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CLUSTER HEAD SELECTION IN WIRELESS SENSOR NETWORK USING HYBRID BFO-BSO

A.RAJAGOPAL[1], Dr.S.SOMASUNDARAM[2], Dr.B.SOWMYA[3], T.SUGUNA[4]

[1] Research Scholar [2]Assistant Professor [3]Professor [4]Lecturer (Senior Scale)
[1&2] Department of Electronics & Instrumentation Engineering, Annamalai University,
Annamalai Nagar, Chidambaram, Tamilnadu, India.
(mobile: +919943294388; e-mail:rajagopalayyasamy@gmail.com).
[3] Department of Electronics & Communication Engineering,
Dhanalakshmi College of Engineering, Tambaram, Chennai, Tamilnadu, India.
[4]Department of Computer Engineering,
Indira Gandhi Polytechnic College, Mahe, Puducherry.India
(email-sugunatamilmani@rediffmail.com).

Abstract—Wireless Sensor Networks (WSN) developers face challenges due to poor communication links, memory/computational constraints and limited energy. Many WSN issues are formulated as multidimensional optimization problems and solved via bio-inspired techniques. Clustering divides networks into interconnected substructures, with a cluster having a Cluster Head (CH) as substructure coordinator. CH rotation protocols ensure balanced node energy dissipation. In this paper, the CH selection is optimized using a hybrid algorithm based on Bacterial Foraging Optimization (BFO) and Bee Swarm Optimization (BSO). BFO tends to get caught in the local optimums, to overcome this, BFO is hybridized with BSO in a pipeline fashion such that the output of each algorithm supplied as an input to the next algorithm

Keywords— Wireless Sensor Networks (WSN), Clustering, Cluster Head (CH), Bacterial Foraging Optimization (BFO), Bee Swarm Optimization.

I. INTRODUCTION

WIRELESS Sensor Network (WSN) are meant to be deployed in large monitoring applications where a WSN may have 100s or potentially 1000s of sensor nodes. Such large networks cannot operate without a structure [1]. Nodes perform measurements, process measured data and transmit it to a base station through wireless channels. These networks differ from conventional wireless ad hoc networks as nodes in ad hoc networks are less energy constrained [2].Besides alleviating scalability issues, clustering combined with in network. Data aggregation is a way to increase system energy efficiency, another important WSN design criterion.

A Cluster Head (CH) controls sensor nodes operation in the cluster by setting their configuration parameters, and aggregating sensor readings from the cluster and storing it or forwarding it to the sink or a higher level cluster head [1]. Sensor nodes in clusters transmit data to respective CHs and this in turn forwards data after aggregation/fusion to sink node through single/multi-hop transmission. Low Energy Adaptive Clustering Hierarchy (LEACH) is a popular distributed single-hop clustering protocol where clusters are formed based on received signal strength. The CHs role is periodically rotated, among sensor nodes in the cluster to ensure nodes balanced energy consumption [3].

LEACH is a popular hierarchical routing algorithm for sensor networks where cluster heads are sensor nodes. The choice of sensor nodes to play the cluster head role is based on probabilistic rules, proximity to nodes, and nodes residual energy to maintain the network lifelong. Optimization makes appropriate trade-offs between conflicting issues to get the best results. In routing, multiple constraints like delivery ratio, bandwidth, energy, delay are to be considered, and hence optimization is necessary in such conflicting Quality of Service (QoS) scenarios [5]. Optimization aims to solve trade-off between energy and delay using heuristic techniques [6].

Swarm intelligence is popularly applied in optimization of routing. Evolution and Natural Genetics inspired Optimization Algorithms like Genetic Algorithms (GA), Evolutionary Strategies (ES) Dominated Optimization Algorithms for more than several decades. Recently Natural Swarm Inspired algorithms like Ant Colony Optimization (ACO), PSO, Artificial Bee Colony Optimization (ABC) entered the domain and proved their effectiveness. Bacterial Foraging Optimization (BFO) is a part of nature which inspired optimization algorithms. BFO algorithm is a newcomer to this field and it was inspired by social foraging behaviour of Escherichia coli bacteria. BFO is a population-based numerical optimization algorithm. The control system of bacteria dictates how foraging should proceed, is subdivided into four sections, ie; chemotaxis, swarming, reproduction and elimination/dispersal [10].Recently, bacterial foraging behaviour was a rich source for solutions to many engineering applications and computational models[9]. BFO was applied to many problems like harmonic estimation, adaptive control, machine learning and optimal power flow scheduling [7].

To perform social foraging, an animal needs communication capabilities and over a period of time it gains advantages that can exploit the sensing capabilities of the group. This helps the group to predate on a larger prey, or alternatively, individuals could obtain better protection from predators while in a group. However, studies show that with complex optimization problems, BFO possess poor convergence behaviour compared to other nature-inspired algorithm and its performance declines with the increase in search space dimensionality [18].

Bee Swarm Optimization (BSO) algorithm was proposed by Karaboga for optimizing numerical problems. Artificial bee colony algorithm is simulating the intelligent foraging behavior of honey bee swarms, and also has been successfully used in clustering techniques. BFO algorithm simulates the intelligent foraging behaviour of honey bee swarms. It is a very simple, robust and population based stochastic optimization algorithm. The performance of the BSO algorithm is superior compared with those of other well-known modern heuristic algorithms such as GA, DE, and PSO on constrained and unconstrained problems [20].

In a robust search process, exploration and exploitation processes must be carried out together. In the BFO algorithm, while onlookers and employed bees carry out the exploitation process in the search space, the scouts control the exploration process. The local search performance of BFO algorithm depends on neighborhood search and greedy selection mechanisms performed by employed and onlooker bees. The global search performance of the algorithm depends on random search process performed by scouts and neighbour hood production mechanism performed by employed and onlooker bees [4].

This paper proposes an improved CH selection for efficient sensor network data aggregation based on BFO and BSO. Section 2 deals with literature related to this work, section 3 reveals the methods used in the work, section 4 deals with results and discusses obtained results and finally section 5 concludes the work.

II LITERATURE REVIEW

Karaboga et al., [11] proposed a novel energy efficient clustering mechanism, based on artificial bee colony algorithm, is presented to prolong the network life-time. The performance of the proposed approach is compared with protocols based on LEACH and PSO, which are studied in several routing applications. The results of the experiments show that the artificial bee colony algorithm based clustering can successfully be applied to WSN routing protocols.

Saleem, and Farooq [12] proposed Bee sensor, a bee-inspired, reactive and event-driven multipath routing protocol for WSNs. Bee Sensor aims at energy efficiency, scalability, and long network lifetime. Energy efficiency is achieved by limiting the number of control messages, as well as data packets through network aggregation. Paths are prioritized on the basis of their remaining energy levels to extend the network lifetime.

Da Silva Rego et al [13] presented the BEE-C, a hierarchical routing algorithm bio-inspired by the behavior of bees for WSN, which aims to save energy of sensor nodes. The BEE-C is based on the LEACH protocol and LEACH-C (LEACH Centered) protocol, which are too well known protocols for WSN in the literature. The BEE-C is applied to sensor networks with continuous data dissemination. The results show gains on BEE-C compared to LEACH and LEACH-C.

BFO technique optimizes the positions of multiple base stations randomly in a network to improve the likelihood of sensor node packets reaching at least one base station (BSs) due to the presence of large black hole regions, thereby ensuring high success [8].

Low energy intelligent clustering protocol (LEICP), an improvement over LEACH to overcome the latter’s shortcomings was proposed by Li et al., [14]. A node called auxiliary cluster-head calculated the cluster-head’s position using BFO in every round. After aggregating received data, the cluster-head node decides whether to choose another cluster-head as next hop to deliver messages or send data to base station directly, using Dijkstra algorithm to compute an optimal path. Simulation proved that LEICP prolonged sensor network life compared to LEACH acquiring uniform number of cluster-heads and messages in a network.

A variation of the original BFO algorithm, namely the Cooperative Bacterial Foraging Optimization (CBFO), which improved the original BFO in solving complex optimization problems was presented by Hui & Yang [18]. This improvement is achieved by applying two cooperative approaches to original BFO, ie; serial heterogeneous cooperation on implicit space decomposition level and serial heterogeneous cooperation on a hybrid space decomposition level.

A novel swarm intelligence optimization method integrating BFO with quantum computing, called quantum bacterial foraging optimization (QBFO) algorithm was proposed by Li et al., [15]. Numeric results showed that the new QBFO had powerful properties in convergence rate, stability and the ability of searching for a global optimal solution than the BFO and quantum genetic algorithms separately. Results indicate that the new QBFO showed better convergence behaviour without premature convergence having powerful properties in convergence rate, stability and in searching for a global optimal solution compared to ant colony optimization algorithm and quantum genetic algorithm.

A simple scheme to adapt the chemo tactic step size of BFO was proposed by Jarraya et al., [16]. With this, two popular optimization techniques called PSO and Differential Evolution (DE) are coupled into a new hybrid approach named Adaptive Chemo tactic Bacterial Swarm Foraging Optimization with Differential Evolution Strategy (ACBSFO _DES) which proved that it could overcome problems of premature convergence both classical BFOA and other BFOA hybrid variants of many benchmark problems.

Xiao Long et al., [17] introduced a new hybrid algorithm to improve efficiency, accuracy and overcome drawbacks of weak ability to perceive the environment and being vulnerable to perception of local extreme in the BFO optimization process. In the new algorithm, PSO is merged into BFO chemo taxis with an elimination probability being proposed for elimination-dispersion according to the bacteria’s energy. To compare the performance of this new hybrid algorithm with BFO/PSO, some high dimensional complex functions were proposed to test the 3 bionic algorithms. Results showed that the new algorithm had better searching speed and an obvious improvement in accuracy.

III. METHODOLOGY

This section explains the hybrid of Bacterial Foraging Optimization (BFO) and Bee Swarm Optimization (BSO).

3.1 Proposed Hybrid BFO-BSO

BFO belongs to a new class of biologically encouraged stochastic global search techniques which mimics E. coli bacteria's foraging behaviour. This method locates, handles and ingests food. During foraging, a bacterium exhibits tumbling or swimming actions. Chemo taxis movement continues till the bacterium goes to a positive-nutrient gradient. After specific complete swims, the population's best half undergoes reproduction eliminating the reminder of the population. An elimination-dispersion event escapes local optima, where some bacteria are killed randomly with a very small probability. New replacements are initialized at random search space locations.

The procedures implemented are:

$$f = \beta . f_1 + (1-\beta). f_2$$

Where f_1 is nodes maximum average Euclidean distance with associated CHs and f_2 is ratio of nodes total initial energy to CH candidate's total energy expressed as follows:

$$f_1 = MAX_{k=1,2,3\ldots k}\left\{\sum_{\forall n_1 \in c_{p,k}} \frac{d(n_i, CH_{p,k})}{|C_{p,k}|}\right\}$$

$$f_2 = \frac{\sum_{i=1}^{N} E(n_i)}{\sum_{i=1}^{N} E(C_{p,k})}$$

Here, N is number of nodes of which K is elected as CHs. |Cp,k | are nodes that belong to cluster Ck in particle p, ensuring that only nodes with above average energy resources are elected as CHs, with minimum average distance between nodes and CHs. LEACH uses energy as the objective function and is based on the energy threshold T. In this work a novel objective function is proposed and given by

$$\min f_i(x) = \alpha_i(\min(PLR)) + \alpha_2\left(\min\left(\frac{E_i^r}{E_{initial}}\right)\right)$$

Where E_i^r is the remaining energy in node i

$E_{initial}$ is the initial energy in the node

PLR is the packet loss rate

BFO tends to get caught in the local optimums, to overcome this, BFO is hybridized with Bee Swarm Optimization (BSO). In the proposed approach, after undergoing a chemo-tactic step, each bacterium also gets mutated by a BSO operator. In this phase, the bacterium is stochastically attracted towards the globally best position found so far in the entire population at current time and also towards its previous heading direction. The BFO and BSO algorithms are run in a pipeline fashion. The output of each algorithm supplied as an input to the next algorithm.

Foraging strategies of colonies of honey bees have been extensively studied [19] but their use for the design of network routing protocols is relatively new. Colonies of honey bees and ants share some common features, such as distributed food collection, individuals with limited capabilities, indirect communication between the individuals, etc. However, as the nature of the insects is different between the two types of colonies, with the foraging ants moving on the terrain and the bees flying, their foraging processes differ significantly from each other. In general terms, during foraging, bees constantly leave the hive searching for new sources of nectar. Once they find it, they bring nectar back to the hive, and try to recruit other bees to exploit the food site found by competing with each other during the recruitment process.

In BSO algorithm, the colony of artificial bees contains three groups of bees: employed bees, onlookers and scouts. A bee waiting on the dance area for making a decision to choose a food source is called onlooker and one going to the food source visited by it before is named employed bee. The other kind of bee is scout bee that carries out random search for discovering new sources. The position of a food source represents a possible solution to the optimization problem and the nectar amount of a food source corresponds to the quality (fitness) of the associated solution, calculated by:

$$\text{fit}_i = \frac{1}{1 + f_i}$$

An artificial onlooker bee chooses a food source depending on the probability value associated with that food source, p_i, calculated by the following expression:

$$p_i = \frac{\text{fit}_i}{\sum_{n=1}^{SN} fit_n}$$

where SN is the number of food sources equal to the number of employed bees, and fit_i, is the fitness of the solution which is inversely proportional to the f_i where f_i is the cost function of the clustering problem.

The steps in proposed BFO-BSO are:

1) Initialization Bacteria swarm
2) Bacteria are randomly distributed in nutrient's map
3) Evaluate fitness
4) Chemo taxis initialized
5) Re production
6) Select best(best fitness) n from the population based on the fitness calculated to generate initial population for BSO
7) Move the employed bees onto their food sources and evaluate their nectar amounts.
8) Place the onlookers depending upon the nectar amounts obtained by employed bees
9) Send the scouts for exploiting new food sources
10) Memorize the best food sources obtained so far
11) If a termination criterion is not satisfied, go to step 4;

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Otherwise stop the procedure and
Display the best solution obtained

IV. Results And Discussion

The experiments conducted for varying number of nodes with single base station in a 2 sq. km area. The number of nodes in a network ranges from 30 to 180. The proposed BFO-BSO is compared with LEACH and BSO based methods. The methods are evaluated for number of clusters formed, end to end delay, packet loss ratio and lifetime.

TABLE I

NUMBER OF CLUSTERS FORMED

Number of nodes	LEACH	Bacterial Foraging Algorithm	Proposed Hybrid BFO-BSO
30	7	8	8
60	9	10	11
90	15	17	18
120	18	18	18
150	19	19	20
180	22	23	24

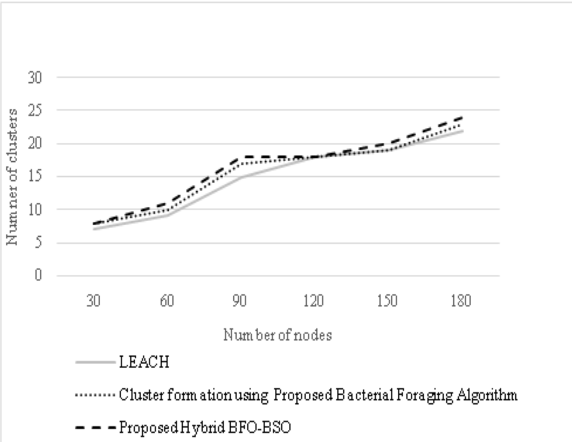

Fig. 1 Number of Clusters formed

It is observed from figure 1, when number of nodes is 30 the percentage of number of cluster formation of hybrid BFO-BSO is increased by 13.33% than LEACH. When number of nodes is 180 the percentage of number of cluster formation of hybrid BFO-BSO is increased by 8.69% than LEACH

TABLE II.

AVERAGE END TO END DELAY (SEC)

Number of nodes	LEACH	Bacterial Foraging Algorithm	Proposed Hybrid BFO-BSO
30	0.001242	0.001183	0.001115
60	0.001138	0.00149	0.001393
90	0.011368	0.013081	0.012633
120	0.018795	0.016424	0.015573
150	0.043275	0.036754	0.034752
180	0.04613	0.037921	0.03626

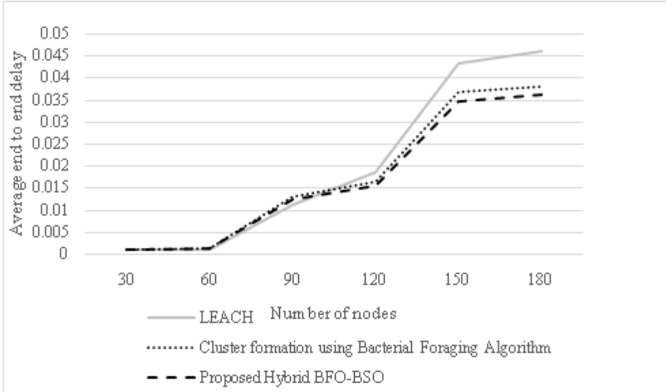

Fig. 2 Average End to End Delay (sec)

It is observed from figure 2, When number of nodes is 30 the percentage of Average End to End Delay (sec) of Cluster formation using Bacterial Foraging Algorithm is decreased by 4.87% than LEACH.

TABLE III.

AVERAGE PACKET DROP RATIO

Number of nodes	LEACH	Bacterial Foraging Algorithm	Proposed Hybrid BFO-BSO
30	0.185	0.0922	0.0879
60	0.16	0.139	0.1305
90	0.163	0.1546	0.1492
120	0.2252	0.21	0.2036
150	0.3129	0.296	0.2765
180	0.4295	0.4028	0.3708

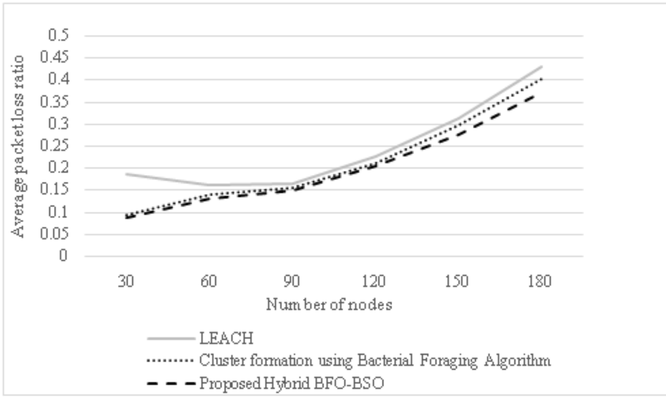

Fig. 3 Average packet drop ratio

It is observed from figure 3, Average packet loss ratio is decreased by hybrid BFO-BSO at 71.16% than LEACH when number of nodes is 30 and by 14.67% than LEACH when number of nodes is 180.

TABLE IV.

LIFETIME COMPUTATION

Number of rounds	LEACH	Bacterial Foraging Algorithm	Proposed Hybrid BFO-BSO
0	100	100	100
100	100	100	96
200	84	94	90
300	72	87	77
400	56	72	64
500	24	58	32
600	0	21	18
700	0	0	14
800	0	0	6

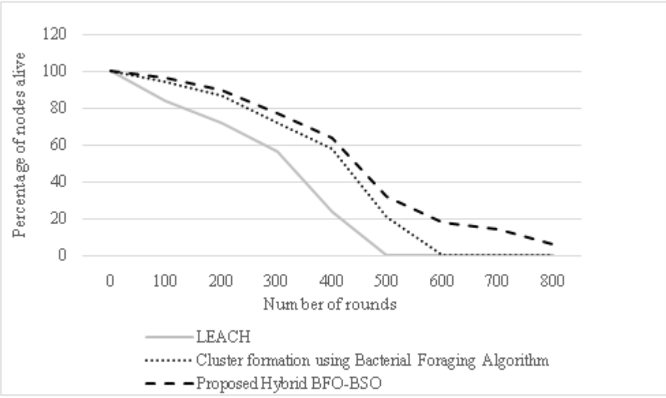

Fig. 4 Lifetime computation

It is observed from figure 4, If the number of rounds is 200 then the percentage of lifetime computation of Cluster formation using hybrid BFO-BSO is increased by 22.22% than LEACH. If the number of rounds 500 then the percentage of lifetime computation of Cluster formation using hybrid BFO-BSO is increased by 200% than LEACH

V. CONCLUSION

WSNs nodes are a mix of mobile and stationary nodes based on applications. Node deployment, energy-aware clustering, localization and data-aggregation problems are formulated as optimization problems. Most analytical methods suffer from slow or lack of convergence to final solutions which call for fast optimization algorithms to ensure quality solutions using less resources. Hybrid BFO-BSO is a popular technique to solve WSN optimization problems due to its simplicity, high solution quality and fast convergence and less computational burden.

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AUTHORS

Mr A. Rajagopal received the B.E(ECE).,degree from Maharaja Engineering College in 1999, He received M.Tech(Applied Electronics)., degree from the Dr M.G.R Educational Research and Institute in 2007.He is currently a Research Scholar in the Dept.of Electronics &Instrumentation Engineering at Annamalai University, Chidambaram, India. He is working as Assistant Professor in the Dept. of ECE, Dr Paul's Engineering College, Villupuram Dt., India.He Published 1 international conference,8 national conferences and journals. He is having 10 years of teaching experience. His research interest includes, communication, wireless sensor networks, RF and microwave Engineering.

Dr S.Somasundaram received the B.E(Electronics & Instrumentation Engg.) degree. He received M.E(Process Control& Instrumentation Engg.).,degree .He received Ph.D Degree in the Dept. of Instrumentation Engineering at Annamalai University ,Chidambaram ,India. He is working as Assistant Professor in the Dept. of Instrumentation Engineering at Annamalai University, Chidambaram, India. He Published 4 international conferences,10 national conferences and journals. . He is having 13 years of teaching experience and 3 years of Research Experience. Currently he is guiding 4 research scholars. His research interest includes Process Control,PI,PD, PID controller and Control system

Dr B.Sowmya received the B.E(ECE) from the Periyar maniyammai college of Technology for women,Tanjore,India in 1994. She received M.Tech in Laser & Electro Optical Engineering ,Anna University ,Chennai in 1999.She received Ph.D in Image processing from Sathyabama University,Chennai in 2011.She is currently working as Professor ,Centre for Research ,Dhanalakshmi College of Engineering,Chennai.She published international Journal 4,National Journal 3,International Conference 10,National Conference 16 and 4 text books. She is having more than18 years of teaching experience. Currently she is guiding 4 research scholars. She is recognized supervisor of Anna University, Chennai. Her Research interest includes Fuzzy clustering, image segmentation and control system

Mrs T.Suguna received the B.E(CSE) from K.S.Rangasamy College of Technology ,Thiruchengode,India in 1999.She has joined as Lecturer under the PIPMATE ,Sponsored by Puducherry Government since 2002.She received M.Tech(IT) from Karnataka State Open University in 2010.She is having good academic records Distinction in B.E., and M.Tech. She is having 2 Years of teaching experience in Engineering College and more than 13 Years of teaching Experience in Polytechnic College. Her research interest includes computer networks, wireless networks, Artificial Intelligence.

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