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A Novel Framework for Nanoscale Wireless Communications Using Minimum Energy Channel Codes

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ABSTRACT

In the world of nanoscale wireless communications, usage of energy plays a vital role in the communications. In our proposed algorithm, a novel minimum energy coding scheme (MEC) and a novel modulation scheme is proposed for wireless nano sensor networks (WSNS). Unlike conventional algorithms, MEC maintains the reliability in the process of minimizing the energy. It is analytically shown that, with MEC, code words can be decoded perfectly for large code distances, if the source set cardinality is less than the inverse of the symbol error probability. The state of-the-art nanoscale power and energy limits are used to obtain high end achievable rates of nano nodes and high performance, which are expected to be on the order of Mbps, neglecting the processing power. Our proposed evaluation results outperform the popular Hamming, golay and Reed-Solomon in the average codeword energy sense.

Index terms- nanosensors, THz channel, CNT antennas, minimum energy coding, and nanoscale wireless communications

INTRODUCTION

“Nano scale wireless communication” is a promising technology which has ability to bring enormous change in daily lives. Nano technology is consider as ‘technology of next generation’, which has capability to produce devices in the range of 1 to few 100 nano meters. As technology is changing every next day, the necessity of new communication is needed which is suitable for nano device characteristics in order to yield the high end results in wireless nano sensor networks (WNSNs).

Employing channel coding at the nanoscale is a vital task in order to assure reliable communication between nano devices. The classical channel codes have various design considerations such as the efficient use of bounded decoding complexity , code space, as in perfect codes as the Shannon capacity is approached, as in Turbo or LDPC codes, or low encoding and decoding complexity as in cyclic and convolutional codes. However, the coding scheme for nano wireless communications should consider the energy dissipation at the transmitter as the main measuring statistic, since nano nodes run on a strict energy budget. Thus, classical codes are not suitable in the scenario of nano communication.

Potential nanosensors have significantly different performance statistics than the macro sensors. Although tremendous progress made in the area of nano communication networks, still no complete nano node has yet been implemented because of extreme low size, it is anticipated that power and energy efficiency are of the most critical measures due to their extremely small size. Hence, developing novel energy-efficient communication techniques is essential for creating a novel and efficient complete nano mode.

WIRELESS NANOSENSOR

Specification Energy efficiency and suitableness for the rate channel ar the previous concerns for the conclusion of WNSNs. Complexity of the nanosensors should even be kept as low as potential. During this section, we have a tendency to explain the communication techniques we have a tendency to develop for nanosensors and discuss a feasible extension to WNSNs. The main functionalities of the nanonode structure shown in Fig. 1 are often found in [3]. We have a tendency to propose victimization multiple CNT antennas to utilize a number of accessible frequency windows in rate band. Needed energy is often provided by the battery via nano energy-harvesting systems [10]. Sensing is also CNT-based.

Nanosensors readings are measure to M levels. No supply coding is utilized thus as not to increase complexness. Each supply amplitude is mapped to length − n channel code words with a combinatorial nano-circuit. Realization of such a processing is not clear today. However, studies on CNT-based logic gate applications [11] increase hope. The processing block is also responsible for carrier generation. Despite the fact that carrier generation in nano domain is not clear, it's shown that, with their unique properties like swiftness down surface EM waves, CNTs may also be wont to generate rate waves a lot of easier than the classical techniques [12].

Management block contains a separate antenna for thecontrolof the nanonode from a central unit. Nanonode activates and transmits only this antenna is happy. This functionality is needed for low complexness multiple access in WNSNs.

A. Multi-carrier OOK Modulation

Motivated with the rate channel characteristics, we have a tendency to propose a multi-carrier modulation scheme for nanoscale wireless communications. Each codeword is transmitted in parallel over totally different carriers. Our frequency alternative considers carriers' suitableness for transmission in the rate channel. As antecedently mentioned, the rate channel consists of many frequency windows with low absorption and low molecular noise, termed as out there windows, which depends on the transmission distance and water vapor amount on the transmission path [4].

Carrier frequencies are chosen among these windows in the rate channel. CNTs are used as nano antennas to radiate each carrier, as shown in Fig. 1. Each frequency window is utilized severally. Information measure increase is prohibited by the molecular absorption lines. Decreasing the information measure ends up in increased energy consumption per image, since image period increases. Hence, we have a tendency to choose information measure because the same because the dimension of the out there frequency windows. Hence, picoseconds long sinusoidal pulses are used, that span a frequency band of 100-200 gig cycles per second, like the dimension of most of the windows in the rate channel [4]. Channel codes with minimum average weight are utilized, at the side of OOK modulation at each carrier to reduce the energy consumption. Proposed coding achieves the minimum codeword energy and guarantees a minimum overacting distance at the value of prolonged code words. Multi-carrier modulation mitigates delays as a result of prolonged code words of MEC in WNSN node. The numbers of multi-carrier signals are often chosen to satisfy a certain delay demand.

B. WNSN CELL ARCHITECTURE

We contemplate a cell-based WNSN for the first time in the literature. A cell consists of a micro node, and nano sensor nodes scattered around it. So as to reduce the interference, nanonode square measure deployed among a radius of αR, where R is the cell radius and α is called the coverage quantitative relation satisfying zero < α ≤ one. to stay the complexity of the nanonode low, all the control and planning problems square measure left to the small node among the cells.

A nanonode starts transmission only when associate degree activation signal is distributed by the small node. As urged in [13], kilohertz band can be used for this activation signal, with moving CNTs. The central small node provides not only management, but also synchronization among the nanosensors. It is assumed that the small node is capable of receiving the terahertz waves. Within the current literature, many studies on CNT primarily based terahertz receivers incontestable that CNT bundles can be used for efficient terahertz detection at temperature [14]. With their employment, multi-wavelength terahertz receivers with small dimensions are going to be out there within the close to future. Let N be the amount of nodes in a very WNSN cell and l the amount of channels for multi-carrier modulation. Assume that each one the nanonodes square measure among a spread to directly communicate with the small node. There square measure 2 reliable medium access techniques, keeping complexity at the small node:

Single control Signal: Nanonodes start transmission simultaneously through disjoint sets of channels (frequencies). To stay complexity at the small node, different sets of frequencies should be utilized by each nanonode, and a common synchronization signal should be broadcast from the small node for signaling the transmission. N_l different terahertz frequency windows, and one kilohertz band square measure allotted to one cell. This can be associate degree FDMA-based theme, as separate frequency windows square measure allotted to every nanosensors node.

Multiple control Signals: Nanonodes use the same set of frequencies for transmission. The small node uses control signals at different frequencies for each nanonode sequentially, as nanonodes utilize the same terahertz channels. Allocation of l terahertz and N kilohertz bands square measure needed. This can be just like TDMA, since all the nodes use the channel in numerous time intervals. within the following, we have a tendency to assume that the small node uses multiple control signals, since the amount of frequency windows within the terahertz channel is limited and demodulating a number of different terahertz signals significant increases complexity.

MINIMUM ENERGY CHANNEL CODING

We propose new channel codes that minimize the common code weight. Such codes area unit cherish the codes minimizing average codeword energy for the systems using OOK which is that the possible cryptography strategy, the received n-tuple is mapped to the nearest codeword. Codes with distance d can correct bd−1c errors, and responsibility increases with distance, since plenty of error patterns are often corrected. Codeword's with lower weight lands up in less energy dissipation, once transmission of zero images desires less energy than the transmission of one symbol. OOK is associate degree example of such modulation schemes; throughout which transmission of 0s would like no energy. OOK is in addition favorable at nanoscale thanks to its simplicity. As seen, there has been a requirement to develop reliable minimum energy codes. To handle this issue, we have a tendency to develop minimum energy channel codes with any code distance d to ensure responsibility. Planned code minimizes the expected codeword weight, hoping on the availability chance distribution.

During this section, we have a tendency to derive MEC and obtain the corresponding minimum average code weight. In the nanonode, every codeword has an equivalent chance of prevalence as a result of the availability outcomes that they're mapped to, since no provide committal to writing mechanism is used. This brings a brand new drawback into the picture: what's the codebook selection that minimizes the common code weight for any input chance distribution? This drawback are often interpreted as finding the burden census taker and mapping between code words and supply words such the expected codeword weight for a given input chance mass perform is reduced. It's trivial that for no code distance constraint, i.e., $d = 1$, assignment code words with most weight of one minimizes the common weight, as planned in [9]. To obtain associate degree analytical resolution, we have a tendency to switch the minimum energy code drawback such codeword length n is unbroken free. Later, we have a tendency to develop the required code length for different cases.

Let M, d, p_{max}, X represent number of codeword's, code distance, maximum likelihood in any discrete distribution and the supply chance variable, severally.

Lemma 1.

For any finite M, there exists a finite n0 such that a constant weight code C of length-n0 containing the codeword c can be constructed with code distance d, if and only if $ht(c) \geq \left[{}^{d}/_{2}\right]$:

$\exists \mathrm{C} : dist(\mathrm{C}) \geq d\ for\ c \in \mathrm{C} \Leftrightarrow weight(c) \geq \left[{}^{d}/_{2}\right]$ (1)

Lemma 2.

Any codebook with code distance of d contains at most a single codeword with weight less than (d/2).

Lemma 3.

Any two codeword c_i and c_j of a code with distance d should satisfy the inequality weight (c_i) + weight $(c_j) \geq d$.

Let Ci be the code with weight enumerator

$$W_c(Z) = z^{\left[\frac{1}{2}\right]} - i + (M-1)z^{\left[\frac{1}{2}\right]} - i \quad (2)$$

The code C_i contains a single codeword with weight [d/2]-i and all the other codeword's have weight [d/2] + i.

Let codeword with weight [d/2]-i be assigned to the source symbol with maximum probability, i.e., p_{max}. Let E_{Ci} represent expected code weight for code C_i.

Lemma 4.

$E_{C_{i+k}<E_{C_i}}, p_{max>0.5}, \forall k > 0$

Proof: Let β represent [d/2]

$$E_{C_i} = p_{max}(\beta - i) + (1 - p_{max})(d - \beta + i)$$

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

$$E_{C_i} - E_{C_{i+k}} = k(2p_{max} - 1)$$

Hence, since k is positive, $C_{i+k} < E_{C_i}$ if $p_{max>0.5}$

MEC PARAMETERS

Power dissipated for codeword i is Pi = w_i P_{sym}, where Psym is the symbol power. Then the average power is

$$E(P) = \sum_{i=1}^{M} w_i p_i P_{sym} = E(w) P_{sym} \quad (3)$$

(6) Also shows the average power per *log (M)* bits, since codewords carry *log(M)* bits of information. For different source distributions, information per codeword will be different from an information theoretic point of view. However, for simplicity, we assume each codeword carries *log (M)* bits of information, leaving the information theoretic analysis to a future study.

We have developed MEC by keeping the codeword length unconstrained. Let us investigate the minimum length of MEC.

A. Minimum Codeword Length

n_{min} is the minimum codeword length required to satisfy the MEC weight enumerator for given M and d. n_{min} is important as it yields the minimum delay due to transmission of codewords. *A (n, d, w)* is the maximum number of codewords of length n with code distance d and fixed code weight w.

1. Pmax < 0.5, d even: Weight enumerator of MEC is $W_C(z) = M z^{d/2}$. Therefore, n_{min} = *min {n : A(n,d,w/2) ≥ M}*. Since 1s in each codeword are disjoint, n_{min} = Md.

2. Pmax < 0.5, d odd: From Theorem 1, we know that the weight enumerator is $W_C(z) = z^{[d/2]} + (M - 1) z^{[d/2]}$). 1s in all the codewords should be disjoint with the 1s in the most probable codeword, i.e., the codeword with weight [d/2].

Hence, $n_{min} = [d/2] + \min \{\tilde{n}: A(\tilde{n},2m+1,m+1) \geq M-1\}$, where $d = 2m + 1$. The following property is helpful [15]:

$$A(n, 2m-1, w) = A(n, 2m, w)$$

$$A(\tilde{n}, 2m+1, m+1) = A(\tilde{n}, 2m+2, m+1) \quad (4)$$

3. Pmax > 0.5: In this case, MEC has the weight enumerator $W_C(z) = z^0 + (M-1)z^d$ and maps the all-zero codeword to the most probable source event. Minimum codeword length is found as $n_{min} = \min \{n : A(n,d,d) \geq M - 1\}$. In the literature, there is no explicit formulation for A(n,d,d). We can use the existing lower bounds on the code size. From [15],

$$A(n, 2m, w) = A(n, 2m-1, w) \geq \frac{1}{q^{m-1}} \binom{n}{w}$$

$$A(n,d,d) \geq \frac{1}{q^{\left\lceil \frac{d}{2} \right\rceil - 1}} \binom{n}{d} \quad (5)$$

Where q is a prime power such that $q \geq n$.

Where n_{min} is $n_{min} = d + (M-2)\left\lfloor {}^{d}/_{2} \right\rfloor$ (6)

B. Error Resilience

The received n-tuples are mapped to the codeword to which they are closest in terms of Hamming distance. Then the probability that codeword is correctly decoded is

$$\xi_d = \sum_{i=0}^{\lfloor {}^{d-1}/_{2} \rfloor} \binom{n_{min}}{i} p_s^i (1-p_s)^{n_{min}-i} \quad (7)$$

We have shown that for sufficiently large distance, codewords are correctly decoded with high probability, if the symbol error probability is less than the inverse of source set cardinality.

$$\xi = \lim_{d\to\infty} \xi_d = \begin{cases} 1, & p_s < {}^{1}/_{M} \\ 0, & p_s < {}^{1}/_{M} \end{cases} \quad (8)$$

Hence, perfect communication can be achieved among nanosensors nodes and micro node, if $M < 1/p_s$, by keeping the code distance sufficiently large. Hence, if symbol error probability is decreased, nanosensors readings can be quantized with smaller quantization steps.

C. Energy per Information Bit

Next, we obtain energy per information bit to demonstrate the energy efficiency of our coding scheme. Probability that a codeword is correctly decoded, which is obtained in (7), can also be obtained as follows using law of large numbers:

$$\xi_d \approx \frac{\text{\# of codewords correctly decoded}}{\text{\# of codewords transmitted}} \quad (13)$$

For a large number of transmitted codewords, for a code with distance d. Hence, if Q codewords are transmitted, then $\log(M)\, \xi_d$ bits of information are received. Average energy transmitted per codeword is $E(w)P_{sym}T_{sym}$, where Tsym is the symbol duration. Then, the total energy dissipated for Q transmissions is $E_C Q$. Therefore, the average energy per bit is expressed as the ratio $E_C Q/\log(M)\, \xi_d$

i.e., $\eta = \frac{E(w)P_{sym}T_{sym}}{\log(M)\xi_d} \quad {joules}/{bit}$

D. Spectral Efficiency

Finally, we investigate spectral efficiency, which is one of the important parameters in a communication system. It is defined as the ratio of data rate to the bandwidth and yields how efficiently channel bandwidth is utilized. Information transmitted per codeword per second is given by $\frac{\xi_d \log(M)}{nT_{sym}}$. Bandwidth required per codeword in Hz is given by l B. Then spectral efficiency of MEC is obtained as

$$v = \frac{\xi_d \log(M)}{nlT_{sym}B} \approx \frac{\xi_d \log(M)}{2nl} \; {bps}/{HZ}$$

SIMULATION RESULTS: