An Energy Efficient Data Redundancy Reduction Approach for Data Aggregation in WSN

Bharathi M. A[1], B.P. Vijaya Kumar[2], Manjaiah D H[3]

[1]Assoc. Prof: Dept of CSE
Reva ITM, Katteganahalli
Bangalore, India

[2]HOD & Prof.: Dept. of ISE
MSRIT
Bangalore, India

[3]Prof.Dept of CSE,
Mangalore University
Bangalore, India

WSN has the potentiality to join the physical world with the virtual world by creating a network of sensor nodes. Here, sensor nodes are usually battery-operated devices, and hence energy reduction of sensor nodes is a major design issue. To extend the network's lifetime, minimization of energy consumption should be used. In cluster-based routing, cluster heads shape a wireless stamina to the sink. Each cluster heads collects data starting from the sensors belonging to its cluster and relay it to the sink. Here, the cluster head position rotates, i.e., each node works as a cluster head for a restricted period of time. Energy saving in BFOA approaches can be done by cluster formation, cluster-head election, data collection at the cluster-head nodes to reduce data redundancy and thus save energy and also to improve energy efficiency of homogeneous WSN. It also defines Bacterial Foraging Optimization Algorithm (BFOA) as an algorithm for selecting best cluster head selection for WSN. The simulation results enhanced performance of BFA based on total energy dissipation and no .of .alive nodes of the network when compared with LEACH.

Keywords:BFOA,Chemotaxis,Swarming,Tumbling

1. Introduction

Wireless Sensor Networks (WSNs) consists of networked sensors that work together in hundreds of thousands of numbers for collaborative signal processing, monitoring, sensing and control tasks. WSNs offer extensive benefits and versatility to low-power and low-cost rapid deployment for many applications that can be automated without any human supervision. Many of the applications include disaster recovery, military surveillance, health administration, environmental & habitat monitoring, target tracking. WSNs can self organize and self-configure independently by inter-node communications possible through multi-hop wireless paths. While the communications of each node is possible via the transceiver unit, each sensor node also consists of a sensing unit, processing unit, and a power basis unit. Each of these units is included together with the help of ICs with integrated signal processing and micro-sensing components. These nodes that form the WSN can be sited far from the actual occurrence, and can still be used for data aggregation and collection from a remote location far away from the point of event-occurrence. This scheme uses bacteria foraging algorithm in wireless sensor network to improve the energy efficiency of each sensor nodes, whereas in previous schemes it used in control system. Nowadays Bacteria Foraging technique is gaining importance in the optimization problems. Because a) Philosophy says, Biology provides highly automated, robust and effective organism, b) Search strategy of bacteria is salutary (like common fish) in nature c) Bacteria can sense, make a decision and act so adopts social foraging (foraging in groups). To perform social foraging an animal needs communication capabilities and it gains advantages that can exploit essentially the sensing capabilities of the group, so that the group can gang-up on larger prey, persons can obtain safety from predators while in a group, and in a certain sense the group can forage a kind of intelligence. BFA is based on the foraging performance of Escherichia Coli (E. coli) bacteria present in the person intestine.

2. Related Work

Efren Mezura-Montes and Betania Hernandez-Ocana [1] has explored another swarm-intelligence-based model: Bacterial Foraging Optimization Algorithm (BFOA), inspired in the behavior of bacteria E. coli in its search for food. Three behaviors were modeled by Passino in his original proposal (1) Chemotaxis, (2) reproduction and (3) elimination-dispersal.

Swagatam Das et al [2] has presented, Bacterial foraging optimization algorithm (BFOA) has been widely accepted as a global optimization algorithm of current interest for distributed optimization and control. BFOA is inspired by the social foraging behavior of Escherichia coli. BFOA has already drawn the attention of researchers because of its efficiency in solving real-world optimization problems arising in several application domains. The underlying biology behind the foraging strategy of E.coli is emulated in an extraordinary manner and used as a simple optimization algorithm.

R. Vijay [3] has presented an overview of the biology of bacterial foraging and the pseudo-code that models this process also explained. This paper presents a novel BFO to solve Economic Load Dispatch (ELD) problems. The results are obtained for a test system with three and thirteen generating units. In this paper the performance of the BFO is compared with Genetic Algorithm (GA) and Particle Swarm Optimization (PSO). The results clearly show that the proposed method gives better optimal solution as compared to the other methods.

Ahmed Y. Saber et al [4] has proposed a novel modified bacterial foraging technique (BFT) to solve economic load dispatch (ELD) problems. BFT is already used for optimization problems, and performance of basic BFT for small problems with moderate dimension and searching space is satisfactory. Search space and complexity grow exponentially in scalable ELD problems, and the basic BFT is not suitable to solve the high dimensional ELD problems, as cells move randomly in basic BFT, and swarming is not sufficiently achieved by cell-to-cell attraction and repelling effects for ELD.

Om Prakash Acharya et al [5] has demonstrated, the task of fault finding in antenna arrays was approached as an optimization problem and was solved using BFO technique. BFO was used to find the amplitude excitations from the pattern of the defected array which was then compared with the excitations of the original array to find the location and level of fault in the defected array. Partial as well as complete fault cases were considered and located successfully. Although a linear Chebyshev array was taken as the test antenna in this work, but the same methodology is applicable for any type of array.

Dong Hwa Kim [6] has proposed method using four test functions and the performance of the algorithm is studied with an emphasis on mutation, crossover, variation of step sizes, chemo tactic steps, and the lifetime of the bacteria. The proposed algorithm is then used to tune a PID controller of an automatic voltage regulator (AVR). Simulation results clearly illustrate that the proposed approach is very efficient and could easily be extended for other global optimization problems.

H. Nouri et al [7] has proposed, an attempt is made to tuning chemo tactic and swarming steps parameters meanwhile taking into consideration bacteria foraging optimization algorithm convergence speed and performance. The factorial designed experiment is suggested to create treatments of experiment. The adequacy of the proposed model is analyzed based on some commonly statistical criteria.

Rajasekhar Anguluri et al [8] presented, a new hybrid algorithm combining the features of BFOA and Particle Swarm Optimization (PSO) for tuning a Fractional order speed controller in a Permanent Magnet Synchronous Motor (PMSM) Drive. Computer simulations illustrate the effectiveness of the proposed approach compared to that of basic versions of PSO and BFO.

Hsuan-Ming Feng et al [9] has proposes a novel bacterial foraging swarm-based intelligent algorithm called the bacterial foraging particle swarm optimization (BFPSO) algorithm to design vector quantization (VQ)-based fuzzy-image compression systems. It improves compressed image quality when processing many image patterns. The BFPSO algorithm is an efficient evolutionary learning algorithm that manages complex global optimal codebook generation problems.

Wael Korani et al [10] has illustrated, a new algorithm Bacteria Foraging oriented by PSO (BF-PSO). The new algorithm is proposed to combines both algorithms' advantages in order to get better optimization values. The proposed algorithm is applied to the problem of PID controller tuning and is compared with conveniently Bacterial Foraging algorithm and Particle swarm optimization.

Yudong ZHANG et al [11] have proposed BFO is a novel and powerful global search technique, and it can find the weights/biases of the neural network quickly and accurately. Experiments indicate that the proposed BFO-NN is superior to GA-NN with respect to convergence speed and forecast accuracy.

A. N. K. Nasir et al [12] has illustrated, a hybrid optimization algorithm referred to as Hybrid spiral dynamics bacterial foraging (HSDBF). The algorithm synergizes spiral adaptive simplified bacterial foraging algorithm (BFA) and spiral dynamics inspired optimization algorithm (SDA).

E. Ben George et al [13] has demonstrated an innovative approach to extract the textural features from the segmented magnetic resonance image to classify the tumors into benign, malignant or normal. Textural analysis methods such as Spatial Gray Level Dependency Matrix (SGLDM) and Surrounding Region Dependency Matrix (SRDM) are used to extract the fourteen Haralick features from the segmented image.

3. Evolution of Bacterial Foraging

During foraging of the real bacteria, locomotion is achieved by a set of tensile flagella. Flagella help an E.coli bacterium to tumble or swim, which are two basic operations performed by a bacterium at the time of foraging. When they rotate the flagella in the clockwise direction, each flagellum pulls on the cell. That results in the moving of flagella independently and finally the bacterium tumbles with lesser number of tumbling whereas in a harmful place it tumbles frequently to find a nutrient gradient. Moving the flagella in the counterclockwise direction helps the bacterium to swim at a very fast rate. In the above-mentioned algorithm the bacteria undergoes chemotaxis, where they like to move towards a nutrient gradient and avoid noxious environment. Generally the bacteria move for a longer distance in a friendly environment. Fig. 1 depicts how clockwise and counter clockwise movement of a bacterium take place in a nutrient solution.

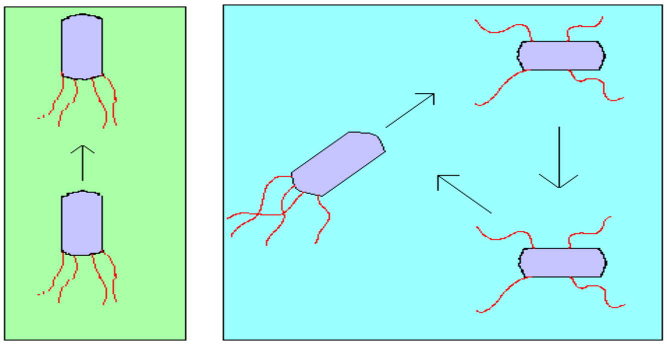

Fig.1 Swim and tumble of a bacterium

When they get food in sufficient, they are increased in length and in presence of suitable temperature they break in the middle to from an exact replica of itself. This phenomenon inspired Passino to introduce an event of reproduction in BFOA. Due to the occurrence of sudden environmental changes or attack, the chemotactic progress may be destroyed and a group of bacteria may move to some other places or some other may be introduced in the swarm of concern. This constitutes the event of elimination-dispersal in the real bacterial population, where all the bacteria in a region are killed or a group is dispersed into a new part of the environment.

4. Proposed System

In this scheme, BFOA (Bacteria Foraging Optimization Algorithm) is used to enhance the energy efficiency in wireless sensor networks. The proposed algorithm aims at balancing the energy consumption among the nodes in every cluster and reducing the energy dissipation of the cluster-heads. Like conventional LEACH protocol [14], this runs many rounds in the lifetime of the network. It includes four phases [2] during the working process: a cluster formation phase, a cluster-head adjustment phase, cooperative nodes selection phase and a steady phase. Algorithm output produced the best cell value where it can be a cluster head. At initial step cell number, problem sizes are given to find the initial population. Based on this population the high energy node is calculated. There are four basic steps[2], such as chemotaxis, swarming, reproduction, removal and dispersal.

$$P(j,k,l) = \{\theta i(j,k,l)| \ i =1,2,K,S\} \qquad (1)$$

Let j be the chemotactic step, k be the reproduction step, l be the elimination and dispersal event, s be the bacteria. Chemotactic is a process of finding nearby nodes. Let Nc be the distance end to end of the lifetime of the bacteria as deliberate by the number of chemotactic steps they take during their life.

Let C(i) λ0, i , λ1, 2, K, S, denote a basic chemotactic step size is to define the lengths of steps during runs. Tumbling is a process of moving to nearby nodes based on the specific set of directions. To signify a tumble, a unit length arbitrary direction, say λ(j), is generated; unit length will be used to define the path of movement after a tumble. In particular, we let,

$$\lambda i(j1,k,l) \ \lambda\lambda i(j,k,l)C(i)\lambda(j) \qquad (2)$$

So that C(i) is the size of the step taken in the arbitrary direction specified by the tumble. Swimming is same as tumbling but it doesn't have a specific set of directions only there is a little displacement. If at θi(j+1,k,l) the cost J(i, j+1,k,l) is better (lower) than at θi(j,k,l), then another step of size C(i) in this same direction will be taken, and again, if that pace resulted in a position with a better cost value than at the previous step, another step is taken. This swim is continued as long as it continues to reduce the cost, but only up to a utmost number of steps, Ns. This represents that the cell will be apt to keep moving if it is headed in the path of increasingly favorable environments.

The proposed algorithm is discussed under following phases:

Cluster Formation Phase: Every node sends its position information to the base station. A certain number of nodes are elected to act as the auxiliary cluster-heads with a certain probability. According to the number of auxiliary cluster-heads, the network is divided into the same number of clusters evenly. If no node dies, the number of auxiliary cluster-heads is fixed, and also the number of members in every cluster is same means fixed. To construct the cluster network, the base station starts with the furthest node from it as the first auxiliary cluster head, which chooses the nearest fixed number of nodes as its member nodes. Then the base station chooses the furthest node from it as the second auxiliary cluster-head from the rest nodes, which chooses the nearest fixed number of nodes as its members. This process continues until all the auxiliary cluster heads and members are chosen out. The base station sends notifications to all the nodes in the network. According to this procedure, if no sensor node dies in the network, this cluster construction is stable. The network owns the same auxiliary cluster-heads and every auxiliary cluster-head owns the same members.

4.1 Cluster Adjustment Phase

The auxiliary cluster-heads are not the final cluster-heads, and BFOA algorithm is used for the adjustment. The algorithm is employed by every node. Auxiliary cluster heads then decide the final cluster-heads by BFOA after every member node sends its position and residual energy information to its auxiliary cluster-head. Each auxiliary cluster-head computes the position of the final cluster-head, and sends notifications to the final cluster-head and other members in the cluster. In this phase, the BFOA algorithm is used by the auxiliary cluster-head for the adjustment. We can use a fitness function which is based upon the relative distance of each node from the auxiliary cluster head and the residual energy of each node.

On the basis of this fitness function and at the end of all chemotaxis steps we can find suitable positions for each sensor node (by following BFO algorithm). At last the bacteriam or all sensor nodes in the cluster send their relative position and residual energy to the auxiliary cluster head, then the auxiliary cluster head compute the final cluster head position. Now suppose before starting iteration, all the bacteria are present at their real position and after iteration all the bacterias are present at their suitable position. Then the most suitable position is mapped into one of the real positions of the nodes in the cluster. Auxiliary cluster head do this mapping according to:

Dmin = min {||Pb-P1| |,| |Pb-P2||, ||Pb-P3||……..||Pb- Pn||}
Hear Pb = real position,
Pn = suitable position

Then the real position of a certain node with dmin will be chosen to the position of final cluster head, which means that the nearest node from the Pb will act as the final cluster-head.

4.2 Cooperative node Selection Phase

After the cluster formation, each cluster head will select J cooperative sending and receiving nodes for wireless sensor network communication with each of its neighboring cluster head (j is fixed). Nodes with higher energy close to the cluster head will be elected as sending and receiving cooperative nodes for the cluster. The cluster head will broadcast a cooperative request message, which contains the ID of the cluster itself, the ID of the neighboring cluster head y, the ID of the transmitting and receiving cooperative nodes and the index of cooperative nodes in the cooperative node set of each cluster head to each cooperative node. The cooperative node on receiving the cooperative request message, stores the cluster head ID and sends back a cooperate-acknowledgement message to the cluster head. In this wireless sensor network cluster head itself act as a sender or receiver means cluster head also take part in cooperatively sending and receiving. Such technique is seen implemented on LEACH protocol, but in that it suffers from lot of draw backs, But in the proposed scheme these draw backs are can be removed by considering a good energy balancing fitness function.

4.3 Data Transmission Phase

During this phase, the data sensed by sensor nodes are transmitted to the cluster head and forwarded to the sink using wireless sensor network scheme according to the routing table.

4.4 Intra Cluster Transmission

In this phase, the non-cluster head nodes send their data frames to the cluster head during their allocated time slot.

4.5 Inter Cluster Transmission

After a cluster head receives data frames from its cluster members, it performs data aggregation and broadcasts the data to J cooperative wireless sensor network sending nodes. When each cooperative sending node receives the data packet, they including cluster head encode the data using space time block code and transmit the data cooperatively. The advantage of using space time block code technique is that they provide diversity gain in both transmits and receive operation in wireless sensor network system. The diversity gain therefore provides reliable and energy efficient transmission. The receiving cooperative nodes use channel state information to decode the space time coded data. The cooperative node relays the decoded data to the neighboring cluster head node and forwards the data packet to the target cluster head.

5. Algorithm Design

5.1 Chemo taxis

This process in the control system is achieved through swimming and tumbling via Flagella. Each flagellum is a left-handed coil configured so that as the support of the flagellum (i.e., where it is connected to the cell) rotates counterclockwise, as viewed from the free end of the flagellum looking in the direction of the cell, it produces a force against the bacterium so it pushes the cell. On the other hand, if they rotate clockwise, each flagellum pulls on the cell, and the net result is that each flagellum operates relatively independently of others, and so the bacterium tumbles about. Therefore, an E. coli bacterium can go in two different ways; it can run (swim for a period of time) or it can tumble, and exchange flank by these two modes of operation in the entire lifetime. To represent a tumble, a unit distance end to end arbitrary direction, say(j), is generated; this will be used to define the way of movement after a tumble[2]. In particular

$$J_{cc}(\theta, P(j,k,l)) = \sum_{i=1}^{S} J_{cc}^{i}(\theta, \theta^{i}(j,k,l))$$

$$= \sum_{i=1}^{S}[-d_{attract\tan t} \exp(-w_{attract\tan t} \sum_{m=1}^{p}(\theta_m - \theta_m^t)^2)]$$

$$+ \sum_{i=1}^{S}[h_{repellent} \exp(-w_{attract\tan t} \sum_{m=1}^{P}(\theta_m - \theta_m^t)^2)] \quad (3)$$

Where Jcc (θ, P(j,k,l)) is the cost function value to be added to the real cost function to be minimized to present a time changeable cost function, S is the total number of bacteria, P is the numeral of parameters to be optimized which are present in each bacterium, and dattract, wattract, hrepellent, wrepellent are different coefficients that are to be chosen properly.

5.2 Reproduction

The minimum healthy bacteria die and the other healthier bacteria each split into two bacteria, which are located in the same location. This makes the inhabitants of bacteria constant.

5.3 Elimination and Dispersal

It is probable that in the local environment, the lives of a population of bacteria changes either step by step (e.g., via consumption of nutrients) or unexpectedly due to some other influence. Actions can occur such that all the bacteria in an area are killed or a group is isolated into a new part of the environment. They have the effect of perhaps destroying the chemotactic progress, but they also have the effect of support in chemotaxis, since spreading may place bacteria near good food sources. From a wide perspective, elimination and dispersal are parts of the population-level long-distance motile behavior.

6 System Design

To explain how chemo taxis motions are generated, we must simply explain how the bacteria decides how long to run, since from the above discussion we know what happens during a tumble or run. First, note with the intention of if an E. coli is in some substance that is neutral in the sense that it does not have food or noxious substances, and if it is in this medium for a long time (e.g., more than 1 min), then the flagella will simultaneously alternate between moving clockwise and counterclockwise so that the bacterium will alternately tumble and run. This alternation between the two modes will move the bacterium, but in arbitrary directions, and this enables it to “search” for nutrients. For instance, in the isotropic homogeneous environment described above, the bacterium alternately tumbles and runs with the mean tumble and run lengths given above and at the speed that was given. If the bacteria are placed in a homogeneous concentration of serine (i.e., one with a nutrient but no gradients), then a variety of changes occurs in the characteristics of their motile behavior. For instance, mean run length and mean speed increase and mean tumble time decreases. They do still produce, however, a basic type of searching behavior; even though the bacterium has some food, it persistently searches for more. Suppose that we call this its baseline behavior. As an example of tumbles and runs in the isotropic homogeneous medium described above, in one trial motility experiment lasting 29.5 s there were 26 runs, the maximum run length was 3.6 s, and the mean speed was about 21 Next, suppose that the bacterium happens to meet a nutrient gradient (e.g., serine). The change in the concentration of the food triggers a reaction such that the bacterium will spend large time swimming and less time tumbling.

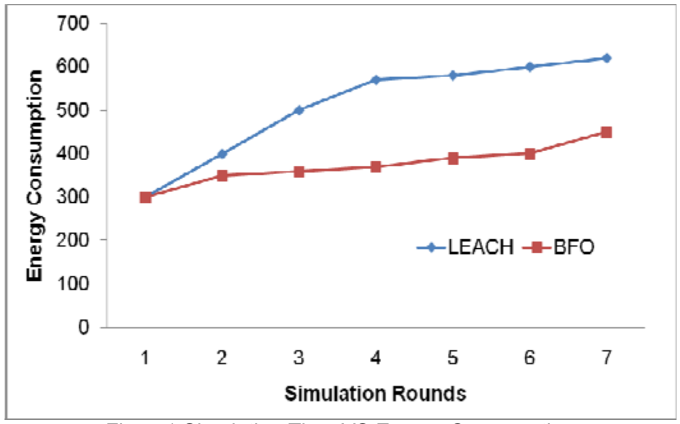

Fig. 4.1 Simulation Time VS Energy Consumption

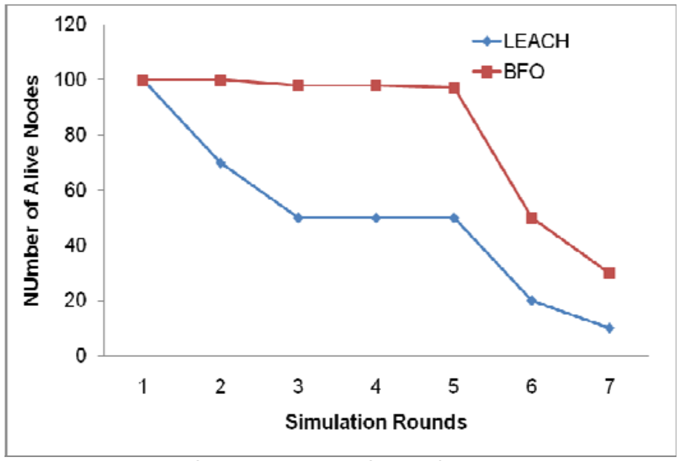

Fig. 4.2 Simulation Time VS No. of. Alive Nodes

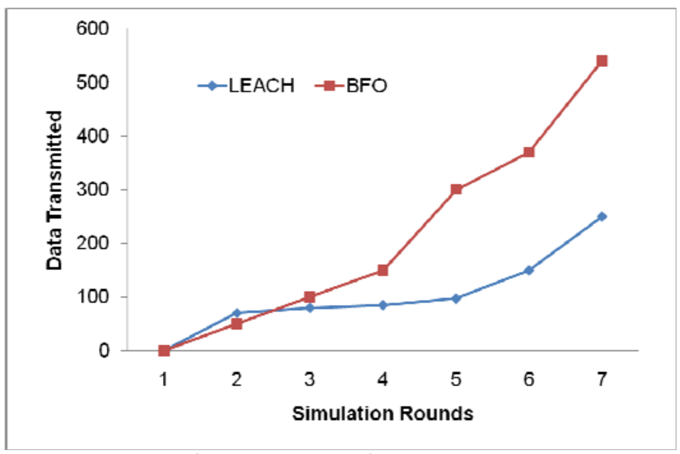

Fig. 4.3Simulation Time VS Data Transmission

7 Conclusion

The first contribution of the scheme is related to use of bacteria foraging algorithm firstly for WSNS for enhancing network lifetime of sensor nodes. To validate the algorithm, simulations had been carried out using Matlab. simulation results showed better performance of BFA as compared to other clustering protocols like leach, in terms of performance metrics like number of alive nodes and total energy dissipation in the system. BFA provides better lifetime for nodes compared to LEACH. It is also seen that BFA is able to provide 100% live nodes for maximum duration. leach provides a considerably higher lifetime compared to k-means clustering.

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