International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Optimizing Energy-Performance Trade-off in WSNs with a TABU Search-based Approach

Ketan Khullar[1] and Dr. Amit Doegar[2]

[1]M. E Computer Science and Engineering , NITTTR, Chandigarh
[2]Associate Prof, Dept of Computer science and Engineering, NITTTR, Chandigarh

ABSTRACT-

Wireless Sensor Networks (WSNs) face a critical challenge in balancing energy consumption with network performance. This paper proposes a novel approach utilizing a TABU Search algorithm to optimize the energy-performance trade-off in WSNs. The TABU Search, a metaheuristic optimization technique, explores the solution space while preventing revisiting recently evaluated solutions. This approach aims to find routing paths and network configurations that minimize energy expenditure while maintaining desired levels of network performance metrics, such as data delivery rate and latency. The paper details the integration of the TABU Search algorithm within an Energy-Performance Management System (EPMS) framework for WSNs. The effectiveness of the proposed approach is evaluated through simulations, comparing its performance to existing methods in terms of energy consumption, network lifetime, and other relevant metrics. The results are expected to demonstrate the efficacy of the TABU Search-based EPMS in optimizing WSN operation and extending network lifetime.

Keywords: Wireless Sensor Networks (WSNs),Energy consumption, Network performance, TABU Search algorithm, Optimization, Energy-performance trade-off, Metaheuristic optimization, Routing paths, Network configurations

1. Introduction

Wireless sensor networks (WSN) consisting of tiny devices, that gather information by cooperating with one another. These tiny sensing devices area unit referred to as nodes and carries with it electronic equipment (for information giving out), memory (for information storage), battery (for energy) and Transceiver. In Wireless sensor network, information collected by sensors is gathered at a distant location for analyzing and computation purpose via wireless links. Some applications of wireless sensor network embody medical, environmental, transportation, military, entertainment, homeland, defence, and crisis management etc. Alike to different communication systems, wireless sensor network systems development has a diversity of origins.

The history of development is often in short alienated into four phases [19]:

Phase 1: During the cold war period, there was a need to monitor and detect the positions of enemies which gave birth to number of projects such as Sound Surveillance System and radar networks developed by United States.

Phase 2: DARPA (Defense Advanced Research Projects Agency) of United States Department of Defence initiated the research programs in the early 1980s that were basically focused on advance developments on new technologies and protocols of wireless sensor networks.

Phase 3: Projects undertaken by DARPA laid the foundation for military applications developments based on wireless sensor networks. Huge amount of money spent on newer technologies made the development faster in early 1990s.

Phase 4: Recent advancements in semi-conductor technologies and networking techniques directed an innovative stage in the growth of sensor network technology. In 2000's IEEE released the first version of IEEE Standard i.e. 802.15.4 standard "Low Rate Wireless Personal Area Networks" which is the base for recently introduced standards such ZIGBEE [11].

1.1 Wireless Sensor Network

A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to considerately monitor physical or environmental conditions, like temperature, sound, vibration, pressure, motion or pollutants, at different locations. • A collection of sensing devices that can communicate wirelessly [42].

1.2.1 Sensor Node

Sensor network supply a robust mixture of spread sensing, computing and communication. They provide themselves to un-numerable application and, at identical moment in time, supply various challenge owing to their peculiarity, chiefly the rigorous energy constraint to that sensing nodes square measure usually subjected. The characteristic traits of device networks have an on the spot impact on the hardware style of the nodes at a minimum of four levels: power supply, processor, communication hardware, and sensors. Varied hardware platforms have already been designed to check the numerous ideas spawned by the analysis community and to implement applications to nearly all fields of science and technology. Wireless device network and to extract most potential info from the police investigation space, correct usage of the facility capability of the device nodes is very important. In the main supported utilizing the remaining power of individual device nodes similarly as properly relocating device nodes so all device nodes will transmit the information they sense to the sink. The maximizes total collected info from the police investigation space before the potential death of the device network by growing accumulative connected coverage parameter of the network. A settled approach is employed to deploy device nodes into the device field wherever polygonal shape Grid positioning is employed to handle and find every device node. Device nodes those don't seem to be planned to be actively employed in the shut future during a specific cell square measure pre-emptivelysettled to the cells those are going to be in would like of extra device nodes to boost accumulative connected coverage of the network the basic plan when WSNs is that, because the capability of every individual device node is restricted, the collective power of the whole network is adequate for the obligatory task.

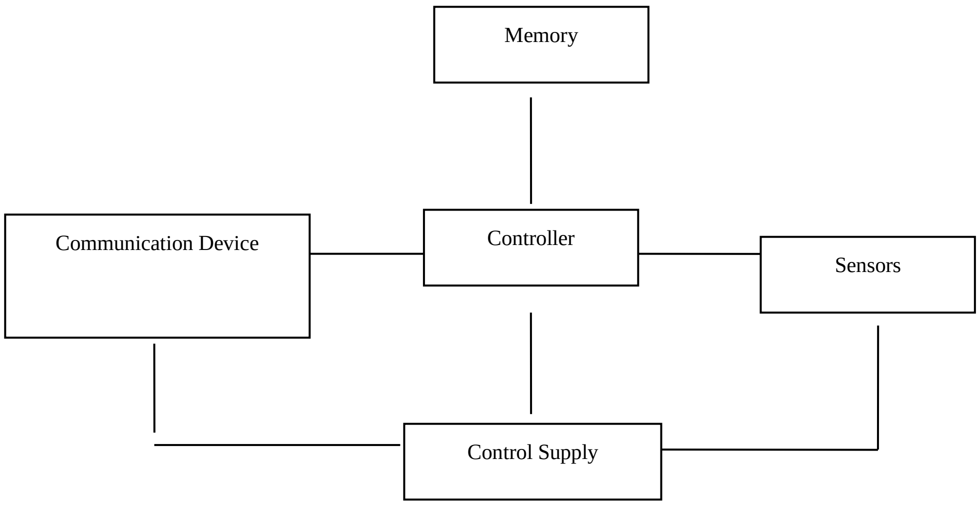

Figure 1.2 Sensor Architecture

Main elements of a WSN node

- Controller
- Communication device(s)
- Sensors/actuators
- Memory
- Power offer

2. Background

Jin Wang at al [1]: In this paper, particle swarm optimization based clustering algorithm with mobile sink for wireless sensor network is proposed. As WSN with fixed sink node often become the reason of hot spots problem since sensor nodes close to the sink generally have more traffic burden to forward during transmission process. After using mobile sink, it has been shown as an effective approach in order to enhance the network performance such as energy efficiency, network lifetime, and latency, etc. This paper describes the principle of EPMS algorithm in detail, where the virtual clustering technique combined with PSO algorithm is utilized to improve the network performance. The two main parameters namely, residual energy and position of the nodes are used to select cluster head. Extensive simulation results shows that the energy consumption is much reduced, the transmission delay is also reduced and the network lifetime is prolonged.

Rajeev Goyal et al [2]: The paper has proposed a novel approach for calculation of trust in the online social network. The approach has used a hybrid of ACO and PSO for searching the best solution. Trust prediction has become one of the most important tools for finding and identifying the potential trust relationship between any online communities. This paper has proposed a new method to provide trust prediction through a hybrid approach of the ant colony optimization algorithm and particle swarm optimization algorithm. The proposed method can give a more efficient result by improving the process of pheromone update by particle swarm optimization. Ant colony optimization is used for trust calculation and particle swarm optimization is used for searching swarm pheromones. Both of these algorithmsare used to find trust or a path among the nodes, by using hybrid approach trust calculation is more efficient. This novel approach provides a new way to solve trust-related issues.

N. Mahendran et al [5] : Wireless sensor networks (WSNs) is collection of small sensor devices for monitoring, gathering and processing data which have low hardware complexity, low energy consumption, high network lifetime, scalability, and real-time support. By Scheduling performance of WSN can be improved. With the Scheduling it will minimizes the energy consumption and increases the lifetime of nodes. In this paper we describe the concept of optimization techniques in WSNs to extend performance. For find optimal solutions quickly there are four optimization techniques through sensor data allows a better quality of service (QoS) in WSN. In this paper, we survey such optimization techniques as ant colony optimization (ACO), particle swarm optimization (PSO), genetic algorithm (GA), and artificial bee colony (ABC) for scheduling methods.Finally, we conclude that on couture these algorithms to various issues in WSN perform better performance in the overall system evaluation.

Amrita Saini et al [4]: The Internet today is highly vulnerable to security threats. The best way to handle DoS attacks is to reach the source of the attack and block it. IP traceback is a proactive and effective approach to detect the origin of the DoS attack. In this paper, we have proposed a hybrid approach by integrating Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO), to find the efficient solution of IP traceback problem. The main focus of our work is to increase the convergence rate and further reduce the computational complexity of ACO algorithm by combining the distance-based search technique used by ACO with particle velocity based search used by PSO algorithm. As a future work, methods could be devised to further improve the convergence rate of algorithm especially in case of larger networks and in more practical conditions. In large search space convergence to local optima is another major challenge, which could be looked upon as future work.

PushpaLakshmi R et al[7]: In wireless networks, the network security and routing considered as challenging task. Swarm intelligence (SI) is that collective behavior of non centralized, self-organized systems, natural or artificial. This paper presents reviews on several ACO and PSO based secure routing protocols in wireless networks. The main goal of this work is to give a general overview of ACO and PSO based protocols for network security and routing. This survey focuses on various points which are protrayal of swarm intelligence in networks, classification of SI based techniques on two main snags security, routing, and comparison and performance analysis of several ACO and PSO based secure routing protocols for wireless networks.

3. Proposed Approach

Energy Efficient ACO PSO based protocol with mobile sink (EAPMS)

The improved energy efficient PSO protocol used the hybrid routing algorithm based on ACO/PSO. In the given calculation, the PSO is utilized to upgrade the characteristics in the ACO, which characterize that the determination of parameter doesn't relies upon fake understanding, however depends on the vigorous pursuit on the particles in the PSO. We additionally utilized an improve use of ACO; by this strategy we have discovered the most limited way or courses of ants. The yield of the investigation demonstrate that the upgrade calculation not just lessen the quantity of ways in the ACO. Yet in addition finding the most brief way at the place of biggest way. The recreation result demonstrates that mix of ACO-PSO performs superior to Energy Efficient PSO. The ACO and PSO are the two best method of the perfect swarm intelligence.PSO copies the sharing of data procedure of a school of fish looking nourishment. While ACO emulates for aging behavior of ants colonization. The hybrid algorithm has been implemented to exploit the advantages of both the algorithm finding the global optimum.

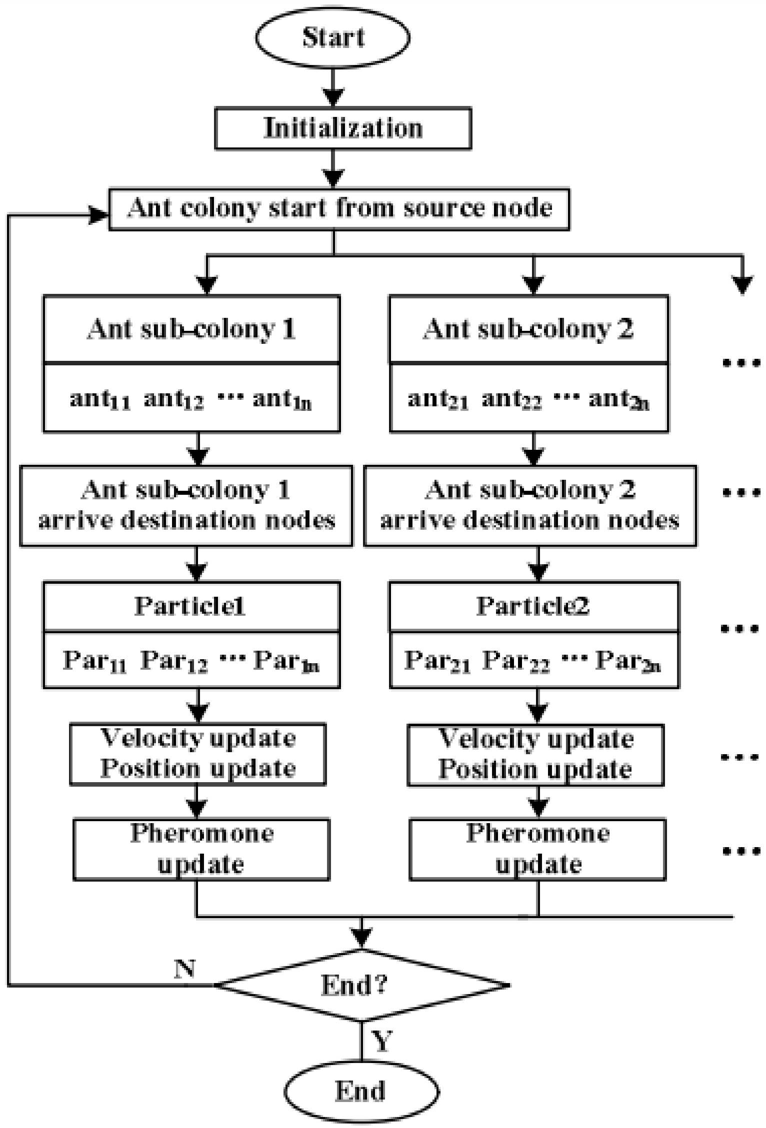

Figure 3.1Flow chart of hybrid ACO/PSO

Hybrid ACO/PSO optimization technique has been applied. Firstly, Ant Colony Optimization (ACO) has been applied for finding smallest route from node to the sink (which in turn generates the values of α-Best and β-Best). The results obtained through ACO technique are given to PSO algorithm for the refinement. It provides a population based search technique that uses Pbest, Gbest and particles current position for finding coming location in the area of search. The PSO algorithm is applied to find the best shortest routes. Transmission of data takes place after finding the shortest routes [6].

4. Results and Discussion

4.1 Simulation Parameters and Results

To evaluate our proposed TBSEPMS algorithm performance is compared with EPMS.To implement the proposed design and implementation has been done. Table 1 has shown the some constants and variables which is used for experimental set up. Here, the parameters are standard values used as benchmark for WSNs

Table 4.1 Experimental setup

Parameter	Value
Area(x,y)	100,100
Base Station(x,y)	Moving
Nodes(n)	100

Probability(p)	0.1
Initial Energy(Eo)	0.5J
Transmitter_energy	50nJ/bit
Receiver_energy	50nJ/bit
Free space(amplifier)	10nj/bit/m2
Multipath(amplifier)	0.0013pJ/bit/m4

4.1.1 Alive Nodes

This is the graph of alive nodes betweenEPMS, EAPMS and TBSEPMS protocol. It has been found that the number of nodes alive much more in TBSEPMS protocol. Here, we can see from the graph that the nodes are alive at the round of 1250 in case of TBSEPMS and 1200 in case of EAPMS and 830 in case of EPMS.

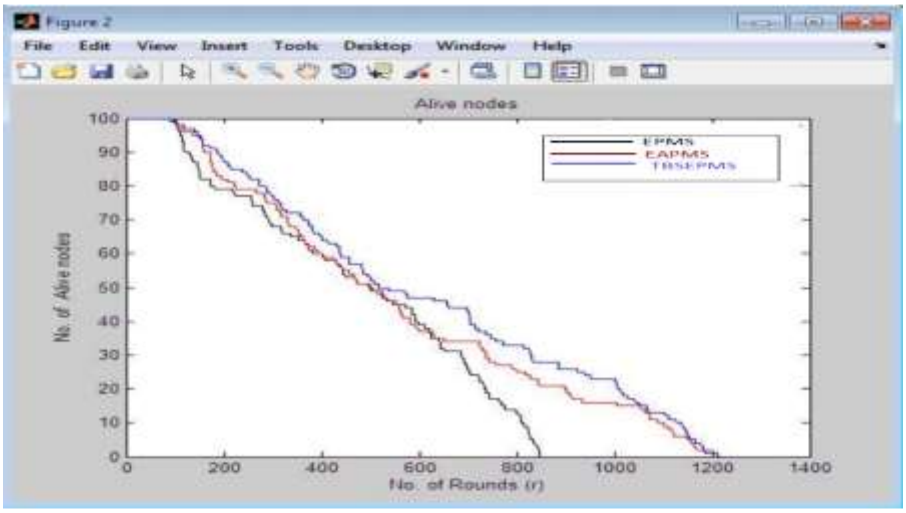

Figure 4.1 Alive nodes vs. rounds

Number of rounds	**EPMS**	**EAPMS**	**TBSEPMS**
200	77	80	89
400	56	59	66
600	39	40	51
800	14	30	36
1000	---	19	26
1200	---	2	10

TABLE2:- Alive nodes vs. rounds

4.1.2 Dead Nodes

This is the graph of dead nodes between EPMS, EAPMS and TBSEPMS protocol.This is the graph of dead nodes in EPMS, EAPMS and TBSEPMS protocol. The network lifetime can be evaluated by using the number of dead nodes. It has been found that the number of nodes die earlier in EPMS protocol. Here, we can see from the graph that all the nodes are die at the round of 830 in case of EPMS and 1200 in case of EAPMS and 1250 in case of TBSEPMS protocol.

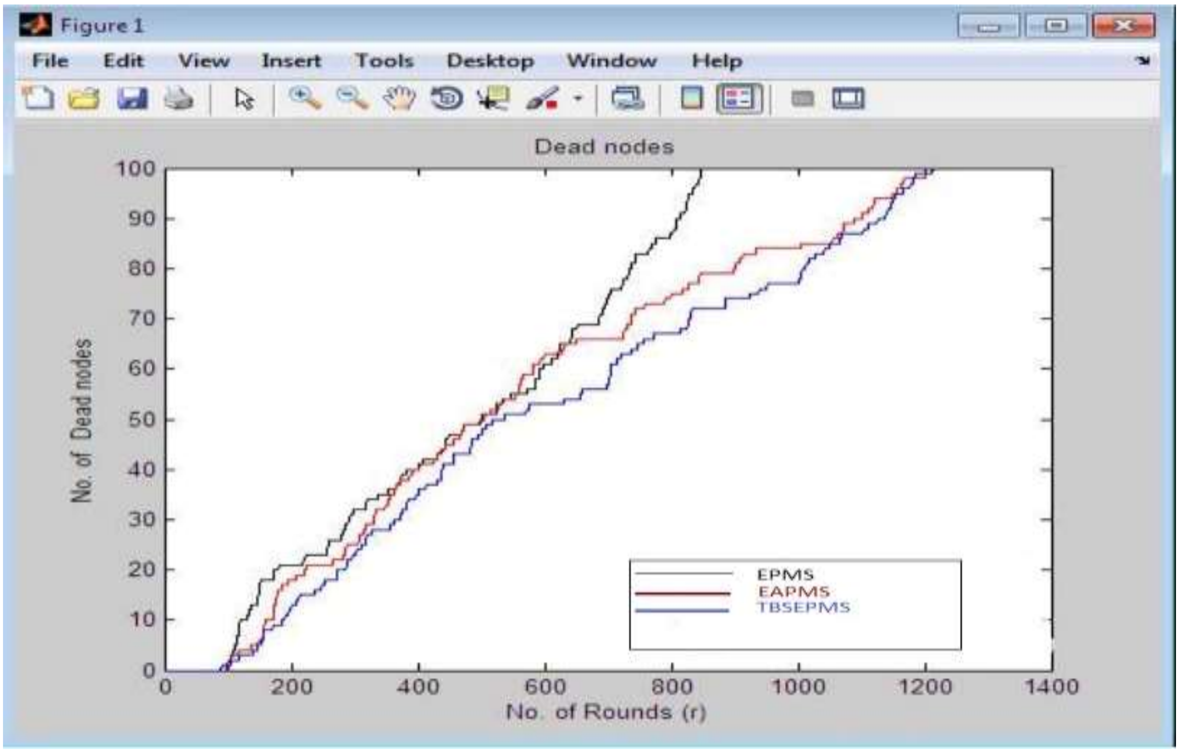

Figure 4.2 Dead nodes vs. rounds

TABLE 3 :- Dead nodes vs. rounds

Number of rounds	**EPMS**	**EAPMS**	**TBSEPMS**
200	23	20	11
400	44	41	34
600	61	60	49
800	86	70	64
1000	---	81	74
1200	---	98	90

4.1.3 Remaining Energy

This is the graph of remaining energy, how much energy is left with the rounds. From the graph, we can see the remaining energy with EPMS goes to 830 rounds, whereas in the case of EAPMS the remaining energy goes to 1200 rounds and in TBSEPMS, having 1250, means more work can be done with TBSEPMS protocol.

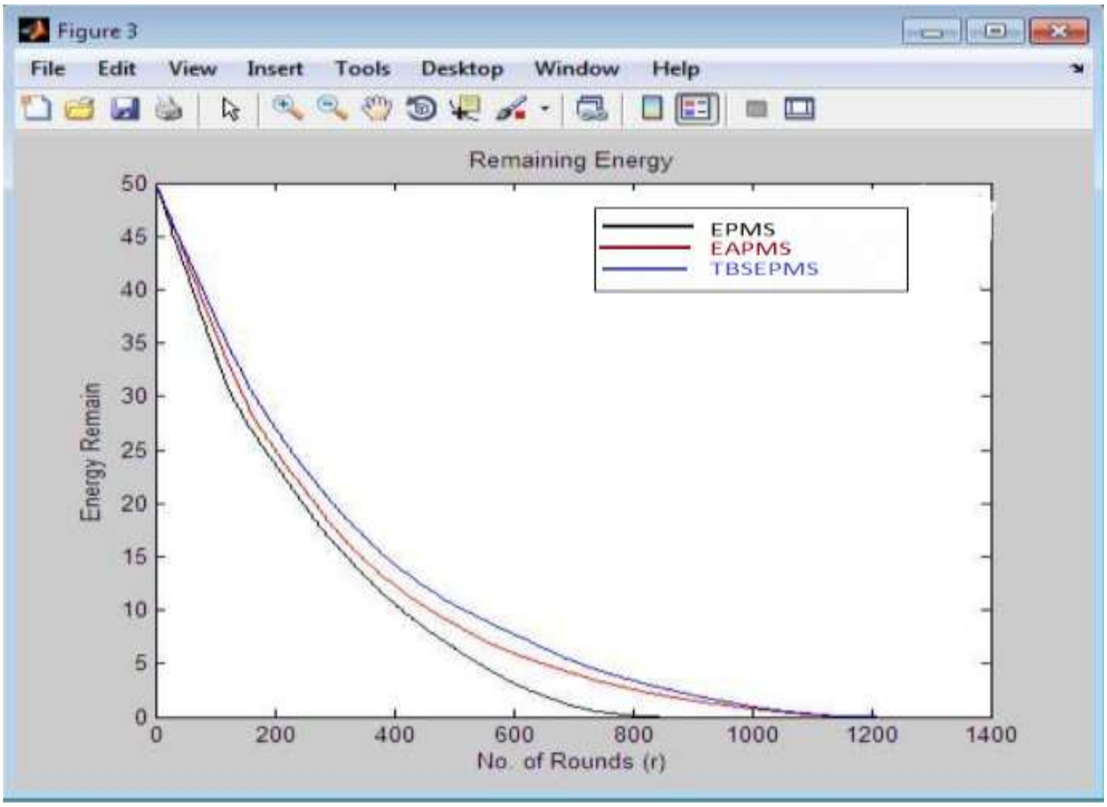

Figure 4.3 Remaining energy vs. rounds

TABLE 4 :- Remaining Energy vs. rounds

Number of rounds	**EPMS**	**EAPMS**	**TBSEPMS**
200	21	24	27
400	10	13	15
600	3	7.56	10
800	--	5	7
1000	---	2	3
1200	---	0.2	0.3

5. Conclusion

Both ACO and PSO suffer from the problem of convergence to local sub-optimal solution. Initial movement of ants in ACO is governed by the initial concentration of pheromone on paths and if more pheromone is there on sub-optimal paths then the algorithm gets trapped into local optima. To overcome this problem a large number of ants are needed thereby increasing the convergence time of algorithm. In PSO also initial position of particles is fixed randomly which may sometimes result in a bad sub-optimal solution. Thus PSO-ACO integrates the local updateinformation obtained from distance metric of ACO with the global update information obtained from velocity metric of PSO (based on pbest and gbest) and selects a more reliable path. Simulation results show that the proposed algorithm outperforms in terms of convergence rate and it successfully generates a more globally optimum solution. We have also observed that PSO-ACO converges to attack path in lesser number of iterations and with less number of particles or ants. From observations, we believe that the proposed hybrid approachis an effective way of finding optimal solution. As a future work, methods could be devised to further improve the convergence rate of algorithm especially in case of larger networks and in more practical conditions. In large search space convergence to local optima is another major challenge, which could be looked upon as future work.

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