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IERI Procedia 10 (2014) 2 – 10
Procedia IERI
www.elsevier.com/locate/procedia

2014 International Conference on Future Information Engineering

Adaptive Clustering Based Dynamic Routing of Wireless Sensor Networks via Generalized Ant Colony Optimization

Zhengmao Ye [a], Habib Mohamadian [a]

[a] *College of Engineering, Southern University, Baton Rouge, LA 70813, USA* *

Abstract

Wireless sensor networks (WSNs) use battery-powered sensor nodes for sensing, thus the energy efficiency is critical to extend the lifespan. The performance depends on the trade-off among energy consumption, latency and reliability. Data aggregation is a fundamental approach to eliminate redundancy and minimize transmission cost so as to save energy. Dynamic clustering based routing is proposed to achieve good performance via adaptive algorithms. The generalized Ant Colony Optimization (ACO) is applied to increase the reliable lifespan of sensor nodes with energy constraints. Each sensor node is modeled as an artificial ant and dynamic routing is modeled as ant foraging. The ant pheromone is released when an energy efficient channel from the source to sink is secured. Route discovery, data aggregation and information loss are modeled as the processes of pheromone diffusion, accumulation and evaporation. Each sensor node estimates the residual energy and dynamically calculates probabilities to select an optimal channel to extend the lifespan of WSNs.

Keywords: Wireless Sensor Networks; Ant Colony Optimization; Data Aggregation; Adaptive Rule; Clustering Based Dynamic Routing.

1. Introduction

Contrary to classical networks, the structure of wireless sensor networks encompasses numerous small or tiny battery powered autonomous devices, serving as the sensor nodes. Each node relies on the wireless channels for transmitting and receiving data with other nodes.

* Corresponding author. Tel.: +01-225-771-4073; fax: +01-225-771-0016.
E-mail address: zhengmao_ye@subr.edu

doi:10.1016/j.ieri.2014.09.063

Adaptive protocols are needed since the WSNs differ in the network densities, from sparse to dense deployments. The combination of computing, sensing and communication technologies makes it possible for compact design. With dense deployment, broadcasting by flooding leads to information redundancy. It gives rise to applications of adaptive routing schemes [1]. WSNs encounter typical challenges, such as interference, security, scalability and handoffs. With respect to an example of wireless cellular networks, despite of the fact that voice and data transmission speed is gradually increasing, optimal distribution of energy consumption remains a tough challenge. The power control strategy based on Signal to Interference plus Noise Ratio (SINR) balancing is necessary to minimize energy consumption and optimize power control in cellular networks to achieve best energy distribution. The energy of the sensor nodes mainly consists of transmission energy and overhead energy, while the transmission energy is subject to attenuation and fading with respect to distance and frequency, which also differs between single-path and multi-path propagation [2]. Optimization of transmission energy consumption is designed to maximize the network lifetime with each single layer. Simplifications are made to decouple layers and maximize the network lifetime. The approach is extended to cross-layer optimization of time division multiple access WSNs with an arbitrary degree of accuracy and efficiency. Numerical examples illustrate benefits of the cross-layer design [3]. Energy efficiency is critical to extend network lifetime. The energy wasted by redundant sensors can be reduced by sensor mode switching, but frequent alteration has negative effect on reliability. Ant colony optimization is proposed to obtain the maximum reliable sensor working periods. The minimum sensor working period is restricted before mode changing. The proposed algorithm enhances scheduling reliability of WSNs [4]. WSN data aggregation is an important technique for data collection which improves the energy efficiency, alleviates data redundancy and reduces congestive routing traffic in message transmission. Ant colony aggregation is also proposed to provide an intrinsic way of exploring the search space to optimize settings for optimal data aggregation. The algorithm yields longer maximum lifetime and better scalability with the same hop-count delay [5]. An artificial ant colony is applied to the distributed sensor wakeup control in WSNs to accomplish both surveillance and target tracking. Communication, invalidation and fusion of target information are modeled as pheromone diffusion, loss, and accumulation. The advantages include that no requirement of cluster leaders, robustness to false alarms, and no need of actual node position [6]. The ACO for data aggregation consists of 3 phases of initialization, transmission and operation. In transmission, each sensor node estimates the remaining energy and pheromone amount of neighbors to dynamically select the next hop. After transmissions, the pheromones are adjusted in terms of global and local merits for evaporating or depositing. It shows high superiority on efficiency in energy constrained WSNs. It also benefits to the network lifetime, computation complexity and success ratio of one hop transmission [7]. Sensor nodes in dense networks generate redundant information, so data aggregation should be conducted to save energy. Packets of diverse applications are unlikely aggregated by heterogenous sensors, thus static routing protocols are substituted by dynamic routing protocols, since the spatial isolation caused by static routing is unfavorable to data aggregation. Attribute-aware data aggregation is introduced to enhance efficiency. Inspired by potential in physics and pheromone in ant colony, dynamic routing is elaborated where the packets of same attribute are made spatially convergent. It is also scalable with respect to network size and adaptable to mobile tracking mobile [8]. A novel clustering based data collection scheme is applied with direct sink access to evaluate performance in terms of energy consumption, latency, and robustness. With joint effect of clustering and data correlation, cluster heads use low overhead and simple medium access control. Since data are collected periodically where the packet arrival is not a continuous random process, the framework is based on transient analysis rather than steady state analysis. Extensive simulations with various protocol parameters show that is is fairly accurate across a wide range of parameters. Despite the trade-off between energy consumption and latency, both can be substantially reduced by proper clustering design [9]. In this work, adaptive schemes using generalized Ant Colony Optimization will be applied to clustering based dynamic routing of WSNs.