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An Efficient RRBN Size Communication Based Power Saving Scheme for Wireless Sensor Networks

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Abstract- **Since battery technology has not progressed as rapidly as semiconductor technology, power efficiency has become increasingly important in wireless sensor networking, in addition to the traditional quality and performance measures, such as Band width, throughput, and fairness. Wireless sensor networks typically require low cost devices and low power applications. Hence, such networks usually employ radios with only simple modulation techniques such as ASK, OOK and FSK [9].We present in this paper, a energy efficient communication schemes for wireless sensor networks which are a redundant radix based number (RBN) representation i.e. RRBN Size Comm (Redundant Binary Number Silent through Zero digit Communication) scheme . We propose a transceiver design that uses a hybrid modulation scheme utilizing FSK the cost/complexity of the radio devices low. Considering an n-bit data representation and assuming that each of the 2^n binary strings is equally likely occur, theoretically obtainable fraction of energy savings by using our proposed RRBN Size Comm transmission protocol is, on the average, Simulation results demonstrate that compared binary FSK, our proposed implementation can extend the batter life of devices from about 33% to 62% on an average in applications like healthcare and wireless Sensor networks for agriculture.**

Index Terms- Energy – efficient communication, wireless sensor networks, silent symbol communication, and redundant binary number system.

I. INTRODUCTION

The demand for high data-rate multimedia wireless communications has been growing rapidly. As standards are addressing higher capacity wireless links to meet increasing demands, device power consumption is also increasing. Although silicon technology is progressing exponentially, doubling about every two years [1], processor power consumption is also increasing by 150% every two years [2]. In contrast, the improvement in battery technology is much slower, increasing a modest 10%every two years [2], leading to an exponentially increasing gap between the demand for energy and the battery capacity offered. Furthermore, the shrinking device sizes are also imposing an ergonomic limit on the battery capacity available. Wireless sensor networks (WSNs) are typically characterized by battery –powered sensor devices that are respected to operate over prolonged periods of timeBecause the difficulties in replacing the batteries of these devices strictly and regularly and communications being a.

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Major source of power drain in such networks, energy-efficient communication protocols are of paramount importance in such networks. To achieve this goal , one needs to address the energy-saving measures in all possible fronts such as physical layer, MAC layer, network layer(egg., energy- efficient routing) and application layer(egg., data aggregation). In this paper , we focus our attention to the energy- efficient measures only in the physical layer along with an appropriate MAC protocol. While various investigations have been carried out in the direction of energy-efficient source coding techniques and digital modulations [13]-[15] , [18] ,[25], the interdependency between source coding and modulation techniques remains to be explored.

In particular, with appropriate source coding of a binary data stream, it may be possible to convert a given binary bit stream into a *m* possible symbols *(m>2)*, with one of the symbols occurring with higher probability than the remaining *m-1* symbols. Most existing transmission schemes not only utilize non- zero voltage levels for both 0 and 1 so asto distinguish between a silent and a busy channel, they also keep both the transmitter and the receiver switched on for the entire duration of the transmissionof a data frame. Communication strategies that requireenergy expenditure for transmitting both 0 and 1 bitvalues are known as energy based transmission (EbT) schemes. In other words, if the energy required per bittransmitted is e_b, the total energy consumed totransmit an n-bit data would be $n{\cdot}e_b$. For example, inorder to communicate a byte of value 124, a node willtransmit the bit sequence < 0,1,1,1,1,1,0,0 >consuming energy for every bit it transmits. Thus, if the energy required per bit transmitted is e_b, the totalenergy consumed to transmit the value 124 would be8 e_b.

In contrast to EbT based communication schemes,a new communication strategy called Communicationthrough Silence (CtS) was proposed in [6] thatinvolves the use of silent periods as opposed to energybased transmissions. CtS, however, suffers from thedisadvantage of being exponential in communicationtime. An alternative strategy, called Variable-Base Tacit Communication (VarBaTaC) was proposed in[7] that use a variable radix-based information coding coupled with Cuts for communication. However, for an n-bit binary string, the duration of transmission is in general significantly longer than *n*.Neither [6] nor [7] talk about the amount of energy saved by Cuts and VarBaTaC for noisy channels and considering real-life device characteristics. A new communication technique was proposed in[3], [4] that recodes a binary coded data using redundant radix based number representation and then uses silent periods to communicate the bit value of'0'. The authors in [3] showed that by using the redundant binary number system(RRBNS) that utilizes thedigits from the set{-1, 0, 1} to represent a number with

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radix 2, it is possible to significantly reduce the number of non-zero digits that need to be transmitted. Considering an n-bit data representation, it was proved that the theoretically obtainable fraction of energy savings by recoding the binary string of lengthen in RRBNS and using the proposed RBN Size Communication transmission protocol from [3], [4] is, on an average,1 – [(n + 2) / 4n]. Another new communication scheme based on recoding data from binary to the ternary radix and the silent symbol strategy, with the aim of generating energy savings simultaneously at the transmitter and the receiver.

The rest of the paper is organized as follows: In Section II provides the basic idea of RRBN Size Comm. Then, in Section III, Survey of Related work is described. Section IV, Algorithm Transmit RRBN Size and hard ware implementation. Simulation evaluations are discussed in Section V. Finally, the paper is concluded in Section VI.

II.BASIC IDEA OF RRRBN Size COMMUNICATION

Table I

Redundant Binary Code	Binary Value
-1	00
0	01
0	10
1	11

The redundant binary representation is a numeral system that uses more bits than needed to represent a single binary digit so that each number will have several representations. RBR is a place-value notation system.

InRBR digit set will have more digits than the radix and digits are pairs of bits, that is, for every place RBR uses a pair of bits. RBR is unlike usual binary numerical systems, including two's complement, which use single bit for each digit. The value represented by an RBR digit can be found using a translation table as shown in **Table 1**. This table indicates the mathematical value of each possible pair of bits. As in conventional binary representation, the integer value of a given representation is a weighted sum of the values of the digits. The weight starts at 1 for the rightmost position and goes up by a factor of 2 for each next position. Usually, RBR allows negative values. There is no single sign bit that tells if a RBR represented number is positive or negative. Most integers have several possible representations in an RBR. An integer value can be converted back from RBR using the following formula, where n is the number of digit and $d_k$is the interpreted value of the k^{th} digit, where k starts at 0 at the right most position .

$$\sum_{k=0}^{n-1} d_k 2^k \qquad (1)$$

In conventional binary number system radix 2 number digit set contains 0, 1. The number of digits equal to radix.

Example 1: Number 6 can be represented in binary as below

0 1 1 0

Number 4 can be represented as below

0 1 0 0

In case of redundant Signed radix 2 number digit set contains {-1, 0, 1}. The number of digits present in the digit set will be more than the radix. So each number can be represented in many ways.

Example 2: Number 6 in decimal can be represented in redundant binary as follows.

0 1 1 0- 6

1 0 -1 0-6

Number 4 can be represented in redundant binary as follows.

0 1 0 0 -4

1 -1 0 0 - 4

The redundant binary number system (RBNS) as used in [3], [4] utilizes the digits from the set {-1, 0, 1} for representing numbers using radix 2. In the rest of the paper, for convenience, we denote the digit '-1' by$\bar{1}$. In RBNS, there can be more than one possible representation of a given number. For example, the number 7 can be represented as either 111 or 100$\bar{1}$. The basic idea of the RBNSize Comm recoding scheme is as follows: Consider a run of k 1's, $k > 1$. Let i be the bit position for the first 1 in this run, $i \geq 0$, 0 (bit position 0 refers to the least significant bit at the rightmost end). Let v represent the value of this run of k 1's. Then,

$$v = 2^i + 2^{i+1} + 2^{i+2} + \cdots .. + 2^{k+i-1} \ (2)$$

Equation (2) can be represented in RBNS by a '1'at bit position (k + i) and a $\bar{1}$ at bit position i , whileall the intermediate 1's between them are converted to0's. Thus, a long run of 1's can equivalently bereplaced by a run of 0's and only two non-zero digits,1 and$\bar{1}$Observe that for a run of k 1's, $k > 1$, the savings in terms of the number of non-zero digits is $k - 2$ .However, the number of non-zero digits remains unchanged for k =2. Thus, if we keep the transmitter switched-off for 0 bit-values, the power consumption of the transmitter will be less than that in energy based transmission

(EbT) schemes. Hence, by combining this approach of silent zero transmission with RBNS-based recoding strategy, a significant reduction in the energy expenditure during data transmission can be achieved when compared to the energy based transmission (EbT) of binary data.

III.SURVEY OF RELATED WORK

The medium access control is a broad research area, and many researchers have done research work in the new area of low power and wireless sensor networks [11], [12], [13], [14]. Current MAC design for wireless sensor networks can be broadly divided into contention-based and TDMA protocols. The standardized IEEE 802.11 distributed coordination function (DCF) [1] is an example of the contention-based protocol, and is mainly built on the research protocol MACAW [15]. It is widely used in ad hoc wireless networks because of its simplicity and robustness to the hidden terminal problem. However, recent work [2] has shown that the energy consumption using this MAC is very high when nodes are in idle mode. Even though redundant arithmetic algorithms produce significant improvements in performance through the elimination of carry propagation, efficient circuit implementations of these algorithms have been traditionally difficult to obtain. This work presents a survey of circuit implementations of redundant arithmetic algorithms. The described implementations are divided into three main groups: (1) conventional binary logic circuits, which encode the multivalve digits of redundant arithmetic into two or more binary digital signals;(2) current-mode multiple-valued logic circuits, which directly represent multivalve redundant digits using on-binary digital current signals; and (3) heterostructure and quantum electronic circuits, intended for very compact designs capable of operating at extremely high speeds [5].Efficient power saving scheme and corresponding algorithm must be developed and designed inorder to provide reasonable energy consumption and to improve the network lifetime for wireless sensor network[12] systems. The cluster-based technique is one of the approaches to reduce energy consumption in wireless sensor networks. In this article, we propose a saving energy clustering algorithm to provide efficient energy consumption in such networks. The main idea of this article is to reduce data transmission distance of sensor nodes in wireless sensor networks by using the uniform cluster concepts [10].

IV. ALGORITHM

Step 1: Recode the n-bit binary data frame to its equivalent RBNS data frame using steps and 1.2 stated below.

Step 1.1: Starting from the least significant bit (lsb) position, scan the string for a run of 1's of length > 1. A run of *k* 1's (*k*> 1) starting from bit position *i* , is replaced by an equivalentrepresentation consisting of a '1' at bitposition *k* + *i* and $\bar{1}$at bit position *I* with 0's in all Intermediatebit positions.

Step 1.2: Every occurrence of the bit pattern$\bar{1}$ 1 In a string obtained after step 1.1, is Replaced by the equivalent bit pattern 0$\bar{1}$.

Step 2: Transmit the RRRBNS data frame obtained From steps 1 above

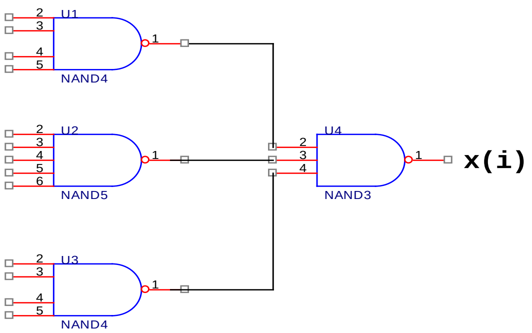
Note that the encoding process of an *n* -bit binary string to its equivalent RRBNS representation can resulting a RRBNS string of length of either *n* or+1symbols. If a run of 1's of length > 1 ends in themostsignificant bit(*msb*) then by virtue of step 1.1of Transmit RRRBNData algorithm, the symbol 1 is placed at the position *msb* +1. Otherwise, if the *msb*was 0, then the RBNS string also has exactly *n*symbols.
Example 1: Consider in a given binary string, substring, say 110111, with only one '0' trapped between runs of 1's. Then following step 1.1,wewould get the string 10$\bar{1}$100$\bar{1}$. Note the presence ofthe pattern$\bar{1}$1 for this trapped '0'. Application of step1.2 of algorithm Transmit RRBNData to the bit pattern$\bar{1}$1 replaces it by 0$\bar{1}$, thus resulting in a further reduction in the number of non-zero symbols to betransmitted.The receiver side algorithm to receive a RRBNSdata frame and convert it back to binary involves executing the reverse process of TransmitRRBNData. Itis to be noted that the application of steps 1.1 and 1.2of the TransmitRRBNData algorithm ensures that the bit patterns $\bar{1}$1 and $\bar{1}$1 cannot occur in thetransmitted data. Hence, there is only a unique way ofconverting the received RBNS data into its binaryequivalent

A. Hardware Implementation

Our proposed transmission strategy involves the execution of the steps,

1).Recodes the binary data frame in RRBNS using reduction rule.

2). Send the RRBNS data frame, transmitting only the 1 and $\bar{1}$ symbols, while remaining silent for the 0 symbols.



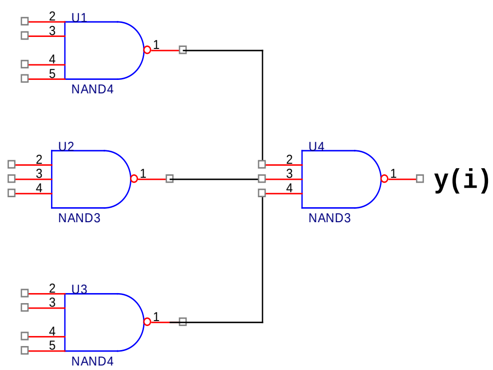


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Fig 1.a Hardware Implementation

Apparently, application of reduction rules 1 and 2 warrants two-pass algorithm. However, it is easy to combine the two rules to obtain a single pass algorithm. As an alternative to software conversion, it is possible to design a simple hardware circuit to convert from binary to RBNS. Let the RBN digit b_i^{rbn} , $0 \leq i \leq n$,corresponding to the bit $b_i$of the givrn binary number be respersented by two bits x(i) and y(i), x(i) being the most stgnificant bit. Assuming an encoding of the RNB digits as 0 by 00, 1 by 01 and $\bar{1}$ by 10, and denoting the bits b_{i+2}, b_{i+1}, b_i, b_{i-1},b_{i-2} by a,b,c,d,e and *f*, respectively, Fig. 1 depicts a representive hardware circuit for evaluating *x(i)*and *y*(i) with b_{-3},b_{-2},b_{-2},b_{-1},b_n and b_{n+1} initialized to 0. Thecircuit in in Fig. 1.a,b can be used for pipelined transmission scheme

where the conversion of the i-th RBNS symbol. On the receiver side, the reverse process has to be done to serially covert the received digits 0, 1or$\bar{1}$ into its binary equivalentation for futher processing by the different layers of the network stack. The details can be found in [1]. The equivalebt harware circuit for coverting each received RBNS symbol to its binary equivalent is show in Fig. 2. In Fig. 2, R_0 , R_1 ,$R\bar{1}$ represent whether the received *i*-th symbol is 0 ,1 or $\bar{1}$ and b_i^* is its equivalent binary form .

Observations 1: The application of the reduction rules on the binary data during transmission ensures that the digit patterns $\bar{1}\bar{1}$, $1\bar{1}$ and $\bar{1}1$ do not occur in the transmitted data.

Observation 2:If the original data was an n-bit binary data frame, RRBNS encoding canresult in a frame size *n +1* RRRBNS digits.

Observation 3*:* The encoding processes need to scan from the least significant digit position to the most significant digit position , andthese can be conveniently over mapped with a pipelined serial transmission /reception of the digits.

V.SIMULATION

A. Energy savings for Ideal Device Characteristics

Thus, the total number of 1's and $\bar{1}$ in the RRBNS coded message obtained after applying reduction rule (considering also the presence of R 1's) is equal to 2S + (n +2). 2^{n-3} = (3n +2). 2^{n-3} . Hence, the fraction of energy savings over *EbT* schems by applying reduction rule is given by,

$$\eta_e = 1 - \frac{(3n+2)2^{n-3}}{n.2^n} = 1 - \frac{3n+2}{8n} \quad (3)$$

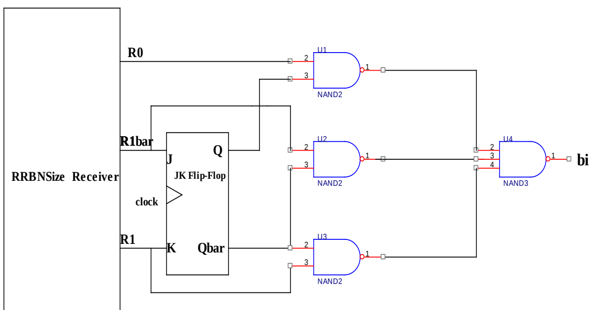


Fig. 1.b Hardware diagram for o/p bits x(i) and y(i) of RRBNS symbol b_i^{rbn} generated from b_i at the transmitter.

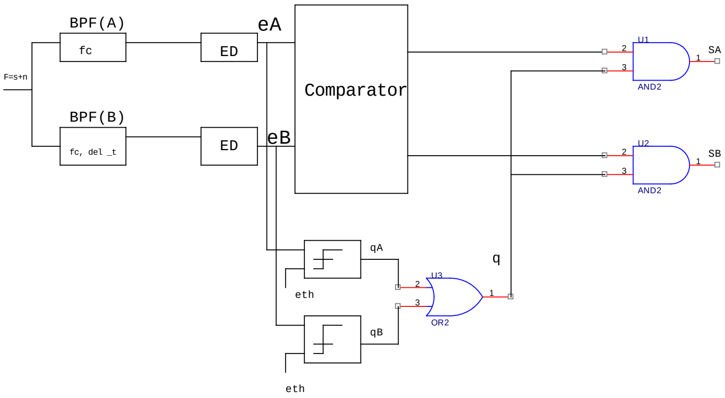


Fig. 2Circuit diagram for converting received i- th RBN symbol to its equivalent binary symbol b_i^* at the receiver

Typically for n = 8, η_e is nearly equal to 60% and for

n = 1024, η_e = 63%.Let us now consider the effect of applying reduction rule on the RBNS coded string (after applying reduction rule. Every appearance of the pattern $\bar{1}1$ in the RBNS coded string will be replaced by $0\bar{1}$ after applyingreduction rule 2, and this appearance corresponds to every single '0' in between two runs of 1's in the original binary string. To compute the total number of so

much appearance of singleton 0's trapped between two runs of 1's, we proceed as follows.Note that the total number of singleton 0's in all possible binary strings of length η is same as the total number of appearance of R_1's, and is equal to $N_1 = (n+2)2^{n-3}$. From this, we subtract the total number of appearance of singleton 0's occurring at either end of the string, i.e., in strings of the from $01*^{n-2}$or $*^{n-2}10$, whose number is equal to $2^{n-2} + 2^{n-2} = 2^{n-1}$.
Thus, the total number of 1's and $\bar{1}$'s in the RBNS coded message after applying both reduction rules is equal to $(3n+2).2^{n-3} - (n+2)2^{n-3}+2^{n-1} = (n+2).2^{n-2}$. Hence, the fraction of energy saving obtained by applying reduction rule is given by,

$$\eta_e = 1 - \frac{n+2}{4n} \quad (4)$$

Typically, for n = 8, η_e is nearly equal to 69% and for

n = 1024, η_e = 75%.

B. Performance comparison with QPSK

Using Coherent Receiver Design: Instead of using the non-coherent FSK-ASK detection with our proposed RBNSiZe Comm technique, if we would have used coherent detection, then a possible receiver diagram would have been as shown in fig. (3).

Figs.(4 to 6). show the energy savings on different data types for the application domains. Fig. 5 depicts the average transmitter power (scaled with respect to noise power) in dB for given values of ρ FER/n.

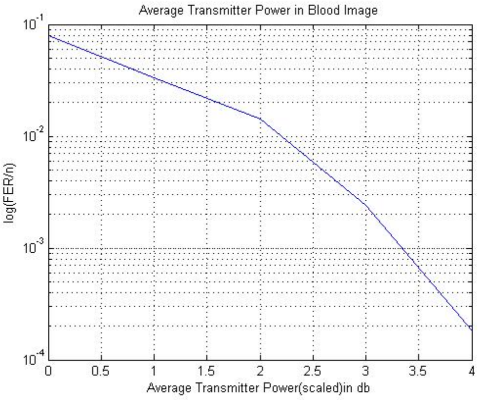


Fig.3 Non- coherent FSK receiver for RRBNS .

Fig.4Average transmitter power of Blood image

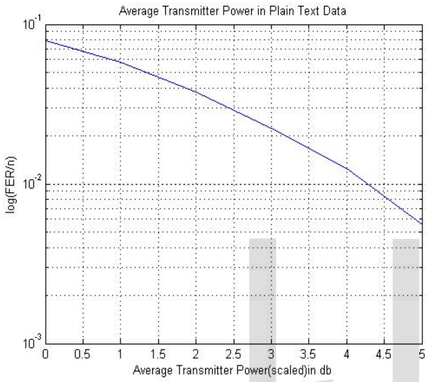


Fig. 5 Average transmitter power of Plain text

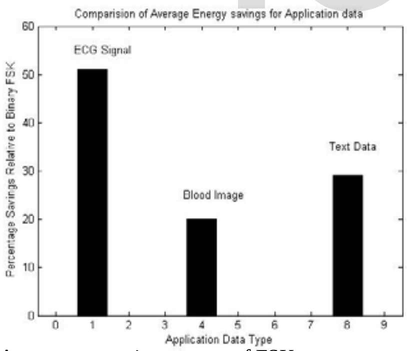
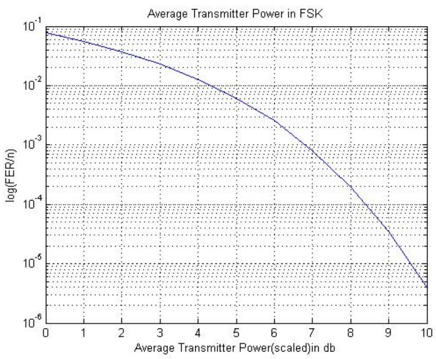


Fig. 6Average transmitter power of FSK



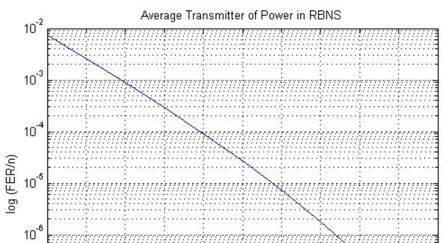


Fig.7 Relative energy savings for variouswirelessapplication data types

averaged over 8 ≤ n ≤ 1024, while Fig. (7) shows the relativeaverage energy savings generated by RBNSiZeComm at the transmitter compared to binary FSK.We evaluate the energy saving generated by RBNSiZeComm for two typical applications in WSNs remote healthcare and agricultural sensor networks. For evaluation of energy saving for the healthcare application, we considered the transmission of, JPEG images of blood samples and ASCII text data

representing various physiological parameters like blood pressure, blood sugar level, temperature.Application scenarios such as remote healthcare, and agriculture wireless sensor networks show that compared to binary FSK, RBNSiZeComm provides an energy benefit of about 33% to 62% at the transmitter in increasing the battery life of the device.

VI.CONCLUSION

We have presented in this paper an energy efficient communication scheme based on encoding the source data in redundant binary number system (RBNS), coupled with the use of silent periods for communicating the 0's in the encoded message. A low cost and low complexity implementation scheme based on a hybrid modulation utilizing FSK has also been presented. We have also shown that for coherent detection, our proposed coherent RBNSiZeComm scheme has comparable performance to QPSK. Simulation results with the different types of data required for communication .

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