Information Sciences 192 (2012) 204–212

Contents lists available at ScienceDirect

Information Sciences

journal homepage: www.elsevier.com/locate/ins

A ladder diffusion algorithm using ant colony optimization for wireless sensor networks

Jiun-Huei Ho [a,*], Hong-Chi Shih [b], Bin-Yih Liao [b], Shu-Chuan Chu [c]

[a] Department of Computer Science and Information Engineering, Cheng Shiu University, 840 Chengcing Road, Niaosong Township, Kaohsiung County 83347, Taiwan
[b] Department of Electronic Engineering, National Kaohsiung University of Applied Sciences, 415 Chien Kung Road, Sanmin District, Kaohsiung 80778, Taiwan
[c] Department of Information Management, Cheng Shiu University, 840 Chengcing Road, Niaosong Township, Kaohsiung County 83347, Taiwan

ARTICLE INFO

Article history:
Available online 7 April 2011

ABSTRACT

In this paper, an algorithm based on ladder diffusion and ACO [5,6] is proposed to solve the power consumption and transmission routing problems in wireless sensor networks. The proposed ladder diffusion algorithm is employed to route paths for data relay and transmission in wireless sensor networks, reducing both power consumption and processing time to build the routing table and simultaneously avoiding the generation of circle routes. Moreover, to ensure the safety and reliability of data transmission, our algorithm provides backup routes to avoid wasted power and processing time when rebuilding the routing table in case part of sensor nodes are missing.

According to the experimental results, the proposed algorithm not only reduces power consumption by 52.36% but also increases data forwarding efficiency by 61.11% as compared to the directed diffusion algorithm. This decrease is because the algorithm properly assigns the transmission routes to balance the load on every sensor node.

1. Introduction

Recent advances in micro-processing, wireless and battery technology, and new smart sensors have enhanced data processing, wireless communication, and detecting capability. Wireless sensor networks consist of many sensor nodes that contain environmental sensing devices for movement, temperature, humidity, exhaust gas, and so on, which are distributed over an area to measure various characteristics of that region. Each sensor node also has limited wireless computational power to process and transfer the sensing live data to the base station or data collection center.

In general, each sensor node has a low level of power, and its battery power cannot be replenished. If the energy of a sensor node is exhausted, wireless sensor network leaks will appear, and failure nodes will not relay data to the other nodes during transmission processing. Thus, other sensor nodes will be increasingly burdened with transmission processing. Given these issues, energy consumption in wireless sensor networks is an important research issue.

This paper proposes a ladder diffusion (LD) algorithm to map out the data relay routes in wireless sensor nodes. The algorithm focuses on balancing the data transmission load, increasing the lifetime of sensor nodes and their transmission efficiency. This study evaluates the performance of this algorithm for random wireless sensor networks with regard to the number of sensor nodes and relay hops required for data collection. The evaluation results show that the LD algorithm can effectively solve the problems related to routing and energy consumption for wireless sensor networks.

* Corresponding author. Tel.: +886 7 7310606; fax: +886 7 7332385.
E-mail address: jhho@mail.csu.edu.tw (J.-H. Ho).

doi:10.1016/j.ins.2011.03.013

2. Related work

In this section, the ad hoc on-demand distance vector (AODV), directed diffusion (DD) and ant colony optimization (ACO) methods are discussed.

2.1. Ad-hoc on-demand distance vector (AODV)

Several routing algorithms for wireless sensor networks have been proposed in recent years [1,2,7–10,12–14]. One of the on-demand type algorithms, namely, the ad-hoc on-demand distance vector (AODV) algorithm [2,9,13], has become a particularly popular algorithm.

The AODV was proposed by Perkins and Royer in 1999 [13]. Some researchers have applied the AODV algorithm in fixed and mobile wireless sensor networks. The AODV algorithm employs three processes: route request, route replying and route maintenance, to build and maintain the routes required by active nodes for data transmission. First of all, the sensor node, which sends the collected data to the sink node, sends a signal to explore the route from itself to the sink node. This signal is forwarded by other sensor nodes and is received by the sink node. Once the signal passes through a sensor node, the sensor node records the consigner and the receiver in a table, and hence, the routing table is created from the terminal node to the sink node when the signal reaches the sink node. The sensor nodes that are not en route from the terminal node to the sink node do not create the routing table since this table is independent of those nodes. Hence, the AODV algorithm reduces power consumption with respect to the overhead control. Furthermore, the AODV algorithm provides a time-out parameter for updating the routing table. The idle route is deleted after a period of time. If the sensor node that deleted the route begins to transmit data, the routing table is rebuilt again.

Nevertheless, the AODV algorithm still can be improved. Since the locations of the sensor nodes are not moved and the built routing table is only a small part of the entire wireless sensor network, rebuilding the routing table for the deleted routes results in wasted power consumption.

2.2. The directed diffusion (DD)

C. Intanagonwiwat et al. [8] introduced the directed diffusion (DD) protocol in 2003. DD aims to reduce the data relay in order to better manage power consumption. Basically, DD is a query-driven transmission protocol. The collected data are transmitted only if they fit the query from the sink node, thereby reducing the power consumption due to data transmission. First, the sink node provides interested queries in the form of attribute-value pairs to the other sensor nodes by broadcasting the interested query packets to the entire network. Subsequently, the sensor nodes only send the collected data back to the sink node in case they fits the interested queries.

In DD, all sensor nodes are bound into a route when broadcasting the interested queries, even if the route is such that it will never be used. In addition, several circle routes, which are built simultaneously when broadcasting the queries, result in wasted power consumption and storage. In the real world, the number of the sensor nodes in a system is in the hundreds or even thousands. The waste of power consumption and storage becomes worse with larger-sized systems, and the circle route problem also becomes more serious.

In this paper, we propose an algorithm based on the ladder diffusion and ACO to reduce both power consumption and processing time needed to build the routing table while simultaneously avoiding the generation of circle routes. Moreover, to ensure the safety and reliability of the transmitted data, the ladder diffusion algorithm provides the back-up routes to avoid wasted power consumption and processing time when rebuilding the routing table in the case that part of a sensor node is out of function. Details of the proposed algorithm are presented in Section 3.

2.3. Ant colony optimization (ACO)

Dorigo et al. [3–6,11] proposed ACO in 1997, which imitates the behavior of ant colonies as ants search for the shortest path from their nest to the food source. The method was developed to solve the traveling salesman problem (TSP). Three key features of ACO are as follows: (1) Ants tend toward the path left higher pheromone. (2) The pheromone is speedily accumulated in the shorter path. (3) Ants communicate indirectly in pheromone.

In this paper, we modify ACO and integrate ladder diffusion to model node routing for sensor networks. The proposed routing algorithm equally distributes the transferring load to each node using ACO. By applying ladder diffusion, routing can avoid the generation of cycles. The simulation results indicate that the algorithm effectively reduces the power consumption involved in routing and extends the life cycle of the wireless sensor nodes. Further details are presented in Section 3.2.

3. The ladder diffusion algorithm

In this section, details on our proposed ladder diffusion algorithm that with ladder diffusion with ACO in order to minimize power consumption are presented.