Utilizing Social Insect-Based Communities for Routing in Network-based Sensor Systems

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ABSTRACT

The emergence of new technologies such as Internet/Web/Network-of-Things and large scale wireless sensor systems requires the collection of data from an increasing volume of networked-based sensors for analysis. This increases the challenge of routing in network-based sensor systems. This paper presents a study to utilize social insect-based communities for routing in wireless sensor networks. The authors will use for discussion two types of insects: ants and termites. Social insect communities are formed from simple, autonomous and cooperative organisms that are interdependent for their survival. These communities are able to effectively coordinate themselves to achieve global objectives despite a lack of centralized planning. The performances of these insect-based algorithms were tested on common routing scenarios. The results were compared with other routing algorithms with varying network density and showed that insect-based routing techniques improved on network energy consumption with a control over best-effort service.

KEYWORDS

Insect-based Algorithm, Routing, Swarm Intelligence, Wireless Sensor Network

INTRODUCTION

Social insect communities are formed from simple, autonomous and cooperative organisms that are able to effectively coordinate themselves to achieve global objectives despite a lack of centralized planning. This paper focuses on simulating insect-based behaviours in their colony for the problem of routing in wireless sensor networks (WSNs). A WSN is a distributed infrastructure composed of a large collection of nodes with the ability to instrument and react to events and phenomena in a specific environment (Saleem et al., 2010; Zungeru et al., 2011; Zungeru et al., 2012b; Zungeru et al., 2012c; Sardar et al., 2014; Sensarma et al., 2012; Akyildiz et al., 2002). WSNs are collections of compact-size, relatively inexpensive computational nodes that measure local environmental conditions or other parameters and relay the information to a central point for appropriate processing using wireless communications. Each sensor node is equipped with embedded processors, sensor devices, storage devices and radio transceivers. The critical factor in the design of WSNs is to maximize the lifetime of the sensor nodes which are battery-powered and have a limited energy supply. A key element that determines the lifetime in a WSN is the way that information is transmitted or routed to a destination node (called sink). A node with information to send to the sink does not transmit the information directly to the sink (single-hop network) (a situation when the sink is not a neighbor of
the source node) because this will require a very high transmission power. Rather, the node sends the information to a neighbouring node which is closer to the sink which in turn sends to its neighbour and so on until the information arrives at the sink (multi-hop network). This process is known as routing. An important problem in WSN is how to design a routing protocol which is not only energy efficient, scalable, robust and adaptable, but also provides the same or better performance than that of existing state-of-the-art routing protocols.

On the one hand, insects are relatively simple creatures. Their small size and small number of neurons makes them incapable of dealing with complex tasks individually. On the other hand, the insect colony can be seen as an intelligent entity for its high level of self-organization and the complexity of tasks it can perform to achieve global objectives despite a lack of centralized planning and direct communications. One way insects communicate is by secreting chemical agents that will be recognized by receptors on the bodies of other insects. One of the most important of such chemical agents is the pheromone. Pheromones are molecules released from glands on the insect body. Once deposited on the ground they start to evaporate, releasing the chemical agent into the air. Individual insects leave a trail of such scents, which stimulates other insects to follow that trail, dropping pheromones while doing so (Matthews & Mattheus, 1942). This use of the environment as a medium for indirect communication is called stigmergy. This process will continue until a trail from the colony to the food source is established. While following very basic instincts, insects accomplish complex tasks for their colonies in a demonstration of emergent behaviour. In the foraging example, one of the characteristics of the pheromone trail is that it is highly optimized, tending toward the shortest path between the food source and the insect nest. This trail creation with the shortest distance from the nest to the food source is a side effect of their behaviour, which is not something they have as an a priori goal.

In this paper, we will focus on how insect colonies use pheromone trails to accomplish complex tasks and show the similarity between the colony behaviors and WSNs. The behaviors which accomplish these tasks are emergent from much simpler behaviors or rules that the individuals are following. In this approach, insect agents are modeled to suit the energy resource constraints in WSNs for the purpose of finding the best paths between sites as a function of the number of visited nodes and the energy of the path. Since communication is an energy expensive function, given a network and a source-destination pair, the problem is to route a packet from the source to the destination node using a minimum number of nodes, low energy, and limited memory space so as to save energy. This implies that when designing a routing protocol for WSN, it is important to consider the path length as well as the energy of the path along which the packet is to traverse before its arrival at the sink, while also maintaining low memory usage at the network nodes. The remainder of this paper is organized as follows. The next section discusses related work and current research findings for artificial insect-based routing algorithms for WSNs followed by ant and termite-based techniques for routing. The paper concludes with performance evaluations with other routing protocols, and comments for future work.

**ARTIFICIAL INSECT-BASED ROUTING ALGORITHMS IN WSN**

Researchers have successfully applied ant-based algorithms to the solutions of difficult combinatorial problems such as the travelling salesman problem and the job scheduling problem (Dorigo et al., 1999). In (Ramos & Almeida, 2000) and (Semet et al., 2004), the ant colony approach is used to perform image segmentation. Heusse et al. (1998) and Merloti (2004) applied the concepts of ant colonies on routing of network packages. The basic ant-based routing algorithm and its main characteristics (Dorigo & Cara, 1998) can be summarized into the following steps:
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