Towards an Optimal Reed Solomon Codes Selection for Sensor Networks: A Study Case Using TmoteSky

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ABSTRACT

We present an effective way to design and implement Reed Solomon codes in traditional wireless sensor networks.They are usually regarded as inappropriate in sensor networks despite their efficiency in terms of link reliability, because of their computational complexity which can require an important amount of energy.

We use *Galois field*, over which code are built, features to reduce code energy consumption. We show that code with small symbol size are more suitable in sensor networks than code with standard symbol size of 8. Finally we propose a smart code selection scheme to tend towards nearly optimal RS code, according to application requirements.

Categories and Subject Descriptors

C.4 [**Computer systems organization**]: Performance of systems—*Design studies*; D.2.10 [**Software Engineering**]: Desing; E.4 [**Data**]: Coding and information theory—*error control codes*

General Terms

Design, measurement, experimentation

Keywords

Error control coding, Reed Solomon, sensor networks, tmote Sky, reliability

1. INTRODUCTION

Due to their ease of deployment WSN are widely used in different applications including environmental and building monitoring, medical application and object tracking. In such networks, sensors are battery powered and hence have a limited lifetime. In this context, energy saving by optimizing power consumption is a crucial issue. Due to sensor limited energy, classical technics such as increase signal power or using ARQ (Automatic Repeat Request) are inefficient. We thus focus our work on error control coding (ECC) such as Reed-Solomon [6](RS) code, to achieve link reliability and minimize energy constraint. Although RS codes are , in general, well suitable for wireless application they can be be inefficient in terms of energy consumption in IEEE 802.15.4 based Wireless Sensor Networks because of their computational complexity. It is then necessary to design an efficient ECC in order to minimize energy consumption in WSN.

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In literature, previous research [5, 2, 4]on error control coding shows mainly the efficiency, in terms of communication reliability, of coded system. In [1], Balakrishnan and *et .al* investigated RS, BCH and convolutional codes power analysis in ASIC FPGA. However since no research has been done on the impact of RS encoder in real WSN, coded system can be inappropriate in such networks due to their stringent energy constraint.

We present the design and implementation of Reed-Solomon (RS) codes and a smart RS selection scheme in real Wireless Sensors Networks (WSN) with star topology. We propose a toolkit to efficiently implement RS code with different symbol size in tinyOS [3] and we show that a good code design can enhance node lifetime.

2. RS CODE DESIGN

To simplify encoders computational complexity and avoid computing energy waste, we perform some encoding operations at compile time and make some assumptions. First, the generator polynomial and code size are determined at compile time. Second, shorten code is used when data handled by application is not large enough to match code size. Finally we adapt the symbol size to application requirement s instead of using default 8-bit symbol. For instance it is more effective to use $RS(31,21)$ instead of $RS(255,245)$ for encoding a data of 8 bytes.

At tinyOs side, we slightly modified the radio stack and we implemented a **C** program to generate RS tinyos module as function of code size and number of error to correct.

error control code selection.

We formalize here the problem of appropriate RS code selection. Given that ARQ usage is not energy efficient in WSN due to retransmission energy waste, the RS code selection must satisfy the following equation in order to be energy efficient.

$$\begin{cases} E_{\text{enc}} + E_T(l_d + l_r) \leq (E_T l_d + E_{\text{ack}})(1 + N_{\text{retrans}}) \\ E_T = V I_t n / R \end{cases} \quad (1)$$

where E_{enc} is the total energy used for encoding, E_T is the mean energy used to transmit one byte, l_d is the length of transmitted data, l_r is the length of redundant data, N_{retrans} is the mean number of retransmission and E_{ack} is energy consumed during acknowledge time.

3. EXPERIMENTS

Procedure.

We perform indoor experiment ; the sensors are put in different rooms from our labs and we lower transmission power in order to make our signal more vulnerable to noise. We first compute sensors

Figure 1: Number of transmitted and received packets as function of code

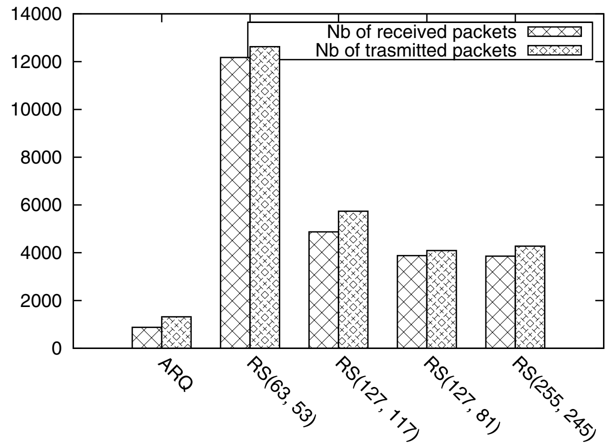
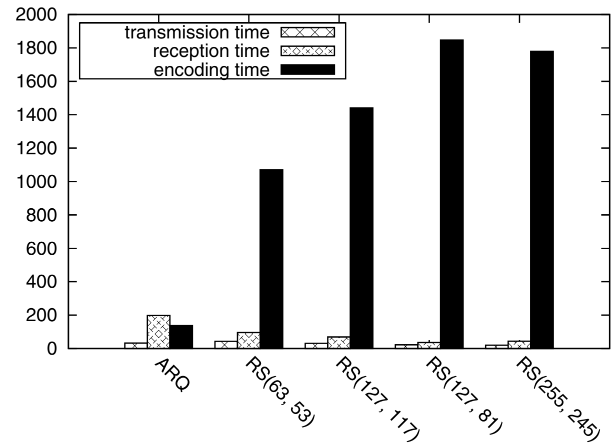


Figure 2: Encoding, transmission and data reception time



lifetime with ARQ use, where we fix the number of retransmission at 3; a node periodically wakes up to send a data of a given length $l = 14$ and goes down after receiving an acknowledge from the receiver. We next assess sensors lifetime with usage of RS code; node, periodically, wakes up to encode the same data of length l and starts its radio to send the encoded data. The data is encode with RS$(63,53)$, RS$(127,117)$, RS$(127,81)$, RS$(255,245)$. The first code is provided by our code selection method where, we decide to correct up to 5 errors. The other codes are used to show the discrepancy between code correcting the same number of errors with different symbol size.

Performance analysis.

In this section we analyse the power consumption of uncoded/coded channel and its influence on sensor lifetime. Figure 1 clearly shows that usage of RS code permits to increase link reliability and hence node lifetime. RS$(63,53)$ code outperforms results from the others codes and leads us to confirm our previous assumption. Except RS$(127,81)$ code which is constructed to correct up to 23 errors, the others codes are designed to correct up to 5 errors and we show that a bad coding rate decreases performance of our coded system.

Figure 2 compares the amount of time used for encoding, reception and data transmission in order to explain the results from figure 1. It shows that when we use ARQ, the radio consumes most of the energy, specially during data reception. When we use RS codes, nodes pass less time in reception and hence transmit more packets. However when the coding rate is not carefully designed, power consumed by encoding dominates the total power consumption and degrades performances.

Discussion.

The studies reported in this paper focus on RS code because of his ability to correct burst errors which can appear in noisy environment. We have presented a RS code implementation on tmote Sky; the results concerning this implementation are the same on others wireless sensor networks platforms. The design assumptions done in section 3 remain true and can be proved on others platforms. As regards our implementation evaluation, results are environment-dependent and symbol size is given from the length of data we want to encode and the number of errors we want to correct instead of using our packet error rate (PER) to determine the number of errors to correct.

4. CONCLUSION

In this paper we present an effective way to design and implement RS code in wireless sensor network in order to make them more energy efficient. We adapt code symbol size to application requirements to reduce encoding consumption and we show that code with small symbol size are more appropriated for sensor networks.

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