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Investigation on Novel Based Metaheuristic Algorithms for Combinatorial Optimization Problems in Ad Hoc Networks

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***Abstract*—**Routing in MANET is extremely challenging because of MANETs dynamic features, its limited bandwidth, frequent topology changes caused by node mobility and power energy consumption. In order to efficiently transmit data to destinations, the applicable routing algorithms must be implemented in mobile ad-hoc networks. Thus we can increase the efficiency of the routing by satisfying the Quality of Service (QoS) parameters by developing routing algorithms for MANETs. The algorithms that are inspired by the principles of natural biological evolution and distributed collective behavior of social colonies have shown excellence in dealing with complex optimization problems and are becoming more popular. This paper presents a survey on few meta-heuristic algorithms and naturally-inspired algorithms.

***Keywords*—**Ant colony optimization, genetic algorithm, Naturally-inspired algorithms and particle swarm optimization.

I. Introduction

MOBILE AD HOC NETWORK (MANET) is a self-configuring infrastructure less network in which the mobile devices are connected by wireless (air medium). Devices in a MANET are free to move independently in any direction, and also can change its links to any other devices frequently. The process of moving a packet of data from source to destination is known as routing which means that the process of selecting best paths in a network. Routing can also be defined as the process of exchanging information from one host to another host in a network [39]. A routing protocol uses software and routing algorithms to determine optimal network data transfer and communication paths between network nodes. In biological inspired artificial intelligence concepts like the approach of swarm intelligence, where the behavior of social insects like ants or bees is copied and with the help of that the communication is carried out exclusively through the environment. The social insects like ants, bees, wasps, and termites are live in colonies. In a social insect colony, every individual seems to act independently of others, but the colony functions as a planned unit [1]. Several algorithms usually inspired by natural phenomena have been proposed in many literatures. Among them, some meta-heuristic search algorithms with population-based framework have shown satisfactory capabilities to handle high dimension combinatorial optimization problems [40].

Lazar and Reynolds defines that the words 'Meta' and 'heuristics' are Greek words. The authors also states that the meaning for the word 'Meta' is 'beyond' or 'higher level' and 'heuristic' is 'to know' or 'to find' or 'to discover' [30].

Some successful meta-heuristics conceived in the last few years are Ant Colony Optimization (ACO) and Bee Colony Optimization (BCO). They are population-based methods that make use of the global behavior that emerges from the local interaction of individuals with one another and with their environment.

The inspiring source of ACO is the foraging behavior of real ants. The ant deposits a chemical pheromone trail on the ground when it forages. The quantity of pheromone deposited, depends upon the quantity and quality of the food that will guide other ants to the food source. The ants find shortest paths between their nest and food sources with the help of indirect communication between them via pheromone trails.

The Artificial Bee Colony (ABC) [36], [2] algorithm is a swarm based meta-heuristic algorithm for solving combinatorial optimization problems. The intelligent foraging behavior of honey bees is the inspiration for the Artificial Bee Colony Algorithm. This algorithm is specifically based on the model for the foraging behavior of honey bee colonies. The foraging behavior of bees has been adapted as a useful computational algorithm to solve complex problems in different domains.

Particle swarm optimization (PSO) [35], [3] is a heuristic global optimization method and also an optimization algorithm, which is based on swarm intelligence approach. It comes from the study on the bird and fish flock movement behavior. This algorithm is widely used and rapidly developed for its easy implementation and few particles required being tuned.

II. Related Works

Meta-heuristic algorithms have been devised to find the proper solutions for the NP-hard problems and traveling Salesman Problem in a reasonable time. Many meta-heuristic algorithms have been proposed earlier. The population based meta-heuristics algorithms play a vital role in finding the best optimal paths in routing.

Genetic Algorithm (GA) [31], a population-based meta-

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heuristic algorithm was introduced by Holland in the year of 1975. This algorithm solves different kinds of optimization problems and also it finds the best solution for many problems. Genetic Algorithm can be easily combined with other algorithms.

Tabu Search (TS) is a meta-heuristic local search algorithm introduced by Glover and McMillan [32] in 1986 and it was formalized in later years of 1989 and 1990 [33], [34]. In local search, the near neighbors of each solution are checked in order to find an improved solution.

Another population-based algorithm is Particle Swarm Optimization (PSO) [35] obtained by Kennedy and Eberhart in 1995. It is a global optimization algorithm which the best solution can be represented as a point or surface in a multi-dimensional search space. In this algorithm the fitness values of the particles are used to estimate them. It obtains the best solution based on the particles which has best fitness values.

Multicast Ad-hoc On-demand Distance Vector (MAODV) protocol which is based on Particle Swarm Optimization approach for MANET is proposed in 2013 [42]. The authors had studied the performance of the MANET with regard to packet delivery ratio, jitter and end-to-end delay. This PSO based MAODV protocol increases the packet delivery ratio, reduces end to end delay and jitter and also enhances the accuracy in prediction of congestion and link breaks.

Ant Colony Optimization (ACO) [37], [38] algorithm is another meta-heuristic approach proposed by Dorigo in 1992. This algorithm replicas the behavior of ants foraging and is useful for problems which require finding the shortest path. The inspiration source of Ant Colony Optimization algorithm is its pheromone trails. The ants lay down its pheromones to direct other ants to the food sources.

The Artificial Bee Colony (ABC) [36] algorithm is presented by Karaboga in 2005 is also a population based approach. The inspiration source for this algorithm is the brainy behavior of the honey bees. Employed bee phase, onlooker bee phase and scout bee phase are the phases used in the proposed algorithm. The Artificial Bee Colony algorithm finds the best solution by applying these three phases [4].

Dhamodharan et al. [17] state that the Swarm Intelligence based algorithmic approaches are best for providing energy-aware; loop free and multi-path routing in mobile ad hoc networks. Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO) improve the efficiency in obtaining the best solution.

Jianping Wang et al. [5] presented a Hybrid Ant Colony Optimization routing algorithm, named as HOPNET in 2009. This hybrid algorithm is based on ACO and zone routing framework. This HOPNET algorithm extracts some of the features from ZRP and DSR protocols. The comparison result of HOPNET with AntHocNet shows that HOPNET is highly scalable for low and high mobility. It is also proven that HOPNET is better than AODV.

An improved ant colony-based multi-constrained QoS energy-saving routing algorithm (IAMQER) was proposed by WANG Ya-li et al. [23] in 2014. This IAMQER algorithm increases the network throughput, improves the packet delivery ratio and reduces the network energy consumption. The performance of IAMQER algorithm is compared with the on-demand MANET routing protocol AODV. Thus, IAMQER increases the packet delivery ratio as well as reduces the packet loss ratio and reduces the average end-to-end delay. And also the energy consumption of IAMQER is low when compared with AODV and Dijkstra algorithm.

Manoj Kumar Patel et al. 2014 [25] presented a swarming agent based intelligent hybrid algorithm (HACOPSO), which is based on the concept of ACO and PSO algorithms. Authors compared the results of proposed algorithm with existing algorithms PSOTREE [41] and TGBACA [43]. Thus it is proven that the complexity of HACOPSO is comparable with the existing algorithms.

The comparison table for various approaches based on naturally inspired routing algorithms proposed so far is represented in Table I. The table contains the methodologies, performance metrics and parametric analysis used by the authors for each approaches mostly based on the concept of population based meta-heuristics.

TABLE I
COMPARISON TABLE

S.No	Title	Methodology	Performance Metrics	Parametric Analysis	Conclusion
1	HOPNET: A hybrid ant colony optimization routing algorithm for mobile ad hoc network [5]	Proposed a hybrid routing algorithm for MANETs based on ACO and zone routing framework of border casting.	End to end delay, delivery ratio and control overhead	The algorithm is efficient and is comparatively better than AODV for end to end delay and delivery ratio. The overhead decreases and is better than AODV as the network size increases.	The result shows that HOPNET outperforms AntHocNet and AODV.
2	Route Optimization in Manets with ACO And GA [6]	In this paper, Ant Colony Optimization for finding out best possible paths, along with Genetic Algorithm which helps in giving the globally optimal solution from all the best possible paths which were produced by Ant Colony Optimization is used.	Delay in packet delivery	Proposed algorithm GA-API overcomes the delay in packet delivery by producing the shortest path and also overcomes the problem of communication interruption due to node or link failure by finding multiple paths between pair of source and destination nodes.	GA-API provides satisfactory or optimum solutions, with much less computational effort. This algorithm works well for large, complex problems with greater dimensionality.
3	Genetic Algorithms With Immigrants and Memory Schemes for Dynamic Shortest Path Routing Problems in Mobile Ad Hoc Networks [7]	Proposed to use GAs with immigrants and memory schemes to solve the dynamic SP routing problem in MANETs.	Packet delivery ratio	Immigrants and memory schemes enhance the performance of GAs for the DSPRP in MANETs.	The experimental results show that these immigrants and memory-based GAs can quickly adapt to the network topology changes and produce high-quality solutions.
4	QoS multicast routing using a quantum-behaved particle swarm optimization algorithm [8]	Proposes the modified quantum-behaved particle swarm optimization (QPSO) method for QoS multicast routing.	Delay-jitter, bandwidth and cost, respectively	QPSO generates the higher-quality solutions on the multicast routing problems.	The simulation results show the efficiency of the proposed method on QoS the routing problem and its superiority to the methods based on PSO and GA.
5	Applied Multiagent Ant Based Hybrid Routing Algorithm For Mobile Ad Hoc Networks [9]	The proposed algorithm uses Ant like agents to discover and maintain paths in a MANET with dynamic topology.	Latency, end to end delay and packet delivery ratio.	The proposed hybrid protocol reduces route discovery latency and the end-to end delay by providing high connectivity without requiring much of the scarce network capacity.	Results shows that Multi agent Ants based Routing Algorithm (MARA) can outperform AODV, both in terms of end-to-end delay and packet delivery ratio.
6	Energy Efficient Routing in Mobile Ad Hoc Networks by Using Honey Bee Mating Optimization [10]	This paper employs Honey Bee Mating Optimization (HBMO) principles to present a new routing protocol, called HBMO-TORA algorithm.	Packet delivery ratio, network life time, system life time and end-to-end delay.	Packet delivery ratio of HBMO-TORA is higher than TORA algorithm. End-to-end delay of HBMO-TORA is lower than TORA. The network life time and system life time of HBMO-TORA are higher than of TORA.	The simulation results indicated that the packet delivery ratio, network life time, system life time and end-to-end delay in HBMO-TORA are better than TORA routing protocol.
7	A Novel Adaptive Bio-Inspired Clustered Routing for MANET [11]	A new general framework has been proposed for achieving QoS and applies Artificial Bee Colony optimization Technique for effective optimal route discovery in MANET.	End-to-end delay, scalability and routing overhead.	Provide the optimal path and minimize the routing overhead and also provides QoS guarantees with ability for minimal end-to-end delay and enhanced scalability.	A novel adaptive Artificial Bee Colony optimization framework with cluster based environment provides scalability and guarantees QoS by minimizes the cluster maintenance overhead.
8	A Biologically Inspired QoS Routing Algorithm for Mobile Ad Hoc Networks [12]	Presents an Emergent Ad hoc Routing Algorithm with QoS provision (EARA-QoS).	Packet delivery ratio, Average ETE delay, Average delay jitter and Path optimality	The packet delivery is increased, as well as delay is reduced by using proposed algorithm.	Simulation results show that this algorithm performs equally well under the situations of various nodal mobility, network density and data loads.
9	Efficient Stagnation Avoidance For Manets With Local Repair Strategy Using Ant Colony Optimization [13]	The present work focuses on development of an efficient routing algorithm “Modified Termite algorithms” (MTA) for MANETs.	Throughput, bandwidth, end-to-end delay and routing overheads.	MTA enhances the performance of the network in terms of throughput, and reduction of End-to-end delay and routing overheads.	The stagnation problems can be overcome by fine tuning of the Pheromone concentration based on node stability factor.
10	Energy-aware multicast routing in manet based on particle swarm optimization [14]	This paper proposes a novel multicast routing in mobile Ad Hoc networks based on particle swarm optimization algorithm.	Speed, bandwidth, delay and power consumption.	Routing algorithm finds optimal path in minimum time, have better performance. The running time of PSO algorithm is smaller than GA algorithm. Then, the PSO algorithm can find optimal multicast tree in shortest time.	The proposed algorithm has better performance and efficiency than GA based algorithms.
11	Optimal Routing In Ad-Hoc Network Using Genetic	In this paper a genetic algorithm for solving the shortest path routing problem	Packet delivery and Forwarding factor, packet failure ratio.	The route failure probability is less in genetic Algorithm compared to DSR approach. The delay for	The proposed algorithm can search the solution space effectively and speedily compared with DSR

S.No	Title	Methodology	Performance Metrics	Parametric Analysis	Conclusion
	Algorithm [15]	is presented.		Genetic Algorithm is less than DSR	algorithm. It performs better and effectively even to the changes in the network due to node mobility and topology changes.
12	Genetic Algorithm for Energy-Efficient QoS Multicast Routing [16]	Presents an energy-efficient genetic algorithm mechanism to resolve quality of service (QoS) multicast routing problem, which is NP-complete.	End-to-end delay and energy cost	The proposed algorithm is a source-based algorithm which reduces energy consumption as well as end-to-end delay in route selection.	Simulation results show that the proposed algorithm is effective and efficient.
13	Bio Inspired and Evolutionary Approaches to Optimize MANET Routing [17]	In this paper we study some PSO and GA algorithms to optimize the MANET routing.	Mobility, overhead, end to end delay and energy awareness	Power consumptions, bandwidth and routing overhead are reduced using proposed algorithm	Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO) are more promising in providing loop free, energy-aware, and multi-path routing in mobile ad hoc.
14	An Efficient Ant Based QoS Aware Intelligent Temporally Ordered Routing Algorithm For MANETs [18]	Designed a new efficient and energy aware multipath routing algorithm based on ACO framework.	Network lifetime and packet loss and average end to end delay	Intelligent version of classical Temporally Ordered Routing Algorithm (TORA) increases network lifetime and decrease packet loss and average end to end delay.	Proposed algorithm decreases number of control packets which reduces routing overhead and utilizes bandwidth properly.
15	Analysis of Routing Protocols in AD HOC and Sensor Wireless Networks Based on Swarm Intelligence [19]	Presented the performance evaluation frameworks and Swarm Intelligence approaches (PSO, ACO) for routing protocols.	Routing overhead, route optimality, and energy consumption.	ACO approaches are very promising for route optimization in MANETs while PSO is very effective for load balancing and energy optimization in WSNs.	PSO and ACO based protocols are advantageous than other approaches applied for the routing optimization in ad hoc and wireless sensor networks.
16	Minimizing Energy Consumption in Wireless Ad hoc Networks with Meta-heuristics [20]	Genetic Algorithm (GA) and Simulated Annealing (SA) is compared to minimize the energy consumption in ad-hoc wireless networks.	Energy consumption	The minimum energy consumption generated by the GAF/GA is 7.716J while GAF/SA generated minimum energy of 7.650J.	Results show that GA and SA meta-heuristics are useful optimization techniques for minimizing the energy consumption in ad-hoc wireless networks.
17	Route Optimization in Manets with ACO And GA [21]	In this paper, Ant Colony Optimization for finding out best possible paths, along with Genetic Algorithm which helps in giving the globally optimal solution from all the best possible paths which were produced by Ant Colony Optimization is used.	Delay in packet delivery	Proposed algorithm GA-API overcomes the delay in packet delivery by producing the shortest path and also overcomes the problem of communication interruption due to node or link failure by finding multiple paths between pair of source and destination nodes.	GA-API provides satisfactory or optimum solutions, with much less computational effort. This algorithm works well for large, complex problems with greater dimensionality.
18	Routing Protocol Based on Grover's Searching Algorithm for Mobile Ad-hoc Networks [22]	Proposed a new routing model based on Grover's searching algorithm.	Delay and anti-jamming capability	The new routing protocol can effectively reduce the network delay, significantly reduce the number of routing hops and minimize the network BER to a certain extent.	Simulation results showed that compared with DSR, the new routing protocol performs effectively.
19	Improved ant colony-based multi-constrained QoS energy-saving routing and throughput optimization in wireless Ad-hoc networks [23]	An improved ant colony-based multi-constrained QoS energy-saving routing algorithm (IAMQER) is proposed.	Bandwidth, end-to-end delay, jitter, packet loss ratio, energy consumption	The proposed algorithm improves the performance of network in multi-constrained QoS routing by reducing average energy consumption and improves network packet delivery ratio.	The proposed IAMQER algorithm performs well and effectively.
20	OANTALG: An Orientation Based Ant Colony Algorithm for Mobile Ad Hoc Networks [24]	Proposed an orientation based ant algorithm (OANTALG) for Routing in MANETs.	Throughput, jitter, path length and packet drop ratio.	OANTALG can send more number of data packets than AODV, DSR, and HOPNET. The throughput in OANTALG is more than AODV, DSR and HOPNET. Average Jitter is also reduced.	The results obtained show that the proposed algorithm performs better than the other state of art algorithms.
21	A hybrid ACO/PSO based algorithm for QoS multicast routing problem [25]	Presented a swarming agent based intelligent algorithm using a hybrid Ant Colony Optimization (ACO)/ Particle Swarm Optimization (PSO) technique to optimize the multicast tree.	Delay, loss rate, Bandwidth and jitter	Algorithm is found to construct the multicast tree patterns more sensibly such that the tree patterns not only satisfy the QoS constraints, but also tries to minimize the tree cost.	The simulation results reveal that the proposed algorithm performs better than the existing algorithms.
22	BeeIP – A Swarm Intelligence based routing for wireless ad hoc Networks	This paper examines Swarm Intelligence based routing protocols, along with a newly proposed bee-inspired routing	Packet delivery ratio, Control overhead, Average end-to-end Delay, Average	In BeeIP, packet delivery ratio is higher. AODV and DSR are found to have more packet loss than BeeIP. Average throughput is less	The results obtained show that BeeIP generally outperforms the other protocols. Its biggest strength is seen when observing the average end-to-

S.No	Title	Methodology	Performance Metrics	Parametric Analysis	Conclusion
	[26]	protocol for providing multi-path routing in wireless ad hoc networks of mobile nodes.	throughput	than DSR and AODV.	end delay and packet delivery ratio.
23	Niched ant colony optimization with colony guides for QoS multicast routing [27]	Proposed a niched ant colony optimization with colony guides (NACOg) algorithm to tackle the MinC/DB problem.	Bandwidth, end-to-end delay, delay jitter, packet-loss ratio	Maximal end-to-end delay obtained by NACOg is low when compared with end-to-end delay of Genetic and KPP heuristic.	Results shows that the proposed NACOg algorithm produces the least cost QoS multicast trees compared to those obtained by genetic algorithm and the KPP heuristic.
24	Smart data packet ad hoc routing protocol [28]	Introduces a smart data packet routing protocol (SMART) based on swarm technology. Presented a new infrastructure where data packets are smart enough to guide themselves through best available route in the network.	Throughput, end to end delay, jitter and routing overhead	Improvement in the throughput and reduction in end to end delay and jitter compared to AODV and AntHocNet protocols.	Result shows that smart data protocol performs better than AODV and AntHocNet.
25	The performance of a hybrid routing intelligent algorithm in a mobile ad hoc network [29]	In this work, a hybrid routing intelligent algorithm that has an ant colony optimisation (ACO) algorithm and particle swarm optimisation (PSO) is used to improve the various metrics in MANET routing.	Distance, bandwidth, delay, load for a path and power consumption	The path outcome using the hybrid routing intelligent algorithm (PSO_ACO) has the shortest distance, a minimum delay, low power consumption, and low cost when compared with the individual performance of the ACO algorithm.	This hybrid routing intelligent algorithm has an improved performance when compared with the simple ACO algorithm in terms of delay, power consumption and communication cost.

Nancharaiah and Chandra Mohan evaluated the performance of a hybrid routing intelligent algorithm in 2014 [29]. Authors improved the various metrics of MANET using hybrid routing intelligent algorithm which has Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO) algorithms. The outcome result shows that the performance of hybrid routing intelligent algorithm (ACO_PSO) is higher than the performance of the individual ACO algorithm.

The above comparison table includes the approaches based on bio-inspired or naturally inspired population based meta-heuristic algorithms proposed since 2009-2014. From the table it is cleared that the meta-heuristic algorithms based on population based approach plays a vital role in improving the efficiency of the routing in Mobile Ad Hoc Networks. Especially, the Ant Colony Optimization (ACO) algorithm [37], [38], Genetic algorithm (GA) [31] and Particle Swarm Optimization (PSO) algorithm [35], have the ability to get combined with the other algorithms.

The performance of the approaches which has the combined features of the Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO) has the competence with the performance of other existing algorithms.

III. Conclusion

The efficiency of the mobile ad hoc network routing can be increased using the developed bio-inspired or naturally inspired routing algorithms. In this paper, survey of most important naturally inspired meta-heuristic algorithms with the population based approach is presented and compared. In these algorithms, several techniques have been considered to improve the performance of meta-heuristics in combinatorial optimization problem in Ad hoc networks. The proposals of new naturally inspired meta-heuristic algorithms to minimize the disadvantages of existing algorithms are improving year by year.

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