Low-Complexity Distributed Encoding Scheme for Low-Density Parity-Check Codes in Wireless Sensor Networks

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Aim

This paper proposes a distributed image encoding scheme that uses low-density parity-check (LDPC) codes over an additive white Gaussian noise (AWGN) channel in wireless sensor networks (WSNs). In the scheme, the encoding task is divided into several small processing components, which are then distributed to multiple nodes in a cluster while considering their residual energy. We conduct extensive computational simulations to verify our methods and find that the proposed scheme not only solves the energy balance problem by sharing the processing tasks but also increases the quality of data by using LDPC codes.

Introduction

• Wireless sensor networks (WSNs) consist of the number of nodes. Each node has two functions: sensor and RF transceiver. These nodes use an ad-hoc protocol to communicate with each other and transfer data to the base station using multi-hop technology.

• Two methods to recover the lost data on WSNs are the automatic repeat request (ARQ) and forward error correction (FEC) methods.

• Since the demands for wireless multimedia applications have increased, the design of efficient communication system for progressive image transmission has recently attracted attention in many literatures [1], [3].

• Challenges in WSNs are: limited resource (i.e., power battery, bandwidth, processing capacities and memory) and low fidelity.

FEC Coding on WSNs

In the FEC conventional way, source nodes capture image data, perform FEC coding and send to the sink node. Since the data size are often large, the source nodes will exhaust their energy in the short time. Therefore, we need to distribute FEC coding task before sending data to the sink to balance energy consumption for nodes in WSNs.

Related Work

• The authors in [2] implemented FEC codes and found that the frequency of bit error was almost zero when the distance between a transceiver and a receiver was less than 10 m. They also show that Reed Solomon (RS) codes are difficult to implement on WSNs since the sensors have their limited resources (i.e., battery power, computational capacity, and memory).

• In [3], Sartipi et al. used low-density parity-check (LDPC) codes for FEC codes, and they showed that LDPC codes improved not only energy efficiency but also the data compression rate compared to Bose and Ray-Chaudhuri (BCH) codes and convolutional codes.

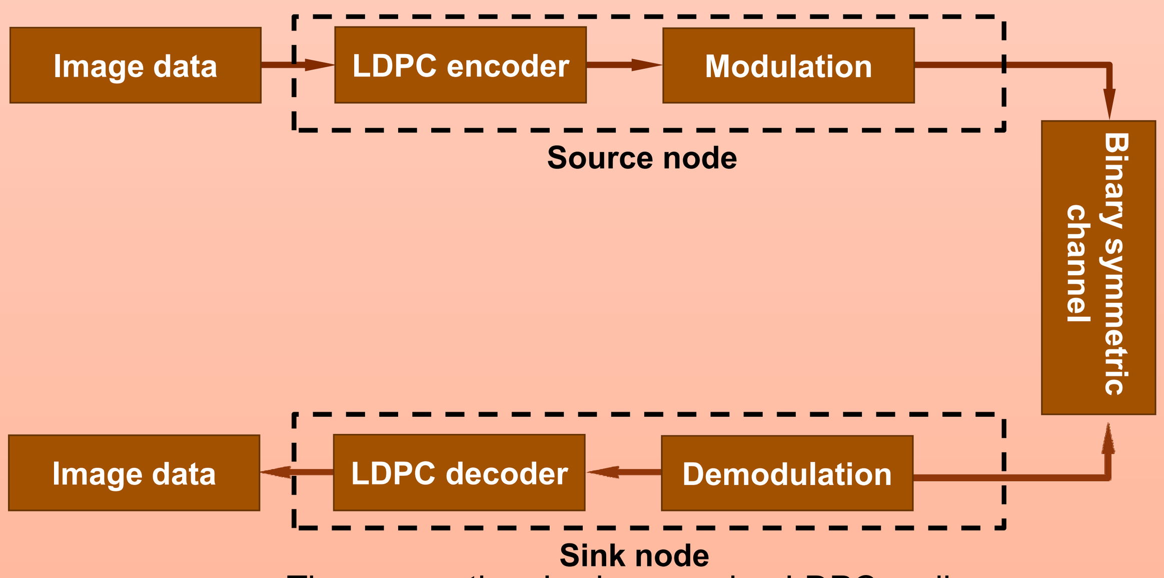
• Based on these results, therefore, we focus attention on LDPC codes and propose a distributed LDPC encoding scheme for WSNs

Approach and Methods

Conventional FEC Method and Problem Statement

• We can divide basic FEC coding techniques into two categories: block code and convolutional code. In these categories, we focus on the first type because of its low complexity. The category of block codes includes Hamming codes, LDPC codes, BCH codes, and RS codes.
• RS codes are difficult to implement on WSNs since the sensors have their limited resources (i.e., battery power, computational capacity, and memory). Therefore, we focus on explaining LPDC and BCH codes which require neither complex processing nor large memory [1].
• The authors in [2] also show that WSNs using LDPC codes gain 45 percent more energy efficient than those using BCH codes and 60 percent more energy efficient than those performing convolutional codes. Therefore, we focus on only LDPC codes which are the most suitable to perform on WSNs.

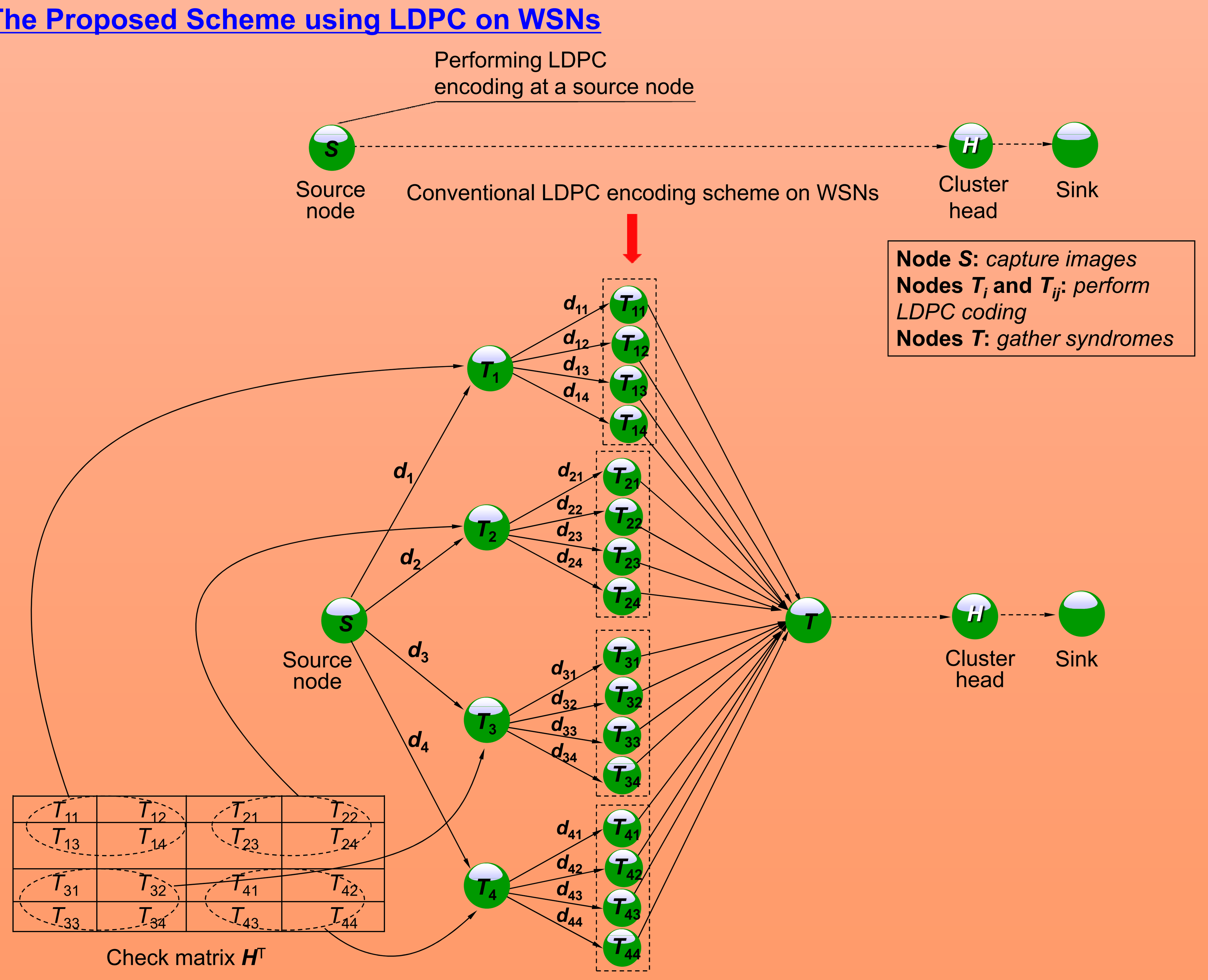
The Conventional Scheme using LDPC coding



The conventional scheme using LDPC coding

In the scheme, encoding LDPC is performed by LDPC encoder at a source node. The encoding data then are sent to the sink node directly. At the sink node, the data are decoded by LDPC decoder.

The Proposed Scheme using LDPC on WSNs



Proposed scheme for LDPC encoding on WSNs with the number of nodes N_n = 16.

For the check matrix H^T, we divide it into 16 parts at a maximum. In this case, the input data are first divided into four equal parts and transferred to four nodes T_1, T_2, T_3, and T_4. Then, the data at each node T_i (with i = 1, 2, 3, 4) are divided again into four equal parts and sent to four other nodes T_{ij} .

Simulation

Simulation Setup

• Network area: 400 m × 400 m
• Initial energy of sensor: 1 Joule
• Base station: The closest node to the center of the field
• Input data: Lena image (64 pixels × 64 pixels) with 8 bps (bits per pixel)

The following five schemes are compared:

• Huffman and RS coding scheme
• Huffman and centralized LDPC coding scheme
• Huffman and distributed LDPC coding scheme
• GZIP and distributed LDPC coding scheme
• miniLZO and distributed LDPC coding scheme

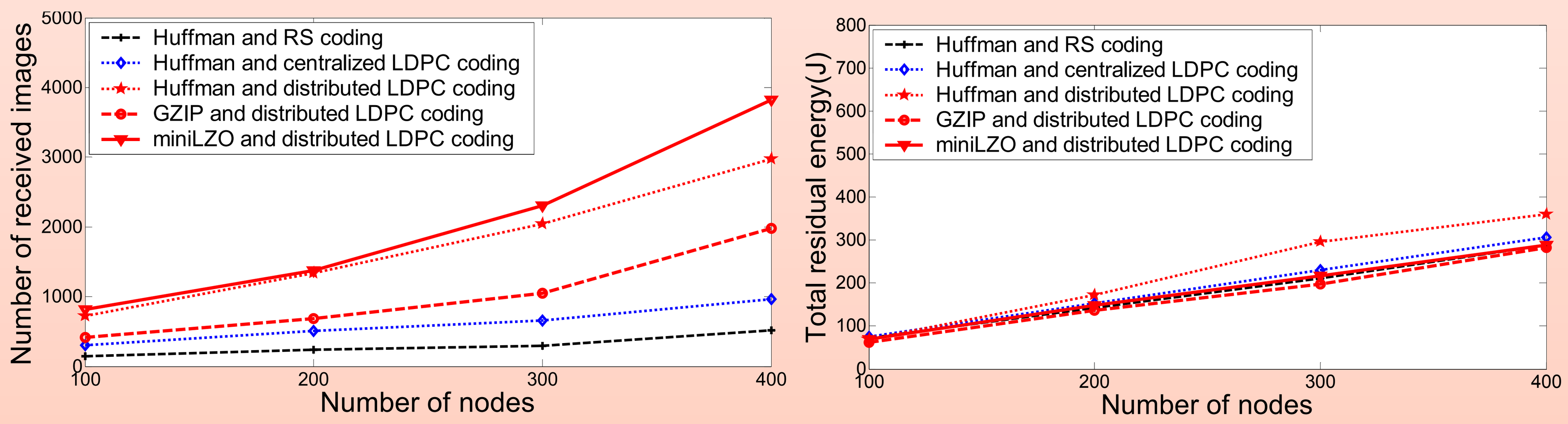
The parameters of the computation energy model

Parameter	Value
Energy transceiver electron (ε_{elec})	50 *nJ / bit*
Energy transmission in free space model (ε_{fs})	10 *pJ / bit / m^2*
Energy transmission in multi-path model (ε_{mp})	0.013 *pJ / bit / m^4*
Energy for preprocessing (e_{pre})	15 *nJ / bit*
Energy for transforming DCT (e_{DCT})	20 *nJ / bit*
Energy for source coding (e_{cod})	90 *nJ / bit*
Energy for LDPC coding (e_{cod})	0.115 *nJ / bit/ iter.*
Threshold distance (d_0)	100 *m*

Simulation Results

Comparison of Network QoS

• Simulation will be stopped when all source nodes deplete their energy.



(a) Number of images (b) Total residual energy

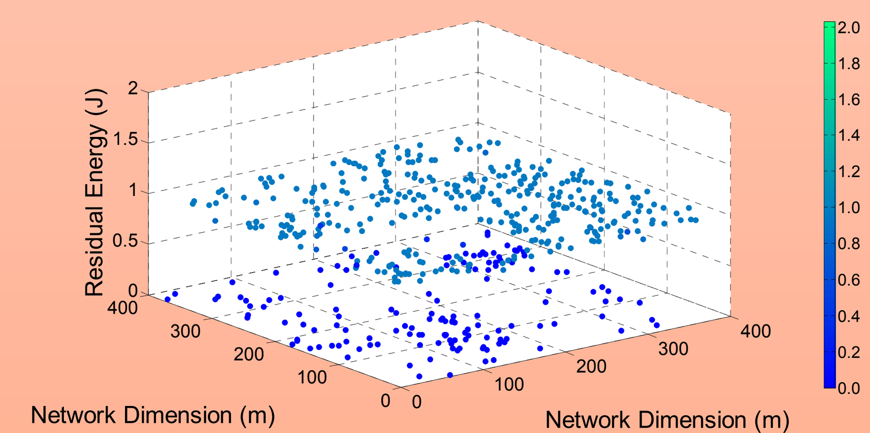
The obtained results by computer simulation with (64 pixels × 64 pixels) Lena image

• The numbers of received images in the proposed schemes, which use Huffman coding, GZIP which combines Lempel-Ziv (LZ77) and Huffman coding [4], or Lempel-Ziv-Oberhumer (miniLZO) with distributed LDPC encoding, are larger than those in the schemes compressing data using LDPC and RS encoding at the source node, while the energy consumptions of all schemes are almost the same.

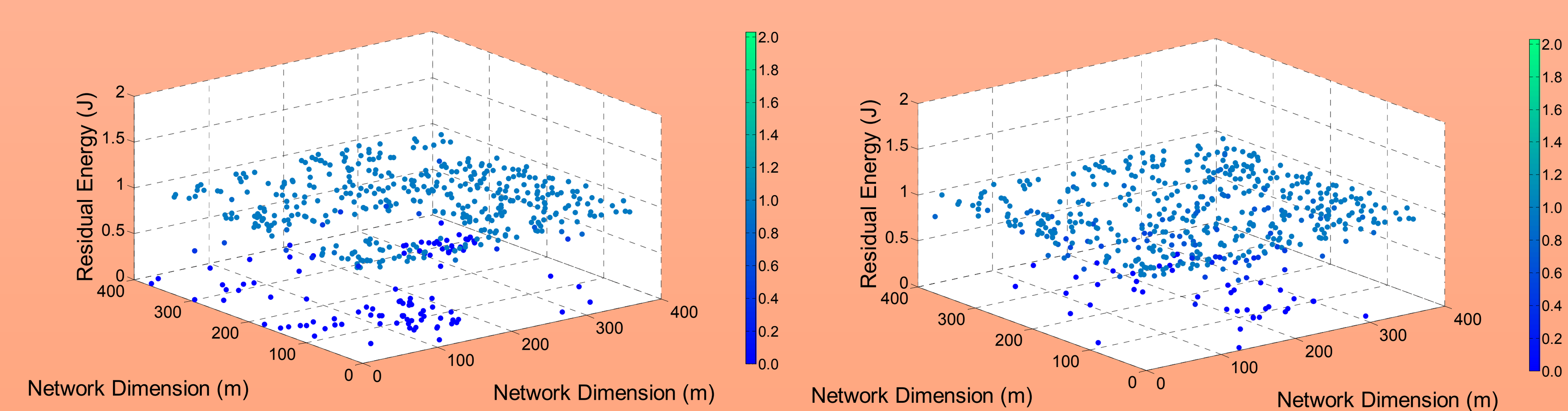
• The results also show that the proposed scheme using Huffman and distributed LDPC coding not only achieves to send more images but also reduces the energy consumption in the network.

Comparison of Energy Consumption

To evaluate energy balance, we conduct the simulation with 500 sensor nodes. We measured the residual energy of nodes after 2000 images were received at the base station. Clearly, the distributions of residual energy of nodes in the proposed scheme are almost balanced.



(a) Huffman and RS coding scheme



(b) Huffman and centralized LDPC coding scheme (c) Huffman and distributed LDPC coding scheme

The distributions of residual energy of sensor nodes after 2000 images received at the base station

Conclusions

• The proposed scheme improves the network QoS by increasing the number of received images at the base station.

• The network lifetime is improved by balancing energy of nodes.

• Since the threshold value is set to be small in this paper, we have to perform the proposed scheme with the nodes in a small cluster in all of our simulations.

References

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