Hybrid Particle based Artificial Fish Swarm Optimization for Intelligent Path Selection in VANETs

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Abstract. Vehicular Ad-Hoc Networks (VANETs) is extremely developing nowadays in various applications of Intelligent Transport Systems (ITS). VANETs are highly mobile in nature, vehicles are travelling in high speed so due to this communication becomes ineffective in VANETs that results in the increase of delay and packet loss during data transmission. So it is essential to develop a model to obtain intelligent path selection in VANETs. In this paper, Hybrid Particle based Artificial Fish Swarm Optimization (HP-AFSO) approach is introduced to enhance the path selection process during the process communication in VANETs. The proposed HP-AFSO approach is the combination of particle swarm optimization (PSO) algorithm and Artificial Fish Swarm Optimization (AFSO) algorithm. In this network, vehicles are separated into two types which are ordinary vehicles and high-speed vehicles (smart vehicles). Here PSO algorithm is used to provide optimal path to the ordinary vehicles and AFSO algorithm provide optimal path to the smart vehicles where these vehicles acquire highest priority in path selection and transmission. As the result the high-speed vehicles are separated and those will not affect the network by increasing the congestion. The simulation is carried out in NS2.35 and four parameters are used for the analysis of performance evaluation such as packet delivery ratio, end to end delay, packet loss and routing overhead which is calculated in terms of varying number of vehicles. For the process of comparative analysis, the proposed results compared with the recent research works EPQHA and HKCRO. From the result analysis it is shown that the proposed HP-AFSO approach produced 5% to 8% better packet delivery ratio, 150ms to 200ms lower end to end delay, 50 packets to 150 packets lower packet loss and 270 packets to 300 packets lower routing overhead when compared with the earlier works EPQHA and HKCRO.

Keywords: VANETs, Hybrid Optimization, PSO, AFSO, Intelligent path selection.

1 Introduction

VANETs are a group of vehicles which communicates through two communication methods such as vehicles to vehicles and vehicles to infrastructure-based data transmissions. Each vehicle is equipped with an On-board Unit (OBU) in order to sense the transmitted messages and it acts like a vehicle interface unit. Due to its specifications it plays a major role in Intelligent Transportation Systems (ITS) [1-3]. Current vehicular technology combines huge number of vehicles in a network where communication become ineffective as well as traffic congestion is highly increased that reflects in the increase of packet loss and routing overhead. To overcome the network from such issues high effective communication with intelligent path selection becomes more essential [4-7]. To achieve this several optimization techniques are introduced but to control and monitor the communication of the high-speed networks hybrid optimization techniques are encouraged [8-9]. So, this paper hybrid optimization is performed by the combination of a two bio-inspired optimization algorithm such as particle swarm optimization (PSO) algorithm and Artificial Fish Swarm Optimization (AFSO) algorithm. The contribution of the research is defined below:

- In order to reduce the congestion in VANETs, intelligent path selection is introduced to reduce the packet loss and overhead in the networks.
- So that Hybrid Particle based Artificial Fish Swarm Optimization (HP-AFSO) approach is proposed which is the combination of as particle swarm optimization (PSO) algorithm and Artificial Fish Swarm Optimization (AFSO) algorithm.
- In VANETs nodes are moving in high speed so that congestion gets increased. This hybrid optimization is performed in two sections. At the initial stage of transmission PSO optimization is used and for high speed vehicles AFSO optimization is used. Through this method high speed vehicles are provided high priority and it get separated as well as they will move very faster so that the congestion of the network gets controlled.
- The performance of the proposed HP-AFSO approach is calculated through the parameters such as packet delivery ratio, end to end delay, packet loss and routing overhead.

The rest of the sections are organized as follows: Section 2 recent optimization techniques in VANETs are discussed. Section 3 demonstrates the basic principles of particle swarm optimization (PSO) algorithm and Artificial Fish Swarm Optimization (AFSO) algorithm. Section 4 elaborates the proposed HP-AFSO approach. Section 5 Results and performance analysis are stated. Section 6 conclusion and future work are discussed.

2 Related Works

In [10], proposed an optimization-based routing protocol to improve the performance of VANETs. The routing protocol used is Ad-hoc On-demand Distance Vector (AODV) and the optimization technique is Ant Colony Optimization (ACO). This method produces high throughput and data transmission rate but fails to produce low overhead during communication. In [11-14], proposed a Reliability Aware routing model for VANETs with the presence of Multi-Objective Optimization with includes the principle of Gaussian Mutation Harmony Searching. This method achieves high data transmission rate and low delay but but fails to produce low overhead. In [15], presented a Multi-Objective Harris Hawks Optimization model to improve the performance of VANETs by achieving high data transmission rate and throughput. However, this method is not suitable for the network with huge vehicle density. In [16-17], proposed a clustering approach to enhance the energy efficiency of the network. This method performs inter and intra cluster cooperative communication with cross-layer optimization. It improves the throughput of the network but fails to produce lower overhead. In [18-21], introduced an improved network optimization technique to generate high throughput and packet delivery ratio during communication. This method achieves moderate results and it is not suitable for the high speed VANETs.

In [22], designed a clustering approach which can able to perform data forwarding in most effective manner as well as multi-objective optimization is performed using firefly algorithm. This method greatly improves the packet delivery ratio and reduces the end-to-end delay using data forwarding and probabilistic forwarding technique. However, it fails to produce lower overhead. In [23], propose a novel approach to achieve faster data transmission in VANET called Hybrid Genetic Firefly Algorithm-based Routing Protocol (HGFA). It is method both the advantage of the genetic algorithm and firefly algorithm is combination to produce effective performance in VANETs communication. The overall performance is moderate but the overhead is high in the method. In [24], proposed an improved Ant Colony Optimization in terms of reducing the overhead. This method produced high throughput and packet delivery ratio with lower delay. However, this approach works with the network of lower density of vehicles and it is not suitable for the network with high speed and density. In [25], presented a improved routing protocol with the combination of Connectivity Aware Routing (CAR) and Greedy Perimeter Stateless Routing (GPSR) to enhance the effective of VANETs communication. This method achieves higher packet delivery ratio and throughput as well as lower overhead and delay. Only the density and the bandwidth utility of the vehicles are lower.

In [26], proposed a cluster-based hybrid optimization approach with the combination of K-means algorithm and Scatter Search optimization algorithm to improve the path selection during the process of communication between the source and the destination in VANETs. These methods produce better results in terms of overhead and delay. However, throughput, density of the vehicles and bandwidth utilization is moderate in this network. In [27], proposed a novel approach to provide intelligent transmission in VANETs. A hybrid machine learning method is combined with meta-heuristics routing approach to improve the stability and effectiveness VANETs communication. Through unsupervised clustering approach effective path selection and maintenance is performed in VANETs, this method achieves high throughput and packet delivery ratio but the produce high overhead in some situation. Once after analyzing the earlier research, it is understood that the effectiveness of communication in VANETs still need an attention. So, in this paper a hybrid optimization with the combination of as particle swarm optimization (PSO) algorithm and Artificial Fish Swarm Optimization is performed and it is elaborated in the upcoming sections.

3 Network Model

Vehicular communication is the combination of ordinary vehicles and high speed vehicles. Through high speed vehicles congestion occurrence are more that affects the overall performance of the network. So in this proposed HP-AFSO approach optimization is performed in spitted way for the ordinary vehicles and high speed vehicles. To find the optimal path between the ordinary vehicles Particle Swarm Optimization (PSO) technique is performed and to find the optimal path for the high speed vehicles Artificial Fish Swarm Optimization (AFSO) performed. In the section the principles of these algorithms are discussed. In section (4) the hybrid optimization technique is elaborated. The work flow of the proposed HP-AFSO approach is shown in the figure 1.

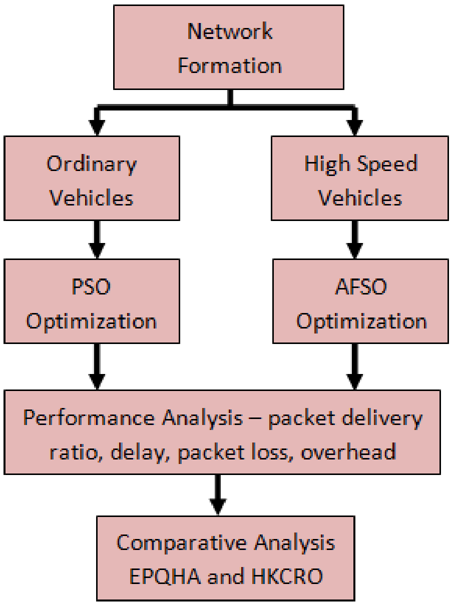

Fig. 1. Work flow of the proposed HP-AFSO approach

3.1 Background of Particle Swarm Optimization (PSO)

Particle Swarm Optimization (PSO) is one among the nature inspired optimization techniques which is used to find the optimal path between the source and the destination using the behavior of the bird's and school of fish. In PSO algorithm each particles (vehicles) selects its own location to search for the neighbors to reach the destination through local search and global search process. Hence PSO is a position-based optimization technique it becomes suitable for finding optimal path between the vehicles. According to the food searching action of bird's optimal path selection is initiated in PSO and followed by that the best finest path is chosen. The parameters considered for the process of best finest path are position, velocity and distance of the particle. According to these parameters' highest fitness value of the path is chosen the packets are transmitted in that path. This is the basic principle of PSO optimization process.

3.2 Background of Artificial Fish Swarm Optimization (AFSO)

Artificial Fish Swarm Optimization (AFSO) is a bio-inspired approach which copies the behavior of the fish to find the optimal path from the source to the destination. In this algorithm, swarm intelligence is combined with artificial intelligence to solve the optimization issues in the network. Hence AFSO is a dynamic search technique it gets more suitable for VANETs based communication system. The praying, swarming as well as the neighbor search characteristics of the fish is imitated in this method. Due to its intelligence AFSO becomes one among the best optimization technique to solve the path selection issues of the high-speed networks. The natural fish characteristics and the artificial fish characteristics are combined to measure the fitness function value. So, it can able to provide better results compared with any other optimization techniques as well as it is most suitable for high speed mobility-based networks.

4 Hybrid Particle based Artificial Fish Swarm Optimization (HP-AFSO) Approach

The basic principles of PSO algorithm and AFSO algorithm is elaborated in the sections (3.1) and (3.2). In order to achieve effective communication in optimal manner PSO and AFSO algorithm is combined together. VANETs are the combination of ordinary vehicles and high-speed vehicles. To achieve better performance in this proposed work the optimization techniques are spitted between the ordinary vehicles and high-speed vehicles. To obtain optimal path between the ordinary vehicles PSO algorithm is used and to obtain the optimal path between the high-speed vehicles AFSO algorithm is used. This spitted method improves the effective and stability of the VANETs during the process of communication. Both the optimization model is elaborated below.

4.1 PSO optimization for ordinary vehicles

particle initialization: population of the particle is determined as P_N where N denotes the dimension.

Fitness function evaluation using the parameters such as position, velocity and speed.

Initial best position P_{best}= P_{best}+ 1 then update P_{best}.

Final global position G_{best}, determines best among all the particles.

Fitness value calculation according to the parameters = $F_{value} = \frac{\sum_{i=1}^{N}(\alpha * dis_{(x,y)}) + (\beta * vel_{(x,y)}) + (\gamma * speed_{(x,y)})}{time_{(x,y)}}$;

Where α, β and γ are the experimental constants that satisfies the condition $\alpha + \beta + \gamma = 1$.

Through this F_{value} optimal path is selected among the ordinary vehicles

4.2 AFSO optimization for high-speed vehicles

particle initialization for AFSO algorithm.

Parameter settings are random such as artificial swarm position, considered two artificial swarms AS_1 and AS_2. The artificial fish is denoted as η with its current position P and P varies according to the movement of η then P = P + 1 which is denoted as P_1

at the initial condition random distribution rate is measured = $AS_{RD} = \frac{\sum_{i=1}^{n} P_1 - P}{|\sum_{i=1}^{n} P_1 - P|}$

Step size calculation of the artificial fish = $AS_{Step} = \frac{Step_{max} * \eta}{Step_{min}}$

Random behavior analysis – it is a default characteristic of the artificial fish to find the next location which is the summation of the random distribution rate and the step size of the artificial fish = $AS_{RB} = (\alpha_1 * AS_{RD}) + (\beta_1 * AS_{Step})$, Where α_1 and β_1 are the experimental constants that satisfies the condition $\alpha_1 + \beta_1 = 1$.

Through this AS_{RB} value optimal path is selected among the high-speed vehicles.

5 Performance Analyses

Simulation of the proposed HP-AFSO approach is carried out in NS2.35 software under Ubuntu 16.04 Operating System. NS2.35 is constructed using two languages; they are Tool Command Language (TCL) (front end) and C++ language (back end). The simulation area is 3000m*3000m. The performance of the proposed HP-AFSO approach and the comparative protocols such as EPQHA [14] and HKCRO [15] are calculated based on the parameters such as packet delivery ratio, end to end delay, packet loss and routing overhead. The simulation parameters are shown in the table 1.

Table 1. Simulation Parameters.

Input Parameters	Values
Operating System	Ubuntu 16.04
Software	NS-2.35
Mobility Generator	MOVE and SUMO
Running Time	200 ms
Simulation Area	4000m*4000m
Vehicle Density	100 to 1000 Vehicles
Antenna Type	Omni-directional Antenna
Propagation Model	Two Ray Ground Model
Queue Type	DropTail
Topology	Urban
Road Direction	Two way
Speed	100 km/hr
Connection Range	Multiple
Packet Size	1024 Bytes

5.1 Packet Delivery Ratio:

It is defined as the rate of total amount of packet received by the destination to the total amount of packets sent from the source. Figure 2 shows the analysis of the proposed HP-AFSO approach and it is compared with the earlier method such as EPQHA and HKCRO in terms of packet delivery ratio. The packet delivery ratio achieved by the proposed HP-AFSO is higher than the earlier methods. This is achieved using hybrid optimization for optimal path selection in VANETs.

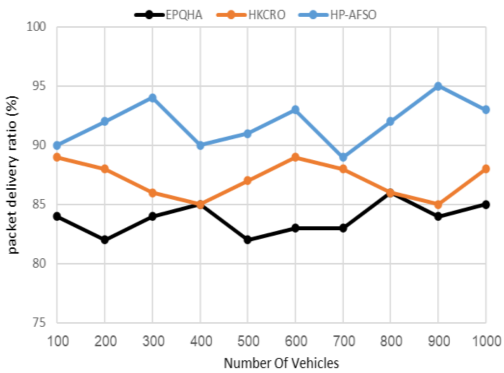

Fig. 2. Packet Delivery Ratio Calculation

Table 2. shows the packet delivery ratio value analysis of the methods used for this research and comparison. The packet delivery ratio achieved by the protocols such as EPQHA (85%), HKCRO (88%) and the proposed HP-AFSO (93%). From this measures it is proven that the packet delivery ratio of the proposed HP-AFSO is 5% to 8% better than earlier research works.

Table 2. Packet Delivery Ratio Values

Number of vehicles	EPQHA	HKCRO	HP-AFSO
100	84	89	90
200	82	88	92
300	84	86	94
400	85	85	90
500	82	87	91
600	83	89	93
700	83	88	89
800	86	86	92
900	84	85	95
1000	85	88	93

5.2 End to end delay

It is defined as the time taken by the sender to receive the destination for the entire communication. Figure 3 shows the analysis of the proposed HP-AFSO approach and it is compared with the earlier method such as EPQHA and HKCRO in terms of end-to-end delay. The end-to-end delay produced by the proposed HP-AFSO is lower than the earlier methods. In order to effective communication in VANETs hybrid optimization methods are considered in practice. PSO and AFSO algorithm greatly performed to reduce the end-to-end delay of the network.

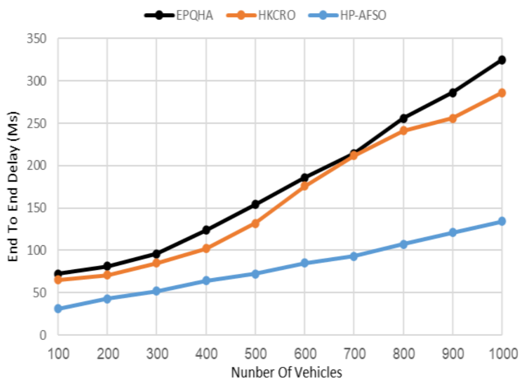

Fig. 3. End to end delay Calculation

Table 3. shows the end to end delay value analysis of the methods present in this research and comparison. The end to end delay produced by the protocols such as EPQHA (325ms), HKCRO (286ms) and the proposed HP-AFSO (134ms). From this measure it is proven that the end to end delay of the proposed HP-AFSO is 150ms to 200ms lower than earlier research works.

Table 3. End to end delay Values

Number of vehicles	EPQHA	HKCRO	HP-AFSO
100	72	65	31
200	81	71	43
300	96	85	52
400	124	102	64
500	154	132	72
600	186	176	85
700	214	212	93
800	256	241	107
900	286	256	121
1000	325	286	134

5.3 Packet Loss

It is defined as the packet loss produced during the data transmission in the networks. Figure 4 shows the analysis of the proposed HP-AFSO approach and it is compared with the earlier method such as EPQHA and HKCRO in terms of packet loss. The packet loss produced by the proposed HP-AFSO is lower than the earlier methods. By the reason of using hybrid optimization in the network packets are reached the destination in an optimal way with congestion occurrences that reflects in the reduction of packet loss during transmission.

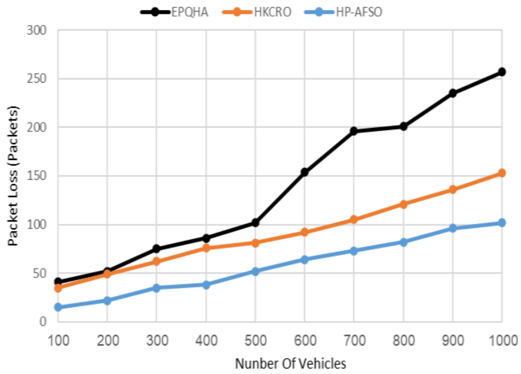

Fig. 4. Packet Loss Calculation

Table 4. shows the packet loss value analysis of the methods used for this research and comparison. The packet loss produced by the protocols such as EPQHA (257 packets), HKCRO (153 packets) and the proposed HP-AFSO (102 packets). From these measures it is proven that the packet loss of the proposed HP-AFSO is 50 packets to 150 packets lower than earlier research works.

Table 4. Packet Loss Values

Number of vehicles	EPQHA	HKCRO	HP-AFSO
100	41	35	15
200	52	49	22
300	75	62	35
400	86	76	38
500	102	81	52
600	154	92	64
700	196	105	73
800	201	121	82
900	235	136	96
1000	257	153	102

5.4 Routing Overhead

It is defined as the measure of forwarded control packets which return back to the source. Figure 5 shows the analysis of the proposed HP-AFSO approach and it is compared with the earlier method such as EPQHA and HKCRO in terms of routing overhead. The routing overhead produced by the proposed HP-AFSO is lower than the earlier methods. Due to hybrid optimization the data transmission is enhanced that reflects in the minimization of packet loss.

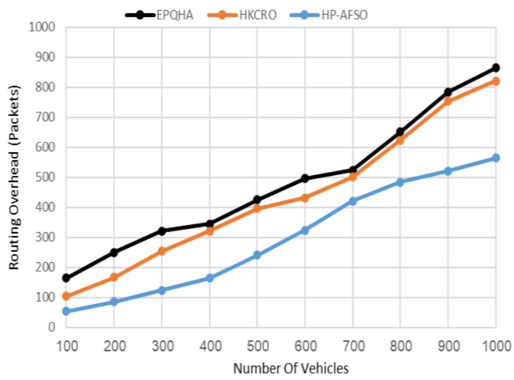

Fig. 5. Routing Overhead Calculation

Table 5 shows the routing overhead value analysis of the methods used for this research and comparison. The routing overhead produced by the protocols such as EPQHA (864 packets), HKCRO (821 packets) and the proposed HP-AFSO (564 packets). From these measures it is proven that the routing overhead of the proposed HP-AFSO is 270 packets to 300 packets lower than earlier research works.

Table 5. Routing Overhead Values

Number of vehicles	EPQHA	HKCRO	HP-AFSO
100	165	104	54
200	250	168	86
300	321	254	124
400	345	321	165
500	425	396	241
600	496	432	324
700	524	502	421
800	652	624	485
900	784	754	521
1000	864	821	564

6 Conclusion:

In this paper, the performance of current VANETs technology is analyzed and the major drawbacks are found such as due to huge mobility delay, packet loss and routing overhead is increased in the VANETs. As so to overcome this drawback intelligent path selection method is introduced in VANETs and it is called as Hybrid Particle based Artificial Fish Swarm Optimization (HP-AFSO). It is the combination of particle swarm optimization (PSO) algorithm and Artificial Fish Swarm Optimization (AFSO) algorithm. By using this HP-AFSO approach intelligent path selection during the process of data transmission between the source and the destination is performed. For the process of performance analysis the considered parameters are packet delivery ratio, end to end delay, packet loss and routing overhead and it is compared with the earlier works called as EPQHA and HKCRO. In the comparative results analysis it shown that by the use of the proposed HP-AFSO approach, packet delivery ratio of the network is increased up to 8%, end to end delay of the network is reduced up to 200ms, packet loss during communication is reduced up to 150 packets and routing overhead is reduced up to 300 packets. In future, to further improve the security of the network's authentication approach needs to get concentrated.

References

1. Bhushan Yelure and Shefali Sonavane, "Particle Swarm Optimization based Routing Method for Vehicular Ad-hoc Network", International Conference on Communication and Signal Processing (ICCSP), 2020.
2. Malik, R. Q., Ramli, K. N., Kareem, Z. H., Habelalmatee, M. I., Abbas, A. H., & Alamoody, A. (2020, September). An overview on V2P communication system: Architecture and application. In 2020 3rd International Conference on Engineering Technology and its Applications (IICETA) (pp. 174-178). IEEE.
3. Habelalmateen, M. I., Abbas, A. H., Audah, L., & Alduais, N. A. M. (2020). Dynamic multiagent method to avoid duplicated information at intersections in VANETs. TELKOMNIKA (Telecommunication Computing Electronics and Control), 18(2), 613-621.
4. 2. Sanjay K. Dhurandher, Jagdeep Singh, et.al, "Geometric Shapes-based PSO Approach for Routing in Vehicular Networks", IEEE AFRICON, 2019.
5. 3. Sadip Midya, Asmita Roy, et.al, "PSO based Optimized Resource Allocation in three tier Cloud Architecture for VANET", Fourth International Conference on Research in Computational Intelligence and Communication Networks (ICRCICN), 2018.
6. Abbas, A. H., Habelalmateen, M. I., Audah, L., & Alduais, N. A. M. (2019). A novel intelligent cluster-head (ICH) to mitigate the handover problem of clustering in VANETs. International Journal of Advanced Computer Science and Applications, 10(6).
7. Abbas, A. H., Audah, L., & Alduais, N. A. M. (2018, October). An efficient load balance algorithm for vehicular ad-hoc network. In 2018 Electrical Power, Electronics, Communications, Controls and Informatics Seminar (EECCIS) (pp. 207-212). IEEE.
8. Xiaoyu Gao, Lei Yu and Shangyang He, "Optimization of Sorting Activities in Automatic Storage and Retrieval Systems Based on Improved Artificial Fish Swarm Algorithm", International Conference on Robotics and Automation Engineering (ICRAE), 2018.
9. Abbas, A. H., Mansour, H. S., & Al-Fatlawi, A. H. (2022). Self-Adaptive Efficient Dynamic Multi-Hop Clustering (SA-EDMC) Approach for Improving VANET's Performance. International Journal of Interactive Mobile Technologies, 17(14).
10. Y. N. Praharshitha, A. Chandrika, et.al, "Route Optimization of Vehicular Ad-hoc Networks (VANETs)", International Conference on Intelligent Engineering and Management (ICIEM), 2022.
11. S. A. Rashid, M. Alhartomi, et.al, "Reliability-Aware Multi-Objective Optimization-Based Routing Protocol for VANETs Using Enhanced Gaussian Mutation Harmony Searching", IEEE Access, vol. 10, pp. 26613 – 26627, 2022.

12. Mostafa, S. A., Mustapha, A., Ramli, A. A., Jubair, M. A., Hassan, M. H., & Abbas, A. H. (2020, July). Comparative analysis to the performance of three Mobile ad-hoc network routing protocols in time-critical events of search and rescue missions. In International Conference on Applied Human Factors and Ergonomics (pp. 117-123). Springer, Cham.
13. Jubair, M. A., Hassan, M. H., Mostafa, S. A., Mahdin, H., Mustapha, A., Audah, L. H., & Abbas, A. H. (2019). Competitive analysis of single and multi-path routing protocols in mobile Ad-Hoc network. Indonesian Journal of Electrical Engineering and Computer Science, 14(2).
14. Hassan, M. H., Jubair, M. A., Mostafa, S. A., Kamaludin, H., Mustapha, A., Fudzee, M. F. M., & Mahdin, H. (2020). A general framework of genetic multi-agent routing protocol for improving the performance of MANET environment. IAES International Journal of Artificial Intelligence, 9(2), 310.
15. M. A. Hossain, R. M. Noor, et.al, “Multi-Objective Harris Hawks Optimization Algorithm Based 2-Hop Routing Algorithm for CR-VANET”, IEEE Access, vol. 9, pp. 58230 – 58242, 2021.
16. F. Yang, J. Han, et.al, “Spectral Efficiency Optimization and Interference Management for Multi-Hop D2D Communications in VANETs”, IEEE Transactions on Vehicular Technology, vol. 69, no. 6, pp. 6422 – 6436, 2020.
17. Abbas, A. H., Ahmed, A. J., & Rashid, S. A. (2022). A Cross-Layer Approach MAC/NET with Updated-GA (MNUG-CLA)-Based Routing Protocol for VANET Network. World Electric Vehicle Journal, 13(5), 87.
18. Aznor Hanah, Rohani S. M. Farook, et.al, “Cross-layer optimization for VANET city scenario using Taguchi mechanism”, IEEE International Conference on Recent Advances and Innovations in Engineering (ICRAIE), 2021.
19. Abbas, A. H., Habelalmateen, M. I., Jurdi, S., Audah, L., & Alduais, N. A. M. (2019, November). GPS based location monitoring system with geo-fencing capabilities. In AIP Conference Proceedings (Vol. 2173, No. 1, p. 020014). AIP Publishing LLC
20. Najim, A. H., Mansour, H. S., & Abbas, A. H. (2022). Characteristic Analysis of Queue Theory in Wi-Fi Applications Using OPNET 14.5 Modeler. Eastern-European Journal of Enterprise Technologies, 2(9), 116.
21. Abdulbari, A. A., Abdul Rahim, S. K., Abedi, F., Soh, P. J., Hashim, A., Qays, R.,& Zeain, M. Y. (2022). Single-Layer Planar Monopole Antenna-Based Artificial Magnetic Conductor (AMC). International Journal of Antennas and Propagation, 2022.
22. Mansour, H. S., Mutar, M. H., Aziz, I. A., Mostafa, S. A., Mahdin, H., Abbas, A. H.,& Jubair, M. A. (2022). Cross-Layer and Energy-Aware AODV Routing Protocol for Flying Ad-Hoc Networks. Sustainability, 14(15), 8980.
23. G. D. Singh, M. Prateek, et.al, “Hybrid Genetic Firefly Algorithm-Based Routing Protocol for VANETs”, IEEE Access, vol. 10, pp. 9142 – 9151, 2022.
24. S. Ghosh and I. S. Misra, et.al, “Enhanced QoS Performance with Reduced Route Overhead by Ant Colony Optimization Algorithm for VANET”, IEEE Applied Signal Processing Conference (ASPCON), 2020.
25. Atul R. Deshmukh, P. Nirmal and S. S. Dorle, “A New Approach for Position Based Routing Protocols Based on Ant Colony Optimization (ACO) Technique in Vehicular Ad Hoc Network (VANET)”, International Conference on Intelligent Technologies (CONIT), 2021.
26. Najim, A. H., Mansour, H. S., & Abbas, A. H. (2022). Characteristic Analysis of Queue Theory in Wi-Fi Applications Using OPNET 14.5 Modeler. Eastern-European Journal of Enterprise Technologies, 2(9), 116.
27. Aveen Othman, “MetoidS: Hybrid K-Medoids-Meta Heuristic Clustering-Based Routing Optimization in Vehicular Ad-Hoc Networks”, Science Journal of University of Zakho, vol. 10, no. 2, pp. 60-65, 2022.Smith, T.F., Waterman, M.S.: Identification of Common Molecular Subsequences. J. Mol. Biol. 147, 195--197 (1981).