Asian Journal of Applied Sciences (ISSN: 2321 – 0893)
Volume 05 – Issue 01, February 2017

Swarm Intelligence Algorithms and its Types

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ABSTRACT— ***Mobile ad hoc networking is a means of communication that does not rely on any available infrastructure such as committed routers, transceiver base stations or even cables. MANETs have been a demanding subject for research scientists and internet forge. A MANET is a type of ad hoc network that can adapt to locations and organize itself on the fly. Swarm intelligence (SI) is a division that is inspired by natural and artificial system. It is a study of natural happening and individual's behavior in decentralized environment. Swarm intelligence routing provides a hopeful alternative to these approaches. A new class of algorithms is being developed inspired by swarm intelligence that can resolve several problems of modern communication networks. Such algorithms depend on the interaction of a multitude of simultaneously interacting agents. Few such algorithms are Ant based Control Algorithm, AntNet algorithm, Ant Colony based Routing Algorithm, Mobile Ant based Routing and Termite. These algorithms differ based on the applications used. This paper presents a survey of such algorithms.***

Keywords— Ant based Control Algorithm, AntNet algorithm, Ant Colony based Routing Algorithm, Mobile Ant based Routing, Termite, Mobile Ad Hoc Networks, and Swarm Intelligence.

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1. INTRODUCTION

A Mobile ad hoc network is an autonomous system of mobile routers connected by wireless links. The routers are free to move randomly and systematize themselves arbitrarily, thus, the network's wireless topology may change rapidly and unpredictably. Such a network may function in a stand – alone fashion or may be connected to the larger internet [1]. Swarm intelligence (SI) appears in biological swarms of certain insect species. It gives rise to complex and often intelligent behavior through complex interaction of thousands of autonomous swarm members. Interaction is based on primitive instincts with no supervision. The end result is accomplishment of very complex forms of social behavior and fulfillment of a number of optimization and other tasks [2].

Ants have small amount of cognitive capability, limited individual capabilities and react instinctively in a probabilistic way to their perception of their immediate environment. They can find the shortest path between the nest and a food source by laying down on their way back from the food source a trail of an attracting substance called pheromone. A pheromone trail of different density depends on the quality of food source found; the colony becomes able to discriminate between food sources of different kinds and quality [3].

1.1 Characteristics of Swarm Intelligence

SI provides network adaptive features and generates multiple paths for routing. SI algorithms are capable of adapting for change in network topology and traffic while giving equivalent performance. It imparts on both passive and active information for gathering and supervising. It makes use of stochastic components like pheromone table for user agents. User agents are sovereign and converse with each other through stigmergy. It sets path that supports load balancing rather than pure shortest path. The algorithm also supports multiple paths, so that load balancing can be achieved [4].

1.2 Principles of Swarm Intelligence

The ability of ants to organize themselves is based on four principles:

1. Positive feedback - used to improve the good quality solution. Ants move from one node to another, which increases the concentration of the pheromone along that path, which helps other ants to travel in this path.
2. Negative feedback – used to destroy bad quality solution. It can be done by the decay of pheromone concentration with respective time. The rate of decay is based on the problem. Low decay rate encourages the bad solution by not destroying it for a longer time and higher decay rate destroys good solution early.

3. Randomness - path chosen by ant is completely random, hence there is possibility of generating new solutions.
4. Multiple interactions - the solution is found by the interaction of many agents. In food searching process, one ant cannot find the food, as the pheromone would decay. It helps the ants in finding the food faster.

1.3 Advantages

Following are the advantages of swarm intelligence:

i. Multipath routing – possible to generate multiple paths between nodes.
ii. Fast route recovery – if optimal path fails, then the packets can easily be sent to other neighbours by re-computing next hop probability, i.e. choosing the next best path.
iii. Distributed and fault tolerance – Swarm Intelligence algorithms are intrinsically distributed. There is no centralized control mechanism, so if any node or link fails, there is no heavy loss.
iv. Scalability and adaptation - populace of ants may vary based on the size of network. The agents may die or reproduce, with minor effect on performance.
v. Speed - transformation in the network can be adapted rapidly.

1.4 Literature Survey

Routing is the method used to identify route for packet travelling from source to destination. Routing, in conjunction with the admission, flow and congestion control components, determines the overall network performance in terms of both quality and quantity of service delivered. Routing refers to the disseminated activity of building and using routing tables. Each node in network will have a routing table. Routing is performed by the routers, which updates the routing tables with minimizing cost function like physical distance, link delay, etc. The metric for optimization can be distance, number of hops or estimated transit time. Protocols are used to implement hand shaking activities such as error checking and receiver acknowledgements.

Routing algorithms can be grouped into two major classes, Non-adaptive and Adaptive. Non-adaptive algorithms do not consider current traffic and topology for routing decision. Routes are computed and stored in advanced. In adaptive algorithms routing decision are based on the current network topology and traffic. These algorithms get information from its adjacent routers every ΔT sec and based on this value, the route is chosen.

The decision on routing is based on the details of the routing table. Routing table may have fatigued list of all destinations or precise entries for the default path for non adjacent nodes. The cost of protection of overall network information is high. Hence, the common objective is to generate a route from source to destination based on nearby available information and user quality of service. The algorithm should work resourcefully for reconfigurable network.

Routing algorithms can be classified as optimal routing and shortest path routing. In optimal routing, the objective is to optimize the flow of the entire network, while the shortest path's goal is to find the minimum cost path between two nodes. Another factor influenced by routing is load balancing, whose goal is to balance the load throughout all network resource without inactivity and overfilling.

Few other algorithms used for routing are destination-sequenced distance vector routing, wireless routing protocol, ad hoc on–demand distance vector routing and dynamic source routing protocol. The algorithms presented in this paper have the following differences compared to existing ones.

- All the aforesaid algorithms have to relocate their routing tables to other nodes over the network. They either transfer them on time based approach or event based approach. This problem does not exist with ant algorithm as there is no necessity to transfer the routing tables. Some of the algorithms do not support multiple paths and hence there is no possibility of load balancing, in case the optimal path is heavily congested. Ant algorithm supports generation of multiple paths and hence holds onto load balancing.
- Aforesaid algorithms need special packets for maintaining the route. Ant algorithm uses data packets for route maintenance.

2. TYPES OF SI

There are different types of SI algorithms used for routing.

a. Ant based control algorithm.
b. Ant net algorithm.
c. Ant colony based routing algorithm.
d. Mobile and based routing.
e. Termite.

2.1 Ant Based Control (ABC) Algorithm

ABC is a routing protocol for circuit switched network. It is the first SI routing algorithm for telecommunication networks is the year 1996. ABC is designed for telephone networks. It shares many similarities with AntNet, but also has certain differences. The basic principle relies on mobile routing agents, which randomly explore the network and update the routing tables according to the networks and update the routing tables according to the current network state. The routing table that stores probabilities instead of pheromone concentrations are exactly same as in AntNet.

Also the probability balanced randomness of the ants' path selection is employed in order to favour the detection of new routes. The major difference applies in the usage of the routing agents: ABC uses a single class of ants i.e. forward ants that are initiated at regular time intervals from every source to a randomly chosen destination. After arriving at a node, they immediately update the routing table entries for their source node.

It is important to note that only backward path is influenced and just packets travelling towards the ants' source profit from that route update. The next difference pertains to the calculation of the routing table update. The probabilities are reinforced by a simple formula without considering any goodness value. Hence, no traffic statistics are required to be recorded at the nodes [5].

2.1.1 General Framework for Ant-Based Control Systems

- Firstly pheromone tables are randomly initialized.
- Ants are generated and allowed to find paths.
- Ants update the probabilities in the pheromone table for the location they were launched from, which increases the probability of selecting their previous location by succeeding ants.
- The increase in these probabilities is a decreasing function of the ant and of the original probability.
- Once the shortest paths are found, then calls are transferred along the path.

ABC uses only single class of agents. The ants begin at source and travel towards destination at regular intervals of time. They are destroyed once they reach the destination. Routing table at each node is updated based on the life of an ant at the time of visit. When an ant arrives at a node, the entry in the pheromone table equivalent to the node from which the ant has just come is increased according to the formula: $p = (p_{old} + \Delta p)/(1+\Delta p)$ here p is the new probability, p_{old} is the existing probability and Δp is the probability or pheromone increase. The other entries in the table of this node are decreased according to: $p = p_{old}/(1+\Delta p)\Delta p$ determined by the age of packet. This is done in order to maintain the sum of probabilities to one. The aim of this algorithm is to find the path which is relatively short and to avoid paths that are crowded. Calls are based on the probability value i.e. the highest hop is followed.

2.1.2 Parameters

There is large number of parameters to tune for these system-choices are based on experience with a variety of previous simulations:

- Let every node initiate an ant with a random destination on every time step of the simulation.
- The probabilities are updated according to the following formula, where age stands for number of time steps that passed since the launch of the ant:$\Delta p=(0.08/age)+0.005$
- The initialization period, that is the period during which the ants initialize the routes on the network without traffic, is between 250 and 500 time steps.

The performance of the algorithm can be enhanced by i) Making age of ant proportional to the number of nodes it has visited till then and ii) Delay the ants at nodes that are heavily congested [6].

2.2 AntNet Algorithm

AntNet is introduced to route information in a packet switched network. It is an algorithm for adaptive best–effort routing in IP networks. AntNet's design is based on the Ant Colony Optimization (ACO) framework, which exploits the mechanism behind the shortest path behaviour observed in ant colonies. This defines a Nature-inspired Metaheuristic for combinatorial optimization [7].

2.2.1 AntNet's General Structure And Behaviour

Behavior of ants can be studied in two phases: forward phase and backward phase. During the forward phase each ant constructs a path from source to destination with the help of local information and indirect communication. After arrival at destination, the backward phase begins. The ant retraces the path from destination to source. At each node, it evaluates the followed path with respect to the destination and updates the local routing information [8].

Due to the realistic implementation of both the forward and backward phases predicts by ACO, the AntNet model is also often referred to as the forward–backward model. For instance, in the model adopted by Schooderwoerd for cost-symmetric network (the end-to-end delay along a path connecting two nodes is the same in both directions) only the forward phase is present [9]. The need for a backward phase comes from the need of completing and evaluating the path before carrying out any update. This is the case of cost-asymmetric networks.

Moreover, in both cost-symmetric and cost-asymmetric networks, there is no guarantee that the agent is not being actually locked in a loop until the destination is reached, such that carrying out updates during the forward phase might result in reinforcing a loop, which is clearly wrong. The AntNets ant-like agents act analogous to data packets.

2.2.2 Ants and Exploration

Ants simulate data packets with the aim of performing inhibited network exploration (i.e., discovering and testing of paths). Ants do not belong to user applications; hence they can freely travel around the network. No user will criticize if an ant gets lost or follows a long-latency path. On the other hand, users would possibly get disappointed if their packets would incur in long delays or get lost for the sake of general exploration or information gathering.

a) Proactive Ant Generation

At regular intervals Δt, source node S generates a forward ant, and is proactively launched toward a destination node D with the objective of discovering a feasible, low-cost path from S to D. At the same time, it examines the load status of the network along the followed path. Forward ants share the same queue as data packets. In this way they experience the same traffic hike as data packets. Forward ants represent a faithful simulation of data packets.

b) Initialization Routing Tables

Initialization of routing tables is one of the most important aspects of any routing algorithm and the parameter for comparison is convergence time. Lower the convergence time faster the routing table initialization. AntNet routing algorithm makes use of broadcasting to accomplish this. In order to do so, each router sends 'hello' packets to all directly connected neighbors, which in turn flood these packets to their neighbors other than the one from which the hello packet originates. Each time the packet reaches a router, the routing metric is updated. Hence, the initial routing map is propagated. Usage of broadcast technique has some generic drawbacks such as increased traffic, redundancy and replication. This trade-off is done in order to achieve faster convergence. Some of the downsides can be triumph over by having time-out mechanism. The time-out value is an optimized value which would just suffice the remote routers to have all the required initial routing entries. At the end of the selected time-out, the initial routing map of the topology is contained in each router from which the routing algorithm table can be extracted. In this regard, "AntNet routing algorithm" follows the link-state behavior.

c) Ant Generation

After initialization, the source node initiates an agent ant to the destination node to establish a reliable path based on the hop count in the initialized routing tables. The ant generation happens without any form of synchronization among nodes. The ant moving from source to destination is called FSD (Forward Ant from Source to Destination). The FSD migrates from a node to another (adjacent) node towards destination based on the information available in the routing table. FSD users stack to store the information of all the nodes visited till then. When FSD has reached destination the stack would have the list of all the nodes visited by ant from source to destination.

d) Retrace Using Backward Ant

On arrival at destination, the forward ant stack stops updating. Forward ant (FSD) copies the contents of its stack on to another agent called the BDS (Backward Ant from Destination to Source) and destroys itself. Now BDS goes back to its source node by moving along the same path [S, V1,V2…Vn, D] as of FSD but in the opposite direction. V1, V2…Vn are the intermediate nodes. When the backward ant reaches the source node, it indicates that a consistent path between the source node and the destination node exists.

e) Data Packets

All the packets intended to be transmitted between the source and the destination nodes are now sent across this reliable path, established by the forward and backward ants.

2.3 Ant Colony Based Routing Algorithm (ARA)

Mobile Ad Hoc Network is the self configuring network of mobile host connected by wireless links, the union of which forms the topology of the networks [10]. The advantages of ad hoc networks are convenience, mobility, productivity, deployment and expandability. The disadvantages are limited range, reliability security and speed. This change in topology makes the route from source to destination flexible and varies with respect to time. The nature of network requires the algorithm to perform route maintenance and detect link failure along the path between a pair of nodes. One class of ant algorithm used for routing in mobile ad hoc network is ARA. This algorithm not only generates route between nodes but also maintains the routes. Hence the algorithm is divided into three main functions namely route discovery, route maintenance and route failure handling.

2.3.1 Route Discovery

This function generates route between given source and destination. This method requires two mobile agents called forward ant (FANT) and backward ant (BANT). These two are similar in structure but they vary in the type of work they carry out. A FANT is an ant agent that establishes the pheromone track to the source node and BANT establishes pheromone track to the destination. FANT packets have exclusive sequence number through which the nodes distinguish the duplicate packets. A forward ant is broadcast by the sender and relayed by the intermediate node till it reaches the destination.

A node receiving a FANT for the first time creates a record in its routing table. The record includes the destination address, next hop and pheromone value. The node interprets the source address of the FANT as the destination address, the address of the previous node as the next hop and calculates the pheromone value depending on the number of hops the FANT requires to reach the node. Then the node forwards the FANT to its neighbors. Duplicate FANT is detected through sequence number. Once the duplicate ants are detected, they are dropped by the nodes. FANTS' information is extracted on reaching the destination and then destroyed. BANT is created with identical sequence number and sent towards the source. BANT creates the path to destination node. Once the source receives the BANT from the destination, the path is generated and the data can be sent along the path.

2.3.2 Route Maintenance

Route maintenance phase basically helps in intensifying the route which has already been established during route discovery phase. As the nodes in the network are itinerant, it is required to refresh and maintain the route between the nodes. Once the path between source and destination is setup, it is upto the data packets to maintain the route. When a node Vi forward the data packet to node Vj to reach the destination Vd, it increments the pheromone value along the path Vj and Vd by $\Delta \varphi$ thus strengthening the path.

2.3.3 Route Failure Handling

Node mobility in ad hoc network may cause certain links to fail. The failure may also occur due to the crashing of certain nodes. Such failures are handled by the route failure handling phase. Every packet is linked with an acknowledgement; hence missing acknowledgement indicates link failure. On detecting a link failure the nodes sends a route error message to the previous node and deactivates this path by setting the pheromone value to zero. The previous node then tries to find an alternate path to the destination. If the alternate path exists, the packet is forwarded on to the path else the node informs its neighbors to relay the packet. This continues till the source is reached. On reaching the source, the source initiates a new route discovery phase. Ant algorithm provides multiple paths. If the optimal paths fail, it leads to choosing next best path. Hence ant algorithm does not break on failure of optimal path.

2.4 Mobile Ants-Based Routing (MABR)

Mobile Ant Based Routing is a routing algorithm for Mobile Ad Hoc Network, which is based on AntNet algorithm. It uses three protocols for routing. Topology Abstraction Protocol (TAP), Mobile Ants-Based Routing (MABR), Straight Packet Forwarding (SPF) [9]. TAP is used for generating simplified networks based on logical links and logical routers. A single routing table may be distributed over all the nodes that are part of a logical router. MABR is used for routing in this simplified topology. An AntNet like protocol with forward and backward ant is applied on the logical topology supplied by TAP. Forward ants are sent to random destinations. Ants are sent to the zones containing these destinations. Ants collect path information during their trip. Backward ants distribute the path information on the way back to their source. Logical link probabilities are updated. SPF is used for data transfer on the simplified topology and is responsible for moving packet between logical routers. Any location based routing protocol could be used. MABR is responsible for determining routes around holes in the network. SPF should not have to worry about such situation.

2.5 Termite

Termite is enhanced version of ABC and related to AntNet [11]. It is similar to ARA with respect to routing data but varies with respect to route discovery and failure handling. Termite uses the hill building technique which is based on the principal of SI. In this method, termites are required to build hill from pebbles. Each termite will carry one pebble and will move along the path where the concentration of pheromone is high. If no pheromone exists, the agent moves randomly in any direction and deposits pheromone along the path. If the agent is not carrying a pebble and if it finds a pebble, it picks up and moves along the higher concentrated pheromone link. If an ant carrying pebble finds another pebble, then it drops pebble, thus increasing the pebbles at that place and hence grows hill. This policy of termite can be used for routing a network. As packets travel from source to destination, each packet follows the termite user pheromone to produce next hop probabilities random routing. Termite aims to reduce control traffic and should scale across network size and volatility.

2.5.1 Termite Route Recovery

If the transmission to a neighbor fails, then the neighbor is removed from the pheromone table. An alternative next-hop is calculated and the packet is re-sent. If no alternative exists, the packet is dropped.

2.5.2 Termite Route Discovery (RREQ)

If a node does not contain a needed destination in its pheromone table, a route request is issued. A route request (RREQ) packet follows a random walk through the network until a node is encountered containing some destination pheromone. A route reply (RREP) is returned to the source.

2.5.3 Termite Route Discovery (RREP)

A route replies (RREP) packet follows the pheromone trial normally back to the RREQ source. The source of the RREP is the requested node, regardless of which node actually originates the packet. The requested node's pheromone is automatically spread through the network.

3. CONCLUSION

The fundamental idea behind using SI from routing is to use the interaction of many packets and to generate routing tables while minimizing the use of explicit routing packets . The arrival of packets is observed, which influences next-hop routing probabilities. In ABC only the highest probability next hop is used to find a route and probabilities are changed according to current values and age of packet. AntNet is a routing algorithm for datagram networks. Explicit test and feedback signals are established with Forward and Backward ants. Routing probabilities are updated according to trip time statistics. In MABR the network topology is abstracted to logical routers and links (TAP). Routing takes place on the abstracted topology (MABR). Packets are routed between logical routers to their destinations (SPF). MABR is still under development. Flooding is used to discover routes. Automatic retransmit is used to recover from a route failure. Packet backtracking is used if automatic retransmit fails. Next hop probability is proportional to pheromone on each link. Termite minimizes control traffic by allowing all packets to explore the networks. Path discovery uses random walk. Route discovery packets are unicast.

4. ACKNOWLEDGEMENT

First of all, I am glad to thank THE LORD ALMIGHTY for giving me the fortitude in finishing this paper. I express my sincere gratitude to my husband and my parents for their continuous guidance, support and encouragement in all my endeavors. I would like to thank my colleagues for their constant support they provided throughout my preparation.

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