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CLUSTERING-BASED ROUTING PROTOCOL FOR VEHICULAR AD-HOC NETWORK USING TWO METAHEURISTIC ALGORITHMS

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ABSTRACT:

Vehicular ad hoc networks (VANET) are a special model of mobile ad-hoc networks (MANETs)and have many applications in safe driving, and entertainment by exchanging information between vehicles (e.g. road conditions, weather, congestion, etc.). the problem is that these Nodes(vehicles) in VANETs have very high mobility and due to this dynamic nature and the instability of wireless links between vehicles, providing an efficient and reliable routing method is a serious challenge for VANETs. Therefore, in order to meet this challenge and maintain the necessary information exchange between vehicles without loss, deletion, or access late, it is necessary to solve this problem by (designing an efficient and secure routing protocol for the exchange of important data in VANET). In this paper two algorithms were used together (Harris Hawks optimization algorithm (HHO) and Artificial Bee Colony algorithm (ABC)), taking into account the best parameters such as (the amount of free buffer size, distance between nodes, speed of nodes, node degree, and the quality of link connection) to improve the results compared to the rest of the articles and HIR. the simulation results indicated that the methodology improves other algorithms with Relevance in terms of parameters of packet delivery rate, throughput, and end-to-end delay.

KEYWORDS: Vehicular ad hoc networks (VANET), Clustering, Harris Hawks optimization (HHO), Artificial Bee Colony (ABC).

1. INTRODUCTION

VANET networks are a subset of MANET networks in which vehicles are considered network nodes. These networks are designed to communicate between vehicles and control traffic on the road. In automotive or van networks, Mobile vehicles are used as nodes in a network to create a mobile network. VANETs separate each device into a wireless router or node (network) and allow them to connect with each other at distances from 100 to 300 meters, instead of forming a wide-area network. Messages and information in the VANET network are transmitted from one vehicle to another, which increases safety and optimizes road traffic. Therefore, the main challenge in the VANET network is effective routing from origin to destination. (Monika & Rahul, 2017) (Shahirah, Shamsul, Norkhushaini, & Mohd, 2018) (Mustafa, et al., 2020) (Chandrashekhar & Satish, 2017) In fact, VANET networks are a special type of MANET network that will be the nodes of those cars. Any car on the road has the ability to recognize at any time the other cars around it as well as connect with them and thus create a network and establish the required connection. This car will create another network a little later with the new cars around it. The main basis of VANET networks is that these networks do not have a specific topology and use wireless communications to send data. Therefore, these types of networks can quickly change the topology and provide a lot of flexibility, given that they have no problem in terms of energy consumption and computing resources. For example, a car can be connected to several nodes in VANET networks at the same time and receive the necessary information. Therefore, another feature of this type of network is its short range. In-vehicle networks, you can also communicate to major stations or the Internet and swap information with each other, but the main basis of the network is VANET communication. It is one of the main components of intelligent transportation systems and in recent years, many researchers and projects have been done on it and there are many hopes for it. The reason for this importance is the direct relationship of this type of network with vehicle safety and traffic. (Asim, Saira, Sana, & Amir, 2017) (Deeksha, Ajay, & Manu, 2017) (Ramin & Saeed, 2018) (Alak & Jayasree, 2015) The main purpose of intelligent transportation systems is to provide safety and security for drivers. Has become one of the most appropriate technologies to achieve this goal. In fact, VANET networks have three main applications: increasing safety, improving efficiency, and applications for welfare, business, service, and entertainment purposes. There are two types of information in the VANET network, information that is sensitive to delay, such as safety messages, and information that is not sensitive to delay and is not required to be delivered immediately, required to be delivered immediately, such as traffic information or welfare service information. Dissemination of safety information is very sensitive due to its direct connection with human lives. Therefore, accurate and timely dissemination of information plays an important role in VANET networks (Chandrashekhar & Satish, 2017) (Seilendria, Subhadeep, Pietro, Juan, & Carlos, 2018) (Michael & Travis, 2021) (Mohammed, Abdeldime, Zhi, & Lian, 2016) Although VANET networks are a kind of MANET (Mobile Ad- hoc Network), they have little time to communicate due to special features such as node dynamics. For this reason, unique protocols should be provided for different applications of this type of network. (Asim, Saira, Sana, & Amir, 2017). The rest of this paper is organized as follows: the related work, methodology, results, and conclusion- future work are described in Sections 2, 3, 4, and 5 respectively.

2. RELATED WORKS

The paper (Christy, Deva, & Sengathir, 2021) is proposed for facilitating reliable data dissemination among vehicular nodes under emergency situations. HHOA utilizes chasing styles and cooperative behavior of Harris hawks termed as surprise pounce for efficient localization based on reference nodes. In particular, the intelligent strategy of Harris hawks' behavior in attacking the prey in all directions is included for localizing the NLOS (non-line-of-sight) nodes from the refer-once nodes positioned in all directions of the network. It is capable of localizing the NLOS nodes based on adaptive localizing (chasing) styles attained through reference nodes depending on the dynamic nature of NLOS nodes. The simulation results prove that the mean localization rate is improved by 23.21%, mean neighborhood awareness rate by 19.82%, mean emergency message delivery rate by 18.32% and mean channel utilization by 17.28% when compared to the baseline Weighted Inertia-based Dynamic Virtual Bat Algorithm(WIDVBA)-based

NLOS-LS (WIDVBA-NLOS-LS), Cooperative Volunteer Vehicular Nodes(CVVN)-based NLOS-LS(CVVN-NLOS-LS), Vote Selection Mechanisms and Probabilistic Data Association (VSMPDA)-based NLOS-LS(VSMPDA-NLOS-LS), and Weighted Distance Hyperbolic Prediction (WDHP)-based NLOS-LS (WDHP-NLOS-LS) for a varying number of vehicular nodes in the network. The paper (Mohamed & K, 2020) presents a K-Medoid Clustering model to cluster the vehicle nodes and after that, energy-efficient nodes are recognized for compelling communication. With the expectation of accomplishing energy-efficient communication, efficient nodes are recognized from each cluster by a metaheuristic algorithm, for example, the Enhanced Dragonfly Algorithm (EDA) which optimizes the parameter as minimum consumption of energy in VANET. The outcome exhibits that the V2V (Vehicle-to-Vehicle) communication improves the energy efficiency in all vehicle nodes additionally it accomplishes less execution time contrasted with existing algorithms. The main aim of the paper (Sami, Lukman, Mustafa, & Sameer, 2020) is to discuss routing based on link stability and to increase the coverage area of the cluster to improve the mobility characteristics and the energy efficiency of the VANET. The summarized studies about both the category are discussed in order to improve the link stability, energy efficiency, network lifetime, data aggregation, quality of service, load balancing, and multipath. A systematic comprehensive survey has been conducted for link stability and energy-efficient clustering-based routing protocols reported from 2012 to 2018. With the help of the survey, a technical direction is provided to the researchers about the pros and cons of the earlier studies. To fulfill the research gap, a novel methodology is introduced which is the prediction-based efficient multi-hop clustering approach with adaptive relay node selection for VANET. The model consists of four layers. They are multi-hop clustering algorithm, prediction-based clustering approach, adaptive link selection method, and improved routing protocol. The paper (Bhasker, Malothu, & Allam, 2020) RIVLP was used to improve clustering and A new algorithm has been improved and matched with the rest of the present algorithms that are improved in terms of stability, throughput, latency, and a lifetime of both clustering and Cluster head. A communication prediction algorithm with real-time monitoring, strong car observation, and life expansion method with road and vehicle lane information is proposed. Based on the clustering algorithm to predict traffic and communication flow, CH is selected which helps reduce the disturbance among CH and members of the group and provides the bestead path to increase network life. The generated VANET connection is utilized to foretell the lifetime of a network in which a connection in a plot is computed at a distance between adjoining nodes moiling along the margin. Each node contains a Global Positioning System (GPS) that helps determine the location to forward the message. Groups are created in the initiation stage and information is transmitted at a stationary stage. The distance information is updated by the existing node and sent to the following adjacent node and persists until the inputs reach the end node. Because of the elevated moving, the network architecture modifications and knowledge of the kinds of communication structures may stabilize it, which requires transit stability and no congestion because outages reduce the performance of the navigation path because the message is not sent at specific times. Using a lifetime foretelling correlation instead of using an edge reliability estimation can optimize the thoroughness of RIVLP because brink computation depends on the timestamp of realization messages sent to network nodes. In the paper (Mojtaba & Ali, 2019) a clustering-based routing protocol is introduced where nodes are clustered according to movement information such as node degree and velocity of vehicles by means of an imperialist competitive algorithm. Then, the cluster head is selected by means of a radial basis function neural network algorithm according to the amount of free buffer space and expected transmission count. Simulation results indicated that the proposed scheme improves the other related algorithms in terms of the parameters of packet delivery rate, throughput, and end-to-end delay.

The paper (Taqwa & Abduladhem, 2018) adopts an optimized integrated multicast, adaptive route lifetime as a routing protocol for VANETs. Whereby only an optimal subset of neighbor vehicles is chosen to relay route request (RREQ) messages based on distance, direction, speed, and future direction information in a combined sender-receiver manner. Among those selected optimal paths for route discovery, the best route with the lowest cost will be chosen for forwarding data packets for a specified duration assigned depending on the obtained cost and number of intermediate vehicles of that route. Fuzzy controllers were employed to assess routes' costs and their lifetimes. Furthermore, the artificial bee colony (ABC) algorithm was used to concurrently optimize all used fuzzy systems and obtain the optimal highest rank of links' cost values within which the neighbors could be selected as relay nodes in the route discovery process. Simulation results prove that the proposed routing scheme significantly improves the network performance in both urban and highway scenarios, under different situations of vehicle density.

3. METHODOLOGY

In the methodology, a clustering-based routing protocol is presented using two metaheuristics algorithms (HHO and ABC) by taking into account important parameters to improve packet delivery rate, throughput, and end-to-end delay. the clustering method is used to select the cluster head and its members, and the fitness function is used to choose the appropriate cluster head. The fitness function of the methodology contains the parameters of the distance between nodes, the size of the node free buffer, the node degree, and the quality of communication between nodes. The short distance between the nodes, the high degree of the node, and the quality of the strong connection will have a higher priority in selecting the appropriate cluster head. After that, cluster members are selected taking into account the distance and speed parameters. Since clustering is one of the NP-Hard problems, it is appropriate to use meta-heuristic algorithms for this process, so we used the HHO (Qian, Zhenjian, & Zhanghua, 2020) algorithm to improve the clustering method. After the clustering process (choosing the appropriate cluster headers and defining the members of each cluster), the data transfer process is carried out from the source node to the destination through the best path by taking the distance parameter into consideration, where the path is chosen using the ABC algorithm by choosing the next hop (next cluster head). *Figure 1* below shows the VANET network model in the methodology

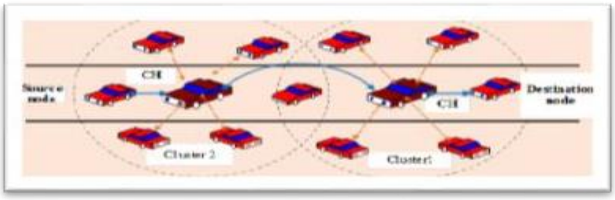

Figure 1: VANET network model in the methodology

3.1 Cluster Head FG Election Using HHO

- **The amount of free node buffer**

A node with more free buffer has a higher priority than other nodes for clustering. A node with a more-free buffer will not delete packets due to congestion. As a result, the package delivery rate will increase. Therefore, a node-free buffer plays an essential role in the selection of clustering heads. So we will have:

$$\textbf{Minimize } \boldsymbol{f_1} = \sum_{i=1}^{m} \frac{1}{Bf_i} \quad (1)$$

In Equation (1), the amount of empty buffer at the cluster head i is equal to Bf.

- **The distance between the nodes**

The end-to-end delay for sending data depends on the distance between nodes and the distance between nodes is obtained from the following equation:

$$\text{Minimize } f_2 = \sum_{i=1}^{m} dist(n_i, CH_i) \quad (2)$$

In the above relation n_i is a node of the network. The Euclidean relation is used to determine the distance between nodes. Assume that the coordinates of the two nodes at the head of the cluster and the member node are (x_1, y_1) and (x_2, y_2), respectively, then the Euclidean distance from Equation (3) is obtained:

$$\boldsymbol{dist(n_i, CH_i)} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (3)$$

- node degree

The number of members in each cluster is called the degree of the node. A cluster head with a higher degree of a node is suitable for clustering. So we will have:

$$\text{Minimize} f_3 = \sum_{i=1}^{m} \frac{1}{Ii} \quad (4)$$

In Equation (4), Ii is the degree of node i.

- Communication link quality

The link quality parameter plays a key role in the package delivery rate. In high quality, package deletion will be reduced and more data will be sent to the destination. Due to the mobility of nodes in VANET networks, data will be sent to a node that has a strong communication link. Equations (5) and (6) are used to calculate the quality of the connection between the two nodes.

$$r(t) = \begin{cases} count(t_0, t) & 0 < t - t_0 < 1 \\ \frac{count(t_0,t)}{(t-t_0)/\tau} & 1 \le t - t_0 < w \\ \frac{count(t-w,t)}{w/\tau} & t - t_0 \ge w \end{cases} \quad (5)$$

In relation (5), w is the window when Hello packets are sent. $count(t_0, t)$ is the number of Hello packets received between t and t_0. τ is the interval between sending the multicast Hello packet. The average number of expected received packets is obtained from Equations (6) and (7):

$$ETX = \frac{1}{r^2(t)} \quad (6)$$

$$\text{Minimize } f_4 = \frac{1}{ETX} \quad (7)$$

The fit function for determining cluster head nodes is obtained from Equation (8):

$$Min\ f = \alpha . f_1 + \beta . f_2 + \gamma . f_3 + \delta . f_4 \quad (8)$$

In relation (9), the coefficients α, β, γ, and δ are parameters Weight is the sum of 1. The value of these parameters is obtained through multiple simulations. In this dissertation, their appropriate values are: 0.3, 0.3, 0.2and 0.2, respectively.

$$\alpha + \beta + \gamma + \delta = 1 \quad (9)$$

In the methodology, the Harris hawk metaheuristic algorithm is used to determine the cluster head. To do this, this fitness function is presented to the Harris hawk algorithm. In order for relation (8) to be established, each of its parameters must be normalized so that their values can be added together. By normalizing their values are without units and will be between 0 and 1. For normalization, equation (10) called the min-max normalization function will be used.

$$F(x) = \frac{f - f_{min}}{f_{max} - f_{min}} \quad (10)$$

In relation (10), f_{min}, f_{max} and f are the minimum, maximum, and value of the function to be normalized, respectively.

3.2 Selection of Cluster Head Members

Cluster head nodes are used to identify the members of each cluster in the methodology of Equation (11). The nodes will be members of a cluster head with a minimum distance from the head of the target cluster. If the distance of a node is equal to two heads, this node will become a member of a head whose speed of movement is close to each other.

$$\text{Minimize } g = w_1\ (Speed(CH_i)) + w_2\ (Dist(n_i, CH_i)) \quad (11)$$

$$w_1 + w_2 = 1 \quad (12)$$

In Equation (11), $Speed(CH_i)$ indicates the velocity of node i and $Dist(n_i, CH_i)$, the distance between node $n_i$and the i, Then the Euclidean distance from Equation (3) is obtained. Therefore, two parameters, velocity, and distance play an essential role in the selection of cluster members. Due to the mobility of the nodes in the VANET networks, if the speed of the nodes and the head are close to each other, the stability of the clusters will be greater. On the other hand, to reduce the end-to-end delay, the distance between the head node and its members is very important, and the nodes will become members of a cluster head that is less distant from it. In relation (12), the coefficients w_1,w_2, weight parameters whose sum is equal to 1. The value of these parameters is obtained through multiple simulations. In this dissertation, the appropriate amount of them is:

$w_1 = 0.5,\ w_2 = 0.5$. Equation (10) is used to normalize the relation (11).

3.3 Routing Process with Artificial Bee Cloning Algorithm

Routing from a source node to a destination will be done through cluster head nodes and step by step. The source node sends its data packets to the corresponding cluster head and the cluster head node to the appropriate cluster head of the adjacent cluster. Finally, the packet will be sent to the destination cluster head and the destination cluster head will deliver the packet to the destination node. In this process, how to select the next head node is very important. In the methodology, to select the next step, the artificial colony meta-innovation algorithm will be used. The methodology uses a suitable fit function to select the next header with the appropriate parameters. The fit function for routing through the artificial bee colony meta-heuristic algorithm is as follows. (Seilendria, Subhadeep, Pietro, Juan, & Carlos, 2018) (Mohammed, Abdeldime, Zhi, & Lian, 2016) (Christy, Deva, & Sengathir, 2021) (Malathi & Sreenath, 2017) (Mohammed, Abderrahmane , & Ahmed , 2016)

To find the path closest to the optimal path, it is best to keep the distance between the source and destination headers to a minimum. For this purpose, Equation (13) is used.

$$Maximize\ g_1 = \frac{1}{\sum_{i=1}^{m} dist(CH_i, CH_j) + dis(CH_j, CH_d)} \quad (13)$$

In relation (13), CH_i, $CH_j$and CH_d are the head of the source cluster, the next step, and the head of the destination cluster, respectively. To find the optimal path, the bee colony meta-heuristic algorithm uses Equation (13). Each heading node determines the next step (next heading) and the next steps, sends the data packet to the destination cluster head and the head cluster head delivers it to its member node using the address in the packet header. *Figure 2* shows the routing operation from the source node to the destination.

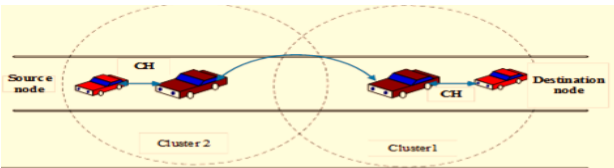

Figure 2: Routing between source and destination nodes

The *Figure 3* below shows flowchart diagram of the methodology, and *Algorithm 1*: Road detection from dispatcher to recipient FG

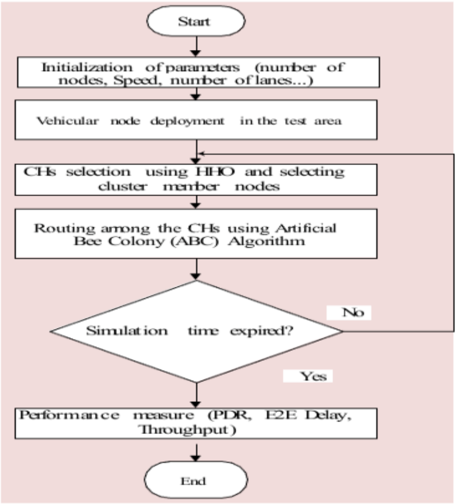

Figure 3: Flowchart diagram of the methodology

Algorithm 1: **Road detection from dispatcher to recipient FG**
step1: **Request**: Ki: cluster, FGi: cluster top of Ki, Kd(i): is next FG node of the cluster Ki, OPi: cluster member of Ki
step2: **If** (FGi take text Send-Packet from its organs) **Then**
step3: **If** (Tracking schedule of FGi Consist OPj as recipient) **Then**
step4: **If** (This path responds a QoS Condition) **Then**
step 5: Choose best Forager of this way for transports Deliver-Packet to OPj step 6: **end if**
step 7: **else**
step 8: FGi Make and preface Forward-Scout (OPj) by deliver to Kd(i)
step 9: **end if**
step 10: **end if**
step 11: **If** (FGi take message Forward-Scout (OPj) from its Kd(i)) **Then**
step 12: **If** (OPj consist in neighbor's roster or in tracking schedule) **Then**
step 13: FGi Make and preface Backward -Scout (FGi) by transmit to Kd(i) step 14: **else**
step 15: FGi indicate this Forward-Scout (OPj) by send to Kd(i) step 16: **end if**
step 17: **end** if
step 18: **if** (FGi draw message Backward-Scout (FGi) from its Kd(i)) **Then**
step 19: **If** (FGi is destination the Backward-Scout (FGi)) Then
step 20: FGi choose best forager for transport Send-Packet to its destination OPj
step 21: **else**
step 22: FGi indicate this Backward-Scout (FGi) by transport to Kd(i) step 23: **end if**
step 24: FGi registered data of Backward-Scout (FGi) as input in own tracking schedule
step 25: **end if**

Algorithm1: Road detection from dispatcher to recipient FG

4. RESULTS

In this part, the methodology is simulated and estimated. We compared our method with the HIR method (Mojtaba & Ali, 2019) where parameters such as end-to-end delay, PDR, and throughput will be tested.

4.1 Simulation Environment

The proposed algorithm is simulated by MATLAB software, version 2014R2. The system used for the simulation has 8 GB of RAM and a Corei5-8400 processor. The scenario used in this paper is a multi-lane highway scenario. The nodes which are the same as the vehicles are evenly distributed in the simulation environment. All nodes are homogeneous and have the same parameters. Other parameters are presented in *Table 1*.

Table 1 Simulation parameter

Parameter name	Parameter value
Highway length	5km
Total number of lines in each track	3
Topology	Highway
Number of vehicles	100,150,200,250
The Minimum speed of vehicles	60km / h
The maximum speed of vehicles	120km / h
Transmission range	250,300 meters
Queue size	50packages
Number of times simulation	20
Package size	1kilobit
Simulation time	100seconds

4.2 Performance Analysis and Numerical Results

4.2.1 Throughput: The evaluation results are shown in *Figure 4* Network throughput is the successful number of bits transmitted per second for a different number of nodes of the network simulation. Equation (14) shows the operational or transient power at which k is the number of tests required, ***SP*** and ***ST*** are the start time and end time of the simulation.

$$\text{Throughput} = \frac{1}{K}\frac{\sum_{i=1}^{n} X_i \times P_s}{S_P - S_T} \times \frac{8}{100} \quad (14)$$

Also in relation (14), P_s is the size of the packet sent in bits and X_i is equal to the number of packets sent.

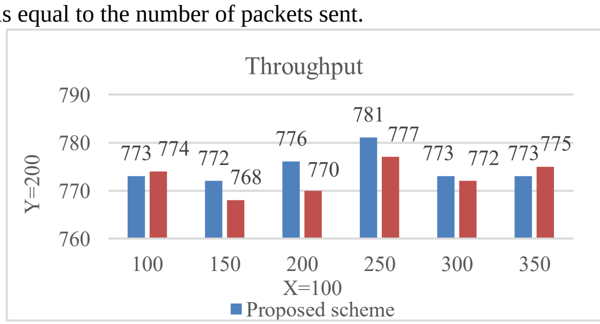

Figure 4: Throughput in terms of number of nodes

According to the diagram in **Figure 4**, it is concluded that the amount of throughput in the methodology is not suitable for a small number of vehicles. The reason for this is that the methodology uses the clustering technique. So that if the number of nodes in this method is small and a uniform distribution is used, the nodes will be spread across the network. Since clustering is based on the distance between nodes, the number of clusters will be very large and clustering will have virtually no meaning. But when the number of cars is large, clustering works properly. Therefore, when the number of vehicles increases, it is observed that the throughput will increase as well. Another reason for the lack of proper functionality in a small number of nodes is the use of two meta-heuristic algorithms for clustering and routing between nodes, which will reduce the operational load.

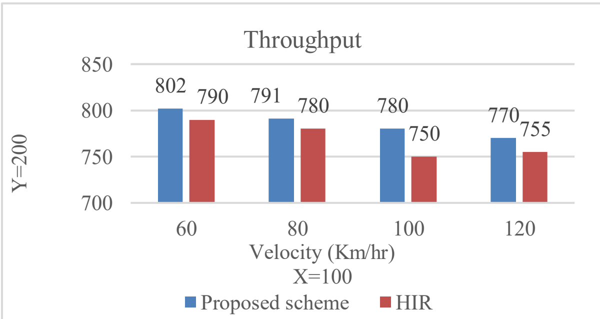

Figure 5: Throughput in terms of velocity

According to the diagram in *Figure 5*, it can be clearly concluded that the rate of transmission is inversely related to the speed of vehicles. The faster the vehicles, the faster the groups, which reduces productivity at higher speeds.

4.2.2 Package Delivery Rate: Package delivery rate is the ratio of the number of successful packets transferred to the total number of packets generated in the network. Equation (15) shows the package delivery rate. In this regard, $\boldsymbol{M_i}$ and $\boldsymbol{N_i}$ show the number of received and sent packages, respectively.

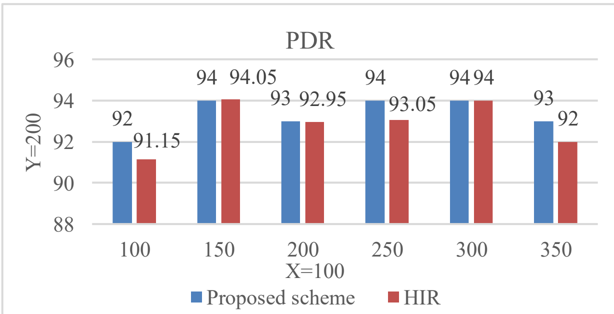

Figure 6: PDR based on the number of vehicles

$$PDR = \frac{\sum_{i=1}^{n} M_i}{\sum_{i=1}^{n} N_i} \times 100\% \quad (15)$$

According to the diagram in *Figure 6*, it can be concluded that the more vehicles there are, the higher the package delivery rate. As it exactly shows the correctness of the relationship has throughput. The reason for this can be attributed to the proximity of vehicles or in other words the density of the environment. But in general, it will be concluded that in both methods the package delivery rates will be similar.

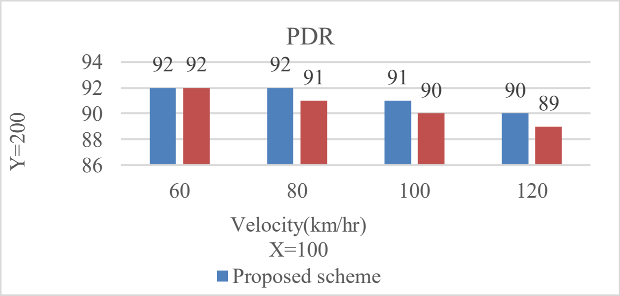

Figure 7: PDR based on vehicle speed

In *Figure 7* the successful packet transfer rate was evaluated based on vehicle speed. The results confirmed exactly what was presented about speed-based throughput. Because as the speed of the vehicles increases, the clusters will change rapidly, and this consistent change in topology will reduce the transfer rate. Of course, since the transfer rate does not depend on the unit of time, this change will not be noticeable much.

4.2.3 End-To-End Delay: On average, the amount of time it takes to successfully transfer a packet from source to destination (delay from the transfer, release, processing, and queuing) is called the average end-to-end delay. *Figure 8* shows the average end-to-end delay per number of different nodes in the network. As shown in the figure, the delay of the methodology will be less in scattered environments. The reason for this is the use of the optimal cost function with the appropriate clustering method and proper routing in the methodology.

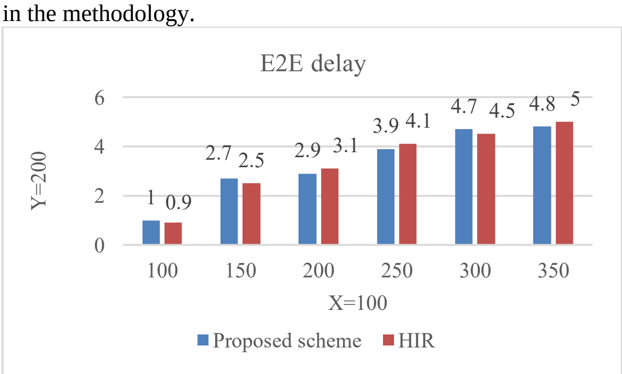

Figure 8: end-to-end delay based on the number of vehicles

The results show that the end-to-end delays in both methods are close to each other. Because in both methods, two meta-heuristic algorithms are used for clustering and selection of clustered nodes as well as routing between nodes, and since meta-heuristic algorithms have a long execution time, it makes sense that the end-to-end delays in both methods are close to each other.

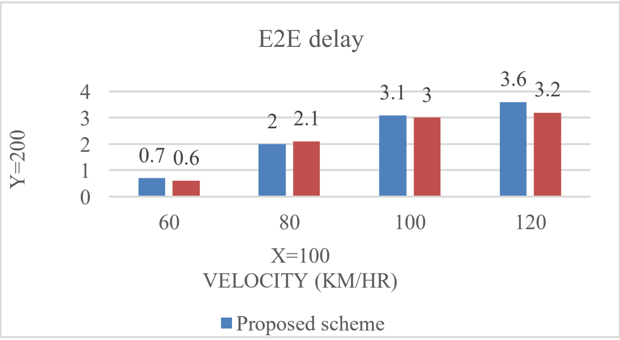

Figure 9: end-to-end delay based on vehicle speed

5. CONCLUSION AND FUTURE WORK

In this paper, an efficient and secure routing protocol is designed for critical data exchange in VANETs using Harris Hawks Optimization and Artificial Bee Colony algorithms are presented. The methodology uses clustering to reduce congestion and reduce end-to-end latency. Due to the fact that the HHO algorithm is one of the new meta-heuristic algorithms that have better results compared to other algorithms. Therefore, it is used in the dissertation and has better results compared to other articles. For clustering, suitable parameters are considered. The simulation results in MATLAB software show that the methodology to some extent improves the parameters of end-to-end delay, PDR, and throughput compared to the HIR method which used a clustering-based routing protocol is introduced and nodes are clustered according to movement information such as node degree and velocity of vehicles by means of an imperialist competitive algorithm. Then, the cluster head is selected by means of a radial basis function neural network algorithm according to the amount of free buffer space and expected transmission count. For further research, other meta-heuristic algorithms can be considered by considering the appropriate parameters.

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