Journal of Advanced Computing and Communication Technologies ***(ISSN:* 2347 - 2804*)***
Volume No.3 Issue No. 4, August 2015

Ant Colony Optimization Based Routing Algorithm in Various Wireless Sensor Network- A Survey

By

Ajeet Pandey, Akhilesh Kumar Singh
Computer Science and Engineering, UIT, Naini, Allahabad
Computer Science and Engineering, UIT, Naini, Allahabad
ajeetpandey29@gmail.com, akhileshvivek@gmail.com

ABSTRACT

Wireless Sensor Network has several issues and challenges due to limited battery backup, limited computation capability, and limited computation capability. These issues and challenges must be taken care while designing the algorithms to increase the Network lifetime of WSN. Routing, the act of moving information across an internet world from a source to a destination is one of the vital issue associated with Wireless Sensor Network. The Ant Colony Optimization (ACO) algorithm is a probabilistic technique for solving computational problems that can be used to find optimal paths through graphs. The short route will be increasingly enhanced therefore become more attractive. The foraging behavior and optimal route finding capability of ants can be the inspiration for ACO based algorithm in WSN. The nature of ants is to wander randomly in search of food from their nest. While moving, ants lay down a pheromone trail on the ground. This chemical pheromone has the ability to evaporate with the time. Ants have the ability to smell pheromone. When selecting their path, they tend to select, probably the paths that has strong pheromone concentrations. As soon as an ant finds a food source, carries some of it back to the nest. While returning, the quantity of chemical pheromone that an ant lay down on the ground may depend on the quantity and quality of the food. The pheromone trails will lead other ants towards the food source. The path which has the strongest pheromone concentration is followed by the ant which is the shortest paths between their nest and food source. This paper surveys the ACO based routing in various Networking domains like Wireless Sensor Networks and Mobile Ad Hoc Networks.

Keywords

Ant Colony Optimization, Routing, Mobile Ad Hoc Networks, Wireless Sensor Networks

1. INTRODUCTION

We With the growing importance of telecommunication and the Internet, low power wireless communications, and low cost and low power sensor node, more complex networked systems like Wireless Sensor Network are being designed and developed. Since these networks are complex and have some limitations therefore they have several challenges and issues. In order to handle complex networking problems such as load balancing, routing and congestion control, there is a requirement for more sophisticated and more intelligent techniques/protocol to solve these problems. Several mobile agent-based algorithms/techniques were designed to solve control and routing problems in networking. These computing techniques are inspired by social insects such as ants. A colony of ants can perform useful tasks such as foraging behavior (searching for food) and finding the optimal path.

2. ANT COLONY OPTIMIZATION

Ant colony optimization (ACO) is an algorithm that utilizes the foraging behavior of the ants in order to find a shortest path from their nest (source) to the food source. This algorithm utilizes the behavior of the real ants while searching for the food. It has been noticed that the nature of the ants are to wander randomly in search of some food source, and upon finding food source they return back to their nest (colony) with some food by laying down chemical pheromone trails on the ground, which attracts other ants to follow the same path (pheromone trail), they themselves lays more pheromone, thus reinforcing the trail. With respect to time the pheromone trail starts to evaporate and its strength decays over time. The more time taken by an ant to travel down the path to their nest and back again to the food source, provide more time for the pheromones have to evaporate. A shortest path gets visited over more frequently, and thus the pheromone concentration becomes higher on shorter paths in comparison to the longer ones. On shorter paths pheromone builds up faster. Pheromone evaporation also has the advantage of finding the shortest path and avoiding the convergence to a locally optimal solution. Therefore, when an ant finds a shorter path from their nest (colony) to a food source, other ants are more likely to follow the same path and this eventually leads to the entire ant's following a single path. The core idea of the Ant Colony Algorithm is to simulate this behavior of ants with "artificial (simulated) ants" and making them to walk around the graph that represents the problem to be solved. In ACO a number of artificial ants are used to build solutions to the considered optimization problem.

ACO Applications: ACO has been used in many Computational and Combinatorial Optimization problems such as the Medicare Shared Saving Problem, Asymmetric Traveling Salesman Problem, Graph Coloring Problem and Vehicle Routing Problem etc. This paper focuses on surveying ACO approaches in network routing and load-balancing.

3. ACO IN NETWORK ROUTING

ACO algorithms can be used in the Wireless Sensor Networks and Mobile Ad Hoc Networks to solve the routing problems in order to find the shortest path. A set of artificial ants (data packets) are simulated from a source (nest or colony) to the destination (food source) in a network routing problem. The forward ants(a mobile node) [4] are used to select the next node arbitrarily for the first time by taking the information from the routing table of the nodes and the ants, who are reaching the destination successfully, are updating the chemical pheromone strength at the edges of the graph, representing the problem, visited by them.

4. ACO IN NETWORK ROUTING

Mobile ad-hoc networks are infrastructure-less networks that consist of wireless mobile nodes, that are organized in a peer-to-peer and autonomous fashion and can communicate in distributed manner without any centralized administration possibly mobile. Whenever, there is a need, the nodes immediately and dynamically form a network. The routing in Mobile Ad-hoc Network is quite challenging due to the following constraints: 1. highly dynamic topology 2. Chaotic load balancing among the processors 3. Unpredictable communication behavior among the nodes 4. Limited bandwidth availability and 5. Energy constraints. Recently a novel family, inspired by Swarm Intelligence, of algorithms emerged, that provides a new way to distributed combinatorial optimization problems. After the initial studies of certain features of SI and mobile ad-hoc network, it has been found that they have a great deal of matching properties in terms of routingrequirements, such as the ability of ant colony to discover a nearly optimal route between source and destination. To solve the routing problem in mobile ad-hoc networks, many algorithms that are based on Ant Colony Optimization were introduced in early years.

4.1 Ant-Colony-based Routing Algorithm (ARA)

The author proposed a very simple and sophisticated algorithm named Ant Routing Algorithm (ARA) [6] using distance vector routing protocol that is very similar as several other routing approaches in construction. The basic aim of the designing of this protocol was to reduce the routing overhead. The algorithm is compared to AODV, DSDV and DSR (Dynamic Source Routing) and the results indicate that ARA and DSR perform comparatively in terms of *delivery rate*, with DSDV and AODV lagging behind. ARA and AODV perform comparatively in terms of *overhead ratio*, with DSDV and DSR lagging behind.

4.2 Termite

Please Roth and Wicker [9] present an algorithm that is closely related to ARA using the Distance Vector Routing protocol principles. Termite differs from ant colony based routing algorithm (ARA) in terms of discovering the optimal route and a response of failure recovery. Authors examine the algorithm and give the performance of the algorithm in terms of data good-put, mean path length, route confidence and node mobility.

4.3 Emergent Ad-hoc Routing Algorithm (EARA)

EARA is an on-demand multi-path routing algorithm. Each node using this algorithm maintains a Probabilistic routing table. On initialization, a neighborhood for each node is built using the single hop HELLO messages. Each node comprising the routing table as well as them also possesses a pheromone table, which tracks the amount of pheromone on each neighbor link. In a dynamic network like MANET, the changes of the network topology create chances for new paths to emerge. To use this property, this algorithm launches LFA (Local Foraging Ants) periodically to search locally new routes.

4.4 AntHocNet

Di Caro, Ducatelle and Gambardella [8] present hybrid multipath algorithm whose design is based on a self-organizing behavior of ants, shortest path discovery in Ant Colony Optimization. The source node sends out reactive forward ants to find the routes to the destination if the it does not have correct routing information to the destination. AntHocNet generates ants in both proactive and reactive schemes. The authors compared it to the AODV after examining the AntHocNet algorithm in an environment with a realistic MAC layer. In all tested experiments, AntHocNet produces superior results over AODV in terms of packet delivery ratio. In complex scenarios (with more nodes or with more node mobility), AntHocNet produces better packet delay while in simpler scenario AODV produces lower packet delay.

4.5 Ant-AODV

The authors [10] combined the features of AODV and AntNet routing protocol and proposed a proactive-reactive hybrid protocol. The Ant-AODV routing protocol maintains a population of forward ants that explore the network with a source-routing list of visited nodes in the packets header. When we compare the Ant-AODV protocol to the AODV protocol then the results indicate that Ant-AODV having a slightly higher normalized routing overhead over end-to-end delay and packet delivery fraction of Ant-AODV and AODV.

4.6 Mobile Ant Based Routing (MABR)

This algorithm [11] consists of three layers: Straight Packet Forwarding (SPF), Topology Abstraction Protocol (TAP), and Mobile Ant Based Routing (MABR). When we compare MABR algorithm with Distance-Vector (DV), Link- State (LS), and AntNet algorithms then after simulation, the results we get, indicate that Adaptive-SDR has lower packet loss, higher delay times, and higher data throughput than the other algorithms

Adaptive-SDR

This Adaptive-SDR algorithm [12] organizes the network into clusters. Once the partition process is complete, the algorithm maintains inter-clustering and intra-clustering routing tables at each node. Multiple colonies of Ants are used to discover and maintain these different routing tables. This algorithm consists of three parts: Clustering into Colonies, Discovering Routes, and Packet Forwarding. When we compare this algorithm with the Distance-Vector (DV), Link- State (LS), and AntNet algorithms, the simulation results indicate that Adaptive-SDR has higher data throughput, higher delay times and lower packet loss than the other algorithms.

4.6 HOP-NET

The HOP-NET algorithm [13] consists of the reactive communication between the neighborhoods and proactive local discovery within a node's neighborhood. The algorithm divided the network into zones that are the local neighborhood of the nodes. When HOP-NET algorithm is compared to AODV, the simulation results indicate that HOP-NET has lower packet delivery ratio, higher control overhead, and better end-to-end delay than AODV. When we compare this algorithm with AntHocNet, the results indicate that HOP-NET is highly scalable for large networks, and HOP-NET performs significantly better for high and low mobility compared to AntHocNet algorithm.

5. ACO BASED ROUTING IN WIRELESS SENSOR NETWORKS

Wireless Sensor Networks (WSNs) [14] consist a large amount of tiny sensor nodes that have the ability to sense the environment nearby, communicate in a small range, and perform little computations. Each node is equipped with wireless communication interfaces, sensing capabilities, limited processing capabilities and energy resources. Generally, the nodes are statically deployed over huge region to gather the information from the field. However, these sensor nodes can also be mobile and capable of interacting with the environment. WSNs can be used in a wide range of applications including information gathering from the field, environmental monitoring, surveillance for safety and security, automated health monitoring, vehicle tracking system, intelligent building control, traffic control, earthquake observations, object tracking etc. Although Wireless Sensor Network are used in wide range of applications but routing in Wireless Sensor Network is more challenging and difficult due to limited battery backup, limited communication and computation abilities, dynamic topologies, and mobility of the nodes. Due to the ability of ants to perceive changes in networks through pheromone in order to find the optimal route, routing algorithms based on Swarm Intelligence (SI) can be an effective approach to deal with dynamic topologies.

5.1 Algorithms adapting AntNet to WSNs

Zhang et al [15] proposed Adaptive AntNet algorithm that is directly derived from AntNet algorithm and also proposed three variant of it known as: **1.** Sensor-driven Cost-aware Ant Routing **(SC) 2.** Flooded Forward Ant Routing **(FF)** and **3.** Flooded Piggybacked Ant Routing (**FPAnt).** These algorithms make use of two types of Ant: Forward Ant and Backward Ant. Forward ants explore the path and collect information between source and destination node and have same number as the source node. Backward ants travel back from destination node to source nodes and updating the information of their pass-by nodes. The AntNet like algorithm makes use of unicast forward ants generated by source sensor) nodes. The number of hops calculated by these algorithms is the cost of the sampled path.

5.2 Energy Efficient Ant-Based Routing (EEABR)

The algorithm is designed to increase the network lifetime by reducing the communication overhead in path discovering and follows an efficient strategy considering the routed path length and energy levels of the nodes. This algorithm minimizes the flooding ability of ants to control congestion in routing and it also maintain intelligent routing table and intelligently update the routing table in case of link or node failure. It is achieved by using ant agents and energy and number of hops metrics for the pheromone update mechanism that allow establishing paths that are energy efficient. These algorithms make use of two types of Ant: Forward Ant and Backward Ant. The author compares the EEABR algorithm with other variants of it then he found that EEABR algorithm performs comparatively better in terms of minimum remaining energy of a node, standard deviation in the battery levels and energy efficiency.

5.3 ACO-based Quality-of-Service Routing (ACO-QoSR)

The author proposed a reactive algorithm, named ACO-QoSR [15], to find out a maximum energy efficient and minimum delay path to deal with the limitation of sensor nodes and routing problem in WSN. In ACO-QoSR, whenever any node wishes to send data it firstly checks its routing table. If there is exist an appropriate path in its routing table then it sends the data otherwise initiating a probe phase to find a new route by initiating route discovery process and "k" forward ants are used for each path probe. These forward ants are unicast to next hop nodes using selection probabilities. ACO-QoSR's performance has been compared in simulation to Adhoc-On Demand Distance Vector (AODV) and Destination-Sequenced Distance Vector routing (DSDV) routing algorithms for MANETs then the simulation results verify that ACO-QoSR algorithm can reduce the selected path's delay and improve the selected path's normalized energy residual ratio at the similar levels of routing overhead.

5.4 Ant-based service-aware routing algorithm (ASAR)

ASAR is a QoS-aware routing protocol proposed by author for multimedia sensor networks. Generally, ASAR protocol uses two kinds of basic service modes: the event-driven mode and the query-driven mode. Event driven service modes includes only one type of service, the R-service that puts strict requirements in terms of error intolerance, delay and reliability for event detection and notification .The query-driven mode includes two types of services, the D-service and S-service. D-service is based on data query and it aims at the error intolerant but query specific delay tolerant applications while S-service which is stream query service is strictly intolerant to errors but more tolerant to delays. The ASAR's performance is compare with Directed diffusion Dijkstra's algorithm. ASAR appears to provide only slightly better performance than its competitive protocols. ASAR's energy consumption is the highest among the three protocols. ASAR algorithm has better convergence and significantly provides better quality of service for multimedia wireless sensor network.

5.5 Self-organizing Data Gathering for multi-sink sensor networks (SDG)

The author proposed a cluster-based data gathering SDG protocol with aim to achieve reliability and scalability in WSNs. Single sink WSN architecture is not robust to energy depletion. In single sink architecture of wireless sensor network when the sink fails or once the nodes around the sink run out of energy, the sink remains isolated and the WSN become useless. The author proposed a multi-sink WSN in which in case of failure, another node can be used as a sink node, even in presence of very lossy communication channels to deal with the problem of single-sink architecture of WSN.

The problem of energy loss during the data collection in single-sink is reduced by using multi-sink WSN. This algorithm uses both static as well as mobile sink node. According to the reported results, the algorithm can also successfully handle both sink node failures and random node failures.

5.6 AntChain

The author proposed a centralized algorithm named AntChain that partitions the responsibilities of sink node and the sensor nodes. This portioning is based on their hardware resources and relative distances to optimize energy consumption and transmission delays. AntChain algorithm can be used with the applications that provide the prior information of the identity and the location of the sensor nodes. The sink node uses location information to calculate a near-optimal chain organization for the nodes, which is used for efficient data transmission.

5.7 Energy-Delay ant-based (E-D ANTS)

The author has proposed the E-D ANTS algorithm to maximize network lifetime and to provide a real-time data delivery service by finding a route with minimum energy-delay product. The E-D ANTS algorithm routes the packets through optimal and energy-efficient paths and also avoids congested paths. The Table-1 depicts the features of the above discussed Ant Inspired Routing Protocols for WSN.

Table 1 Ant Inspired Routing Protocols for WSN.

Characteristics	**Routing Protocols used in Wireless Sensor Network**						
	SS/FF/FP	EEABR	ACO QoSR	ASAR	SDG	ANT CHAIN	E-D ANTS
Fault Tolerance	Y	Y	Y	Y	Y	N	Y
Energy Aware	N	Y	Y	Y	Y	N	Y
Load Balancing	Y	Y	Y	Y	Y	Y	Y
Best Effort (B) / QoS (Q)	B	B	Q	Q	B	B	Q
Reactive (R) / Proactive (P) / Hybrid (H)	H	P	R	P	P	R	R

6. CONCLUSION

In this paper a review of ACO based algorithms for routing in Wireless Sensor Networks and Mobile AdHoc Networks are presented, some of the key features of routing protocols presented above are compared and summarized. The advantages and disadvantages of Ant Colony Optimization (ACO) based Routing algorithms over the traditional Routing Algorithms is also summarized.

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