International Journal of Engineering Sciences Paradigms and Researches (IJESPR)
(Vol. 22, Issue 01) and (Publishing Month: July 2015)
(An Indexed, Referred and Impact Factor Journal)
ISSN (Online): 2319-6564
www.ijesonline.com

Energy Efficient Routing in Wireless Sensor Network Based on Fuzzy Ant Colony Optimization

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Abstract

This paper designs a routing based on the fuzzy & ACO. The designed technique hybrid the fuzzy and the ACO. The FANT finds the all possible path from the source to the destination. Then the required path is selected by using the fuzzy i.e. BANT follow the path selected by the fuzzy. The fuzzy inference engine takes the decision by using 5 parameters. the whole process is simulated using the MATLAB and the result shows the reduced energy consumption and the enhanced throughput.

Keywords: *ACO, Energy Efficient ACO, Energy Efficient routing, Fuzzy.*

1. Introduction

Wireless Sensor Networks comprises of small sensor nodes communicating with each other in a network topology which keeps on varying in the network. It deploys tiny wireless sensor nodes to communicate with each other with limited processing speed, power and security measures. The main task of a wireless sensor node is to sense in network and collect data from a certain domain, process them and transmit it to the given destination [2] in secure way where the application lies. So, it is finding that due to thehigh network density andrestricted communication range, the data forwarding in WSNs becomes a very challenging task. This transmission in network requires multihop data forwarding for transmitting data from source to destination. With purpose of to solve the problem we proposed a new technique called Bio-Inspired mechanism for routing purpose in WSN. From many different Bio-inspired mechanisms like PSO, BEE, BFO, ACO and some others ACO is one of the selected Bio-inspired mechanisms here. ACO isa dynamic and reliable protocol for routing. It provides energy-aware, data gathering routing structure [1] in wireless sensor network. It can avoid network congestion and fast consumption of energy of individual node. Then it can prolong the life cycle of the whole network. ACO algorithm reduces the energy consumption. It optimizes the routing paths, providing an effective multi-path data transmission [3] to obtain reliable communications in the case of node faults. The main goal is to maintain the maximum lifetime of network, during data transmission in a efficient manner.

2. ACO

Ant Colony Optimization (ACO) is a flavor of Swarm Intelligence based approaches applied for optimization problems [3]. ACO meta-heuristic approach models the real ants. In ACO, a number of artificial ants build solutions to an optimization problem. In ACO, the exchange of information is done by pheromone value like real ants. The path optimization between nest and food is achieved by ant colonies by exploiting the pheromone quantity dropped by the ants. There are some representative application areas of ACO, meta-heuristic algorithmic approaches [4], i.e. NP-hard problems, telecommunication networks, industrial problems, Dynamic optimization problems, stochastic optimization problems, Multi-objective optimization, Parallel implementations and Continuous optimization. Real ants foraging for food lay down quantities of pheromone (chemical cues) marking the path that they follow. An isolated ant moves essentially guided by a heuristic function and an ant encountering a previously laid pheromone will detect and decide to follow it with high probability thus taking more informed actions based on the experience of previous Artificial 'ants' - simulation agents - locate optimal solutions by moving through a parameter space representing all possible solutions. Real ants lay down pheromones directing each other to resources while exploring their environment. The simulated 'ants' similarly record their positions and the quality of their solutions, so that in later simulation iterations more ants locate better solutions.

Ants can be divided into two sections:

- FANT (Forward Ants)
- BANT (Backward Ants)

The main purpose of this subdivision of ants is to allow the BANTs to utilize the useful information gathered by FANTs on their trip time from source to destination. Based on this principle, no node routing information updates are performed by FANT, whose only purpose in life is to report n/w delay conditions to BANT. The various steps how these ants are passing routing information to each other are as follows:

1. Each network node launches FANT to all destinations at regular time intervals.
2. Ants find a path to destination randomly based on current routing tables.
3. The FANT creates a stack, pushing in trip times for every node as that node has reached.
4. When destination is reached, the BANT inherit the stack.
5. The BANT pop the stack entries and follows the path in reverse.
6. The routing table of each visited node is updated based on trip times.

When ants search for food, real ants start move in a random manner, and upon finding food they return to their colony along with laying down pheromone trails [5]. This means that if other ants find such a path, they begin to follow that path. The better the solution, the greater the amount of the pheromone deposited, and the higher probability the path will be chosen by other ants in later iterations. However, over time the pheromones laid by the ants starts to evaporate, thus reducing its attractive strength. When shorter and longer paths are compared, it can be easily seen that a shorter path can be traversed faster as compared to the longer one and thus the pheromone density remains high. This is shown in Figure 1. Thus, if an ant finds a shorter path (from the optimization point of view, it means a good solution) [6] when moving from the colony to the food source, other ants are more likely to follow that path, and positive feedback eventually encourages all the ants in following the same single path.

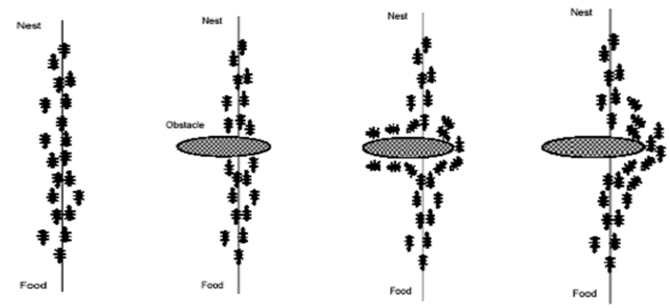

Figure 1: All Ants take the Shortest Path after an Initial Searching Time

"ACO algorithms are a class of constructive meta-heuristic algorithms that mimic the cooperative behavior of real ants to achieve complex computations and have been proven to be very efficient to many different discrete optimization problems". Due to nature inspired characteristics of the algorithms, such as collaborate cooperation, distributed computation and stochastic search, Ant Colony Optimization is particularly suitable for large scale self-organize system and exceeds the traditional metrics in three aspects: scalability, robustness and suitability for dynamic environment. There are number of reasons that ACO algorithms are a good fit for WSN routing. ACO algorithms are decentralized just as WSNs are similarly decentralized. WSNs are more dynamic that a wired network. Nodes can break, run out of energy, and have the radio propagation characteristics change. ACO algorithms have been shown to react quickly to changes in the network.

In a series of experiments on a colony of ants with a choice between two unequal length paths leading to a source of food, biologists have observed that ants tended to use the shortest route. A model explaining this behavior is as follows:

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1. An ant runs more or less at random around the colony;
2. If it discovers a food source, it returns more or less directly to the nest, leaving in its path a trail of pheromone;
3. These pheromones are attractive; nearby ants will be inclined to follow, more or less directly, the track;
4. Returning to the colony, these ants will strengthen the route;
5. If there are two routes to reach the same food source then, in a given amount of time, the shorter one will be traveled by more ants than the long route;
6. The short route will be increasingly enhanced, and therefore become more attractive;
7. The long route will eventually disappear because pheromones are volatile;
8. Eventually, all the ants have determined and therefore "chosen" the shortest route.

The basic philosophy of the algorithm involves the movement of a colony of ants through the different states of the problem influenced by two local decision policies, viz., trails and attractiveness. Thereby, each such ant incrementally constructs a solution to the problem. When an ant completes a solution, or during the construction phase, the ant evaluates the solution and modifies the trail value on the components used in its solution. This pheromone information will direct the search of the future ants. Furthermore, the algorithm also includes two more mechanisms, viz., trail evaporation and daemon actions. Trail evaporation reduces all trail values over time thereby avoiding any possibilities of getting stuck in local optima. The daemon actions are used to bias the search process from a non-local perspective.

3. Fuzzy and Ant Based Routing

This algorithm uses the concept of the fuzzy and the ANT. One ant is used for each node. The FANT are used to find the path from the source to the destination. Then the fuzzy is used to select the path as shown in fig 2.

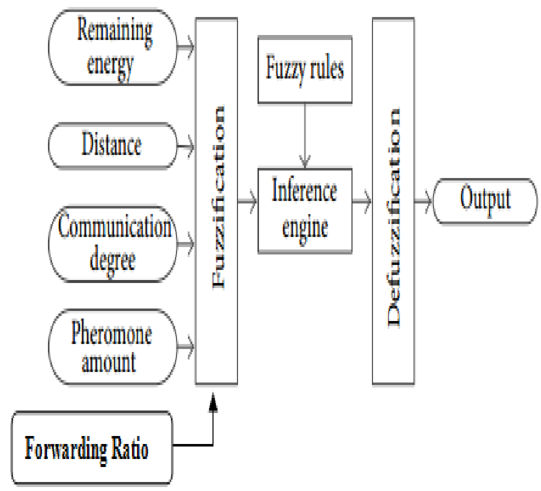

Fig 2: Fuzzy Inference Engine

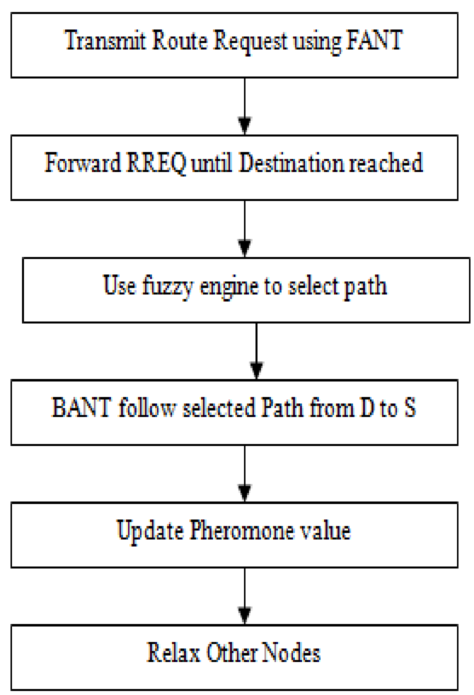

Fig 3: Proposed Process

Then the data is travelled by using selected path. The overall process can be given by fig 3. The range of the fuzzy parameters and the some fuzzy rules are shown in table 1 & table 2.

Table 1: Membership Function

Parameter Name	Parameter Type	Range	Linguistic Values
Residual Energy	Input	0-10	High,Med, Low
Distance	input	10-300	Far,near,Very Near
Communication Degree	Input	0-8	High,med, low
Pheromone Amount	input	0-30	High,Med, Low
Forwarding Ratio	input	0-1	High,Med, Low
Selection	output	0-1	High,med, low

Table 2: Some Fuzzy Rule

Residual Energy	Distance	Communication Degree	Pheromone Value	Forwarding Ratio	Selection
High	Very near	High	High	High	High
Low	Far	Low	Low	Low	Low
High	Far	Low	Low	Low	Low
High	Near	Med	High	High	Med.
Med	Far	Med	High	High	Low

Total 243 fuzzy rules exist while the table shows only 5 of them. The work is implemented using the MATLAB described in next section.

4. Implementation and Results

The MATLAB doesn't contain any toolbox for WSN so the script files are used to design the network and the algorithm and analyze the performance. Three parameters i.e. Throughput, Energy left and the time consumed are analyzed.
The performance is shown in the table 3 & table 4.

Table 3: Performance Analysis of Existing System

Number of Executions	Throughput	Energy Left	Time Consumed
1	4.5652	96	0.2192
2	3.1168	109	0.3208
3	3.0378	108	0.3292
4	4.5980	96	0.2175
5	2.3257	94	0.4300
6	3.0570	101	0.3271

Table 4: Performance Analysis of Proposed System

Number of Executions	Throughput	Energy Left	Time Consumed
1	9.3789	117	0.1066
2	11.4158	112	0.0876
3	11.3568	96	0.0881
4	10.4833	106	0.0954
5	11.4205	116	0.0876
6	11.3444	117	0.0881

The performance shown in table3 and table 4 can also be analyzed graphically shown in fig 4,5,6.

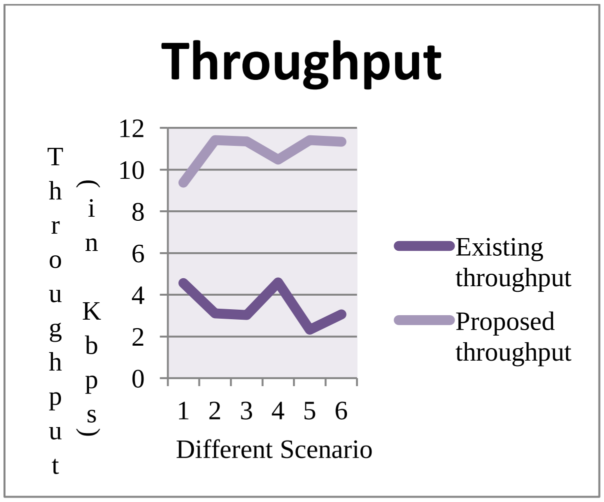

Fig 4: Throughput comparison

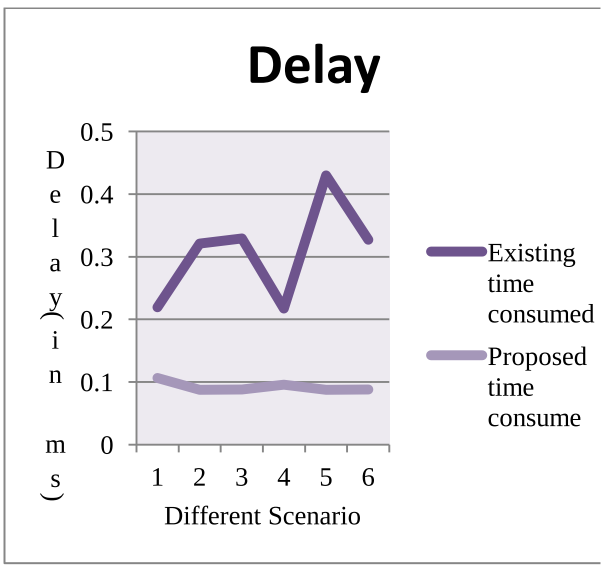

Fig 5: Comparison of Time Consumed

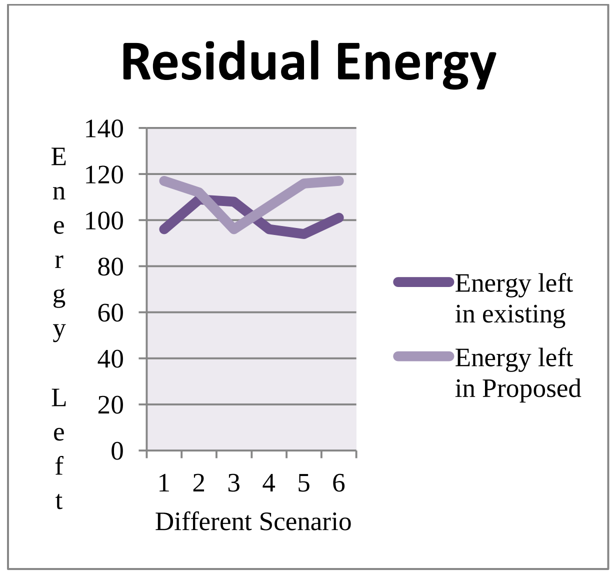

Fig 6: Comparison of Energy Left

The comparison clearly shows the better performance of the proposed system as compared to existing system.

5. Conclusion

The paper describes the ANT based fuzzy routing in the WSN. The algorithm is implemented by using the MATLAB and analyzed over different scenarios. The performance comparison by using energy left, time consumed and the throughput shows the enhancement in throughput and energy left while reduction in time consumed. In future the work can be extended in terms of security.

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