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Ant-Based On-Demand Clustering Routing Protocol for Mobile Ad Hoc Networks

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ABSTRACT: Ant Colony Optimization (ACO) comes underthe swarm intelligence which imitates the collective behaviour of some biological species to solve the network routing problems. Ant Colony Optimization is designed to find a better routing path by continually issuing routing packets (ants) to leave the pheromone information on the path from the source to the destination, so that ACO could maintain the routing path according to the pheromone trail. ACO would follow periodical routing packets transmission. However, this feature may also occur when there are no data packets which need to be sent and result in lower network performance. AODV routing protocol is adopted to make the efficiency of ACO better and also Weakly Connected Dominating Sets (WCDS) construction scheme is implemented to cluster network nodes to achieve an efficient packet transmission since only the nodes in WCDS sends the routing packets only to their neighbours. The characteristics of Ad hoc On-Demand Distance Vector (AODV) routing protocol and ACO are combined to complement the deficiencies and also use WCDS constructed by Least Cluster Change (LCC) as an auxiliary structure to elevate the efficiency of maintaining the network topology.The performance of AOCR is compared with AODV and it is analyzed in terms of throughput and packet delivery ratio.

KEYWORDS: ant colony optimization, weakly connected dominating set, cluster, cluster head.

I. INTRODUCTION

Ad Hoc Networks are self-configuring network of mobile routers connected by wireless links without access point and are dynamic networks. Every node in the network is autonomous and is free to move. The network is an ad hoc network because it does not rely on any pre existing infrastructure, such as routers in wired networks or access points in the managed (infrastructure) wireless networks. Instead,each node that participates in routing by forwarding data for other nodes, so the determination of which nodes forward data is made dynamic on the basis of network connectivity. The communication in ad hoc network takes place by using multi-hop paths. Nodes share the wireless medium and the topology of the network changes dynamically. Some of the properties of ad hoc network include the following:

- Requires devices to cooperate autonomously
- No user intervention
- Rapid self-organizing wireless network
- Independent of infrastructure
- Heterogeneous & adaptive

Ad hoc network is a wireless network having a wide collection of nodes to terminals and that are autonomous. They form a radio network between the nodes and maintain connectivity in decentralized manner. It is very easy to setup and its speed is very fast than other networks. It reduces the dependency on infrastructure. It can be connected from anything to anything like it can be connected between two vehicles. They are used in same type of work like in war all fighter planes, tankers, helicopters are connected to other through an ad hoc network and like fire brigade, taxi and ambulance.Figure 1.1 shows an Ad Hoc Network.

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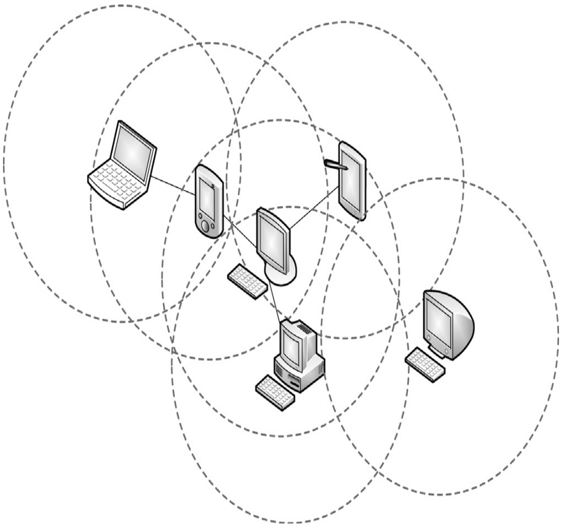

Figure 1.1 Ad Hoc Network

A routing protocolspecifies how the routers communicate with each other, disseminating information that enables them to select routes between any of the two nodes. Routing algorithms determine the specific choice of route. Each router in the network has prior knowledge about the network attached to it directly. A routing protocol shares the information first with the immediate neighbors, and then with the entire network. This way, routers gain knowledge of the topology of the network.Most of the routing algorithms involved can be categorized as being proactive, reactive or hybrid protocols.

1) In a proactive protocol, each node periodically transmits control packets throughout the network to refresh a list of available destinations and their associated routes. Like this, a request to send data can quickly obtain a route from the source node to the destination node.
2) In a reactive protocol, the node transmits control packets only on demand, thus it conserves more bandwidth. However, the node may have to wait a considerable amount of time for a route to be established before it can start to send data.
3) A hybrid protocol is usually based on a proactive protocol but italso contains some features and advantages of a reactive protocol. The routing is initially established by some proactively prospected routes and then it serves the demand from additionally activated nodes through reactive flooding.

Minimal configuration and quick deployment of ad hoc networks helps in emergency situations like natural disasters or military conflicts.

II. RELATED WORK

2.1. Ant-based routing protocol

In the last few years, some self-configuring, self-stabilizing and self-organizing algorithms are considered as a possible solution for multi-hop networks. Recently, there is an interest growing in the use of swarm intelligence or nature-inspired algorithms for routing in networks. Swarm intelligence is a computational intelligence technique to simulate the collective behaviour of biological species to solve the node distribution problems without any extracentral control. Ant colonies, flocking of birds, herds of animals and schools of fish are some natural examples for the swarm intelligence. The foraging behaviour of bees and ants and the hill building behaviour of termites has inspired to develop efficient routing algorithms.

In the natural world, ants communicate and exchange information with each other by leaving pheromone which is a volatile chemical factor. While searching food, each ant takes a random route from its anthill. Different ants follow different routes to reach the food. On the way back to the anthill, ants deposit pheromone on their trajectories to allow other ants to detect the leftover food and thus, reinforcing the pheromone on the trail. In this way, a number of

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paths may beavailable from the nest to the food. Always the reinforcement in shorter tracks tends to be more attractive due to shorter end-to-end travel time. Over time, however, the pheromone trail starts to evaporate, thus it reduces its attractive strength. For an ant,the more time it takes to travel down the path and back again, the more pheromone have to evaporate. Hence a short pathgets marched over frequently and thus the pheromone density becomes higher on shorter paths than the longer ones. Finally, the shorter path can become the best path between anthill and food. Figure 2.1 shows an example of food searching ants.

In the networks, the ants are considered as routing packets that travels through the network to search a better path to the food which is considered to be the sink node.

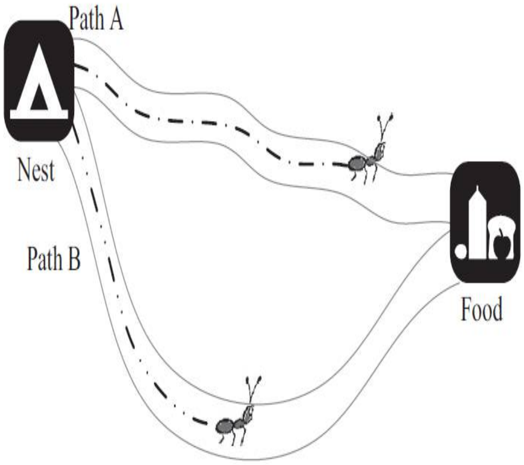

Figure 2.1 Food searching ants.

The source node periodically and randomly sends a forward ant to one of its neighbours. The selected neighbour then estimates the pheromone, updates the pheromone table, and finally forwards the forward ant to one of its neighbours till the forward ant arrives at the destination node. After that, the destination node initiates a backward ant and sends it along the path that the forward ant just takes, for returning back to the source node. When the backward ant reaches the source node, the path is established and then the data packets can be transmitted to the destination node. Hence this ant based routing algorithm establishes the packet delivery path based on the energy-aware mechanism.

2.2. Weakly Connected Dominating Set A node set is called a Dominating Set (DS) if every node in the network is either in theset or a neighbour of a node in the set. In graph theory, a dominating set for a graph G = (V, E) is a subset D of V such that every vertex not in D is adjacent to at least one member of D. If any two nodes in dominating set can be connected through the intermediate nodes from dominating set, then it is called connected dominating set. A connected dominating set of a graph G is a set D of vertices with two properties:

1) Any node in D can reach any other node in D by a path that stays entirely within D. That is, D induces a connected sub graph of G.
2) Every vertex in G either belongs to D or is adjacent to a vertex in D. That is, D is a dominating set of G.

WCDS is a variant of the dominating set. A dominating set S for a graph G = (V, E) is a node subset $S \subseteq V$ such that, for every node $v \in V$, either $v \in S$ or V can find a neighbour u in S. In contrast, in a graph G = (V, E), the sub graph weakly induced by a subset S' (S'⊂ V) is the graph $S_w = (N[S], E \cap (N[S] \times S'))$, where N[S] includes the nodes in S' and all of their one-hop neighbours. The edges of S_w are all edges in G having at least one end point in S'. A subset S' is a WCDS if S' is a DS and S_w is connected.

WCDS has already been applied in many fields. For example, in ad-hoc networks, messages are forwarded between the nodes in a multi-hop mode. Clustering the nodes can reduce the complexity of routing the packets, and this concept of WCDS is very suitable for the formation of clusters.

III. PROPOSED WORK

Ant Colony Optimization is adopted as the main concept for routing path selection and WCDS is adopted as an additional structure that assists the Ant-based On-demand Clustering Routing (AOCR) protocol for wireless ad-hoc networks. This protocol is classified under the hybrid protocol since thecluster distribution is proactive and the communication among clusters is reactive. This protocol uses ant-like agents inspired by the foraging behaviour of ant colonies to explore networks and discover a routewith several Quality of Service (QoS) requirements including minimal traffic overhead or energy-efficiency.

AOCR is an on-demand routing protocol based on the ant colony algorithm and a clustering architecture. AOCR explore the network using Forward_Ants with the assistance of special nodes called cluster heads, as well as reinforce and select a better path from the source to the destination using Backward_Ants based on the pheromone values available in the pheromone table built by the Forward_Ants.

AOCR adopts the on-demand feature of the AODV routing protocol in the ant based algorithm and cluster formation from the WCDS procedure. This algorithm develops a concept that is based on the traditional ant-based algorithm. First, we adopt broadcasting of the ant packets instead of randomly unicasting it to one of the neighbouring nodes which reduces the time consumed by routing discovery. However, it may increase the number of generated ant packets. Hence, we use the clustering architecture of WCDS which may reduce the packet load. In the proposed scheme, only the node in the WCDS can broadcast Forward_Ants.

3.1. WCDS Construction

The WCDS procedure is used to find the cluster head by executing the following Algorithm 1. Each node in the network would execute the ClusterHeadDetermination()periodically.

Algorithm 1: Procedure for WCDS construction

```
//N: Null node
//C: cluster head
//O: ordinary node
//N[v]: neighbor nodes of node v
//clusterID(v): clusterID of node v
//degree(v): degree of node v
//status(v): role of node v
ClusterHeadDetermination()
if status(v) == N then
  foreach u 2 N[v]
   if status(u) == N then
    if degree(v) < degree(u) then
     Exit()
    else if (degree(v) == degree(u)) && (nodeID(v) > nodeID(u)) then
     Exit()
    end if
    end if
   end if
  end foreach
  status(v) = C
  clusterID(v) = nodeID(v)
  Send CH(v) to N[v]
 else
  if status(v) == O then
   foreach u 2 N[v]
    if (status(u) == O) && (clusterID(v) < clusterID(u)) then
     status(v) = C
```

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```
   end if
  end foreach
 end if
 LeastClusterChange()
end if
```

In Algorithm 1, each node's role should be N (Null node), C (Cluster head) or O (Ordinary node) during the construction of the WCDS initially and eventually each node's role would be C or O when the WCDS is established. If the status of node v is N, the node v becomes the cluster head if it has the largest degree and smallest ID when compared to its neighbouring nodes with status N. The cluster head would then broadcasts a CH message to its neighbouring nodes to indicate that it had became a cluster head. When the nodes with a NULL clusterID receive the broadcast message, they would join the cluster as in Algorithm 2. After all the nodes have joined in their own clusters, an ordinary node vfinds that its clusterID is smaller than its neighbour node u's clusterID, then node v may become an additional cluster head.

Algorithm 2: Procedure for receiving CH(u)

OnReceivingCH(u)

```
 if clusterID(v) == NULL then
  status(v) = O
  clusterID(v) = nodeID(u)
 end if
```

3.2. LCC strategy implementation

In this module, the Least Cluster Change strategy is implemented in the WCDS structure. LCC is mainly used to maintain better WCDS architecture in the networks and to minimize the WCDS maintenance cost. The LCC strategy is that the cluster head will be changed under the following circumstances:

1) If cluster head v is close to cluster head u, cluster head v would be changed to cluster head u's member if it has the smaller degree.
2) If an ordinary node moves out of range of all clusters, it would be changed as the cluster head of a newly formed cluster.

The LCC strategy is shown in Algorithm 3.

Algorithm 3: Procedure of LCC

```
//C: cluster head
//O: ordinary node
//N[v]: neighbor nodes of node v
//clusterID(v): clusterID of node v
//degree(v): degree of node v
//status(v): role of node v
```

LeastClusterChange()

```
 if status(v) == C then
  foreach u 2 N[v]
   if (status(u) == C) && (clusterID(v) != clusterID(u)) then
    if degree(v) < degree(u) then
     status(v) = O
     clusterID(v) = nodeID(u)
     break
    else if (degree(v) == degree(u)) && (clusterID(v) > clusterID(u)) then
     status(v) = O
     clusterID(v) = nodeID(u)
     break
    end if
   end if
```

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Vol. 5, Issue 9, September 2017

```
  end if
 end foreach
else
 min_clusterID = INT_MAX
 foreach u 2 N[v]
  if status(u) == C then
   if clusterID(v) == nodeID(u) then
    Exit()
   else if min_clusterID > clusterID(u) then
    min_clusterID = clusterID(u)
   end if
   end if
  end if
 end foreach
 if min_clusterID < INT_MAX then
  clusterID(v) = min_clusterID
 else
  status(v) = C
  clusterID(v) = nodeID(v)
end if
```

3.3. Construction of Ant based algorithm

In this module, the ant based algorithm is constructed. In traditional ant-based protocols, a node generates a Backward_Ant if it contains the routing information to the destination node and receives a Forward_Ant. However, in this proposed scheme, the Forward_Ant is forwarded until it reaches the destination node. The destination node can generate a Backward_Ant and no other node can, thus preventing loops and reducing the complexity of routing packets for loop-free control. The proposed ant-based algorithm changes its behaviour from proactive to reactive without periodically sending the ant packets so that it reduces the network overhead.

When a node needs to send a data, it first checks the routing table available with it, for a route to the destination node. Failure to find such a route triggers the routing discovery process. Before sending Forward_Ants, the node determines its status whether it is a cluster head or a cluster member. The node then finds and initializes its remaining energy Er, the node minimal remaining energy Emin of the nodes in the path that is taken by the Forward_Ant, the average path energy Ep, and the average network energy E_N. These valuesare combined to evaluate the network fitness G and are carried by the Forward_Ant.

When a node j receives the Forward_Ant, it evaluates the path fitness G_{ij}^{j}as in (1) defined from the previous node i to the node j.

$$G_{ij}^{j} = G_{hi}^{i} + \frac{P_C}{M_{ij}} \quad (1)$$

where G^i_{hi} is the path fitness. It is evaluated from the node h to the node i by the previous node i and G^j_{ij} is equal to the sum of $G^i_{hi}$and Pc / M_{ij}, where Pc is the power for receiving a packet by the current node from the previous node, and M_{ij} is the evaluation of energy consumption from node i to node j and it is determined by (2).

$$M_{ij} = E^j . E^j_{min} . \frac{\bar{E}^j_P}{\bar{E}^j_N} \quad (2)$$

where E^j is the remaining energy of node j, E^j_{min} is the minimal remaining node energy of the path from the source node to the current node j when the Forward_Ant passes, given as (3).

$$E^j_{min} = \mathrm{Min}\left(E^i_{min}, E^j\right) \quad (3)$$

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Vol. 5, Issue 9, September 2017

$\overline{E}_P^j$ is the average remaining path energy and is formulated as (4).

$$\overline{E}_P^j = \frac{\overline{E}_P^i . H_P^i + E_j}{H_P^j} \quad (4)$$

where $\overline{E}_P^j$ is the average remaining path energy estimated by the node i, H_P^i is the current hop count of node i and H_P^j is the current hop count of node j.

Following the path fitness evaluation, the node will update the pheromone in the pheromone table by (5).

$$\tau_{ij} = (1 - \rho) . \tau_{ij} + \Delta\tau_{ij} \quad (5)$$

where ρ is the pheromone evaporation factor, $\Delta\tau_{ij}$ is the updating pheromone and is calculated by (6).

$$\Delta\tau_{ij} = \frac{1}{G_{ij}^j} \quad (6)$$

The Forward_Ants that areappended with the network fitness are sent to explore the network and to find a route to the destination node. If the node is a normal member node in the cluster, then it unicasts the Forward_Ant to its cluster head. Else, it broadcasts the Forward_Ant to other cluster heads.

The process then checks whether the Forward_Ant has arrived at the destination node. If the visited node is the destination node, the node sends a Backward_Ant back to the source node. Otherwise, if the node is a cluster head, it broadcasts the Forward_Ant to its neighbouring nodes or if it is a normal node, it unicasts the Forward_Ant to its cluster head.

If the destination node receives the Forward_Ant, itwill be killed and the destination will do a pseudorandom-proportional-selection strategy to select the next hop and then it sends a Backward_Ant back to the source node.

As the pheromone value increases, it increases the probability ofa node thathas to be picked as the next hop. Once the next hop is selected, the node will update the routing table and forward a Backward_Ant. The node which receives the Backward_Ant would repeat this path-selection strategy until the Backward_Ant reaches the source node. Whenthe Backward_Antis received by the source node, it updates its routing table and thus concluding the routing discovery. Finally, the source node can start sending the data packets to the destination node through the route established by the Backward_Ant.

IV. RESULTS AND DISCUSSION

4.1. Simulation environment

The simulation environment used for the proposed work is given in Table 4.1. It describes the various parameters used in the simulation environment.

Table 4.1 Simulation Parameters and Values

PARAMETERS	VALUE
1. Channel	Wireless channel
2. Radio Propagation	Two-ray ground

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3. Antenna Model	Omni antenna
4. MAC Protocol	IEEE 802.11
5. Traffic Type	CBR/UDP
6. Routing Protocol	AODV
7. Number of Nodes	48

4.2. Performance parameters

The performance analysis of the AOCR protocol based on the ant based algorithm and WCDS procedure is done with the help of the parameters such as Throughput, Packet Delivery Ratio and Residual Energy.

4.2.1. Throughput

Throughput denotesthe rate of data bits received by the destination node in a unit time. It is usually measured in bits per second (bps). Figure 4.1 shows that AOCR has increased throughput of 38.5% when compared with AODV.

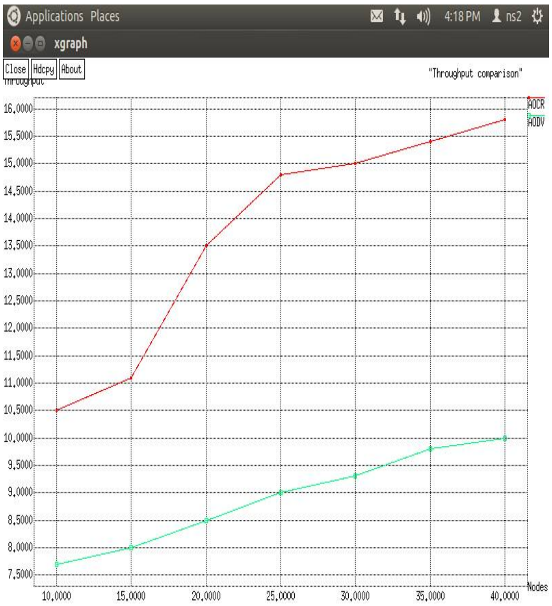

Figure 4.1 Throughput

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4.2.2. Packet Delivery Ratio

Packet Delivery Ratio is defined as the ratio of number of packets successfully received by the destination node to number of packets transmitted by the source node. It increases due to successful transmission of packets by the intermediate nodes. Figure 4.2 shows the increased Packet Delivery Ratio of AOCR protocol which is compared with AODV. It is increased by 36.4%.

Figure 4.2 Packet Delivery Ratio

V. CONCLUSION AND FUTURE WORK

The AOCR protocol uses a WCDS procedure assisted by ACO mechanism. AOCR can find more efficient routes in wireless ad-hoc networks, since AOCR uses a pre-established WCDS architecture to quickly spread ant packets to find routes to the destination. The pheromone levels indicate the path energy quality. The algorithm follows the pseudo-random-proportional-selection policy to select the most efficient route. The number of ant packetscan be decreased since the WCDS structure can facilitate the efficient issuing of probe packets to find a routing path and only the destination node can generate Backward_Ants to prevent routing loops.Thus the AOCR protocol provides better efficiency and it outperforms the AODV protocol while considering the packet delivery ratio, throughput and residual energy. However, the malicious node may take advantage of the topology exposure to perform some attack on the network. It may be overcome in future by hiding the link connection information in the routing packets.

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