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Computer Network Routing using Swarm Intelligence

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Abstract: **- With the revolution in computing, particularly in telecommunication there has been a considerable amount of research how to include phenomenon in nature for network routing particularly Swarm Intelligence in telecommunication routing. Various algorithms have been proposed time to time by various researchers for performing efficient routing in wired and wireless adhoc networks. This paper provides overview of novel routing algorithms inspired by communicative and evaluative methods and procedures of Social Insects like Ants and Bees.**

Keywords**: - Stigmergy, Antnet. Ant Colony Based Routing Algorithm. Termite, Foragers, Bee Hive, Pheromone.**

I. INTRODUCTION

The Swarm Intelligence can be defined as a framework for designing and analyzing the large system consisting of numerous smaller and simpler units, interacting locally [1]. The behavior of the total system is defined by the result of interaction between the individuals, thus defining the property of a system as a whole. The methodology of swarm intelligence is devised from the behavior of swarms or social insects like ants, honeybees and termites [2]. Swarm insects have intellectual ability, restrained capability and react naturally in a probabilistic manner based on the environment. For example, initially ant wanders randomly around its nest. Once the food is found, the ant finds the shortest path between the nest and sources of food by leaving trails of pheromones with different density depending upon the quality and quantity of food. The Swarm intelligence exhibit the characteristics like; self-organized, homogenous nature, local interaction based on simple rules, scalability and robustness [3] [4].

II. PRINCIPLES OF SWARM INTELLIGENCE

The design framework of Swarm Intelligence is based on four main principles which are:

A. Positive feedback

The positive feedback is used to encourage the good solutions over rest of the solutions.

B. Negative feedback

The negative feedback is used to weed out the poor or old solutions.

C. Randomness

The randomness principle allows the Swarm Intelligence to find the solutions at random, thus exploring different and new solutions. This principle is usually used when solutions to the problem are very large and it's unpredictable coming out with a good solution.

D. Multiple Interactions

The individuals also known as agents communicate using multiple interactions. The information collected locally needs to be interacted from one portion of the system to another. This multiple interaction allows proper coordination of events at local level. For example, in adhoc network, there is the need to coordinate local routing information between the nodes during the communication process.

III. ROUTING USING SWARM INTELLIGENCE

The routing can be defined as the process of transferring information between the different networking using a device called as a router. The effective routing process in conjunction with congestion control and flow control determines the performance of the network. The routing algorithms can be mainly categorized into two groups; Adaptive and Non- Adaptive. The Non-Adaptive routing does not take into consideration the current status and topological information of network., while Adaptive routing do. In MANETS the routing algorithms can be classified as proactive, reactive and geographical based. In proactive, the routing information is maintained all the time for each and every node [5][6][7], while in reactive a route information is maintained only on demand basis [8][9][10].In geographical

based routing, location information is used for routing[11][12].

The decentralized and adaptive nature of swarm motivates it to be used in routing algorithms. There are different types of Swarm Intelligence based routing algorithms which are as:

A. Antnet Algorithm

Antnet is the adaptive routing algorithm that was versed in for performing routing in the packet switching network [13] [14]. The Antnet is based on a framework of Ant Colony Optimization with the aim of exploring the behavior of an ant colony for finding the shortest path. Antnet model works in two phases; forward and backward, so it is often known by the name of Forward-Backward model. Initially at regular intervals, the source node generates forward ants towards the destination with the aim of exploring the path in a controlled fashion. The forward ants and the packets share the same queues, so forward ants can determine the status of the network effectively as both packets and forward ants will experience same network conditions. The forward ant generation process is followed by initialization of the routing table. For initialization of routing table with lower convergence time Antnet makes use of broadcasting with time out mechanism. Initially router sends the Hello packet to all of its connected nodes, which in term floods to all of its neighboring nodes other than the node where the Hello packet originated from. At the end of time out, the routing table can be extracted from the topology table contained in each and every router. After the initialization is over, the source node generates an ant also known as agent toward destination for establishing reliable and efficient path using hop count as a metric by referring to initialized routing table. This forward movement of an ant, from source towards the destination is known as Forward ant from Source to Destination. The ant moves from one node to another adjacent node based on the routing table and stores the information of all the visited nodes in a data structure called a Stack.

This is followed by retrace using backward ant. The forward ant upon arrival at the destination stops updating the stack and copies the contents of stack onto the agent called as backward ant, finally destroying itself. Now Backward ant from Destination to source goes from destination to source following the same path of that of a Forward ant from Source to Destination. The Backward ant upon reaching the source indicates the existence of a reliable path from source to destination. Finally, the data packets are transmitted from source to destination through a reliable set up path using forward and backward ant.

B. Ant Based Control Algorithm

Ant Based Control algorithm is a circuit switching routing protocol [15]. This routing protocol uses ants known as agents for generating a route between two nodes. When the ants move, depositing artificial pheromone that is the function of path from source to current node and congestion till encountered. The selection of the next hop is based on pheromone value. Each and every node maintains the pheromone table. The entries in the table are the probabilities influencing the selection of the next node on the way to the destination. The Ant Based Control Algorithm uses only forward ant (agent). At regular intervals the ants are forwarded from source to destination and are finally destroyed upon reaching destination. Routing Table at each node is updated based on the life of an ant. As the ant arrives at a node, the probability entry in the pheromone table is increased based on the formula:

$$Pnew = (Pold + \Delta P) / (1 + \Delta P) \quad (1)$$

Where is new probability, is old probability and is change in probability. The probability for rest of the entries in the pheromone according to formula:

$$Pnew = Pold(1 + \Delta P) / \Delta P \quad (2)$$

The final goal of the algorithm is to find the shortest path while avoiding the congested path, with call routing via the path with highest probability.

C. Ant Colony Based Routing Algorithm

This type of routing algorithm is used for MANET [15]. The Adhoc network possesses some characteristics like decentralized control, mobility, deployable and expandable. The disadvantages of MANET Includes limited range, security, speed and reliability. Since the topology MANET keeps on changing with respect to time, therefore requiring a special type of routing algorithm that not only performs route maintenance, but also detects the path failure between the pair of nodes. The working of Ant Colony Based Routing Algorithm is divided into two stages:

1) Maintenance of Route: This phase helps in maintaining and strengthening the route that has already been created during route discovery phase. Since the nodes are mobile in nature, so there is constant requirement of refreshing or maintaining the route between the nodes. Once the route between source and destination is determined, its then it relies on data packets to maintain the route. Suppose node Ni forward the packet via node Nj to destination node Nk,this phase will strengthen the path by increasing the value of pheromone along the path Nj and Nk by some value
[16].

2) Handling of Route Failure: This phase deal with failure of links that may be caused due to mobility or due to crash of nodes. Since each and every packet is coupled with acknowledgement, indicating link failure. Once the link failure is detected, the route error message is passed to preceding node and path is deactivated by setting value of

pheromone to zero. The preceding node then tries to find the alternate path. If path is found, then packet is forward via that particular path. If no path is found, then the node tries to broadcast message to its neighbors until source node is found. The source node on receiving the route error message reinitializes the route discovery phase. This algorithm is able maintain multiple paths, if the optimal path breaks, then it chooses next leading path, thus providing multiple paths in case failure of optimal path.

D. Mobile Ant Based Routing

The Mobile Ant Based Routing is the extension of AntNet Algorithm for large scale adhoc networks. This particular algorithm divides the large scale network into rectangular zones and corresponding geographical areas [4]. It is actually a combination of three routing protocols; Topology Abstracting Protocol, Straight Packet Forwarding and Mobile Ant Based Routing [17]. The Topology Abstracting Protocol uses logical links and logical routers to generate simplified network. The logical router is the collection of all the nodes with the zone. Mobile Ant Based Routing is used for routing within the simplified topology generated by the Topology Abstracting Protocol. Ants are used at this level to periodically update routing table. The forward ants are transmitted towards the zones containing the destination, the path information collected by the forward ants during their traversal are sent back to their sources with the help of backward ants. Followed by updating logical link probabilities. The Straight Packet Forwarding is used for the movement of data within the simplified topology and for transferring packets between the logical routers.

E. Termite

The Termite is the extension of Ant Based Control Algorithm. It is similar to Ant Colony Based Routing Algorithm with the difference in route discovery and failure handling mechanism [18]. The Termite is Hill Climbing Technique with principle based on Swarm Intelligence. Each termite collects a pebble and moves towards the path with high pheromone deposit. Initially, if no pebble is present, the agent moves in a random path to find the pebble while depositing pheromone on its path. When the agent finds the pebble, it picks the pebble and moves toward the path with high concentration of pheromone. If the agent finds another pebble on its way, the agent puts the original pebble down and infuses it with pheromone which evaporates, thus creating a gradient for others to follow. With this rule, a group of termites can collect a number of pebbles in one place. This Termite policy can be utilized for routing the packets from source to destination by using artificial pheromone to produce next hop probabilities for random routing. The control traffic is reduced using Stigmergy. Let S be the source node, C be the current node where packet has arrived and K be previous hop node. The current node updates the pheromone table as:

$$P_{P,K} = P_{K,S} + \gamma \quad (3)$$

And decay the pheromone value periodically with rate τ as:

$$P_{C,d} = P_{C,d} . e^{-t} \quad \forall C \in N, \forall d \in D \quad (4)$$

1) Termite Route Discovery using PREQ and RREP: Initially, if the node fails to find a destination in pheromone table, a route request is initiated with the help of PREQ packet following a random walk until it finds the node containing destination pheromone. Then a route reply is sent using RREQ packet following the same pheromone trail to the source.

2) Handling route failure: If the node is unable to transfer to its neighbor, the neighbor is removed from the pheromone table and next hop for the packet is calculated and sent via new calculated path. If there is no possibility of alternate route, then the packet is simply discarded.

F. BeeHive

BeeHive [19] [20] [21] is the routing algorithm inspired from honey bee, where paths are constantly tried out to learn new routes and get used to varying network environment, and data are spread over multiple paths to enhance network performance and resources utilization. Since the majority of foragers explore the food within the vicinity of hive while only minority of foragers explore the source of food to distant locations. Therefore, this approach of forager bees can be transformed into a model with two agents; short distance agent and long distance agent. The short distance agent collects and dissimilate the routing information within the neighborhood while as a long distance agent collects and dissimilates the routing information to all the nodes in the network. The network is divided into forage zones and forage regions. A forage can be defined as collectively set of nodes forming around a node from which short distance bee can reach. The same node can participate in multiple forage zones, further the network can be viewed as non-overlapping set of clusters called as forage regions. For each forage region, there is the represented node, which is the node with smallest IP address and is used for long distance communication. Each node maintains route information of all the nodes within the forage zone and representative node maintains information for forage regions. The entire process can be summarized as:

1. Initially forage regions are formed and the first generation of short distance bee agent communication is launched to communicate their identifiers in neigh hood.
2. If a node receives a short distance bee, whose IP address is less than representative node address then it is discontinued as representative node and new representative node is chosen the smallest IP address of the two.

3. If a node learns that its representative node has joined another foraging region, then it repeats the step 1.

4. Step 1-3 is continued until network is divided into overlapping zones and disjoint regions.

5. The algorithm enters into normal phase. The non-Representative nodes periodically send its short distance bee agents by broadcasting to each of its neighbors.

6. If the node has received a replica of bee agent, then it updates its local table and updates its local table, broadcasting the information to its neighbors except for the one it received from. This process continues until agent expires or replica of the same message is received.

7. Representative nodes launch long distance communication with the same procedure as for short distance communication with exception of longer expiry timer.

8. Finally each node maintains routing information for reaching node within the zone and to reach the representative node. If the Communication is beyond the zone, then it is forwarded to representative node of foraging region containing the destination node.

IV. CONCLUSION

Swarm Intelligence has emerged as a novel field for reconstructing old-fashioned algorithm design paradigm of developers by enabling them to aim for working principle found in nature and using them for design and development of new algorithms. Inherent properties of swarm intelligence as observed in nature include: massive system scalability, emergent behavior and intelligence from low complexity local interactions, autonomy, and Stigmergy. Communication network management is becoming gradually more challenging due to the increasing size, rapidly changing topology, and complexity of communication networks. Therefore, Swarm Intelligence based approach offers to be a powerful means to solve routing problems.

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