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Optimal Pheromone Distribution for ANCOR

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Abstract— **This work investigates the utilization of a new pheromone distribution model for ANCOR. ANCOR is a novel routing algorithm for sensor networks. The main idea behind the algorithm is imitating the real acts of ants for finding new food resources and bringing them to their nests. A new pheromone distribution model for ANCOR, i.e. Optimal Pheromone Distribution Model will be presented, and its performance profits over the existing model will be discussed.**

I. Introduction

A routing algorithm ANCOR (*Ant Colony Routing)* was recently developed by Demiray and Altilar[1]. In this paper, a new pheromone distribution model over the network is implemented and its performance is investigated. The main idea behind the algorithm is imitating the real acts of ants for finding new food resources and bringing them to their nests. In a colony of ants, all individuals work together to achieve a single goal. There is no global management mechanism telling them what to do or how to act. Each individual uses local interactions and follows some simple rules to establish complex structures in a broader perspective.

II. Ant Colony Optimization

Ant colony optimization is a stochastic combinatorial optimization method, based on the behaviors of real ant colonies [2]. Since there is no global manager, decisions are taken with local interactions and positive feedback. In an ant colony, individuals can find new food resources and bring them back to their nests in an optimal path. Each ant is a simple agent following simple rules: follow the highest pheromone density and emit pheromone on the road.

Pheromone is an odorous chemical substance. This mechanism reinforces the road as the optimal path. However, there are always a small number of ants which do not follow the highest pheromone, providing yet another mechanism to search environment for a better food resource or a shorter path than the existing one. If a better resource or a shorter path is found, more and more ants will follow the new path since the ant will emit extensive amount of pheromone upon finding a better source. Since the pheromone on the old path would evaporate over the time, the existing path would be replaced by the new one.

III. ANCOR: An Ant Colony Routing Algorithm

ANCOR is a routing algorithm designed for sensor networks. Sensor networks consist of a large number of nodes, capable of sensing different events such as vibration or pressure. It is assumed that the sensor network is deployed densely and each node in the network has a small capacity of processing, memory and energy [3, 4].

Contrary to the real-world use of pheromone, i.e., the existence and the density of positive pheromone, the ANCOR model contains negative pheromone as well. Thus, three different properties of pheromone, existence, positive density and negative density are represented by using a single pheromone density varying between 0.0 and 2.0. NULL pheromone which means there is no pheromone is represented by 1. Pheromone densities greater than 1 and lower than 2 represents positive pheromone which has attractive effect in the ants, and densities lower than 1 and greater than 0 represents negative pheromone which has repulsive effect.

In the ANCOR, each ant follows previously given two simple rules with a slight modification. The first rule is always to follow the highest positive pheromone except for the ant which arrives at the target first. It follows the highest negative pheromone. As the second rule, emit negative pheromone during the target search process. Once target is located, start emitting positive pheromone to reinforce the path in the way back to the sink. In practice, each ant represents a query or a data packet which moves across the network. Each packet (ant) consists of an id, query/data, and a flag indicating whether this is the ant which arrives at the target first or not. ANCOR mainly differs from other routing approaches in the packet contents. In ANCOR, packets (ants) do not carry a list of visited nodes. This helps to reduce packet size, eventually will require less time in broadcasting which leads to conserve energy of the broadcasting node.

ANCOR consist of 3 essential phases; initialization, reinforcement and routing.

Initialization is the first stage of the algorithm. In this phase, artificial ants are created and spread over the network to search the target node. Initially, all of the nodes have null pheromone. In order to spread ants effectively, ants emit negative pheromone on the nodes they passed by. In contrast to positive pheromone (or normal pheromone which natural ants uses), negative pheromone has a repulsive effect over ants. Since both negative and positive pheromone is represented by a single variable, the value of the variable

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indicates whether the none is attractive, repulsive or neutral for travelling ants. Negative pheromone does not exist in nature, whereas it is used to spread ants and to search the space effectively. As ants emit negative pheromone during the search process, any visited node will have negative pheromone, which is smaller than initial set value of NULL pheromone, will be repulsive compared to the not visited nodes.

When an ant arrives at a new node, it checks whether this node is the target or not. If not, it updates pheromone density of the node and chooses a new node relying on pheromone densities within the neighborhood nodes as well as a random factor. Node with updated pheromone density broadcasts its new pheromone value to disseminate its current value. If the node which ant arrives at the target node, the initialization phase ends and the reinforcement phase begins.

In the reinforcement phase the main objective is to establish a route between target and sink nodes. The first ant arriving at the target resets its variables and act as a new-born ant to return to the sink node by following highest negative pheromones while emitting highest possible positive pheromone on the visited nodes. In other words, it establishes a route made of positive pheromones between sink and target node. The third phase, i.e. the routing phase is the actual operational phase. Since a route between sink and target is established ants start to carry data between target and sink nodes. Note that because of the randomness of the decision making on the next node selection, there are some ants searching for different routes.

IV. Optimal Pheromone Distribution Model (OPDM)

In the first implementation of the ANCOR algorithm, the pheromone density of a single node does not have any impact of neighboring nodes regardless of the actual value of the density. However, in the nature there is a mutual dissemination of pheromone. OPDM is a new pheromone distribution model for the ANCOR algorithm. The essential idea behind the model is that every node on the network must be affected by the pheromone densities of the neighboring nodes. However the developed approach does not mimic the natural model. A single node surrounded by its neighbors with high pheromone densities, must include some of its neighbor's pheromone. This method is called *optimal* because it does not require any additional communication overhead over the network. Each node uses only its local information which is already acquired in order to perform OPDM.

The pheromone added to node is called *environmental pheromone* and its amount is controlled by a tuning parameter called *envPh*.

A node checks its immediate neighbor tables and computes over their pheromone values. The computation includes finding the average pheromone density value of the immediate neighbors and adjusting self pheromone value depending on this average. If the average pheromone value lays in the positive pheromone interval, the neighboring node with the highest positive pheromone density is multiplied by a constant, i.e., *envPh*, and added to the self pheromone value to the node. In contrast, if the average pheromone lays in the negative pheromone interval the same procedure takes place with the neighboring node having the highest negative pheromone density value.

The value of *envPh* changes between 0.0 and-1.0. 0.0 *envPh* represents no addition of environmental pheromone, while 1.0 represents a full additonal environmental pheromone.

$$\pm\Delta = \frac{maxHop - hop}{maxHop}\rho \qquad \rho\epsilon[0..1] \tag{1}$$

Eq.1 represents pheromone refreshing mechanism which is initially developed for the ANCOR algorithm. *maxHop* refers to maximum hop count that a packet in the network can travel, whereas *hop* refers to munber of nodes passed by packet. The amount of pheromone that will be added to node is represented by Δ. If the node has positive pheromone, Δ would be taken as positive, othervise if the node has negative pheromone, Δ would be taken as negative. ρ is used to control the effectiveness of Δ.

$$\pm\Delta = \frac{maxHop - hop}{maxHop}\rho + envPh * \max/\min\,(nhgPhDen) \tag{2}$$

Eq.2 represents new pheromone update mechanism used in OPDM. The additional term indicates max or min (depending on the average value of neıghboring nodes) pheromone value of the neighboring nodes. In this paper the value of envPh, which varies between 0.0 and 1.0, is investigated.

V. Results

In this section, performance results of the existing pheromone distribution model and the optimal pheromone distribution model are given.

Our first performance criterion is the number of nodes which an ant passes through until it finds the target node. Our second performance criterion is the number of nodes passed through to return to the sink by the ant arriving at the target first.

First three figures are generated using existing pheromone distribution model in ANCOR, mean and variance values are represented against number of ants on the network

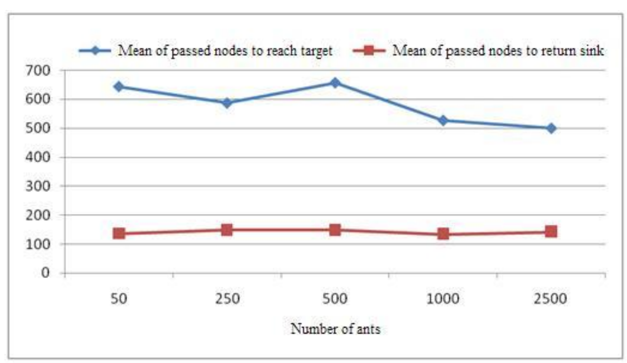

Fig. 1. Mean values for finding target and returning to sink in a network of 2500 nodes.

consisting of 2500 nodes. Next three figures are generated using OPDM, comparing mean and variance values against envPh. A network of 2500 nodes, and 250 ants are used in OPDM tests (Fig. 4, Fig. 5, and Fig. 6).

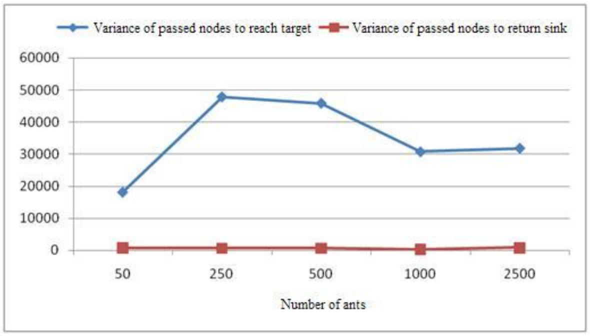

Fig. 2. Variance values for finding target and returning to sink in a network of 2500 nodes.

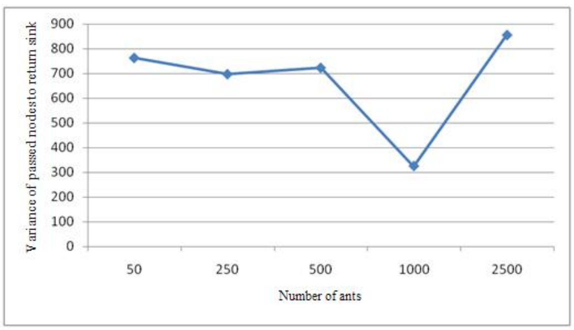

Fig. 3. Detailed variance values for returning to sink in a network of 2500 nodes.

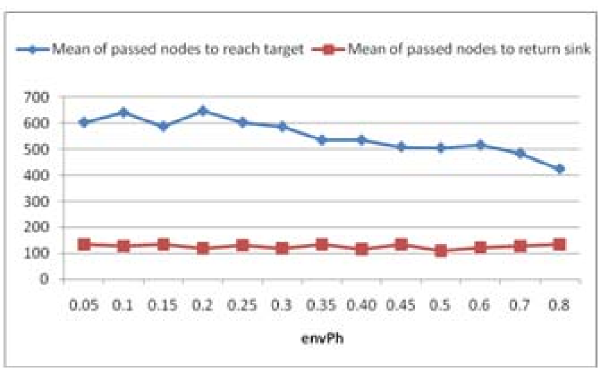

Fig. 4. Mean values for finding target and returning to sink in a network of 2500 nodes (OPDM).

VI. CONCLUSION

Although the mean values for finding target node and returning to the sink are not excessively different for two pheromone distribution models (Fig. 1 and Fig. 4), OPDM shows better results for variance values. Especially in variance values for returning to the sink (Fig. 3 and Fig. 6), OPDM has a significant performance. If we compare two best values in Fig. 3 and Fig. 6, OPDM resulted under 100 for envPh values between 0.5 and 0.6 (Fig. 3), whereas in Fig. 6, the best value of variance is over 300 with 1000 ants.

If we compare the variance values for finding target node, OPDM best performed at envPh 0.7, resulting in a variance nearly 10000 (Fig. 5), whereas the best variance value for the other method is nearly 20000 for 50 ants.

In conclusion, OPDM showed better performance, especially in the terms of variance. More tests using different ant populations will be done in near future.

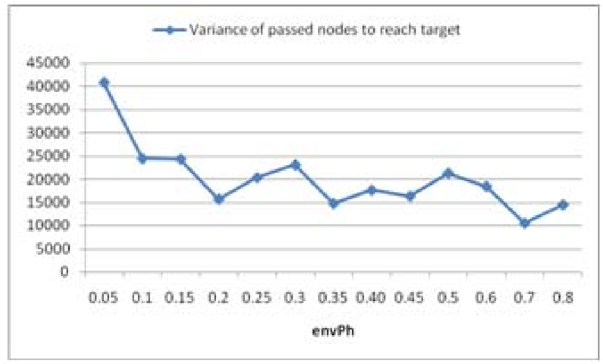

Fig. 5. Variance values for finding target in a network of 2500 nodes (OPDM).

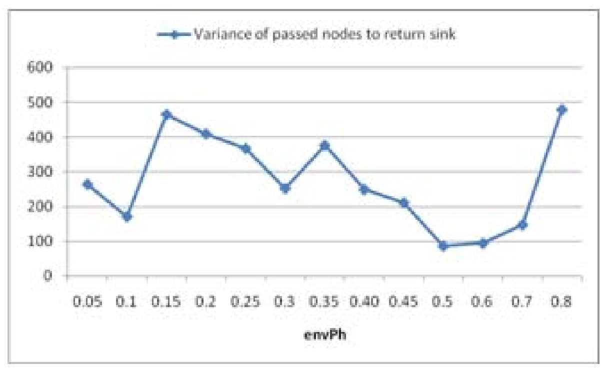

Fig. 6. Variance values for returning to sink in a network of 2500 nodes (OPDM).

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