Swarm Intelligence Techniques in Mobile Ad hoc Networks

Anupama Potluri

Department of Computer and Information Sciences
University of Hyderabad

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Outline

ANSI: A Unicast Routing Protocol Using Swarm Intelligence

ANSI has the following characteristics

1. A reactive routing protocol
2. Very similar in operation to DSR and AODV
3. Takes into consideration the following when choosing the optimal path
   - Congestion on a link
   - Hop cost/distance from a node to the destination

Protocol Overview

1. A *forward reactive ant* similar to RREQ is sent out from S to D with source routing
2. D source-routes a *backward reactive ant* to the source S which updates the routing tables on all the nodes in the path
3. On link failure, performs local repair using a *forward reactive ant* and a route error message with a *backward reactive ant*
4. Deterministically chooses the next hop to reach the destination

Data Structures

1. Ant Structure
   - Ant ID : $(nodeID, sequencenumber)$ pair
   - Number of nodes visited by the ant, m
   - Stack of IDs of visited nodes, S_π which consists of the set $V = \{v_1, v_2, ..., v_m\}$
   - Pheromone amount at $v \in V, p_v$
2. Ant Decision Table at a node i : For every destination-next hop, there is a row in this table A_{jd} where j is the next hop to destination d from i. In this row, it stores the following information:
   - Pheromone trail concentration, $\tau_{ijd}(t)$
   - Hop cost or distance to destination d, η_{ijd}
   - Congestion information of the link (i, j), ψ_{ijd}
   - 'Goodness' value of the entry - a_{ijd}
3. Routing Table at a node i - contains, for every known destination, d, the entries of the Ant Decision Table for which a_{ijd} value is maximum.

Calculation of various values

Pheromone level deposited by an ant, τ_{ijd} is calculated as follows:

$$\tau_{ijd} = \frac{1}{p_j - p_i} \quad (1)$$

where p_j and p_i are the pheromone levels at nodes i and j.

Hop cost, η_{ijd} is calculated as

$$\eta_{ijd} = \frac{1}{depth(d)} \quad (2)$$

where $depth(d)$ is the depth in the stack of visited nodes

Updation of pheromone levels

Pheromone level evaporated by time $(t + \Delta)$ is given by the equation

$$evaporate(\tau_{ijd}(t), \Delta) = \frac{\tau_{ijd}(t)}{2^{\frac{\Delta}{c}}} \quad (3)$$

The updated pheromone value at time $(t + \Delta)$ is given by

$$\tau_{ijd}(t + \Delta) = evaporate(\tau_{ijd}(t), \Delta) + \tau_{ijd}^{\pi} \quad (4)$$

where τ_{ijd}^{π} is the pheromone deposited by the new ant π

Positive and Negative Reinforcement of Pheromone Levels

1. Positive Reinforcement happens
   - Through *forward and backward* reactive ant activity
   - Hello messages between neighbors, which also carry congestion information
   - During data packet transmission
2. Negative Reinforcement happens
   - Due to link failure or congestion
   - Evaporation over time

Summary

1. ANSI is a reactive protocol which uses ants that deposit pheromone over trails they travel from source to destination or vice versa
2. It uses local reinforcement via data packets and Hello messages to positively reinforce pheromone levels
3. It uses route error or congestion error information to negatively reinforce pheromone levels along with evaporation
4. It uses a combination of congestion and hop cost information along with pheromone values to compute “goodness” of a route
5. Uses the best path found deterministically to route packets
6. Updates the routing table periodically by using the new pheromone, congestion and any change in hop cost values

AntHocNet: Swarm Intelligence for Routing in MANETs

AntHocNet has the following characteristics:

1. A hybrid routing protocol
2. Uses *Stigmergic Learning* with *Information Bootstrapping*
3. Multi-objective optimization of
   - End-to-end delay
   - Hop cost/distance from a node to the destination
4. Stochastic Data Routing

Protocol Overview

1. A *forward reactive ant* similar to RREQ is sent out from S to D with source routing. An intermediate node drops duplicate ant packets.
2. D source-routes a *backward reactive ant* to the source S which updates the routing tables on all the nodes in the path. So, only one path is established initially.
3. Path maintenance and multiple path setup is done with proactive path exploration and bootstrapping
4. On link failure, performs local repair using a *forward reactive ant*
5. A route error message with a *backward reactive ant* is sent only if local repair fails

Updation of pheromone values

Pheromone value is calculated as a function of end-to-end delay estimated at a node and its hop distance

$$\tau_{id}(t) = \left(\frac{T_{id}(t) + hT_{hop}}{2}\right)^{-1} \tag{5}$$

where $T_{ijd}(t)$ is the estimated time to go from i to j on the path to d and T_{hop} is the time taken to go from one hop to the other in unloaded conditions.

The updated pheromone value at time $(t + \Delta)$ is given by

$$\Gamma_{ijd}(t + \Delta) = \gamma\Gamma_{ijd}(t) + (1 - \gamma)\tau_{id}, \gamma \in [0, 1] \tag{6}$$

Stochastic Data Routing

Data is transmitted along the path selected out of the multiple paths known to the destination as follows:

$$P_{ijd} = \frac{T_{ijd}^{\beta}}{\Sigma T_{ijd}^{\beta}}, \beta \geq 1 \tag{7}$$

where P_{ijd} is the probability of selection of neighbor j through which the packet will be routed to d from i.

Proactive Path Maintenance

1. Proactive *forward reactive ants* are sent out to update the information about currently used paths.
2. In addition, to reduce the rate of proactive ants, short messages are exchanged between neighbors as follows:
   - A node i broadcasts to all its neighbors a list of all the destinations d known to it along with the best pheromone values to them.
   - A neighbor, j, receiving this message will update its pheromone table to add or update the entry to each d through neighbor i after updating the pheromone value advertised with its own hop cost and delay estimate values.

Link Failures

1. When a node *i* detects a link failure, it removes the node *j* from its neighbor list.
2. It then broadcasts a *link failure* message consisting of a list of all destinations to which the best path was lost along with the new best pheronome value.
3. All neighbors receiving this message update their pheromone values.
4. If the neighbor's best path to any destination *d* is changed by this updation of pheromone value, it sends the list of all such destinations to its neighbors.
5. The original node *i* will also initiate *local repair*. If it is not successful, it sends a *route error* message to the source.

Summary

1. AntHocNet is a hybrid protocol which uses ants to discover paths reactively but maintains the path through proactive messages during the course of communication.
2. It uses bootstrapping similar to the distance vector protocol during proactive path maintenance.
3. It uses a combination of end-to-end delay and hop cost information to update the pheromone values and compute “goodness” of a route
4. It uses stochastic routing during data packet transmission to automatically balance the load across multiple paths.

References I

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