Nanoscale Communication via Molecular Diffusion

D.Prabhu, Anand Kumar Prasad, Samrat Talukder, Pranay Karemore

Abstract: Electromagnetic waves lose their effectiveness in a range of nanoscale. To manipulate and control these waves in the nanoscale we use molecular diffusion. This method helps in the transportation of information in nanonetworks. Information is carried from one molecule to another via diffusion. This is a new technic to enhance the effectiveness of electromagnetic waves in nanoscale systems. The durability of this communication method is very important. In this paper, we use simulation and calculate the susceptibility of the technic used.

Index Terms: Nanoscale communication, molecular diffusion, nanonetworks.

I. INTRODUCTION

The processing of information by means of molecules is called molecular communication. Use of such a communication protocol is necessary because it involves some significance. [1] In the literature, the use of ions as a signal, the use of microtubes and many other types of communication havebeen proposed, but the communication with diffusion is a high molecular communication type with a potential to be used in future applications because of the low energy requirements. [2] Diffusion communication is the name given to communication by absorption of the carrier molecules released by a donor into the donor by diffusion. Here, the information can be coded according to the type or intensity of the molecules. [3]

Once the molecule is released, the molecules are expected to have a symbol duration for recipient transport. Molecules that are born of diffusion are acting randomly. This state causes all the released molecules to reach the receiver within the specified symbol period. While some of the molecules that are not accessible to the receiver arrive at the receiver within the next symbol period, the other portion continues to move in a free motion in the environment. Except for its own symbol period, the molecules reaching the receiver cause the instrumental invocation. This phenomenon in molecular communication is one of the most important factors limiting the speed of communication. The reason for this is that as the symbol period is shortened, that is, as the communication speed is increased, the composer molecules cannot reach the receiver within their symbol period and create an entree for the symbols coming after them. Channel coding aims to improve the rate of coding of the data length, to correct the erroneous transport data to the receiver, or to detect the occurrence of an error. Especially, the channel coding for correcting the error is long and it is used for different types of communication. Since the complexities ofcoding types are not meant to be implemented on nano- machines, this study encoder and decoder have been analyzed for the simpler linear codes than the others.

Studies on channel coding for use in molecular communication in the literature are very limited. The reason for this is that the mathematical demonstration of the channel as in my classical communication can be shown without the white Gaussian noise being worked up and worked for many years. In [4] and [5], Hamming coding, a linear block code, has been analyzed and performance curves have been given. Euclidean geometric low-density intrusive auditing (EG-LDPC) and transient Reed- Muller (CRM) codes [6] have been studied. "ISI-free" codes with a low-complexity encoder and decoder developed for use in the molecular communication channel have been proposed [7]. In this study, the BCH and RS codes have been analyzed for different symbol durations and encoding grades, and the performance analyzes have been shared.

The rest of the report is arranged in the following format: Section 2 discusses the studied channel and the basis of diffusion and communication. Error correction codes are discussed in Section 3. In Section 4, the simulation results are given and a performance analysis is performed. Section 5 concludes the paper and discusses what will be done in future studies.

II. INSERTING AND DIFFUSION

Scavenger molecules follow a random pathway in the Brownian motion rules during diffusion and motion [8]. The position of each molecule can be represented by a time dependent random variable. When this movement is examined, it has been seen that within a certain period of time, the movements in each dimension are independent of each other and normally distributed. The position of a molecule after Δt can be calculated for any dimension.

$$x(t+\Delta t) = x(t) + N(0,2D\Delta t) \quad (1)$$

In this equation, the average of N (u, σ2) u is the normal distribution with variance σ2, and D is the diffusion coefficient. The assumption that there is a point transmitter and a spherical receiver with radius rr, and that the constants of these two are constant, is realistic for diffusion communication and is easy to model, so it is preferred in the study.

Manuscript published on 30 April 2019.
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A portion of the molecules released by the transmitter at the end of the t period will continue to move in the medium. The ratio of the total molecules released by the acceptor to the acceptor is proportional to the distance between r0 and the centers of the donor.

$$F_{hit}(t) = \frac{r_r}{r_0} erfc(\frac{r_0 - r_r}{\sqrt{4Dt}}) \quad (2)$$

If each symbol is sent in ts intervals, the channel coefficients

$$p_k = F_{hit}(kt_s) - F_{hit}((k-1)t_s) \quad (3)$$

The coefficient p1 represents the ratio of the intramolecular molecules within the symbol period to the symbol to be transmitted, while the other coefficients represent the proportion of the intramolecular molecule due to the previously transmitted symbols. Therefore, the p2, ..., pk coefficients indicate the molecular ratios that cause inter-symbol interference. How many NTX molecules are emitted from the donor at the end of the symbol's duration can be modelled.

$$N_1^{Rx} \sim B(N^{Tx}, p_1) \quad (4)$$

In Equation (4), B (n, p), n is attempted, p denotes the binomial distribution. In this case the number of molecules up to the recipients shown.

$$N_i^{Rx} \sim \sum_{k=1}^{i} B(N_k^{Tx}, P_{i-k+1}) \quad (5)$$

As can be clearly seen from thickness (3), the symbol duration selection has a direct effect on the channel coefficients, the rate at which the molecules reach their symbol durations. As the icon duration increases, inter-symbol interference will decrease and the error rate of the communication will decrease. However, an increase in the duration of the icon will result in a low speed communication.

The receiver decides that the information received is 1 or 0, compared to a predetermined value of the value of the molecules received during the symbol duration interval. The values that exceed the value of 1 cannot pass the value 0 are evaluated.

III. ERROR CORRECTION CODES

Many different types of error correction code are available in the literature. These codes are divided into block codes and overlay codes. Although the overlay codes are stronger, the nano machines are not suitable for decoding because the decoding algorithms are complex. The coding and decoding algorithms of the block codes have a simpler structure compared to the overlay code, so they are more suitable for implementation on nano machines. In this study, two BCH and RS codes are examined.

3.1. Binary BCH Codes –

The binary BCH codes can be seen as more than one error- correcting version of Hamming codes [9]. The BCH codes are defined as BCH (n, k), with the k message size and the n block size. Such a coding can easily be seen if the coding ratio R = k

/ n. In other words, the message of each k size, which is to be coded, will reach the n dimension after it is encoded. k = n is a special case and does not indicate any coding. BCH codes will guarantee to correct the error.

$$t = b(d_{Hmin} - 1)/2c \quad (6)$$

In Density (6), dHmin shows the minimum value of the bit difference between two code words. This is the shortest Hamming distance. As the coding rate decreases, the value of the dHmin will increase, but the speed of the communication will slow down.

For BCH encoding, the data to be sent is divided into vectors of the k-length. Each of these vectors is shown in M1 × k. The vector is then multiplied by the production matrix. This product is the result of C1 × n code is formed and codingis completed. Code words are distorted because of the effect of the channel when sent and the receiver detects the code word as C1 × n. This code word is not difficult to be the same as the code word that is sent. The process of decoding the codename, C1×n the vector starts with the creation of syndromes by multiplying the control matrix by Hk × n. With the help of the calculated syndromes, the number of errors and the locations of these errors are calculated. If errors are found, these errors are corrected. According to the definition of binary BCH codes, each symbol is actually a bit against. Therefore, the error correction process terminates by inverting the faulty bits found.

3.2. RS Codes –

RS codes are a subset of BCH codes and are customized [9]. These codes are expressed in RS (n, k, s) to indicate the length of each icon. The most important difference from the binary BCH codes of RS codes is that the symbols are not 1 bit. In the case of RS codes, the correction of the symbol order results in better error correction performance than BCH codes in the case of erroneous bits are lost. For RS codes, n cannot be greater than 2s-1. In addition, the biggest error correction capacity is found as t = b (n - k) / 2c.

The most important difference of RS coding from binary BCH coding is that both the M1 × k and Gk × n matrices consist of numbers at the base of the bits, not the bits, and the generation matrix is the pattern of creation. In the decoding process, as in BCH decoding, first the syndromes then have errors. Unlike the binary BCH encoding, since the symbol- based correction is corrected, the power of the error must be present and the power level corrected.

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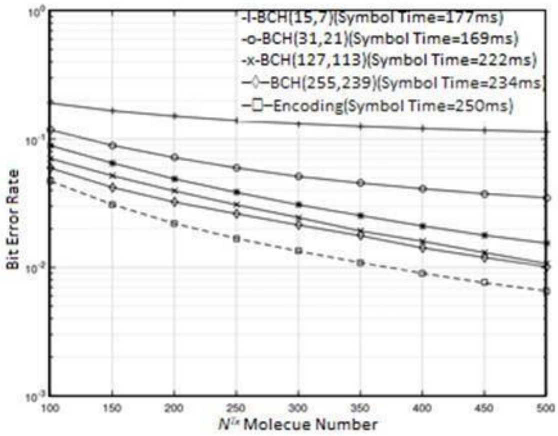

Figure 1: BCH coding analysis for t=2 and ts=250ms

IV. SIMULATION RESULTS AND EVALUATION

In this part of the paper, the error curves of the binary BCH and RS codes in the applications of diffusion communication are presented. In order to make a fair comparison, the symbol duration should be shortened by the changeover rate and the amount of data sent in one second should be set to the same level. Also, the average power must be taken into account and the power used should be levelled with the non-coding state.The operation of the coding with high performance is directly related to the failure of the system. In a system with a bad error failure, since the number of errors exceeds the maximum number of errors that can be corrected, error correction cannot be performed and the coding techniques will give poor results. Therefore, coding is expected to have a good success when the symbol duration is long and the average power is high. Otherwise, it is expected that if coding is not used, it will not contribute to the error failure, and because of the lower rate of coding and the average duration of the code and the duration of the symbol, it will have a worse error curve than if the coding is not used.

The bit error curves of the aforementioned encodings were generated by Monte CarloI simulation method. The channel coefficients for different symbol durations vary, as described in Section II. Therefore, error curves are given in separate shapes for different symbol periods. For the high number of NTx, the binomial distribution given in equation (5) behaves as if it had a normal distribution in the form of − NRx pi N (NTxpi, NTxpi (1 NR pi)). Using this approach, simulations are accelerated and the number of molecules taken is derived from the Gaussian distribution. The parameters used during the simulation are as follows:

- Distance between receiver and transmitter centres r0 =10µm is selected.
- Receiver radius rr = 5µm selected.
- Diffusion coefficient D = 79.4x10-12 is selected.
- Symbol times and average power are reduced at the coding rate and error curves are obtained accordingly. The number of error correction t = 2 is selected. For RS encoding, the values of the highest possible value for different s values are selected.
- The lower values are selected in such a way that the encoding is not used if the coding is low, and in the cases where the coding is used, it has the lowest error rate of the coded data.

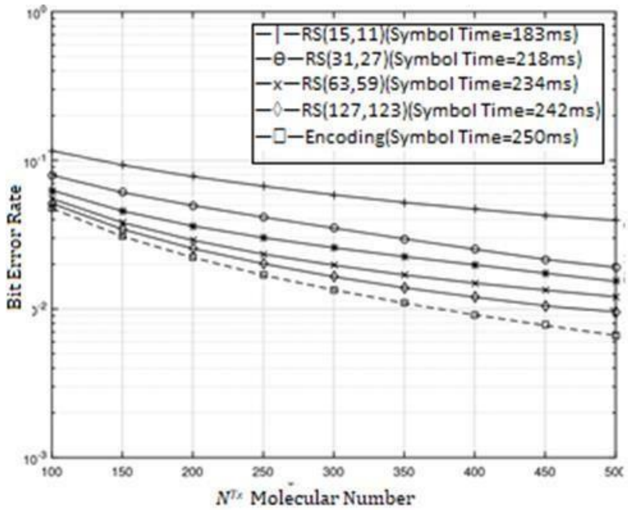

Figure 2: BCH coding error analysis for t=2 and ts=350ms.

Results of simulations of binary BCH coding for different symbol durations under the specified conditions in Figures 1 and 2, the results of the simulations of RS coding are given in Figures 3 and 4. As can be seen from the results, it is advantageous to use the encoding for the high icon duration ts while it is logical to use the encoding for the low symbol duration without using coding. This result is parallel to the non- aggregated Gaussian channel that the encodings do not rendered meaningless use of coding techniques at low coding rates. This can be seen in Figures 2 and 4, which are the simulated simulation results for high symbol durations, give the expected performance increase in the low performance regions. In addition, the lower symbol duration and average power usage resulting from the coding rate have by comparing the error rate in the low coding ratios and by comparing the error rate when no coding is used.

V. CONCLUSION

In this study, BCH and RS codes were analysed for error succession by means of diffusion. High icon durations and high molecule numbers have been found to improve the error performance for NTx. Although RS coding has a more complex structure than BCH coding, it is concluded that the channel

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structure cannot show better performance than BCH encoding. For high data rates, it is concluded that the channel coding techniques used in classical communication are inadequate and that channel codes specific to molecular communication should be discontinued. Finally, since coding techniques show higher error-correction success in systems with a low error rate, it can be foreseen that the vein where there is a run-off, because the inter-symbol interference will be less. In future studies, high- performance code groups will be available at high data rates.

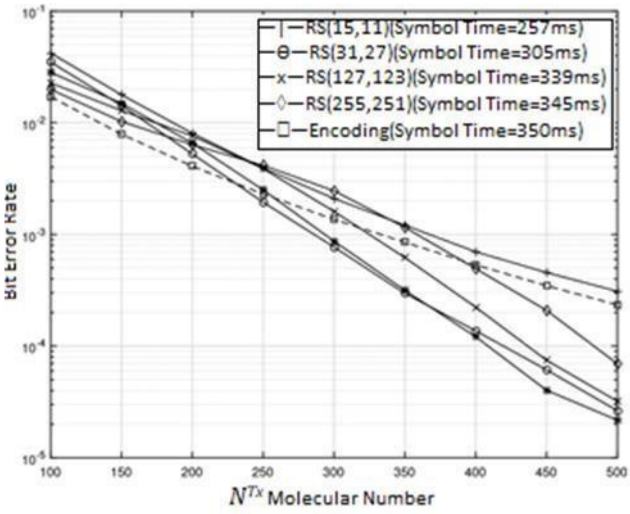

Figure 3: Error analysis for RS coding t = 2 and ts = 250ms

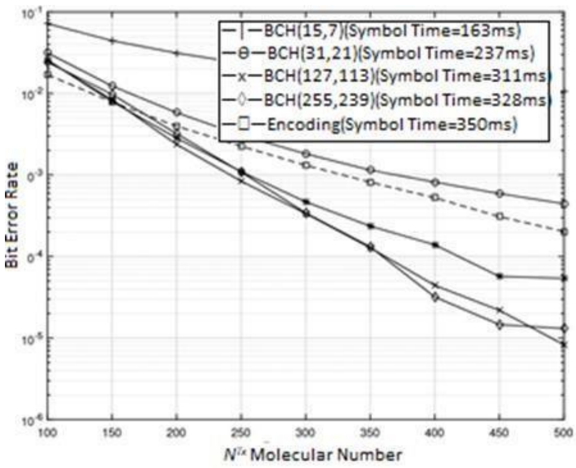

Figure 4: Error analysis for RS coding t = 2 and ts = 350ms.

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