Suitability of Ant Colony Optimization as an Application to MANET

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ABSTRACT

Mobile ad-hoc networks (MANETs) are infrastructure-less networks consisting of wireless devices called as mobile nodes which are organized in autonomous fashion. The highly dynamic topology, limited bandwidth availability and energy constraints make the routing problem a challenge in MANETs. Ant colony optimization (ACO) is a population based meta-heuristic for combinatorial optimization problems such as communication network routing problem. In real life, ants leave a kind of chemical substances to mark the visited path that they pass through. Ants on reaching destination came back to the source node. Ants on their way, back to source choose the path with the highest pheromone. ACO technique matches the routing requirements of Mobile Ad-hoc Networks because of its motivating properties like foraging and self-organizing nature. Optimal paths can be proposed with negligible overhead in this way by using ant based routing algorithm. The problem of stagnation can also be rectified. This paper reviews the appropriateness of using Ant Colony Algorithm for mobile Ad-hoc Networks.

Keywords: **Mobile ad hoc network, Ant colony optimization, Routing Algorithm, Wireless networking.**

I INTRODUCTION

With the fast growth of the Internet, everybody wants to get connected to the networks. In the world, millions of people use the internet daily for their business [1]. Today the Internet has become very large, complex and dynamic. At every step, failures and challenges occur. Routing is the process of selecting paths from the source to the destination for sending data. Routing is an important aspect of network communication, which affects the performance of any network; because the characteristics of the network like throughput, reliability and congestion depend heavily on routing process [2]. Present scenario in communication networks and challenges in technology in data communication networks are developing rapidly and this generates a range of new challenges in relation to network management and routing. Wireless mobile networks are increasing, which are increasing the volume of traffic, thereby increasing the complexities of the network topology. Finally, the increasing adoption of mobile facilities requires a network that can dynamically adapt its topology. A mobile node can join or leave the network any time, based on its position resulting in frequent changes in topology [1] [3] [4]. The network must be flexible enough to adapt to such changes with an appropriate span of time. Challenges in communication networks demand new routing strategies for network management. Routing algorithms are one of the important areas of network management that organize the traffic in a network efficiently [2] [4]. New routing algorithms are required to meet the changing environment. Traditional routing protocols which are used in wired networks can support routing in fixed wireless networks and mobile networks with fixed access points. Whereas, routing in mobile ad hoc networks are multiple-hop. Routing protocols for wireless network should not only be able to maintain paths to other nodes, but must also handle changes in paths due to mobility of nodes. That is why; traditional routing cannot properly support routing in a MANET [2] [7].

Properties of Ad-Hoc Routing protocols

The properties that are desirable in Ad-Hoc Routing protocols are [5] [6]:

i. **Distributed operation:** The protocol should be distributed. It should not be dependent on a centralized controlling node. This is the case even for stationary leave the network very easily and because of mobility the network can be partitioned
ii. **Loop free:** To improve the overall performance, the routing protocol should assurance that the routes

supplied are loop free. This avoids any misuse of bandwidth or CPU consumption.

iii. **Demand based operation:** To minimize the control overhead in the network and thus not misuse the network resources the protocol should be reactive. This means that the protocol should react only when needed and should not periodically broadcast control information.

iv. **Unidirectional link support:** The radio environment can cause the formation of unidirectional links. Utilization of these links and not only the bi-directional links improves the routing protocol performance.

v. **Security:** The radio environment is especially vulnerable to impersonation attacks so to ensure the wanted behavior of the routing protocol we need some sort of security measures. Authentication and encryption is the way to go and problem here lies within distributing the keys among the nodes in the ad-hoc network.

vi. **Power conservation:** The nodes in the ad-hoc network can be laptops and thin clients such as PDA's that are limited in battery power and therefore uses some standby mode to save the power. It is therefore very important that the routing protocol has support for these sleep modes.

vii. **Multiple routes:** To reduce the number of reactions to topological changes and congestion multiple routes can be used. If one route becomes invalid, it is possible that another stored route could still be valid and thus saving the routing protocol from initiating another route discovery procedure.

viii. **Quality of Service Support:** Some sort of Quality of service is necessary to incorporate into the routing protocol. This helps to find what these networks will be used for. It could be for instance real time traffic support.

II ANT COLONY OPTIMISATION

ACO is a famous swarm intelligence approach that has taken the inspiration from the social behaviors of the real world of ants. Most often real ants wander around their nests to forage. After finding their food, they return back to their nests. During searching, the real ants deposit pheromone over the traversed paths. Other ants follow the pheromone trails. They are more likely biased towards paths with stronger pheromone concentration and as a result, they may not keep on traveling randomly [8]. Therefore, they move through these paths and reinforce the existent pheromone. This kind of indirect communication is called stigmergy. Pheromone being a chemical substance evaporates over time, thus reducing the attractive strength of the path build due to its concentration. Analogously, ACO, one of the state-of-the-art paradigms in designing metaheuristic algorithms for combinatorial optimization problems, utilizes artificial mobile agents, namely ants, which are capable of solving various kinds of routing and congestion problems [8] [9].

A systematically examination of the pheromone laying nature of ants were conducted. As an experiment an obstacle was put on the way, where ants were moving from nest source to food destination [10]. The following observations were made

1. Real ants pursue a path from nest and food. Along their path between food source and nest, ants deposit pheromone.
2. An obstacle appears on the way. Then ants choose whether to turn left or right with equal probability as shown in figure 1 (a).
3. Pheromone is deposited more speedily on the shorter path because of less traversal time, therefore, attracts more ants.
4. After some time all ants start following the shorter path and converges towards the shorter path as shown in figure 1 (b).

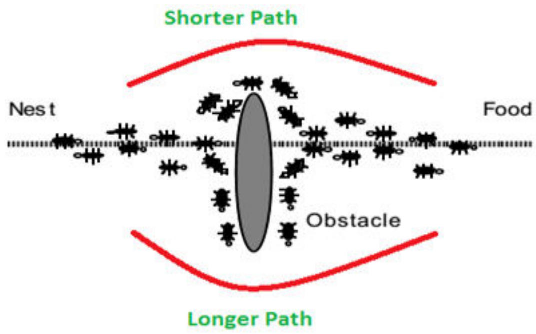

Figure 1 (a): Ants facing obstacle experiment

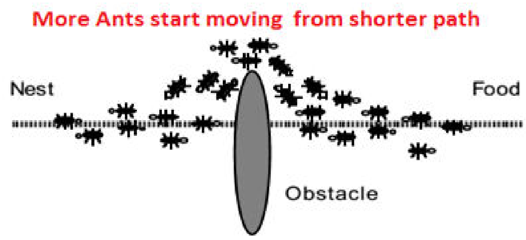

Figure 1 (b): Ants answering obstacle experiment

The ability of ants to self organizes relies on four principles: positive feedback, negative feedback, randomness, and multiple interactions. A fifth principle, stigmergy, arises as a product of the previous four. In general, such self organization is known as swarm intelligence [11] [12].

The following flowchart represents the basic steps involved in solving an optimization problem using the meta-heuristic of ACO technique [11].

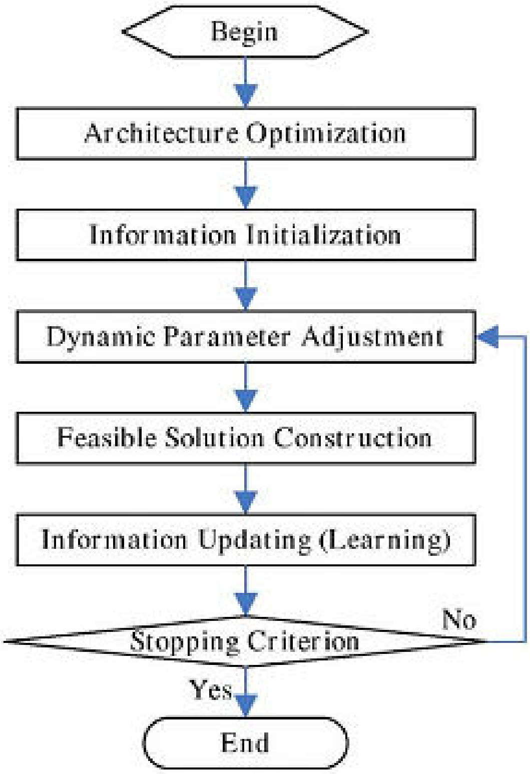

Figure 2: Ants solving optimization Problem

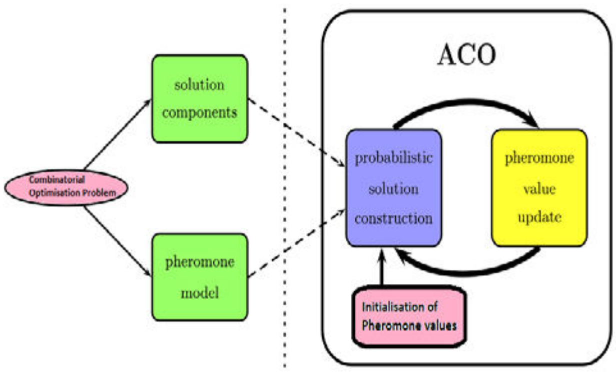

Figure 3: Basic Working of ACO Meta-Heuristic

The basic working of an ACO algorithm is graphically shown in figure 3. For a given Combinatorial Optimisation (CO) problem to be solved firstly one has to derive a finite set of solution components which are used to assemble solutions to the CO problem. After that there is need to define a set of pheromone values [13]. This set of values is commonly called the pheromone model, which can be seen as a parameterized probabilistic model from a technical point of view. The pheromone model is one of the central components of the ACO metaheuristic. The computed pheromone values are usually associated to solution components. The ph [15] [16eromone model helps in generating solutions to the problem. Broadly, the ACO approach normally solves an optimization problem by repeating the following two steps as a loop [14]:

- Candidate solution values are constructed using the pheromone model which represents a parameterized probability distribution over the solution space.
- Candidate solutions are further employed to modify the pheromone values which are deemed to bias future sampling toward high quality solutions.

The pheromone update aims to focus over the search in the problem regions of high quality solutions. The reinforcement of solution components enhances the solution quality and is an important ingredient of ACO algorithms [14].

III ANT COLONY OPTIMIZATION META-HEURISTIC SUITS TO AD-HOC NETWORKS

The characteristics of ants described above are pleasing in the context of ad-hoc networks. Such a systems may be composed of simple nodes working together to deliver messages, while flexible against changes in its environment. The environment of an ad-hoc network might include topology representing the communications links, traffic patterns across the network [15]. A noted difference between biological and engineered networks is that the former have an evolutionary incentive to cooperate, while engineered networks may require alternative solutions to force nodes to cooperate [15] [16].

The ant colony optimization meta-heuristic shown in the previous section following experimental figures clearly illustrates reasons and make background that why this kind of techniques could perform well in mobile multi-hop ad-hoc networks. Let us also discuss various reasons by considering important properties of mobile ad-hoc networks [17]:

- ACO is based on agent (ants) systems and works with individual ants. This allows a high adaptation to the current dynamic topology of the network.
- ACO is based only on local information (pheromone), that is, no routing tables or other information have to be transmitted to neighbors or to all nodes of the network.
- It is also possible to integrate the link quality towards the calculation of the pheromone concentration. This can further be used to evaluate the probability value for choosing a particular path.
- Each node can also maintain a routing table with entries for all its neighbors holding the pheromone concentration as the judgment metric.
- After looking at all the above statements, thus, this approach can also support multi-path routing.
- This approach is also traffic-adaptive which can be communicated indirectly through pheromone.
- Making use of stochastic components and not allowing local estimates to have global impact.
- Setting up paths in a less selfish way than in pure shortest path schemes favoring load balancing.

IV ACO BASED ROUTING

Combinatorial optimization problems arising in computer networks such as routing can be solved using ACO. The theme of food searching by the ants is the basic idea of this optimization. The foraging behavior of real ants can be implemented by ACO. Initially, the ants walk randomly when multiple paths are available from nest to food. The chemical pheromone laid by the ants while traveling serves as the route mark. The path having higher pheromone concentration is selected by the new ants and that path is also reinforced by the decisive ants selecting that path.

A quick solution can be obtained as a result of the above process' effect. Forward ants (FANTs) and backward ants (BANTs) are used for creating new routes. The pheromone track to the source node is established by a FANT and to the destination node by a BANT. A unique sequence number is attached to the packet created as the FANT. By referring to the sequence number and the source address of the FANT, the duplicate packets can be distinguished by the intermediate nodes receiving FANT [18].

The route from source node to destination node frequently changes in the MANET because of the moving nodes. Detection of dynamic topology, generation of path between nodes and handling route failures has to be performed by the efficient routing algorithm [19] [20]. So, routing using ACO in MANETs can be discussed in three phases.

Route discovery phase – The route discovery is done by flooding the network with ants in a broadcast way as FANTs. Both FANTs and BANTs are used to fill the routing tables with probabilities calculated on the basis of obtained pheromone values. These probabilities reflect the likelihood that a neighbor will be selected so that to advance the FANT towards the given destination. Multiple paths are created between source and destination. First of all, neighbors are discovered using FANTs, but entries are only inserted in the routing table after receiving BANTs from the destination node. Each neighbor receives a probable value in the form of pheromone helping in calculating probability for moving towards destination. The pheromone value is increased by BANTs coming from the destination node further helping in establishing the required path [21] [22].

The ant algorithms use sequence numbers to avoid duplicate packets resulting due to flooding. Only the greater sequence number from the same previous hop is taken into account. FANTs with a lower sequence number are dropped. All feasible paths from source node to destination node are found in this phase.

Route maintenance phase – The route maintenance phase is accountable for improving the routes during the communication. A route may become invalid or unreachable due to the movement of intermediate nodes. The nodes experiencing the change in link will conduct a local repair procedure and try to find an alternative path to the destination and mean while buffers all the packets it receives. If the intermediate node successfully finds a new path to the destination, it will send all the buffered packets to the destination via the newly found route [22]. In the meantime, a notification ant will be sent to the source to inform the source node about the change of route. All the nodes, from where the notification ant passes will also update their routing table to remove any invalid routes. The source will also replace the broken path with the new path value being intimated by the notification ant. If no such alternative path can be found by intermediate node then an error ant will be sent to the source node. After receiving the error ant, if the source node needs a route to the destination, it will initiate a new route discovery procedure by sending FANTs [23].

Route failure handling – This phase is liable for generating alternative routes in case of failure in the existing path. Node mobility in MANETs may cause certain links to fail. Every data packet moving from the source node to the destination node is associated with an acknowledgement. Therefore, if a source node does not receive an acknowledgement from destination, then it assumes that the link has broken. On detecting a link failure the node sends a route error message to the previous node and deactivates the current path by changing the pheromone value to zero [22]. The previous node receiving the error message, then tries to find an alternate path to the destination by the help of its neighboring. If the alternate path is found then the pending packets are forwarded using new identified path else the node informs its neighbors to relay the packet towards source. This process continues till the source is reached or new path to destination is found. The source node on receiving the error message initiates a new route discovery phase. Ant algorithms are able to find multiple paths. If one of the optimal paths fails then new best path is chosen. Next best path will be the path having the second best pheromone value [23]. Hence ant algorithm does not break down on failure of optimal path.

V CONCLUSIONS

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. This work investigates recent research trends in Ant based routing for MANETs. We found that some issues such as Quality of service routing and route failure management attracted much attention. Many techniques were proposed based on ant based routing protocol which can effectively find the globally best solution in terms of routing for a given ad hoc network. It is observed that due to nodal mobility, unstable links and limited resources in MANET, routing algorithm found to be unsuitable for routing after link failure. But, these types of problems can easily be tackled with the help of ACO meta-heuristic.

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