OPTIMAL PATH IDENTIFICATION USING ANT COLONY OPTIMISATION IN WIRELESS SENSOR NETWORK

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ABSTRACT.

Wireless Sensor Network WSN is tightly constrained for energy, computational power and memory. All applications of WSN require to forward data from remote sensor node SN to base station BS. The path length and numbers of nodes in path by which data is forwarded affect the basic performance of WSN. In this paper we present bio-Inspired Ant Colony Optimisation ACO algorithm for Optimal path Identification OPI for packet transmission to communicate between SN to BS. Our modified algorithm OPI using ACO considers the path length and the number of hops in path for data packet transmission, with an aim to reduce communication overheads.

KEYWORDS

WSN, Ad-Hoc Network, ACO, Optimal path Identification

1. INTRODUCTION

A WSN is an ad-Hoc network composed of hundreds or even thousands of SN. These nodes are capable of sensing at least one phenomenon in the environment. SN's are battery powered. Replacing or recharging of battery is not possible in scenarios like battlefield surveillance, rescue operation and unmanned missions. The sensors have to perform tasks such as object monitoring & tracking, detecting the presence of certain objects, event monitoring, data fusion & localization. These tasks of SN cause to generate a vast amount of information. The sensor has to forward this information to BS (sink node). Hence it is desired, If WSN consumes minimum energy for its task then its network lifetime will increase. The reporting between SN & BS consumes energy based on the type of communication protocol, communication path & number of hops between SN and BS. This requires finding out optimal path OP between BS to SN which will be useful in efficiently forwarding data, reducing power consumption and communication overhead in WSN.

In our work we are focus on identifying shortest communication path between SN and BS. There are several routing protocols like Direct diffusion [9], LEACH (Low Energy Adaptive Clustering Hierarchy) [8]**,** SPIN (Sensor protocols for Information via Negotiation) [8] [10].The Shortest path finding is the backbone to the routing techniques in WSN. So it is a graph based problem to find out the shortest path between two vertices. As WSN is resource constrained applying conventional shortest path finding techniques is not desirable.

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So we should look at soft computing techniques. It can help us in dynamically changing environment for setting communication paths in WSN**.** ACO is a soft computing technique for Optimisation. This method is having characteristic like achieving global optimization through local interaction, and high degree of self-organization.

1.1 Motivation

Routing in WSN is challenging due to the following reasons like dynamically changing communication links and network topology, abrupt failure of sensor nodes etc. To handle these challenges many routing techniques exist, such as data centric, location based and hierarchical routing. Finding shortest path in WSN during routing can help to optimise communication and computation overhead.

In target or object tracking, surveillance vast amount of data is generated. It is necessary for BS to process that data in real time to take further action. So data forwarding time from sensor node to BS should be as minimum as possible, due to this forwarding data from the path which is having list distance and reduced hop count is desirable. A Greedy algorithm like Dijkstra's algorithm, Bellman Ford and Dynamic programming algorithm are useful in shortest path finding but it is having high computational complexity. Greedy algorithm doesn't give a guarantee of finding the globally OP and these techniques is helping to identify a single static shortest path.

Bio-Inspired shortest path algorithm realised using ACO proves to be efficient in the OP detection. By studying traditional ACO we found its following drawback for WSN which is possible to overcome. Firstly ACO based routing [1] [4] algorithm which is the present finds path by creating ants in the form of data packets, Data packets are transmitted between each node i.e. peer to peer. This increases the communication overhead which is likely to result in increased network traffic. Also packet collision and packet loss can result decrease in efficiency**.**

By studying existing routing protocols we found that improvement can be done by considering the path length and the number of nodes in path as a critical parameter to detect the optimal path between SN to BS. Secondly the traditional ACO [11] considers only path length not the number of hops in the path and it isnot guaranteed to lead optimal solution. Considering these challenges we have modified the Traditional ACO in an appropriate way .Our work overcomes above mentioned issues & BS computes the OP and communicates it with the sensor node.

1.2 Overview of Our Work

In our work we are proposing BS driven OPI. Here directly or indirectly BS is made aware about the all SN their position and topology of the network. Now the problem of finding the optimal path becomes graph based problem.

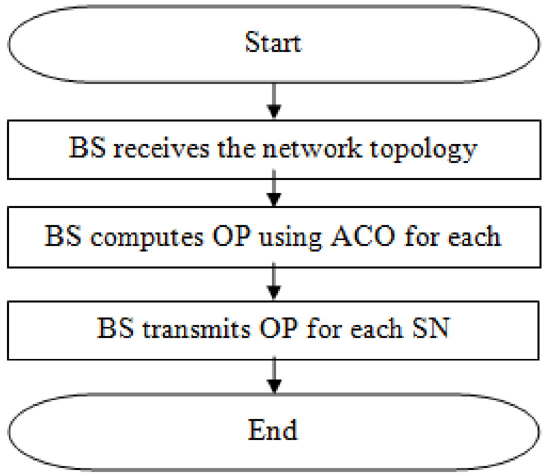


Fig. 1 Shows overview of our work

In which BS calculates OP using ACO & communicates that path with SN. So in 1st step BS receives the network topology. In 2nd step computation of OP is done. Then in the 3rd step OP is communicated with the respective SN. After these steps are done with any node who wants to send data to BS can use above calculated OP.

1.3 Assumptions & Experiment Parameters

ForapplyingACO for finding OP our assumptions are as follows.

Assumption at BS & SN

BS knows co-ordinate of all SN present in the network and it is aware about the topology of the entire network. BS is responsible for ACO calculation. These are assumption about BS. In case of SN it is assumed that localization of all SN is already done. All SN's are static. SN's cannot be recharged. Communication range of all SN is same**.**

Assumption for OPI Using ACO

Traditional ACO is explained in this paper, for our experiment we have taken the value of parameters α=1, β =3, ρ =0.2 which are used. In our experiment WSN is treated as a graph. All the sensor nodes which are in communication range of each other are represented as adjacent nodes in the graph. θ is no of nodes (hops) in the path from source to destination. **Ω** a is a parameter which manages relative importance of path length & ψ controls the importance of nodes in path (equation 6). The value of these two variables is 3.

2. ROUTING USING ACO

Routing using ACO is a complex task, resource constrained WSN make it more challenging. In routing SN node route data to BS using the most efficient path. In ACO based approach behaviour of real ant searching for food through pheromone deposition is used to find the optimal path.

2.1 Routing using Traditional ACO

When ants trace out a path from their nest to a food source, ant drop pheromone on that path, the shorter a path is, the more pheromone gets accumulated on the path. This is because shorter paths accumulate pheromone deposits at a faster rate. Suppose each ant starts from the source "s" to destination "*d*", it tries to find the shortest path between these nodes. At each node "*i*" ant "*k*" decides to visit the next node "*j*" based upon the probability given by formulae in equation 1.

$$p_{ij}^{k} = \begin{pmatrix} \dfrac{[\tau_{ij}]^{\alpha} * [\eta_{ij}]^{\beta}}{\sum [\tau_{ij}]^{\alpha} * [\eta_{ij}]^{\beta}} & \forall j \in N_j \;\&\; j \notin M^{k} \\ 0 & otherwise \end{pmatrix} \quad (1)$$

Where τ_{ij} is the pheromone concentration on edge between node "*i*" to node "*j*". η_{ij} is the value of heuristic related to path length, α and β are two parameters that control the relative importance of pheromone trail and heuristic value. Related to path length N_j is set of SN. M^k Is the memory of ant "k" The heuristic value related to path length is

$$\eta_{ij} = \frac{1}{l(i, j)} \quad (2)$$

Where $l(i, j)$ is the edge length between nodes "i" and "*j*".
After each iteration "*t*", ants deposit quantity of pheromone which is given by

$$\Delta \tau^{k}(t) = (1 / j^{k}(t)) \quad (3)$$

Where $j^k(t)$ is the length of the path from source to destination traversed by ant "k". Total Amount of pheromone quantity on edge "*i*" to "*j*" is given by the equation

$$\tau_{ij}(t) \leftarrow \tau_{ij}(t) + \Delta\tau_{ij}(t) \quad (4)$$

But as the time passes the pheromone deposited on the edge start evaporating. A control coefficient $\rho \in [0,1]$ decides the amount of pheromone on each edge at any specific iteration which is given by the equation

$$\tau_{ij}(t) \leftarrow (1 - \rho)\tau_{ij}(t) \quad (5)$$

As no of iteration increases pheromone concentration on shortest path becomes more as compared to relative longer paths present in the network. So more no of ants start taking the path with greater concentration of pheromone which keeps increasing pheromone level. Eventually paths with shorter length are more preferred by ants.

2.2 OPI using ACO

As the traditional ACO doesn't consider the number of hops and path length together. Here we present the modified algorithm. Our algorithm considers above mentioned two parameters and finds OP.

Steps

Step 1: When the base station starts calculating shortest path, it selects one Destination node from all other SN. So an ant is created which will generate a path from BS to the destination node.

Step 2: Ant "*k*" on node "*i*" selects the next node "*j*" using formula in equation 1.Here "*j*" is an adjacent node of "*i*". An ant "k" has more probability to choose the node with larger values of p_{ij}^{k} the next node selected is stored in memory of ant k (M^k).

Step 3: If any ant visits the node which is already visited by the same ant that ant Is discarded.

Step 4: Step 2 and 3 are repeated till ant k finds a destination node or discarded.

Step 5: Step 1 to 4 is repeated for all ants in that iteration.

Step 6: When all ants complete above procedure pheromone is updated by the amount$\Delta\tau$on each edge between node i to j using formulae in the equation 3 and 6.

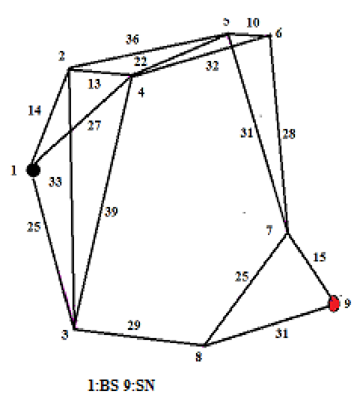
$$\tau_{ij}(t) \leftarrow \tau_{ij}(t) + ((\frac{1}{\theta^{\Psi}}) \times (1 + (\frac{1}{j^{k}(t)^{\Omega}})) \quad (6)$$

Step 7: Then the evaporation of pheromone is calculated by equation 5.

As the above process is repeated for many iterations BS comes to know about the optimal path between it and the destination. Similarly the BS can calculate distance between it and all other sensor nodes.

2.3 Result

This section describes the identified path using modified ACO and using the traditional ACO. Figure given below shows WSN and its network. The distance between corresponding sensors is indicated near the edges.



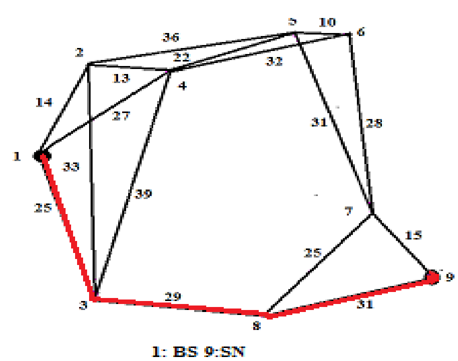


Fig. .2 WSN and its networkFig.3 OP using modified ACO

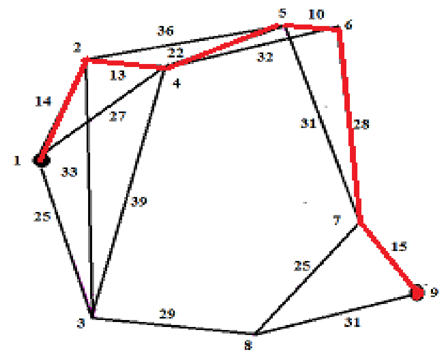


Fig.4 Optimal Path using traditional ACO

In the above scenario of figure 1 node 9 senses some data and it want to forward that information to node 1. Node 1 which is BS knows co-ordinates and topology of entire network it implements proposed algorithm and finds the optimal paths between sensors 1 and all other nodes. The optimal path found is communicated with all SN. So all SN including 9 come to know about the optimal path between itself to BS. In this way finding the optimal paths is done. These paths are communicated with the respected SN so every SN knows how to forward that data.

The initial pheromone concentration on all edges is as shown in table number 1.Where left most column and top row denote the node number. Here N intop most left block in table 1 stand for node each edge is initialised with pheromone quantity 0.00001. This is initialisation necessary to start the execution of ACO. This pheromone quantity is kept small so that initial concentration will not affect the final result.

As the Ant starts traversing the path pheromone concentration on that starts increasing. Finally more pheromone gets deposited on the path with the shorter length converges After implementing the modified algorithm the pheromone concentration in a 5th iteration is shown in table 2. Where left column and top row denote the node number. Here N in top most left block in table 2 stand for node.

Table 1 Pheromone value

N	1	2	3	4	5	6	7	8	9
1	0	0.00001	0.00001	0.00001	0	0	0	0	0
2	0.00001	0	0.00001	0.00001	0.00001	0	0	0	0
3	0.00001	0.00001	0	0.00001	0	0	0	0.00001	0
4	0.00001	0.00001	0.00001	0	0.00001	0.00001	0	0	0
5	0	0.00001	0	0.00001	0	0.00001	0.00001	0	0
6	0	0	0	0.00001	0.00001	0	0.00001	0	0
7	0	0	0	0	0.00001	0.00001	0	0.00001	0.00001
8	0	0	0.00001	0	0	0	0.00001	0	0.00001
9	0	0	0	0	0	0	0.00001	0.00001	0

Optimal Path Identification from Pheromone Table

OP is found out from pheromone concentration which is given in table 2For choosing the optimal path we just have to look at the edges (table block) with a maximum pheromone concentration starting from sensor 1 (in row 1) till we reach sensor 9. So from 1st node pheromone concentration is maximum in the 3rd column (3rd column in 1st row) which is 0.0001059. So edge from 1 to 3 is added. Then from the 3rd sensor (from 3rd row) look for maximum pheromone value. 8th column value is 0.0001138 which is the maximum. So add edge from 3 to 8.After 8 maximum pheromone concentration is 0.001153, so edge from 8 to 9 is added. By proceeding this way one can find a path In this In Figure 2 the path with the maximum pheromone concentration is marked with red colour. This path is optimal path.

From table 2 it is clear that the pheromone concentration on the path 1 to 3, 3 to 8, 8 to 9 is higher. So our optimal path is the 1-3-8-9.The length of this path is 85.We can also get a parallel path if we initially choose 2nd highest node from node 1 & then keep choosing highest pheromone node. The Other parallel path we are getting is 1-2-4-5-6-7-9.This path is not optimal but it is sub optimal.

Table2 Pheromone value

N	1	2	3	4	5	6	7	8	9
1	0	0.0000353	**0.0001059**	0.000015	0	0	0	0	0
2	0.0000353	0	0.0000185	0.0000317	0.0000166	0	0	0	0
3	0.0001059	0.0000185	0	0.0000205	0	0	0	**0.0001138**	0
4	0.000015	0.0000317	0.0000205	0	0.0000221	0.0000158	0	0	0
5	0	0.0000166	0	0.0000221	0	0.0000227	0.0000216	0	0
6	0	0	0	0.0000158	0.0000227	0	0.0000208	0	0
7	0	0	0	0	0.0000216	0.0000208	0	0.0000145	0.000309
8	0	0	0.0001138	0	0	0	0.0000145	0	**0.001153**
9	0	0	0	0	0	0	0.000309	0.001153	0

The length of suboptimal path is 102

Table 3 gives the number of ants choosing the sensor nodes. Where left column and top row denote nodes. Here N in top most left block in table 3 stand for node. The number of Ants choosing a path is proportional to the pheromone concentration on the path. Hence many times the path Find out by Ant table is same as the result given by the pheromone value. Instead of

Table 3 Ant count

N	1	2	3	4	5	6	7	8	9
1	0	42	63	15	0	0	0	0	0
2	0	0	11	35	20	0	0	0	0
3	0	12	0	12	0	0	0	69	0
4	0	14	16	0	21	14	0	0	0
5	0	1	0	3	0	22	28	0	0
6	0	0	0	2	12	0	23	0	0
7	0	0	0	0	3	7	0	13	36
8	0	0	5	0	0	0	8	0	69
9	0	0	0	0	0	0	0	0	0

Choosing edge with highest ant count if 2nd highest edge is taken at node 1,then we get other suboptimal path. That path is 1-2-4-5-7-9.This alternate path very useful as using same OP will reduce energy contain in that SN.

2.4 Comparison of Results with Traditional ACO

Traditional ACO is already described in this paper. The comparison of results of these two algorithms is given below. The initial pheromone concentration of Traditional ACO is in the table 1.After 5th iteration the pheromone concentration is as shown in table 4 From table 4, it is clear that pheromone concentration is more on the path 1-2-4-5-6-7-9.The length of this path is 102. So ants will startpreferring this path. In the result section 6 by modified ACO we have found an optimal path which is equal to 85.So it proves that our modified algorithm outperforms the traditional ACO. Figure 4 shows path found by traditional ACO with red color. This path is optimal in length but this also contains the less number of SN i.e. hops in path.

Table 4 Pheromone value

NODE	1	2	3	4	5	6	7	8	9
1	0	**11.462**	0.3922	0.4440	0	0	0	0	0
2	11.462	0	0.6559	**10.930**	0.3302	0	0	0	0
3	0.3922	0.6559	0	1.066	0	0	0	1.564	0
4	0.4440	10.930	1.0663	0	**4.457**	1.422	0	0	0
5	0	0.3302	0	4.457	0	**13.41**	1.257	0	0
6	0	0	0	1.422	13.414	0	**3.530**	0	0
7	0	0	0	0	1.2572	3.53	0	0.539	**8.275**
8	0	0	1.564	0	0	0	0.539	0	1.799
9	0	0	0	0	0	0	8.275	1.799	0

Now we will compare the same algorithm for sensor node 7. So in this case BS will try to find out the optimal path between1 to 7

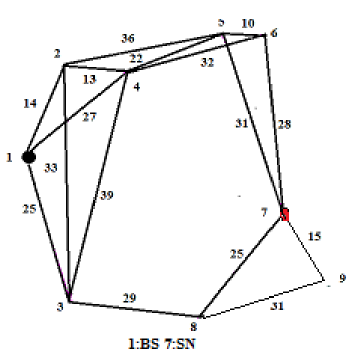


Fig. 5WSN and its network

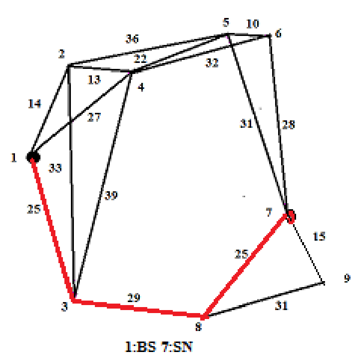


Fig. 6 OP using modified ACO

Table 5 shows the pheromone value for modified ACO after the 5th iteration. From node 1 to 7 if we chose the maximum pheromone value then our path becomes 1-3 -8-7.Toatal path length of this path is 79

Table 5 Pheromone value

N	1	2	3	4	5	6	7	8	9
1	0	0.02483	0.2753	0.0176	0	0	0	0	0
2	0.02483		0.017981	0.0273	0.0143	0	0	0	0
3	0.2753	0.0179		0.0168	0	0	0	0.2777	0
4	0.0176	0.0273	0.0168	0	0.0209	0.01636	0	0	0
5	0	0.0143	0	0.0209	0	0.0200	0.0213	0	0
6	0	0	0	0.0163	0.0200	0	0.0187	0	0
7	0	0	0	0	0.0213	0.01873	0	0.2737	0.01399
8	0	0	0.2777	0	0	0	0.2737	0	0.01399
9	0	0	0	0	0	0	0.0139	0.0139	0

Table 6 shows the pheromone concentration after 5th iteration using traditional ACO. If we find the path from that table its length is 87. Figure 7 shows the path found using traditional ACO.

Table 6 Pheromone value

NODE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	9	**10.0473**	0.8629	0.9620	0	0	0	0	0
2	10.0473	0	0.5367	**10.6427**	0.7705	0	0	0	0
3	0.8629	0.5367	0	0.8124	0	0	0	1.2242	0
4	0.9620	10.6427	0.8124	0	**5.9729**	0.3712	0	0	0
5	0	0.7705	0	5.9729	0	**13.809**	0.3143	0	0
6	0	0	0	0.3712	13.8091	0	**4.9842**	0	0
7	0	0	0	0	0.3143	4.9842	0	0.3086	1.8103
8	0	0	1.2242	0	0	0	0.3086	0	0.8999
9	0	0	0	0	0	0	1.8103	0.8999	0

Figure 7 shows OP using traditional ACO. The OP found using this method is in red color. These two comparisons show that our algorithm finds out the path which is smaller in length and consist of less number of hops.

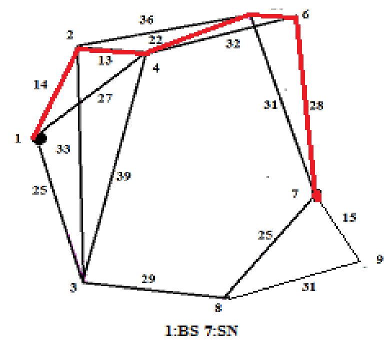


Fig. 7 Optimal Path using traditional ACO

3. CONCLUSION

Finding the optimal path in dynamically changing resource constrained WSN is challenging. Our work proposes an approach to identify an optimal path for communication between SN to BS .Existing greedy approach is static in providing optimal path. In our computational approach and communication overhead is reduced as BS takes the responsibility of computation & optimal path is calculated based on pheromone concentration. It and contributes to enhance network life time by proposing an alternative path for communication between BS and SN.

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