks (IJWMN) Vol* 3, 2011, pp. 103-111.

[9] Dhaka, V. S., Ramesh C. Poonia, and Linesh Raja. "The Realistic Mobility Evaluation of Vehicular Ad-Hoc Network for Indian Automotive Networks." *International Journal of Ad hoc, Sensor & Ubiquitous Computing* 5, no. 2, 2014, pp. 1.

[10] Franz, Walter, Hannes Hartenstein, and Martin Mauve. "Inter-Vehicle-Communications Based on Ad Hoc Networking Principles." *The FleetNet Project, Karlsruhe, Germany: Universtatverlag Karlsruhe* 6, 2005, pp. 16.

[11] Festag, Andreas, Gerhard Noecker, Markus Strassberger, Andreas Lübke, Bernd Bochow, Marc Torrent-Moreno, Sascha Schnaufer, Robert Eigner, Catrinel Catrinescu, and Jürgen Kunisch. "'NoW–network on wheels': Project objectives, technology and achievements." 2008.

[12] Reichardt, Dirk, Maurizio Miglietta, Lino Moretti, Peter Morsink, and Wolfgang Schulz. "CarTALK 2000: Safe and comfortable driving based upon inter-vehicle-communication." In *Intelligent Vehicle Symposium, 2002. IEEE*, vol. 2, pp. 545-550. IEEE, 2002.

[13] Morris, Robert, John Jannotti, Frans Kaashoek, Jinyang Li, and Douglas Decouto. "CarNet: A scalable ad hoc wireless network system." In *Proceedings of the 9th workshop on ACM SIGOPS European workshop: beyond the PC: new challenges for the operating system*, pp. 61-65. 2000.

[14] Perkins, Charles E., Elizabeth M. Royer, Samir R. Das, and Mahesh K. Marina. "Performance comparison of two on-demand routing protocols for ad hoc networks." *IEEE Personal communications* 8, no. 1, 2001, pp. 16-28.

[15] Saini, Trilok Kumar, and Subhash C. Sharma. "Recent advancements, review analysis, and extensions of the AODV with the illustration of the applied concept." *Ad Hoc Networks*. 2020, pp. 102-148.

[16] Li, Baozhu, Yue Liu, and Guoxin Chu. "Improved AODV routing protocol for vehicular Ad hoc networks." In *2010 3rd International Conference on Advanced Computer Theory and Engineering (ICACTE)*, vol. 4, pp. V4-337. IEEE, 2010.

[17] Kumar, Rakesh, Siddharth Kumar, Sumit Pratap Pradhan, and Varun Yadav. "Modified route-maintenance in AODV Routing protocol using static nodes in realistic mobility model." 2011.

[18] Thirumurugan, S. "C-AODV: routing protocol for Tunnel's network." *International Journal of computer science and technology* 2, no. 1, 2011.

[19] Rathi, Divya, and Rashmi Ranade. "Performance evaluation of AODV routing protocol in VANET with NS2." *IJIMAI* 4, no. 3, 2017, pp. 23-27.

[20] Noguchi, Taku, and Kanta Hayashi. "Enhancement of AODV Routing Protocol by Using Large Vehicles in VANETs on Highway." In *2017 IEEE 42nd Conference on Local Computer Networks Workshops (LCN Workshops)*, pp. 91-96. IEEE, 2017.

[21] Manel, Kchaou, and Chaari Lamia. "SODV speed based ad hoc on demand vector link routing protocol: A routing protocol for VANET networks." In *2017 Sixth International Conference on Communications and Networking (ComNet)*, pp. 1-8. IEEE, 2017.

[22] Sharma, Vivek, Bashir Alam, and M. N. Doja. "Performance enhancement of AODV routing protocol using ANFIS technique." In *Quality, IT and Business Operations*, pp. 307-312. Springer, Singapore, 2018.

[23] ur Rehman, Sabih, M. Arif Khan, Tanveer A. Zia, and Lihong Zheng. "Vehicular ad-hoc networks (VANETs)-an overview and challenges." *Journal of Wireless Networking and Communications* 3, no. 3, 2013, pp. 29-38.

[24] Venkatesh, AIndra, and R. Murali. "Routing protocols for vehicular adhoc networks (VANETs): A review." *Journal of Emerging Trends in Computing and Information Sciences* 5, no. 1, 2014, pp. 25-43.

[25] Li, Yutong, Yutong Liu, and Kai Shi. "Performance Study of AODV Protocol with Ant Colony Algorithm in VANETs." In *2019 IEEE 9th International Conference on Electronics Information and Emergency Communication (ICEIEC)*, pp. 1-4. IEEE, 2019.

[26] Li, Yutong, Yutong Liu, and Kai Shi. "Performance Study of AODV Protocol with Ant Colony Algorithm in VANETs." In *2019 IEEE 9th International Conference on Electronics Information and Emergency Communication (ICEIEC)*, pp. 1-4. IEEE, 2019.

[27] Saha, Soumen, Utpal Roy, and D. D. Sinha. "Re-Broadcast AODV (reAODV) Based Routing Protocol Modification Over AODV for VANET In City Scenario." *International Journal of Synthetic Emotions (IJSE)* 9, no. 1, 2018, pp. 51-65.

[28] Al-Shabi, M. A. "Evaluation The Performance of MAODV and AODV Protocols In VANETs Models." *International Journal of Computer Science and Security (IJCSS)* 14, no. 1, 2020, pp. 1.

[29] Jhajj, Harshdeep, Rijutha Datla, and Nan Wang. "Design and implementation of an efficient multipath AODV routing algorithm for MANETs." In *2019 IEEE 9th Annual Computing and Communication Workshop and Conference (CCWC)*, pp. 0527-0531. IEEE, 2019.

[30] Darabkh, Khalid A., Mohammad G. Alfawares, and Saud Althunibat. "MDRMA: Multi-data rate mobility-aware AODV-based protocol for flying ad-hoc networks." *Vehicular Communications* 18, 2019, pp. 100163.

[31] Saini, Trilok Kumar, and Subhash C. Sharma. "Prominent unicast routing protocols for Mobile Ad hoc Networks: Criterion, classification, and key attributes." *Ad Hoc Networks* 89, 2019, pp. 58-77.

[32] Alotaibi, Eiman, and Biswanath Mukherjee. "A survey on routing algorithms for wireless ad-hoc and mesh networks." *Computer networks* 56, no. 2, 2012, pp. 940-965.

[33] Walikar, Gyanappa A., and Rajashekar C. Biradar. "A survey on hybrid routing mechanisms in mobile ad hoc networks." *Journal of Network and Computer Applications* 77, 2017, pp. 48-63.

[34] Ding, Yuan Ming, Hao Qu, and Xue Wang. "An Improved AODV Routing Protocol for High Moving VANET." In *Applied Mechanics and Materials*, vol. 380, pp. 2286-2291. Trans Tech Publications Ltd, 2013.

[35] Arya, Tripti, Ashok Kumar, and H. L. Mandoria. "Augmented AODV Using Clustering in VANET." *International Journal of Emerging Research in Management & Technology* 4, no. 7, 2015.

[36] Mittal, Shubham, Swati Singh, and Kamlesh C. Purohit. "Enhancing the Performance of AODV by Exchanging Neighboring Node Information with Hello Packets in VANET." *International Journal Of Engineering And Computer Science* 5, no. 11, 2016, pp. 18806-18811.

[37] Naanani, Hassan, Youness Farah, Mohamed Ouamer, and Ibtihal Mouhib. "Enhanced AODV Routing Protocol for An architecture V2V in VANET." *European Journal of Scientific Research* 142, no. 3, 2016, pp. 1-9.

[38] Garg, Neha, and Puneet Rani. "An improved AODV routing protocol for VANET (Vehicular Ad-hoc Network)." *International Journal of Science, Engineering and Technology Research (IJSETR)* 4, no. 16, 2015, pp. 1024.

[39] Tewatia, Dolly. "Performance improvement of AODV protocol in vehicular ad hoc network (VANET)." *International Journal of Engineering Research and General Science* 3, no. 3, 2015, pp. 880-886.

[40] Abdolhosseini, Vahid. "Increasing the scalability and reliability of AODV routing protocol in mobile vehicular ad hoc networks using multi-verse meta-heuristic Algorithm." *International Journal of Computer Science and Network Security (IJCSNS)* 17, no. 3, 2017, pp. 133.

[41] Liu, Haiqing, Licai Yang, and Yao Zhang. "Improved AODV routing protocol based on restricted broadcasting by communication zones in large-scale VANET." *Arabian Journal for Science and Engineering* 40, no. 3, 2015, pp. 857-872.

[42] Ding, Ben, Zehua Chen, Yan Wang, and Hui Yu. "An improved AODV routing protocol for VANETs." In *2011 international conference on wireless communications and signal processing (wcsp)*, pp. 1-5. IEEE, 2011.

[43] Ebadinezhad, Sahar, Ziya Dereboylu, and Enver Ever. "Clustering-based modified ant colony optimizer for internet of vehicles (CACOIOV)." *Sustainability* 11, no. 9, 2019, pp. 2624.

[44] Ahizoune, Ahmed, and Abdelhakim Hafid. "A new stability based clustering algorithm (SBCA) for VANETs." In *37th Annual IEEE Conference on Local Computer Networks-Workshops*, pp. 843-847. IEEE, 2012.

[45] Fahad, Muhammad, Farhan Aadil, Salabat Khan, Peer Azmat Shah, Khan Muhammad, Jaime Lloret, Haoxiang Wang, Jong Weon Lee, and Irfan Mehmood. "Grey wolf optimization based clustering algorithm for vehicular ad-hoc networks." *Computers & Electrical Engineering* 70, 2018, pp. 853-870.

[46] Khan, Ammara Anjum, Mehran Abolhasan, and Wei Ni. "5G next generation VANETs using SDN and fog computing framework." In *2018 15th IEEE Annual Consumer Communications & Networking Conference (CCNC)*, pp. 1-6. IEEE, 2018.

[47] Center GA. "Institute of Transportation Systems". SUMO Simulation of Urban Mobility [online].[Consulted in: June of 2018].

[48] Ema, Romana Rahman, Md Faisal Ahmed, Md Humayan Ahmed, and Tajul Islam. "Effect of number of nodes and speed of nodes on performance of DSDV, AODV, AOMDV, DSR and GPSR routing protocols in VANET." In *2019 10th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*, pp. 1-6. IEEE, 2019.

[49] Amiri, Esmaeil, and Reza Hooshmand. "Improved AODV based on TOPSIS and fuzzy algorithms in vehicular Ad-hoc networks." *Wireless Personal Communications*. 2019, pp. 1-15.

[50] Kabir, Tanjida, Novia Nurain, and Md Humayun Kabir. "Pro-AODV (Proactive AODV): Simple modifications to AODV for proactively minimizing congestion in VANETs." In *2015 International Conference on Networking Systems and Security (NSysS)*, pp. 1-6. IEEE, 2015.