Sio-Iong Ao
Haeng Kon Kim
Mahyar A. Amouzegar *Editors*

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Editors
Sio-Iong Ao
IAENG Secretariat
International Association of Engineers
Hong Kong, Hong Kong

Haeng Kon Kim
School of Software Convergence
Daegu Catholic University
Daegu, Korea (Republic of)

Mahyar A. Amouzegar
Provost
University of New Orleans
New Orleans, LA, USA

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Preface

A large international conference on Advances in Engineering Technologies and Physical Science was held in San Francisco, California, USA, October 23–25, 2018, under the auspices of the World Congress on Engineering and Computer Science (WCECS 2018). The WCECS 2018 is organized by the International Association of Engineers (IAENG). IAENG, originally founded in 1968, is a non-profit international association for the engineers and the computer scientists. The WCECS Congress serves as an excellent platform for the members of the engineering community to meet and exchange ideas. The Congress in its long history has found a right balance between theoretical and application development, which has attracted a diverse group of researchers, leading its rapid expansion. The conference committees have been formed with over two hundred members including research center heads, deans, department heads/chairs, professors, and research scientists from over 30 countries. The full committee list is available at the Congress' Web site: www.iaeng.org/WCECS2018/committee.html. WCECS conference is truly an international meeting with a high level of participation from many countries. The response to the WCECS 2018 conference call for papers was outstanding, with more than four hundred manuscript submissions. All papers went through a rigorous peer-review process, and the overall acceptance rate was 51%.

This volume contains seventeen revised and extended research articles, written by prominent researchers, participating in the congress. Topics include chemical engineering, electrical engineering, communications systems, computer science, engineering mathematics, manufacture engineering, and industrial applications. This book offers the state of the art of tremendous advances in engineering technologies and physical science and applications; it also serves as an exceptional source of reference for researchers and graduate students working with/on engineering technologies and physical science and applications.

Sio-Iong Ao
Haeng Kon Kim
Mahyar A. Amouzegar

Contents

A Novel Multi-layer Detection Scheme for Diffusion-Based Molecular Communications

Mohammed S. Alzaidi(✉), Walid K. M. Ahmed, and Victor B. Lawrence

Stevens Institute of Technology, Hoboken, NJ 07030, USA
{malzaidi,victor.lawrence}@stevens.edu, walidmail@yahoo.com

Abstract. Molecular communication (MC) is the new nano-bio-communication paradigm that inspired by the nature to perform communication tasks at nanoscale networks. Although power utilization and large computation abilities are important factors that play a role in designing detection schemes for traditional communication systems, the MC is more sensitive to these factors due to its operating scale and power resources. Transmitters and receivers can be bio-cellular, bio-organisms, or nano-machines that can perform simple tasks due to their natural limitation with respect to size, power supply, and required simplicity. Accordingly, there is a need for efficient low-complexity detection schemes that can enable reliable communications despite impairments such as inter-symbol interference (ISI), noise and distortion. In this chapter, we propose a novel detection scheme for molecular communication via diffusion (MCvD) that achieves low computational complexity, yet deliver reliable information detection. Our proposed scheme encompasses a multi-layer structure where each layer performs a certain level of pin-pointing (or zoom-in) of the estimated received bits in a fashion that can be regarded as a form of sub-optimal minimum mean-square estimation (MMSE) that tradeoffs complexity for performance. Our detection method has been able to achieve un-coded bit error rate levels down to 10^{-5} at signal-to-noise ratios where traditional threshold-based detection achieves worse than 10^{-2}.

Keywords: Correlation · Diffusion · Entropy metric · Logarithmic metric · Molecular communication · Molecular concentration

1 Introduction

Electromagnetic and acoustic propagations are the primary and centric ways for communication systems. However, their waves still do no propagate effectively due to severe obstruction or path loss [1] for some propagation media such as various types of fluids, biological and tissue-based environments. Nano-molecular communication has been an emerging mechanism for intra-body communications that has been attracting growing attention in the research community [2]. Molecular communication (MC) is based on communicating information in a manner

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inspired by chemical signaling that naturally occurs in our bodies, for example. Information can be conveyed by letting the transmitter (Tx) release a perfect number of molecules of certain types that propagate through mediums such as fluid or gaseous and eventually hit the desired receiver (Rx) that able detect such molecules and determines the information content from the pattern and amount of the received molecules [3–8]. Molecular communications offer a viable link for short, medium and long distances of the order of micro-meters [9]. Moreover, MC is envisioned to be used in a variety of domains including industrial, environmental, and biomedical applications [10–12]. Transmitter (Tx) and receiver (Rx) can be either a biological organism/cell, or fabricated nanomachines (NMs) which can perform simple tasks [13,14] with respect to their tiny resources of power, size, and design complexity [2,15]. Accordingly, any detection scheme that requires a large consumption of power or complex computational operations will not be practical to apply for MC. The design of detection schemes always needs to acquire simplicity and low complexity.

In literature, several detection schemes have been introduced for the diffusion-based channel model. Some of these schemes are new and designed specifically for MC while others have been used previously with the traditional communication systems. Amplitude detection and energy detection schemes have been proposed in [15], the amplitude detection detects each bit by measure the amplitude of the concentration in a pre-specific time instant. The energy detection measures the energy of the received signal of each symbol duration. Both of these detection methods make their decision on bits by comparing signal measurements with a pre-determined threshold. In [18], two coherent detection schemes, the maximum-likelihood (ML) sequence detector and the maximum a posterior detector that commonly used in traditional communications have been applied to the MC. These methods need a large number of computational operations and power consumption, which is not efficient for MC.

In this chapter, we provide the details and evaluate the performance of our novel detection scheme which has been designed based on a multi-layer approach for MC via diffusion. By utilizing a discrimination layer followed by small-size of low-complexity correlation operations layer, our algorithm will be able to perform the lowest operations that are needed to detect received signals. Our performance evaluation results show significant waterfall un-coded bit error rate (BER) down to 10^{-5} at low signal-to-noise ratios where traditional threshold detection achieves worse than 10^{-2}. Moreover, our approach focuses on short signaling periods to increase data rates that most states of art detection schemes in MC avoid it for better performance.

The remainder of the chapter is structured as follows. Section 2 shows the details of the MC system model based on the free diffusion-based channel. In Sect. 3, we introduce a novel multi-layer detection scheme. In Sect. 4, we discuss the simulation results that evaluate our proposed detection scheme while Sect. 5 concludes the chapter.

2 System Model

Our MC system model consists of a single Tx, information molecules, a fluid medium, and single Rx. The Tx is a point source that releases molecules in the medium. The Rx is a NM spherical shape to detect those molecules as illustrated in Fig. 1. We assume that the Tx and the Rx are located in a stationary environment where both are synchronized over time. In this chapter, we apply a binary ON-OFF keying modulation scheme with equally likely transmitted binary information bits. However, we did not apply any coding technique to our system model.

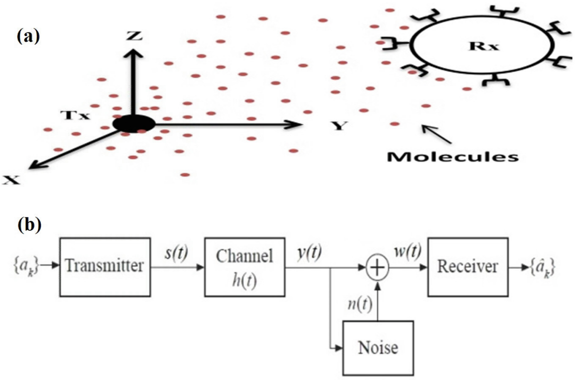

Fig. 1. Diffusion-based MC system components. (a) Graphical illustration. (b) Block diagram of MC system.

The Tx encodes information bits a_k to molecules concentrations pulses, $s(t)$, which can be considered as a rectangular pulse given as [20]:

$$s(t) = Q.\sum_{k=0}^{\infty} a_k.rect(\frac{(t - \frac{T_w}{2})}{T_w - kT_b}) \tag{1}$$

where T_w is the pulse width at the beginning of each symbol duration T_b.

Then, the concentration of the molecule pulses $s(t)$ diffuse randomly based on the Brownian motion process until they hit the Rx. In this type of channel, the propagation relay on some factors such as diffusion coefficient, distance, and time between Tx and Rx. The second Fick's law of diffusion represents the propagation environment [21]. The concentration of the molecules, which is at the location (x,y,z) that diffuse based on the diffusion coefficient D, and time t is given by the equation [22]:

$$h(t; x, y, z) = \frac{Q}{4\pi Dt^{\frac{3}{2}}} e^{(\frac{-(x^2+y^2+z^2)}{4Dt})} \tag{2}$$

The response of the diffusion channel $y(t)$ is basically the convolution between the modulated signal $s(t)$ and the impulse response of the diffusion channel $h(t)$. The total received concentration signal that detected by Rx, which is caused by sending original transmitted bits sequence a_k that distorted through the channel is donated by w(t), which can be represented as:

$$w(t) = \sum_{j=0}^{\infty} a_k . y(t - jT_b) + n(t) \tag{3}$$

where $n(t)$ is the counting noise that generated by the random process. It is assumed to be zero-mean Adaptive-white-Gaussian-Noise (AWGN) with a variance of $\sigma_n^2, i.e., n(t)\ N(0, \sigma_n^2)$.

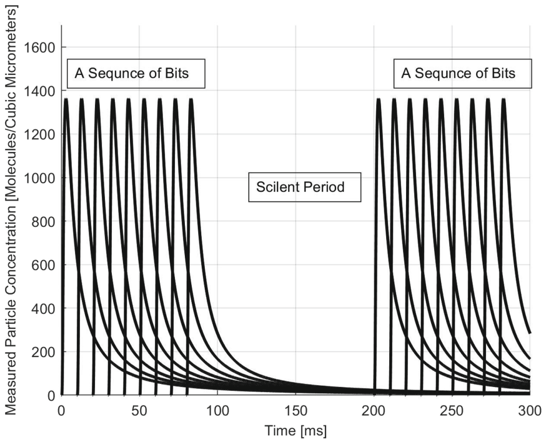

Fig. 2. The impulse response of the diffusion-based channel. The Tx approach sends a number of bits, gets silent for another number of bits, and sends another number of bits again.

To mitigate the inter-symbol interference (ISI), we use the same technique that introduced in [23]. Thus, the Tx sends a number of N-consecutive-bits and then get silent, before sending another N-consecutive-bits to mitigate the ISI as shown in Fig. 2. In this chapter, we call these N-consecutive-bits *words*. The received word samples r_k can be defined as:

$$r_k = y_k + \sum_{i=k-m}^{k-1} y_{k-m} + n_k \tag{4}$$

where y_k is original received bits, $y(k - m)$ is ISI coming from the previous words and n_k is the AWGN noise.

3 The Detection Scheme

Our idea is to detect a sequence of bits together and adapt it to the MC resources limitations. However, detecting a sequence of N-bits will require correlating 2^N possible bit combinations to identify the transmitted bits. Obviously, this approach will consume more power and will require more computational operations which is not the optimal case for the MC. It is worth to mention that the number of possible states will grow rapidly by a factorial factor as N become larger which complicates the detection process. Thus, we have designed our detection scheme by answering two characterization questions about the received bits: How many "bit-1" bits are in the transmitted bits and what are their exact locations in the transmitted sequence of bits? We take "bit-1" in consideration because it is the bit that represents the information molecules as we use the ON-OFF modulation scheme. Each question is answered by passing the received word samples r[k] through two layers respectively that leads to clear detection decisions. The main point in our algorithm is that we used a statistical discrimination metrics, to measure the amount of information in the received word as follows:

1. Entropy metric layer:

$$Entropy_{metric} = \frac{1}{k}(log_{10} \sum_{k=1}^{k} |r_k|) \tag{5}$$

   where k is the number of samples of the received word.
2. Logarithmic metric layer:

$$Logarithmic_{metric} = log_{10}(\frac{1}{k} \sum_{k=1}^{k} |r_k|) \tag{6}$$

   where k is the number of samples of the received word.

In this chapter, we chose the word length case of detection to be eight-bit length to show how our detection method can detect eight bits in a novel and reduced-complexity approach. The eight-bit case will generate two hundred and

Table 1. Zone's patterns based on discrimination values

	Number of "1"s per word	Number of patterns
Zone 1	One	8
Zone 2	Two	28
Zone 3	Three	56
Zone 4	Four	70
Zone 5	Five	56
Zone 6	Six	28
Zone 7	Seven	8
Zone 8	Eight	1

fifty-five bits combinations, excluding the combination of all eight zero bits. Therefore, we calculated the discrimination values for all possible eight-bit combinations by sing both metrics in Eqs. (5) and (6). Then, we noticed that their discrimination values are clustered in eight non-overlapping zones as shown in Table 1. Thus, we can distinguish how many "bit-1" bits occur in each received word by assigning two thresholds to each zone. The minimum and maximum discrimination values of each zone are considered as the lower and the upper thresholds respectively.

3.1 Layer One: Discrimination Layer

The goal of this layer is to distinguish how many bits are in the received word $r[k]$ that equal to "bit-1"? To answer this question, we need to calculate the discrimination value of the received word $r[k]$ by using either the Eq. (5) or the Eq. (6). Then, we can identify the zone that is a candidate to be correlated in the second layer. This process is accomplished by comparing the discrimination value with the zones' threshold values to specify the number "bit-1" bits. The discrimination value of the received word will lead to two possible cases as follow:

- If the discrimination value falls between the upper and the lower threshold values of a specific zone, only the patterns that belong to this zone will be taken to layer two, as indicated in Fig. 3(a).
- If the discrimination value is not related to a specific zone because it falls between two different zones, all patterns that belong to both zones will be merged and taken to the second layer as indicated in Fig. 3(b).

Consequently, the discrimination metric determines a smaller number of bit combinations to correlate instead of correlating all the bits combination.

For the first case, the maximum number of combinations that could possibly be taken to the second layer is thirty-five combinations which are only 13.67% of all bit combinations (86.33% excluded). For the second case, the maximum number of bit combinations that could possibly be taken to the second layer

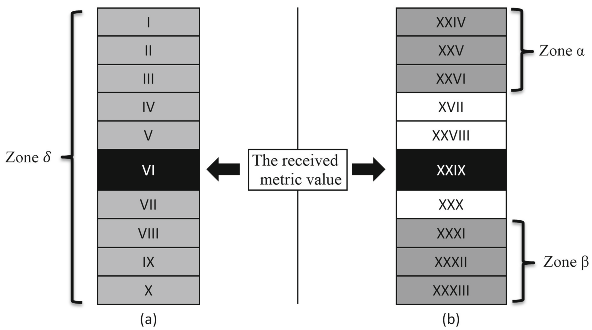

Fig. 3. Scenarios of choosing the zone patterns based on the threshold evaluation

is seventy combinations which are only 27.34% of all bit combinations (72.66% excluded). To point out, our proposed algorithm consumes less power and time to detect a sequence of bits, and there is no need to correlate all bit combinations.

3.2 Layer Two: Correlation Layer

The outcome of layer one classifies the number "bit-1" bits in the received word. Consequently, the goal of Layer two is to identify precisely where the locations of these "bit-1" bits in the sequence. We assume that non-noisy concentration waveforms $z[k]$ for a selected number of bit combinations have been prior stored at the receiver. The correlation calculations in this layer are divided into two stages. The designer of the system has the choice to apply one stage of correlation or two stages based on the case limitations. Every stage of correlation reduces the error probability and help to maintain better performance. The first stage of correlation aims to identify only one candidate pattern from the main bit combinations by calculating the Pearson correlation coefficient between the received word samples $r[k]$ and all main combinations samples $z[k]$ that are related to the assigned candidate zone by layer one as follow:

$$Corr_{coff} = \frac{\sum_{k=1}^{n}(r_k - \bar{r}_k)(z_k - \bar{z}_k)}{\sqrt{\sum_{k=1}^{n}(r_k - \bar{r}_k)^2 (z_k - \bar{z}_k)^2}} \tag{7}$$

where $Corr_{coff}$ is the correlation coefficient, $\bar{r_k}$ is the mean value of r_k and $\bar{z_k}$ is the mean value of z_k.

Although our proposed algorithm reduces the number of patterns that are needed for correlation, we still can reduce the number of patterns more if we only deal with the unique patterns. These unique patterns are the main bit combinations that represent more than one combination. For instance, the first zones' combinations are eight bits combinations which all of them have only one "bit-1" digit and seven "bit-0" digits. So, we only store their main bit combination as shown in Table 2.

Table 2. Zone number one patterns

First zone combinations	The unique pattern	Number of patterns
1 0 0 0 0 0 0 0		8
0 1 0 0 0 0 0 0		28
0 0 1 0 0 0 0 0		56
0 0 0 1 0 0 0 0	1 0 0 0 0 0 0 0	70
0 0 0 0 1 0 0 0		56
0 0 0 0 0 1 0 0		28
0 0 0 0 0 0 1 0		8
0 0 0 0 0 0 0 1		1

As shown in Table 3, the difference between the number of all patterns and unique patterns is considered a decent improvement in terms of reducing the number of correlations operations. Additionally, correlating unique patterns instead of all patterns will reduce the probability of errors because of the differences between the patterns will be more prominent in term of the discrimination value and the correlation coefficient.

Table 3. Comparison between the number of all patterns and unique patterns

	Number of "1"s per word	Number of all patterns	Number of unique patterns
Zone 1	One	8	1
Zone 2	Two	28	7
Zone 3	Three	56	21
Zone 4	Four	70	35
Zone 5	Five	56	35
Zone 6	Six	28	21
Zone 7	Seven	8	7
Zone 8	Eight	1	1
		255	128

Thus, using unique patterns will demand us to identify the time lag between the received signal samples and the unique candidate pattern that has the highest correlation coefficient. The second stage of correlation measures the time lag between the received word samples and the candidate pattern samples by using the cross-correlation formula as follow:

$$R_{yz} = \sum_{m=1}^{n} r[m]z[m-L] \tag{8}$$

where L is the lag value between the received signal $r[m]$ and the chosen candidate pattern.

4 Performance Evaluation

This section shows the performance of our novel detection schemes for various parameters that have significant impacts on our proposed method. We used MATLAB as the simulation platform for all evaluation process in addition to using the Monte Carlo simulations approach to get a reliable bit error estimation. All the simulation parameters reflect real parameters for a realistic environment [23]. The distance between Tx and Rx is equal to 3 μm; the diffusion coefficient is equal to 1 $(\text{nm}^2)/\text{ns}$, and the number of released molecules is 1×10^4 molecules.

4.1 The Impact of Symbol Duration Variations

The symbol duration is an essential factor in designing our algorithm; it affects the distances between the zones due to ISI. Thus, we have simulated the BER versus the symbol duration to show the best symbol duration choice that can help to reach the lowest BER. In this manner, we are interested in increasing the high data rate which is a concern in the molecular communication via diffusion (MCvD) due to the ISI. For the Entropy metric, as shown in Fig. 4, we have we evaluated the performance of various symbol durations in the range between 1 ms to 14 ms.

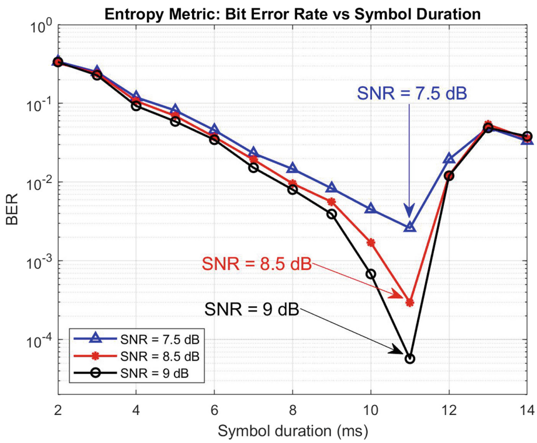

Fig. 4. BER vs. symbol duration for the Entropy metric

As a result, we noticed that the 11 ms is the best symbol duration where the discrimination distances between the zones are the widest, which reduces the BER. Meanwhile, we have simulated the duration between 1 ms and 15 ms for the Logarithmic metric as shown in Fig. 5. Based on the simulation results, we found that at 10 ms, the distances between the zones is the widest, which reduce the BER too.

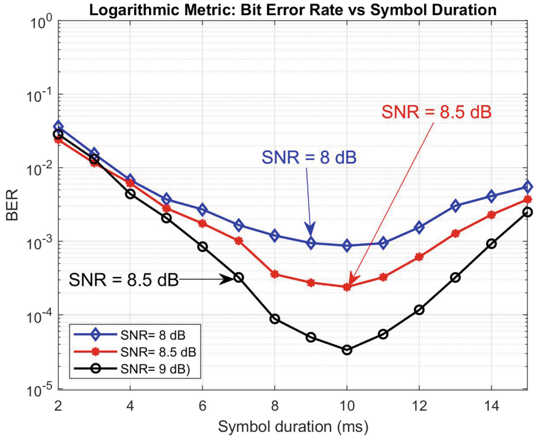

Fig. 5. BER vs. symbol duration for the Logarithmic metric

4.2 The Impact of Signal to Noise Ratio Variations

To show the performance of our scheme in the presence of different levels of the signal to noise ratio (SNR), we have simulated the BER versus SNR for different word lengths such as $N = 6$, 7, 8 and 9. The evaluation performance of the first discrimination metric, Entropy metric, is shown in Fig. 6. It can be clearly seen that the BER of word lengths equal to $6, 7, 8$ is close from each other. In contrast, the BER becomes almost flat at $N = 9$ due to the impact of the ISI on the discrimination distances between the zones.

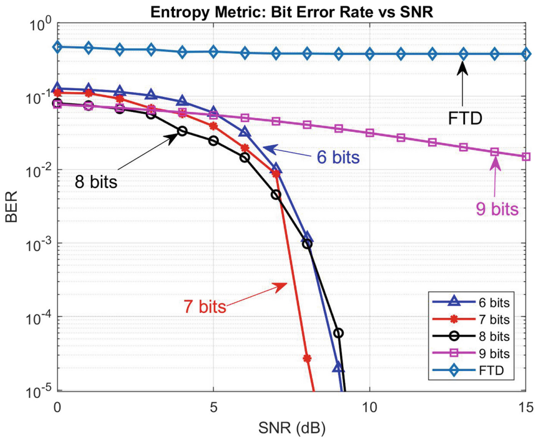

Fig. 6. BER vs. SNR for the Entropy metric

Our proposed algorithm shows a significant low un-coded BER compared to the traditional Fixed-Threshold Detection (FTD) scheme, which has the worst BER. The Logarithmic metric shows a promising performance as shown in Fig. 7 where it reaches lower SNR as 10^{-5} comparing with the Entropy metric. The Logarithmic metric introduces wider discrimination distances between the zones that help to reduce the BER.

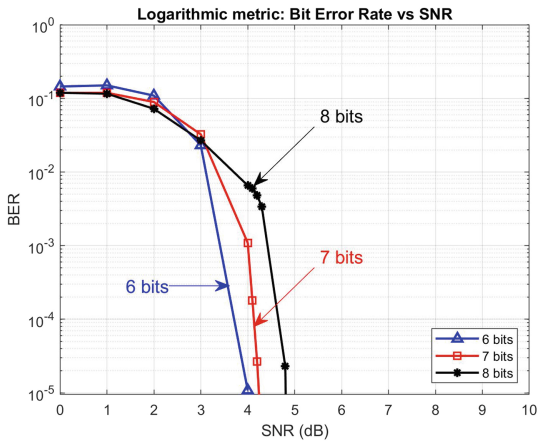

Fig. 7. BER vs. SNR for the Logarithmic metric

4.3 The Impact of Distance Variations

Figure 8 and Fig. 9 show the impact of distance variations for both metrics as they are simulated versus the probability of error. Our proposed scheme shows

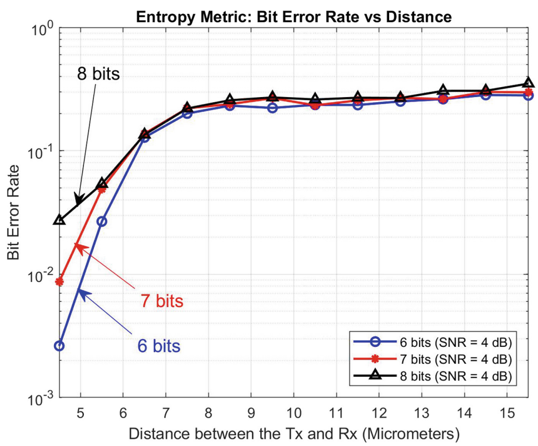

Fig. 8. BER vs. Distance for the Entropy metric

a decent BER as we have evaluated it under a noise to noise ratio equal 4 dB. In both metrics, as the transmitter is getting closer to the receiver, the BER will decrease and vice versa. Our algorithm is designed to perform in short ranges of communications which usually not exceed the size of the cell.

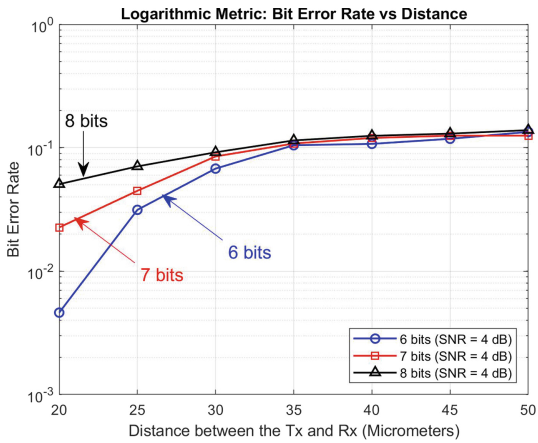

Fig. 9. BER vs. Distance for the Logarithmic metric

5 Conclusion

We proposed a novel detection scheme for molecular communications via the diffusion-based channel. The work aims to develop a reduced complexity fast detection scheme. Based on the entropy metric and Logarithmic metric, the proposed algorithm identifies the required zone to correlate which ultimately identify the transmitted signal. These metrics help to make detection of a group of bits faster by small computational operations in a short measurement period. To date, most groundbreaking studies pursue detection based on a bit-by-bit discrimination approach, which consumes power and time. Our approach can be applied to any modulation scheme and also can be generalized to be applied to any other traditional communication system. Furthermore, our algorithm allows the system developer the ability to choose the number of bits that they would like to detect together (e.g., we simulated N = 6, 7, 8). The simulation results demonstrate that our scheme able to achieve low un-coded BER as 10^{-5} at SNR levels where classic approaches such as FTD scheme achieved BER levels of the order of only 10^{-2} only.

Appendix

This an example for the measurements of a 6-bits length bits that show a clustering in 6 zones by using the Entropy metric.

Table 4. Table for primary patterns of 6-bits Entropy Documentations.

No.	6-bits states						Entropy value
1	1	0	0	0	0	0	0.425031
2	1	1	0	0	0	0	0.540144
3	1	0	0	0	0	1	0.56851
4	1	0	1	0	0	0	0.569986
5	1	0	0	0	1	0	0.580819
6	1	0	0	1	0	0	0.58187
7	1	1	1	0	0	0	0.751513
8	1	0	0	0	1	1	0.770681
9	1	1	0	1	0	0	0.787195
10	1	0	1	1	0	0	0.789276
11	1	0	0	1	1	0	0.794195
12	1	1	0	0	1	0	0.805368
13	1	1	0	0	0	1	0.806243
14	1	0	0	1	0	1	0.817112
15	1	0	1	0	1	0	0.818978
16	1	0	1	0	0	1	0.828056
17	1	1	1	1	0	0	0.930657
18	1	0	0	1	1	1	0.941125
19	1	0	1	1	1	0	0.954485
20	1	1	1	0	1	0	0.958117
21	1	1	0	1	1	0	0.963388
22	1	1	0	0	1	1	0.969308
23	1	1	1	0	0	1	0.970083
24	1	0	1	0	1	1	0.976249
25	1	0	1	1	0	1	0.976761
26	1	1	0	1	0	1	0.984607
27	1	1	1	1	1	0	1.073479
28	1	0	1	1	1	1	1.08204
29	1	1	1	1	0	1	1.094016
30	1	1	0	1	1	1	1.095143
31	1	1	1	0	1	1	1.098036
32	1	1	1	1	1	1	1.189797

References

1. Guo, W., Mias, C., Farsad, N., Wu, J.L.: Molecular versus electromagnetic wave propagation loss in macro-scale environments. IEEE Trans. Mol. Biol. Multi-Scale Commun. **1**(1), 18–25 (2015)

2. Akyildiz, I.F., Brunetti, F., Blázquez, C.: Nanonetworks: a new communication paradigm. Comput. Netw. J. **52**(12), 2260–2279 (2008)
3. Hiyama, S., Moritani, Y., Suda, T., Egashira, R., Enomoto, A., Moore, M., Nakano, T .: Molecular communication. In: Proceeding NSTI Nanotechnology Conference (2005)
4. Nakano, T., Suda, T., Moore, M., Egashira, R., Enomoto, A., Arima, K.: Molecular communication for nanomachines using intercellular calcium signaling. In: Proceeding 5th IEEE Conference on Nanotechnology, pp. 478–481, July 2005
5. Nakano, T., Moore, M., Wei, F., Vasilakos, A., Shuai, J.: Molecular communication and networking: opportunities and challenges. IEEE Trans. NanoBiosci. **11**(2), 135–148 (2012)
6. Nakano, T., Suda, T., Okaie, Y., Moore, M., Vasilakos, A.: Molecular communication among biological nanomachines: a layered architecture and research issues. IEEE Trans. NanoBiosci. **13**(3), 169–197 (2014)
7. Wyatt, T.D.: Fifty years of pheromones. Nature **457**(7227), 262–263 (2009)
8. Nakano, T., Eckford, A.W., Haraguchi, T.: Molecular Communication. Cambridge University Press, Cambridge, UK (2013)
9. Veiseh, O., Gunn, J.W., Zhang, M.: Design and fabrication of magnetic nanoparticles for targeted drug delivery and imaging. Adv. Drug Deliv. Rev. **62**(3), 284–304 (2010)
10. Wang, J., Yin, B., Peng, M.: Diffusion based molecular communication: principle, key technologies, and challenges, China Commun. **14**(2), 1–18 (2017)
11. Yager, P., et al.: Microfluidic diagnostic technologies for global public health. Nature **442**(7101), 412–418 (2006)
12. Farsad, N., Yilmaz, H.B., Eckford, A., Chae, C.B., Guo, W.: A comprehensive survey of recent advancements in molecular communication. IEEE Commun. Surv. Tutor. **18**(3), 1887–1919 (2016). Third Quater
13. Suda, T., Moore, M., Nakano, T., Egashira, R., Enomoto, A., Hiyama, S., Moritani, Y.: Exploratory research on molecular communication between nanomachines. In: Proceeding Genetic and Evolutionary Computation Conference (GECCO), Late Breaking Papers, vol. 25, p. 29 (2005)
14. Nakano, T., Moore, M., Enomoto, A., Suda, T.: Molecular Communication Technology as a Biological ICT. Springer, New York (2011)
15. Llatser, I., Cabellos-Aparicio, A., Pierobon, M., Alarcon, E.: Detection techniques for diffusion-based molecular communication. IEEE J. Sel. Areas Commun. **31**(12), 726–734 (2013)
16. Zheng, O.Z., Ali, M., Basu, K.: Comparing the complexity of two network architectures. Ann. Emerg. Technol. Comput. (AETiC) **1**, 7–18 (2017)
17. Kuzmics, G., Ali, M.: Intra-building people localisation using personal bluetooth low energy (BLE) devices. Ann. Emerg. Technol. Computi. (AETiC) **2**, pp. 24-36, April 1 2018
18. Kilinc, D., Akan, O.: Receiver design for molecular communication. IEEE J. Sel. Areas Commun. **31**(12), 705–714 (2013)
19. Guo, W., Asyhari, T., Farsad, N., Yilmaz, H.B., Li, B., Eckford, A., Chae, C.B.: Molecular communications: channel model and physical layer techniques. IEEE Wirel. Commun. **23**(4), 120–127 (2016)
20. Pierobon, M., Akyildiz, I.F.: A physical end-to-end model for molecular communication in nanonetworks. IEEE J. Sel. Areas Commun. **28**, 602–611 (2010)
21. Bossert, W.H., Wilson, E.O.: The analysis of olfactory communication among animals. J. Theor. Biol. **5**(3), 443–69 (1963)

22. Mahfuz, M.U.: Achievable strength-based signal detection in quantity-constrained PAM OOK concentration-encoded molecular communication. IEEE Trans. Nanobiosci. **15**(7), 619–626 (2016)
23. He, P., et al.: Improving reliability performance of diffusion based molecular communication with adaptive threshold variation algorithm. Int. J. Commun. Syst. **29**(18), 2669–2680 (2016)
24. Alzaidi, M.S., Ahmed, W.K.M., Lawrence, V.B.: Achieving very low un-coded BER via a novel reduced-complexity fast-detection for diffusion-based molecular communications. In: Proceedings of The World Congress on Engineering and Computer Science 2018, Lecture Notes in Engineering and Computer Science. San Francisco, USA, 23-25 October pp. 24-29 2018

Enterprise Mobile Ad-Hoc Implementation

William R. Simpson(✉) and Kevin E. Foltz

Institute for Defense Analyses, 4850 Mark Center Drive, Alexandria, VA 22311, USA
{rsimpson,kfoltz}@ida.org

Abstract. Threat intrusions have led to a formulation of guarded enterprise systems. The approach was to build an impenetrable fortress to prevent hostile entities from entering the enterprise domain. However, this defense and its many re-enforcements have repeatedly been found to be inadequate. The current complexity level has made the fortress approach to security, which is implemented throughout the defense, banking, and other high-trust industries unworkable. An alternative security approach, called Enterprise Level Security (ELS), is the result of a concerted multi-year program of pilots and research. The primary identity credential for ELS is the Public Key Infrastructure (PKI) certificate, issued to the individual who is provided with a Personal Identity Verification (PIV) card with a hardware chip for storing the private key. All sessions are preceded by a PKI mutual authentication (secondary authentication may be employed when necessary), within Transport Layer Security (TLS) 1.2, and a secure communication pipeline is established. This process was deemed to provide a high enough identity assurance to proceed. However, mobile ad hoc networking allows entities to dynamically connect and reconfigure connections to make use of available networking resources in a changing environment. These networks range from tiny sensors setting up communications based on a random or unknown configuration to aircraft communicating with each other, the ground, and satellites. Scenarios have differing requirements in terms of setup, reconfiguration, power, speed, and range. This paper presents an adaptation of the ELS principles to the mobile ad hoc scenario.

Keywords: Enterprise Level Security · Field connectivity · Mobile Ad-hoc · Mobil nexus · Networking · Service requirements

1 Introduction

Mobile ad hoc networking includes a broad range of possible implementations. These implementations range from unstructured networks like MANETs [1], where there is no existing infrastructure and nodes must dynamically configure themselves into a functioning network, to situations in which a mobile node connects to existing infrastructure. This document focuses on situations in which nodes come in and out of communication range of fixed infrastructure and situations in which nodes dynamically connect and disconnect to each other and different networks. These situations allow many of the higher-layer functional and security protocols to function properly. The following

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