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ENERGY OPTIMIZATION IN WSN USING CHANNEL CODING

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ABSTRACT

The Wireless Sensor networks are highly distributed networks of small, lightweight wireless nodes, deployed in large numbers to monitor the physical or environmental conditions. The major challenges of WSN arerobust, reliability and power consumption Source of Power supply used in sensor nodes are often battery powered. Hence a frequent requirement for charging of battery or sometimes replacement of sensor nodes itself is necessary. For maximizing the lifetime of sensor node, Optimization[5] of power consumption plays an important role. Error correction codes (ECC) is an efficient method implemented to optimize the transmitted power. In this paper a systematic approach for selection of suitable error correction codes for wireless sensor networks is followed. Coding gain of ECC results in energy conservation during transmission. Suitable Error correction code will be chosen based on the trade off in performance between BER (Bit Error Rate) and power consumption.

KEYWORDS: Turbo codes, processing, decoding, algorithm.

INTRODUCTION

The tremendous usage of wireless sensor networks in recent years is due to the recent advances of wireless communication systems, signal processing and high speed processors and light weight advanced sensor nodes. Each node of Wireless sensor network consists of three subsystems: the sensor subsystem which senses the environment, the processing subsystem which performs local computations on the sensed data, and the communication subsystem which is responsible for message exchange with neighbouring sensor nodes.

Due to recent advances in micro-electro mechanical systems (MEMS) technology, the various miniaturized sensors are designed. Sensor nodes operate indifferent modes like transmit mode, receive mode, idle mode and sleep mode.Each sensor is responsible for sensing of physical parameters such as temperature, pressure, or relative humidity and converting into respective voltage or current. However the major challenge of WSN is the power consumption of the sensor nodes which affects the lifetime of the sensor node. This results in periodic charging or replacement of the battery which is hectic in case of WSN as the nodes will be placed in remote areas in most of the applications. The data collected can be sent regularly over the network to automated monitoring systems. The power consumed during sensing and processing is far less than the consumption during transferring of data to nearby nodes or destination. The power consumption during Receive mode is also comparatively less.

Fading and Random noise induced by the Channel may result in corruption of data being sent. On receipt of the corrupted data receiver requests for the retransmission through negative acknowledge (NACK) which results wastage of energy.[3] So to avoid the data corruption in the channel, it is preferred for channel coding through Error control codes. Error control codes are one of the methodfor minimizing the power consumption in wireless sensor network. Error control codes are classified into Forward Error correction codes (FEC) and Backward Error correction codes. Most commonly used FEC codes are Block codes and Convolutional codes. So by using the suitable channel coding techniques, channel errors can be avoided thereby reducing the Transmission energy.[1]

In block codes the encoder of a block code divides the information sequence into message blocks of k information bits each, called message block. Hence, there are total 2^k different possible messages. Then the encoder converts each message block into code word of size of length n.

Examples of block codes are Hamming codes, Golay codes, etc

Convolution codes are widely used in practice, with several hardware implementations available for encoding and decoding as they use memory registers. Convolution codes often operate on continuous streams of symbols not partitioned into discrete message blocks. These codes accept k new symbols each time step and produce n new symbols. Convolution codes uses complex decoders which require high power consumption. Turbo codes have very long code words with only modest decoding complexity and low power consumption. Turbo codes are also known as hybrid codes.Further, decoding is done at base station for Turbo codes, energy conservation is very less.

However, in case of Back ward error correction there is a requirement of retransmission for the corrupted data through Automatic Repeat request (ARQ) for the negative acknowledge (NACK). Hence, retransmission leads to the more energy requirement.

Coding For Wireless Channels

Error correction codes provide the capability for bit errors introduced by transmission of modulated signal through a wireless channel to be either detected or corrected by a decoder in the receiver.Channel coding can significantly reduce the power required to achieve a given BER. Conventional error control codes use block or convolution code designs: the error correction capability of these codes is obtained at the expense of an increased signal bandwidth or a lower data rate. Trellis codes use a joint design of the channel code and modulation to provide good error correction without any bandwith or rate penalty. Turbo codes and the more general family of codes on graphs minimize transmit power, but the associated processing complexity may compromise these power gains. All of these codes can also be designed for fading channels to limit required energy.

FEC codes are classified intoBlock codes and Convolutional codes

A block code is called a linear code when the mapping of the k information bits to the n codeword symbols is a linear mapping. An (n,k) block code is linear if the 2k length-n codewords of the code form a subspace of Bn. Thus, if Ci and Cj are two codewords in an (n,k) linear block code, then Ci + Cj must form another code word of the code.

Cyclic codes are a subclass of linear block codes where all codewords in a given code are cyclic shifts of one another. The cyclic nature of cyclic codes creates a nice structure that allows their encoding and decoding functions to be of much lower complexity than the matrix multiplications associated with encoding and decoding for general linear block codes. Thus, most linear block codes used in practice are cyclic codes.

A convolutional code generates coded symbols by passing the information bits through a linear finite-state shift register. The shift register consists of K stages with k bits per stage. There are n binary addition operators with inputs taken from all K stages: these operators produce a codeword of length n for each k bit input sequence.

In this paper, we analyze four codes: RS code, hamming codes, golay code and turbo codes. The most common type of block code is a Hamming code, which is parameterized by an integer m≥2. For an (n,k) Hamming code, n = 2m-1, and k=2m-m-1, so n-k=m redundant bits are introduced by the code. The minimum distance of all Hamming code is dmin=3, so t=1 error in the n = 2m-1 codeword symbols can be corrected. Although Hamming codes are not very powerful, they are perfect codes with the error probability.

$$P_e \leq \sum_{j=t+1}^{n} \binom{n}{j} p^j (1-p)^{n-j} \qquad \text{……………… Eq (1)}$$

Golay and extended Golay codes are another class of channel codes with good performance. The Golay code is a linear (23,12) code with dmin = 7 and t=3. The extended Golay code is obtained by adding a single parity bit to the Golay code, resulting in a (24,12) block code with dmin = 8 and t = 3.The extra parity bit does not change the error correction capability since t remains the same, but it greatly simplifies implementation since the information bit rate one half the coded bit rate.

The most common nonbinary block code is Reed Solman (RS) code, they have the similar properties as the binary codes. RS codes achieve minimum distance of d_{min} = N-K+1, which is the largest possible minimum distance between codewords for any linear code with the same encoder input and output block lengths. Probability of symbol error associated with the non binary code is upper bounded by.

$$P_s \leq \sum_{j=t+1}^{N} \binom{N}{j} P_M^j (1-P_M)^{N-j} \qquad \text{……………… Eq (2)}$$

Similar to the form for the binary code The probability of bit error is then.

$$P_b = \frac{2^{k-1}}{2^k - 1} P_s \qquad \text{……………… Eq (3)}$$

Another powerful class of block codes is the BCH codes. These codes are cyclic codes, and typically outer perform all other block codes with the same n and k at moderate to high SNRs. Designing an error correction code is always a tradeoff between energy and band-width efficiency. More errors arecorrected by using lower rate codes the system operates with a lower transmit power, when more error is corrected.

But the lower code rate codes have excess of overhead and thus there is large bandwidth consumption. It also increases the decoding complexity.

Convolution codes are said to have memory since thecurrent codeword depends on more input bits (kK) than the number input to the encoder to generate it (k). There are multiple ways to characterize convolutional codes, including atree diagram, state diagram, and trellis diagram. The tree diagram represents the encoder in the formof a tree where each branch represents a different encoder state and the corresponding encoder output.A state diagram is a graph showing the different states of the encoder and the possible state transitions and corresponding encoder outputs. A trellis diagram uses the fact that the tree representation repeatsitself once the number of stages in the tree exceeds the constraint length of the code. Viterbi Algorithm[2] is used for decoding of Convolution code.

However, similar to the block codes, Convolution codes are not able to correct the block errors. Hence, a convolutional interleaver, is designed to spread out burst errors but it delays the transmission through the channel.

Concatenated codes may have the inner and outer codes separated by an interleaver to break up block errors introduced by the channel. Concatenated codes typically achieve very low error probability with less complexity than a single code with the same error probability performance. A common concatenated code has a convolutional inner code and a Reed Soloman (block) outer code.

However, the maximum-likelihood decoder for a concatenated code, which performs joint decoding, is highly complex. It was discovered that a near-optimal decoder for concatanated codes can be obtained based on iterative decoding, and that is the basic premise behind turbo codes.

Turbo codes[4] are the more general family of codes on graphs with iterative decoding algorithms. Turbo codes consist of two key components: parallel concatenated encoding and iterative, “turbo” decoding. Parallel concatenated encoder consists of two parallel convolutional encoders separated by an interleaver, with the input to the channel being the data bits m along with the parity bits X1 and X2 output from each of the encoders in response to input m.

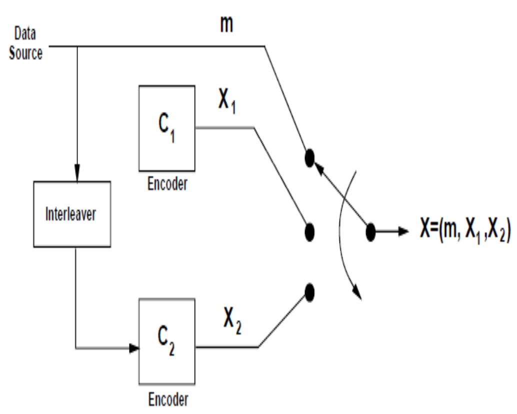

Figure 1: Turbo Encoder Code.

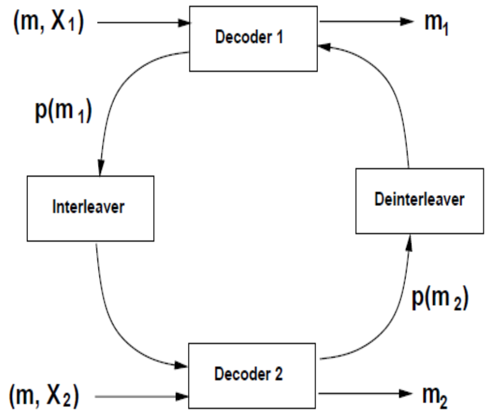

Figure 2: Turbo Decoder.

Iterative or "turbo" decoding exploits the component-code substructure of the turbo encoder by associating a component decoder with each of the component encoders. More specifically, each decoder performs soft input/soft output decoding.

Optimal Code Selection

In this paper, we select the optimal code among different Error correction codes (ECC). The code selection depends on the sensor network constraints of network size, environmental conditions of application, type of channel and also modulation techniques used. In this type of modulation and the optimal ECC of the specified application attains 50% of energy. For every application it is considered a maximum BER for the better QOS. To reduce the BER, it is preferred to use the Error control codes. Energy minimization also obtained with coding gain of ECC. Hence, along with the type of modulation, ECC also selected in the format selector To obtain the optimum energy of the network, first we calculate the node energy and the energy consumed by the network in the simulation block repeatedly until the optimal ECC is selected. Accordingly, life time of the network will be improved.

In this paper, for additive white Gaussian channel noise (AWGN) channels using BPSK modulation technique, ECC performance i. e. BER vs E_b/N_0 (SNR) are evaluated.

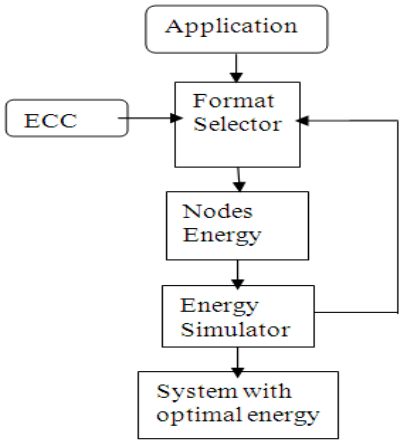

Figure 3: Optimal Code Selection.

Sensor Node energy calculation

Two types of energy models used for calculating energy consumption are Radio energy model and Computation energy model.

Radio energy model: this model focuses on energy consumed by the circuit and the transmitting modulated signal.

The radio energy per bit in transmitting N number of bits is given as

$$E_{rad} = \frac{(P_s + P_{tot\,ckt})T_o}{N} \quad \text{.. Eq (4)}$$

Where,

P_s: power consumed while transmitting the signal.

$P_{tot\,ckt}$: power consumed by the circuit.

T_o: duration for which the transceiver is ON

The signal transmission power requirement is given by

$$P_s = \left(\frac{4\pi}{\lambda}\right)^2 d^n \frac{P_{rec}}{G_{ra}G_{ta}} \quad \text{.. Eq (5)}$$

Where λ is the wavelength; d is the distance; n is the path loss componet; $P_{rec}$is the power received; $G_{ra}$is the gain of the receiver antenna and $G_{ta}$is the gain of the transmitter antenna.

The power consumed by total circuit is given by

$$P_{tot\,ckt} = P_{PA} + P_{ckt} \quad \text{.. Eq (6)}$$

Computation energy model: Energy consumed with the encoding and decoding process of ECC.

Let E_{encd} is the Energy consumed during encoding

&E_{decd} is the Energy consumed during encoding

Then Computational energy per bit E_{comp} is given by

$E_{comp} = \frac{E_{encd} + E_{decd}}{N}$ .... Eq (7)

Hence, addition of computation energy model and radio energy model gives the Sensor node energy per bit. That is Node Energy Enodeenergy

$$E_{ne} = \frac{(1+\propto)P_s T_{on} + P_{ckt} T_{on} \frac{M}{K} + M E_{comp} \frac{M}{K}}{N}$$ .... Eq (8)

Energy of the Network

In the Turbo codes Transmitter Energy will be reduced by increasing the decoder complexity and the decoding is considered at the base station where enough energy is available.

Hence, overall sensor network energy is given by

$E_{TNE} = Eencoder + E_{TR} + E_{RR}$ .... Eq (9)

Where E_{TNE} is the total energy of the network;

Eencoder is the encoding energy of the node;

E_{TR} is thetransmitting energy of all the sensor nodes

E_{RR} is the receiving energy of all the nodes.

If M is the total number of bits that has been transmitted and

E_{tr} is the Eenergy consumed for a single bit transmission from thenode,

$E_{rr}$is the energy consumed for a single bit reception by the node.

Then,

$$E_{TNE} = E_{enc} + \sum_{i=1}^{M} ME_{tr} + \sum_{i=1}^{M-1} ME_{rr}$$ .... Eq (10)

Simulation Environment

Sensor node energy as well as wireless sensor network energy consumption are calculated using Network simulator version. Performance of the network and scaling of the protocols are evaluated using NS2. NS2 is also used to runthe large scale experiments which are difficult to implement in real case. It uses OTcl interpreter as the front end and simulator is written in C++.For various error correction codes Performance evaluation of BER to SNR is obtained using MATLAB and is shown in graphs below.Based on the application and required power consumption as well as the required BER suitable Error Correction code is chosen.

Sensor node and sensor network energy consumption simulation parameters are shown in the table below:

Table 1: Simulation parameters.

P_{FS}	13.7mW	α	1.9
P_{LNA}	0.55mW	G_r,G_t	1
P_{BPF}	6.12mW	n	4
P_{IFA}	0.2mW	NF	10 dB
P_{LPF}	0.29mW	P_{eb}	10^{-3}
P_{ADC}	4.1mW	BW	1MHz
T	100ms	f_c	2.4GHz

Following graph shows the comparision for uncoded system with coded system of various ECCs: In fig 4. performance of various ECCs in terms of bit error rate for hamming codes, extended Golaycodes and Reed Solomon codes is shown. It indicates that compared to the Hamming and Golay codes, RS codes are performing better. Coding gain of Hamming code is 1.4dB. In fig 5. for various code rates, the RS codes performance evaluation was simulated.

However, the problem of energy consumption by coding gain is resolved by Turbo codes that saves the transmitter's energy.

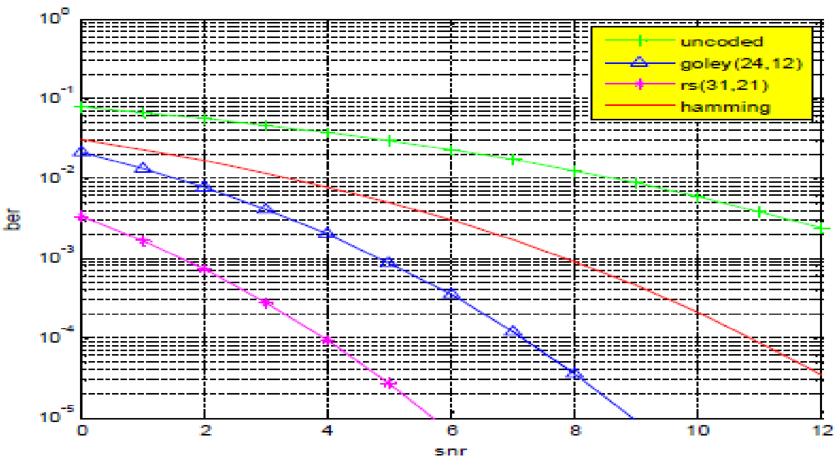

Figure 4: Performance Evaluation of various Error Control Codes.

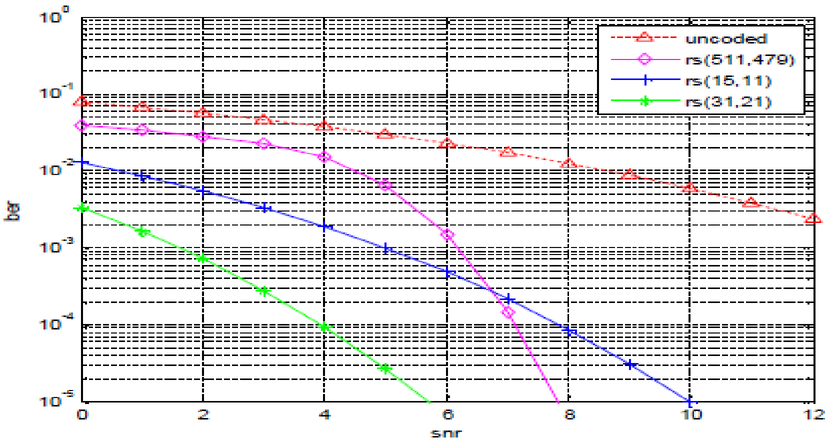

Figure 5: Performance Evaluation of RS Codes.

CONCLUSION

Power consumption is one of the major constraints in the wireless sensor network. The sensor nodes are located in the areas where it is difficult to replace and WSN is powered by battery. Hence, it is preferred the minimum power utilization. To achieve this ECC is preferred using coding gain. Out of these ECC techniques Turbo code is preferred, since Turbo codes decoding is done at Base station where there is availability of enough energy which achieves power conservation.

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