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Communication and Vehicle Routing Optimization using Bio-Inspired Algorithm

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Abstract: A dependable routing protocol for Intelligent Transportation Systems is critical for efficient communication between cars and infrastructure. Because of the high mobility and recurring topology variations of Vehicular Ad-hoc Networks (VANets), finding a linked route with acceptable latency is a significant problem with various constraints and drawbacks. To address this, we offer an efficient multimetric routing protocol for Intelligent Transportation Systems. The suggested protocol takes into account five metrics: throughput, bandwidth and end-to-end delay. The suggested strategy aims to maximize the Packet Delivery Ratio (PDR) while minimizing network delay. It seeks to find the path with the least latency, distance, and relative velocity while also providing the most bandwidth and V2V connectivity. A common Swarm Intelligence (SI) technique. Specifically, we provide a communiqué architecture for linked automobiles to share traffic flow information. The Genetic Bee Colony algorithm is proposed to allow communication between nearby vehicles and vehicle-to-nearby roadside units, vehicle routing optimization, traffic management system enhancement, and vehicle-to-vehicle (V2V) communication protocol improvement are some of the applications If traffic management is unsuccessful, there is possibility of coincidences and law infractions. Furthermore, to evaluate the efficiency of the planned strategy, it developed an agenda for modelling and simulating the road traffic structure in an IoV context.

Keywords: *VANET, Communication Architecture, Internet of Vehicles (IoV), Swarm Intelligence*

1. Introduction

The Intelligent Transport System (ITS) is a fully combined utility that uses communication, electronics, advanced sensors and computers to enable innovative skills. These apps provide important info for travellers while also improving the security and dependability of the public transportation system. The intelligent transport system seeks to improve traffic flow efficacy by reducing traffic congestion. It seeks to cut commuters' travel time while also improving their security and ease [1]. Use does not only belong to the observation and information of crowding on the roads but also road safety and the optimal use substructure. Vehicle-to-vehicle communication allows a vehicle to share information with some other vehicle-to-vehicle (V2V) communication or an automobile could communicate with equipment like a Roadside Unit. The development of wireless communication technology and the vehicle industry gave rise to vehicular ad-hoc networks this field is emerging as the most encouraging exploration field. VANET is a subclass of the MANET network which allows communication between nearby vehicles and vehicles to nearby Roadside Units, each vehicle to the VANET network is considered as a node. VANET primarily uses capabilities for the safety of the public, peace of mind, passenger data, traffic management, road traffic management, and help, among other purposes. If traffic control fails, there is a hazard of coincidences and rule violations [2].

Solving automobile congestion is challenging due to its dynamic nature., as well as the vehicular environment's network topology, is incalculable.

2. Literature Survey

VANets have unique properties such as velocity and frequent topological changes, making traditional mobile ad-hoc network protocols ineffective for Intelligent Transportation Systems. An efficient routing system is essential for VANets due to their extremely dynamic behaviour. Vehicular ad-hoc networks require a reliable path for more info. A multimetric routing protocol is necessary to ensure service quality. A brief overview of related studies is provided under.

Toutouh et al. [3] future an efficient link-state routing technique that uses best limitation selections. To deliver data, the protocol employs a revised path connecting the origin and target nodes. The key downside of this directing procedure is the necessity to update the directing tables for all ways frequently [4]. Control packets can consume additional bandwidth and cause network jamming in densely populated networks.

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Yussof et al. [5] planned an equivalent genetic technique (GA)-depending on the smallest direction-finding technique. However, data transmission between nodes is not always optimal via the quickest route. Computation time and accuracy depend on a set of nodes and population. The accuracy of computing nodes decreases linearly, but calculation time decreases exponentially. Larger population sizes lead to increased accuracy and computing time. Wang et al. [1] proposed a routing protocol with multiple metrics for quality of service. They considered CPU use ratio, buffer size, and network bandwidth. However, the proposed technique does not address critical network factors such as bandwidth, jitter and delay. Sun et al. [2] suggested a Quality of Service (QoS) uses multiple metrics for the broadcast directing technique. Our suggested solution optimizes connection utilization, multicast tree cost, long-term path selection, average latency, and extreme end-to-end delay. However, the provided technique did not take into account other important aspects like connection, relative velocity, distance [3].

3. Architecture

In this part, we will discuss the vehicular ad-hoc network system architecture. We will see the Main Components of VANET, as per the IEEE We can achieve VANET structure by substances that can be separated into 3 areas: Mobile domain, Infrastructure domain, and Generic domain [4]. The mobile region is separated into two distinct parts: the vehicular domain and the mobile device domain, which is shown in Figure 1. The vehicle domain includes several vehicles and various transportation systems every vehicle has incorporated different types of sensors and gadgets. The mobile domain includes devices such as personal navigation devices and cell phones. The infrastructure domain is separated into two parts: the roadside infrastructure domain and the central infrastructure domain. The roadside infrastructure space includes elements such as traffic lights on the side of the road.

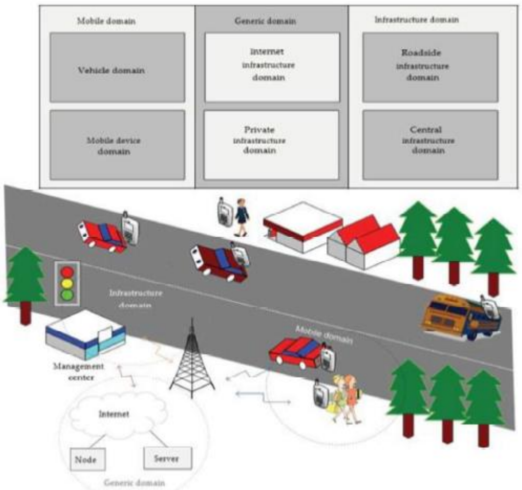

Fig 1: VANETs framework [5]

3.1. Communication Architecture

Correspondence types in the VANET structure are ordered into four sorts. Generic Communication domain, V2V, V2B, and V2I.

3.1.1. In-vehicle communication (generic domain)

In this domain, the vehicle consists of different devices that would keep an eye on vehicle conditions such as speed of the vehicle, condition of the engine, temperature near the engine and fuel tank area. Also in this domain, the driver's condition is taken into consideration so that if any of the drivers is unable to perform well while driving then automatic control of the vehicle will be shifted to the onboard control module of the vehicle to rescue from any kind of hazardous situations.

3.1.2. Vehicle-to-broadband cloud (V2B) communication

Indicates that vehicles might use remote wireless internet systems like 3G/4G to communicate.

3.1.3 Vehicle-to-vehicle (V2V) communication

This type of architecture helps drivers share facts and cautionary communications so that they can use it for safety purposes.

4. Internet of Vehicle (IoV)

The Internet of Things is a network of an object containing sensors that capture and gather data from the environment and send it through the Internet.[6] That allows data from connected vehicles and vehicular ad-hoc networks to be used more easily. The IoV provides five different types of communication networks: 1) Intra-vehicle technologies that use onboard units for tracking the vehicle's internal operations (OBUs). 2) Vehicle-to-Vehicle (V2V) systems, which allow for the wireless interchange of information about a vehicle's speed and location, as well as the position of nearby vehicles. 3) Vehicle to Infrastructure (V2I) technologies, which allow for the wireless transmission of data between a vehicle and a roadside assistance unit. 4) Vehicle to Cloud (V2C) systems that allow the vehicle,[6] via application program interfaces (APIs), to access additional information from the internet. 5) Vehicle to Pedestrian (V2P) systems, such as pedestrians and cyclists, that promote awareness of vulnerable road users (VRUs). IoV enables data collection and sharing of information about roads, vehicles, and their surroundings[7]. Also, IoV requires data processing, data computing, and safe exchange of data over a network platform [8]. The network platform can effectively control and track vehicles and provide various services, such as media and Web applications, using this information. The Internet of Vehicles (IoV) integrated network offers traffic management, intelligent transportation control, and dynamic information services, showcasing how IoT technology is commonly used in intelligent transportation systems (ITS) [6].

4.1 Bio-Inspired Algorithms

Bio-inspired optimization techniques are a developing strategy for developing new and more reliable computer systems depending on biological evolutionary ideas and inspirations. Evolutionary algorithms swarm intelligence algorithms, and other biology-based algorithms are the three kinds of VANET biological routing algorithms [9]. This Evolutionary algorithm is subdivided into two type’s Sequential genetic algorithm and the Parallel genetic algorithm. The second kind is the Swarm Optimization procedure, this is based on the behaviour of animal sets and specific insects in wildlife, like ant colonies, bee swarming, bird flocks and fish schooling, and has piqued the interest of researchers in tackling a variety of problems. Several swarm optimization procedures are skilled in delivering speedy, less costly, multiple criteria, and effective alternatives for several difficulties such as routing and scheduling.

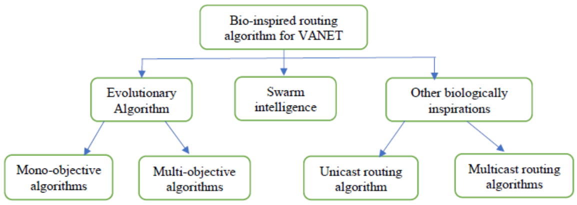

Fig 2: Classification of Bio-Logical Routing Algorithm [9]

The intelligence of swarms in IoV speeds up and enhances the analysis of IoT data. Swarm intelligence is a relatively new method of problem-solving based on the societal actions of insects and other animals. Particularly, Swarm Intelligence methods are distributed also personal organizing to tackle the challenging problem, which, due to active events, an absence of information, and restricted computation resources, is vital in the Internet of Things agenda. Several SI utilities for data optimization, including linked cars, data routing and cloud computing [15], have recently been applied to Internet of Things operations. Vehicle makers and researchers are beginning to investigate how vehicles might communicate [15], and function to share knowledge to provide a solution when ITS control and communication technology advances.SI is thus an influential technique for automobile vehicles to act like a single Swarm and help transportation organizations. [10,25]

- **Ant Colony Optimization (ACO)-**
  The ACO is an technique that depends upon how Ants seek meals. They can notify one another by putting down scents to detect food.
- **Particle Swarm Optimization (PSO)-**
  This is a population-based optimization technique. It is affected by the activities of flocks of birds and schools of fish [10,25]. PSO resembles evolutionary computation approaches in several ways. The system starts with a set of random choices and iterates over generations to find the best one [11,26].

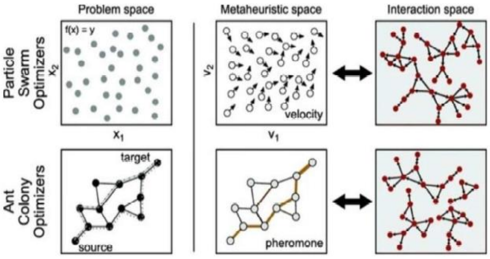

Fig 3: ACO and PSO[11]

- **Cuckoo Search Algorithm (CS)-**
  It is a nature-inspired system that uses cuckoo birds' brood reproductive mechanism to increase their number.
- **Genetic algorithm (GA)**
  The GA is a seeking-based technique of optimization that uses both genetics and natural selection. Genetic algorithms rely on Mutation, crossover, and selection are elements of biologically inspired operation. [10].

4.1.1 Artificial Bee Colony Algorithm

Honey Bees' Foraging Behaviors When Look for A Good Food Source Influenced the Artificial Bee Colony Algorithm. The Genetic Bee Colony (GBC) is a revolutionary swarm optimization technique inspired by biology. It's a novel optimised approach that combines the advantages of the Genetic approach (GA) and the Artificial Bee Colony (ABC) techniques. The artificial bee colony (ABC) technique has proven effective in a huge scale of uses, including engineering efficiency issues. The artificial bee colony technique was inspired by honeybee foraging behaviour when hunting for a good food source. It searches for food using a collective intelligence mechanism. The honey bee swarm has several characteristics, including the ability to communicate information, memorize the environment, retain and distribute knowledge, and make decisions based on that information [12]. The swarm updates itself in response to changes in the environment and allocates tasks dynamically. The Fundamental aspect of Swarm is a division of labour and Self-organization.

- **Self-organization-** The algorithm organizes the bee without any outside information.
- **Division of labour-** Division of labour makes the algorithm robust in all conditions in search space as the task is distributed through the division of labour.

The most important aspect of the Artificial Bee Colony technique is the information exchange communication done through dancing. Once scouts find a food source they will “waggle dance’ in the dancing area. The bees choose the position of the food sources at random at the beginning, and their nectar quality is determined. The employed bees then transmit information about nectar sources to the onlooker bees. As its position in the food supply has been recorded, each used bee will travel to the approved source of food in the preceding cycle after an exchange of information, and then Choose a different food source near the present supply of food based on the data gathered [13,24]. Data were collected from the dance area's employed bees, a onlooker bee chooses a suitable source of food. First, choose a food source that has greater nectar. To replace the one that the observer bees discarded, a scout bee creates a new source of food at random.[14,19] Figure 4 displays the Phases of the Artificial Bee Colony procedure.

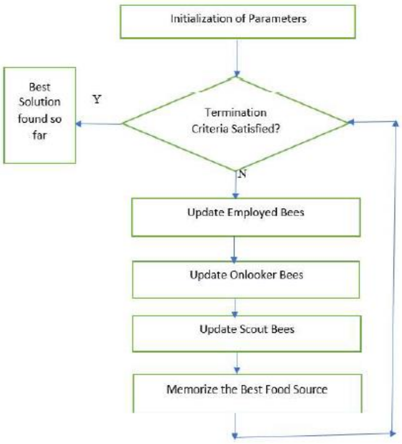

Fig 4: ABC Algorithm Phases

Algorithm 1: Artificial Bee Colony Algorithm

Parameters should be initialized Continue until all of the Termination Criteria are meet.

Step 1: Generating new food source by using the employed bee phase

Step 2: Using observer bee phase, the optimum food source is determined by the quantity of nectar they contain.

Step 3: To discover a new source of food Scout Bee Phase used to replace food sources that have been rejected

Step 4: recollect the best source of food discovered up to this point.

Output: The best solution discovered up to this point.

4.1.2. Genetic Algorithm

Nature has consistently served as an ongoing source of great inspiration for each of us. A genetic algorithm is one of the more often used evolutionary algorithms which is a kind of heuristic algorithm that uses nature's ideas to optimize anything based on some sort of heuristics in the case of genetic technique.

The genetic algorithm (GA) is a seeking-based technique of optimization that uses both genetics and natural selection. Genetic algorithms rely on Utilizing bio-inspired operators like mutation, crossover, and selection [10].

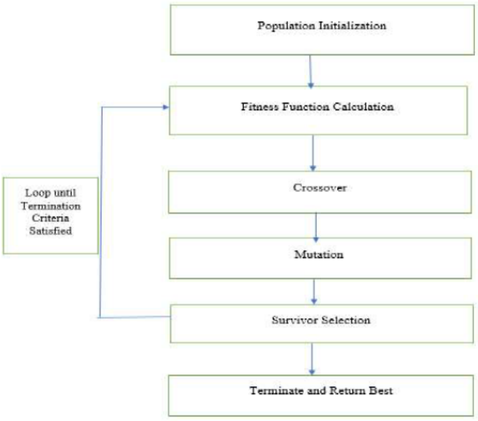

Fig 5: Genetic algorithm Phases

Algorithm 2: Genetic Algorithm

Step 1: Create an initial number of individuals.

Step 2: Analyse each entity's fitness.

Step 3: If the termination requirement is not met, go to the next step.

Step 4: Choose the most physically fit individuals for reproduction.

Step 5: interaction between individuals.

Step 6: Individual mutagenesis is the sixth step.

Step 7: measure the changed individuals' fitness.

Step 8: Create a brand-new population.

Step 9: Come to an end.

4.1.3. Genetic Bee Colony Algorithm (GBC)

The Genetic Bee Colony (GBC) algorithm is a bio-inspired swarm optimization algorithm. It's a Hybrid optimization algorithm that unites the benefits of both the Genetic algorithm (GA) and the Artificial Bee Colony (ABC) algorithms. There are 3 types of bees in the artificial bee colony algorithm1)Employed bee This is the new solution generation process Employed bees use their memory to check for food surrounding the food source, while also sharing their knowledge of these food sources with observer bees. 2)Onlooker bee: The Onlooker bees are likely to select quality sources of food from the employed bee's source [15,23]. A food supply that has a higher quality (fitness) would have a better opportunity for the onlooker bees to be selected than the one of lower quality. 3) Scout bee: From a few employed bees, the scout bees are translated Find solutions based on the value of limit if fitness value is not improved then they abandon their food source and search for new ones. then we add a genetic operator to the Artificial Bee Colony algorithm from the Genetic algorithm. From Figure 6 get a detailed idea of the Genetic Bee colony Algorithm and how it works.

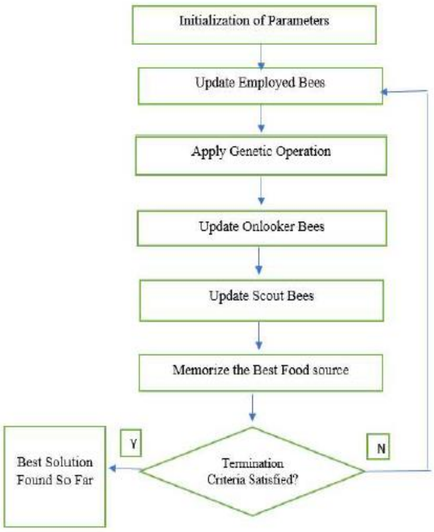

Fig 6: GBC Algorithm Phases

Algorithm 3: Genetic Bee Colony algorithm
The parameter should be initialized Continue till the terminating requirements are met. Step 1: In the Employed bee phase, calculate the innovative food source. Step 2: To improve the excellence of the result Crossover phase Step 3: Update the food supply based on its nectar amount during the onlooker phase. Step 4: During the scout bee phase, instead of the deleted source of food, find an alternative one. Step 5: Remember the best food sources that have been recognized. Result: The best solution has been determined.

5. Mathematical Model

5.1. Initialization of Population (Swarm)

The algorithm of an artificial bee colony (ABC) has three parameters: i) Population (Number of Sources of food) ii) Limit (Quantity of tests required to jilt a food source) iii) Termination Criteria

The following procedure is used to create each Food Source: -

$$x_i^j = x_{min}^j + rand(0,1)(x_{max}^j - x_{min}^j), \forall j = 1, 2, \dots, D \quad (1)$$

Xi-i th food source-(i = 1, 2, ..., SN).

-D is the number of variables in the optimization problem.

5.2. Employed Bee

According to the expertise and fitness worth of the preceding discovered solution, the Employed bee stage improves the present solution. A new source of food with a greater fitness value replaces the existing food source. [16] In this phase, the positional updating equation for the dimension of the I th contender is as follows:

$$v_{ij} = x_{ij} + \phi_{ij}(x_{ij} - x_{kj}) \quad (2)$$

where ϕij (xij − xkj) is called step size, k ∈ {1, 2, ..., SN}, j ∈ {1, 2, ..., D} are two randomly selected indices. ϕij is a chosen number in [–1, 1].

5.3. Onlooker Bee

Onlooker Bees have the same amount of food sources as employed bees. Through this time, every employed bee shares its fitness with onlooker bees, and information about new food sources is shared. Each food's selection probability is calculated by the onlooker bee That source is produced by the employed bee. The observer bee selects the most suitable food source. The probability pi

$$\mathcal{P}i = \frac{fit_i}{\sum_{i=1}^{SN} fit_i} \quad (3)$$

Fiti reflects the fitness value of the ith solution.

5.4. Scout Bee Phase

If the source of food’s position isn't updated for a defined period, After a given number of cycles, the food supply is presumed to be disregarded, and scout bees emerge. During the same time, bees linked with neglected food sources are shifted into scout bees, and the food supply is replaced with a randomly chosen food source within the search space. scout bees phase is initialized.

$$x_{ij} = x_{\min j} + rand[0,1](x_{\max j} - x_{\min j}) \forall j = 1,2, \dots \dots D \quad (4)$$

6. Methodology

The bio-inspired GBC optimization algorithm[17,18] to find the optimal solution is stimulated by the normal Honeybee foraging behaviour. Several parameters need to be set for the algorithm, namely: number of scout bees (n), number of sites selected out of n sites visited (m), and number of best sites out of m sites selected (e). In the ABC optimizing algorithm, the following steps are followed

1. Configuring ABC parameters
2. Start populating bee solutions
3. Evaluation of the population of bee solutions
4. Identification of employee bee

v. Identification of onlooker bee

vi. Identification of scout bee

vii. Genetic operators

The Genetic Bee Colony (GBC) algorithm is a hybrid selection approach that combines the Genetic Algorithm (GA) and Bee Colony Optimization (BCO)[19,22] approaches. It is intended for site selection in microarray cancer classification jobs. The GBC method has demonstrated higher performance in terms of classification accuracy and number of selected sites, making it a promising approach in bioinformatics. It displays success in achieving high classifier accuracy with a small number of sites, which is required for efficient microarray cancer classification. In addition, research has been undertaken on the convergence analysis of the Gravity Clustering (GBC) algorithm, which is closely related to the GBC algorithm and provides new insights into its mathematical features.

7. Results

Packet Delivery Ratio: PDR is the ratio of packets successfully delivered to a destination to the total number of packets sent by the sender. It is determined using the following equation and the awk script, which contains the trace file and generates the output.

$$PDR = \frac{Total\ number\ of\ packets\ recieved}{Total\ number\ of\ packets\ sent} \quad (5)$$

Delay is the difference between the time the sender produced a packet and the time when the recipient received the packet. Delay is premeditated as follows:

Delay(i) = (Receiving time (i) - Sending time (i))

Where, i is the packet number

Total Delay = Total Delay + Delay (i)

$$Average\ Delay = \frac{Total\ Delay}{count} \quad (6)$$

Throughput is the number of successfully received packets in a unit of time and it is represented in Kbps. It is calculated using the following equation:

$$Throughput = \frac{ReceivedData \times 8}{DataTransmissionPeriod \times 1000} \quad (7)$$

7.1 Monitore and Traceback Procedure:

Algorithm 4: GBC Monitore Procedure

```
Step 1: Monitor system movement F.
Step 2: Development of parameter changes P over period intervals Δt
Step3:  If movement suspends
    3.1: Inspect for security assaults, malfunctions, and insecure communication.
Step 4: Else continue the development
Step 5: Exchange collected information with nodes that are nearby.
```

Algorithm 5: Traceback procedure

```
Consider a system N
Step 1: Defining the movement F
Step 2: Compute variations of entropy E
Step 3: If any delay is identified before the source,
    3.1 Append details to the node.
    3.2 Request to Apply Traceback.
    3.3 Repeating differences of information.
Step 4: Else
    4.1 The Efficiency resource has been identified.
Step 5: Give Nodes that are tracked data.
```

Table 1: Simulation parameters

Simulator	Network Simulator 2.35
Interface type	Phy/WirelessPhy
Mac type	IEEE 802.11p
Queue length	50 Packets
Area	800m x 800m
Routing protocols	AODV
Traffic type	UDP
Antenna type	Omni Antenna
Number of nodes	9
Packet size	512 bytes
Propagation type	TwoRayGround
Simulation time	15 sec
Interface queue type	DropTail/Priority Queue

7.1.1. Network Topology for Monitoring and Traceback Procedure

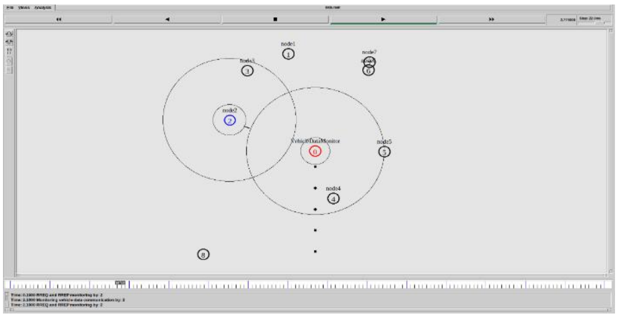

Fig 7: Network Animation using NAM

This network structure has nine nodes, one of which is marked as a motor vehicle monitoring the data node and the other as affecting the node. In the model below, node 0 acts as a tracking node, gathering data from everywhere other nodes. Node messages will take place; if nodes do not deliver there is a correct data risk of excessive traffic flow. So, we use information tracking and traceback to identify the node that generates road traffic.

End to end delay

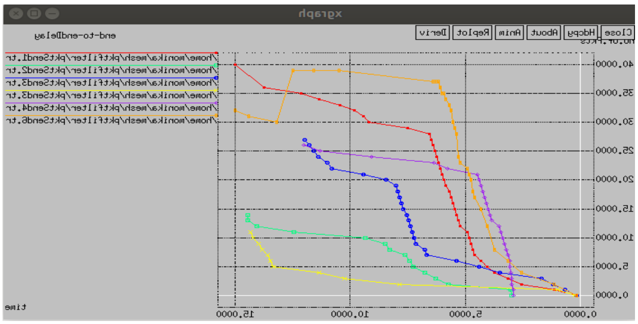

Fig 8: Number of Packets vs Time

Bandwidth

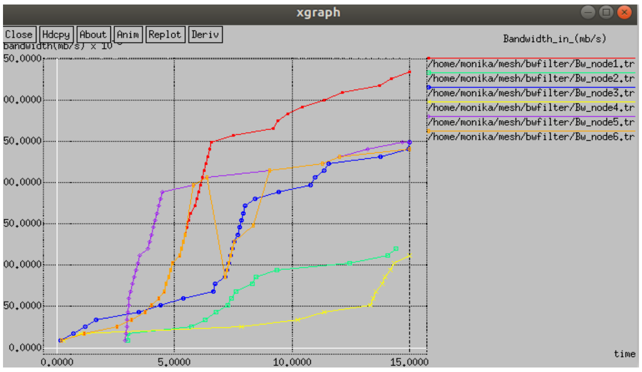

Fig 9: Bandwidth Vs. Time

Here we set the no of maximum packets sent it should be 35 Packets but from Figure 8 we can see that node 1 sends no of packets more than the limit value and from Figure 9 we see that no bandwidth required to node 1 is also high so we can say that node due to node 1 traffic occur by using We identified the node through monitoring and traceback procedures.

Table 2: Simulation Parameter

Simulator	**Network Simulator 2.35**
Number of nodes	26
Propagation type	Two ray ground
Packet size	1000 byte
Interface type	Phy /wireless
Mac type	IEEE 802.11p
Queue length	50 Packet
Traffic type	UDP
Simulation time	100 sec

7.1.2. Network Topology for GBC

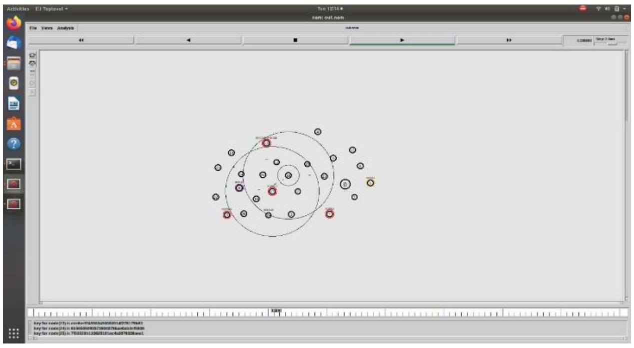

Fig 10: Network Animation using NAM

In this network topology, we consider 26 nodes for evaluating the QoS parameter

7.2. Performance Evaluation

7.2.1. Throughput

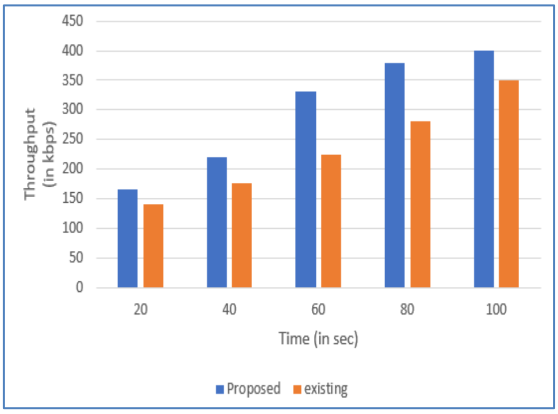

Fig 11: Bar graph of Throughput vs Time

Throughput is an important parameter of Quality of Services(QoS) to track network utilization so from the above diagram we can see that there is a significant improvement in Throughput by using a proposed approach that is Genetic Bee Colony Algorithm(GBC) as compared to Existing one.

7.2.2. Delay

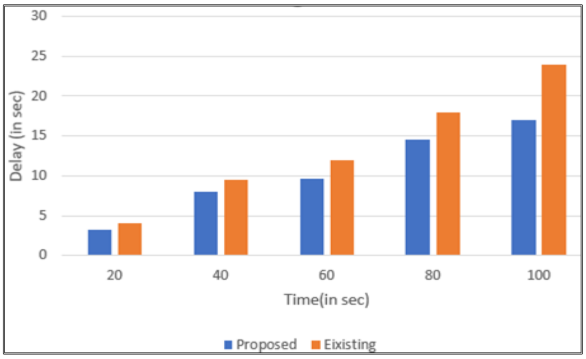

Fig 12: Bar Graph of Delay vs Time

It seems that for every simulation Delay for the existing approach is greater as compared to the Delay in the proposed Genetic Bee Colony Algorithm. We all know that Delay should be as minimal as possible. Delay is the most important parameter for safety applications.

7.2.3. Packet Delivery Ratio

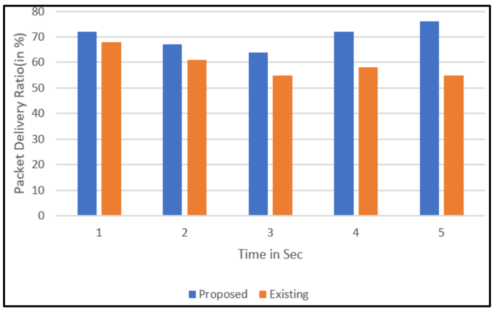

Fig 13: Bar graph of Packet Delivery Ratio vs Time

From the above diagram, we can see that by using the proposed approach that is the GBC algorithm we get a high Packet Delivery Ratio as compared to the existing one.

8. Discussion

The algorithm's performance was evaluated using simulations with various numbers of agents in the system. The Packet Delivery Ratio (PDR) is an important statistic for determining the efficiency and dependability of communication networks. It indicates the ratio of properly delivered packets to the total number of packets sent by the sender, providing information on the network's performance. Monitoring and traceback processes are used to detect nodes generating traffic congestion in a network architecture consisting of 9 nodes, one of which is designated as a Vehicle Data Monitoring node and the others as moving nodes. Setting a maximum packet limit of 35 packets allows you to detect excessive packet transmission from a node, such as node 1, which indicates possible traffic difficulties. However, issues remain in applying GBC to various problem domains, optimising its parameters, and assuring scalability for large-scale applications. Continued research and development efforts are required to fully realize GBC's potential and reap its benefits in a variety of domains, including engineering optimization problems, decision support systems in IoV and beyond.

Using the Genetic Bee Colony Algorithm (GBC) results in considerable improvements in Quality of Service (QoS) measures, particularly throughput and delay. Throughput, an important QoS indicator, improves significantly with the GBC technique compared to prior methods, indicating enhanced network performance. The performance of the proposed method is more efficient than the existing algorithm, and the Genetic Bee Colony algorithm requires less time than the existing algorithm. Furthermore, avoiding delays is critical, especially for safety applications that require quick data transfer. The GBC algorithm outperforms conventional approaches in terms of Packet Delivery Ratios, demonstrating its usefulness in maximizing data transmission and network efficiency. Thus, the use of the GBC algorithm helps to improve network performance and reliability, thereby improving the overall quality of service in communication networks.

9. Conclusion

The recent tendency in research has been to improve Internet accessibility, which has resulted in the creation of many technologies (for example, fog computing and edge computing). Bringing intelligence to the edge to improve decentralized administration in IoT-based systems, particularly in ITS. This work based on emerging vehicular technology Proposes a new technique for incorporating computational intelligence into interconnected Vehicles in terms of dynamic decision-making by using a new approach that is a Hybrid Bio-inspired algorithm that is an Artificial Bee Colony Algorithm and Genetic algorithm taking advantage of both Algorithms. Results have demonstrated that the proposed approach beats the current routing solutions in terms of packet delivery ratio and average end-to-end delay.

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