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An Energy Efficient Network Coding Model For Wireless Sensor Networks

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Abstract

Energy efficiency techniques is a important subject for Wireless Sensor Networks (WSNs), that have received extensive attention from academic and industrial societies to reduce energy consumption and improve network lifetime. The network coding methods is one of the techniques that can help to improve some issues of WSNs such as load balancing, reliability and lifetime. This paper proposes a coding solution as an algorithm for reducing energy consumption in WSNs to prolong the lifetime. Simulation results show that the proposed algorithm increases network throughput and energy efficiency.

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Keywords: Network coding, Wireless Sensor Network, Energy efficiency, Transmission range, Multi-cast, Lifetime.

1. Introduction

Wireless sensor networks (WSNs) made up of many small, inexpensive distributed sensor nodes. WSNs are important for a number of pervasive applications such as target detection, surveillance, and localization. The sensors are often powered by battery, and energy-efficient operations are critical to prolong the lifetime of the connections. Designing an energy-efficient and maximizing the lifetime of such networks is a challenging issue[1].

Network coding has emerged as a potentially powerful tool for the design of communication networks and has been widely studied since its introduction. Recently, network coding was emerged by wireless networks. However, in wireless network systems, intermediate nodes have a low complexity limit their network coding manipulations to the binary field, and as a result all coding operations are restricted to XOR-ing of bits. The establishment of a network-coding-based-multicast connection can be decomposed into two phases: routing (determining which links and how much bandwidth resource will be used) and coding solution construction (defining the operation function for each node on the selected multicast route)[2].

In this paper, at first, we present an energy-efficient algorithm for linear network coding coefficient selection in multicast networks. Then, we propose a solution to ensure that the sinks have the ability to decode data. Finally, our proposed algorithm is compared with the similar network coding scheme and routing without coding. In this comparison, parameters such as transmit

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power, number of nodes in network, and message interval is used. Simulation results show that our proposed algorithm has better performance compared with similar network coding scheme and routing without coding.
The rest of the paper is organized as follows: related work is studied in Section 2. Section 3 describes proposed algorithm, and performance evaluation is described in Section 4 and finally Section 5 shows conclusions and feature works.

2. Related Work

Ahlswede et al.showed that with network coding, a source can multicast information at a rate approaching the smallest minimum cut between the source and any receiver. Linear coding can be used for multicasting with rate and finite alphabet size [3]. Koetter and Médard[4, 5] give an elegant algebraic characterization of the linear coding schemes that achieve the max-flow min-cut bound. They show that finite fields (FFs) of size are sufficient and give a polynomial time algorithm to verify a given linear network coding scheme. However, their algorithm for constructing coding schemes involves checking a multivariate polynomial identity with an exponential number of coefficients.

The important issue of network code design is to select coding coefficients. A simple algorithm is to have each node in the network select uniformly at random the over the field $F2$s, in a completely independent and decentralized manner. With random network coding, there is a certain probability of selecting linearly dependent combinations [6].

It is shown that even for small field sizes this probability becomes slight[7]. However, deterministic algorithms to design network codes can be used. A polynomial-time algorithm for multicasting was proposed in [8], progressively check nodes of the network, and choose what linear combinations each node utilize. Since nodes use fixed linear coefficients, the message only need to move the information vector.

There also exist deterministic decentralized algorithms that apply to restricted families of network configurations [9].Authors of [10,11] study on the minimum-energy multicast trees. Their study of the problem of finding a set of relaying nodes and their respective power levels, such that all nodes in receiving the message, whereby the total energy consumption for the task is minimized.

However, the problem of constructing a minimum-energy multicast tree in a wireless ad-hoc network is NP-hard [10, 11].An important benefit of network coding is energy saving and throughput for a single multicast session in wireless networks. Author of [12, 13] investigate on the benefit of network coding in terms of reducing the number of transmissions of a broadcast session that achieve the factors of 2 and 4/3. They presented an energy-efficient algorithm for linear network coding coefficient selection in multicast networks and presented a solution to ensure that the sinks have the ability to decode data. Their proposed algorithm was compared with the similar network coding scheme and routing without coding. In this comparison, parameters such as transmit power, number of nodes in network, and message interval is used. Simulation results show that proposed algorithm has better performance compared with similar network coding scheme and routing without coding.

In [14], Khalily et al. stated a theoretical determination of the achievable maximum multi-cast-information flow for various topology control mechanisms. Their simulation results demonstrated topology control mechanisms decrease both energy consumption and maximum-information flow. Note, maximum multi-cast-information-flow can be obtained by network coding approach. Khalily et al. proposed a joint optimal design of topology control and network coding in [15]. They formulated the problem of topology control in network-coding-based-multi-cast WSN with the delay and reliability constraints as a non-convex-mixed-integer-nonlinear-optimization problem that was named OTRA. For obtaining an optimal solution of OTRA, there is no polynomial-time algorithm and it is NP-hard problem.

3. Network model and system definition

In this paper, a WSN was modeled by a directed graph $G(V, E)$, where V is the set of nodes and $E$is the set of links in G. Each message is an element of FF 2, Fq $=$ GF(q) and can be showed by a binary vector of length $n = log2(q)$ bits. Table 1 shows the notations that were utilized in this paper.

Table 1. Paper notations

Notation	Definition
$\boldsymbol{E_t}$	Set of arriving links of sink t.
$\boldsymbol{\lambda e', e}$	Local encoding coefficient.
$\boldsymbol{P_e}$	The message transmitted on each link e.
$\boldsymbol{\theta_e}$	Global encoding vector.
$\boldsymbol{\mu_t}$	Transmission matrix ($h \times h$).
$\boldsymbol{P}$	multiplication of the determinants of the transfer matrixes for every sink t.
$\boldsymbol{z}$	Adjacency matrix.
$\boldsymbol{w_i}$	Transmit power of each sending node of the multicast tree.
$\boldsymbol{Sum_w}$	The sum power of the multicast tree.
$\boldsymbol{d_{ij}}$	The distance between node i and node j.
$\boldsymbol{r_j}$	Signal to noise ratio (SNR) for node j.
$\boldsymbol{\alpha}$	The link attenuation coefficient with the value from 2 to 4.
$\boldsymbol{\omega_e}$	Set of arriving links in G of its tail node v.