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Energy Efficient Routing for Wireless Sensor Network using Ant Colony Algorithm

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Abstract

A vast growth in Industry 4.0 leads to huge increase in the use of artificial intelligence, Internet of Things (IoT) and Wireless Sensor Network (WSN) for various industrial, commercial and societal automation applications. As the performance of the WSN depends upon the limited powered battery operated nodes, the lifetime of network in limited that causes inferior throughput, higher packet drop, high latency, and lesser network lifetime. This paper presents energy efficient routing using Ant Colony Optimization (ACO) algorithm in the WSN to select the optimal path to improve the network lifetime and enhance the network throughput. The simulation results of the suggested approach are estimated based on network lifetime, throughput, packet deliver ratio etc. The simulation results of the suggested approach are compared with the traditional state of arts and it is noticed that proposed method provides superior performance and network lifetime.

Index Terms - Ant Colony Optimization, Internet of Things, Routing, Wireless Sensor Network.

1.Introduction

Wireless Sensor Network (WSN) is set of sensor node deployed over the surface in the structured or unstructured fashion. The WSN are widely used for the various applications such as earthquake detection, landslide detection, transportation, habitat monitoring, environmental monitoring, industrial automation, robotics, control, society applications, wildlife monitoring, etc. The WSN are available in static as well as mobile network [1-3]. The deployment medium divides the WSN into terrestrial, underground, aerial and underwater WSN. The sensor node consists of transducer, amplifier circuit, trans-reviewer, memory, processing unit and battery. The battery operated nodes has limited lifetime which constrains the performance of the WSN for the critical applications. The WSN deals with clustering and routing phenomenon. In clustering the nodes are clustered to form the group and routing deals with data transmission from one node to another node, from node to cluster head (CH) and from CH to base station. In mobile WSN the energy requirement is more compared with static WSN as sensor nodes are continuously moving over the deployment surface which causes additional energy consumption [4-6]. Therefore, it is essential to implement the energy efficient routing scheme for the mobile WSN to improve the network performance. The IoT is currently attracting the attention of users because of its prominent features. The IoT helps to connect the billions of the devices over the network on the single platform and gives exclusive access of the sensor nodes to the operator. It makes the monitoring and control of the network much easier. IoT becomes popular in many remote control applications because of capability to handle the homogeneous and heterogeneous network [7-10].

Various ACO based schemes are presented for WSN routing in past to improve the network performance. Ghotra [11] applied an inter cluster ACO algorithm for the rendezvous nodes (RN) and mobile sink node (MS) to improve the energy efficiency. It worked efficiently for the large dense network and resulted in the 30 % more lifetime than the existing techniques. The simulation of the system is done in MATLAB considering the routing in the dense network without any compression algorithm while data transmission. The use of run length coding, Huffman compression coding is presented in their future scope. ACO has been used for solving the layout problem in WSN to get better connectivity and full coverage. It was applied for a 500x500 grid area of WSN with a 30 m radius. They have given the placement of the sensor in the forbidden area as future scope [12]. An optimized path between sensor nodes to the base station has been discovered using ACO in which computation responsibility has been taken by a sensor node based on the concentration of pheromone. ACO has been used to find out the optimal and suboptimal path between the sensor node and base station with increasing throughput and higher network lifetime [13]. For secure and optimized routing in WSN ACO have been presented which are used to solve the problems of energy utilization, constrained computational power, packets delivery and routing overheads [14]. Jingyi Bo et al. [15] have presented an energy based routing protocol using an ACO algorithm. The performance was measured based on the lifetime of the network, packet throughput and energy consumption. Gradient based routing protocol has been used for energy aware routing in the WSN. Results show that vitality mindful steering with subterranean insect state improvement gives progressively attainable directing arrangements in source hub to sink hub and give a huge upgrade on the lifetime of the network [16]. Anand Nayyar et al. [64] have presented the review paper on the WSNs optimization using an ACO. It focused on Energy Efficiency, lower computational capability, routing overhead, Packet Delivery. It also exhibited far reaching an overview of Ant Colony Optimization based directing conventions for WSNs to give a better stage for analysts to chip away at different deficiencies of conventions created to date to create proficient steering convention for WSN in not so distant future. Jian-Feng Yan et al. [17] have presented a paper on WSNs routing algorithms utilizing two sorts of

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ACO and an improved AS calculation. The reproduction results demonstrate that the directing calculation executed by ACO can diminish the utilization of vitality successfully. At the point when bunches measure of a WSN builds, the normal decrease was increasingly self-evident. ACO demonstrates to be a compelling method to diminished the vitality utilization and amplify the lifetime of WSNs.

Chi Lin et al. [18] have given Data aggregation ant colony algorithm (DAACA) for which consists of three phases like initialization, packet transmission and operations on pheromones. After the introduction, every hub apprised the rest of the vitality and the measure of pheromones to process the probabilities utilized for powerfully deciding the following bounce. Subsequent to definite rounds of transmissions in DAACA, the pheromones change was performed intermittently, which joins the benefits of both local and global pheromones alteration for saving or dissipating pheromones. Four exclusive pheromones amendment techniques were planned to achieve the WSN lifetime, specifically Basic-DAACA, ES-DAACA, MM-DAACA and ACS-DAACA. Finally, they examined the normal applications for DAACA in the parts of vigor, adaptation to internal failure and versatility. Nasir et al. [19] have studied the approaches of an ACO applied for the different problem solutions in WSNs. It studied common performance evaluation parameters and criteria for ACO in WSN. Misra et al. [20] have proposed the data aggregation using NPhard ACO which has been implemented in MATLAB software. It was shown that data aggregation depended on the number of sensor nodes and achieved 25 % energy efficiency. An improved energy and mobile ACO algorithm (IEMACO) have been used for routing problem in the WSN. By using transition probability and offset coefficient, the speed of routing has been increased firstly. Later on, the lifetime of the network has been optimized based on energy consumption. The results of the systems were compared with the ad-hoc on demand multi path distance vector routing (AOMDV) and it was found that IEMAACO performed better than AOMDV [21]. Nayyar et al. [22] have presented the comparison of ACO based algorithm with the existing routing protocols such as DSR, DSDV, AODV on the basis of packet delivery ratio, end to end delay, routing overheads, energy consumption, It has shown better performance in the fields like localization of sensor nodes, deployment of nodes, routing and security and energy efficiency. Energy efficient ant based routing has been applied for the optimal routing algorithm with low energy consumption, lower computation overhead and lower memory requirement. They have used the concept of lightweight ants to locate the most favorable path between two sensor nodes [23].

This paper presents ACO based routing in the WSN to establish the alternative routing pathway in case of route failure to get better the network lifetime and enhance the packet delivery ratio. The results of the offered routing scheme is estimated based on the live nodes per round, dead round per round, packet delivery ratio, packet transmitted to CHs and BSs.

The remaining paper is arranged as follow: section 2 presents the information regarding proposed ACO based routing scheme, Section 3 provides the simulation results and discussions on the results. Section 4 provides the conclusion and future scope to improve the work in future.

2. Proposed Methodology

The process of suggested methodology is represented in Fig. 1 that consists on network set-up phase, clustering phase, routing phase, data transmission phase and network performance evaluation phase. The network is grouped into clustered using fuzzy-C mean clustering algorithm [24]. The Fuzzy C-mean clustering considers the inter-sensor distance, sensor to CHs and sensor to CHs distance for the clustering purpose. The clustering of sensor nodes provides better performance of routing and enhances the network lifetime.

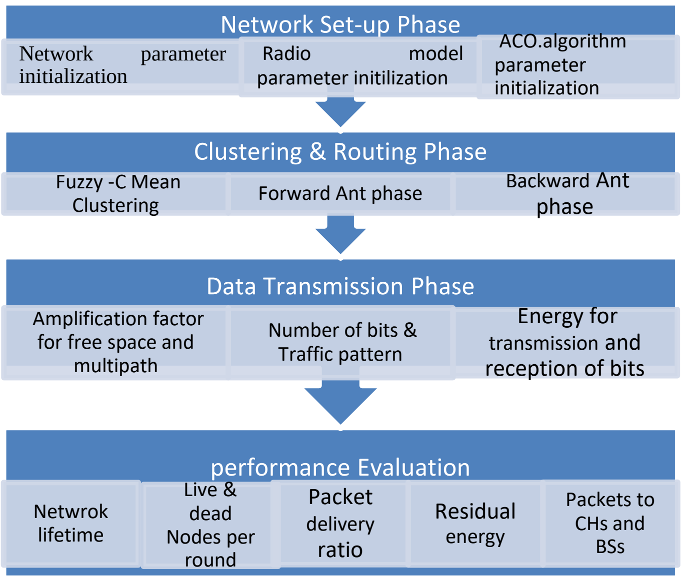

Fig. 1 Flow diagram of proposed system

ACO is a multi-agent method inspired by real time biological behavior of ants. Path finding in the real ant system depends upon the chemical substance called a pheromone. It is popular for vehicle routing and internet routing. Real ants put down pheromones on each path while exploring their food in the environment. The ants then record their position and quality of pheromone solution to find their path in the future or backward path towards the nest [24][25].

It is a model based search algorithm and similar to distribution algorithms. In the usual world, ants travel arbitrary and upon discovery of food come back to their ant colony while putting down pheromone trails. If other ants discover such a pathway they pursue the same path instead of following any random path. In due course, the pheromone trail begins to vanish due to evaporation which reduces its strength. The more time ants take to travel to and fro from the path, the more is the rate of evaporation of the pheromone. The shorter path is followed by more frequently by the ants, thus the strength of pheromone becomes higher for the longer duration. The influence of the pheromone evaporation in factual ant systems is ambiguous, but it is significant in simulated ant systems. When one ant finds the shortest and optimized path to the food, all other ants tend to pursue that path. With the positive feedback from the ants, other ants follow the same path thus increases the density on a popular path [26][27].

ACO algorithm has become a popular choice for solving wireless sensor network routing problems. The network includes sensor nodes and links between different sensor nodes through which they communicate with each other. In WSN ACO is applied to find the optimized path from the sensor node to neighboring sensor node or the sensor node to CH or sensor node to a BS or CH to the BS.

Algorithm:

Step 1: At regular intervals, from the source node, a forward ants k are sent to find a route until it reaches to the destination (all visited node is stored onto a memory Mk of ant).

Step 2: Transition probability for an ant k to shift from i to j is given as by equation 1.

$$p_{ij}^{k} = \begin{cases} \frac{\tau_{ij}^{\alpha}\eta_{ij}^{\beta}}{\Sigma_{\mathrm{l}\epsilon \mathrm{j}_{\mathrm{i}}^{\mathrm{k}}} \tau_{ij}^{\alpha}\,\eta_{ij}^{\beta}} \dots\dots\dots..\ \mathrm{j}\ \epsilon j_{j}^{k}. \\ 0 \qquad \dots\dots\dots\dots else. \end{cases} \quad (1)$$

Here ant "k" at node "i" chooses the next node "j" by using equation (1). "j" is solitary contiguous node of "i", ant "k" has extra likelihood to opt the next node with superior values of P_{ij}^{k}.

Where,

jik stands for list of non-visited nodes so that an ant k can skip visiting a node i more than once.

τij is the pheromone level of edge (i,j).

ɳij is the visibility of j when standing at i.

ά and β are pheromone level edge and visibility of node adjustment parameters (The value of ά and β lies between 0 to 1).

τ is the routing table which stores quantity of pheromone trail on the connection (i, j).

ɳ is the node visibility factor which can be given by $\frac{1}{\mathrm{C} - \mathrm{e_s}}$ (Where, c is the initial energy level of the sensor nodes and es is the real energy level of sensor nodes).

Step 3: Once a forward ant arrives at to the target node, it updates the pheromone trail level of the pathway to arrive at the target and stores the path information in its memory and then transforms it into a backward ant.

Step 4: Prior to backward ant "k" establishes its reverse journey, the target node calculates and computes the quantity of pheromone trail that the forward ant k had dropped throughout its journey by equation 2.

$$\Delta\tau_{\mathrm{k}} = \frac{1}{(\mathrm{N} - \mathrm{Fd_k})} \quad (2)$$

Where

$\Delta\tau_{\mathrm{k}}$ is the amount of pheromone trail that the forward ant k will drop during its journey.

N is the total number of nodes.

Fdk is the distance traveled by the forward ant k which are stored in its memory.

Step 5: When a node "i" receive a backward ant "k" coming from a adjoining node "j", it revised its routing table by equation 3.

$$\tau_{\mathrm{ij}}^{\mathrm{k}} = (1 - \rho)\tau_{\mathrm{ij}}^{\mathrm{k}} + \Delta\tau_{\mathrm{k}}(3)$$

Where,

ρ is an evaporation coefficient whose value lies between $0 \leq \rho < 1$

Step 6: As soon as the backward ant reaches the source node, the ant is eliminated and communication initiated with the best neighbors.

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3.Experimental Results and Discussions

The overall routing scheme is simulated using MATLAB software on the personal computer. The network and radio model parameters are described in Table 1.

Table 1: Network parameter specification

Network Parameters	Specification
Area of Simulation	500m × 500 m
Sensor Nodes	100, 200, 300, 400, 500
Base Station Position	(250,250)
MAC Protocol	802.11
Traffic Patterns	CBR (Constant Bit Rate)
Range (do)	200 m
Transmission Power/ bit(ETX)	50 nJ
Receiver Power/bit (Eelec)	50 nJ
Free spcace Amplification Factor (Efs)	1.0 x10-12
Multi-path Amplification Factor (Emp)	1.3 x 10-12
Number of bits per Packet	500

The simulation parameters considered for ACO algorithm are given in table 2.

Table 2 ACO simulation parameters

ACO Parameter	Specification
Number of ants	100
Initial energy level (c)	200 J
Pheromone evaporation rate (ρ)	0.02
Initial value of visibility of node j when standing at i (n_{ij})	0.001
Initial value of pheromone on edge (T_{ij})	0.001
Variable to adjust effect of n_{ij} (β)	0.2
Variable to adjust effect of T_{ij} (α)	0.4

More the number of ants increase the probability of finding an optimized path. Lower value of pheromone evaporation rate increases the stability of routing path. The initial value of pheromone and visibility of a node is taken as smaller, which can be further controlled by factors α and β respectively for each of iteration. The experimental results suggested routing technique are compared with traditional state of arts such as LEACH [9] and DEEC [10] algorithm. The results for the 100 nodes for the 500m×500m simulation area for the random sensor nodes position for LEACH, DEEC and proposed algorithm are illustrated in Fig. 2.

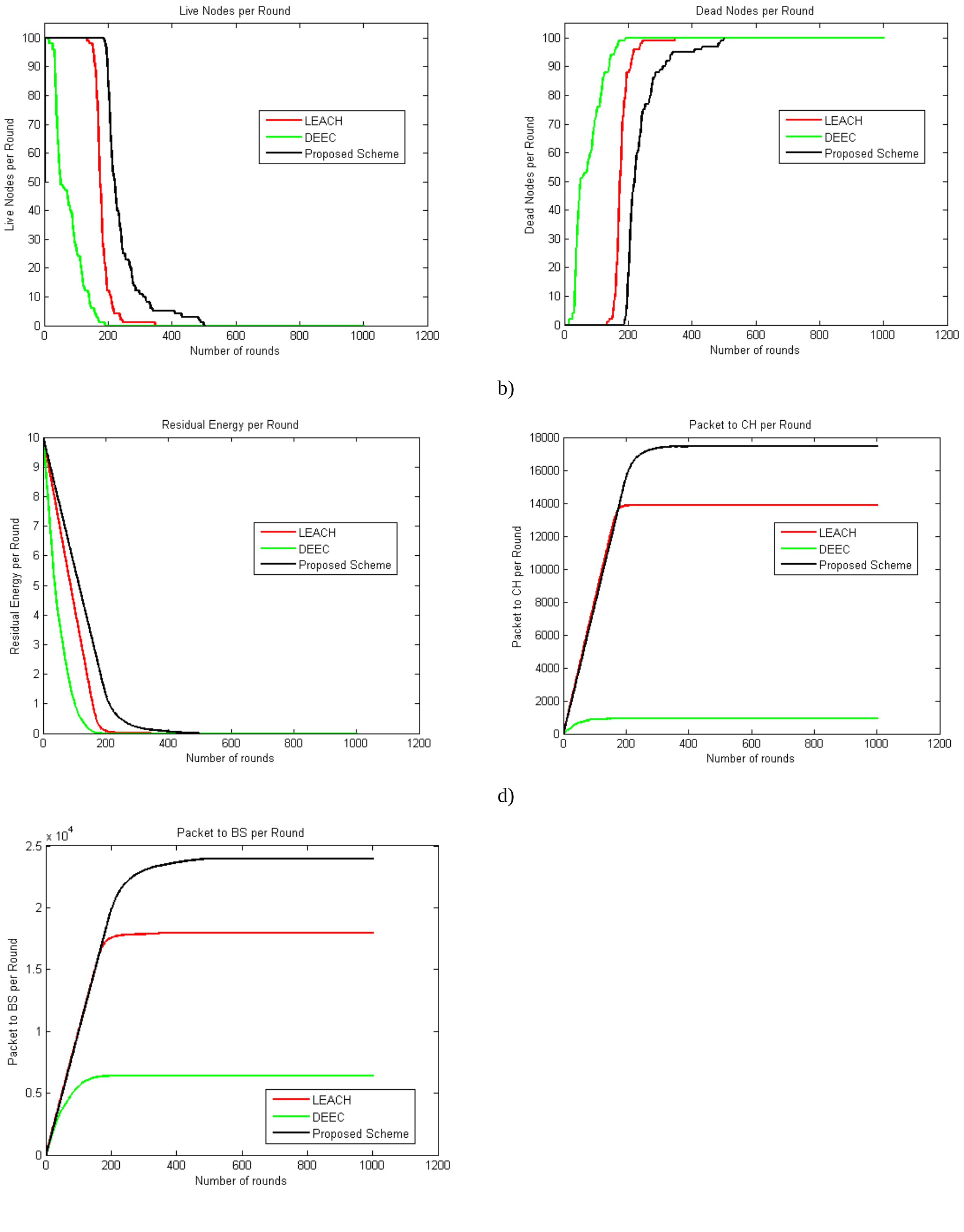

Fig. 2 Experimental results a) Live nodes b) Dead nodes c) Residual Energy d) Packets to CH e) Packets to BS The proposed routing scheme shows significant enhancement in the packet delivery to the BSs and CHs. It selects the routing path based on the various factors that considers the energy, distance from CH and BS, total connected nodes to the particular nodes and alternative path availability.

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4. Conclusions

Thus, this paper presents WSN routing based on ACO algorithm which provides capability to provide the shortest path for the WSN routing and alternative path when any current path gets failed due to disaster condition or node failure or network attack. The effect of the anticipated scheme is assessed for the different number of nodes and various network conditions. The usefulness of the projected routing scheme is compared with the previous techniques and it shows significant improvement over the previous methods based on network lifetime, packet throughput to the BSs and CHs. In future the routing scheme can be employed to WSN by considering the various network attacks and security measures.

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