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Minimum Energy Channel Codes with High Reliability for Wireless Nano-Sensor Network

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Abstract—

For nanosensor networks, it is essential to have high energy efficiency, and proper modulation for proper communication. Energy efficient codes are needed for nanoscale communication. In this paper, Bit error rate (BER) has been measured for high reliability, and compared with different error correcting codes. It minimizes energy depending on various source cardinality. Here we analyze some paremeter to increase the efficient of the wirless nano-sensor network. In this paper, it is shown that for lower code weight, average energy is decreasing for the codes taken into consideration and also reliability is measured using Bit Error Rate (BER).

Keywords-MATLAB, MEC, Hamming, BER;

I. INTRODUCTION

Today in advance technology low power circuit, simple wireless communication and minimal computation facilities required(for future nano-devices) i.e. nano communication. It is a wide communication research area in recent years. To develop a new ideal communication technique suitable for nano-devices to design essential WNSN. In this paper, we try to minimize code weight as well as bit error rate for efficient communication.

Nanosansor/nanoscale technology different from traditional macro sensor, because they are too much small and highly energy detrainment and they also have limited computation capability. That means ,energy efficiency is one of the important issue in the practical design. As nanonodes works on faithful energy allocation. So all nodes are not fit. Thus average codeword energy can reduce by minimum energy coding.

Proposed scheme allot average minimum energy codeword of all block codes, on that OOK used as modulation scheme. In OOK modulation, when '0' is transmitted less energy or no energy is generated. When '1' is transmitted more energy is generated. Sourceword- codeword and codeword weights mappings are selected as that the supposing code weight reduced the cost of expanded codeword length, hence expanded delay. Long code words are responsible for energy consumed in transmitter of nanosensor circuitry. This suggests a deal between processing energies and transmission and thus a discontinuous optimization issue emerge. The satisfactory of nano-scale MEC is to present by getting the attain rate of nanonode.

To make high performance communication with less energy depletion in nano-sensor nodes, coding scheme must be chooose accordingly. Efficient energy coding scheme are broadly explain in literature. Researchers mainly used to calculate energy efficiency by E_b/N_0, where E_b denotes energy per bit and N_0 denotes noise power spectral density. But E_b/N_0 is not a real matric to reach minimum energy objective. For every probable source outcome the power of average codeword is less than any selective codeword sets for MEC, for selecting codeword. To fulfil this requirement here propose minimum energy code is proposed. In this paper we mainly discuss about Hamming code constraint. MEC also introduce in minimum energy coding which minimize system energy codeword using OOK modulation technique. Some channel coding also developed to yield minimum energy consumption for every codeword.

Nanotechnology aims many applications such as biomedical, industrial and also in military fields as well as in consumer and industrial goods. The internet describes it a new networking prototype that tends to Internet of Nano-things, defines link of nanoscale devices with existing communication networks . The newfangled work in electromagnetic communication among nanoscale devices is described in [1], including channel modelling, information encoding and protocols in it. The properties of having high resolution for data collection and sensing and low power consumption is described in [2]. For reliable communication OOK modulation is needed, which reduces average codeword energy for wireless nanosensor network, where energy dissipation on transmitter side need to be considered[3]. The low-weight codes with femto second OOK pulses to shrink the intrusion in nano networks. A new modulation scheme minimum energy coding , to achieve energy efficiency and reliability is proposed[5].

The rest of the paper is organized as follows. In section II, we describe about architecture of WNSN. Section III presents the minimum energy code. Section IV deal with the parameter of MEC. In section V, discuss about the performance of MEC.

II. WSNS SLOT ARCHITECTURE

A particle which is able to sense environmental and physical properties at nanoscale is known as a nanosensor . So, such a device is assumed to be capable of sensing properties of environmental conditions at very small as well as gaseous levels. Hence it holds unique properties of nanomaterials as well as nanoparticles to detect various events in nanoscale. Nanosensors have the special sensing ability,to detect information as well as data.

Nano-Nodes: They are able to perform simple computation, have limited capacity, and can only transmit over short distances, because of their reduced energy and limited communication capabilities.

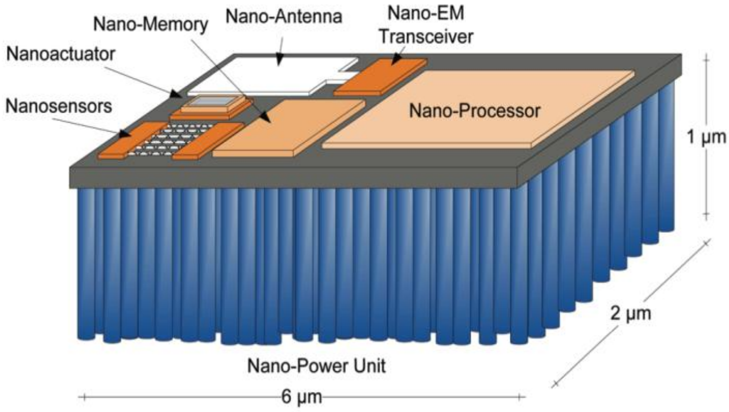

Fig 1. WSNS

Nano-routers: These nano devices have comparatively larger computational resources than nano-nodes and are suitable for aggregating information coming from limited nano-sensor devices. Nano-routers can also control the behaviour of nano nodes by exchanging very simple commands. This increase in capabilities invloves an increase in their size and hence makes their deployment more invasive.

Nano-micro interface devices: They are able to aggregate the information coming from nano-router, to convey it to the microscale and vice versa.

Gateway: This part will enable the remote control of nano sensor network throughout the internet.

III. MINIMUM ENERGY CODING SCHEME

Hamming Code: It is an error correcting code, was introduced by R.W. Hamming at Bell Labs. It can detect upto two errors and can correct a single error, hence it is known as single error correcting code. This cecking is done by having k parity-check bits at position 1,2,...2^{k-1}, checking each and every element whose binary representation having a '1' at position ki-1.

Reed-Muller Code: These are the oldest known codes, discovered by Muller and decoding algorithm was provided by Muller in 1954.For spanning vectors, using data bits a polynomial is created. Then an oversampled section of this polynomial is send by them. The original polynomial is reconstructed by multiplying data points with the vectors that are perpendicular to the spanning vectors. For positive integer 'm' and each integer 'r' with $0 \leq r \leq m$, there is an r^{th} order Reed-Muller Code R(r,m), where m>>1. For example R(1,2)={0000,0101,1010,1111,0011,0110,1001,1100}. It can correct upto $(2^{m-r}-1)/2$, i.e. 2 rounded down.

Reed Solomon Code: These are block based error correcting codes. These are linear block codes and subset of BCH codes. For (n,k) RS codes, symbol length has parameter of 'm' bits per symbol, block length of $n=2^m-1$ and data length of 'k' symbols. For parity symbols, it can correct upto t=(n-k)/2 (for n-k even) and (n-k-1)/2 (for n-k odd).

Let d, M, x, P_{max} represent code distance, number of codewords, the source random variable and maximum probability in any discrete distribution respectively.

Lemma 1: For any finite M, there exists a finite n_0 such that a constant weight code Ć of length n_0 containing the codeword 'c' can be constructed with code distance d, if and only if weight(c)≥ $\lceil \frac{d}{2} \rceil$:

$$\exists \acute{C} : dist(\acute{C}) \geq d \text{ for } c \in \acute{C} \leftrightarrow weight(c) \geq \lceil \frac{d}{2} \rceil .$$

Lemma 2: Any codebook having code distance 'd' containing mostly a single codeword with less than $\lceil \frac{d}{2} \rceil$.

Lemma 3: Any of two codeword C_i and C_j of a code, with code distance 'd' should satisfy inequality: weight (C_i)+weight(C_j)≥d.

Let $\acute{C}_i$ be the code with weight numerator

$$W_{\acute{C}_i}(z)=z^{\lfloor \frac{d}{2} \rfloor -i} + (M-1)z^{\lceil \frac{d}{2} \rceil +i}$$

Code $\acute{C}_i$ containing single codeword having weight $\lfloor \frac{d}{2} \rfloor$ -i

and all other codewords having weight $\lceil \frac{d}{2} \rceil$ +i. Let codeword having weight $\lfloor \frac{d}{2} \rfloor$ +i be assigned to source symbol with P_{max}. Let $E_{\acute{C}_i}$ represent the expected code weight for code $\acute{C}_i$.

Lemma 4:

$$E_{\acute{C}_{i+k}} < E_{\acute{C}_i} \; if \; P_{max} > 0.5, \forall k > 0$$

Proof: $E_{\acute{C}_i} = P_{max}(\beta - i) + (1 - P_{max})(d - \beta + i)$

$=P_{max}(2\beta - 2i - d) + d - \beta + i$

Similarly,

$$E_{\dot{C}_{i+k}} = P_{max}(2\beta - 2i + 2k - d) + d - \beta + i + k$$

$$E_{\dot{C}_i} - E_{\dot{C}_{i+k}} = k(2P_{max} - 1)$$

Since k is positive, $E_{\dot{C}_{i+k}} < E_{\dot{C}_i}$, if $P_{max} > 0.5$

Using these lemmas two theorems are derived

Theorem1.

Let X=x_i be distributed with $P_i \in \{P_1, P_2, ..., P_M\}$ and P_{max} be max(p_i). For a desired code distance 'd', the minimum expected codeword weight, E(w) is given by

$$\min(E(w)) = \begin{cases} (1 - P_{max})d, & P_{max} > 0.5 \\ \frac{d}{2} & P_{max} < 0.5 \\ \lceil \frac{d}{2} \rceil - P_{max}, & P_{max} < 0.5, d\ odd \end{cases}$$

Theorem2 2: Let X=x_i be distributed with $P_i \in \{P_1, P_2, ..., P_M\}$ and P_{max} be max(P_i). For a desired code distance 'd', the maximum expected codeword weight ' k ', for $\lceil \frac{d}{2} \rceil \le k \le d$ is satisfied, minimum expected codeword weight ,E(w) is given by

$$\min(E(w)) = \begin{cases} P_{max}(d - 2k) + k, & P_{max} > 0.5 \\ \frac{d}{2} & P_{max} < 0.5, d\ even \\ \lceil \frac{d}{2} \rceil - P_{max}, & P_{max} < 0.5, d\ odd \end{cases}$$

IV. ANALYTICAL RESULT OF THE MEC PARAMETER

A. Code Weight

It denotes the number of non-zero entries in a codeword. As discussed earlier, that codeword that has lower weight will undergo minimum energy dissipation. To minimize average average code weight, codebook selection must be done by calculating weight enumerator, such that expected code weight is minimized for given input probability function.

TABLE I. COMPUTATION OF MINIMUM EXPECTED CODE WEIGHT FROM THEORM 1 AND 2

P_{max}	Min E(w) for Hamming (7,4) d=3	Min E(w) for Binary R s (7,4) d=3	Min E(w) for Hamming (16,11) d=3	Min E(w) for Golay (23,12) d=3
0.1	1.9	3	1.9	3.9
0.2	1.8	3	1.8	3.8
0.3	1.7	3	1.7	3.7
0.4	1.6	3	1.6	3.6
0.5	1.5	3	1.5	3.5
0.6	1.2	2.4	1.2	2.8
0.7	0.9	1.8	0.9	2.1
0.8	0.6	1.2	0.6	1.4
0.9	0.3	0.6	0.3	.7
1	0	0	0	0

B. Bit Error Rate :

Bit error rate is also called probability of error. The bit error rate (BER) is the number of bit errors per unit time. The bit error ratio is the number of bit errors divided by the total number of transferred bits during a studied time interval.

C. Average Energy per bit :

Next, we obtain energy per information bit to demonstrate the energy efficiency of our coding scheme. Average energy transmitted per codeword is $E_c = P_{sym} E(w) T_{sym}$ joules,
where T_{sym} is the symbol duration. Then, the total energy dissipated for Q transmissions is ECQ. Therefore, the average energy per bit is expressed as the ratio $ECQ/\log(M)Q\xi_d$, i.e.,

$\eta = \frac{E(w) P_{sym} T_{sym}}{\log(M)\xi_d}$, Symbol power $P_{sym} T_{sym} = 10^{-5} pJ$

V. PERFORMANCE EVALUATION AND DISCUSSIONS

We have analyze the parameter and find the relation between some parameter

A. Bit Error Rate (BER) Vs Signal to Noise Ratio (SNR) :

To improve the reliability of data transmission, the designer has to increase the signal power or reduce the noise power so as to maximize the ratio S/N.When we have increased the value of SNR, the BER will be decreased. So if we can decreased the BER, we can get a reliable transmission medium.

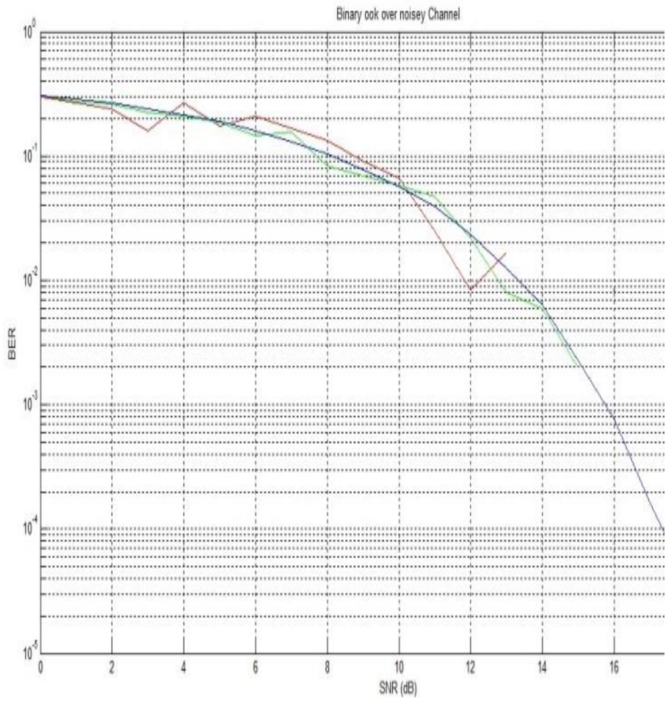

Fig 2 : BER Vs SNR for (7,4) Hamming, (21,6) Binary Reed-Solomon, (15,11) Hamming and (23,12) Golay code

From the MATLAB simulation, we observed that with increasing of SNR, BER is decreased for channel coding. From this graph, we can find that Golay Code is performed well respect to other channel code. In Golay code, BER is decreased efficiently compare to other channel code.

B. Minimum expected codeword weight Vs Maximum Probability in any discrete distribution :

Weight is the number of non-zero entries in the codeword. As we deal with binary codes, weight is equivalent to the number of 1*s* in the codeword [5]. For efficient code we can minimize the expected codeword weight, depending on the probability distribution. If we can minimize the expected codeword weight with respect to maximum probability, then the average energy of codeword will be minimized. From theorem 1, we analysis the min E(w) and found a graph which presents the relation between maximum probability in any distribution and minimum expected codeword weight for (7,4) (15,11) Hamming, (21,6) Binary Reed-Solomon and (23,12) Golay code.

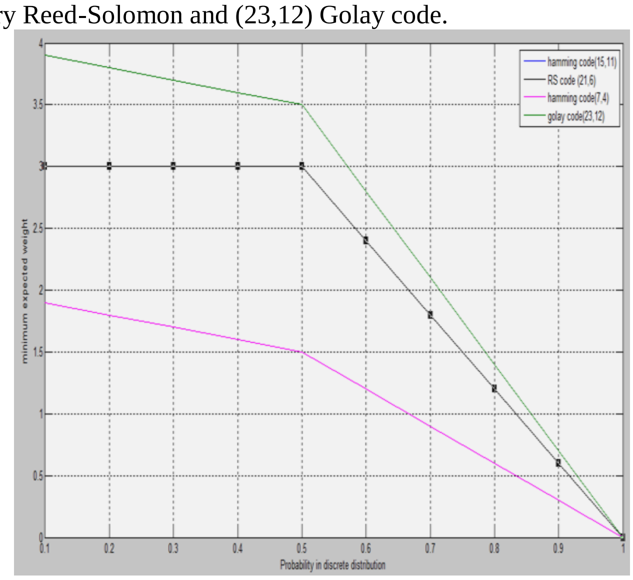

Fig 3 : Minimum Expected codeword weight Vs Maximum probability (Pmax) for (7,4) Hamming, (21,6) Binary Reed-Solomon, (15,11) Hamming and (23,12) Golay code.

Fig 3 Shows clearly that when probability will be maximum, expected code word will be minimum which is needed for a reliable in a wireless nano-sensor networks.

C. Average Energy Vs Minimum Expected Codeword Weight:

We calculated the average energy for (7,4) (15,11) Hamming, (21,6) Binary Reed-Solomon and (23,12) Golay code. If we compare the average energy with weight, then find that decreasing the weight, energy is also decreased that means weight and energy is directly proportional.

TABLE II. COMPUTATION OF AVERAGE ENERGY PER BIT FOR (7,4) HAMMING CODE

P_{max}	Min E(w) for Hamming (7,4) d=3	(η) Average Energy Per Bit for Hamming (7,4) d=3
0.1	1.9	9.5×10^{-5}
0.2	1.8	9×10^{-5}
0.3	1.7	8.5×10^{-5}
0.4	1.6	8×10^{-5}
0.5	1.5	7.5×10^{-5}
0.6	1.2	6×10^{-5}
0.7	0.9	4.5×10^{-5}
0.8	0.6	3×10^{-5}
0.9	0.3	1.5×10^{-5}
1	0	0

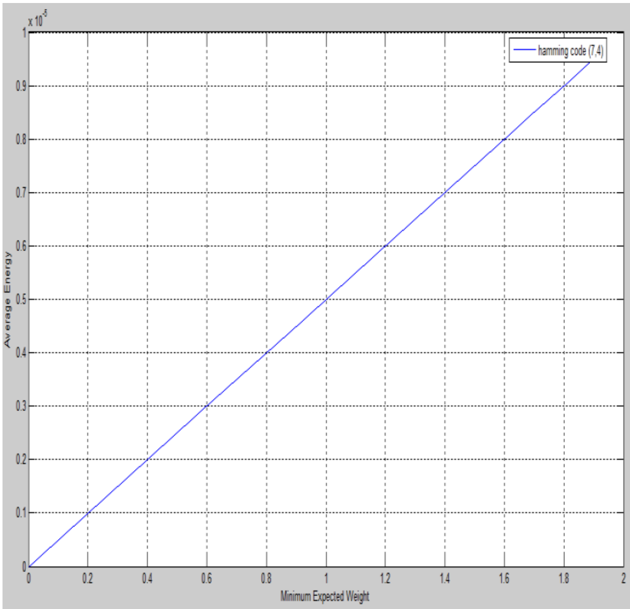

Fig 4 : Average Energy per bit Vs Minimum Expected codeword weight for (7,4) Hamming

TABLE III. COMPUTATION OF AVERAGE ENERGY PER BIT FOR (21,6) BINARY RS

P_{max}	Min E(w) for (21,6) Binary RS-M=64,d=6	(η) Average Energy Per Bit for (21,6) Binary RS-M=64,d=6
0.1	3	8.3×10^{-5}
0.2	3	8.3×10^{-5}
0.3	3	8.3×10^{-5}
0.4	3	8.3×10^{-5}
0.5	3	8.3×10^{-5}
0.6	2.4	6.6×10^{-5}
0.7	1.8	4.9×10^{-5}
0.8	1.2	3.32×10^{-5}
0.9	0.6	1.6×10^{-5}
1	0	0

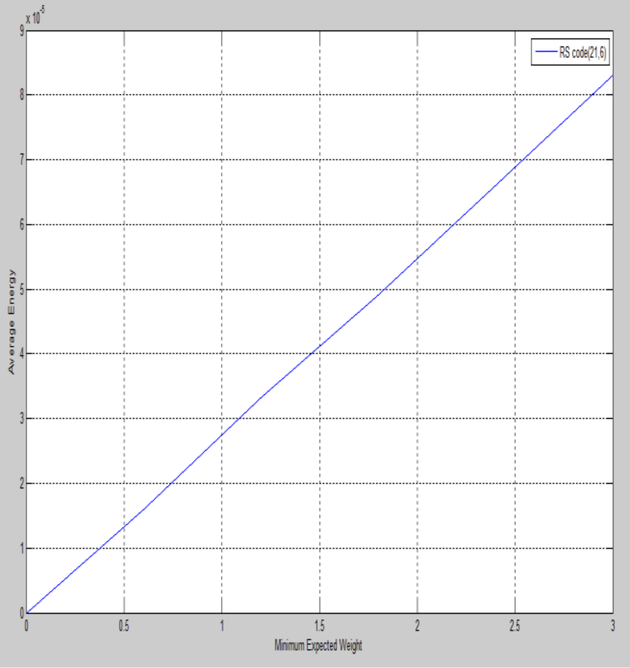

Fig 5 : Average Energy per bit Vs Minimum Expected codeword weight for (21,6) Binary R S

TABLE IV. COMPUTATION OF AVERAGE ENERGY PER BIT FOR ((15,11) HAMMING CODE

P_{max}	Min E(w) for Hamming(15,11) d=3	*(η)* Average Energy Per Bit for Hamming (15,11) d=3
0.1	1.9	2.8×10^{-5}
0.2	1.8	2.7×10^{-5}
0.3	1.7	2.5×10^{-5}
0.4	1.6	2.4×10^{-5}
0.5	1.5	2.2×10^{-5}
0.6	1.2	1.8×10^{-5}
0.7	0.9	1.35×10^{-5}
0.8	0.6	0.9×10^{-5}
0.9	0.3	0.4×10^{-5}
1	0	0

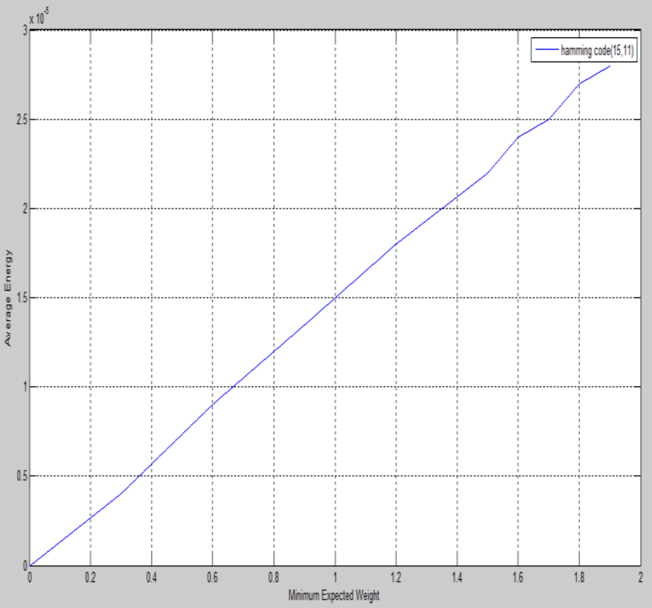

Fig 6 : Average Energy per bit Vs Minimum Expected codeword weight for (15,11) Hamming

TABLE V. COMPUTATION OF AVERAGE ENERGY PER BIT FOR ((21,12) GOLAY CODE

P_{max}	Min E(w) for (23,12) golay –M=4096, d=7	(η) Average Energy Per Bit for (23,12) golay –M=4096, d=7
0.1	3.9	5.3×10^{-5}
0.2	3.8	5.2×10^{-5}
0.3	3.7	5.12×10^{-5}
0.4	3.6	4.98×10^{-5}
0.5	3.5	4.84×10^{-5}
0.6	2.8	3.87×10^{-5}
0.7	2.1	2.9×10^{-5}
0.8	1.4	1.93×10^{-5}
0.9	0.7	0.96×10^{-5}
1	0	0

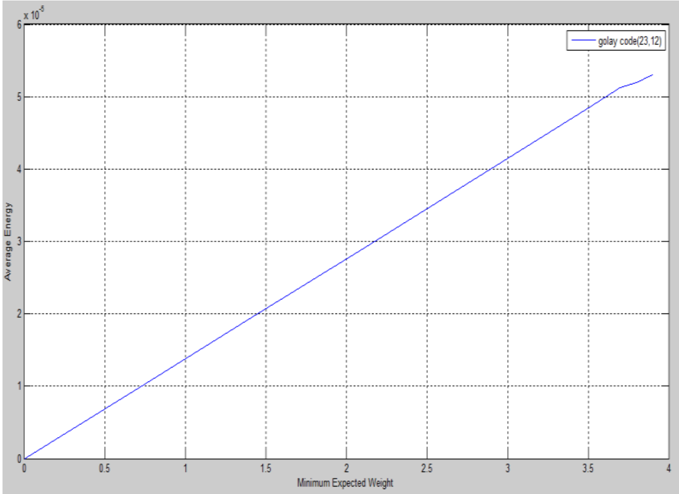

Fig 7 : Average Energy per bit Vs Minimum Expected codeword weight for (23,12) Golay Code

VI. CONCLUSION

In this paper, we have analysis the some parameter for minimize the energy of codeword and increase the efficiency. Thus we can get reliable communication in the nano-sensor network .From above analysis, we can conclude that Golay and Hamming Channel code is better efficient code for wirless neon-sensor network to get minimum energy.

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