A Comprehensive Study in Wireless Sensor Network (WSN) Using Artificial Bee Colony (ABC) Algorithms

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Abstract - Artificial bee colony algorithm could be a good optimization algorithm supported the bee's acquisition model. This review proposed a comprehensive study in wireless sensor networks (WSN) using an artificial bee colony (ABC) algorithm. Finally, this paper compares various bees' algorithm with testing on optimization problems. The results of various algorithms shown that the algorithm proved to be effective to improve the search performance and advanced optimization problem.

1. Introduction

In recent years an efficient design of a Wireless Sensor Network has become a leading area of research. A Sensor is a device that responds and detects some type of input from both the physical or environmental conditions, such as pressure, heat, light, etc. The output of the sensor is generally an electrical signal that is transmitted to a controller for further processing.

1.1 Wireless Sensor Networks (WSN)

Wireless Sensor Networks (WSN) are intended for monitoring an environment. The main task of a wireless sensor node is to sense and collect data from a certain domain, process them and transmit it to the sink where the application lies[1].In the wireless sensor networks, the queue mechanism is adopted which is used for the transmission of the data packets. If heavy traffic load condition occurs, then queue handling capacity of the sensor node is not efficient which may cause a data queue overflow in the sensor nodes, lost. So that efficiency and reliability in the transmission of data cannot be obtained. The sensor nodes create the energy hole in the routing path, this is then created by multiple hops operation which is based on relaying the data packets [2]. Because of this energy holes, the lifetime of the wireless sensor networks is greatly reduced. Wireless sensor networks can be used for many mission-critical applications such as target tracking in battlefields and emergency response. In these applications, the reliable and timely delivery of sensory data plays a crucial role in the success of the mission.[1] The major problem with wireless sensor networks is their limited source of energy, the coverage constraint, and high traffic load. Routing of sensor data has been one of the challenging areas in wireless sensor network research.[2]

1.2 Wireless Sensor Networks (WSNs)

A Wireless sensor network can be defined as a network of devices that can communicate the information gathered from a monitored field through wireless links. The data is forwarded through multiple nodes, and with a gateway, the data is connected to other networks like wireless Ethernet. WSN is a wireless network that consists of base stations and numbers of nodes (wireless sensors). These networks are used to monitor physical or environmental conditions like sound, pressure, temperature and co-operatively pass data through the network to the main location.

1.3 WSN Network Topologies

For radio communication networks, the structure of a WSN includes various topologies like the ones given below

Star Topologies

Star topology is a communication topology, where each node connects directly to a gateway. A single gateway can send or receive a message to several remote nodes. In star topologies, the nodes are not permitted to send messages to each other. This allows low-latency communications between the remote node and the gateway (base station). Due to its dependency on a single node to manage the network, the gateway must be within the radio transmission range of all the individual nodes. The advantage includes the ability to keep the remote nodes' power consumption to a minimum and simply under control. The size of the network depends on the number of connections made to the hub.

Tree Topologies

Tree topology is also called as a cascaded star topology. In tree topologies, each node connects to a node that is placed higher in the tree, and then to the gateway. The main advantage of the tree topology is that the expansion of a network can be easily possible, and also error detection becomes easy. The disadvantage with this network is that it relies heavily on the bus cable; if it breaks, all the network will collapse.

Mesh Topologies

The Mesh topologies allow transmission of data from one node to another, which is within its radio transmission range. If a node wants to send a message to another node, which is out of the radio communication range, it needs an intermediate node to forward the message to the desired node. The advantage of this mesh topology includes easy isolation and detection of faults in the network. The disadvantage is that the network is large and requires a huge investment.

1.4 Types of WSNs (Wireless Sensor Networks)

Depending on the environment, the types of networks are decided so that those can be deployed underwater, underground, on land, and so on. Different types of WSNs include:

- **Terrestrial WSNs**
- **Underground WSNs**
- **Underwater WSNs**
- **Multimedia WSNs**
- **Mobile WSNs**

Terrestrial WSNs

Terrestrial WSNs are capable of communicating base stations efficiently, and consist of hundreds to thousands of wireless sensor nodes deployed either in unstructured (ad hoc) or structured (Preplanned) manner. In an unstructured mode, the sensor nodes are randomly distributed within the target area that is dropped from a fixed plane. The preplanned or structured mode considers optimal placement, grid placement, and 2D, 3D placement models. In this WSN, the battery power is limited; however, the battery is equipped with solar cells as a secondary power source. The Energy conservation of these WSNs is achieved by using low duty cycle operations, minimizing delays, and optimal routing, and so on.

Underground WSNs

The underground wireless sensor networks are more expensive than the terrestrial WSNs in terms of deployment, maintenance, and equipment cost considerations and careful planning. The WSNs networks consist of many sensor nodes that are hidden in the ground to monitor underground conditions. To relay information from the sensor nodes to the base station, additional sink nodes are located above the ground. The underground wireless sensor networks deployed into the ground are difficult to recharge. The sensor battery nodes equipped with a limited battery power are difficult to recharge. In addition to this, the underground environment makes wireless communication a challenge due to the high level of attenuation and signal loss.

Under Water WSNs

More than 70% of the earth is occupied with water. These networks consist of many sensor nodes and vehicles deployed underwater. Autonomous underwater vehicles are used for gathering data from these sensor nodes. A challenge of underwater communication is a long propagation delay, and bandwidth and sensor failures. Underwater WSNs are equipped with a limited battery that cannot be recharged or replaced. The issue of energy conservation for underwater WSNs involves the development of underwater communication and networking techniques.

Multimedia WSNs

Multimedia wireless sensor networks have been proposed to enable tracking and monitoring of events in the form of multimedia, such as imaging, video, and audio. These networks consist of low-cost sensor nodes equipped with microphones and cameras. These nodes are interconnected with each other over a wireless connection for data compression, data retrieval, and correlation. The challenges with the multimedia WSN include high energy consumption, high bandwidth requirements, data processing and compressing techniques. In addition to this, multimedia contents require high bandwidth for the contents to be delivered properly and easily.

Mobile WSNs

These networks consist of a collection of sensor nodes that can be moved on their own and can be interacted with the physical environment. The mobile nodes can compute sense and communicate. The mobile wireless sensor networks are much more versatile than the static sensor networks. The advantages of MWSN over the static wireless sensor networks include better and improved coverage, better energy efficiency, superior channel capacity, and so on.

1.5 Limitations of Wireless Sensor Networks

Possess very little storage capacity – a few hundred kilobytes

Possess modest processing power-8MHz

Works in short communication range – consumes a lot of power

Requires minimal energy – constrains protocols

Have batteries with a finite lifetime

Passive devices provide little energy

1.6 Wireless Sensor Networks Applications

These networks are used in environmental trackings, such as forest detection, animal tracking, flood detection, forecasting and weather prediction, and also in commercial applications like seismic activity prediction and monitoring.

Military applications, such as tracking and environment monitoring surveillance applications use these networks. The sensor nodes from sensor networks are dropped to the field of interest and are remotely controlled by a user. Enemy tracking, security detections are also performed by using these networks.

Health applications, such as Tracking and monitoring of patients and doctors use these networks.

The most frequently used wireless sensor networks applications in the field of Transport systems such as monitoring of traffic, dynamic routing management and monitoring of parking lots, etc., use these networks.

Rapid emergency response, industrial process monitoring, automated building climate control, ecosystem and habitat monitoring, civil structural health monitoring, etc., use these networks.

2. Artificial Bee Colony Algorithms

Artificial bee colony algorithm inspired by the foraging behavior of bee by Dervis Karaboga in 2005 [3]. In the ABC algorithm, the artificial bee colony contains three groups of bees: employed bees, onlooker bees, scout bees. The search carried out by the artificial bees can be summarized as follows: Employed bees determine food source within the neighborhood of the food source in their memory and they shared about foods information with onlooker bees and then the onlooker bees select one of the food sources. Onlooker bees select a food source within the neighborhood of the food sources by themselves. Scout bees search for a new food source randomly when an employed bee has been abandoned by a food source.

At the beginning of the ABC algorithm that generated a population of food sources randomly. A food source represents a possible solution. The employed bees produce a modification on the position of the food source in their memory and the nectar amount of a food source corresponds to the quality that represents the fitness value of the solution then used it to calculate probability values. While the onlooker bees selected the largest probability values of the food source, then onlooker bees produce a modification on the position of the food source. The new food sources were calculated fitness value and were compared with the fitness value of the old food source than the largest fitness value of the food source was recorded as the best solution currently. The best food source was recorded in each iteration until reached the maximum number of iterations.[4][5]

The major advantages which ABC holds over other optimization algorithms include its:

Simplicity, flexibility, and robustness

Use of fewer control parameters compared to many other search techniques

Ease of hybridization with other optimization algorithms.

Ability to handle the objective cost with stochastic nature.

Ease of implementation with basic mathematical and logical operations. Particle swarm optimization

Particle swarm optimization (PSO) is a computational method that optimizes a problem by iteratively trying to improve a candidate solution about a given measure of quality. ABC is based on PSO.

2.1 How the ABC algorithm works?

The ABC was first proposed to solve numerical optimization problems by Karaboga [38]. ABC consists of employed and unemployed foragers and food sources. The ABC consists of three groups of artificial bees: employed foragers, onlookers, and scouts. The employed bees comprise the first half of the colony whereas the second half consists of the onlookers. In the basic ABC [38], there are 3 kinds of bees: employed, onlooker, and scout bees.

2.2 Phases of ABC

It generally consists of four phases.

1. Initialization of ABC. Determine the number of artificial bees. 50% are employed bees and 50% are onlooker's bees. Generate the random initial candidate solutions for employed bees using equation. [38] Determine the limit value.

2. Employed bee phase for all employed bees Generates new candidate solution using equation. [6] Calculate the fitness value of the new solution using Equation. [38] If the fitness of the new candidate solution is better than the existing solution replace the older solution. Calculate the probability for each individual.

3. Onlooker bee phase. For all onlooker, bees Select an employed bee using a roulette wheel. Produce a new candidate solution. Compute the fitness of the individual. If the fitness of the new candidate solution is better than the existing solution replaces the older solution.

4. Scout bee phase if any food source exhausted then replace it by randomly generated solution by scout memorize the best solution. Until (stopping criteria is not met).

2.3 Three types of Bees in ABC

1. Employed bees

2. Onlooker bees, and

3. Scouts.

Employed and onlooker bees perform the exploitation search.

Scouts carry out the exploration search.

2.4 ABC employs four different selection processes

1. A global selection process used by onlookers.

2. A local selection process carried out in a region by employed and onlooker bees.

3. A greedy selection process used by all bees.

4. A random selection process used by scouts.

2.5 Steps of the ABC algorithm

Step 1: Initialize by picking k random Employed bees from data.

Step 2: Send Scout bees and test against Employed bees (replace if better than Employed is found).

Step 3: Send Onlooker bees to Employed.

Step 4: Test Onlooker bees against Employed (replace if better than Employed is found).

Step 5: Reduce the radius of Onlooker bees.

Step 6: Repeat steps 2 to 5 for a given number of iterations.

2.6 Application of ABC

Applications of Artificial Bee Colony are as follow:

Travel Salesmen Problem

This problem belongs to the category of NP-Complete issues. ABC finds higher resolution than GA and alternative ABC is widely used for optimization.

Graph Coloring

This application has been done mistreatment artificial bee colony (ABC) optimization algorithm rule. Graph coloring no two adjacent edges having the same color. This can be found by mistreatment ABC with higher results than an alternative algorithm rule.

Bioinformatics application

Within the field of Bioinformatics ABC leads to optimizing the polymer sequencing problem with the higher results as compared to alternative algorithms.

Image process Applications

ABC has its application to the image process. Many troublesome issues exist in pattern recognition and image process analysis areas. ABC optimization works higher and optimized the pattern recognition problem. Thus, it's widely used for the image process.

Benchmarking optimization

Varied operate exits which may be optimized mistreatment ABC algorithmic rule.

3. Review of Literature

Fatma Bouabdallah et al. [1], [2009] recommended that sending the traffic generated by each sensor node through multiple paths, instead of a single path, allows significant energy conservation. Specifically, they derive the set of paths to be used by each sensor node and the associated weights (i.e., the proportion of utilization) that maximize the network lifetime. Wireless sensor networks (WSNs) require protocols that make judicious use of the limited energy capacity of the sensor nodes.

Chongmyung Park et al. [2], [2010] presented based on dominant gene sets in a genetic algorithm, the proposed method selects suitable data forwarding sensor nodes to avoid heavy traffic congestion. In experiments, the proposed method demonstrates efficient data transmission due to much less queue overflow and supports fair data transmission for all sensor nodes. In the proposed method, the sensor nodes are aware of the data traffic rate to monitor network congestion. From the results, it is evident that the proposed method not only enhances the reliability of data transmission but also distributes the energy consumption across wireless sensor networks. Since the high traffic load causes a data queue overflow in the sensor nodes, important information about urgent events could be lost. However, the short sensing cycle increases the data traffic of the sensor nodes in a routing path.

Huayu Xu et al. [3], [2008] proposed a multi-objective model of Vehicle Routing Problem with Time Windows (VRPTW), where the total distance, the vehicle number, and the time penalty of customers are taken into account. NSGA-II has been performed as an efficient algorithm in solving multi-objective problems, and the Or-opt heuristic is well-known as one of the classic optimization algorithms. A hybrid algorithm involving both the two algorithms above is introduced in this article. Data from the distribution center in Utica (Michigan, US.) has been tested with this hybrid algorithm in MATLAB. Faster running speed has been proved and some improvements in solutions have been shown.

D. Karaboga et al. [4], [2008] presented the performance of ABC algorithm with that of differential evolution (DE), particle swarm optimization (PSO) and evolutionary algorithm (EA) for multi-dimensional numeric problems. The simulation results show that the performance of the ABC algorithm is comparable to those of the mentioned algorithms and can be efficiently employed to solve engineering problems with high dimensionality.

D. Karaboga et al. [5], [2011] suggested for constraint handling, ABC algorithm uses Deb's rules consisting of three simple heuristic rules and a probabilistic selection scheme for feasible solutions based on their fitness values and infeasible solutions based on their violation values. Moreover, a statistical parameter analysis of the modified ABC algorithm is conducted and appropriate values for each control parameter are obtained using analysis of the variance (ANOVA) and analysis of mean (ANOM) statistics. Paper describes a modified ABC algorithm for constrained optimization problems and compares the performance of the modified ABC algorithm against those of state-of-the-art algorithms for a set of constrained test problems. ABC algorithm is tested on thirteen well-known test problems and the results obtained are compared to those of the state-of-the-art algorithms and discussed. The artificial Bee Colony (ABC) algorithm was firstly proposed for unconstrained optimization problems on where that ABC algorithm showed superior performance.

Wei Zheng et al. [6], [2014] suggested a new routing protocol based on the Artificial Bee Colony algorithm is introduced for solving the delay-energy trade-off problem. The proposed approach every food source represents a possible and feasible candidate path between each original and destination node. Obtained simulation results show that the proposed protocol can achieve a good trade-off between routing delay and energy. The positions of food sources are modified by some artificial bees in the population to discover the places of food sources. The food source with the highest nectar value seems to be a solution that is evaluated by the fitness function. They presented an intelligent approach for modeling Routing in wireless sensor networks.

Zahid Muhammad et al. [7] [2017] presented Scheduling is an effective approach for an energy-efficient IoT-based-WSNs by categorizing the smart devices into an optimal number of disjoint subsets which completely cover all objects in the monitored area. Scheduling is an effective approach for energy-efficient IoT-based-WSNs by categorizing the smart devices into an optimal number of disjoint subsets that completely cover all objects in the monitored area. Results show that HABCA-EST takes less number of fitness evaluations (up to 10%) and schedules less number of smart devices (up to 94%) which leads to a reduction (93%) in simulation time as compared to the existing techniques.

Ying Gao Yue et al. [8], [2016] suggested traditional data collection methods only focus on increasing the amount data collection or reducing the overall network energy consumption, which is why they designed the proposed heuristic algorithm to jointly consider cluster head selection, the routing path from ordinary nodes to the cluster head node, and mobile Sink path planning optimization. They focused on a large-scale and intensive MWSN which allows a certain amount of data latency by investigating mobile Sink balance from three aspects: data collection maximization, mobile path length minimization, and network reliability optimization. The energy of nodes around the Sink can be untimely depleted because sensor nodes must transmit vast amounts of data, readily forming a bottleneck in energy consumption; mobile wireless sensor networks have been designed to address this issue.

Dervis Karaboga et al. [9] [2012] recommended the results of the experiments show that the artificial bee colony algorithm based clustering can successfully be applied to WSN routing protocols. a novel energy-efficient clustering mechanism, based on an artificial bee colony algorithm, is presented to prolong the network lifetime. Artificial bee colony algorithm, simulating the intelligent foraging behavior of honey bee swarms, has been successfully used in clustering techniques. The performance of the proposed approach is compared with protocols based on LEACH and particle swarm optimization, which are studied in several routing applications.

Celal Ozturk et al. [10], [2012] suggested an artificial bee colony algorithm is applied to the dynamic deployment of mobile sensor networks to gain better performance by trying to increase the coverage area of the network. The good performance of the algorithm shows that it can be utilized in the dynamic deployment of wireless sensor networks. Dynamic deployment is one of the main issues that directly affect the performance of wireless sensor networks.

Wei-Lun Chang et al. [11], [2015] presented to minimize the energy consumption on the traveling of the mobile robot; it is significant to plan a data collection path with the minimum length to complete the data collection task. Each sensor has a limited transmission range and the mobile robot must get into the coverage of each sensor node to obtain the sensing data. In sparse wireless sensor networks, a mobile robot is usually exploited to collect the sensing data.

Xiangyu Yu et al. [12], [2013] recommended the simulation results showed that compared with the deployment method based on original ABC and particle swarm optimization (PSO) algorithm, the proposed approach can achieve a better performance in coverage rate and convergence speed while needing a less total moving distance of sensors.

Celal Ozturk et al. [13], [2015] suggested the superiority of the proposed algorithm is demonstrated by comparing it with the basic discrete artificial bee colony, binary particle swarm optimization, genetic algorithm in dynamic (automatic) clustering, in which the number of clusters is determined automatically i.e. it does not need to be specified in contrast to the classical techniques. One of the most well-known binary (discrete) versions of the artificial bee colony algorithm is the similarity measure based discrete artificial bee colony, which was first proposed to deal with the uncapacitated facility location (UFLP) problem. The obtained results indicate that the discrete artificial bee colony with the enhanced solution generator component can reach more valuable solutions than the other algorithms in dynamic clustering, which is strongly accepted as one of the most difficult NP-hard problems by researchers. Although it is accepted as one of the simple, novel and efficient binary variant of the artificial bee colony, the applied mechanism for generating new solutions concerning to the information of similarity between the solutions only consider one similarity case i.e. it does not handle all similarity cases. To cover this issue, the new solution generation mechanism of the discrete artificial bee colony is enhanced using all similarity cases through the genetically inspired components.

Sung-Soo Kim et al. [14], [2017] suggested the simulation results illustrate that the ABCC algorithm outperforms particle swarm optimization (PSO), group search optimization (GSO), low-energy adaptive clustering hierarchy (LEACH), LEACH-centralized (LEACH-C), and hybrid energy-efficient distributed clustering (HEED) for energy management in CWSNs. This paper presents a novel cognitively inspired artificial bee colony clustering (ABCC) algorithm with a clustering evaluation model to manage the energy consumption in cognitive wireless sensor networks (CWSNs). Artificial bee colony (ABC) optimization is attractive for this application as the cognitive behaviors of artificial bees match perfectly with the intrinsic dynamics in cognitive wireless sensor networks.

Palvinder Singh Mann et al. [15], [2017] proposed a clustering algorithm that presents an efficient cluster formation mechanism with improved cluster head selection criteria based on a multi-objective fitness function, whereas the routing algorithm is devised to consume minimum energy with least hop-count for data transmission. Extensive evaluation and comparison of the proposed approach with existing well-known SI-based algorithms demonstrate its superiority over others in terms of packet delivery ratio, average energy consumed, average throughput and network life. Swarm intelligence (SI)-based metaheuristics are well applied to solve real-time optimization problems of efficient node clustering and energy-aware data routing in wireless sensor networks.

Palvinder Singh Mann et al. [16], [2019] proposed an improved Artificial bee colony (iABC) metaheuristic with an improved search equation to enhance its exploitation capabilities and in order to increase the global convergence of the proposed metaheuristic, an improved population sampling technique is introduced through Student's-t distribution, which requires only one control parameter to compute and store, hence increase efficiency of proposed metaheuristic. Swarm intelligence (SI) based metaheuristic like Ant colony optimization, Particle swarm optimization and more recently Artificial bee colony (ABC) has shown desirable properties of being adaptive to solve the optimization problem of energy-efficient clustering in WSNs. Further, an energy-efficient bee clustering protocol based on iABC metaheuristic is introduced, which inherit the capabilities of the proposed metaheuristic to obtain optimal cluster heads and improve energy efficiency in WSNs. The proposed metaheuristic maintains a good balance between exploration and exploitation search abilities with least memory requirements, moreover, the use of first of its kind compact Student's-t distribution, makes it suitable for limited hardware requirements of WSNs.

Tauseef Ahmad et al. [17], [2018] proposed the sensor network design problem (SNDP) consists of the selection of the type, number, and location of the sensors to measure a set of variables, optimizing specified criteria, and simultaneously satisfying the information requirements.

Angel Panizo et al. [18], [2018] suggested several extensions have been proposed that allow the classical ABC algorithm to work on constrained or on binary optimization problems. For this purpose, the proposed ABC algorithm has been designed to optimize binary structured problems and also to handle constraints to fulfill information requirements. Therefore the proposed approach is a new version of the ABC algorithm that combines the binary and constrained optimization extensions to solve the SNDP. The sensor network design problem (SNDP) consists of the selection of the type, number, and location of the sensors to measure a set of variables, optimizing specified criteria, and simultaneously satisfying the information requirements. The classical version of the ABC algorithm was proposed for solving unconstrained and continuous optimization problems.

Ying Gao Yue et al. [19], [2019] proposed simulation experiments show that compared the random distribution of nodes, genetic algorithms with the proposed algorithm, from the coverage and the number of nodes perceived relationship, the number of nodes connectivity rate and perceived relationship, covering connectivity efficiency, the number of nodes in the network lifetime and perceived relationship, achieving the same coverage and connectivity required time-consuming aspects of WSNs coverage and connectivity issues related to study, the proposed algorithm has the higher of the coverage and connectivity, and reduce data redundancy and network traffic, improve network efficiency.

4. Conclusion

In review, the various wireless sensor network using bee colony algorithms and works of literature show that different algorithm gives a different result if compare one to another algorithm then they give a better result. There are lots of opportunities to improve the search performance, reduce power consumption, shortest routing path and reduce data access time. In research, it is still needed to identify the problems where the ABC algorithm can do better as compared to other optimization algorithms. In the future, there is an opportunity to improve the search performance, reduce power consumption, shortest routing path and reduce data access time using artificial bee colony algorithm and particle swarm optimization.

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