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Efficient coding techniques algorithm for cluster-heads communication in wireless sensor networks

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ABSTRACT

Random network coding (RNC) for Error Correction have been the subject of intense research lately. However, in wireless sensor networks (WSNs) the correlation between the received symbols, from the same cluster head (CH), provoke the column correlation on the generator matrix of array Low-Density Parity-Check (LDPC) codes, whereby many columns of this matrix do not offer any additional information, thus the most important properties are lost despite the fact that the generator matrices are more easily dispersed. In this paper, the authors describe each step of the problem-solving algorithm employing efficient coding techniques focusing on improvement planning at Bit-error rsate (BER) vs signal-to-noise ratio (SNR) curves, in dense WSN, between CHs and the base station (BS) node. They use efficient coding techniques approach based on RNC and LDPC codes using the Time Division Multiple Access (TDMA) method. They generalize the notion of RNC-LDPC, study their properties and formulate the main steps of the proposed algorithm reconstruction method. The simulation results demonstrate that this approach is more effective in improving the BER using the proposed algorithm. Moreover, subsequently ameliorate the technical properties offered by this codification type.

1. Introduction

Network coding (NC) [1] is a particular in-network data processing technique that exploits the characteristics of the wireless medium (in particular, the broadcast communication channel) in order to improve the performance in data broadcasting [2]. NC can decrease the End-to-End (E2E) delay as described in [3], improves the Round-Trip Time [4,5] in wireless Narrowband RF communications, and also increases the capacity or the throughput of the network. Energy efficient broadcasting with NC [6]. RNC has many benefits, including: significantly facilitates the design of efficient algorithms to compute and achieve optimal throughput; improves BEs the computational complexity for computing and achieving the optimal throughput. LDPC codes were first introduced by [7] but rested almost forgotten till MacKay and Neal retook them in [8]. They are a special type of error correcting codes that is known for their good decoding performance and high throughput. Their main advantage is that they provide a performance that is very close to the capacity for many different channels and linear time complex algorithms for decoding. The best-known decoding algorithm for LDPC codes is called the Sum-Product Algorithm (SPA) [9]. The SPA is the basic "decoding" algorithm for codes on graphs. However, because all its operations are local, it may also be applied to graphs with cycles; then it becomes iterative and approximate, but in coding applications it often works very well. It has become the standard decoding algorithm for capacity-approaching codes (e.g., turbo codes, LDPC codes).

Low-density generator matrices (LDGM) are a particular case of LDPC matrices in which the columns corresponding to the redundant packets have been simplified. Three variants of LDGM have been described [10].

In the context of WSNs the Clustering technique [11,12] divide the network into a set of groups named clusters [13] or into multi-cell graph [14]. The clusters are formed on the similarity of sensor nodes(SN). Each cluster consists of a set of Cluster Members (CMs) in which single or multiple ones are selected as the cluster representatives. The cluster representatives are called CHs and responsible for collecting and aggregating intra-cluster data samples [15,16]. Aggregated results are hierarchically forwarded from CHs to sink via single or multi-hop paths.

The source nodes collect and transmit data samples to CHs using TDMA [17–19] to avoid intra-cluster collisions. CHs collect and aggregate data samples and then transmit the results to the

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BS, which is responsible for collecting and processing the data. This protocol allows the data consumer to partially collect and aggregate data samples from each region of network in which data is desirable.

The SNs periodically transmit their data to the corresponding CH nodes. When CHs are organized in networks, they could use either single hop or multi-hop mode of communication to send their data to their respective BS.

In order to simplify the tasks of the nodes, the medium access mode to be used is a TDMA as applied in [20]. TDMA is effective method for preventing Packet Collisions. However, time slot allocation must be realized in order to use TDMA.

TDMA with sleep and wake periods has attracted interest because of their collision free operation and low power consumption. The best strategy is to use TDMA and assign each transmission a time slot. This approach will require four time slots. In this paper, we propose a simple hop communication mode using TDMA scheduling in order to avoid collisions on one hand among CHs, on the other hand among the BS. All clusters directly communicate with the BS. Most of the clustering-based protocols use a single-hop communication to send data from the CHs to the BS. In fact, they assume that all SNs can communicate directly with each other or with the BS [21].

The cooperative scheme has been proposed for WSN to produce multiple symbol differential space time codes [22] and it is implemented in the algorithm with Amplify and forward (AF) relays networks [23]. In this paper, an important distributed coding scheme for WSNs, namely, adaptive network coded cooperation (ANCC) [24], has been proposed [25]. Based on the basic idea of ANCC, extrinsic information transfer (EXIT) charts are used in the design of irregular LDGM codes [25] for WSNs over Rayleigh fading channels in [26].

BER measuring relative number of errors per transmitted sequence is an excellent indication of the performance of a data link and is the major characteristics of an error-correction scheme (e.g. iterative decoding of an LDPC code) performance. At low values of the SNR, the BER of an LDPC code can be analyzed numerically via Monte Carlo simulations. It can also be shown that in the low SNR range the performance of the iterative decoding is close to the Maximum Likelihood optimum.

The main aim of this paper is to propose an algorithm as solution to improve the BER in dense WSN as [27] by using the network coding (NC) with the LDPC codes at the level of CHs that participate in communication with the BS. We compare the results of simulated scenarios using the bases of the inspection of characteristic curves, BER versus SNR, of LDPC codes in which three regions can be distinguished [28]. The performance of a WSN is improved through optimizing communication, solve the column correlation problem on the generator matrix by reducing BER.

The remainder of the paper is organized as follows. In the next Section 2, the authors give the scenario description and basic method. In the Section 3, they state the problems and give a proposed remedy of the particular problematic. The Section 4 descripts the proposed algorithm and explains the details. Validating simulation results are presented in Section 5. Finally, the authors conclude the paper in Section 6.

2. Scenario description and basic method

2.1. E2E BER in multi-hop wireless networks

In this section, we study the simplest scenario for a multi-hop network in which all the individual links that form the path have the same statistical behavior in their *E2E* BER by ‘‘Identical behavior statistical”.

Considering a scenario (see Fig. 1) and using the index $h \in \{1, 2, \ldots H\}$, we define:

$BER(h)$ as the individual BER from the node $h-1$ to the node h.

BER_h as the E2E BER from node 1 to the node h.

We refer to the individual BER of all hops as equal, so we have:

$$BER_h = BER_{hop} \quad (1)$$

The simplification of (1) is often assumed in the current literature [27] [29] when the individual BER is unknown, the BER_{hop} value is obtained from the statistical properties of a channel model.

It is also appropriate to consider this scenario involved to get a compact expression of the end to end BER, BER_h, the expression only depends on the BER in each retransmission, the BER_{hop},H is number of retransmissions making up the path. Consider the following Theorem: Each bit transmitted by nodes with DAF regeneration (Decode-and-Forward) from a source node to a destination node H through H retransmission broadcasts over channels with identical statistical behavior or characterized by individual $BER_h = BER(h)$, with $h \in \{1, 2, \ldots H\}$, then, the probability, that the bit received, on the destination node, is different from the original, it is obtained as:

$$BER_H = \frac{1}{2}\left(1 - (1 - 2BER_{hop})^H\right), \forall H \geqslant 0 \quad (2)$$

Currently, the expression used in the literature to determine the *E2E* BER on paths, with the same BER individual value in all hops is [29]30.

$$BER_H = 1 - (1 - BER_{hop})^H \quad (3)$$

Firstly, we consider the simplest channel, without fading, affected only by noise Additive White Gaussian Noise (AWGN), and a modulation scheme BPSK (Binary Phase Shift Keying). In this scenario, an individual BER can be calculated by function according to the expression Q the one-dimensional Gaussian Q-function (often referred to as the Gaussian probability integral) [31].

$$BER_{hop} = Q\left(\sqrt{2\bar{\gamma}}\right) \quad (4)$$

where $\bar{\gamma}$, is the average SNR per bit, substituting (4) and (2) we obtain the expression for the *E2E* BER on DAF paths of H hops in AWGN channels with the same statistical behavior and BPSK modulation:

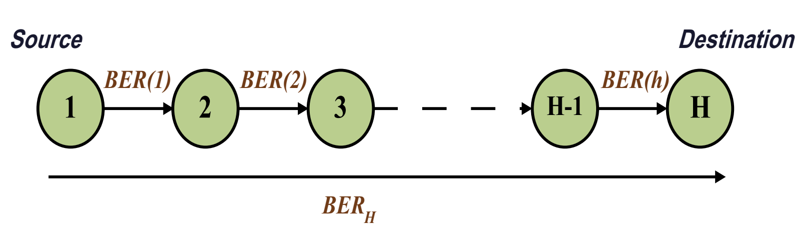

Fig. 1. Multi-Hop Path with H node, Individual BER associated at the hop from node 1 to node H. BER end to end from node 1 to node H.