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Comparison of Ant Based Routing Protocols in Ad hoc Networks

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Abstract— ***Mobile Ad Hoc Networks (MANETS) are infrastructure less network consisting of mobile nodes, with constantly changing topologies that communicate via a wireless medium. Therefore, routing is a challenging issue in MANETs. Swarm Intelligence (SI) [1] is an artificial intelligence technique based around on the study of collective behavior in decentralized, self-organized systems. Ant Colony Optimization is popular among other Swarm Intelligent Techniques. In this paper a detailed comparison of different Ant based algorithms is presented. The algorithms discussed here are AntNet Routing, Ant Colony based Routing Algorithm Routing, Ad hoc Networking with Swarm Intelligence Algorithm, Termite Routing Algorithm.***

Keywords— ***MANET, AntNet, ARA, ANSI.***

I. INTRODUCTION

Mobile ad hoc networks consist of a group of mobile nodes which autonomously establish connectivity via multi-hop wireless communications. Without relying on any existing, preconfigured network infrastructure or centralized control, they are useful in many situations where impromptu communication facilities are required such as battlefield communications and disaster relief missions . In *proactive* protocols such as [5], nodes in the network maintain routing information to all other nodes in the network by periodically exchanging routing information. The proactive or table driven routing protocols maintain routes between all node pairs all the time. It uses periodic broadcast advertisements to keep routing table up-to-date. This approach suffers from problems like increased overhead, reduced scalability and lack of flexibility to respond to dynamic changes e.g AntNet, Termite. Nodes using *reactive* protocols, delay the route acquisition until a demand for a route is made e.g. ARA. *Hybrid* protocols use a combination of both proactive and reactive activities to gather routes to the destinations in a network – nodes using ZRP e.g. ANSI. In this paper we compare various ant routing protocol.

A. Ant Colony Optimization:

Two of the most successful swarm intelligence [6],10] techniques are Ant Colony Optimization (ACO) [4] and Particle Swarm Optimization (PSO). ACO is a meta-heuristic optimization algorithm that can be used to find approximate solutions to difficult combinatorial optimization problems. In ACO artificial ants build solutions by moving on the problem graph and they, mimicking real ants, deposit artificial pheromone on the graph in such a way that future artificial ants can build better solutions. ACO has been applied successfully to an impressive number of optimization problems.PSO is a global minimization technique for dealing with problems in which a best solution can be represented as a point or surface in an n-dimensional space.

B.Basic Ant Algorithm

The basic idea of the ant colony optimization Meta heuristic is taken from the food searching behavior of real ants. Figure 1 shows a scenario with two routes from the nest to the food place. At the intersection, the first ants randomly select the next branch. Since the route below is shorter than the upper one, the ants that take this path will reach the food place first.

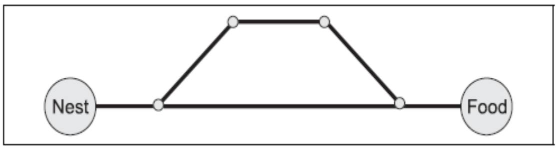

Fig 1: All ants take the shortest path after an initial searching time.

On their way back to the nest, the ants again have to select a path. After a short time the pheromone concentration on the shorter path will be higher than on the longer path, because the ants using the shorter path will increase the pheromone concentration faster. The shortest path will thus be identified and eventually all ants will only use this one. This behavior of the ants can be used to find the shortest path in networks. Especially, the dynamic component of this method allows a high adaptation to changes in mobile ad hoc network topology, since in these networks the existence of links are not guaranteed and link changes occur very often.

II. ANT BASED ALGORITHMS

A . Antnet – Ant Algorithm

In Antnet algorithm [2],[8],[9] at regular intervals Δt from every network node *s*, a forward ant $F_{s\to d}$ is launched toward a destination *d* to discover a feasible, low-cost path to that node and to investigate the load status of the network along the path. If *fsd* is a measure (in bits or in number of packets) of the data flow $s\to d$, then the probability of creating at node *s* a forward ant with node *d* as destination is:

$$p_{sd} = \frac{f_{sd}}{\sum_{i=1}^{N} f_{si}} \quad \text{(i)}$$

While travelling toward their destination nodes, the forward ants keep memory of their paths and of the traffic conditions found. The identifier of every visited node *i* and the time elapsed since the launching time to arrive at this *i*-th node are stored in a memory stack. At each node *i*, each forward ant headed toward a destination *d* selects the node *j* to move to, with a probability *Pijd* computed as normalized sum of the pheromone *τijd* with a heuristic value *ηij* taking into account the length of the *j*-th link queue of the current node *i*:

$$P_{ijd} = \frac{\tau_{ijd} + \alpha\eta_{ij}}{1+\alpha(|N_i|-1)} \quad \text{(ii)}$$

The heuristic value *ηij* is a normalized value function of the length *qij* of the queue on the link connecting the node *i* with its neighbor *j*:

$$\eta_{ij} = 1 - \frac{q_{ij}}{\sum_{l=1}^{|N_i|} q_{il}} \quad \text{(iii)}$$

If a cycle is detected, the cycle's nodes are removed and all the memory about them is deleted. When an ant reaches a node that is already in its memory, a cycle is detected and all the nodes until this recurrent node are deleted from the ant's memory.
When the destination node *d* is reached, the agent *Fs→d* generates backward ant *Bd→s*, transfers to it all of its memory, and is deleted.

B. Ant Colony Based Routing Algorithm

Ant Colony Based Routing Algorithm (ARA) [3] works in an ondemand way, with ants setting up ***multiple*** paths between source and destination at the start of a data session FANTs are broadcasted by the sender to all its neighbors. Each FANT has a unique sequence number to avoid duplicates. A node receiving a FANT for the first time creates a record ***[destination address, next hop, pheromone value]*** in its routing table. The node interprets the source address of the FANT as destination address, the address of the previous node as next hop, and computes the pheromone value depending on the number of hops the FANT needed to reach the node. Then the node relays the FANT to its neighbors. When the FANT reaches destination, it is processed in a special way. The destination node extracts the information and then destroys the FANT. A BANT is created and sent towards the source node. In that way, the path is established and data packets can be sent. Data packets are used to maintain the path, so no overhead is
introduced. Pheromone values are changing Let *G* = (*V*, *E*) be a connected graph with *n* = |*V* | nodes. The pheromone concentration, Φ*i,j* is an indication of the usage of the edge i, j. An ant located in node *vi* uses pheromone Φ*i,j* of node *vj* and *Ni* to compute the probability of node *vj* as next hop. *Ni* is the set of one-step neighbors of node *vi*.

$$p_{i,j} = \begin{cases} \frac{\varphi_{i,j}}{\sum_{j \in N_i} \varphi_{i,j}} & \text{if } j \in N_i \\ 0 & \text{if } j \notin N_i \end{cases} \quad \text{(iv)}$$

The transition probabilities *pi,j* of a node *vi* fulfill the constraint:

$$\sum_{j \in N_i} p_{i,j} = 1, i \in [1, N] \quad \text{(v)}$$

An ant changes the amount of pheromone of the edge *e*(*vi*, *vj*)
when moving from node *vi* to node *vj* as follows:

$$\varphi_{i,j} = \varphi_{i,j} + \Delta\varphi \quad \text{(vi)}$$

Like real pheromone the artificial pheromone concentration
decreases with time to inhibit a fast convergence of pheromone
on the edges.

$$\varphi_{i,j} = (1-q).\varphi_{i,j}, \; q \in [0,1] \quad \text{(vii)}$$

The backward ant takes the same path as that of its corresponding forward ant, but in the opposite direction. Arriving at a node *i* coming from a neighbor node, the backward ant updates the local model of the traffic *Mi* and the pheromone matrix *Ti*, for all the entries corresponding to the destination
node *d*.

C. Ad hoc Networking with Swarm Intelligence (ANSI)

ANSI (Rajagopalan, Jaikaeo & Shen, 2003) is a hybrid combination of both proactive and reactive routing. The objective of ANSI[11] is to leverage the potential of proactive routing with the flexibility and scalability of a purely reactive routing. Each node maintained and managed the connectivity with neighbors located within a zone radius in a pure proactive approach. The zone radius is dependable on the whole network size and mobility. For a bigger size or a higher mobility network, the zone radius is set to be larger so that the amount of proactive activity can be increased. In norm, the zone radius is about two-hop range. Reactive method is only applied when the destination node is not located within the zone radius of the source node. In this case, ANSI resonate the route discovery mechanism used in AntNet where forward ants would be broadcast in search of the destination node. Because each node maintains routes to every other node within its zone radius, the network does not incur high delay for route discovery or route setup. It provides good reliability especially in high mobility network. Nevertheless, due to the proactive nature, every node in ANSI creates high overhead as periodic updates need to be 29 frequently broadcast.

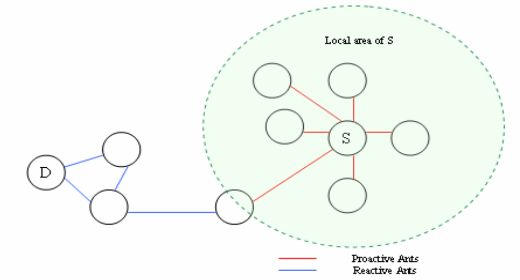

Figure 2: Proactive and reactive scheme in ANSI

D. The Termite Algorithm

Termite is a routing protocol for mobile wireless ad-hoc networks that is inspired by the social insect analogy. Theprinciples of swarm intelligence are used to define rules for each packet to follow which result in emergent routing behavior This routing algorithm (Roth & Wicker, 2003) adopts the analogy of termites instead of ants. Each network node is an analogy to a termite hill. The more termites passing through a node, the more pheromone would be collected at the node, making it a preferred next-hop node for other packets. There are five types of packets used in Termite. These are data, hello, RREQ, RREP and seed. Data packets are routed following the pheromones of each outgoing links. Each node will increase the pheromone of the previous node that the packet came from. There is no flooding involve in Termite. A limited number of RREQ packets perform a random walk over the network in search for the destination. The reply packet is routed by following the pheromone trail left by the request packet [7]. However, such random walk may sometimes results in the destination not being found or poor route being discovered. Termites also adopt the hello mechanism. Hello packets are broadcast at regular interval until a reply is received. A reply is sent by all nodes who hear the hello. Seed 30 packets are used to actively spread a node's pheromone throughout the network. Seeds make a random walk through the network and serve to advertise a node's existence. The drawback of Termite is that it has a high rate of dropped packets especially in highly mobile networks. It does not define any route failure handling mechanism. Packets are dropped immediately if there is no alternate route.

III. COMPARISON OF DIFFERENT ANT BASED ROUTING ALGORITHM

Table 1 below summarizes the similarity and differences between AIR and other ant-based routing algorithm for MANET.

IV.. SIMULATION PARAMETERS

We can now define the performance evaluation parameters which can be considered for the comparison of the ant based algorithms. There are two types of traffic which can be taken into consideration:

1. Session oriented: All packets have same destination for a given session.
2. Session less: Destination of each packet selected from uniform distribution the parameters which can be considered are:

Average Throughput. Throughput is a measure of how much traffic is successfully received at the intended destination in a unit interval of time. A routing protocol should try to maximize this value.

Packet Delay. A good algorithm should be able to deliver packets with minimum delay.

Session Delay. In case of session-oriented traffic, the most important parameter is time needed to complete a session. An application layer at the destination node only gets the packets after all the packets are received in the correct order. Packet delay factors out this waiting time and hence favors multi-path algorithms which deliver packets in an out-of-order manner but with smaller delays.

Sessions Completed. The percentage of sessions which are completed without any support from transport layer protocols. For example if only one packet in a session is dropped due to congestion or TTL expiration, we report the session as an incomplete one. This parameter reports the way packets were deleted due to congestion.

Packet Delivery Ratio. This measure tells us how many data packets are successfully delivered at their destinations. Under saturated loads a 1% improvement in packet delivery ratio at times means about few 100,000 more data packets delivered at their destination.

Packet Drop Ratio. The percentage of data packets that are dropped because their time to live timer (TTL) value expired or the queue buffers were full.

Packet Loop Ratio. The percentage of data packets that followed a cyclic path. A cyclic path is an error in an algorithm and should be reported.

Routing Overhead. The ratio of the bandwidth occupied by the routing/control packets and the total available bandwidth in the network. This parameter shows the control overhead of the routing algorithm.

Suboptimal Overhead. The difference between the bandwidth consumed when transmitting data packets from all the sources to destinations and the bandwidth that would have been consumed should the data packets have followed the shortest hop count path.

V. CONCLUSION

Ant Colony Optimization is popular among other Swarm Intelligent Techniques. Ants-based routing algorithms have attracted the attention of researchers because they are more robust, reliable, and scalable than other conventional routing algorithms. Since they do not involve extra message exchanges to maintain paths when network topology changes, they are suitable for mobile ad-hoc networks where nodes move dynamically and topology changes frequently. For wired networks Antnet works best in maintaining the established paths as compared to ABC routing because ABC uses greedy approach and Antnet chooses best paths based on probability. In ARA both forward and backward ants update pheromone value.

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Criteria	**AntNet**	**ARA**	**ANSI**	**Termite**
Scheme	Proactive	Reactive	Hybrid	Proactive
Discovery mechanism	Flood	Flood	Flood	Random
Loop Prevention	None	Sequence Number	Visited node stack	Message identification
Ring Search Model	No	No	No	No
Third-Party Reply Model	No	Yes	No	Yes
Table-Based	Yes	Yes	Yes	Yes
Table updating	Unidirectional	Bidirectional	Unidirectional	Unidirectional
Two Way Route Establishment	No	No	No	No
Multiple route	Yes	Yes	Yes	Yes
Optimal path criteria	Time travel	Time travel	Amount of transmission energy	Time travel
Pheromone Enforcement	By forward and backward ants	By data packets	By forward and backward ants	By data packets
Pheromone Evaporation	Yes	Yes	Yes	Yes
Remove stale routes	Yes	Yes	Yes	Yes
Network Saturation	Yes	Yes	Yes	Yes
Update and Maintenance	Yes. Periodic forward ants	No	No	Yes. Periodic seed packets
Hello mechanism	No	No	No	Yes
Route Failure Notification	Not define	Link layer	Not define	Missing Hello packets
Route Failure	None	Backtracking	Local Repair Error message	None

Table 1: Similarities and differences between ant-based routing algorithms

