Ant Colony Optimization and Data Centric Routing Approach for Sensor Networks

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요 약

최근 센서 네트워크 기술 발전은 효과적인 라우팅 방법 개발로 부터 시작되었으며, 라우팅 프로토콜이 응용프로그램이나 네트워크 아키텍처에 의존적이라는 차이 때문에 라우팅 프로토콜은 많은 주의를 요한다. 빠른 환경 변화와 능동적인 네트워크 구조의 특징은 효과적인 라우팅과 에너지 소비에 매우 치명적이다. 센서 네트워크는 에너지 소비라는 부분에서 전통적인 네트워크와는 다르며, 따라서 데이터 중심적인 기술들은 효율적인 에너지 보급을 위하여 라우팅을 실행하곤 한다. 본 논문에서는 네트워크 라우팅에서 ant colony 최적화 기술과 전송 데이터 구성을 위한 데이터 집중 라우팅 능력 등 두 가지 이점을 이용하여 효율적인 자율 센서 네트워크 구축방법을 제시한다.

ABSTRACT

Recent advances in sensor network technology have open up challenges for its effective routing. Routing protocol receives most of the attention because routing protocols might differ depending on the application and network architecture. In the rapidly changing environment and dynamic nature of network formation, efficient routing and energy consumption are very crucial. Sensor networks differ from the traditional networks in terms of energy consumption. Thus, data-centric technologies should be used to perform routing to yield an energy-efficient dissemination. By exploiting the advantages of both ant colony optimization techniques in network routing and the ability of data centric routing to organize data for delivery, our approach will cover features for building an efficient autonomous sensor network.

키워드

Ant colony optimization, data centric routing, sensor networks

Ⅰ. INTRODUCTION

Ant colony optimization (ACO) is the acquisition of routing information through path sampling using ant agents. An ant agent is capable of solving various kinds of routing and congestion problems in networking by continuously modifying routing tables in responseto congestion. Related researches [2][3][4][5][6]had extensively implemented ACO algorithm in network routing but it is only limited to mobile ad hoc networks or traditional network environment where power consumption is not a significant limitation. Since ACO can be computationally expensive, it might not be applicable to sensor network directly but ant colony algorithms have the potential of providing a formal basis upon to develop an effective framework for routing optimization in sensor networks. The end-to-end routing

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schemes that have been proposed in the literature for mobile-ad-hoc networks are not appropriate for sensor network as well. Instead of end-to-end routing, data-centric routing have been studied extensively and claimed to be a particularly useful paradigm for wireless routing in sensor networks. The idea is to combine the data coming from different sources be aggregated at intermediate nodes thereby eliminating redundancy, minimizing the number of transmissions and to allowenergy-efficient communication by abstracting the physical location of data. We do not propose any new protocols in this paper, but rather attempt to address at a higher level gains that can be achieved by using the ACO algorithm and data-centric approach routing.

This paper will cover ACO related researches for network routing in section II, background information on Ant Colony Optimization algorithm and Data-Centric Routing in Section III, and lastly a description of joint optimization scheme of ACO routing and Data-Centric Routing that we proposed.

II. RELATED RESEARCH

2.1 Multiple Ant-Colony Optimization (MACO)

In general, the Ant Colony Optimization (ACO) algorithm suffers from two issues which are stagnation and adaptiveness. Stagnation occurs when a network is converged and the path is continuously chosen by the ant agent where it is an optimal path. This leads to network congestion of the particular path and the probability of selecting other paths is dramatically reduced. The second issue is adaptiveness. It refers to the degree of sensitivity of network dynamics. Thus, the main contribution of the paper is to reduce stagnation and to promote adaptiveness.

Table. 1 . Comparisons between classic routing algorithms and ANT algorithms. [2]

	Routing Algorithms	ANT algorithms
Building Routing Preference	By Transmission time/ delay	By pheromone laid
Routing information exchanges	Separate routing entries transmission	Can be piggybacked in data packets
Adaptive to topology changes	Slow	Fast
Routing overhead	High	Low
Routing control	Centralized/ static	Decentralize/ adaptive

Instead of one colony, multiple ant-colony optimization (MACO) [2] approach for network routing is proposed. As a result, adaptiveness is enhanced and stagnation is reduced due to the increased probability of finding a better path. Hence, MACO can be used to solve the load-balancing problem in a circuit-switched network.

2.2 AntNet

Gianni Di Caro and Marco Dorigo introduced a new algorithm for communications networks which is adaptive, distributed and mobile-agents-based algorithm named AntNet [4]. The ant packets in AntNet are the control packets for the whole algorithm. Packets are forwarded based on next-hop probabilities and each of the ants will discover and maintains the routes. The Forward and Backward ants are used to establish explicit test and feedback signal. AntNet algorithm had been experimented and has been concluded that it has the best distribution of packet delays compare with other algorithms. It also shows an excellent performance of adaptiveness and robustness.

2.3 AntHocNet

AntHocNet [6] is an Ant Colony Optimization algorithm for routing in mobile and ad hoc networks. AntHocNet introduces a proactive component inside the algorithm to obtain efficient and reliable process. In the algorithm, a forward ant is broadcasted by the source to finds multiple paths to the destination. Meanwhile a backward ant will travel back to the source and establishes a path towards the destination by updating the entries in the routing table. For load balancing, data packets are forwarded probabilistically over available links after the route setup phase. AntHocNet had been compared with AODV and AntHocNet outperformed in terms of delivery ratio, average delay and jitter without causing much more overhead.

III. BACKGROUND

3.1 Sensor Network Routing

Sensor Network is differs from traditional network in a number of ways. The primary goal in a sensor network is to efficiently establish routes between nodes dynamically due to the random movement of nodes. If there is any node that either join or leave the network the network must adapt accordingly. Hence, fast convergence between sensor nodes is very much favorable. A typical mode of communication in a sensor network is from multiple data sources to a data recipient/sink rather than communication between any pair of nodes. Since the data being collected by multiple sensors is based on common phenomena, there is likely to be some redundancy in the data being communicated by the various sources in sensor networks. Besides, the single major resource constraint in sensor networks is that of energy. The scale of sensor networks and the necessity of unattended operation for months at a time mean that energy resources have to be managed even more carefully.

With these factors in mind, the key parameters to adhere to are effective routing and energy consumption. In order to successfully discover and deliver the packet from the source to the destination, ACO algorithm is adapted in sensor network environment. We are also well aware of energy limitation in network nodes. Despite adaptive routing that can be achieved by ACO, data-centric routing can minimize the energy consumption of the individual nodes.

3.2 Ant Colony Optimization

Ants live in colonies and have their very unique way of social interaction. Ants interact with one another using a simple form of indirect communication mediated by pheromone secretion. Inspired by the behavior of ants in finding paths from the colony to food, ant colony algorithm is modeled as a heuristics for path based optimization. This cooperative activity of the ants is a phenomenon that is known as swarm intelligence. A colony of ants wanders randomly, laying down pheromone trails upon finding food. The chemical substances (pheromone) that have been laid down on the trails become guidance to other ants to follow certain trails and not wander about randomly. This feedback mechanism implies that when ants trace out a path from their nest to a food, the shorter path is more likely to be followed by the ants since pheromone rate at the shorter path accumulates at a faster speed. Over time the pheromone trails start to evaporate, reducing its strength and this actually helps to avoid the convergence to a locally optimal solution. The exploration of the solution space would be constrained without this phenomenon.

3.3 Data Centric Routing

When a source trying to send data to a sink, routing nodes will enroute by looking at the content of the data and perform data aggregation on multiple source nodes. As illustrated by the figure below, the data from the two sources is aggregated at node B and combined before it is sent from B to sink. In some sensor network environment, sensor tends to send identical information that is considered complete redundancy. If data aggregation cannot be performed, additional transmission task will be performed for transmitting data from source A to sink through node A. By aggregating information coming from multiple sources results in energy savings as fewer transmissions are required.

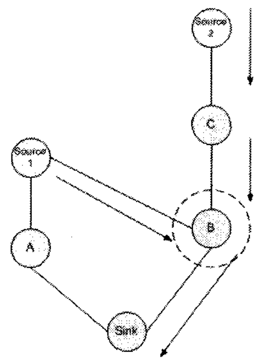

Fig. 1 Data Centric Routing

Ⅳ. ANT COLONY AND DATA-CENTRIC ROUTING IN SENSOR NETWORK

4.1 Description of ACO algorithm

ACO algorithm proactively generates ant agents in the network. An ant will faithfully simulate a data packet to discover, sample a good path and update routing information in sensor nodes. Each ant is a simple agent which chooses the destination to go to with a probability that is a function of the distance and of the amount of pheromone present on the connecting edge. Routing in sensor networks can be formalized as follows. Assume that the network is represented by a graph G= (V, E), where V is the set of nodes and E is the set of edges. To force the ant to make legal tours, transitions to already visited nodes are disallowed until a tour is complete. When it completes a tour, it lays a substance called pheromone on each edge Eij visited.

Pheromone intensity is updated following the completion of each algorithm cycle, at which time every ant will have completed a tour. Each ant subsequently deposits pheromone of quantity Q/Lk on every edge Eij visited in its individual tour. The sum of all newly deposited pheromone on trial is denoted by $\Delta\ \tau ij$.

Following pheromone deposition by all ants, the trail value is updated using $\tau ij(t + n) = p \times \tau ij(t) + \Delta\ \tau ij$, where p is the rate of trail decay per time interval.

There are two factors drive the probabilistic model:

1) Visibility, denoted ηij, equals the quantity 1/di

2) Trail, denoted $\tau ij(t)$

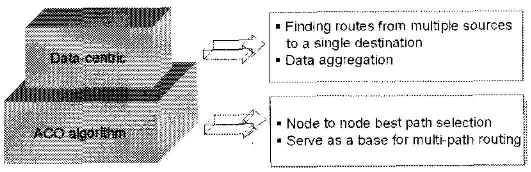

Fig. 2 ACO and data-centric routing approach

These two factors play an essential role in the central probabilistic transition function of the Ant System. In return, the weight of either factor in the transition function is controlled by the variables α and β, respectively. Significant study has been undertaken by researchers to derive optimal α:β combinations.

Probabilistic Transition Function

$$P_{ij}^{k}(t) = \begin{cases} \dfrac{\lfloor \tau_{ij}(t) \rfloor^{\alpha} \cdot [\eta_{ij}]^{\beta}}{\sum_{l \in allowed_k} \lfloor \tau_{ij}(t) \rfloor^{\alpha} \cdot [\eta_{ij}]^{\beta}} & if l \in allowed_k \\ 0 & otherwise \end{cases}$$

A high value for α means that trail is very important and therefore ants tend to choose edges chosen by other ants in the past. On the whole, the ANT algorithm will go through idealization phase, placing ants, build tours, deposit trail, update trail to build to make routing decisions.

4.2 Data Centric Routing

In Multi-source, Single-destination Data-Centric routing, there exist a set of source sensors and a single-destination node. For example, the destination may be interested in a particular phenomenon and a set of sensors in the vicinity or related to this phenomenon may subsequently send information to this sink. In this case, all sensors are assumed to be sending the same information. Data can be aggregated at intermediate nodes and duplicate data can be suppressed hence power consumption can be saved. All in all, ACO can perform node to node best path selection and later on serve as a base for multi-path routing. Many variants of ant systems have been proposed on giving solutions to shortest-path problem however sensor network routing need fairly more than this. By incorporating data aggregation paradigm, multiple sources routing and some forms of consolidation function can be performed and thus building efficient routing model in the constrained environment.

V. CONCLUSIONS

We have tried to understand the rationale behind the brilliant performance achieved by ANT algorithm and discuss the reasons of the general efficacy of the ACO approach for network routing as compared to classical routing. Lastly, we have informally presented our idea that is to exploit both ACO routing and data-centric routing advantages to be implemented on wireless sensor nodes. The approach tries to optimize routing by finding their best shortest path and optimize energy consumption by data-centric routing. This algorithm has a lot of scope for future improvements and extensive testing needs to be performed to verify the comparison of this algorithm with de-facto routing algorithms.

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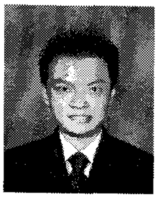

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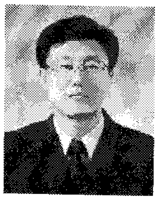

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