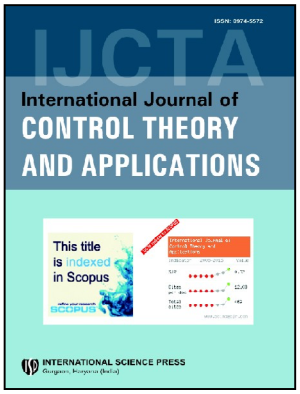

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Energy Efficient Traffic Protocol in Wireless Sensor Networks Using Improved Metaheuristic Algorithm

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Abstract: This paper proposes an improved Ant Colony Optimization (iACO) algorithm with improved search patterns using Fractional Brownian Motion for improving the exploitation capability. To improve the global convergence and to increase the energy efficiency using proposed iACO, Fractional Brownian Motion is used. This maintains a proper balance between the exploitation and exploration abilities using this motion and this limits the hardware requirement of routing. Additionally, the energy efficiency of the clustering protocol using iACO algorithm inherits the capabilities of attaining the optimal cluster head (CH) selection and further improves the energy efficiency. The results obtained through the simulator proves that the proposed iACO protocol performs well than the other known protocols in terms of its throughput, packet delivery ratio, and energy consumption.

Keywords: energy efficiency, improved metaheuristic algorithm, wireless sensor networks, ant colony optimization.

1. INTRODUCTION

In cluster WSNs, the Sensor Nodes (SNs) are divided into several clusters with a Cluster Head (CH). The advantages of clustering involves: Data Aggregation over the data obtained from several SNs within a single cluster. This reduces the data to transmit over BS for reducing the energy consumption in WSN. The CHs rotation balances the energy consumption and prevents the energy starvation in WSN nodes [1]. The selection of optimal CH for energy consumption is a NP-hard problem [2]. Hence, the use of Computational intelligence [3] approaches like Evolutionary algorithms (EAs), Artificial Immune systems (AIS) and Ant Colony Optimization (ACO) is used as metaheuristic algorithm to improve the energy efficiency in clustering protocols [4]. The performance of performance of ACO algorithm is better than other population algorithms with certain like less control parameters and simplicity in its implementation [5]. Conversely, like other population algorithms, the standard ACO poses certain challenges like poor exploitation and exploration of ants with slower convergence rate during multi-optimization problems [6]. Hence, to improve the problems associated with ACO, an improved Ant Colony Optimization (iACO) algorithm is proposed with improved searching abilities to improve the exploration capability for finding out the optimal CHs in the WSN. The finding of optimal CHs in the cluster WSN helps in improving the energy efficiency with Fractional Brownian motion behavior over ants.

The outline of the paper is shown as follows: Section 2 provides the conventional protocols for energy efficiency in WSNs. Section 3 proposes the contribution of the algorithm in WSN to attain the energy efficiency. Section 4 discusses the results of the proposed protocol with various parameters. Section 5 concludes the entire work.

2. RELATED WORKS

Several clustering protocols are designed in WSNs, where the proposed protocol provides similar approach like the conventional protocols in WSNs. LEACH protocol [7] combines the routing based energy efficient clustering with data aggregation for achieving better lifetime. HEED [8] clustering protocol selects the optimal CH using node hybridisation on residual energy and proximity neighbour node selection for uniform distribution of CH. PEACH [9] helps in selection of CH without overhead and helps in better support for multi-level clustering. T-ANT [10], exploits the swarm principle: separation of ants and alignment of ants using a pheromone control for obtaining uniform and stable distribution for CHs section. EEMC [11] attains lesser energy consumption in WSNs using multi-level clustering with less overhead. EEHC [12] attains CHs using election of weighted node probabilities using its node heterogeneity and residual energy. Multi-path Routing Protocol (MRP) [13], uses dynamic clustering with ACO and selects CHs using residual node energy. EECF [8] is a distributed clustering for the selection of CHs using 3-way message exchange function between the neighbour nodes and the each sensor with high residual energy. MBC protocol [14] selects the CHs based on mobility and residual energy and non-CH maintains link stability during its setup phase.

UCFIA [15] uses fuzzy logic for determining the CH using residual energy. DEECIC [16] uses minimum CHs to cover the network using distribution and residual energy information.

Energy-Aware Evolutionary Routing Protocol (ERP) [17] attains better lifetime and using energy utilization in WSN.

The HSACP [18] reduces the intra-cluster distances between the clusters and optimizes the energy efficiency in WSNs. BeeSensor [19] is an on-demand routing protocol that uses bee model for providing better performance over energy efficiency in WSN. Linear/ Nonlinear Programming [20] uses PSO to optimize the energy efficient and routing in WSNs.

It is clear that comparison with classical Computational Intelligence approaches possess its own features and limitations. Also, approaches discussed here are good in its self-organization and node balancing behaviour with less overhead and provides average energy efficiency. However, metaheuristic based algorithm proves better energy efficiency and higher lifetime in network. Hence, metaheuristic algorithm further needs to be redesigned for its improvement in energy efficiency over WSNs.

3. PROPOSED METHODOLOGY

The proposed method involves following steps:

(A) Improved Ant Colony Optimization (iABC)

This method attempts to improve the rate of convergence rate to perfectly balance the phase of exploitation of route and exploration of ant capabilities in conventional ACO algorithm. Hence, an improved Ant colony optimization (iABC) is proposed with Fractional Brownian Motion to improve the search pattern in WSN node.

(B) Fractional Brownian Motion based ACO

This section defines the improved ACO clustering protocol that Utilises the capabilities of the metaheuristic algorithm, A Fractional Brownian Motion is used to improve the search pattern of ants in the ACO algorithm for better cluster and easier selection of CHs using NP-hard optimization problem. Additionally, the optimal location of BS is determined using estimation of energy equations for reducing the consumption of the energy in WSN with increased network lifetime.

The Ant Colony Optimization (ACO) algorithm uses foraging ant behaviour to schedule, plan and route between the WSN nodes. Here, the ants finds the minimum path length for connecting the source with destination node. To achieve this, ants uses a graph that incorporates the local component solution. The probability random function of k ants moving from node *i* to *j* gives the probability of incorporating the *j* over local solution.

$$p_{ij}^{k} = \frac{\eta_{ij}^{\beta}\tau_{ij}^{\alpha}}{\sum_{u\in N_i^k}\eta_{iu}^{\beta}\tau_{iu}^{\alpha}} \tag{1}$$

Here,

τ_{ij} - heuristic function describing the incorporation of *j*.

η_{ij} - pheromone value representing the solution quality included in *j*.

α and β - parameters for measuring the pheromone influence and the heuristic influence.

η_{ki} - feasible nodes from *i* as per the local solution by *k* ants.

The communication between the *k* ants is usually performed within the clustering environment. If an ant has provided a complete set of solutions, the ant returns to the nest and deposits the pheromones in its path for guiding the other ants to build better solutions. The pheromone quantity, which is deposited between *i* and *j* is η_{ij}, which is directly related to the solution quality. This represents the better solutions with higher pheromone value and the path attracts other using Eq.1. To increase the non-optimal solutions and to attract more ants, pheromone are reduced as per the evaporation rate ρ. Also, the motion of the ants are determined using Fractional Brownian motion.

Based on the destination node selection, a single server queue of packets is fed at constant service rate, *C* [B/s] using FBM input, mean input rate m [B/s], Hurst parameter H, and variance σ_1^2. The mean input, $\mu = m-C$, characterise the queueing model through: *H*, μ and σ_1^2. Hence, the PDF of Q is:

$$\frac{P\left(Q\in\left(x,x+dx\right)\right)}{dx} \approx \frac{v\alpha^{\beta/v}}{\Gamma\left(\beta/v\right)}x^{\beta-1}e^{-\alpha x^{v}} \tag{2}$$

$$\alpha = \frac{\left(1-H\right)^{2(H-1)}\left|\mu\right|^{2H}}{2H^{2H}\sigma_1^2} \tag{3}$$

Where,

$$B = \left(1-H\right)/H^2$$

$$v = 2\left(1-H\right)$$

The distribution of FBM queue size or the Generalised Gamma distribution (GGD) is treated as the Amoroso distribution. This helps in modeling the income rates and the density function is shown below:

$$f_x\left(x:a,d,g,p\right)=\frac{p\left(x-g\right)^{d-1}\exp\left(-\left(\left(x-g\right)/a\right)^{p}\right)}{a^{d}\Gamma\left(d/p\right)} \tag{4}$$

Here,

a, d and $p > 0$ and $x \geq g$, with $g \in R$

$\Gamma(\cdot)$ - gamma function.

The Amoroso distribution with $g = 0$ is defined in terms of cumulative distribution and moment-generating function,

$$F\left(x:a,d,p\right)=\frac{\gamma\left(\left(d/p\right),\left(x/a\right)^{p}\right)}{\Gamma\left(d/p\right)} \tag{5}$$

$$M\left(t:a,d,p\right)=\sum_{k=0}^{\infty}\frac{a^{k}t^{k}}{k!}\frac{\Gamma\left(\left(d+k\right)/p\right)}{\Gamma\left(d/p\right)} \tag{6}$$

where, $\gamma(\cdot)$ - incomplete Gamma function. Finally, the mean and variance value, respectively at $g = 0$,

$$E\left[Q\right]=a\frac{\Gamma\left(\left(d+1\right)/p\right)}{\Gamma\left(d/p\right)} \tag{7}$$

$$Var\left[Q\right]=a^{2}\left[\frac{\Gamma\left(\left(d+2\right)/p\right)}{\Gamma\left(d/p\right)}-\left(\frac{\Gamma\left(\left(d+1\right)/p\right)}{\Gamma\left(d/p\right)}\right)^{2}\right] \tag{8}$$

$$E\left[Q-E\left[Q\right]^{3}\right]=\frac{a^{3}\Gamma\left(\left(d+3\right)/p\right)}{\Gamma\left(d/p\right)}+2\left(a\frac{\Gamma\left(\left(d+1\right)/p\right)}{\Gamma\left(d/p\right)}\right)^{3}-\frac{3a^{3}\Gamma\left(\left(d+1\right)/p\right)\Gamma\left(\left(d+2\right)/p\right)}{\Gamma^{2}\left(d/p\right)} \tag{9}$$

The 3rd central moment function is calculated from the MGF to form GGD with $g = 0$, $p = \nu$, $d = \beta$ and $a = \alpha^{-1/\nu}$ and established the distribution of FBM queue for better packets delivery using GGD.

The ACO algorithm also considers the network topology information, i.e. the information related to the links and connections between the nodes for performing the task of finding. τ_{ij} measures the incorporation of the user e_i with C_j cluster through analysis of varied connections exist between the e_i and C_j. This is shown in Eq.10.

$$\tau ij=\frac{|N_i \cap C_j|}{|N_i|} \tag{10}$$

Where

N_i - elements set for connecting e_i

$|\cdot|$ - function for computing the elements over a specific set.

Therefore, this establishes the connection exist between the e_i over the cluster C_j. Depending on the selection of best route, the cluster head is selected using the maximum nodal energy and the node nearest to the best pheromone path.

4. RESULTS AND DISCUSSIONS

The performance of iACO with fractional Brownian motion protocol is compared with conventional protocols like Artificial Bee Colony [19], MRP [13] and ERP [17] using NS2 simulator. The proposed is evaluated under BS position scenarios for evaluating its behavior towards the packet delivery ratio, energy consumption and network throughput. The simulation measurement is performed under a standard protocol using free space propagation. This is carried out under CBR traffic type and the other parameters are shown in Table 1.

Table 1
Simulation Parameters

Parameter	*Value*
Size of the cluster	150×150 m^2
Protocol Type	802.11
Propagation Space	Free Space
Propagation limit	-100 dB
Traffic Type	CBR
Data rate	2.4 Mbps
Message size	500 bits
Packet size	4000 bits

The results of the proposed method are shown below:

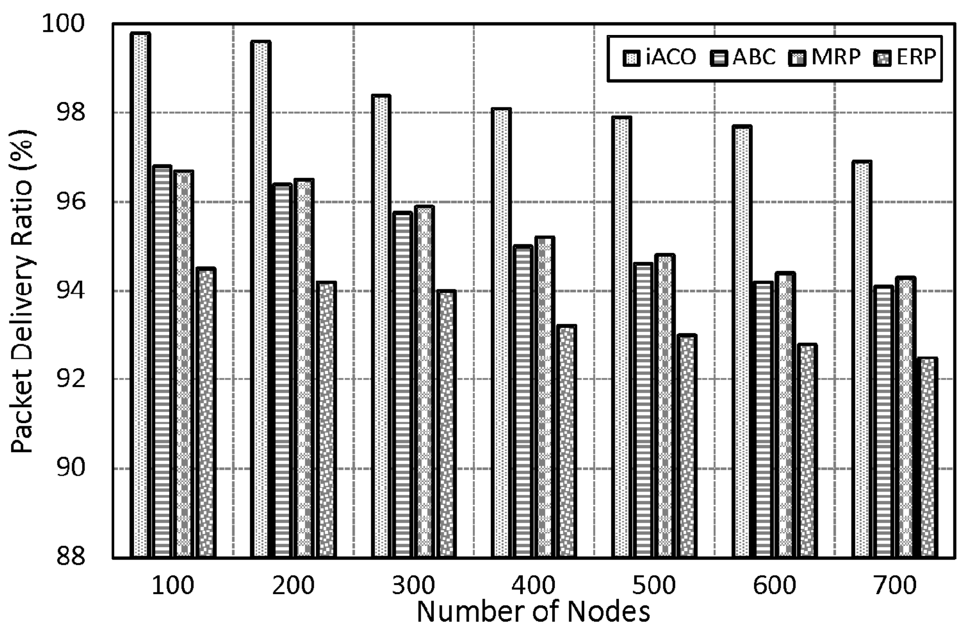

Figure : Packet Delivery Ratio

In this scenario, Fig. proves that the proposed iACO protocol design delivers most packets than the other peers. This is also proved better in terms of higher node density. The iACO delivers nearly 100% of its packets during the cluster density of 100 nodes, where the BSs is placed at at an optimal location. Also at the node density ranging 200-700 nodes, the packet delivery ratio of iACO is highest than Bee, MRP and ERP protocols.

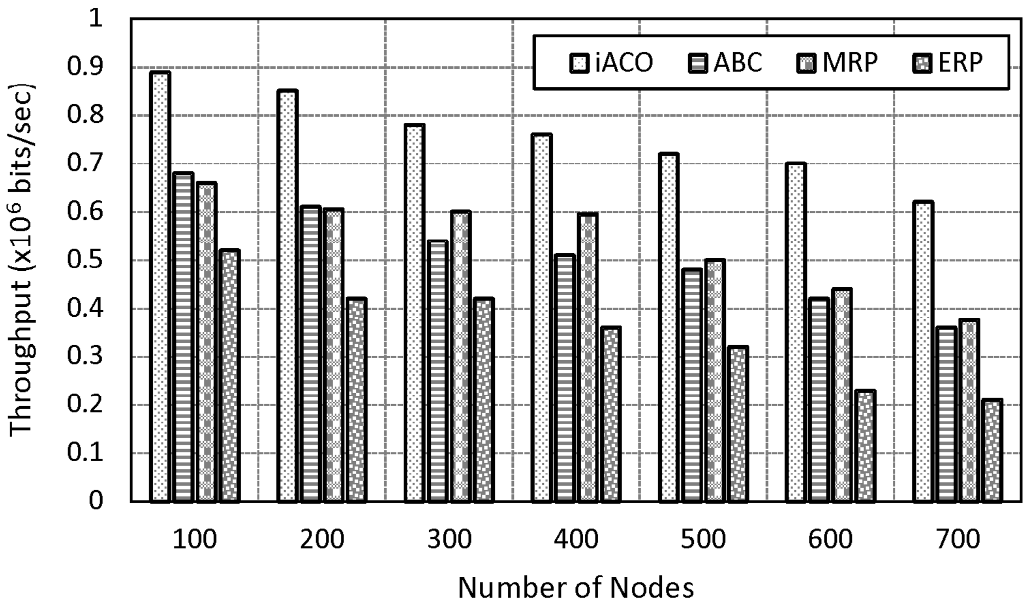

Figure: Packet Delivery Ratio

The throughput is calculated in terms of measuring the protocol robustness. From the Fig. it is seen that the iACO protocol delivers highest packets in a second than other protocols. Also, when the node density increases up to 700 nodes, the throughput of the proposed method seems higher than the other protocols. The performance of Bee, MRP and ERP is low, since they are non-clustered protocols and this lacks the performance during the data delivery of WSN nodes to its BSs.

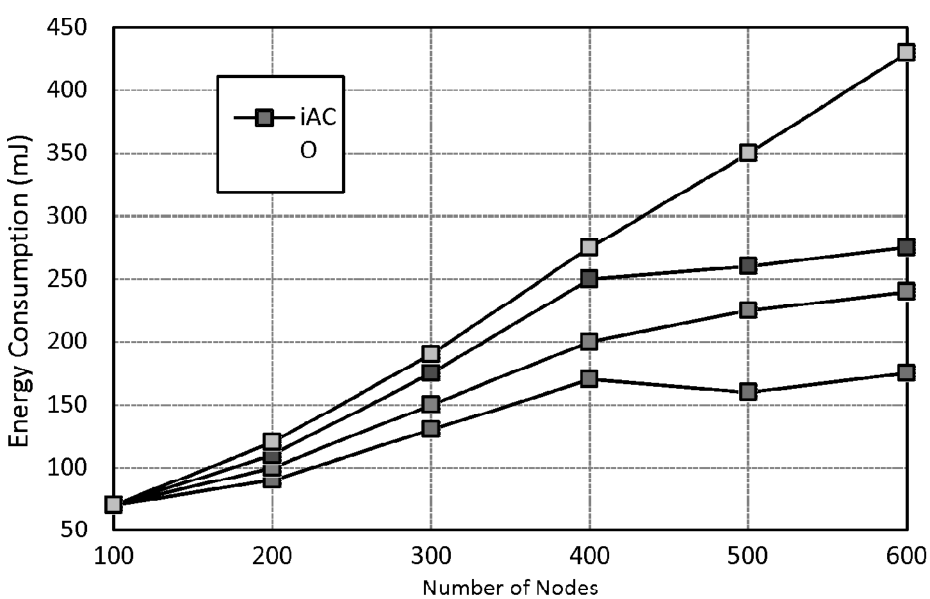

Figure: Energy Consumption (mJ)

The Fig. proves that the consumption of the energy with the proposed iACO protocol is approximately 30%, 70%, 130% lesser than the Bee protocol, MRP protocol and ERP protocol, respectively.

The usage of Fractional Brownian motion in the WSN clusters further improves the path performance of the ants in the routing path. This helps in improving the solution search to obtain the optimal Cluster heads, which reduces the energy consumption. In iACO, the selection of optimal CHs are dependent purely on BS nearest proximity to minimize the consumption of power during data transmission. Further, the assignment of SNs with nearest CH, reduces the consumption of energy and hence the overall energy consumption is reduced further.

In MRP protocol, the CH is used as a relay node, which forwards the packets to its BS and hence it consumes higher energy than Bee and ERP protocols. Finally the optimization of nodes to attain nearest CHs cannot be done to reduce energy using Bee, MRP and ERP protocols in WSN scenario.

5. CONCLUSIONS

The proposed iACO metaheuristic using fractional Brownian motion improved the search solution and improved the capabilities of exploitation and rate of convergence than other algorithms.

Toa achieve this, iACO clustering protocol is proposed as a metaheuristic model for WSNs that uses optimal selection of CHs using improved search pattern. Additionally, optimal BS position is calculated using analytical evaluation and then the performance is compared with existing protocols. Different performance metrics is used to evaluate the performance of the proposed method against the conventional techniques. Results proves that iACO consumes approximately 30-130% energy, which is less than other protocols. Also, the life of the network is prolonged with high packets delivery and higher throughput in WSN scenarios.

Further, the iACO protocol can be implemented on real time scenarios, where the sensor nodes are deployed for real world application to test its performance.

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