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Jumping ant routing algorithm for sensor networks

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Abstract

Enterprises that may rely on critical equipments which are constantly moving around, for example, hospitals – need to ensure they can know the current location of vital but mobile assets. Besides, the sensor node on each device should inform us whether those relative equipments are functional or does not work at all in a hazardous environment, so that vital equipments can be maintained or fixed beforehand. A sensor network is a potential solution to this kind of application, because every node can be found through the routing processes. Due to its working environment and the mobility of sensor node, this kind of sensor network is very similar to MANETs (Mobile Ad-hoc Networks). This study proposes a jumping ant routing algorithm (JARA) which combines the advantages of reactive and proactive routing to speed up the route discovery time and reduce the route discovery overhead in sensor network.

Keywords: JARA (Jumping Ant Routing Algorithm); MANET; ARAMA (Ant Routing Algorithm for Mobile Ad-hoc Networks); Ad-hoc

1. Introduction

Enterprises that rely on critical equipment which is constantly circulating around, for example, in hospitals – we need to ensure those equipments can be located instantly. A sensor network is a potential solution to this kind of application because every node can be found through the routing processes. Due to its working environment, this kind of sensor network is very similar to MANETs (Mobile Ad-hoc Networks) which the sensor node can be moved freely.

Many routing algorithm protocols have been developed for sensor networks. They can be categorized into proactive [2,3], reactive [4,5] and hybrid [6,7]. In a proactive algorithm, each node knows the entire topology. Therefore, a proactive algorithm must maintain a routing table periodically. By contrast, a node in a reactive algorithm starts to build the routing information when it knows the location of another node, then sends a packet via the path that it constructs, while the hybrid protocols are trying to use a combination of these two ideas.

Ant routing is a self-configured, self-built protocol, which can reduce the number of broadcast messages that need to be sent and which maintains several multi paths. An alternative path for sending packets can be quickly found when the network changes, thus reconditioning the network quickly.

Ant routing has some disadvantages because it is considered as a reactive routing. A node performs route discover when it wants to send a packet to a destination. It will keep sending packets. However, proactive routing consumes bandwidth. Therefore, this research proposes an algorithm, called the jumping ant routing algorithm (JARA), which combines the advantages of ant routing and proactive routing. JARA has its own zone. The entire algorithm can be classified into two parts. First, each node adopts pro-active routing protocol to determine the topology of ρ hops, then utilizes ant routing to discover path outside the zone.

Section 2 introduces some related routing algorithms. Section 3 proposes the jumping ant routing algorithm. Section 4 analyzes and compares the proposed algorithms with

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ARAMA. Section 5 presents the simulation results. Section 6 draws the conclusion.

2. Related works

Sensor networks are a decentralized network of autonomous nodes that collect information to send to a sink over wireless links. In some situation, the sensor node can move randomly. The mobility of the nodes means that the topology of the network may change from time to time, making traditional routing tables which are maintained at fixed points (routers) impossible to be used. Instead, each node is required to find its own best route to the sink. This kind of sensor network is very similar to MANETs (Mobile Ad-hoc Networks).

2.1. Ant Routing Algorithm for Mobile Ad-hoc Networks (ARAMA) [1]

Ant colony optimization algorithms are inspired by the behavior of real ant colonies. Many studies have discussed the use of ant colony algorithms to solve various problems [1,8–10]. ARAMA is addressed in this investigation, since it is reliable, survivable and dynamic. The optimum solution for ARAMA is determined by creating artificial ants. The artificial ants search the solution space as real ants search their environment for food. The probabilistic movement of ants in the system allows the ants to study new paths and to re-explore old visited paths. The strength of the pheromone deposit directs the artificial ants towards the best paths, while the pheromone evaporation lets the system forget old information and avoid quick convergence to sub-optimal solutions. The probabilistic selection of the paths enables searching large numbers of solutions.

Each node in the network can function as a source, destination or intermediate node. Fig. 1 shows the high-level flow chart for these functions. When a node wishes to find and maintain a path to its destination, it sends forward ants searching for this destination. A forward ant moves in the network searching for the destination using the intermediate nodes' probability routing tables and the local heuristic information. Forward ants collect information about paths and intermediate nodes local information as they travel along the path. When a forward ant reaches its destination, the information carried by this forward ant is graded. The forward ant is then killed, and a backward ant is generated. The backward ant carries its corresponding forward ant's grade and the identities of the intermediate nodes in the path. The backward ant is sent back along the reverse path of its corresponding forward ant. As backward ants move in the reverse path, the intermediate nodes modify their pheromone table based on the path grade carried by the backward ant, and accordingly update their pheromone table probability. Finally, the source node receives the backward ants, updates its tables and kills the backward ant.

2.2. Zone routing protocol [11]

Proactive and reactive protocols both have particular flaws. The Zone Routing Protocol (ZRP) combines the advantages of both into a hybrid scheme, utilizing a proactive mechanism to discover a node's local neighborhood, and applying a reactive protocol to communicate between neighborhoods.

As mentioned earlier, the ZRP provides a framework for other MANET protocols. The separation of nodes local neighborhood from the global topology of the entire network allows the application of different methods, thus exploiting each technique's features in given situation. These local neighborhoods are called zones. Each node may be within multiple overlapping zones, and each zone may be of a different size. The "size" of a zone is not determined by geographical measurement, as might be expected, but instead is given by a radius of length ρ, where ρ denotes the number of hops to the perimeter of the zone.

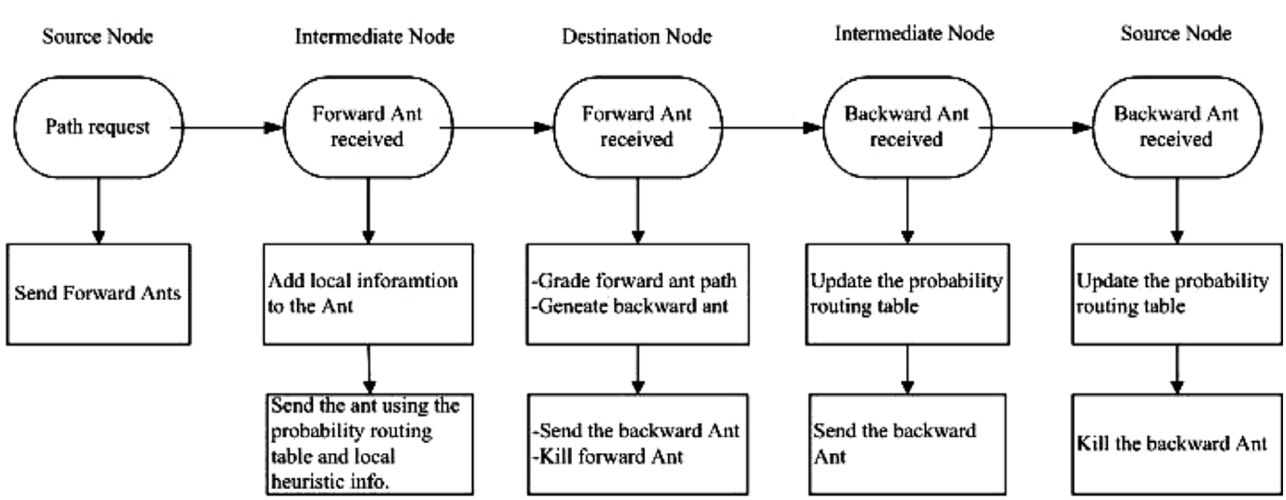

Fig. 1. ARAMA flow chart.

3. Jumping ant routing algorithm

This investigation presents a jumping ant routing algorithm (JARA) that combines the advantages of both ARAMA and ZRP, while also employing jumping mode to reduce the pro-active overhead. The algorithm is discussed in two parts. The first part relates to how each node uses proactive routing protocol to maintain the topology of ρ hops. The intra-network is assumed to have been already established by one of proactive routing protocols, and thus to have already generated an intra-network table. This work does not focus on the best proactive routing mechanism. The other part concerns how each node applies ant routing to discover paths outside its zone. Each node has its own zone, and each ant obtains a route within ρ hops. Hence, each ant jumping ρ hops distance is considered as one movement. This work explains and simulates the proposed algorithm, using $\rho = 2$. The setting $\rho = 2$ was chosen because it is sufficient to demonstrate the predominance of the proposed algorithm.

Each node in our algorithm can discover detailed information of neighboring nodes within ρ hops. These neighboring nodes can be organized into a zone called the intra-network. Those nodes within a zone are classified into boundary and interior nodes. The minimum distance of a boundary node minimum distance to the central node is exactly equal to the zone radius ρ. Nodes with minimum distances of less than ρ are called interior nodes. Fig. 2 displays an example of a zone where $\rho = 2$. The central node in the figure is node A. Nodes B, D, E, H, F and J denote the boundary nodes; nodes C, G and I are interior nodes, and node K and L are outside the routing zone. Each ant in node A adopts the pheromone table to choose a boundary node as the next node. If the ant specifies node B, then it must move to node B via node C. Node C only relays packets from the central node A to a boundary node. Hence, the JARA can speed up the route discovery and find a better path. The following subsection explains route discovery, then discusses the effect of changes in network topology. The Fig. 20 is the flow chart of this algorithm.

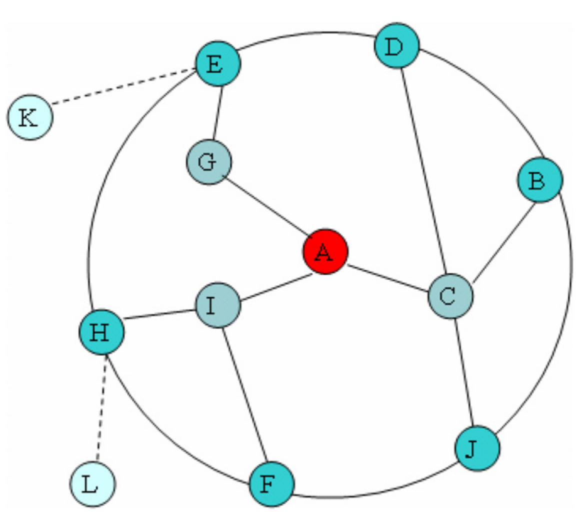

Fig. 2. Zone of node A with $\rho = 2$.

3.1. Route discovery

Ants are classified as forward, backward and guide ants. Forward and backward ants are similar to the ants stated in ARAMA, and are responsible for collecting path information and updating pheromone. A guide ant constructs an optimal path when all the backward ants have arrived at source a node, or when the network topology has changed. Every node also has a pheromone table such as Table 1.

The movement of route discovery is as follows:

1. The source node creates several forward ants to search for destination. The ants gather path information as they travel along the path.
2. A node creates a backward ant when a forward ant arrives there.
3. The backward ants are sent back following the reverse path, and update the pheromone table.
4. The guide ant is generated when all backward ants have arrived at the source. It updates the routing table along the optimized path, and constructs an optimal path.

The following subsections explain the procedure in detail.

3.1.1. Forward ant

Every node in the network can be considered as a source, destination or intermediate node. A node that wants to find a path to a destination sends forward ants to search for this destination and obtain path information.

When a forward ant is generated by source node, it adopts the pheromone table to obtain the next visiting node and record the path information. According to the routing principle of ARAMA, the next visiting node of

Table 1
Pheromone table

B_n	B_1		B_2		...		B_n	
DST	*PH*	*Vit*	*PH*	*Vit*	*PH*	*Vit*	*PH*	*Vit*
D_1	τ_{D_1,B_1}		τ_{D_1,B_2}				τ_{D_1,B_n}	
D_2	τ_{D_2,B_1}		τ_{D_2,B_2}				τ_{D_2,B_n}	
$\vdots$	$\vdots$		$\vdots$			$\vdots$	$\vdots$	
D_k	τ_{D_k,B_1}		τ_{D_k,B_2}				τ_{D_k,B_n}	

B_n is the boundary node.
PH is pheromone; *Vit* is the number of visit; n is the number of destination; k is the number of boundary node; $\tau D_{i,j}$ is he pheromone value on link (i,j).