Simple ant routing algorithm strategies for a (Multipurpose) MANET model

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Ad Hoc Networks(2010)
Outline

- Introduction
- SARA architecture
  - Route discovery
  - Route maintenance
  - Route selection
  - Route repair
- Simulation
- Conclusions
Ant colony optimization

- Real ants can converge on the shortest path that connects their nest to a source of food.

- While moving, the ants deposit the "pheromones" and tend to follow the paths with the highest intensity of pheromones.
In the traditional ACO
- The source node starts a route discovery process by sending Forward ANT (FANT) packet
- The destination node will send another packet back, the Backward ANT (BANT)

CNB (controlled neighbor broadcast)
- Each node broadcasts the FANT to all of its neighbors, but only one of them broadcasts the FANT again
- The policy used is to select different nodes each time a FANT is generated using a probabilistic approach.
The probability

\[ p_{(u,j_i,d)} = \frac{C_{(u,j_i,d)}}{\sum_{k=0}^{k=M} C_{(u,k,d)}} \wedge C_{(u,j_i,d)} = \frac{1}{1+n}, \]

n is number of times the link was selected

M is the number of adjacencies of node u
SARA architecture - route discovery

- **Two timers**
  - Route discovery confirmation timer (T0)
    - The timer is initiated by the source node
    - If the timer ends and the source node does not have a route to the destination, a new FANT is created
  - FANT confirmation timer (T1)
    - The timer is initiated by all network nodes which are responsible for forwarding the FANT
    - The timer is cancelled upon the reception of an acknowledgment packet (C_FANT_n) sent by the next forwarding node
    - If the timer expired, a copy of the FANT is transmitted.
When receiving the FANT message, any node with destination route information must generate a BANT.

The FANT message continues traveling in the network until:
- It reaches the destination node
- The node responsible to forward the FANT has a valid route to the destination node

All nodes that received the FANT have the responsibility to update the source node route entry, this is used to form the network topology.
SARA architecture - route discovery

\[ C_{(s,B,d)} = 1/1 + 1 \]
\[ p_{(s,B,d)} = 0.5 \]

\[ C_{(s,A,d)} = 1/1 + 1 \]
\[ p_{(s,A,d)} = 0.5 \]

\[ C_{(s,A,d)} = 1/1 + 2 \]
\[ p_{(s,A,d)} = 0.4 \]

\[ C_{(s,B,d)} = 1/1 + 1 \]
\[ p_{(s,B,d)} = 0.6 \]

Node 'J2' has a route to destination node 'd'
SARA architecture - route maintenance

- Pheromone level
  - An indicator of the activity and the quality of a link

- Increase pheromone intensity
  - Every packet (data or control) that crosses a link increases the pheromone intensity by $\alpha$

- Decrease pheromone intensity
  - As time goes, the pheromone level decreases automatically by $\gamma$
SARA architecture - route maintenance

- **Increase**
  \[ \forall \text{pkt}(T_i), \; ph_{(u,j,T_i)} = ph_{(u,j,t)} + \alpha, \]
  where:
  \[ t = T_{i-1}, \quad \text{if} \; T_{i-1} > \tau_{i-1} \]
  \[ t = \tau_{i-1}, \quad \text{if} \; T_{i-1} < \tau_{i-1} \]

- **Decrease**
  \[ \forall \text{pkt}(\tau_i), \]
  \[ ph_{(u,j,\tau_i)} = \begin{cases} 
  ph_{(u,j,T_i)} - \gamma, & \text{if} \; ph_{(u,j,T_i)} > \gamma, \\
  0, & \text{if} \; ph_{(u,j,T_i)} \leq \gamma. 
\end{cases} \]
Fig. 3. Pheromone level evaluation.
SARA architecture - route selection

The route selection is a probabilistic procedure used to choose the next hop to forward traffic to the destination.

\[
\forall j_i \in \text{Adj}[u], \exists p_{(u,j_i,d)} : p_{(u,j_i,d)} = \frac{\Phi_{(u,j_i,d)}}{\sum_{k=0}^{k=M} \Phi_{(u,j_k,d)}}
\]

\[
\Phi_{(u,j_i,d)} = \frac{(p h_{(u,j_i,d)} + 1)^F}{e^{n h_{(j_i,d)}}}
\]

\(n h_{(j_i,d)}\) is the number of hops from node \(j\) to destination node \(d\).
SARA architecture - route repair

- To detect a broken link, SARA calculates MAX_Tx that indicates maximum transmission attempts.

\[
NTx_{(u,j,t_i)} = \begin{cases} 
NTx_{(u,j,t_{i-1})} + \lambda & \text{if unsuccessful transmission,} \\
NTx_{(u,j,t_{i-1})} - \delta & \text{if successful transmission.}
\end{cases}
\]

\[
NTx_{(u,j,t_i)} > MAX_{-Tx}.
\]
Fig. 4. Route repair procedure.
Simulation

Setup

- The simulations were implemented on NS2
- Transmission range 100 m
- Transmission rate 2Mbps
- 1000 m * 1000 m for 104 nodes
- Simulation time 60 s

Table 2
SARA’s reference values.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference value</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>5</td>
</tr>
<tr>
<td>T0</td>
<td>100 ms</td>
</tr>
<tr>
<td>T1</td>
<td>100 ms</td>
</tr>
<tr>
<td>RRT</td>
<td>100 ms</td>
</tr>
<tr>
<td>( \tau )</td>
<td>1 s</td>
</tr>
<tr>
<td>( \delta )</td>
<td>1.0</td>
</tr>
<tr>
<td>MAX_Tx</td>
<td>5</td>
</tr>
</tbody>
</table>
Simulation

- Convergence factor – F
  - It is used by SARA to converge the traffic into one route or to balance the load among multiple routes

<table>
<thead>
<tr>
<th>N. sessions</th>
<th>F</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5</td>
<td>1.0</td>
<td>2.0</td>
<td>5.0</td>
<td>10.0</td>
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<tr>
<td>1</td>
<td>65</td>
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<td>8</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>81</td>
<td>45</td>
<td>21</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>134</td>
<td>62</td>
<td>35</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>143</td>
<td>80</td>
<td>39</td>
<td>24</td>
<td>24</td>
</tr>
</tbody>
</table>
Simulation

(a) Overhead

(b) End-to-end delay
Simulation

- FANT generation rate

### FANT generation rate: number of used routes.

<table>
<thead>
<tr>
<th>N.sessions</th>
<th>FANT TX rate ($T_0$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>4</td>
<td>23</td>
</tr>
</tbody>
</table>

![Graph showing FANT generation rate over network load with different $T_0$ values](image-url)
Simulation

Routing protocol overhead

(a) CBR traffic

(b) FTP traffic
Simulation

Goodput

(a) CBR traffic

(b) FTP traffic
This paper presents an improved version of the ACO framework, that aims at reducing the overhead by using a new route discovery technique (CNB).

The results show that small values of F are adequate for heavy loaded networks because of more routes enables load balancing and reduces overhead and collisions.

The future work is to develop an algorithm that can dynamically adapt the convergence factor according to network traffic conditions.