School of Engineering and Applied Science (SEAS), Ahmedabad University

B.Tech(ICT) Semester V: Wireless Communication (CSE 311)

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- Base Article Title: Molecular Communication

  Base Article: [1] X. Qian, M. Di Renzo, and A. Eckford, "Molecular communications: Model-based and data-driven receiver design and optimization,"IEEE Access, vol. 7, pp. 53 555-53 565, 2019.

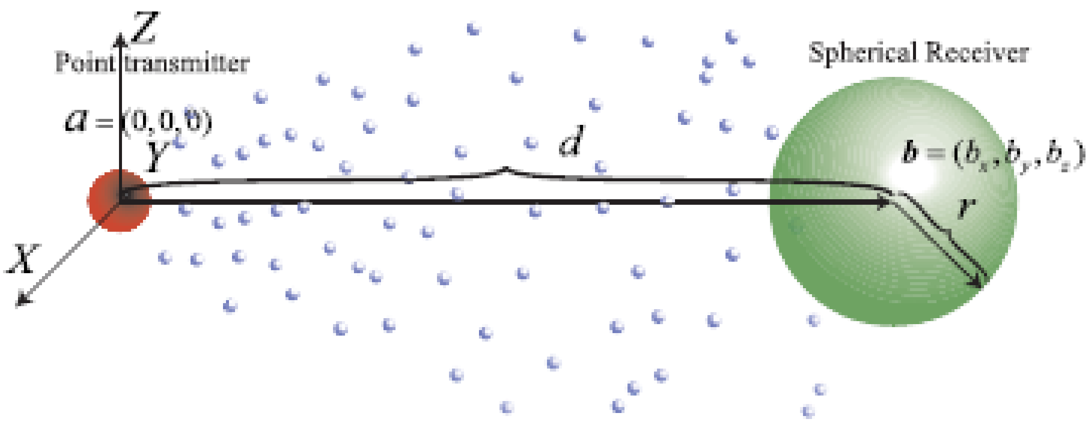
1 Performance Analysis of Base Article

1.1 List of symbols and their description

Symbol	Description
λ_0	Background noise power
r	Radius of spherical receiver
d	distance between transmitter and receiver
D	Diffusion coefficient
ΔT	Discrete Time length
T	Slot time
L	Channel length

1.2 System Model/Network Model

- The channel considered in the article works on the Fick's second law of diffusion i.e. the molecules will moves towards the less concentration from the higher concentration. It uses CSK (Concentration Shift Keying).
- It shares (on-off shift keying) to transmit information particles towards the receiver. Also the the diffused particles follow Brownian motion and moves randomly and independently. This creates the interference between the molecules reaching at different time slots. This interference is known as Inter Symbol Interference(ISI) and we try to model different threshold based receivers to identify correct transmitted bit and lower BER.[2]



1.3 Detailed derivation of performance metric

- The basic terminologies of transmission (Ntx particles) and receiving bits are:

$$bit = 0 \implies t_x = 0$$

$$bit = 1 \implies t_x = Ntx$$

- The hitting rate of of particles can be given by:

$$f_{hit}^{3D} = \frac{r(d-r)}{4\sqrt{4\pi Dt^3}} e^{-\frac{(d-r)^2}{4Dt}}$$

- Based on hitting rate, the probability of hitting particle can be given as:

$$P_{hit}(t) = \int_0^t f_{hit} dt = \frac{r}{d} * erfc(\frac{d-r}{\sqrt{4Dt}})$$

- Therefore the probability of hitting particle in (i-1)th time slot is:

$$p_{i-1} = \frac{r}{d} * erfc(\frac{d-r}{\sqrt{4Dit}} * erfc(\frac{d-r}{4D(i-1)t}))$$

- If C_j is the number of average particles that hit at j^th time slot then, $C_j = N_{tx} P_j$.

  To find the average particle hitting the receiver at particular time slot then it can be represented by poisson RV[3]:

$$r_i = Poisson(I_i + s_i C_0)$$

  where I_i can be gievn as,

$$I_i = \lambda_0 T + \sum_{j=1}^{\infty} s_{i-j} C_j$$

- Thus the probability of particle hitting is:

$$P(r_i | I_i + s_i C_0) = \frac{e^{(I_i + s_i C_0)} * (I_i + s_i C_0)^{r_i}}{r_i!}$$

And from this we can get SNR as:

$$SNR = 10log_{10}\frac{C_0}{2\lambda_0 T}$$

and based on the Signal to Noise ratio the number of transmitted particles can be given by:

$$N_{TX} = \frac{2\lambda_0 T 10^{\frac{SNR}{10}}}{P_0}$$

- Now based on the transmitting and channel information we have so far, we can go for different threshold based receivers.

- For Optimal Zero Bit Memory Receiver:

$$f(x) = \begin{cases} 1, & r_i \leq \tau \\ 0, & r_i \geq \tau \end{cases}$$

Probability of receiving n-particles:

$$p(r_i|s_i) = \frac{e^{\frac{-\lambda}{s_i}}(\frac{\lambda}{s_i})}{r_i!}$$

$$\text{where,} \frac{\lambda}{s_i} = \lambda_0 T + C_0 s_i + \sum_{j=1}^{\infty} C_j$$

Based on this sub-optimal threshold can be given by:

$$\tau = \frac{C_0}{\ln(1 + (\frac{C_0}{\sum_{j=1}^{\infty}\frac{c_j}{2} + \lambda_0 T}))}$$

- For Optimal One Bit Memory Receiver:

$$\bar{s_i} = \begin{cases} 1, & r_i \leq \tau|_{s_{i-1}} \\ 0, & r_i \geq \tau|_{s_{i-1}} \end{cases}$$

BER can be given as:

$$P_e(\tau, s_{i-1}) = \frac{1}{2^{L-1}} \sum_{s_{i-2} \ldots s_{i-L}} P_e(\tau, s_{i-1})$$

2 Numerical Results

2.1 Simulation Framework

Symbol	Description	Values
λ_0	Lambda	$100s^{-1}$
r	Receiver Radius	45nm
d	Distance	500nm
D	Diffusion Coefficient	$4.265*10^{-10}m^2/s$
ΔT	Discrete Time Length	9us
T	Slot Length	$30\Delta T$
L	Channel Length	5

2.2 Reproduced Figures

1. Reproduced Figure-1

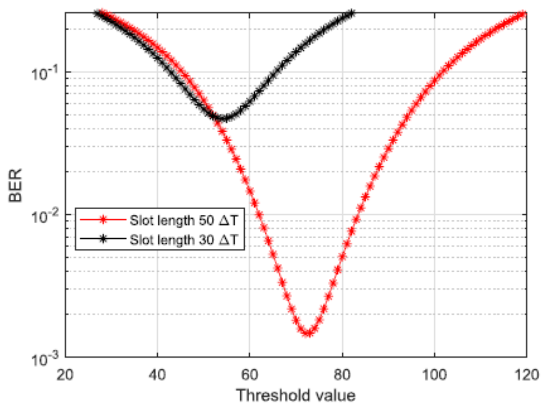


Figure 1B

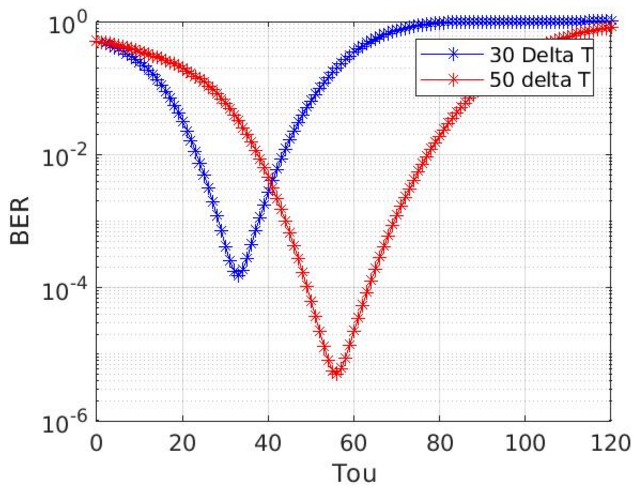


Figure 1R

Here, Figures 1B and 1R show the plot of Threshold Value(τ) versus Bit Error Rate (BER).

- For Graph 1(Inferences) : The graph shows the relation between the threshold value and the BER. On increasing slot length the BER performance decreases. The optimal threshold can be obtained by looking at the minimum value of the BER corresponding to a particular slot length.

2. Reproduced Figure-2

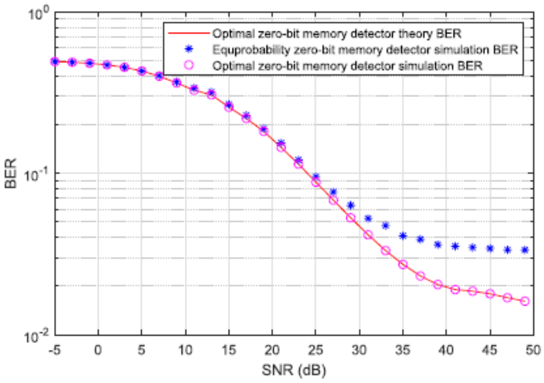


Figure 2B

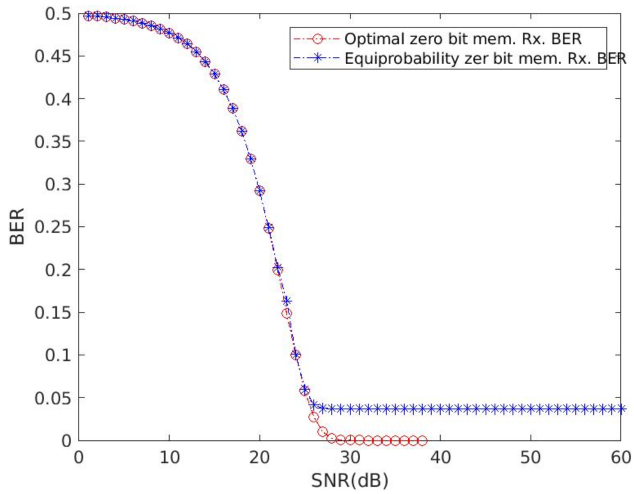


Figure 2R

Here, Figures 2B and 2R show the plot of SNR (Signal to Noise Ratio) Value versus Bit Error Rate (BER).

- For Graph 2(Inferences) : This graph shows both simulated and theory curves of optimal zero bit detector and one additional curve of Equiprobability zero bit memory detector simulation BER.

3. Reproduced Figure-3

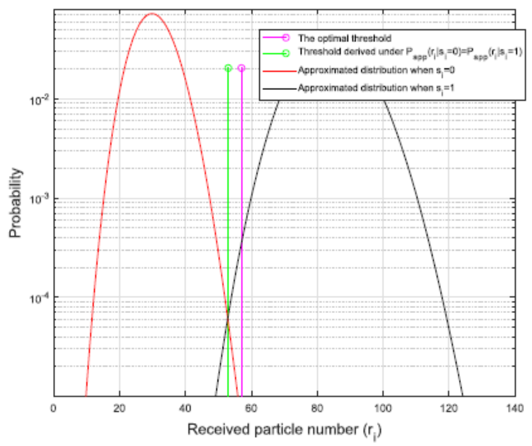


Figure 3B

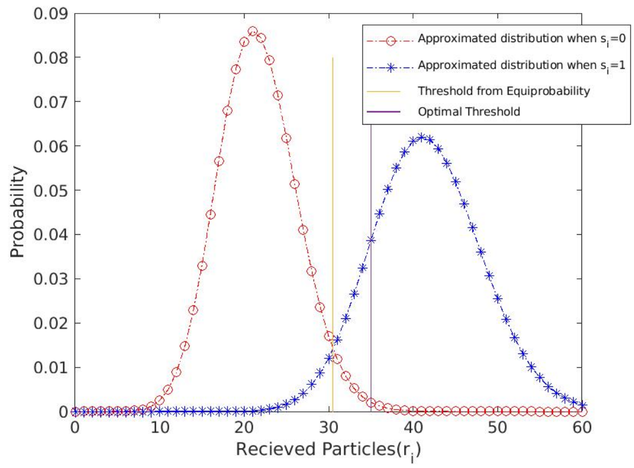


Figure 3R

Figures 3B and 3R show the plot of Received Particles(ri) versus Probability.

- For Graph 3(Inferences) : Here, the graph shows trends of 2 thresholds. 1) Sub-Optimal Threshold and 2) Optimal Thresholds. Where The optimal threshold is more idealistic in comparison to sub-optimal threshold. This 2 curves show the approximate distribution when the symbol $s_i = 0$ and 1.

3 Contribution of team members

3.1 Technical contribution of all team members

Tasks	**Samarth Shah**	**Yash Patel**	**Yugamsinh Chavda**
System Model along with parameters	-	+	+
Optimal zero/one bit receivers analysis	+	-	+
Data driven model analysis	+	+	-
Reproducing results	-	+	+
Code Analysis and graph ploting	+	-	-

3.2 Non-Technical contribution of all team members

Tasks	**Samarth Shah**	**Yash Patel**	**Yugamsinh Chavda**
Article (Topic 1)	-	+	-
Article (Topic 2 and 3)	+	-	+
Mind map (1 and 2)	+	+	+
Mind map (3)	+	+	+

4 References

1. X. Qian, M. Di Renzo, and A. Eckford, "Molecular communications: Model-basedand data-driven receiver design and optimization,"IEEE Access, vol. 7, pp. 53 555-53 565, 2019.

2. Xuewen Qian, Marco Di Renzo. Receiver Design in Molecular Communications: An Approach Based on Artificial Neural Networks. 2018 15th International Symposium on Wireless Communication Systems (ISWCS), Aug 2018, Lisbon, Portugal. ff10.1109/ISWCS.2018.8491088ff. ffhal-01923667

3. R. Mosayebi, H. Arjmandi, A. Gohari, M. Nasiri-Kenari, and U. Mitra, Receivers for diffusion-based molecular communication: Exploiting memory and sampling rate," IEEE J. Sel. Areas Commun., vol. 32, no. 12, pp. 23682380, Dec. 2014.