Routing in a Wireless Sensor Network using a Hybrid Algorithm to Improve the Lifetime of the Nodes

1Dr.M.Senthilkumar, 2Dr.V.R.Kavitha, 3Dr.M.Suresh Kumar, 4Dr.P.Anantha Christu Raj, 5*Dr.Ruth Anita Shirley,
1Assistant Professor, Sri Krishna College of Engineering and Technology, 2Associate Professor, Prathyusha Engineering College, 3Associate Professor, Sri Sairam Engineering College, 4Assistant Professor, Karunya Institute of Technology and Sciences, 5Assistant Professor, Sri Krishna College of Engineering and Technology.

1senthilkumarm@skcet.ac.in, 2vr.kavitha.cs@gmail.com, 3sureshkumar.it@sairam.edu.in
4anantha.be@gmail.com, 5*ruthanitad@skcet.ac.in

Abstract. A reliable and secure routing protocol for Wireless Sensor Networks should be easy to maintain, reliable and cost-efficient. In this paper, we propose a hybrid routing algorithm using Ant Colony Optimization and Minimum Hop Count scheme. The proposed hybrid methodology provides an optimal routing path that ensures balanced and minimal energy consumption. The hybrid algorithm is unique in maintaining network topology, balancing network load and searching for the optimal route. The proposed algorithm with the WSN model is implemented in C++ and the simulation output proves our algorithm to outperform other similar routing algorithms. The proposed work indicates an improvement in network lifetime, success rate in finding the best solution and rate of convergence. The existing techniques are reviewed and their strengths and weaknesses are diagnosed and compared with our proposed hybrid methodology that integrates the strengths of both the algorithms.

Keywords: Wireless Sensor Network, Minimum hop count, Ant Colony Optimization, Routing algorithm, network load balancing

1 Introduction

One of the basic requirements of the Wireless Sensor Networks (WSN) is their lifetime. A number of methods have been proposed over the years for increasing the WSNs’ lifetime, paying attention to details such as device control, topology management, routing, data processing and device placement. Of these criteria, routing plays a crucial role in increasing the lifetime using an energy efficient mechanism. However, there are a number of challenges to be addressed which emerge due to large scale of network, dynamic nature of the network [8], inherent unreliability in communication and energy constraint on the nodes. Hence ease of maintenance, high reliability and low cost are the key aspects that are required to ensure optimal routing protocol in WSN. When compared with other algorithms, WSN routing using Minimum Hop Count (MHC) as well as WSN routing with Ant Colony Optimization (ACO) [10] are said to be the optimal method used to identify the shortest route. Hence we have proposed a hybrid algorithm which integrates these two routing algorithms, taking into consideration dynamic network topology, network load balancing and energy constraints in the nodes. The following are the basic algorithms of operation used by the proposed hybrid algorithm:
1. Based on the distance in hop count with respect to the sink node, sensor nodes are segregated with various gradations.

2. A neighbouring hop which has a lower count will be preferred when compared with the node itself, following MHC algorithms’ hop count-classification.

3. Nodes that are farther away are chosen to transfer data, providing a means to choose the optimal path.

4. Success rate in searching for the optimal path is improved using the mutation strategy introduced. Taking battery depletion into consideration, use of multiple paths is encouraged.

5. The proposed work uses a dynamic energy threshold strategy wherein energy consumption of the individual nodes are taken into consideration to stop the depletion of certain nodes.

6. Load balancing is achieved by equalizing the workload of data transmission.

This paper provides a review of the two algorithms involved namely multiple hop count and ant colony optimization, in Section 2. This is followed by Section 3 which gives a description of the proposed model. Section 4 gives an extensive simulation results and a conclusion is drawn in section 5.

2 Related Work

Over the years, the behaviour of fishes, bees and ants have been used in swarm intelligence (SI) to successfully develop and apply ways to solve major optimization issues as per [1] and [2] by Jana and Kuila and Di Caro. Doriego et al. In [3] a group of Italian scholars proposed Ant Colony Optimization (ACO) which resembles the ants which look for the shortest path towards their destination which is food. Based on the Zhan [4], Zhang [5], Jose et al. [6], Stutzle and Hoos [7] and Dorigo and Gambardella [8] research, it has been found that ACO has been successful in solving many industrial and scientific optimization process. During the past decade a number of challenges in WSN have been addressed by ACO based routing algorithm. Since energy is one of the crucial criteria that has an impact on the performance of WSN. Multipath Routing Protocol (MRP) based ACO was proposed in [9] which uses multiple paths to locate the optimal nodes which have minimum energy consumption. Another algorithm, Breadth First Search was combined with ACO by Khoshkangini et al in [10] to find the shortest and best path which will decrease energy consumption as well as the transaction time.

In [11] Han et al. Introduced the novel methodology of MHC which works on the basis of flooding algorithm and Directed Diffusion algorithm. Based on the hop count between the sink node and the source node, the transmission path is decided using this algorithm. The 2 major disadvantages when using this algorithm are as follows:
1. Though the MHC is able to find the optimal path, there is no reasonable methodology to pick the next node except to transfer data through the parent node thereby increasing the energy consumed and also increasing the redundant information.

2. In order to update the route, flooding is initiated by the sink node at regular intervals. This will result in energy overhead and will also increase the cost of the network due to redundant data transmission.

In order to address the issue of transmission routing and energy consumption, Ho et al. in [12] proposed the use of ladder diffusion algorithm based on ACO. This was further modified by Du et al. in [13] using an energy-aware ladder diffusion methodology which uses Ho’s proposal and further solves ‘energy pole’ and ‘hot spot’ problems based on the residual energy of the node [14], [15] and [16].

3 Proposed System Model

3.1 WSN Network Model

A WSN comprises of a sink node along with many distributed wireless sensor nodes in an organised manner. The data is transferred from the target area till it reaches the sink node where it is processed further [17]. There are 6 assumptions in the proposed algorithm:

1. Data collection is done periodically by the sink node and the data is then forwarded based on routing.

2. Based on the distance, transmission power can be adjusted accordingly.

3. Link errors resulting in overtime retransmission and packet error are not taken into account.

4. It is not possible to replenish the sensor nodes from energy, but are constrained.

5. All the nodes present in the network will have same amount of initial energy, communication capability and computing power, making them homogenous.

6. In the monitoring area, the nodes are deployed in a random fashion. This location remains constant and will not change at any point of time. The sink node will be provided adequate knowledge of the location of the entire network.

3.2 Model of Energy Consumption

In general, the energy consumed by a node for the purpose of data communication is comparatively high
and our work focuses on reducing this energy consumed [18]. Power amplifier energy consumption and electronics energy consumptions are the two major parts which contribute to data transmission energy consumption. Power control is used to decrease the distance such that it is lower than the pre-defined limit set. This way the energy consumed for data transmission can be reduced such that as the distance between the receiver and the sender decreases, the energy consumed during data transmission also decreases simultaneously.

### 3.3 Hop Count Classification

The purpose of the proposed algorithm is to increase the lifetime of the nodes in a typical Wireless Sensor Networks. A planar network topology based hop-count classification network is used in the hybrid algorithm [19]. First, the location information of every individual node is examined and hop-count classification is used to count the hop values. Based on this algorithm, there are two alternatives based on the hop count.

- If the hop count is h±2, the h-hop node will not be able to transmit data.
- If the hop count is h-1, then the h-hop will be chosen.

Thus this type of methodology will be able to pick the next hop node at a quicker pace, thereby decreasing time complexity and accelerating the convergence speed. Maintenance of the network topology will commence on failure of a sensor node or on detecting wireless link breakage. Fig.1. represents the hop count classification network topology.

![Fig.1. Hop Count-Classification](image-url)
3.4 Dynamic Energy Threshold Strategy

In this paper, we have implemented a dynamic energy threshold strategy which will be useful in balancing energy consumption for the WSN. The lower bound energy threshold \( e_{th} \) and energy threshold \( e_{th(min)} \) are defined during initialization for all the nodes. In general, when an ant is searching for a new hop node \( 0 \), the energy threshold is determined. Based on it, the next hop will be fixed to be a node on a priority order. When the network is running, there is a constant consumption of energy. When the energy present in the node is below that of threshold, a new route discovery process will be initiated by the sink node.

4 Results and Discussion

4.1 Convergence Characteristics Comparison

It is important to find the optimal path with least cost calculation because of the dynamic network topology and limited energy power. Hence the proposed algorithm must excel in finding the optimal routing path, with high success rate and convergence speed. The convergence speed of ACO-GA, LTAWSN and ACO is compared with that of the proposed methodology and it is found that the proposed hybrid routing protocol requires lesser number of iteration as observed in Fig.2.

4.2 Network Lifetime

Since most of the energy in a WSN is used for data transmission, network lifetime plays a crucial role. Data transmission is possible only if the nodes that are to forward data have enough power to transmit the information to the sink node. The lifetime of a network is the time when the node is said to be active with power. The network lifetime of the proposed algorithm is compared with EALD, ACO-GA, LTAWSN and Classic ACO in Fig.3. It is identified that the proposed methodology will be able to increase the
lifetime of the network using the dynamic energy threshold strategy which will help the network nodes which have less energy and use the other nodes to transfer data.

![Fig.3. Network Lifetime Comparison of Various Algorithms](image)

5 Conclusion

A hybrid routing protocol is proposed in this work, taking into consideration the improvement in terms of dynamic networking capability, speed of convergence, balancing network load and total power consumption. Our proposed work provides an optimal routing methodology by combining the strengths of Ant Colony Optimization and Minimum Hop Count, which leads to an optimal solution of routing. This has resulted in an overall improvement in the performance and efficiency of the network. To find the optimal path of routing, we have implemented the use of a dynamic energy threshold strategy. Simulation results indicate that the proposed methodology increases network lifetime and is also very cost-efficient when compared to other algorithms.

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