Advanced Greedy Hybrid Bio-Inspired Routing Protocol to Improve IoV

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ABSTRACT New vehicles are now expected to be involved in the rapid development of Intelligent Transport Systems (ITS). Vehicular Ad hoc NETwork (VANET) is the basic equipment used for the production of ITSs with a rapid and dynamic network topology. The increasing number of connected vehicles and the need for real-time data processing has created a growing demand for turning real VANETs into an automotive Internet of Vehicle (IoV) for achieving a goal of an effective and smart future transportation system. In this paper, an Advanced Greedy Hybrid Bio-Inspired (AGHBI) routing protocol with a greedy forwarding system is proposed to improve the performance of IoV, where a modified hybrid routing scheme with the help of a bee colony optimization is used to select the highest quality of service route and maintain the path with minimum overflow. Simulation results confirm that the proposed protocol can cope well with both Vehicle to Vehicle (V2V), and Vehicle to Infrastructure (V2I) environments and has a great impact on improving the packet delivery ratio, and the delay, while attaining acceptable overhead and hops count among all vehicles.

INDEX TERMS ITS, VANET, IoV, V2V, V2I, routing, bee colony optimization.

I. INTRODUCTION
Vehicular Ad hoc NETworks (VANETs) [1] are a special type of Mobile Ad hoc NETworks (MANETs) [2] where an On-Board Unit (OBU) like vehicles can act as data exchange nodes; this data can vary depending on different applications (e.g., online vehicle status checking, intelligent route navigation and rescue, and avoiding illegal cyber operations) [3]. Generally, VANET communication modes are categorized as Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) [4], [5]. The Road Side Units (RSUs) [6] operate as assistants to reinforce the transmission procedure if the V2V wireless communication mode is not accessible. The challenges contributed to VANETs accessibility [7] such as dynamic topology, high mobility that causes less scalability, and signal losses have led to a growing demand for turning real VANETs into the automotive Internet of Vehicle (IoV) for achieving a goal of the effective and smart future transportation system. The structure of the IoV network is seen in Fig. 1.

Routing is a significant issue in IoV. Because of high mobility and changes in network topology, it requires new types of routing protocols that have to be performed by mobile and unreliable nodes (vehicles). The specific protocols for IoV can be grouped into four general categories [8]; topology-based, position-based, broadcast-based and multicast-based routing.

The topology-based routing protocols [9] can be divided into two categories; proactive (table-driven) and reactive (on-demand) routing protocols. In proactive protocols [10],
all connected nodes’ routing information is stored in tables and updated periodically. However, with fast topology changes in IoV, proactive routing might also generate many control packets which cause more overhead. In reactive protocols [11], the required paths are only available when needed and designed to reduce broadcast and transmission delays when new routes are required. However, the route acquisition process causes significant delays before data transfer, which is not easy for IoV in the event of emergency information. In position-based routing [12], packets are routed based on the vehicle’s location information; it is considered a promising routing approach in dynamic environments, because of its scalability and robustness against frequent topology changes. In broadcast-based routing [13], packets are flooded in the network; it is usually used in IoV for sharing street conditions, traffic, climate, and emergency events among vehicles in the network. In multicast-based routing protocols [13], routing packages are distributed in a multicasting group to prevent flooding. These protocols are divided into geo-cast and cluster routing. In geo-cast routing [14], a packet is forwarded from one source to all the vehicles located in a fixed geographical area called a Zone of Relevance (ZoR) [6]. In cluster routing [15], the network is split into several cluster members, a cluster head is responsible for inter and intra-cluster coordination. To make a routing decision, each node monitors the status of its one-hop neighbors via periodic hello messages [13], [15]. The weaknesses of these protocols are the high control overhead and the increased data transfer delays.

Due to high mobility and dynamic topologies within IoV, the use of an optimization algorithm is strongly required. Generally, bio-inspired algorithms fall into three main classes; evolutionary algorithms, swarm intelligence algorithms, and other hybrid algorithms, as seen in Fig. 2, this paper introduces, a new bio-inspired optimization algorithm based on the Artificial Bee Colony (ABC) optimization that is used to select the best route and improve the automatic adjustment of the parameter configuration in IoV network.

FIGURE 2. Taxonomy of bio-inspired algorithm.

In this paper, an efficient Advanced Greedy Hybrid Bio-Inspired (AGHBI) routing protocol with an advanced greedy forwarding system is proposed to improve the performance of IoV. The proposed protocol comprises:

1) A greedy forwarding scheme where each vehicle chooses an adjoining hop with the shortest distance to the destination.
2) A modified hybrid routing scheme is used to discover the optimal Quality of Service (QoS) route with minimum delay and high packet delivery ratio between vehicles; by using the Artificial Bee Colony (ABC) algorithm [16].
3) In addition, an efficient route maintenance mechanism is launched in which, a backup path is used when the link failed without making much more overhead.

The remainder of the paper is organized as follows: Section II presents the related work for VANETs and IoVs. Section III introduces the problem background and motivations of the proposed protocol and is followed by the functionality of the proposed protocol in Section IV. The evaluation methodology and Simulation results are shown in Section V. Finally, the conclusion is drawn out in Section VI.

II. RELATED WORK

Due to high mobility and rapid changes in the IoV network topology, the most significant research direction is in its routing challenge. Some of the proposed routing algorithms in the literature are as follows:

In Geographic routing [17], [18], routing decisions are taken locally based on location, vehicles send packets for knowing the position of adjacent and destination nodes. An intelligent greedy forwarding data dissemination protocol is proposed in [19] where, the best link is selected based on stability criteria with a greedy forwarding algorithm. However, this protocol ignores traffic density and speed which are very important metrics to cope with network scalability. A position-based protocol with fuzzy logic called FPBRTDNT [20] is proposed to improve the greedy routing and avoid absurd nodes for routing using three modes including; greedy, perimeter, and DTN. However, a neighboring node that has the highest chance value is being selected for the greedy forwarding, this value is calculated by applying fuzzy logic and different parameters. This greedy scheme enhances the efficiency of routing protocol; however, the authors have not proposed a method for selecting the most reliable route by the destination vehicle. The approach in [21] proposed a hybrid position and opportunistic based protocol to select optimal candidate nodes and determines appropriate priority for transmitting data, it can estimate link failure by evaluating link quality and predict the location of the nodes using different metrics but fails to ensure reliable communication with the high packet drop rate.

Many other protocols are proposed to eliminate the conventional geographical routing protocol limitations and adapt to variable traffic conditions, they are integrated with infrastructure-based routing protocols [22]. An adaptive mechanism for selecting intersections is proposed in [23], where the route is constructed between two consecutive intersections by finding a promising path based on multiple QoS problems by using the ant colony optimization algorithm. The approach in [24] switches the routing in
between software-defined networks [25] and fog computing [26], it selects the best path for data packet transmission either through inter-vehicle communications or the internet to improve the performance in terms of the delay and overhead; however, it suffers from high packet loss rate. The routing algorithm in [27] used the vehicle prediction trajectory by combining the vehicle moving position probability matrix with the association matrix. The vehicle data transmission capacity can be obtained by normalizing the distance and cache of the vehicle, then the vehicle with high forwarding capacity is selected as the next-hop forwarding node. A Distance weighted Back-pressure Dynamic Routing protocol (DBDR) is proposed in [28], it prioritizes the vehicles that are close to the destination and have a large backlog differential of buffer queues to provide dynamic hop-by-hop forwarding and is jointly designed with multi-hop internet gateway discovery procedure and vehicle mobility management for the internet services. A connectivity aware of the quality of transmission guaranteed geographically routing protocol in [29] presents a novel geographic routing in urban IoV. Each road segment is assigned to a weight based on the information collected related to the connectivity and the transmission quality. Using the weight information, the road segment can be dynamically selected one by one to comprise the best routing path. In [30], a traffic aware and link quality sensitive routing protocol is a geographic protocol used for urban IoV with the help of introducing intersection backbone nodes, each road segment is assigned to a different weight according to the designed link transmission quality to select the routing path for data transmission. In [31], author proposed an efficient Clustering V2V Routing Based on Particle swarm optimization (CRBP), which is composed of three components; cluster creation, route particle coding, and routing in the cluster or among clusters. CRBP can improve the stability of the network, and reduce the delay of information transmission; however, it has the limitation of tunning network stability with delay. In [32] author proposed a QoS-based routing protocol (FBQoS-VANET), which it uses the ABC approach for discovering the routes submitted to QoS criteria and also uses fuzzy logic to identify a feasible path among several discovered ones, where the path must satisfy criteria such as; bandwidth, delay, jitter, and link expiry time. The performance results show the benefits of using this scheme for routing various classes of traffic in IoV. In [33], the author concentrates on the QoS multicast routing problem by using a firefly with the Levy distribution (FF-L) algorithm to prevent the local optimal convergence. Experimental results show that FF-L detects optimal routes and can be implemented for network stability. In [34] A Modified Cognitive Tree Routing Protocol (MCTRP) is proposed, it incorporates a routing protocol with the cognitive radio technology for efficient channel assignment. This procedure includes a genetic whale optimization algorithm which helps in selecting a root channel for data transmission, the analytical results show that MCTRP promises minimum overhead with effective channel utilization. However, this type of tree-based solution is no more appropriate for IoV networks due to sparse and dense traffic situations.

III. MOTIVATION

Classical geographic routing protocols designed for IoV utilize only position information. Unfortunately, many existing geographic protocols adopt the greedy forwarding strategy based on the location of the vehicle information, which does not fully consider the urban road network information. In large scale IoV, overhead related to localization services and path discovery steps can deploy network resources and network overload. RSUs are deployed at intersections and along the roads to enhance network connectivity, data delivery and service providing [35]. In addition, many emerging applications depend on infrastructure such as: public or private cloud, government official server, security management, etc. [35].

However, RSUs large scale deployment is hindered by their high cost of deployment and management, therefore, it is necessary to develop a reliable routing protocol that copes with different IoV components. In this paper an Advanced Greedy Hybrid Bio-Inspired (AGHBI) routing protocol with a greedy forwarding system is proposed to enhance the routing performance on scalable IoV networks. The main contributions of this paper are as follows:

- A novel routing protocol based on a decision making algorithm for the V2V and V2I communication modes coupled with infrastructure location service is proposed, where the suitable routing path is selected based on the in-time routing information.
- For packet forwarding within road segments, a novel distributed V2V approach is launched by exchanging the bee scout packets between the vehicles.
- For packet forwarding at intersections, an RSU assisted dynamic adjacent intersection selection strategy based on an advanced greedy procedure is proposed to deliver data packets in a short time and with a minimum number of packet loss.

IV. PROPOSED AGHBI ALGORITHM

This section introduces the routing process in IoV, it contains two main processes; Greedy Road Selection (GRS) and Hybrid Route Setup Procedure (HRSP). GRS is a distributed process in which, vehicles choose the next road segment for travelling from multi-criteria considering the global view of the network topology by taking into consideration two attributes: Shortest distance and road density. As shown in Fig. 3, GRS is implemented using a greedy mechanism that predicts a weight value for each segment and the vehicle selects the next junction independently. In addition, the HRSP is a distributed procedure in which the ABC algorithm is used to select the optimal route to the destination; based on aggregating multi-criteria such as the link’s expiration time, moving direction, bandwidth and delay. Table 1 shows the notations used in the system.
Fig. 4 depicts the route discovery of the proposed GRS procedure. Consider a road network model, where the network is a directed graph $G = (H,R)$ which consists of road junctions $H = \{h_0, h_1, h_2, h_q\}$, and $R$ road segment that joins two intersections. To discover the existing routes between the source and the destination, let the vehicle in intersection $A$ needs to reach the destination $I$ through a number of intersections and segments in the road, there are four routes between source and destination points, as given below:

$$A \rightarrow B \rightarrow E \rightarrow H \rightarrow I$$
$$A \rightarrow F \rightarrow G \rightarrow H \rightarrow I$$
$$A \rightarrow F \rightarrow E \rightarrow H \rightarrow I$$
$$A \rightarrow B \rightarrow C \rightarrow D \rightarrow I$$

To decide which route can provide effective routing, it needs two key requirements; the shortest distance and the number of vehicles. A heuristic function illustrated in (1) is developed to calculate the priority value of each road junction $P_n$ as shown in the following:

$$R_{nm} = w_1 \frac{\xi_{nm}}{e_{nm}} + w_2 R_{nm}$$  \hspace{1cm} (1)

$$P_n = \frac{R_{nm}}{\sum_{n=0}^{k} R_{nk}}, \quad k = \{\text{adjacent}(n)\}$$  \hspace{1cm} (2)
where, $R_{nm}$ is the function value of the junction between the sender and receiver junctions, $R_{nd}$ is the sum of all function values from sender to adjacent junctions and $K$ is the number of adjacent junctions of selected one.

If the locations of the senders’ heading junction and next hop are $(x_n, y_n), (x_m, y_m)$, the formula for the positional distance between junctions can be obtained by the Euclidean distance as in (4), and the priority shortest distance from adjacent junction to destination $ε_{nm}$ is computed by (4), where $D_{nm}$ is the maximum distance from source to destination junctions.

$$D_{nm} = \sqrt{(x_n - x_m)^2 + (y_n - y_m)^2}$$  \hspace{1cm} (3)

$$ε_{nm} = \frac{D_{nd} - D_{nm}}{D_{nd}}$$  \hspace{1cm} (4)

The method for estimating traffic density is employed in [23]. This method depends on the calculation of the local density per vehicle using its neighboring table. The road density $ρ_{nm}$ is calculated by (5), where $NDN$ is the number of nearby vehicles detected, $d_{front}$ and $d_{back}$ are the distance between the sender and the furthest detected vehicles that are located in front and behind the sender vehicle; respectively, and $NL$ is the Lanes’ number of the road. The details of greedy road selection step are illustrated in Algorithm 1.

$$ρ_{nm} = \frac{NDN}{d_{front} + d_{back} \times NL}$$  \hspace{1cm} (5)

Algorithm 1 Greedy Road Selection

1. for all $H_m \in H_k$ do
2. Compute $ε_{nm}$ by Eq.(4);
3. Compute $ρ_{nm}$ by eq.(4);
4. Compute Maximum value of $R_{nm}$
5. end for

B. ROUTING MECHANISM

The location of the vehicle $V_i$ on the road is denoted by $(x_i, y_i)$. Given a vehicle $V_i$ that has a transmission range of $\rho$, all the vehicles within the $\rho$ are considered as its neighbors denoted by $N_i$ (one-hop vehicles). By analyzing the routing procedure and based on data collected from the simulations, it concluded that the vehicle selection is influenced by multiple attributes such as, the link time from the transmitter to the receiver, the movement direction of vehicles, the delay time and the channel bandwidth size of OBU between sender and receiver vehicles. The proposed routing mechanism consists of three main phases:

1) CANDIDATE VEHICLE SELECTION PHASE

In the Candidate Vehicle Selection (CVS) phase, each sender vehicle selects the best next candidate node to forward the packets through, based on the functional value as seen in (6), it uses four key parameters such as the vehicle’s moving direction $θ_{ij}$, link expiration time $LET_{ij}$, end to end delay $E2E_{ij}$, and buffer bandwidth $B_{ij}$. The probability $P(i,j)$ of selecting vehicle $j$ as the next forwarding one is shown in (7), where $C_{ij}$ is the objective value from the sender to receiver and $\sum_{j \in N} C_{ij}$ is the total value from sender to neighbor vehicles.

$$C_{ij} = \bar{\theta}_{ij} \left( LET_{ij} + \frac{1}{E2E_{ij}} + B_{ij} \right)$$  \hspace{1cm} (6)

$$P(i,j) = \frac{C_{ij}}{\sum_{j \in N} C_{ij}}, \hspace{1cm} N_i = \{\text{Neighbor} (i)\}$$  \hspace{1cm} (7)

If the locations of the sender $V_i$, the receiver $V_j$ and the destination $V_d$ are $(x_i, y_i), (x_j, y_j)$, and $(x_d, y_d)$; respectively, then the selection of the next forwarder direction, determined by the angle of two vectors $\bar{θ}_{ij}$ between $V_i, V_j$ and $V_i, V_d$, is given by (8). As shown in (9), to allocate higher priority for vehicles within the same direction, a smaller value of direction priority $\bar{θ}_{ij}$ is assigned, where $\bar{θ}_{ij} \in (0 < \bar{θ}_{ij} < 1)$ indicates that the receiver is closer to the destination, and the higher value of $\bar{θ}_{ij} \epsilon (1 < \bar{θ}_{ij} < 3)$ indicates lower priority for the receiver in the opposite direction.

$$\bar{θ}_{ij} = \frac{\cos^{-1} \left( \frac{y_d - y_i}{x_d - x_i} \right)}{\pi}$$  \hspace{1cm} (8)

$$\bar{θ}_{ij} = \begin{cases} 1 & \text{if } \bar{θ}_{ij} < 0.5 \text{ in same direction} \\ 3 & \text{if } \bar{θ}_{ij} > 0.5 \text{ not in same direction} \end{cases}$$  \hspace{1cm} (9)

The bandwidth of communication links in the network can be determined by the minimum number of packets at the end-to-end vehicles’ queue as seen in (10), where the number of packets in the queue of $V_j$ is denoted by $m_j$, and $m_{max}$ is the maximum number of packets in the queue for each vehicle.

$$B_{ij} = \frac{m_{max} \times e^{-m_j}}{m_{max} + m_j}$$  \hspace{1cm} (10)

$LET$ metric is used for detecting the stability of the link [21]. $LET$ can be measured by (11), where the velocity of the sender and receiver are $v_i, v_j$; respectively, $\rho$ is the vehicle’s communication range and $\alpha$ is the direction factor between two vehicles.

$$LET = \rho - \alpha \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$$  \hspace{1cm} (11)

$E2E$ is an important metric for measuring not only the delay incurred by intermediary vehicles which relaying the packets towards the destination, but also the initial route discovery. This metric is defined by (12) where, $DL_i$ and $DL_j$ are the delay for sender and receiver; respectively. The main processes of CVS are shown in Algorithm 2.

$$E2E_{ij} = DL_i - DL_j$$  \hspace{1cm} (12)

2) HYBRID ROUTE SETUP PROCEDURE PHASE

The ABC algorithm [36], [37] is a well-designed optimization algorithm that mimics the behavior of bee insects in finding food, to do this, some bees (called scouts) roam and explore...
the region in the searching food. When found, they come to
the hive to share their findings with their nest partners by
waggle dance indicator quantity, and quality of the obtained
food. The ABC is used in this paper to minimize the control
packets and to speed up the convergence speed [38]–[40].
Fig. 5 illustrates the HRSP procedure, in which, when the
source has packets to send, it checks that the next vehicle is
within the same road segment, then, it enables route discovery
based on the ABC algorithm. It firstly generates two different
Forward Scout (FS) packets to the destination, the source
will select the best candidate vehicle to forward the FS as in
Algorithm 2, and then each FS updates the objective func-
tion value of its path that depends on the minimum num-
ber of hops, link expiration time and end-to-end delay. The
pseudo-code of HRSP procedure is shown in Algorithm 3.

Algorithm 2 Candidate Vehicle Selection
1. for all $V_j \in N_i$ do
2. Compute $\alpha_{ij}$ by Eq.(9);
3. Compute $B_{ij}$ by Eq.(10);
4. Compute $LTE_{ij}$ by Eq. (11);
5. Compute $E2E_{ij}$ by Eq.(12);
6. end for
7. Compute Maximum value of $C_{ij}$

Algorithm 3 Hybrid Route Setup Procedure
1. for all $FS_s \in S$ do
2. for all $V_p \in NS_r$ do
3. Select next candidate vehicle by Algorithm 2
4. If ($V_p != NULL$)
5. Receive packet ($FS_s$)
6. Calculate $fit_s$ by Eq.(16)
7. If ($Fit < LTH$)
8. Update $Fit_s$
9. else
10. Discard $Fit_s$
11. end if
12. end if
13. P++
14. end for
15. S++
16. Select Poptimal by Eq.(18)
17. Source sends data packet on Poptimal
18. end for
19. Procedure Receive Packet($FS_s, V_p$)
20. If $V_p == V_d$
21. Send $BS_s$ to the source
22. Calculate error rate of $BS_s$
23. end if
24. end procedure

$\alpha$: THE FITNESS FUNCTION

The selection of the optimal route is mainly based on the
fitness function. For a certain point selected by forager bees,
the obtained route should be as close as possible to the desti-
nation node with minimum vehicles’ hops and the link should
remain as stable as possible. If the route that $FS_S$ discovered
has $L_p$ links, $L_p\epsilon(p = 1, 2, \ldots, NS_r)$, then the total number
of hops constituting the route is given by (13):

$$Hop(r_s) = \sum_{p=1}^{NS_r} L_p$$ (13)

The perfect path between vehicles should have a lower
end-to-end delay calculated by (14), so more packets can be
transmitted on the link with less time.

\[ E_2E(r_s) = \sum_{p=1}^{N_S} E_2E_p \]  \hspace{1cm} (14)

To ensure the link reliability under the high-speed movement of vehicle nodes, the route time should be the minimum time of links constituting the route as in (15).

\[ \text{let} \ (r_s) = \text{arg} (\min_{l \in \text{NS}} \text{LET}(l_p)) \]  \hspace{1cm} (15)

so the fitness function is expressed by (16):

\[ \text{Fit}_s = \alpha \times \text{Hop}(r_s) + \beta \times E_2E(r_s) + \delta \times \text{LET}(r_s) \]  \hspace{1cm} (16)

\[ \text{s.t} : \text{Fit}_s < \text{LTH} \]  \hspace{1cm} (16a)

\[ \alpha, \beta, \delta \in [0, 1] \]  \hspace{1cm} (16b)

The constraint (16a) indicates that the fitness value \( \text{Fit}_s \) of \( FS_s \) packets cannot exceed a Limit THreshold (LTH), the fitness value is updated by (17).

\[ \text{Fit}_s(p)_{\text{new}} = \text{Fit}_s(p)_{\text{old}} + \sum_{p \in \text{NS}_r} \text{Fit}_s(p - 1) \]  \hspace{1cm} (17)

Given the source and destination vehicles, the protocol can find the routing path with the lowest weights. Assume there are \( M \) available routes between the source and destination vehicles, each given route \( r_i \in \{1, 2, \ldots, M\} \) then, the optimized route will be chosen at the source vehicle based on the following formula:

\[ P_{\text{optimal}}(S, D) = \arg \min_{i \in M} (r_i) \]  \hspace{1cm} (18)

3) ROUTE MAINTENANCE PHASE

Due to the fast speed of the vehicles in the network, the communication link is more probably broken between vehicles. The proposed protocol handles this problem with the alternative links, so when a link is broken, the source automatically selects another back up one to take over and in turn the time of link reestablishment is reduced and the performance is enhanced. When each \( FS \) reaches the destination, it generates a Backward Scout (BS) to the source, then it calculates the error rate value \( \text{err} (r_i) \). If \( \text{err} (r_i) < \epsilon \), where \( \epsilon \in [0, 1] \), the source sends a data packet on \( r_i \) the path, if the second backup packet has a small error factor, the source selects it to send the data. Else, if \( \epsilon < \text{err} (r_i) \), all the discovered routes will be invalid, and the source restarts the routing procedure.

\[ \text{err} (r_i) = \text{fit}_{\text{BS}} (r_i) - \text{fit}_{\text{FS}} (r_i) \]  \hspace{1cm} (19)

C. AGHBI ALGORITHM DESIGN

The structure of AGHBI protocol is illustrated in Fig. 6. When a vehicle node has a data packet to transmit, it performs the following steps:
• Step 1: It first checks that the destination is on the same road segment, then it launches HRSP procedure to choose the best route to the destination; otherwise, the vehicle starts to check the distance to the nearest heading junction $D_h$.

• Step 2: If ($D_h > £$), the vehicle uses HRSP procedure to select the best route to the next junction; otherwise, the vehicle sends request packet to the nearest heading junction to switch the routing process.

• Step 3: After switching, the heading junction selects the nearest junction that is closest to the destination as in Algorithm 1, and then starts HRDP again by switching the data packet to the intermediate vehicles on the road.

These steps are repeated until the data packet reaches its destination. The pseudo-code of the AGHBI algorithm is shown in Algorithm 4.

Algorithm 4 AGHBI Data Routing Mechanism
1. Procedure sendpacket (Packet, $V_i$)
2. if ($V_d R_{nm}$)  
3. Select the best path $P_{optimal}$ by Algorithm 3
4. for $V_j$ path
5. if $V_j == V_d$
6. Routing is finished
7. end if
8. $J++$
9. end for
10. else
11. if ($D_h < £$)
12. Send Packet to next junction $R_{nm}$
13. RSU send packet (Packet)
14. else
15. Select best path to $R_{nm}$ by Algorithm 3
16. RSU send packet (Packet)
17. end if
18. end if
19. Procedure RSUSendPacket (packet)
20. Select next $R_{nm}$ by Algorithm 1
21. Select $V_j R_{nm}$ by Algorithm 2 //next candidate vehicle
22. Send packet (packet, $V_j$)
23. end procedure

V. SIMULATION IMPLEMENTATION AND RESULTS
Simulation scenarios had been carried out using DOT NET 4.5 environment using C# [41] and OMNET++ [42] platforms. The performance of AGHBI protocol and the corresponding comparative protocols are evaluated based on the commonly used metrics of packet delivery ratio, average delay, normalized routing overhead, and average hops count. The comparing protocols are examined on dual mobility scenarios in urban and highway environments. For urban and highway simulations, the map was extracted from OpenStreetMap [43] database. SUMO [44] is used to generate the movements of the vehicle nodes. The resulting output from SUMO is then converted into mobility input files for the OMNET++ and DOT NET platforms, as shown in Fig. 7. The veins [45] simulation framework is used as a popular framework for combining the SUMO mobility model with the recently released network simulators.

A. EXPERIMENTAL SETTINGS
The simulation area used is about $4000 \times 4000 m^2$, the starting position of vehicles is randomly distributed on the road network. Vehicles travel with a maximum speed of $90 km/h$ and a minimum speed of $30 km/h$. The OBU employs IEEE 802.11p PHY / IEEE 1906.4 MAC layers with a communication range of $300 m$ for all vehicles. The packet size is set as 1024 bits for the data packet while 256 bits for the control packets considering the tradeoff of packet delivery ratio, transmission delay and routing overhead, all FS and BS packets use a LTH value of 50. The default simulation parameters are listed in Table 2.

| Parameter               | Value                  |
|-------------------------|------------------------|
| Simulation area         | 4000 $\times$ 4000 m$^2$ |
| Vehicle No.             | 200 to 500             |
| Bandwidth               | 2 Mb/s                 |
| Number of source vehicles | 50                    |
| Junctions               | 20                     |
| Traffic type            | CBR (Constant bit rate)|
| Mobility model          | SUMO                   |
| Periodic FS interval time | 3 s                   |
| Packet size             | 1024 Byte              |
| Speed                   | 30-90 km/h             |
| Communication Range     | 300 m                  |
| Packet sending rate     | 2 packets/s            |
| Simulation time         | 150 s                  |
| Packet type             | UDP, HTTP              |
| Routing protocol        | AODV, GPRS, VSIM, AGHBI |
| $a, b, \delta$           | 0.3, 0.5, 0.2          |
| $w_1, w_2$              | 0.4, 0.6               |
| Fit LTH                 | 50                     |
B. PERFORMANCE FOR VARYING VEHICLES’ NUMBER ON ROUTE PREDICTION

Fig. 8 shows the error rate value between the fitness function of forward and backward paths. At low density, the network connectivity is small and paths are dropped quickly between the source and destination, so the error value is high. With the increase of vehicle density, the error rate decreases, because the increase in vehicle density makes the forwarding node holds a better choice. However, when the number of vehicles increases from a specific value, the error rate increases due to the higher load in the network.

![Error rate of scout packets](image)

**FIGURE 8.** Fitness error rate versus number of vehicles.

C. PERFORMANCE FOR VARYING $w_1$ AND $w_2$

Fig. 9(a) shows the effect of varying the distance factor $w_1$ with a number of vehicle factor $w_2$ on the packet delivery ratio. For the proposed protocol, as $w_1$ value increases from 0.6 to 0.9 and $w_2$ value increases from 0.6 to 0.8, the delivery ratio rises to 90%, this is because the larger partitioned network denotes that there will be more junctions to be chosen, but the $w_2$ value should be higher than a specific value to ensure the reliability of the links between the source and destination. In Fig. 9(b), the overhead increases to 200 when $w_1$ value rises from 0.1 to 0.5 and $w_2$ value rises from 0.2 to 0.5, this is because the paths are not stable and more packets are dropped. When the $w_2$ value increases from 0.6 to 0.9 and $w_1$ value increases to 0.8, the overhead grows quickly, this is because of the packet collisions in high network connectivity. Fig. 9(c) shows the growth of average delay to 0.9 sec when the $w_2$ value increases from 0.6 to 0.9, regardless of the $w_1$ value.

D. PERFORMANCE COMPARISON WITH DIFFERENT SCHEMES

In this section, the performance of AGHBI protocol is compared with three main protocols; AODV [46], that is a topology based protocol, in which, when a source node wants to send a packet, it checks the routing table for a route to the destination, if not exist; it broadcasts a route request packet and the nodes receiving these request packets rebroadcast them till reaching the destination. GPSR [18] is a geographically based protocol, in which a source or an intermediate node forwards the packet in a greedy mode, where the next hop is the closest geographic neighbor to the destination, the process is repeated until the destination is reached. VSIM [41] is a distributed-based protocol modeling the routing process as an aggregation of multi-criteria by using a fuzzy inference system and runs in two main processes; road segment selection and relay vehicle selection. The purpose of the road selection is to select multiple successive junctions whereby the packets are transmitted to the destination, while the relay selection process is designed to select relay vehicles from the selected road segment.

The results are concluded by varying three evaluation conditions; Scalability Scenario (number of vehicles), Mobility Scenario (distance between vehicles) and Traffic Scenario (data transmission rate), they are individually explained in the following three sub-sections. The reported result is the average of 1000 independent run times of the same experiment configurations.

1) PERFORMANCE OF SCALABILITY SCENARIO

A different number of vehicles are tested with the proposed protocol and the other comparable ones, in which the number of vehicles varies from 200 to 500, and the number of sources is set to 50. Each source vehicle randomly selects a destination with a different distance, and each vehicle sends two sequences of packets every 2 sec. In Fig. 10(a), AGHBI protocol outperforms other protocols in packet delivery ratio; this is because the opportunistic routing scheme makes vehicles select the next hop without flooding the network with more packets. The delivery ratio decreases after a certain range, this is because many packets are sent and this makes collision in the network, so many packets are dropped. The degrading performance of GPSR than other protocols is interpreted as it uses only greedy method which is not working well with urban intersections and makes many packets drop. The AGHBI protocol improves the packet delivery ratio by about 7%, 13.9% and 29.7% compared with VSIM, AODV and GPER protocols; respectively.

In Fig. 10(b), AGHBI achieves about 39%, 72% and 61% lower delay than VSIM, AODV and GPER; respectively. This is because the ABC optimization method used in AGHBI makes the total path between sender and receiver consumes low delay. When the density increases, the delay decreases, as AGHBI always selects the road segments with higher connectivity and shortest distance. In VSIM with sparse density, packets are dropped while increasing the times of carry-and-forward, which in turn increases the latency. With higher density, the delay of AODV and GPSR increases due to the high overhead.

In Fig. 10(c), the overhead increases with the increase of vehicle density. The performance of VSIM is degraded at the dense network; this is because more control packets are transmitted in the neighbor discovery process. With GPSR, the additional overhead increases, due to the exchange of hello beacons to maintain the active location of vehicles.
FIGURE 9. Effects of varying $W_1$, $W_2$ factors values on: (a) Packet delivery ratio. (b) Normalized routing overhead. (c) Average delay.

However, AGHBI outperforms VSIM and GPSR because of its efficient route repair mechanism that uses the backup path when communication links fail. The AODV consumes less overhead due to its low control packets. On average, AGHBI reduces the overhead by 48%, 19.8% compared with that of VSIM and GPSR, respectively.

Fig. 10(d) shows that the number of hops increases while increasing the number of vehicles. The AODV has the worst
performance compared to others; this is because it does not have a global view. The performance of VSIM is degraded due to its fuzzy method that ensures a reliable communication link and in turn, selecting many hops to the destination. In AGHBI with low density, the hops count jumps up to ensure reliable communication; however, after a specific number of vehicles, the hops count decreases. This is because AGHBI uses the least number of hops in the selection of links, and this also raises the packet delivery ratio. The GPSR consumes a lower hops count than other protocols because it uses a greedy method in forwarding packets with the shortest path to the destination. In summary, AGHBI reduces the hops count by 14% and 39% compared to VSIM and AODV, respectively.

As shown in TABLE 3, the proposed method outperforms the VSIM, AODV, and GPSR in terms of packet delivery ratio and delay, and outperforms VSIM in term of overhead while varying the number of vehicles.

TABLE 3. Comparison values of various parameters with varying number of vehicles.

| Algorithm Metrics | Number of Vehicles | AGHBI | VSIM | AODV | GPSR |
|-------------------|-------------------|-------|------|------|------|
| AVG. PDR %        | 200-300           | 98    | 94   | 25.5 | 17   |
|                   | 300-400           | 89    | 85   | 27   | 22.2 |
|                   | 400-500           | 77    | 84   | 29.5 | 22.7 |
| AVG. Delay(sec)   | 200-300           | 1.87  | 2.55 | 13.64| 8.64 |
|                   | 300-400           | 0.227 | 1.884| 11.5 | 11.03|
|                   | 400-500           | 0.563 | 0.67 | 22.75| 13.02|
| Overhead          | 200-300           | 99.1  | 91.76| 58.5 | 43   |
|                   | 300-400           | 175.11| 279.5| 47   | 98.5 |
|                   | 400-500           | 234   | 618  | 38   | 47.8 |

3) PERFORMANCE OF TRAFFIC SCENARIO
This scenario evaluates AGHBI and other compared protocols while varying the data transmission rate. The number of 100 packets is generated simultaneously between source and destination vehicles with a size of 1024 bits. Fig. 12(a) shows the performance of packet delivery ratio, while varying transmission rate. Both AODV and GPSR have higher delivery ratios than others, because VSIM and AGHBI have more complicated packet transmission processes than others. The simulation shows that, when the rate increases by more than 30 Mbps, the delivery ratio of AGHBI increases. The performance of VSIM decreases after 38 Mbps because more packets should be transmitted and in turn, the congestion in the network increases. The AGHBI still achieves a higher delivery ratio than VSIM, and this confirms that the proposed protocol works well in different conditions. Fig. 12(b) shows the result of varying data transmission rates with the delay, both AODV and VSIM have the worst performance with the higher rates. This is because, forwarding more data packets requires more time in transmitting and receiving these additional control packets, while AGHBI protocol outperforms VSIM and AODV protocols since the proposed scheme considers congestion and delay for selecting the paths, so the delay decreases at higher rates. Fig. 12(c) shows that with higher rates the overhead of AODV increases because of flooding the network with many control packets, which in turn makes the network busy and increases the overhead. However, GPSR overhead slightly decreases at higher rates, because control packets are low compared with AODV. The overhead of VSIM and AGHBI decreases after 30 Mbp.
Although the controlling packet is slightly bigger, the higher rate achieves more received packets and less link breakage error.

To support the simulation results, the analytical analysis is used in this paper. TABLE 4 presents the optimum fitness function and the error rate between the forward and backward selected paths under a different number of vehicles. From TABLE 4, with increasing the vehicles in the network, the fitness value increases because of the consideration of many traffic conditions. As shown, at 200 and 500 vehicles, the max values of the fitness function are 52.5 and 55.013; respectively, so AGHBI protocol fulfills the performance criteria of IoV, and the performance can be optimized.

VI. CONCLUSION AND FUTURE WORK

In this paper, an Advanced Greedy Hybrid Bio-Inspired routing protocol (AGHBI) is proposed. To select the optimal route for forwarding data on IoV environment, AGHBI uses two basic steps; first, a greedy forwarding scheme that is used to choose the closest segment to the destination, then a modified hybrid routing scheme with the help of an ABC optimization algorithm is used to select the highest QoS route and maintain the path with minimum overflow. Simulation results confirm that AGHBI protocol is scalable with large urban and highway areas and outperforms VSIM, AODV and GPSR by about 7%, 13.9% and 29.7% for packet delivery ratio, and 39%, 72% and 61% for the delay; respectively, while attaining tolerable overhead by about 48% and 19.8% compared with that of VSIM and GPSR, also it gains lower hops count by about 14% and 39% compared to VSIM and AODV; respectively.

Ongoing work is focusing on applying an in-depth analysis of some key protocol parameters for adaptation to more complex IoV scenarios. In addition, the weights in the GRS and HRSP procedures can be determined by using the popular machine learning algorithms that depend on real traffic data to enhance routing in IoV environments.

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