Stable Weight based Routing Protocol using Ant Colony Algorithm for Mobile Ad Hoc Networks

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ABSTRACT:
This paper proposed a new routing protocol named Ant-based Stable Weight Routing Protocol (ASWRP). This protocol is a combination of Ant-based Routing Algorithm (ARA) and Stable Weight Routing Protocol (SWRP) with multi-route capability, which uses a weight-based solution in order to choose a stable path to enhance efficiency. In this algorithm, the weight of each link is defined based on three factors including expiration time of link, amount of pheromone and hop count. The objective of this protocol is to use intelligent algorithm of ant and a weight-based algorithm in order to recognize and use routes with higher stability and reach a lower number of lost packets. Simulation results show that the efficiency of ASWRP is much higher than that of SWRP.

KEYWORDS: Mobile ad hoc networks; Weight-based routing; Ant-based routing algorithm; Stable path

1. INTRODUCTION

Each society includes of many people who carry hand devices such as cell phones, mini computers and personal digital assistants. These people like to use their hand devices not only for specific applications but also for network access. For example, they want to be able to send messages, check their e-mails and do their work wherever they are. In wireless networks, mobile nodes move in an ad-hoc way. These principles lead to the definition of Mobile Ad-hoc Networks (MANET).

Mobile ad-hoc networks consist of a set of mobile nodes which can communicate with each other without any supporting infrastructure. There is no designated router on this network and all nodes are able to serve each other as a router and drive the data packets forward. In other words, in such networks, each node can communicate to other nodes which are within its transmission range. To communicate with nodes out of its range, a node uses the help from other nodes which play a “bridge” role to receive and forward messages. Therefore, a node in mobile ad-hoc networks acts as both a terminal and a router. These kinds of networks are very flexible and suitable for different situations and applications. For instance, these networks can be applied for military fields, search and rescue operations, and any remote area where is no base station for communications [2].

During recent years, many studies have been done on mobile ad-hoc networks, especially routing protocols. One reason of making routing difficult in such networks is that network topology is constantly changing and routes which were initially effective can quickly become inefficient and impractical. Hence, routing algorithms must detect or update the routes immediately and with less control overhead. Also, the capacity of nodes' battery is limited and this limitation requires the packets to be distributed on multiple paths if possible, leading to reduced battery consumption in different nodes and consequently increased network lifetime.

There are two main issues in mobile ad-hoc networks: the quality of service (QOS) and mobility. QOS is very important since multimedia services have become popular. In a mobile environment, because of the mobility of nodes in mobile ad-hoc networks, the shortest path is not necessarily the best path. If the stability of route is not considered, the wireless links may be easily broken. Many efforts have been made to design reliable routing protocols that enhance network stability [1]-[4]-[8]-[9].

This paper, propose a new routing protocol which is combination of Ant-based Routing Algorithm (ARA) and Stable Weight Routing Protocol (SWRP). The new algorithm is multipath and uses the weight-based strategy to select a stable route in order to enhance system performance.

The rest of the paper is organized as follows. In the next section, we will present the existing on-demand routing protocols. In section 3, we will explain stable weight based routing protocol using ant colony algorithm for mobile ad hoc networks. Section 4 presents the performance evaluation of the algorithm compared to SWRP routing protocol. Finally, we will present our conclusion.

2. RELATED WORK

In this part, two on-demand routing protocols including ARA and SWRP are briefly introduced.

2.1. Ant colony algorithm

Ant algorithms are a subset of swarm intelligence which use of the behavior of swarm insects as a model to solve complex problems. The exploratory behavior of ants is based on indirect communications using a substance called "pheromone". They deposit the pheromone on the ground while commuting from food source to their nest and vice versa. Ants can smell pheromone and use it for route selection. Following the footprints of pheromone by ants has been studied by many researchers. Deneubourg and colleagues established a trial on the use double bridge from the nest to the food source. They ran experiments varying with the ratio of $r = l_1/l_s$, between the length of the two branches of the bridge, where l_1 and l_s represent the length of the longer branch and the length of the shorter branch, respectively [11].

In the first experiment, the bridge has two branches of equal length (r = l, Fig. 1a). In the beginning, ants are free to move between the nest and the food source. Although the selection is completely random in the initial phase, eventually all the ants use one branch. It is for this reason that there is no pheromone on the two branches of bridge in the beginning, so ants do not have any preference for choice and they select with the equal probability any of the branches. Due to the deposition of pheromone by ants, branch of bridge that more ants move on has a higher amount of pheromone. This large amount of pheromone in turn stimulates more ants to re-choose that way of bridge, so that ants eventually converge into a single path [11].

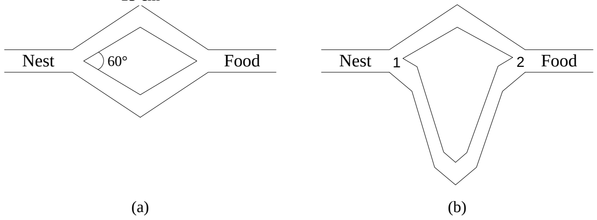

Fig. 1. Double bridge experiment: (a) Branches have equal length. (b) Branches have different length [11].

In the second experiment, ratio of length between the two branches of bridge was changed to r = 2, meaning that the length of the longer branch is twice of the shorter branch (Fig. 1b). in most experiments, After a little time, all ants use only the short branch; in the beginning of experiment when ants arrive at a decision point, where they have to choose one of the two branches, all ants randomly choose one of two branches. Over time, the higher level of pheromone on the shorter branch causes converges to this branch. Therefore, pheromone concentration quickly increases on this branch, which will eventually use by all the ants because of the autocatalytic process [11].

Ant-based Routing Algorithm (ARA), introduced by Gunes et al, is one of the first algorithms of ACO for finding paths in mobile ad-hoc networks. This is a reactive algorithm which includes three phases of route discovery, route maintenance, and error detection. Forward ants (FANT) and backward ants (BANT) are used in the route discovery phase. ARA does not need any special packets for route maintenance. Instead, data packets are applied to maintain the route between source and destination. If the source node receives a message of route failure, the route discovery phase would begin again [3]-[5]-[6].

The foraging behavior of the ants can be used to find the shortest route in networks. Especially, the dynamic component of this method provides a high degree of adaptation for changes in mobile ad-hoc networks topology [3].

2.2. Stable weight based routing protocol

Stable Weight based Routing Protocol (SWRP) is another routing algorithm in mobile ad hoc networks. The main goal of this algorithm is to improve the quality of routing by using the information available in the network. This algorithm has three phases including route discovery, route selection and route maintenance [7].

In this algorithm, the route discovery phase is similar to DSR and initiates whenever the source node wants to communicate with another node and there are no routing information in its table. The source node broadcasts the route request (RREQ) packet to its neighboring nodes. If the node is within the transmission radius, it forwards the RREQ packet to its neighboring nodes and adds its ID, the route expiration time, the error count, and the hop count of the RREQ packet to the packet entry. In the route discovery phase, when the destination node receives a RREQ packet, it waits for a certain amount of time to receive other RREQ packets. Then, this node computes the weight value using a weight function and selects the path with the maximum weight value as the primary routing path among all feasible paths, and sends a RREQ packet to source node along primary routing path. In the route maintenance phase, when a mobile node moves out of another mobile node's radio transmission range, link failure occurs. The mobile node that discovers the link failure broadcasts a RERR packet to other mobile nodes. Mobile nodes that receive the RERR packets will find this malefactor in their route cache and add one to their error count. On receiving a RERR packet, the source node stops sending the data and then restarts the route discovery process or finds an alternative path for routing [7].

3. STABLE WEIGHT BASED ROUTING PEOTOCOL USING ANT COLONY ALGORITHM FOR MOBILE AD HOC NETWRKS

In this paper, we propose a Stable Weight based routing protocol using Ant colony for MANETs. The proposed scheme is a reactive and on-demand algorithm. The objective of proposing this algorithm is to improve the quality of routing in MANETs by using the information available in the network and the intelligent algorithm of ants in order to recognize and use shorter routes. The main idea to use this algorithm is select a stable path to reduce the routing overhead and packet loss. This algorithm consists of three phases of route discovery, route maintenance, and error detection, and proposes a multi-path routing solution using the ant colony routing which increases the tolerance to errors, and is advantage to this algorithm.

3.1. Route discovery

In the proposed algorithm, route discovery process is similar to that of ARA. Whenever a source node wants to send a packet to the destination node but finds no route to the destination in its table, route discovery phase begins.

First, a forward ant is sent to other neighbors by the source node. The node that receives a FANT for the first time creates a record in its routing table. Routing table provides information such as destination address, the next hop, pheromone value, and link weight. The node which receives the FANT, takes the source address as destination address and the address of previous node as the next hop. This node also computes the pheromone value, which is based on the length of route the FANT has passed to get that node, and then determines the link weight using link expiration time, the amount of pheromone, and the hop count and records them in the routing table. Then, this node again sends the FANT to another neighbor.

When the FANT reaches the destination node, it extracts the information of the FANT and destroys it. Subsequently, it creates a BANT and sends it to the source node (The FANT and BANT format is shown in Fig. 2). The BANT has the same task as the FANT; when the sender receives the BANT from the destination node, the route is established and data packets can be sent.

Src. Add	dest. Add	SSN	Hop Count	Location	Velocity	Direction

Fig. 2. The FANT and BANT packets format in ASWRP.

Factors needed to compute the weight function in the proposed algorithm include link expiration time, amount of pheromone, and hop count. Link expiration time is obtained from (1). When the source node sends a request packet, its state information such as position, speed, and direction is also added to the packet. The next hop of the source node receives the request packet to predict the link expiration time between itself and the source node. For example, if node B is the next hop for the node A, node A will insert its location information in the packet, so the node B will be able to compute the link expiration time between node A and node B [10].

$$DT = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-cb)^2}}{(a^2+c^2)} \qquad (1)$$

Note that:

$a = v_1 \cos\theta_1 - v_2 \cos\theta_2$,

$b = x_1 - x_2$,

$c = v_1 \sin\theta_1 - v_2 \sin\theta_2$,

$d = y_1 - y_2$.

Let (x_1, y_1) and (x_2, y_2) denote the x - y position for nodes n_1 and n_2, respectively. Also let v_i and v_j denote their speed along the directions θ_1 and θ_2, respectively.

3.1.1 Route weight function

In the proposed algorithm, the weight function is defined as an empirical mean value, which effectively all three weight factors can be combined using the constants C_1, C_2, and C_3. Since the route expiration time is very important in MANETs, thus the coefficient of this factor can be made large. The flexibility of changing in the coefficients of factors helps in selection of the best route in the proposed algorithm. A larger route expiration time and pheromone value represents higher reliability, but more hop count lead to lower reliability. More precisely, $W_{i,j} = (C_1 \times \phi_{i,j}) + (C_2 \times LET_{i,j}) + (C_3 \times HC)$, where $W_{i,j}$, $\phi_{i,j}$, $LET_{i,j}$, and HC, respectively, represent link weight between the nodes i and j, the amount pheromone available in the link, link expiration time between the nodes i and j, and hop count. Also, $|C_1| + |C_2| + |C_3| = 1$.

In this algorithm, each node refers to its routing table to select the route and, among several routes to the destination in the routing table, the link with highest weight is chosen for the next hop. This is done in all nodes to send the packet to the destination through a stable route.

3.2. Route maintenance

The second phase of the ASWRP is called route maintenance. Like ARA, this algorithm dose not requires any special packet for route maintenance, because the FANT and BANT packets have created the pheromone acid tracks for the source and destination nodes and data packets are used for the route maintenance. When the node i sends data packets to destination node D through its neighboring node j, it increases the pheromone value of the entry (D, j, φ, w) by $\Delta\varphi$ and consequently amount of weight function is increased, meaning that this route to the destination is strengthened by the data packets. On the other hand, j as the next hop increases the pheromone value of the entry (S, i, φ, w) by $\Delta\varphi$ and consequently weight function is increased. This means that the route to the source node is also strengthened by sending data packets.

The evaporation process of the real pheromone is modeled by decreasing the pheromone values by over time according to (2) and also weight function is decreasing.

$$\varphi_{i,j} = (1-q)\,.\,\varphi_{i,j} \quad , \qquad q \in (0,1] \tag{2}$$

3.3. Error detection

In the error detection phase, when a node gets a ROUTE-ERROR message from a certain link, the node first deactivates this link by setting the weight value to zero, and then looks for another route in its routing table. If there is another route to that destination, it is used. Otherwise the node informs its neighbors hoping they have a route to that destination.

3.4. Advantage proposed algorithm

One of the advantages of this algorithm is that it supports multi-path routing, allowing in each route discovery phase several routes to the source and destination to be created. The following is an example which you will find the routing tables of nodes 3 and 4.

In Fig. 3, forward and backward ants fill out the routing table while performing the route discovery phase. Routing tables for the nodes 3 and 4 are shown in Fig. 3.

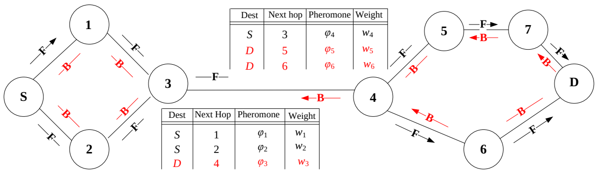

Fig. 3. Route discovery process and filling out the routing tables in ASWRP.

As shown in the routing tables, forward ants have created two pheromone tracks to the source node S by the nodes 1 and 2, in the node 3 and backward ants (spotted in red) have created one track to the destination by the node 4. On the other hand, in the node 4, forward ants have created only one track to the source node and backwards ants have created two tracks to the destination node. These all show that multi-path routing is supported by ASWRP.

When the node 3 sends a data packet to the node 4, the amount of pheromone and the weight function for the destination node D is increased in the routing table of the node 3. The amount of pheromone and the weight function for the source node S is also changed in the routing table of the node 4.

4. SIMULATION RESULTS

In this section, performance of the proposed ASWRP is compared with that of SWRP. The simulation models a network in a 500 m × 500 m area with 10-50 mobile nodes. The radio transmission range is assumed to be 200 m and speed of each mobile node is assumed to be 5-30 m/s. In this model, each node selects a random destination within the simulation area and moves in a speed uniformly distributed between 5 m/s and the maximum speed of 30 m/s.

The simulations evaluate the end-to-end delay, the number of packets dropped, and the packet delivery ratio for different numbers of mobile nodes and different speeds of nodes. The end-to-end delay is the time it takes for a packet to be sent by the source node to the destination node. Number of packets dropped is the total number of packets dropped during routing. The packet delivery ratio is the ratio of the number of data packets received by the destination node to the number of data packets transmitted by the source node.

Figs. 4 and 5, show the end-to-end delay of ASWRP and SWRP for different numbers of mobile nodes and mobility speeds, respectively. As observed in Figs. 4 and 5, the end-to-end delay increases as the number of mobile nodes or the mobility speed increases.

In Fig. 4, as is expected, ASWRP has better end-to-end delay compared with SWRP. This is because SWRP spends a lot of time to compute the weights of all paths found in the destination node and select the main route between them, while ASWRP calculates the weight in each node and this will have far less delay. In ASWRP, with the compute of expiration time and pheromone value between two links, ants can move on some links or ignore certain links as the weight decreases. Expiration time helps the discard of failed links. All these allow ASWRP to produce a better end-to-end delay.

In Fig. 5, as the speed of nodes increase, SWRP shows a more delay than ASWRP. This is because, by increase speed of nodes, link failure occurs more and since there are various routes to the destination in the routing table of ASWRP, route is more likely to be found, and this reason allows that packets spent less time in queues or along the route.

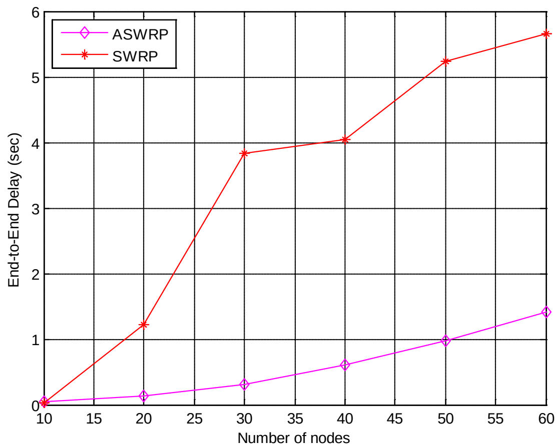

Fig. 4. End-to-end delay vs. number of mobile nodes with a mobility speed of 10 m/s.

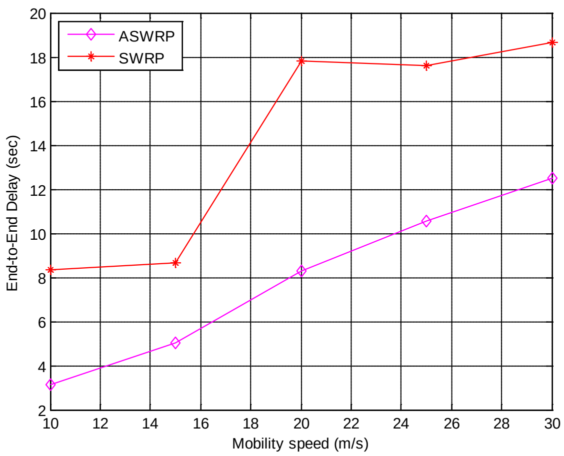

Fig. 5. End-to-end delay vs. mobility speed for 40 mobile nodes.

Fig. 6 shows the end-to-end delay of ASWRP and SWRP for different numbers of nodes and packets. Here, there are two different values for rate of data transmission: 5 and 10 packets per second. As observed in Fig. 6, when the number of packets is less, end-to-end delay is lower, but by increasing the number of packets sent, it increases. This is because by increasing the number of packets in the network, Amount of traffic increases, and the time required for packets to get the final destination increases.

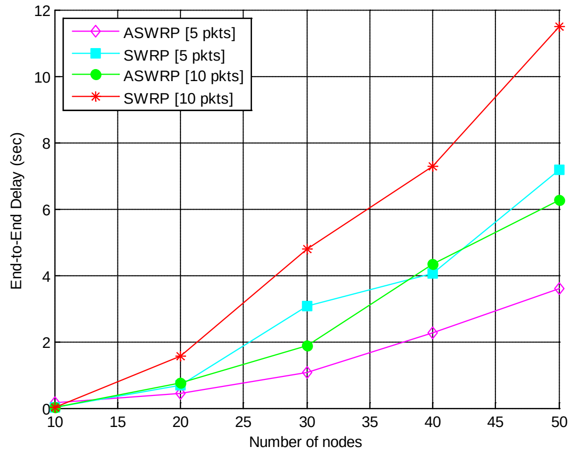

Fig. 6. End-to-end delay vs. number of mobile nodes and number of different packets with a mobility speed of 10 m/s.

Fig. 7 shows the number packets dropped of ASWRP and SWRP for different mobility speeds. As seen in Fig. 7, the number of packets dropped increases as the mobility speed increases. The number of packets dropped in SWRP is more than that of ASWRP. This is because as the speed of nodes increases, link failure occurs more and since ASWRP has more routes to the destination and is more stable than SWRP, routes are more likely to be found in ASWRP and fewer data packets are lost.

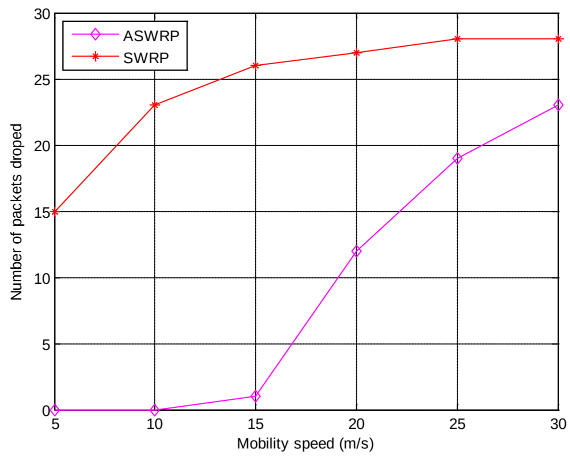

Fig. 7. Number of packet dropped vs. at mobility speed for 40 mobile nodes.

Fig. 8 shows the packet delivery ratio of ASWRP and SWRP for different mobility speeds. We can see that, ASWRP transmits and receives more data packets than SWRP. This is because ASWRP supports multi-path routing solution.

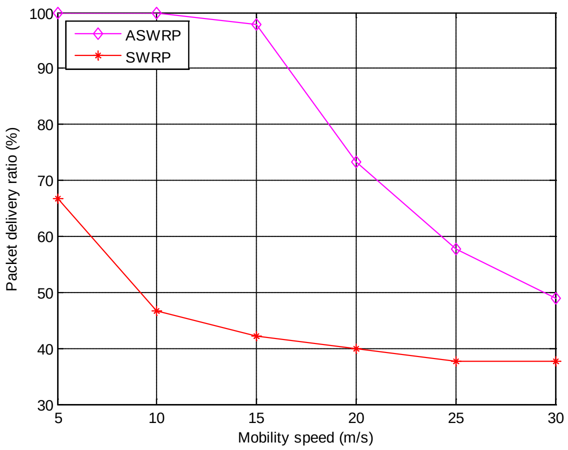

Fig. 8. Packet delivery ratio vs. mobility speed for 40 mobile nodes.

5. CONCLUSION

In this paper, we proposed a stable weight based routing protocol using ant colony algorithm for MANETs. The proposed algorithm selects a stable link in each node by maximizing the weight among the feasible links in the routing table. There are three parameters in this algorithm which are used to compute the weight. Include link expiration time, pheromone value, and hop count. Route selection is based on the weight of each link. In each link, the lowest weight has the lowest reliability and the highest mobility for each node. Another advantage of this algorithm is that it supports multi-path routing. Simulation results show that the efficiency of ASWRP is much higher than that of SWRP.

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