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Implementation of Energy Efficient scheme for wireless communication network

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Abstract— The Proposed system for Wireless sensor networks on average require low cost devices and low power operations. Thus, such networks usually employ radios with only plain modulation techniques such as ASK, OOK and FSK [1]. We propose a novel energy efficient communication scheme for wireless sensor networks that is based on the redundant radix based number (RBN) representation for encoding and transmitting data. Coupled with silent periods for communicating the digit zero, this encoded communication scheme, called as RBNSiZeComm, provides a highly energy efficient technique for data transmission. consider an -bit data representation and assuming that each of the 2 binary strings is equally possible to occur, theoretically available fraction of energy savings by using our proposed RBNSiZeComm transmission protocol is, on An typical, $1 - \frac{n+2}{4n}$.
Hybrid modulation scheme using FSK and ASK with non-coherent detection based receiver for the RBNSiZeComm protocol has been presented. Our RBNSiZeComm protocol communication scheme is similar in concepts Ternary with Silent Symbol (TSS) in [3][5].Assuming equal probability of all possible binary strings of a given length, there is nearly 53% savings in energy on an average at the transmitter relative to binary FSK, over additive white Gaussian noise (AWGN) channels.[1][2].

Keywords—Energy-efficient communication, wireless sensor networks, silent symbol communication, redundant binary number system.

I. INTRODUCTION

Typically low cost and low power devices characterized by battery-powered sensor devices that are expected to operate over extended periods of time. Because of the difficulties in replacing the batteries of these devices rapidly and regularly and communication being a major source of power drain in such networks, energy-efficient communication protocols are of supreme importance in such networks. To achieve this goal, one need to address the energy-saving measures in all possible fronts such as physical layer, MAC layer, network layer and application layer in this paper, we focus our interest to the energy-efficient measures only in the physical layer along with an appropriate MAC protocol.

In practice, most existing transmission schemes not only utilize non-zero voltage levels for both 0 and 1 so as to 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 transmission of a data frame. Communication strategies that require energy expenditure for transmitting both 0 and 1 bit values are known as energy based transmission (EbT) schemes. In other words, if the energy required per bit transmitted is eb, the total energy consumed to transmit an n-bit data would be n eb. Most current research efforts on reducing energy consumption have focused on the MAC layer design, optimizing data transmissions by reducing collisions and retransmissions and through intelligent selection of paths or special architectures for sending data In all such schemes, the underlying communication strategy of sending a string of binary bits is energy based transmission.

In distinction to EbT based communication schemes, a new communication strategy called Communication through Silence (CtS) was proposed in [4][5] that involves the use of silent periods as opposed to energy based transmissions. CtS, however, suffers from the disadvantage of being exponential in communication time. An alternative strategy, called Variable-Base Tacit Communication (VarBaTaC) was proposed in [2] that use a variable radix-based information coding coupled with CtS for communication. Borrowing from the concepts of CtS and VarBaTaC, [6] proposed a new energy efficient scheme called RBNSiZeComm for wireless sensor networks that recodes a binary coded data using a redundant radix based number representation and then uses silent periods to communicate the bit value of '0'. The authors in [10], showed that by using the redundant binary number system (RBNS) that utilizes the digits from the set {-1, 0, 1} to represent a number with radix 2, it is possible to significantly reduce the number of non-zero digits that need to be transmitted.

Simple modulation techniques such as ASK, OOK and FSK [9]. The family of phase and frequency modulations such as phase-shift keying (PSK), frequency-shift keying (FSK), -ary PSK, -ary FSK and their variants are superior to the amplitude-shift keying (ASK) and -ary ASK techniques employed for transmission of RBNS data. When one chooses to employ -ary PSK/FSK modulation scheme along with silence intervals for the dominant symbol which corresponds to an ASK transmission, the instantaneous power levels of the − 1 non-silent symbols may have to be increased fittingly, due to the comparatively inferior SNR necessities of ASK for the same bit error rate (BER) value compared to -ary PSK/FSK.

1.1 Our Contribution

In this paper, we first proposal a communication technique for WSNs, called RBNSiZeComm, wherein we combine the conversion of the data to be transmitted to its equivalent redundant binary number (RBN) representation with the strategy of using silence for communicating the digit zero. We show that by using the redundant binary number system (RBNS) that utilizes the digits from the set {-1, 0, 1} to represent a number with radix 2, we can significantly reduce the number of non-zero digits that need to be transmitted. Considering an n-bit data representation and assuming that each of the 2 binary strings is equally likely to occur, we derive the number of non-zero digits to be transmitted on an average $1-\frac{n+2}{4n}$ Finally, the simulation results demonstrate that compared to binary FSK, RBNSiZeComm can provide a benefit of about 33% to 62% in improving the battery life of transmitters for the various communication data types required in these applications

II. RELATED WORK

Mainly existing research efforts on dropping energy consumption have focused on the MAC layer design optimizing data transmissions by sinking collisions and retransmissions [8], [9] and through intellectual selection of paths or special architectures for transfer data. In all such schemes, the fundamental communication strategy of sending a string of binary bits is energy based transmissions (EbT) [5], [6], which implies that the communication of any information between two nodes.

Involves the expenses of energy for the broadcast of data bits. These novel new communication approaches called Communication through Silence (CtS) has been proposed in [5] that involve using silent periods as opposed to energy based transmissions. CtS experience from the disadvantage of being exponential in time. A substitute approach called Variable-base tacit communication (VarBaTaC) has been proposed in [6] that use a variable radix-based information coding attached with CtS for communication.

III. BASIC PROPOSAL

In the redundant binary number system (RBNS) [1] utilize the digits from the set (-1, 0, 1) for representing numbers using radix 2. In the rest of the paper, for expediency, we indicate the digit '-1' by 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 $100\bar{1}$ in RBNS. In this work, we utilize this property of RBNS to recode a message string so as to reduce the number of 1's in the string while transmitting the message

Reduction Rule 1: A run of k 1's (k > 1) starting from bit position i, is replaced by an equivalent representation consisting of a '1' at bit position k + i and a 1 at bit position i, with 0's in all intermediate bit positions. 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. Note that the number of non-zero digits remain unchanged for k = 2. Also, if we consider a string, say 110111, with only one '0' trapped between runs of 1's, then after applying reduction rule 1, we would get the string $10\bar{1}100\bar{1}$. A second reduction can now be applied to the trapped bit patterns $\bar{1}1$ so as to replace it by $0\bar{1}$. Thus, from $10\bar{1}100\bar{1}$, we would get the string $100\bar{1}00\bar{1}$ with further reduced number of non-zero digits

Reduction Rule 2: Every occurrence of the bit pattern 11 in a string obtained after applying reduction rule 1, is replaced by the equivalent bit pattern 01 [1].

IV. PROJECTED PROTOCOL

Our projected transmission policy involves the implementation of the following two steps:

1) Recode the binary data frame in RBNS using reduction rules 1 and 2.

2) Send the RBNS data frame, transmitting only the 1 and 1 symbols, while remaining silent for the 0 symbols.

Observation 1: The application of the reduction rules 1 and 2 on the binary data during transmission ensures that the digit patterns 11, 11 and 11 do not occur in the transmitted data.

Observation 2: If the original data was an n-bit bi-nary data frame, RBNS encoding can result in a frame of size n + 1 RBNS digits.

Observation 3: The encoding and decoding processes need to scan from the least significant digit position to the most significant digit position, and these can be conveniently overlapped with a pipelined serial transmission/reception of the digits.

A. Energy Savings for Ideal Device Characteristics and Ideal Channel

Let us denote a run of 1's of length k by Rk. Clearly, two consecutive runs of 1's of length k1 and k2, 1 · k1; k2 · n in a string of bits of length n will be separated by at least one zero

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

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

Typically, for n = 8, η is nearly equal to 60% and for η = 1024, ηe =63%.

Let us now consider the effect of applying reduction rule 2 on the RBNS coded string (after applying reduction rule 1). Every appearance of the pattern 11 in the 2n-3 RBNS coded string will be replaced by 01 after applying reduction rule Note that the total number of singleton 0's in all possible binary strings of length n is same as the total number of appearances of R1's, and is equal to N1 = (n + 1)2n-3 .Thus, the total number of 1's and $\bar{1}$s in the RBNS coded message after applying both reduction rules 1 and 2 is equal to (3n+2).2n-3 - (n+2)2n-3 +2n-1 = (n+ 2).2n-2. Hence, the fraction of energy saving obtained by applying reduction rule 1 followed by reduction rule 2is given by,

$$\eta e = 1 - \frac{(n+2).}{4n}$$

(2)Typically, for n = 8, ηe is nearly equal to 69% and for n = 1024, ηe =75% [1][3].
A. Physical Implementation Issues: consider various issues arising out of the practical implementation of the proposed protocol as discussed below.

B. Representation of RBN encoded numbers: Representation of three levels (1 0 -1) followed by rule 1 and rule2 mentioned above.

C.Synchronization Issues: A necessary underlying requirement for the correct detection of silent symbols in the RBNSiZeComm protocol is the presence of clock synchronization between the sender and the receiver [7]. We assume that the receiver and the transmitter are i) either synchronized for every packet on the MAC packet header - as commonly done in most wireless and wired communication protocols ii) there exists a global clock.

D. Collision Avoidance Issues: For contention based medium access protocols, an issue that arises with the use of silence-based symbols in the transmitted data is how do the neighboring nodes determine whether the channel is actually free for trans-mission or whether there is an ongoing transmission containing a run of 0'sFor contention based medium access, we propose three possible MAC layer schemes for handling the issues of collision and correctly detecting the channel status [8].

E. Effect of Device Characteristics: To see the device characteristics take example [7][8].
Consider example: Example 1: For the CC1100 chip supporting O-QPSK modulation, we have Ilow= 1.9 mA and Itran= 8.7 mA. At 868/915 MHz, values of Ihigh are 30.3 mA, 19.7 mA, 16.6 mA and 14.0 mA for 10 dBm, 5 dBm, 0 dBm and -5 dBm output power respectively. Also, trise = 88.4 us and for a data rate of 2.5 Kbps, we have tp= 400 us. Assuming = 1024, we thus get from equation (3.11), ne' = 74.20%, 70.81%, 69.01% and 66.87% for 10 dBm, 5 dBm, 0 dBm and -5 dBm output power, respectively.
Example 2: For the CC2420 chip, Ilow = 0.426 mA, Itran ≈ Ilow and values of Ihigh are 17.4 mA, 14 mA, 11 mA, 9.9 mA and 8.5 mA at 0 dBm, -5 dBm, -10 dBm, -15 dBm and -25 dBm output power respectively. trise = 0.1 us. As in the case of CC1100, we assume that tp= 400 us and n= 1024. Hence, from equation (3.11), we get ne' = 73.12%, 72.68%,72.05%, 71.73% and 71.20% for 0 dBm, -5 dBm, -10 dBm, -15 dBm and -25 dBm output power, respectively. Observation: ne' approaches the asymptotic value of ne = 75% for radios where Ilow << Ihigh Two examples of such radios include the RFM TR1000 (Ihigh = 12 mA, Ilow = 7.0×10^{-4} mA) and the Maxim 1479 (Ihigh = 7.3 mA, Ilow = 0.2×10^{-6} mA).[1]

Table 1.o/p power of real time transceiver chip cc1100 ***Table 2.o/p power of real transceiver chip*** cc2420

Chip CC2420	O/p Power
0 dBm	73.12
5 dBm -	72.67

10 dBm-	72.05
15 dBm-	71.73
25 dBm-	71.2

Chip CC1100	**O/p Power**
10dBb	74.19
5dBm	70.81
0dBm	66.01
5dBm-	66.87

Energy required when device in Active state
Pbase=n*2^n*tb*Ilow*Vcc=0.00607
Extra energy required to transmit one and reverse
P11=(n+2)*2^(n-2)*(tb-Trise)*Io*Vcc=0.02208
extra energy Prise required energy during edge transition from 0 to 1 or 1 to 0
Prise=(n+2)*2^(n-2)*Trise*(I_tran-Ilow)*Vcc=0.00607
Hense,the total energy required to transmit an n-digit RBN data frame%
E_rbn= Pbase + P11 Prise =0.0296
using EbT scheme
Eebt=n*(2^n)*tb*(Ihigh-I_tran)*Vcc= 0.069

F. Performance Comparison with QPSK

We now present a comparison with QPSK, using both non-coherent and coherent receivers for the RBNSiZeComm scheme.

1) Using Non-coherent Receiver Design: To compute the required SNR values with QPSK for a given from the following relation:

$P=Q\ (\sqrt{2}_{\gamma}) = 1/\sqrt{\pi}_{\gamma}\ e^{-}{}_{\gamma}$

2) Using Coherent Receiver Design: Instead of using the non-coherent FSK-ASK detection with our proposed RBNSiZeComm technique, assuming the threshold voltage level as $|x^{+}_{th}| = |x^{-}_{th}|$ =xth , 0≤ xth ≤ 1 . Due to the presence of Gaussian noise, the expression for α ,β ,δ would have been modified as

$\alpha = 1\text{-}2Q\ (\sqrt{\gamma/2}\ xth)$

$\beta=\delta== 1\text{-}Q\ (\sqrt{\gamma/2}\ \ (1\text{-}xth))$

G. Performance Comparison with CtS and VarBaTaC

We now compare the performance of RBNSiZeComm scheme with those of CtS [5] and VarBaTaC [6], which are also based on communication through silence. We first consider the transmission length duration. The trans-mission time in CtS is exponential in the number of bits to be sent. VarBaTaC uses a variable coding base and controls the communication time by suitably tuning the base value. Suppose, without any loss of generality, we want to transmit a value M, where 0≤M < 2k, 0≤ k. Then the representation of M in base r will have is then [1] $m = \frac{k}{\log r}$ Transmitted using CtS with a pulse separating each digit. Let tavg be the average number of time slots required in the VarBaTaC scheme. We need to transmit m + 1 pulses for the m digit to be transmitted. In addition, we need on an average $\frac{m(r-1)}{2}$ time slots for the digits (assuming equal likelihood for all possible values of the message). Hence, tavg is given by,

$$\text{tavg} = (m+1) + \frac{m(r-1)}{2} = \frac{m(n+1)}{2} + 1$$

Let r=2p , hence , m=$\frac{k}{p}$,and from above eqn. have

$$\frac{2p+1}{2} + 1 \le \text{tavg} < \left(\frac{k}{p} + 1\right)\left(\frac{2^p+1}{2}\right) + 1$$

Thus, for a given k, tavg monotonically increases with tavg p due to the function$\left(\frac{2^p+1}{p}\right)$ Thus, in CtS and VarBaTaC, the energy savings generated during transmissions would be substantially outweighed by the excessive receiver energy due to much longer duration of communication than that with RBNSiZeComm [9].

V. SIMULATION RESULTS

We evaluate the energy savings generated by RBN-SiZeComm for two typical applications in WSNs

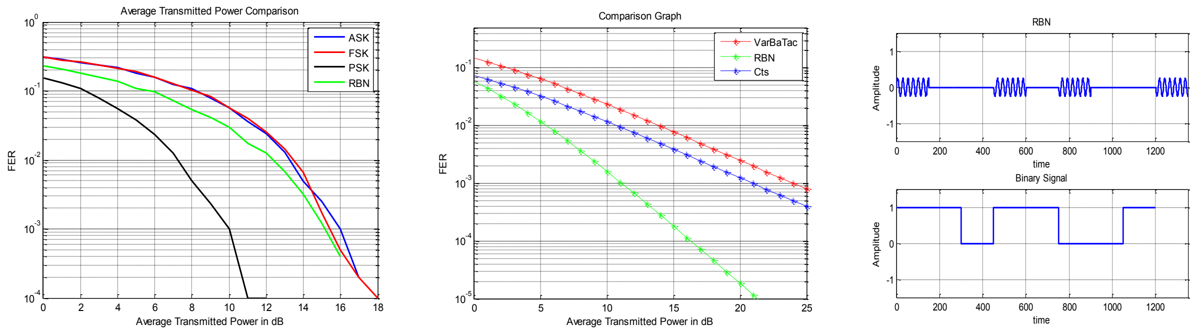

Table 3.Calculation of energy required To Transmit an N-Digit RBN Data

Total Energy Required To Transmit An N-Digit Rbn Data	**Total Energy Required To Transmit An N-Digit Data Using EbT Scheme**
0.0296	0.069

VI. CONCLUSION

The presented paper on an energy efficient communication scheme based on encoding the source data in redundant binary number system (RBNS), attached 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 and ASK has also been presented. Using the extra precise concept of FER for error analysis, we have shown that for AWGN noisy channels, there is an average savings of about 53% in energy at the transmitter for equal probability of all possible binary strings of a given length. We have also shown that for coherent detection, our proposed coherent RBNSiZeComm scheme has comparable performance to QPSK.

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