PERFORMANCE ANALYSIS OF MINIMUM ENERGY CODE IN WIRELESS SENSOR NETWORKS

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***Abstract:** In Wireless Sensor Network (WSN) data is corrupted by errors due to noisy channels and other factors. To detect and correct error control codes are used. The different error correcting codes used in wireless network are ARQ, Block codes, BCH codes, RS codes, Convolutional codes, Turbo codes etc. These codes are designed keeping in mind about band width used for data storage, where as energy consumption by these codes is not taken into account. But in case of WSN the error correcting codes must be designed to use energy efficiently in order to increase the battery life of the sensor nodes which in turn will increase sensor node life. Therefore conventional error correcting codes can not be used in WSN. Our main objective in this paper is to come up with energy efficient coded modulation scheme that consumes comparatively less power both at system and circuit level. A simple On/Off keying (OOK) digital modulation scheme is used for this purpose. Minimum Energy (ME Codes) code is the one which uses very less energy for transmission of data. ME codes use On Off Keying Modulation (OOK), in which carrier signal is sent during data bit '1' called 'high bit' and no carrier signal is sent during data bit '0'. Thus by reducing number of high bits in data we can save energy. ME codes map the original data with code words with less high bits, thus reducing energy used by code. Simulating ME codes in Matlab R2007a with communication toolbox we observed that energy consumed by these coeds decreases considerably as message length (and hence codeword length) increases.*

***Keywords:** Error Control Codes, WSN, BER, Minimum Energy Code, ME Code*

1. INTRODUCTION

A wireless sensor network (WSN) is a computer network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations.[7] The development of wireless sensor networks was originally motivated by military applications such as battlefield surveillance. However, wireless sensor networks are now used in many civilian application areas, including environment and habitat monitoring, healthcare applications, home automation, and traffic control.[7][8]

CHARACTERISTICS AND REQUIREMENTS

In this section we discuss some characteristics and requirements of a sensor node.

i) Energy-efficiency

Sensor node must be energy efficient. Sensor nodes have a limit amount of energy resource that determines their lifetime. Since it is unfeasible to recharge thousands of nodes, each node should be as energy efficient as possible. Hence, energy is the major resource, being the primary metric for analysis.

ii) Low-cost

Sensor node should be cheap. Since this network will have hundreds or thousands of sensor nodes, these devices should be low cost.

iii) Distributed sensing

Using a wireless sensor network, many more data can be collected compared to just one sensor.Even deploying a sensor with great line of sight, it could have obstructions. Thus, distributed sensing provides robustness to environmental obstacles.

iv) Wireless

The sensor node needs to be wireless. In many applications, the environment being monitored does not have installed infrastructure for communications. Thus, the nodes should use wireless communication channels. A node being wireless also enable to install a network by deploying nodes and can be used in many others studies for example liquid flow of materials.

vi) Multi-hop

A sensor node may not reach the base station. The solution is to communicate through multi-hop. Another advantage is that radio signal power is proportional to r4, where r is the distance of communication. Thus, depending on radio parameters as shown in [4], it can be more energy economic to transmit many short-distance messages than one-long distance message.

vii) Distributed processing

Each sensor node should be able to process local data, using filtering and data fusion algorithms to collect data from environment and aggregate this data, transforming it to information[9].

Applications of WSN

The applications for WSNs are many and varied. They are used in commercial and industrial applications to monitor data that would be difficult or expensive to monitor using wired sensors. They could be deployed in wilderness areas, where they would remain for many years (monitoring some environmental variable) without the need to recharge/replace their power supplies. They could form a perimeter about a property and monitor the progression of intruders (passing information from one node to the next). There are a many uses for WSNs.

Typical applications of WSNs include monitoring, tracking, and controlling. Some of the specific applications are habitat monitoring, object tracking, nuclear reactor controlling, fire detection, traffic monitoring, etc. In a typical application, a WSN is scattered in a region where it is meant to collect data through its sensor nodes. [10]

- Environmental monitoring
- Habitat monitoring
- Acoustic detection
- Seismic Detection
- Military surveillance
- Inventory tracking
- Medical monitoring Smart spaces
- Process Monitoring

Error Control Codes

Error control coding (ECC) is nothing but calculated use of "redundancy". The functional blocks that accomplish error control coding are "channel encoder" at the transmitter and channel decoder" at the receiver. For this reason ECC is also termed as "channel encoding". ECC improves the data quality to great extent and another great advantage is the reduction in (Eb/No) for a fixed bit error rate. This reduction in Eb/No reduces the transmitted power and hence the hardware costs. The disadvantages of ECC are increased bandwidth and more system complexity[11].

In Wireless Communication data is corrupted Bby errors due to noisy channels and other factors. To detect and correct error control codes are used. The different error correcting codes used in wireless network are ARQ, Block codes, BCH codes, RS codes, Convolutional codes, Turbo codes etc. These codes are designed keeping in mind about band width used for data storage, where as energy consumption by these codes is not taken into account. But in case of WSN the error correcting codes must be designed to use energy efficiently in order to increase the battery life of the sensor nodes which in turn will increase sensor node life. Therefore conventional error correcting codes can not be used in WSN. Minimum Energy (ME Codes) code is the one which uses very less energy for transmission of data.

Minimum Energy Codes

ME codes use a digital modulation scheme On Off Keying Modulation (OOK). In ME-coding scheme, source bits are mapped to constant length codes (ME odes) which has less number of high-bits in it. Since the OOK transmitter consumes energy only when transmitting a high-bit, mapping to ME- Codes reduces the total energy consumed in RF transmitter. In this paper, we have come up with ME- Coding scheme for sources with unknown statistics and we further propose a new method of code-by- code detection that can detect and correct certain errors in the codeword received. The inferior performance of OOK when compared to other simple modulation schemes is overcome by ME-Coding[4].

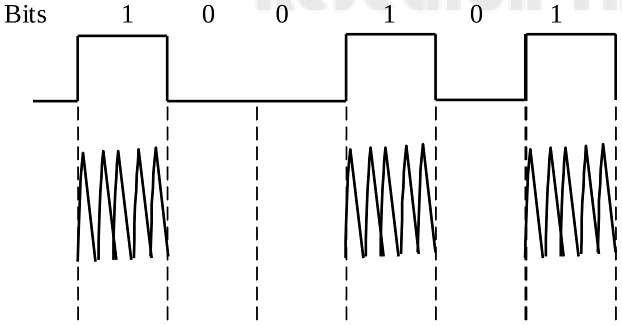

Fig (1) OOK Modulation Scheme

Erin and Asada[5][6], have discussed many approaches Towards optimizing the energy consumption problem and have proposed efficient source coding scheme for information transmission in wireless environment. We propose to use the basic idea of minimum energy source coding scheme proposed by them.

2. RELATED WORKS

Various authors are surveyed WSN with respect to different criteria. In [1] the survey on WSN is made with present state of the art WSN architecture giving the protocol stack of WSN, applications, technical issues etc. In [2] also survey about WSN is carried out with respect to applications of WSN, energy and computational constraint and solutions for them is given. In literature many authors have tried to explain energy efficient codes in WSN. [3] presented performance Analysis of Error Control Codes in Wireless Sensor Networks in terms of their BER performance and power consumption on different platforms. In detail, error control codes with different constraints are implemented and simulated using VHDL. Based on the study and comparison of the three different error control codes, the authors have identified that binary-BCH codes with ASIC implementation are best suitable for wireless sensor networks. In [4] the Minimum Energy (ME) coding scheme for sources with unknown statistics and a new method of code-by- code detection that can detect and correct certain errors in the received codeword is proposed. This research combines the modulation with the error control scheme to minimize power consumption. The on/off key modulation performance is improved with a ME-Coding. However, the ME codes have no capability of error correction. [5] explains the basic idea of Minimum Energy coding in wireless communication for source with known statistics (probabilities of occurrence of symbols). [6], have discussed many approaches towards optimizing the energy consumption problem and have proposed efficient source coding scheme for information transmission in wireless environment.

3. METHODOLOGY

Consider k binary bits (1's and 0's, with k >1) from the source. ME-encoder groups these bits together and maps it to a ME-Code word of length n, where $n > k$. Thus, there can be a total of M = 2k possible incoming symbols mapped on to M codewords that are predetermined. As already mentioned these codewords have less number of high bits compared to the original information sequence but with more number of bits in it. Our main idea is to apply the ME-coding to sources with unknown statistics. That is, say, a source symbol 1011000 or 1101011 can be mapped only to a code with not more than two ones or four ones in it respectively. [23]

Table 1 shows the source symbol and their corresponding mapped code words for M = 4 and 8. For mapping of M = 2k source symbols, we need a codeword of length n = M-b1. This is because the all-zero source symbol is mapped to an all-zero codeword sequence and the remaining M -—1 source symbols can be mapped to codeword with M -3 1 bits in it, with each codeword having one of its bit high. In general, for grouping k bits we need a code length of 2k -0 1. The code rate for this form of source coding is k/n = k/(2k -ž 1).

Table 1, K=Message Length

K = 2, ME(3,2)		K= 3, ME(7,3)		K= 4, ME(15,4)	
00	000	000	0000000	0000	000000000000000
01	001	001	0000001	0001	000000000000001
10	010	010	0000010	0010	000000000000010
11	100	011	0000100	0011	000000000000100
		100	0001000	0100	000000000001000
		101	0010000	0101	000000000010000

		110	0100000	0110	000000000100000
		111	1000000	0111	000000001000000
				1000	000000010000000
				1001	000000100000000
				1010	000001000000000
				1011	000010000000000
				1100	000100000000000
				1101	001000000000000
				1110	010000000000000
				1111	100000000000000

Similarly we can extend ME coding for K=5, 6, 7. From the table it is clear that the me codeword contains only one high bit to transmit that data.

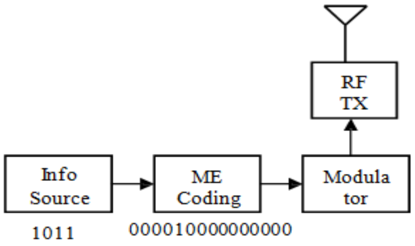

Fig 2. Block Diagram of ME Coding

The minimum euclidean distance between any two ME-code is *dmin* = 1. Thus, these codes have no capability of correction or detection of errors. However, the basic characteristic of the code (maximum of one high bit in the codeword) makes it possible to detect errors when the receiving codeword has more than one high bit in it. [5]However, the basic characteristic of the code (maximum of one high bit in the codeword) makes it possible to detect errors when the receiving codeword has more than one high bit in it.

4. PERFORMANCE ANALYSIS OF ME CODE

a) Bit By Bit Decoding of ME code

ME coded information can be decoded by bit-by-bit hard decision with 0.5 threshold on demodulated signal (Refer fig (3)). For simulation purpose, we consider a source generating binary bit sequence (1's and 0's) and additive white Gaussian noise (AWGN) channel. Matlab 7.4.0 (R2007a) with communication toolbox was used for simulation purpose. When ME(3,2) code from the above table is applied to the source symbols, and a bit-by-bit hard decision with 0.5 threshold is made without any error correction at the receiver, there is an improvement of 2 dB in the SNR per bit for a probability of error of 10-34. An improvement of 5 dB and 7 dB is seen with a ME(7,3) and ME(15,4) codes respectively.

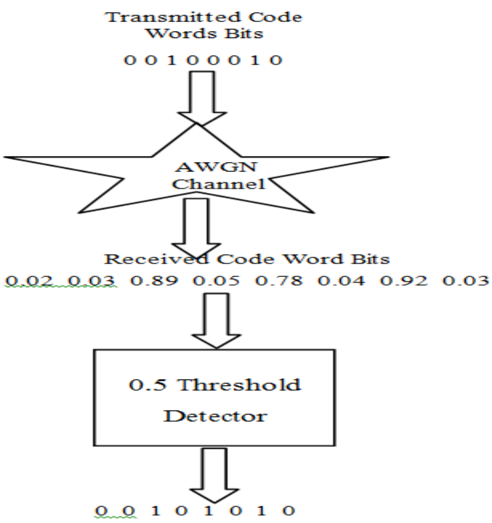

Fig 3. Bit by Bit detection Method

Performance Analysis of Bit By Bit Detection Method

Below figure (4) depicts the Bit Error Rate (BER) plot of bit by detection of different ME coding for different Eb/No values. It is noted that BER of ME Coding decreases as message length k and hence codeword length increases. Also we note that BER is significantly reduced for reduced Eb/No. The Performance of ME(127,7) code is better among all other ME Codes.

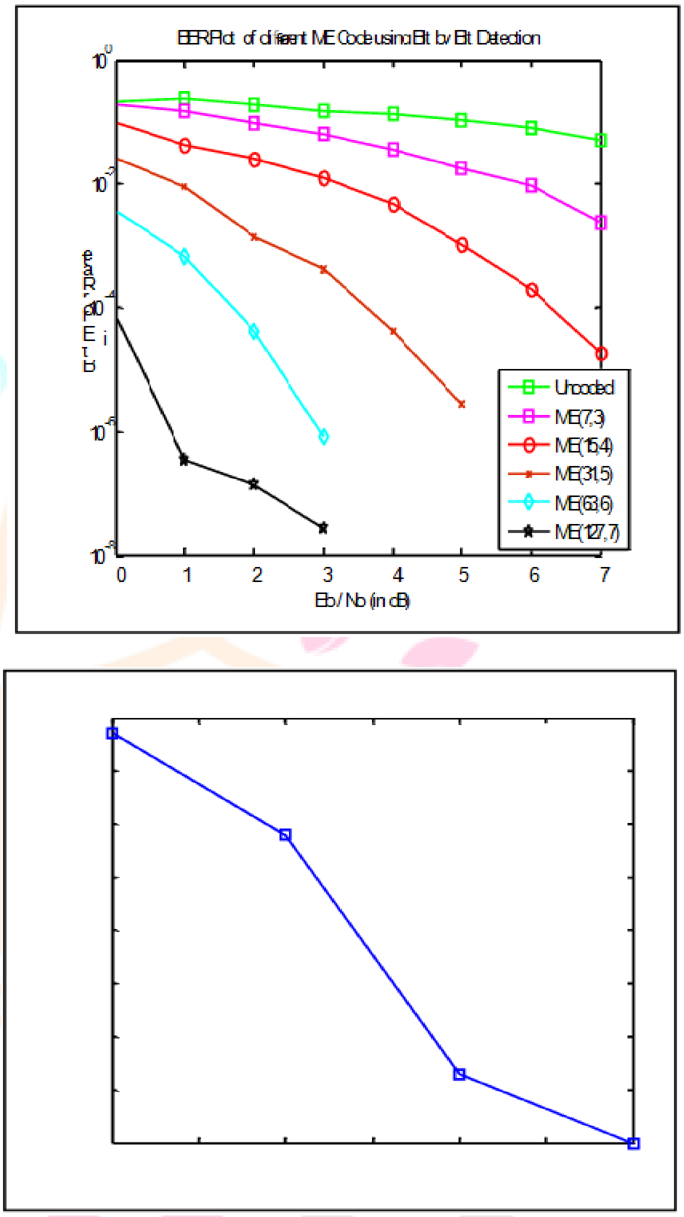

Fig 4 BER Plot of ME Code with Bit by Bit Detection Method

b) Code By Code Decoding Method of ME code

The signal strengths of the demodulated bits vary due to the presence of noise in the channel, the bits may not be the same as it was sent from the transmitter. We consider AWGN with zero mean and unit variance. After a bit-by-bit 0.5 threshold detection is made, a codeword bit sequence say, 0 1 0 0 0 0 0 might be sent and may be detected as 0 1 0 0 1 0 1. As already discussed, the basic property of the codeword has made it possible to detect an error in the codeword. Instead of declaring this codeword as one to be in error, we follow a different approach for codeword detection.Before a bit-by-bit hard detection is made,-5 we observe the energy levels of all the incoming *n* bits of the codeword. Then we make the bit with highest strength as a high-bit and the rest as low-bit. Figure 6 shows the process of our code-by-code detection for a codeword. It shows a transmitted codeword 0 1 0 0 0 0 0. This is demodulated as 0.0635, 1.236, 0.012, 0.001, 0.564, -

0.02, 0.64. In our earlier approach of bit-by-bit detection with 0.5 threshold, it would have been detected as 0 1 0 0 1 0 1. Now, by our approach we look at the bit with highest strength in the entire codeword. The original high-bit of energy 1.236 is set as bit-1 and the rest is made as bit-0's. Thus, it is detected as 0 1 0 0 0 0 0. Since the noise is AWGN, the probability of energy of genuine bit-1 being greater than the energy of the error bit-1 is more. ie. if energy of genuine bit-1 is *ei* and that of the error bit-1 is *ej*, then, *P*(*ei* > *ej*) is more than *P*(*ej* > *ei*). This fact is clear from a Gaussian distribution curve. By code-by-code detection process we accomplish two things. Firstly, we eliminate the occurrence of an invalid codeword at the receiver and improve the error performance of ME Coding. Secondly, this method performs exactly like an optimal detector.

Performance of ME-Coding with Code-by- Code Detection Below Figure (5) shows performance of ME Codes with bit by bit decoding method.

In this Figure, ERCN represents the code-by- code detection which has error correction capability. For an error probability of 10-Ừ4, a total of about 3 dB, 6 dB and 9 dB improvement in SNR per bit was seen with ME(3,2), ME(7,3) and ME(15,4) respectively compared to uncoded OOK. ie. ME- Coded OOK can now perform a given probability of error with lesser SNR per bit value. In this plot ME(255,8) code performance is better than remaining ME Codes As was in bit by bit decoding method here also performance of ME codes increases as codeword length (message length) increases.

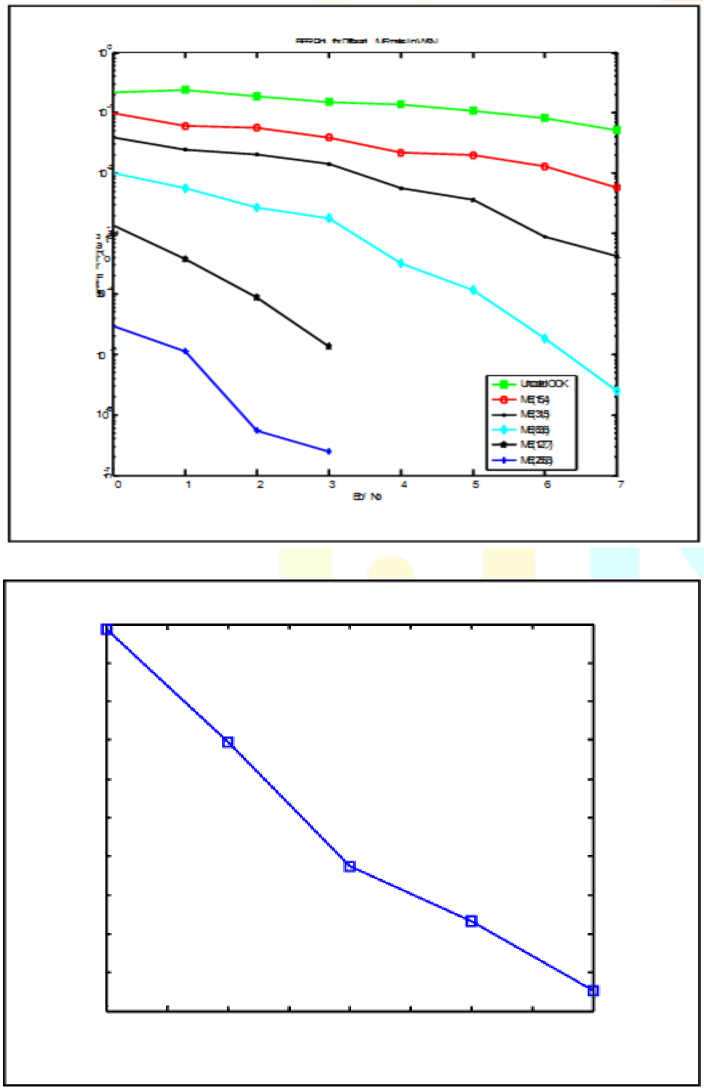

Fig 5 BER Plot of ME Code with Code by Code Detection Method

The main reason for such a comparison is to emphasize the fact that ME-coded OOK is more energy efficient than other simple schemes like block-coded BPSK/BPAM and also to propose a new and simple approach of improving the inferior error performance of the OOK scheme. Although this scheme is based on On-Off Keying modulation technique, the characteristic of the code makes it look like an orthogonal signaling scheme [8], except for the presence of an all-zero code. As a matter of fact, it is quite different compared to orthogonal signals in terms of transmission / reception techniques and also performance. In orthogonal signal scheme, each symbol (group of *k* bits) is transmitted as one of 2*k* orthogonal signals and received as one of 2*k* orthogonal signal vector. However, in ME-coding scheme used here, a code representing a group of *k* bits is transmitted bit-by-bit and received bit-by-bit.

c) Comparison of performance of Bit by bit and

Code by code method of decoding of ME Codes.Below figure shows the comparative analysis of bit by bit and code by code method of decoding of various ME Codes

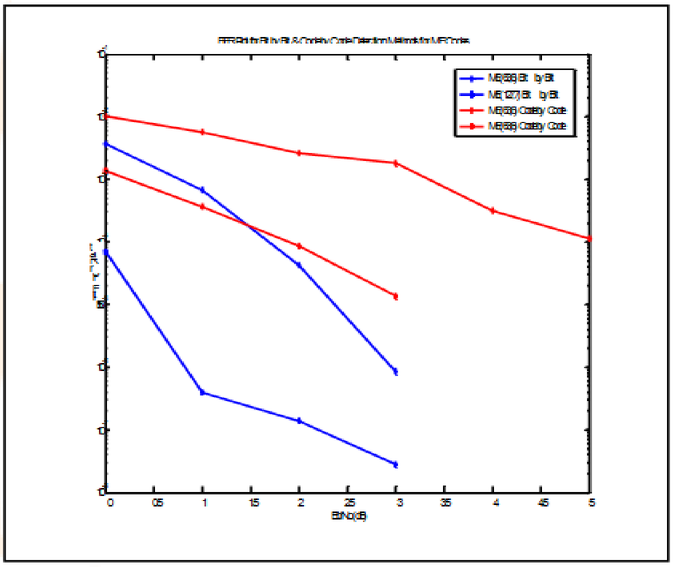

Fig 6 BER Plot of ME Code with Code by Code and Bit by Bit Detection Methods

5. CONCLUSION

Wireless Sensor Network is a new field in wireless communication and researches are going in that field. From literature survey of Error control codes in Wireless Sensor Network, we can note that BCH codes can be used in WSN as they draw less energy for data transmission. ME codes are another type of error correcting codes can be used in WSN. ME codes use OOK modulation technique to transmit data. ME codes can detect errors but can not correct them. Bit by bit detection method for decoding of ME code can be implemented. Code by code detection method can be used in ME codes to detect errors and recover the original data. From BER plot of both method reveal that BER decreases as Eb/No increases as in other error control codes. Important notice in simulation of ME code is that energy consumed for the transmission of data in WSN decreases considerably with increase in message length of data (and hence ME code length). Thus from literature survey of WSN we conclude that ME codes are the one among other energy efficient error correcting codes in WSN.

6. REFERENCES

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