Enhancing the Reliability of Large-Scale Multiuser Molecular Communication Systems

Maheshi Buddhinee Dissanayake, Yansha Deng,
Arumugam Nallanathan, Maged Elkashlan, and Urbashi Mitra
Contact Email: maheshi@ieee.org

Motivation

A practical large scale molecular communication (MC) environment consist of swarms of transmitters causing,

1. multi-user interference (MUI)
2. intersymbol interference (ISI)

These interferences cause in bit and burst errors, and degrades the overall system performance and its reliability.

We study;

1. the interfering effect of swam of point transmitters on the desired signal in a large-scale MC system.
2. Apply RS coding as an error correction technique.

System Model

- The partially absorbing receiver with a finite absorption rate of k_1, a radius of r_r and volume of Ω_{r_r} located at the origin.
- Desired point transmitters at |d| away from the centre.
- Swarm of active point transmitters, with density of λ_a.
- Binary concentration shift keying with N_{tx} molecules to represent bit-1 and t 0 molecule to represent bit-0

Numerical Results

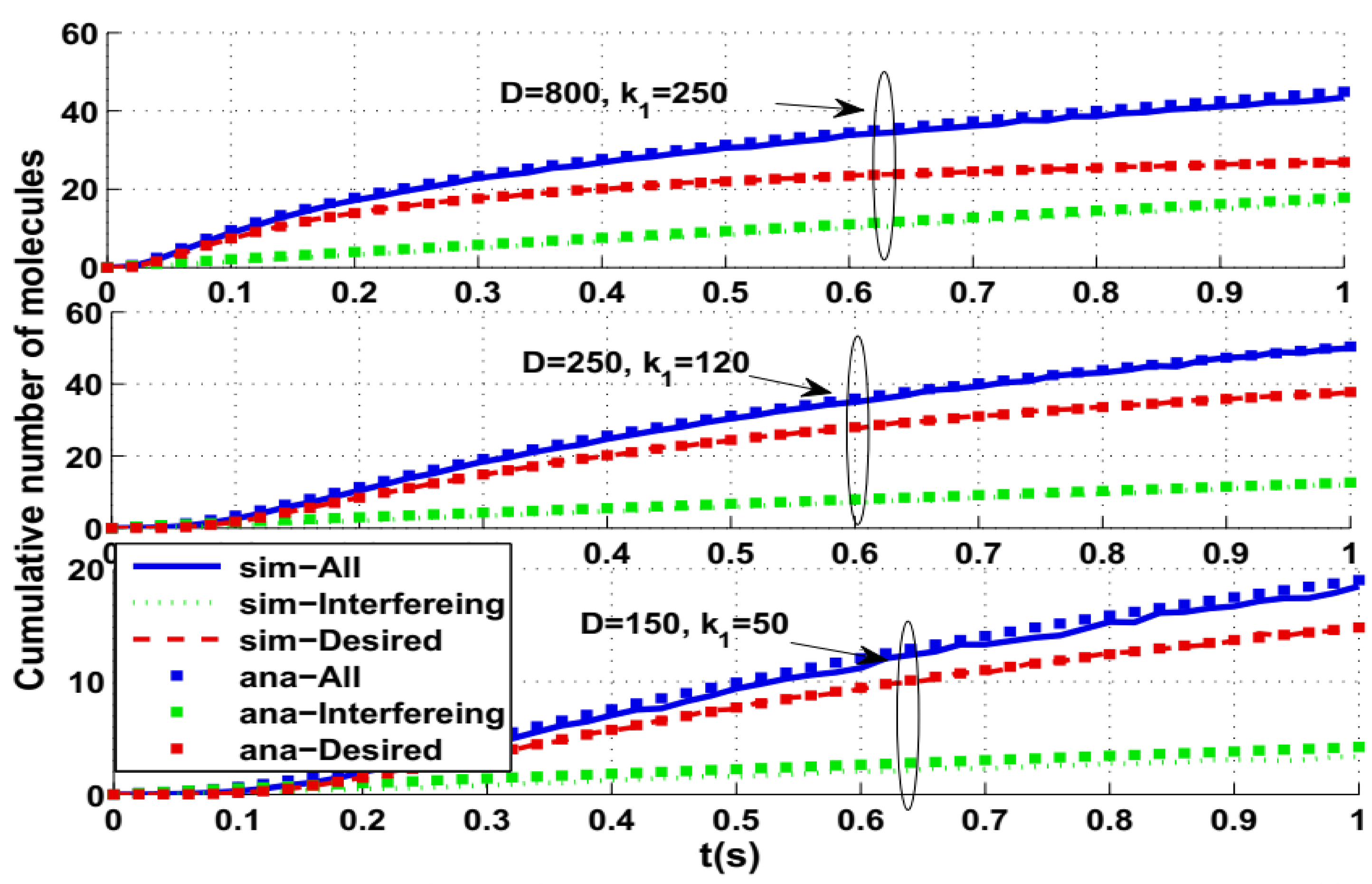

Fig. 1. Expected number of molecules observed at the Partial absorption receiver with *Ntx* = 1000, repetition=1000, *tb* = 0:5s, *R* = 100*μm*, *λa* = 8 × 10-6, **d** = 20*μm*, *rr* = 5*μm*

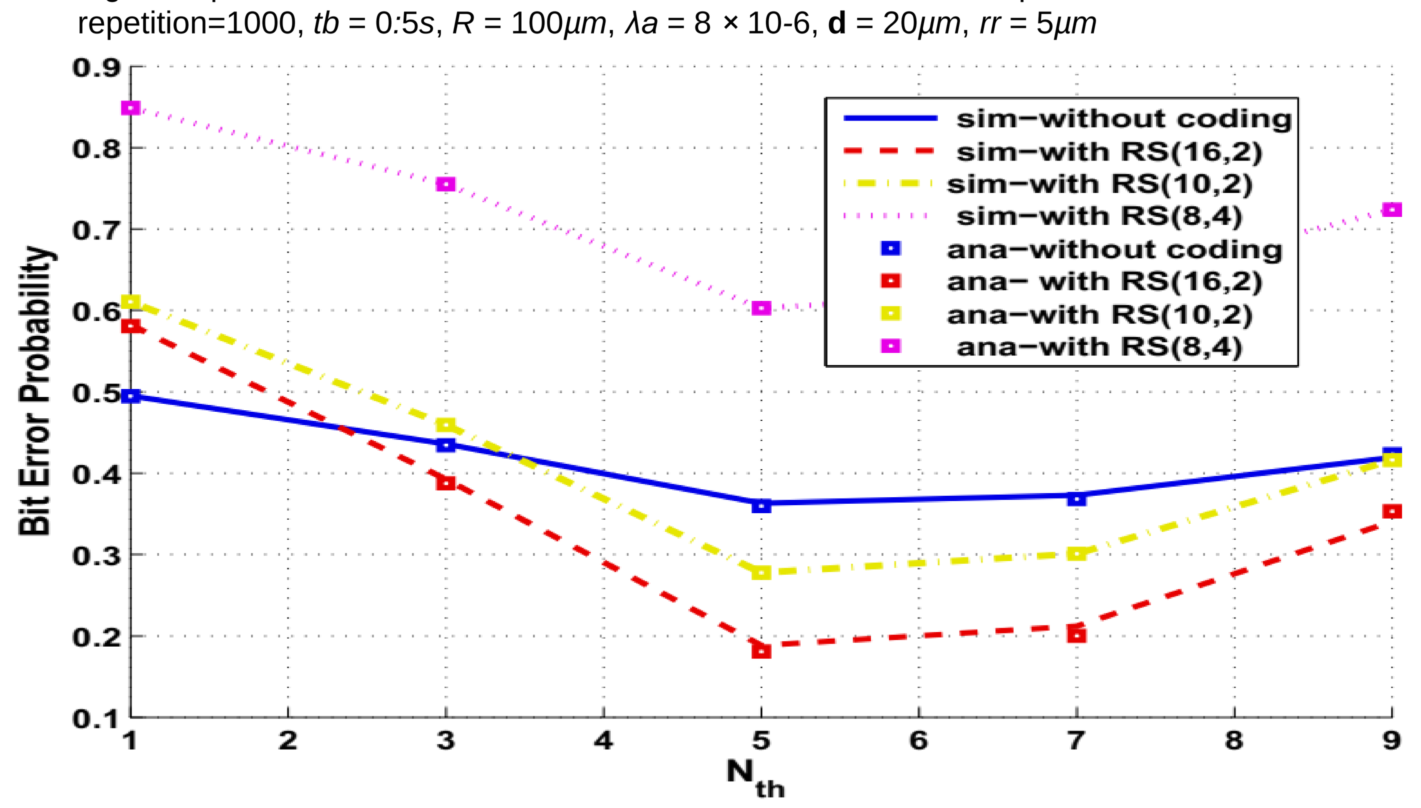

Fig. 2. Bit error probability for Partial Absorption Receiver *Ntx* = 100, repetition=1500, *tb* = 0:25*s*, *R* = 100*μm*, *D* = 250*μm2*=*s*, *k1* = 120*μm*=*s*, *λa* = 8 × 10-7, **d** = 20*μm*, *rr* = 10*μm*.

Mathematical Modelling

Receiver Observation:

The fraction of absorbed molecules at the receiver during [(j -i)Tb; jTb] sampling interval due to the desired transmitter at |d|,

$$F_{\rm D}(\Omega_{r_r},(j-1)T_b, jT_b|\,\|\mathbf{d}\|) = \sum_{i=1}^{j} b_i \int_{(j-1)T_b}^{jT_b} K((t-(i-1)T_b)|\,\|\mathbf{d}\|)\,{\rm d}t,$$

The total fraction of absorbed molecules due to all the interfering transmitters can be written using Slivnyak Meekes' Theorem as,

$$F_{\rm I}^{all}(\Omega_{r_r},(j-1)T_b, jT_b|\,\|\mathbf{x}\|) = \sum_{i=1}^{j} b_i \int_{(j-1)T_b}^{jT_b} K((t-(i-1)T_b)|\,\|\mathbf{x}\|)\,{\rm d}t,$$

Where $K((t-(i-1)T_b)|\,\|\mathbf{r}|)$ is the reaction rate of the receiver.

Bit error probability (BEP):

The BEP of the large-scale MC system for the j^{th} bit can be written as,

$$P_e[j] = P_r[e \mid b_j = 0, b_{1:j-1}]P_r[b_j = 0] + P_r[e \mid b_j = 1 b_{1:j-1}]P_r[b_j = 1]$$

Where,

$$P_r[e \mid b_j = 1, b_{1:j-1}] = P_r\Big[N_{\rm net}[j] < N_{\rm th}\Big] = \mathscr{L}_{R_{\rm Tot}}(N_{\rm tx}) + \sum_{n=1}^{N_{\rm th}-1} \frac{1}{(-\phi)^n n!} \frac{\partial^n[\mathscr{L}_{R_{\rm Tot}}(N_{\rm tx}\phi x)]}{\partial x^n}\Big|_{x=\phi^{-1}}$$

$$P_r[e \mid b_j = 0, b_{1:j-1}] = P_r\Big[N_{\rm net}[j] \geq N_{\rm th}\Big] = 1 - P_r\Big[N_{\rm net}[j] < N_{\rm th}\Big]$$

and

$$R_{\rm Tot}(\Omega_{r_r}, j) = F_{\rm D}(\Omega_{r_r},(j-1)T_b, jT_b|\,\|\mathbf{d}\|) + \sum_{x\in\Phi_a} F_{\rm I}(\Omega_{r_r},(j-1)T_b, jT_b|\,\|\mathbf{x}\|)$$

BEP for the jth bit of a RS(n,k) coded system can be written as

$$P_b[j] = \sum_{i=\frac{n-k}{2}+1}^{n} \binom{n}{i} P_e[j]^i (1-P_e[j])^{n-i}$$

Conclusions

- It is necessary to have an error mitigation scheme for ISI and MUI in a large-scale molecular communication system with a swarm of interfering transmitters.
- The minimum BEP can be improved with the RS codes in the above system.