Ant Colony Optimization Algorithm and its Applications

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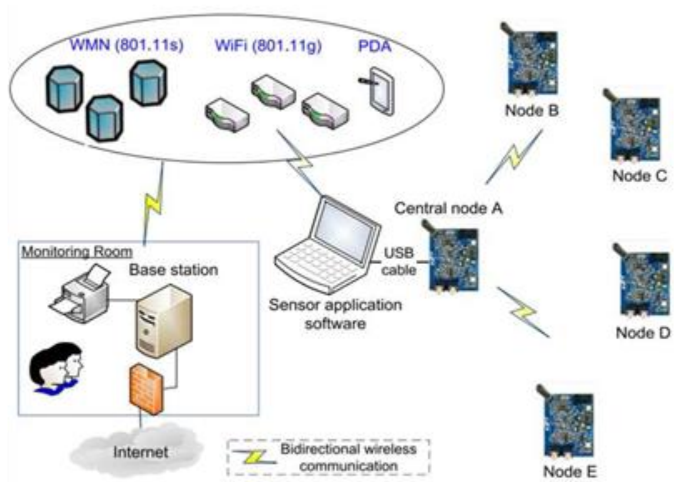
Abstract – Wireless sensor networks have been growing rapidly due to technology invention. Sensor nodes perform some processing, gathering required information and communicating with other connected nodes in the network. Sensor nodes are of limited energy. The limitation in vitality is one of the drawbacks in a sensor node. Always energy is of primary concern in a wireless sensor networks. There are various approaches used for optimizing energy conservation. Some of the methods include Ant Colony optimization (ACO), Particle Swarm optimization (PSO), Heuristic approach etc. For enhancement of network lifetime, ant colony optimization plays a significant role. In this paper, we have made a study on some of the algorithms and there are many applications where the ant colony optimization techniques can be used. Some of the applications of ACO include travelling salesman problem, scheduling, assignment problem etc. Any constraint specification problem can be solved using ACO approaches.

Index Terms – Wireless Sensor Networks, Ant Colony Optimization, Particle Swarm Optimization.

1. INTRODUCTION

Wireless sensor network (WSN) is one of the most important technologies in this century. A WSN typically consists of a large number of low-cost, low-power, and multifunctional wireless sensor nodes. The number ranges from 100-1000 nodes. These sensor nodes are composed of sensors, transceiver, battery, and the processor for performing local processing. The processor converts the analog information which is sensed by the sensors about their environment into digital format [1]. These nodes have sensing, wireless communications and processing capabilities. These sensor nodes communicate over short distance via a wireless medium. Wireless sensor network (WSN) has a wide range of applications in military, environmental monitoring which includes agriculture monitoring, habitat monitoring, greenhouse monitoring and forest monitoring, health care monitoring, industrial monitoring, space exploration and so on.

Individual sensor node's capability is limited and hence all the nodes aggregate power is used to accomplish the task. Sensor nodes organize autonomously in the wireless network. Sensor nodes are battery-powered and are expected to operate for a relatively long period of time. Always power is a critical resources in the wireless network. It is very difficult to change or recharge batteries for the sensor nodes. WSNs are characterized with denser levels of sensor node deployment, higher unreliability of sensor nodes, and sever power, computation, and memory constraints. Thus, the unique characteristics and constraints present many new challenges for the development and applications of WSNs.

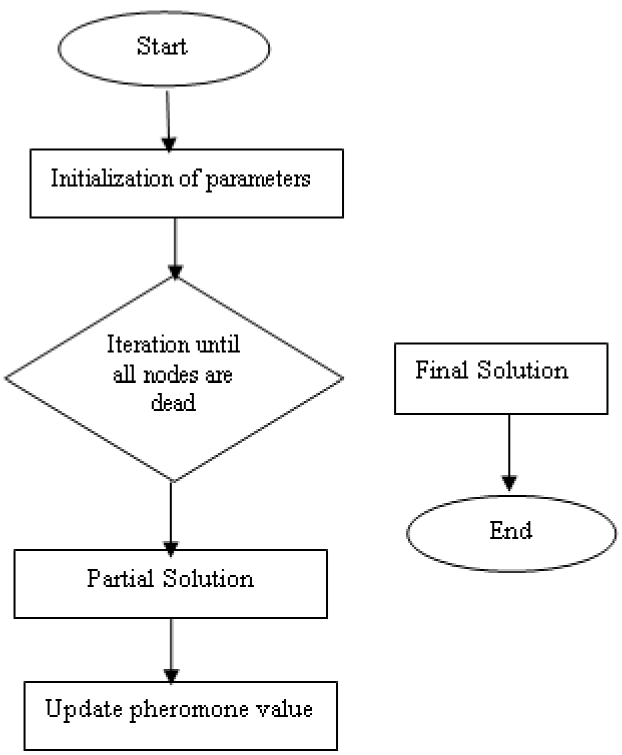


Architecture of WSN

2. RELATED WORK

ACO (Ant Colony Optimization). Routing comes under the optimization problem for finding the shortest path from source to the destination. Ants have been there for millions of years and they detect shortest path between the food sources and nest. An ant secretes a volatile chemical substance called pheromone that helps in converging over the shortest path among multiple paths. Ants secrete pheromone on the ground while moving and follow the path with maximum pheromone concentration. This mechanism helps the ant to choose the best path and the same has been proved to be to generate optimal path from among multiple paths [2]. The ant behavior is mapped in electronic devices for solving various combinatorial problems. While traversing through the phases of the problem, asynchronous agents are included to produce partial results. Greedy approach is followed for arriving at the solution in incremental way in each phase. The same approach is used for routing the data packets from the source to destination in the wireless sensor networks. Amount of network packet transmission, energy efficiency and increasing the network lifetime are very important in a wireless sensor network.

An ACO algorithm has two phases where the capability of the algorithm is enhanced which is trail evaporation and daemon actions. To refrain the unlimited accumulation of trail over specific component trail evaporation is done. To implement the actions that cannot be performed by a single ant, the Daemon actions are used.



ACO (Ant Colony Optimization)

3. VARIOUS APPROACHES

3.1 Basic Ant Based Routing Algorithm (BABR)

The simplest way to describe the Ant Colony concept in WSNs is to put the concept of Basic Ant Colony Algorithm (BABR).The implementation of this algorithm is as follows:

- A Forward ant is launched to source node with the aim of finding an optimal path from source to the destination.
- Each ant forwards to the destination node by using the neighbor nodes with minimum cost joining the source and sink.
- As the ants move forward to reach up to the destination, greedy stochastic policy is applied to choose the successive node.
- For every movement, the agents collect information regarding the network and update the routing table.
- On reaching the destination node, a backward ant is created to travel in the same path but in opposite direction.
- During the backward travel, the network status and the routing table of each node are updated related to the path they followed.

Thus in the Basic Ant Routing Algorithm the ant travels in both forward and reverse path to update the routing table periodically.

3.2 Sensor-driven and cost-aware ant routing (SC):

One of the problems of the basic ant-routing algorithm is that the forward ants normally take a long time to reach the destination, even when a table list is used. This happens since the ants initially do not have an idea where the destination is.

Only when an ant reaches the destination and traverses back in the same link, probabilities of the path changes. In sensor driven method, we assume that ants have sensors to find the path to reach the destination even at the beginning. Something like that where ants smell the food at the very beginning. This approach is a realistic assumption in sensor networks, as the

Feature-based routing dominates address-based routing in that space. If the destination is not clearly known, then pre-building the feature potential is sometimes very efficient. Cost awareness generalizes the objective of shortest path length so that ants can apply other routing metrics as well, e.g., energy-aware routing. This algorithm may produce misleading solution due to loss of visibility of the destination node. This is disadvantage of this algorithm.

3.3 Flooded Forward Ant Routing (FF)

This routing method is based on flooding of agents from source node to the sink node. In this method, even when the ants are equipped with sensors, they might get into wrong path due to obstacles or due to loss of visibility of nodes.

There may also exist situations where sink or destination node may not be known to the agents and estimation of cost of the path also difficult. This leads to wandering of agents around the network to find the destination. Broadcast method is used for sending data packets in the wireless network to overcome this problem.

3.4 Flooded Piggyback Ant Routing (FP)

The basic functionality of this method is the same as flooded forward ant routing except that a new ant called data ant is used to carry the forward list. The energy dissipation of nodes during the sending of data packets in the network is reduced by coupling the data with the forward flooding ant. Two tasks are performed by the ants; one is forwarding the packets and second is keeping the identity of the nodes along the path to sink note. The same information can be used by the backward ants.

3.5 Energy Efficient Ant Based Routing (EEABR)

EEABR is considered to be an improvised version of ant based routing. While selecting the node over the traversal path, this algorithm considers the energy level along with distance. In the basic ant algorithm, large amount of memory is required for storing identity of each neighboring node and their corresponding pheromone information in the routing table. By storing the information about only the last two nodes EEABR significantly reduces the memory requirement. Only drawback in this algorithm is the delay in packet delivery.

4. ANT COLONY OPTIMIZATION APPLICATIONS

Whenever we model a problem, the main task involved will be to give a model where searching of minimum feasible path with respect to a set of constraints becomes important. This is applicable to all the combinatorial optimization problems involving ACO meta-heuristics. The constraints are mostly satisfied in apriori way. In every step, the successor node is chosen based on the set of possible candidate nodes that are consistent with to the constraints of the problem and the nodes construct "feasible" paths. Every ant will be maintaining a list of visited nodes and from the list of nodes not visited, a node will be selected at each step of process. Here the difficulty is not in finding a possible solution but a solution which will be the best with regard to an objective function in a constrained problems. In this paper, we study the capabilities of ACO for solving solution that satisfies all the constraints.

Procedure ant-solver

Set parameters and initialize pheromone trails

Repeat

For k in 1 ..n do

Construct an assignment A_k

update pheromone trails using $\{A_1, A_2, \ldots A_n\}$

until cost $(A_i) = 0$ *or maximum cycles reached*

end

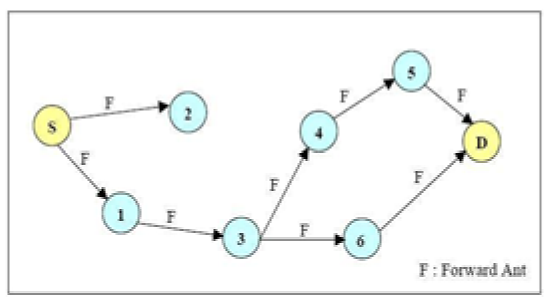
A CSP is defined by triple(X, D, C) such that X is a finite set of variables, D is a function that maps the variable to the domain D. C is a set of constraints which is the relation between variables which restrict the set of values assigned to the variables. The CSP is generalized to max-CSP in a CSP framework because of the reason that CSPs are over constrained. The goal here would be not to find a consistent solution but complete assignment that maximizes the number of constraints.

An assignment is a key value pairs and here it corresponds to assignment of values $V_1 \ldots V_k$ to keys $X_1 \ldots X_k$ respectively. A violation in the assignment A takes place when a constraint c_i € C if the variables involved is assigned in A and relation defines by c_i is not satisfied by when replaced with variables associated with value in A. The cost(A) is defined by the number if constrains violated by A. A solution will be complete assignment which satisfies all the constraints in C.

The real time applications have more constraints that it is hard to find the solution. Hence the CSP framework is generalized to max-CSP. So the goal is to trace an assignment that maximizes the number of constraints that are satisfied. One of the aims would be to reduce the violated constraints. *Ant colony based routing approach consists of three phases namely Route Discovery, route maintenance and route failure handling*

Route Discovery

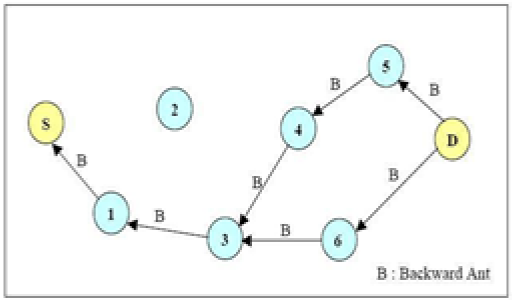
Route discovery is responsible for creating new routes. A *forward ant* (FANT) and a backward ant (BANT) are used for the creation of new routes. A *forward ant* (FANT) is initiated at the source and a *backward ant* (BANT) is initiated at the destination. The FANT is a small packet with a unique sequence number. The sender broadcasts the FANT which will be relayed by the neighbors of the sender



Route discovery phase by forward ant

A record will be created by the node which receives the FANT for the first time. The routing table consist record with destination address, next hop, and pheromone value. The node forwards FANT to the neighboring node after interpreting the source address as destination address, computing the pheromone value depending on number of hops needed to reach the sink, address of previous node as next hop node. Once the FANT reaches the destination, a BANT will be returned to the source using these entries made by the nodes. Hence the

BANT will take the same path as the FANT but in opposite direction.



Route discovery phase by backward ant

Route Maintenance

The improvement of the routes during the communication is done in Route maintenance phase. Special packets are not needed for route maintenance. Once the FANT and BANT have established the pheromone tracks for the source and destination nodes, subsequent data packets are used to maintain the path. The established path does not keep the initial pheromone values forever. The pheromone value gets reduced with high decay rate. Looping is prevented by using simple method in the route discovery phase. The unique sequence number is used to identify the duplicate ants. Flag for duplicate will be set, if a supplicate packet is identified. The packet is sent back to the previous node where the node deactivates the link to avoid further movements of the packet.

Route Failure Handling

In a mobile adhoc networks, routing failure may happen often due to the mobility of the nodes. Route failure handling phase is responsible for handling the failures. A missing acknowledgement indicates a route failure. The route_error flag will be set on missing acknowledgement. Disabling the link and finding the alternative route to reach the destination will be the first task done on occurrence of route failure. If there exists a path to destination, the packet will be forwarded to the neighbor, so that the packet reaches the destination. If a path doesn't exist, then the packet is sent back to the previous node, so that the packet reaches the source node.

5. CONCLUSION

The main challenge in a changing environment of wireless sensor network is finding an optimal path and thereby improving the network lifetime. Even when a node is not participating in a communication, energy will be wasted when they are live in the network. More energy is waste due to redundant data transmission also. One way to choose an optimal path is through Ant colony optimization approach. The ant colony optimization is a probabilistic technique that can be applied for solving travelling salesman problem, assignment problem, scheduling problem, pattern recognition etc.

In future, study can be done incorporating ACO with cluster head selection mechanism and applying with routing algorithms like LEACH, PEGASIS etc.

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