Adapting HOPNET algorithm for Wireless Sensor Networks

Alexandre Massayuki Okazaki and Antônio Augusto Fröhlich
Laboratory for Software and Hardware Integration (LISHA)
Federal University of Santa Catarina (UFSC)
P.O.Box 476, 88040900 – Florianópolis – Brazil
{alexandre,guto}@lisha.ufsc.br

***Abstract*—HOPNET is a novel hybrid routing protocol based on Ant Colony Optimization (ACO) and Zone Routing Protocol (ZRP) for Mobile Ad Hoc Networks (MANETs). In this paper, we present an adaptation of the HOPNET algorithm in a real ad hoc Wireless Sensor Network (WSN), which tends to be more critical than MANETs in terms of energy amount, processing power, memory and communication. Our proposed algorithm has been validated through a prototype implementation for ZigBit, an IEEE 802.15.4/ZigBee(TM) OEM module. We are collecting measures about overhead, data delivery ratio, latency, and evaluating the routing algorithm in a sensor network environment.**

I. Introduction

Wireless Sensor Networks (WSNs) consist of a collection of autonomous sensor nodes spread over an environment. WSNs provide operations in various application areas and have their own constraints unlike other networks [1]. These constraints include limited energy time, limited communication range, processing power and storage in each node. Due to advances in that resources, low-power sensor nodes have received increasing attention.

Low-power sensor nodes are devices with one or more sensors. They are usually equipped with a processor, memory, power energy supply, radio and various mechanisms to measure environments conditions.

Sensor networks typically compose a wireless ad hoc network. An ad hoc WSN is a system of sensor nodes which intend to communicate with each other, but the communication infrastructure is little or nonexistent. The nodes of these networks can share and cooperate to carry out functionalities like synchronization, localization and routing.

However, several routing schemes of end-to-end devices and *Mobile Ad Hoc Networks* (MANETs) are inadequate for WSNs [2].

Also, MANET is a kind of wireless ad hoc network. It is an autonomous system of mobile routers which moves randomly and self-organize arbitrarily. This unforeseeable behavior can change the network topology quickly [3].

Nevertheless, ad hoc WSNs can be considered like a subset of MANETs. Both usually have the same problems, but these problems tend to be more critical in WSNs, because it is mostly stationary then a MANET and its nodes have less amount of energy, processing power and communication. Moreover, routing protocols need to be more simple in sensor networks.

In this paper, we propose the adaptation of a hybrid routing algorithm for MANETs in a real ad hoc WSN. The chosen routing algorithm is HOPNET [4], also an ant-based routing protocol. The main goal of our research is to evaluate this implementation in a sensor network environment. However, the peculiar difficulty of routing protocols in WSNs lies in the fact that sensor nodes have low hardware resources. We present some ideas to improve the HOPNET algorithm in order to increase the adaptability, the efficiency and to reduce the routing complexity in WSNs.

The rest of the paper is organized as follows. Section II presets informations about the proposed algorithm. In section III, we will explain details about our implementation and the changes carried out in the algorithm. Finally, we will present our conclusion of the study in the last section.

II. HOPNET

HOPNET is a hybrid routing algorithm for MANETs which involves *Swarm Intelligence* to solve routing problems.

Swarm Intelligence is an Artificial Intelligence sub-area which includes methodologies and technics inspired in collective intelligence. *Ant Colony Optimization* (ACO) is a Swarm Intelligence technical based in ant collective behavior to solve computational problems [5].

In the real world, an ant travels a random walk from its anthill to detect some kind of bread. In the return to anthill, the ant deposits an amount of pheromone on the trail. Thus, other ants will be able to utilize this pheromone trail to find the leftover food. Then, the pheromone amount will be increased. However, in the course of time, if the trail is not utilized, the trail pheromone will be evaporated gradually.

The HOPNET algorithm also involves characteristics of *Zone Routing Protocol* (ZRP), a hybrid protocol which combines benefits of proactive and reactive protocols [6]. In ZRP, the network is divided into zones and each node maintains a proactive routing table for nodes in its zone. The reactive routing occurs for nodes which lies beyond its zone.

Routing protocols based on ACO are usually able to find the shortest route between two nodes in an ad hoc network. They also can efficiently maintain updated the routing table due to the proportionate dynamism by ability of ants to detect changes in the network topology. Besides, the ZRP purpose is to reduce the control overhead of proactive routing protocols and the latency of reactive routing protocols. This is an important feature in the HOPNET algorithm.

Its route discovery occurs by intrazone and interzone routing. In intrazone routing, each node periodically sends an ant in order to maintain the intrazone routing table updated. When the source node wishes to transmit a data packet to a node within its zone, the packet travels the trail pheromone. Figs. 1-2 shows this behavior of route discovery.

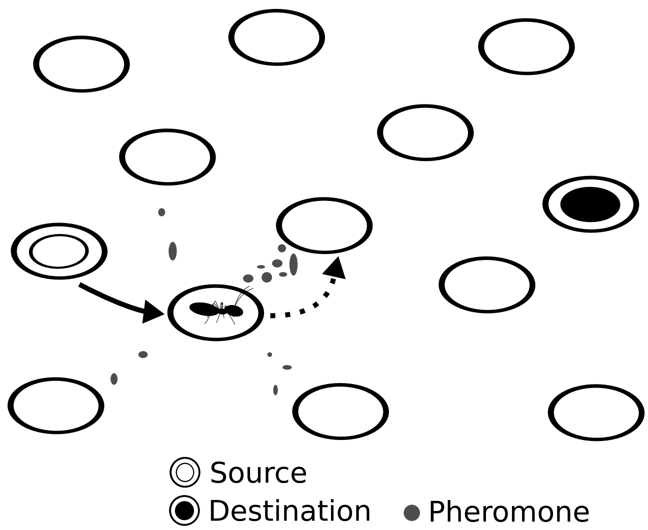

Fig. 1. Route Discovery (a)

In Fig. 1, at the current node, the ant verifies the pheromone amount for each neighbor which has a route to destination. The neighbor which has the biggest pheromone amount is chosen to receive the data packet.

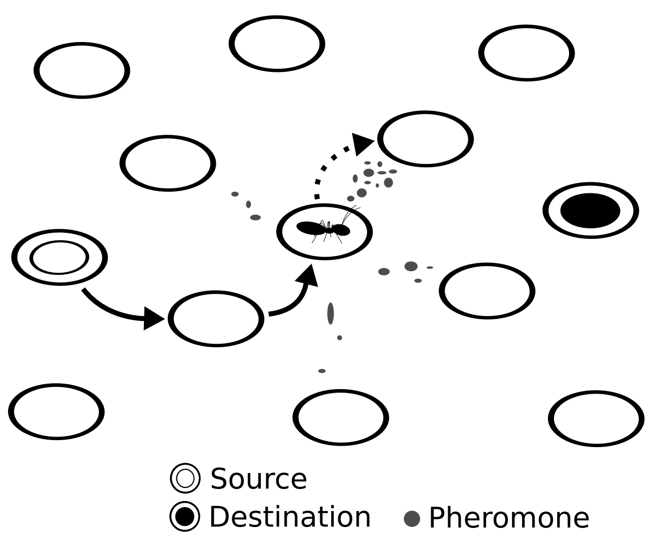

Fig. 2. Route Discovery (b)

In Fig. 2, this process occurs again. The entire process repeats until the data packet arrives at the destination node.

In interzone routing, the pheromone deposit on a trail is nonexistent. When some node wishes to send a data packet to a destination node, it verifies the interzone routing table to discover an existent route. If the route exists, then the node merely transmits the data packet. Otherwise, the node starts a search process to find a new path to destination.

Despite the pheromone does not contribute to route discovery in interzone routing, this ants can still lay down pheromone on some trails. When a source node wishes to transmit a data packet to a node beyond its zone, the border nodes from its zone transmit an ant to localize the destination. These ants hop between the border zones until an ant localizes a zone with the destination. This ant propagation through the border zones is called *bordercast*. When an ant achieve the destination, it will have a route from source to destination node, so, this discovered route returns to source node. After that, the data packet is transmitted.

III. Adapted HOPNET for WSN

A. Routing Table

The HOPNET algorithm has two routing tables, *Intrazone Routing Table* (IntraRT) and *Interzone Routing Table* (InterRT).

IntraRT is a routing table maintained proactively by HOPNET. Its goal is to map the deposit of pheromone on each node within its zone. InterRT is a responsible routing table for storing routes to a destination out of its zone. Therefore, when a route to an external node is reactively discovered, this route is stored in InterRT. After that, it can be used in a new transmission.

However, in order to reduce memory resources and to adapt the HOPNET algorithm in a WSN, the InterRT was excluded. Although the proposed algorithm does not have a InterRT, the absence of this table does not affect its behavior.

The main goal of InterRT is to store routes, so this routing table is verified when the node wishes to transmit a packet data to some external node. Actually, if the external node is not in the table like a destination but it is like a node inside of some existent route, then the InterRT have to be verified minutely in order to find a path to external node. That kind of problem does not happen in the IntraRT, because this table does not store the entire route. It just store an amount of pheromone to some destination node. Thus, if the used routing table is IntraRT instead of InterRT, then it is not necessary to have an entire route to a destination node. This advantage provides dynamic and efficient changes along the routes and can be applied to perform the interzone routing.

The IntraRT basic structure is a matrix whose rows are its neighbors and the columns are all identified nodes within its zone. It did not undergo structural changes in the proposed algorithm although the columns must support a bigger number of nodes.

B. Ant

An ant acts through functionalities like communication and routing table maintenance. Besides, it can determine the best route between either nodes in a network.

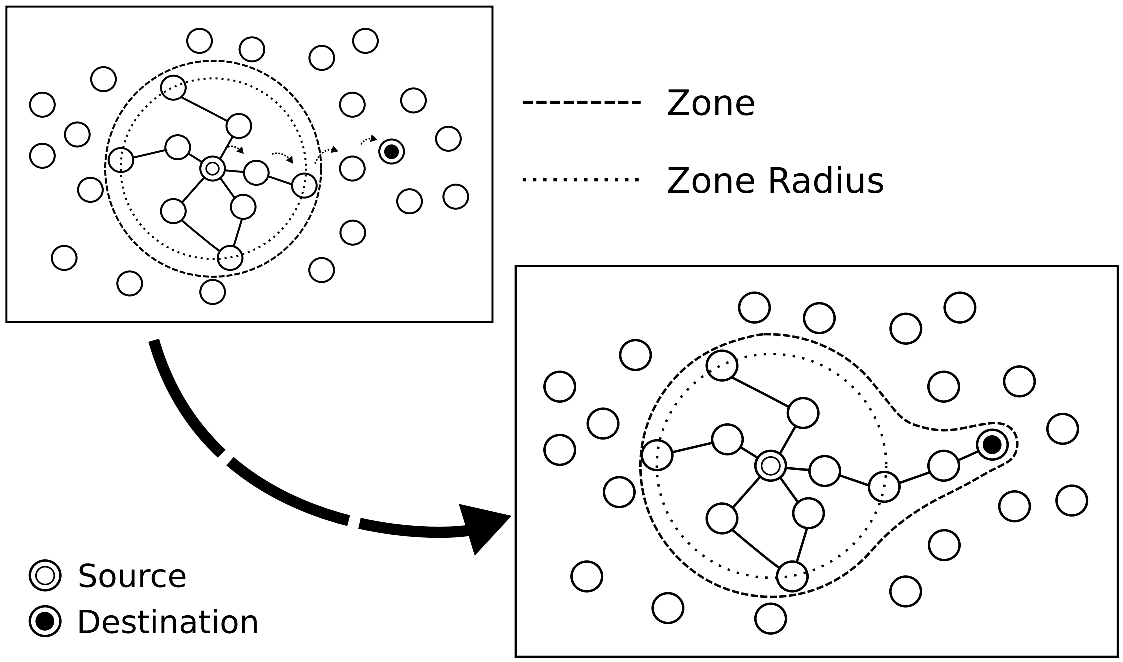

Fig. 3. Dynamic Zones

The defined ants in the HOPNET algorithm are classified in 5 types: *internal forward ant*, *external forward ant*, *backward ant*, *notification ant* and *error ant*. The internal forward ant is the responsible for maintaining the proactive routing table continuously within its zone. The external forward ant performs the reactive routing to nodes beyond its zone. When an external forward ant is received at the destination, it is converted to a backward ant and sent back along the discovered route. If a new route is reactively discovered, then a notification ant will be sent to source node and to all nodes on the route to update their reactive routing table. The error ant is utilized to warn some changes in the network topology and to restart a new search by the destination if the source still needs a route.

Nevertheless, these types of ants do not enough to adapt the HOPNET algorithm in a WSN. They need to be simpler and offer better tactics to diffuse and verify the pheromone by the WSN.

For instance, the transmission to an unknown node out of its zone would begin with a border node sending an external forward ant. Through bordercast, the ant would achieve the destination node. It would send back a backward ant to source node, and only after the reception of this ant the data would be sent to destination node.

Thereupon, new types of ants were defined: *internal forward ant* (IFA), *internal transport ant* (ITA) and *exploratory transport ant* (ETA). The IFA has the same goal as its correspondent ant in the HOPNET algorithm. That is, it is the responsible by maintaining the table updated and maintaining a large amount of pheromone to the best routes. Both transport ants perform the data delivery. But, the ITA is the responsible by delivering data packets into its zone while the ETA delivers to nodes beyond its zone or to a destination which is not known. The dissemination of the ETA is accomplished by *broadcast* and the ITA is accomplished by flooding into the zone.

Therefore, we can replace that complex process of transmission to an unknown node out of zone simply sending an ETA from source node.

Another factor to reduce the complexity is to define efficient manners to improve the movement of ants between the nodes. This new collection of ants has a means to obtain informations about the last visited node and the next node which will be visited. Thus, each ant can be able to move and to deposit pheromone efficiently without additional processing.

C. Route Discovery

In spite of changes over the ants and the routing table, the routing behavior was not affected, however, the manner in which routing occurs was affected. The behavior keeps on the same because the algorithm works on like an ant-based hybrid routing protocol and the route discovery is accomplished by the interzone and intrazone routing like ZRP.

Basically, the intrazone routing is almost the same. Each node sends a IFA periodically to its zone. These events allow to maintain updated the routing table within the limits determined by zone radius. In this proposed algorithm the data delivery is accomplished by a transport ant. Thus, the pheromone deposit can be accomplished by all types of ants within zones. That is, when an ITA or ETA transports the data packet, in the meantime, it deposits the pheromone on the trail which it travels.

However, the main change occurs in the interzone routing. Without the InterRT, the IntraRT is responsible by stores the discovered routes by reactive routing. This process starts with the transmission of an ETA which will be able to find the destination node and its route. Fig. 3 shows when a new route is discovered and introduced in IntraRT, then this route become part of source node zone. Actually, the route is not introduced in IntraRT. This routing table just denotes the next step to the destination. However, the zone radius keeps the same size in order to prevent IFA escape. Thus, the nodes within its zone radius are maintained proactively while the other nodes within its zone and out of zone radius are maintained on demand.

By the way, when a source node wishes to transmit a data packet, the first delivery will be performed by the ETA, and the following transmissions will be performed by ITAs while all pheromone amount do not evaporate. Due to that, the algorithm avoids many broadcast transmissions because ITA transmits only over its source node zone unlike ETA. Therefore, we compensate loss of InterRT with dynamic routing zones.

When a route to an external destination becomes part of zone, the zone changes its shape. That can be noticed in Fig. 3. So, this behavior cased by shape changes of zones determines a dynamic routing zone.

IV. Conclusion

In this paper, we have present an adaptation of the HOPNET algorithm in a WSNs. Our adapted routing algorithm proved to be able to run in a real sensor network environment. The most important change in the HOPNET algorithm was the removal of InterRT which allowed to obtain some benefits. The algorithm becomes more simple and efficient in terms of data packet transmissions and pheromone diffusion. The messages exchanged between the nodes was reduced, mainly when the destination is out of zone and its route is unknown. We obtain a new manner of perform the routing with just one table through a routing using dynamic zones. These dynamic zones allow us to improve the routing and to avoid the necessity of an interzone routing table. We are planning to improve the evaluation of our proposed algorithm in order to compare measures with other routing algorithms for WSNs. We will also simulate our proposed algorithm on GloMoSim for the purpose of comparing with the HOPNET algorithm.

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