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Orthogonal Codes convolution with Closest Match Error Control Coding for Wireless Sensor Networks

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Abstract : Conventional hamming code adopted in Wireless Sensor Networks (WSN) increases the link reliability and reduces the transmitted power but with a limitation of single bit error correction capability. A 16 bit Orthogonal Codes convolution with Closest Match(OCCM) error detection and correction technique has been proposed for LEACH, PEGASIS and LBSEE network routing protocols with better Bit Error Rate performance and coding gain when compared to hamming code. Also the technique is of low complexity and is suitable for Wireless sensor networks (WSN) whose channel has random error pattern and burst errors of length one to three bits.

***IndexTerms* - WSN, Channel, Error control codes, OCCM, Routing**

I. INTRODUCTION

The reliability of data transmission plays a major role in Wireless Sensor Network (WSN). Sensors are deployed in the sensor field to sense, process and communicate with each other. Reliability of data transmitted from nodes to sink plays important role in WSN. The data transmitted from the sensor nodes are corrupted by errors induced by channel noise and other signal interference. Many times sensors operate in a complex and noisy real world where transmission link state varies sporadically inducing packet collision, transmission error and interference which lead to packet loss. Due to the short operating range of sensor nodes, data needs to be transmitted via a multi-hop manner as compared to single hop in case of wireless networks [1]. Multi-hop networks introduce a lot of entry points for errors leading to packet loss. Power and noise related impairments lead to fading, random errors and interference produce burst errors. To improve QOS (quality of Service) of WSN numerous error control methods are utilized. Three primary order of error control plans are FEC (Forward Error Correction), ARQ (Automatic Repeat Request) and Hybrid ARQ. In FEC locating the error and its correction is done at the receiver and there is no re transmission of information in this technique whereas in ARQ strategy, recipient sends solicitation to transmitter to retransmit the information if mistake is identified. Hybrid ARQ technique is a combination of FEC and ARQ.

Contribution: Main contribution of this work is simple error control coding based on channel error characteristics for error control in wireless sensor networks. Accordingly we implement OCCM for three WSN routing protocols PEGASIS, LEACH, LBCEE and analyze the network life time for all the three routing protocols.

Organisation: In Section III, OCCM error control code is portrayed in detail. Section IV and V provide power model and overview of routing protocols. In Section VI, OCCM performance is investigated for LEACH, PEGASIS and LBCEE routing algorithms. The paper is concluded in Section VII.

II. EXISTING WORK

Channel coding techniques are responsible for error control in WSNs. Mohammad [2] explained many error detection and correction techniques for WSNs. RS(31,11) RS(31,16), RS(31,21), RS(31,26)and RS(15,11) Reed Solomon codes with different code and message length are considered for simulation. Power consumption and Bit error ratio is analyzed for all RS codes.

Jaein Jeong and Cheng-Tien Ee[3] investigated hamming code versions (DECTED (16,8)), (SECDED (30,24)) and (SECDED (13,8)) in indoor and outdoor environment. Packet drop rate for outdoor test is zero for 1-bit, 2-bit errors.

Cheng-Lai et al.[4], showed that RS code gives better BER performance for distances less than 40 meters. Range of communication is improved by 10m compared to without FEC. RSSI is improved by about 8DB compared to without FEC for 10-3 Packet error rate.

Imad et al.[5] used LDPC codes and RS codes adaptively based on node distance and channel condition. If channel condition is good and inter node distance is less RS encoding is adopted else LDPC coding is adapted. Adaptive technique improves network life time by using less complex RS coding for shorter node distance.

Mallanagouda & Rajashekhar [6] proposed a dynamic technique which controls errors in adaptive fashion based on channel characteristics and noise energy at the receiver. This work builds models for both the error and channel assessment. Examination and simulated result for different message error conditions and sizes show that there is an improvement in throughput, BER and the likelihood of retransmission when contrasted with ARQ Scheme with Adaptive Error Control (ASAEC)

M.P.Singha & Prabhat Kumar [7] designed an effective Forward error correction scheme for WSN's to avoid repeated transmission which consumes less energy as well as extends its usefulness to deal with burst errors.

Nashat et al.[8] presents a low power decode and-forward methodology for the multi-hop WSNs; a serial concatenation convolutional codes (SCCC) encoder is configured at sensor nodes while the complex iterative decoding is implemented at the sink (base station). The turbo decoder at the base station along with Viterbi algorithm at the intermediate nodes can correct most errors at low SNR.

Daniel et al. [9] Proposed relevance based partially reliable transmission technique. Data to be transmitted is arranged into one of three different levels of reliability. Critical data are constantly retransmitted while data packets with auxiliary data is not. Hop by hop retransmission recovers complimentary or redundant data. For higher PER, the proposed approach won't just avoid energy utilization also saves energy.

Phat et al. [10] proposed error control scheme using RS(Reed Solomon) (7, 3) which not only minimizes energy but also improves quality of data by distributing processing tasks. Also it is demonstrated that the proposed scheme can be applied for RS codes with a large size values of (n, k).

Nabil Ali et al. [11] analyzed various error control codes. Melike & Vehbi Cagr Pnar [12] analyzes performance of hamming codes for smart grid applications. Y. Cui et al. [13] implemented single error correcting and double error detection codes.

III. ORTHOGONAL CODES CONVOLUTION WITH CLOSEST MATCH

Widely used error correcting codes in WSNs are Hamming, Goley, Reed Solomon and convolution codes. Among these codes convolution codes performs better but consumes more energy because of complex decoder. The Hamming codes have lower performance but their simple decoder structure consumes less energy therefore they are used in low power WSN applications where errors are random and the error rate is low. Hamming code is able to correct all single-bit errors. SEC-DED codes are extended Hamming codes which can detect and correct a single-error and at the same time detect (but not correct) a double bit error.

Choice of error detection and correction technique depends on WSN application and characteristics of WSN channel. This paper considers low power and small memory WSN application. Types of errors expected due to channel noise are single bit or double bit errors and burst errors are present but rare [14]. We propose Orthogonal Codes convolution with closet Match (OCCM)[15] for WSNs which can correct up to 3 bit random and burst errors. OCCM technique is based on property of orthogonal and antipodal codes. It has simple decoder with only X-OR operation at decoder side, thus reducing the complexity of decoder.

3.1 Orthogonal code

Orthogonal codes are binary codes with equal number of 1's and 0's. An n-bit orthogonal code has n/2 number of 1's and 0's; i.e., parity of each pattern of orthogonal codes is equal to 0, because of even number of 1's. Also each pattern of antipodal code will generate a zero parity bit. Antipodal codes are complement of orthogonal codes.8 bit Orthogonal and antipodal codes are listed in Table I. 8 bit orthogonal code has 8 orthogonal codes and 8 antipodal codes with zero parity.

Table I
8 Bit orthogonal codes

Orthogonal Codes	Parity	Antipodal codes	Parity
00000000	0	11111111	0
01010101	0	10101010	0
00110011	0	11001100	0
01100110	0	10011001	0
00001111	0	11110000	0
01011010	0	10100101	0
00111100	0	11000011	0
01101001	0	10010110	0

In n bit OCCM technique 4 bit data is encode in to n bit data at transmitter side. At receiver side Error correction is carried out by decision process using cross correlation function

R(x,y).The received *n* bit code is compared with each *n* bit code in look up table by exclusive OR operation for detection of errors. Correlation should be less than or equal to threshold value d_{th} .Threshold value is represented by $d_{th}=n/4$.

Correlation function is given by

$$R(x, y) = \sum_{i=1}^{n} x_i y_i \leq d_{th} \quad (1)$$

Where *dth* is threshold value

Error correction capability is calculated by the equation

$$N= R(x, y)-1\leq n/4-1 \quad (2)$$

Where, N = Number of errors that can be corrected.

3.2 16 bit OCCM

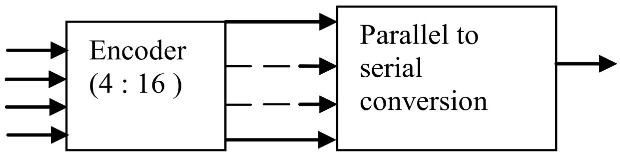

Fig.1Transmitter

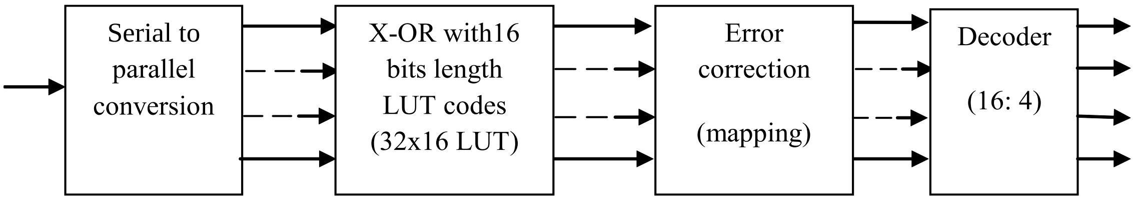

Fig.2 Receiver

The transmitter and receiver of OCCM is shown in Figure 1 and Figure 2 respectively. Transmitter converts 4 bit message to 16 bits code, then it is transmitted through the channel in serial fashion. At the receiver side serial data is converted in to parallel. With the help of look up table, error detection and correction is done at receiver and 16 bit data is converted back to 4 bit parallel data. Error correction capability and design complexity of OCCM and Hamming code is compared in table II and III respectively.

TABLE II

Error correction Capability of OCCM and Hamming code

Error control code	(n,k)	Correction capability
OCCM	(4,16)	3 bits
Hamming	(4,8)	1 bit

Table III

Design Complexity Comparison

Error control code	Computational blocks that must be designed in detail
OCCM	Adder
Hamming	Adder, Multiplier

IV. ROUTING PROTOCOL DESCRIPTION

LEACH (low energy adaptive clustering Hierarchy) LEACH allocates cluster head job among nodes in random fashion which makes it dynamic. Nodes which are not cluster heads transmit data to their cluster head, where as cluster heads transmit data to base station[16].LBCEE stands for Loop Based Chain and Energy Efficient routing protocol is a chain based routing protocol .This protocol forms a chain of all sensor nodes in the sensor field to transmit data to sink/base station. Protocol chooses the first node in random fashion, after each round of data transmission [17]. In each chain formation process dead nodes are removed from the chain. PEGASIS (Power Efficient Gathering in Sensor Information Systems) is a category of hierarchical routing protocol. PEGASIS follows chain based methodology and adopts greedy algorithm. The sensor nodes are organized in such a way that there is formation of a chain. If there is any dead node found in the chain, it reconstructed the chain to bypass the dead node. Protocol assigns the task of transmitting data to cluster head which transmits the data to the sink node/ base station [18].

V. POWER MODEL

Energy required for transmission and reception of single bit of information is given by (By neglecting encoding energy as energy consumption for encoding is very small compared to decoding energy of error control code) equation (3)

$$E_{total}=E_{elec}+E_{tx}+E_{rx}+E_{amp}+EDA+ E_{dec} \quad (3)$$

Where E_{elec} is energy required to run the circuitry. E_{tx} and E_{rx} is energy required for transmission and reception of a bit. E_{amp} is amount of energy spent by the amplifier.EDA is data Aggregation Energy. Power required for decoder of error control code is represented as E_{dec}.

VI. Simulation results

In this section, the performance of OCCM code, coordinated with the different routing plans, is assessed. Moreover, the network life time is also analyzed without utilizing OCCM code.

A. Simulation parameters

OCCM code for different WSN routing protocol is implemented in MATLAB simulation tool. Simulation parameters are listed in Table IV

Table IV
Simulation parameters.

Parameter	Value
Initial node energy(Joules)	1J
Number of nodes	50/100
Area	$50m^2/200m^2$
Packet size	4000 bits
E_{elec}	$50x10^{-9}$Joules/bit
E_{tx} and E_{rx}	$50x10^{-9}$Joules/bit
E_{amp}	$50x10^{-9}$Joules/bit/m^2
EDA	$50x10^{-9}$Joules/bit
Eadd	3:3 X 10^{-5} (mW/MHz)

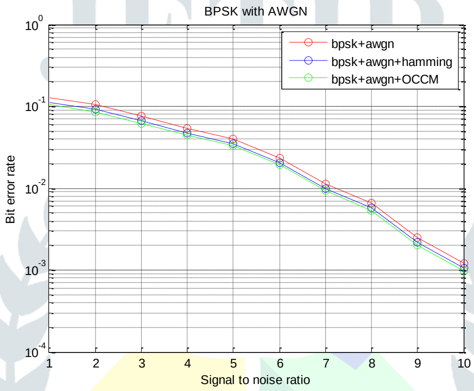

Fig.3 BER performance of Hamming and OCCM technique

BER versus SNR is plotted for OCCM and Hamming code as shown in figure 3. As shown in table V There is BER minimization of 0.007471 by OCCM code when compared to Hamming code when SNR is 6dB.SNR improvement is about 0.5 dB when compared to hamming code. OCCM is implemented for different WSN routing protocol in MATLAB. E_{add} denote the energy consumption per m-bit in the addition of field elements in Galois Field ($GF2^m$).where m=log2n+1[19]. Simulation [20] parameters are given in Table IV.

Table V
Comparison of OCCM and Hamming code BER and coding gain

Error control code	*(n,k)*	Correction capability	Coding gain (BER=0.01076)	BER (SNR = 6dB)
OCCM	(16,4)	1,2,3, bit random errors, burst error up to length of 3 bits	6.5dB	.011809
Hamming	(7,4)	1 bit random error	7dB	.019280

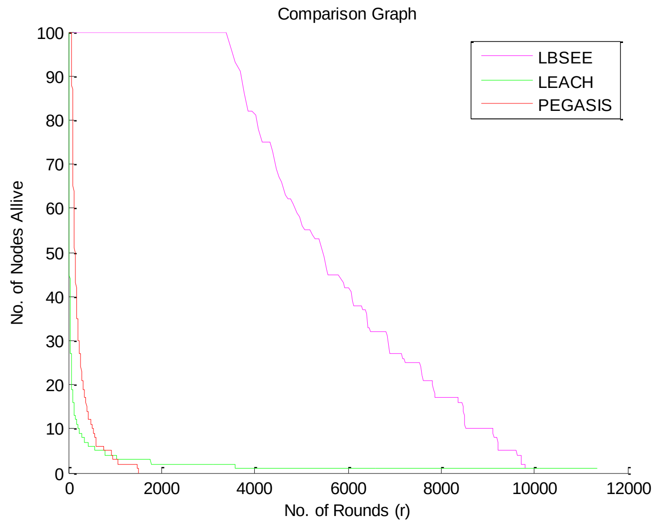

Fig 4. Network life time comparison for 50m^2 area.

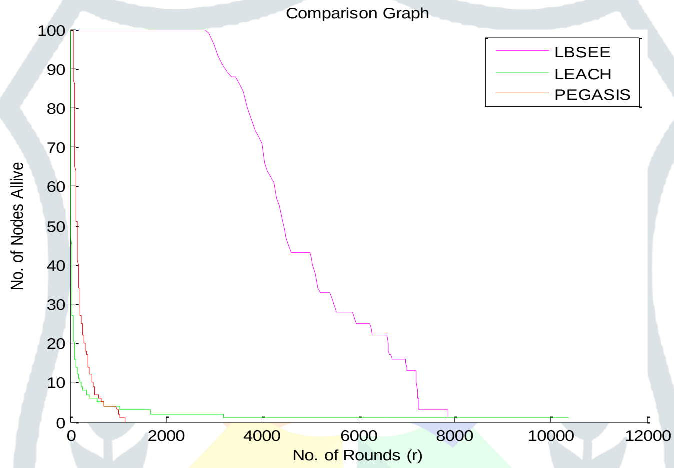

Fig 5. Network life time comparison for 200m^2 area.

TABLE VI

Statistics of leach, LBCEE and PEGASIS with OCCM code

Routing Scheme	LEACH				PEGASIS				LBCEE			
Number of nodes	50		100		50		100		50			100
Network Dimension in m^2	50	200	50	200	50	200	50	200	50 200	200	50	200
10% nodes dead	587	565	218	159	587	465	551	337	6982	2294	9492	3278
50% nodes dead	62	62	139	23	266	216	141	134	5083	2057	5376	2858
90% nodes dead	34	32	81	14	156	144	81	78	3565	18235	3586	2185

As shown in figure 4,when OCCM is simulated with 50 nodes and 50m^2 area WSN for LEACH routing protocol 10%, 50% and 90% of nodes are dead after 587,62 and 34 rounds respectively. In case of PEGASIS 10%, 50%and 90% of nodes are dead after 587,266 and 156 respectively. In case of LBCEE 10%, 50%and 90% of nodes are dead after 6982, 5083 and 3565 respectively. Difference in number of nodes dead when area is increased to 200m^2 as shown in figure 5 is very less for LEACH and PEGASIS when compared to LBCEE. Still WSN life span is more for LBCEE routing protocol with OCCM error control technique.

VII. Conclusions

OCCM decoder is less complex because of simple X-OR operation at decoder side. This technique works well for WSN applications whose channel characteristics has 1, 2 and 3 bit random and burst errors where less complex Hamming code fails to correct 2 bit random errors and burst errors. OCCM when implemented for WSN routing protocols, network life time is prolonged for LBCEE routing technique when compared to LEACH and PEGASIS. Performance of PEGASIS is in between LEACH and LBCEE. Though the proposed work shows improved BER performance it uses more redundant (4,16)bits for encoding compared to hamming code (4,7).As a future enhancement for the proposed work security algorithms can be adopted along with error recovery. Real time hardware implementation of proposed work is another challenging work.

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