Research Paper Presentation

Aman Panwar - CS20BTECH11004

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BER Analysis of a NOMA Enhanced Backscatter Communication System

Abstract

1. Analyses the BER performance of a NOMA enhanced BackCom system with imperfect SIC. One reader and two BNs are considered.
2. Compares the effective non-errornous transmitted bits over a large period in NOMA vs OMA
3. Derives equation for optimal reflection coefficients for the two BNs

Introduction

Keywords

1. **BackCom:** Backscatter Communication
2. **BN:** Backscatter Node
3. **BER:** Bit Error Rate
4. **NOMA:** Non-Orthogonal Multiple Access
5. **BSPK:** Binary Phase Shift Keying
6. **AWGN:** Additive White Gaussian Noise
7. **SIC:** Successive Interference Cancellation

System Model

Figure

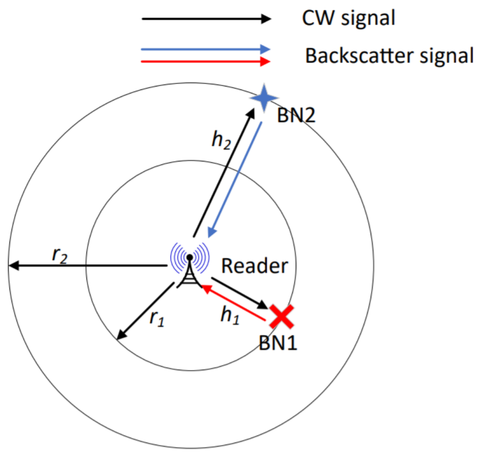

Fig. 1. Illustration of uplink NOMA-BackCom system

System Model

Important Formulae

The signal received by the reader is

$$y = \sqrt{P_r \xi_1} h_1 x_1 + \sqrt{P_r \xi_2} h_2 x_2 + w$$

Here,

P_r is reader transmitted power
ξ_i are the power reflection coefficient
h_i are channel coefficients b/w BNs and reader
x_i is the BPSK modulated information signal of BNi
w is the AWGN with 0 mean and N_0 varinace

(A strong line-of-sight is assumed in this model. Also, the BNs are numbered such that $\xi_1 > \xi_2$)

System Model

BER for User 1

Probability that the bit read from the first BN has error

$$P_1(e) = \frac{1}{4}\left(\operatorname{erfc}\left(\frac{\epsilon_b\xi_1 + \sqrt{(\epsilon_b\xi_1)/R}}{N_0}\right) + \operatorname{erfc}\left(\frac{\epsilon_b\xi_1 - \sqrt{(\epsilon_b\xi_1)/R}}{N_0}\right)\right)$$

where erfc () is the complementary error function

$$\operatorname{erfc}(z) = \frac{2}{\sqrt{\pi}}\int_z^\infty e^{-t^2}\,dt$$

System Model

BER for User 2

NOMA uses SIC i.e. to recognise the second signal, the first signal is subtracted from the received signal. Thus, probability of error in second signal depend on P_1

When first signal is correctly decoded,

$$P_{2(I)} = \frac{1}{4}\left(2\text{erfc}\left(\sqrt{\frac{(\epsilon_b \xi_1)/R}{N_0}}\right) - \text{erfc}\left(\frac{\sqrt{\epsilon_b \xi_1} + \sqrt{(\epsilon_b \xi_1)/R}}{\sqrt{N_0}}\right)\right)$$

When first signal is incorrectly decoded,

$$P_{2(II)} = \frac{1}{4}\left(\text{erfc}\left(\frac{2\sqrt{\epsilon_b \xi_1} + \sqrt{(\epsilon_b \xi_1)/R}}{\sqrt{N_0}}\right) + \text{erfc}\left(\frac{\sqrt{\epsilon_b \xi_1} - \sqrt{(\epsilon_b \xi_1)/R}}{\sqrt{N_0}}\right) - \text{erfc}\left(\frac{2\sqrt{\epsilon_b \xi_1} - \sqrt{(\epsilon_b \xi_1)/R}}{\sqrt{N_0}}\right)\right)$$

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System Model

BER for User 2

The final probability of error in bit read from the second user

$$P_2 = \frac{1}{4}\left(2\mathrm{erfc}\left(\sqrt{\frac{(\epsilon_b\xi_1)/R}{N_0}}\right) - \mathrm{erfc}\left(\frac{\sqrt{\epsilon_b\xi_1} + \sqrt{(\epsilon_b\xi_1)/R}}{\sqrt{N_0}}\right)\right.$$
$$+ \mathrm{erfc}\left(\frac{2\sqrt{\epsilon_b\xi_1} + \sqrt{(\epsilon_b\xi_1)/R}}{\sqrt{N_0}}\right) + \mathrm{erfc}\left(\frac{\sqrt{\epsilon_b\xi_1} - \sqrt{(\epsilon_b\xi_1)/R}}{\sqrt{N_0}}\right)$$
$$\left. - \mathrm{erfc}\left(\frac{2\sqrt{\epsilon_b\xi_1} - \sqrt{(\epsilon_b\xi_1)/R}}{\sqrt{N_0}}\right)\right) \tag{20}$$

Simulation Result

Simulation 1: BER vs SNR

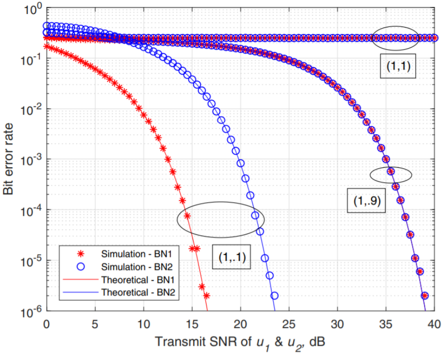

Fig. 7. BER plots of BN1 and BN2 for three reflection coefficient pairs (ξ_1,ξ_2)

Greater separation in reflection coefficients(ξ_1 and ξ_2) leads to smaller BER. This is due to decreased inter-user interface(IUI).

Simulation Result

Simulation 2: Effective bits transfered vs SNR for NOMA and OMA

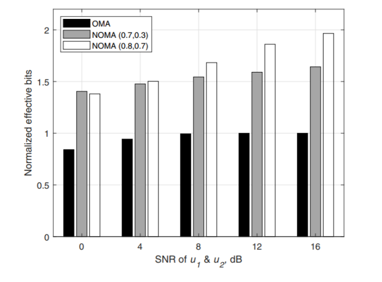

Fig. 8. Comparison of normalized effective bits transmitted in NOMA for two reflection coefficient pairs (ξ_1,ξ_2) and OMA

1. This simulation shows that NOMA does outperform OMA-TDMA (Orthogonal Multiple Access - Time Division Multiple Access)
2. The separation in reflection coefficients greatly effect the no. of correctly transmission of bits.

Simulation Result

Simulation 3: ξ_1 vs ξ_2 for specific BER

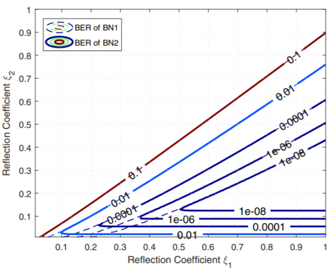

Fig. 9. BER contour plot by varying ξ_1 and ξ_2 values

1. Only a small range of ξ_2 achieves acceptable performance.
2. BER performance of BN1 is independent of ξ_2

Simulation Result

Simulation 3: ξ_1 vs ξ_2 for specific BER

Parameter	Value
P_r	20dBm
N_0	-90dBm
Path loss exponent	2
r_1	25m
r_2	25m
Effective SNR	24.08 dB

Table: Simulation Parameters

Simulation Result

Simulation 4: Effective bits transfered vs SNR for NOMA and OMA

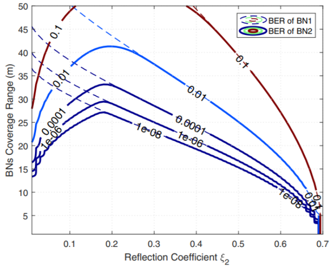

Fig. 10. BER contour plot of BackCom coverage range versus ξ_2

1. In this given case, the optimal ξ_2 is about one-fourth of ξ_1.
2. If $\xi_1 = 0.7$, QoS requirement of BER is 10^{-3} and coverage range is 33m then optimal $\xi_2 = 0.19$

Simulation Result

Simulation 4: Effective bits transfered vs SNR for NOMA and OMA

Parameter	Value
P_r	20dBm
N_0	-90dBm
Path loss exponent	2
r_1	25m
r_2	25m
Effective SNR	24.08 dB
ξ_1	0.7

Table: Simulation Parameters

Conclusion

Conclusion

1. The numerical results are found to match perfectly with Monte Carlo simulations
2. Moreover, derived BER expressions have been evaluated for different reflection coefficients and ranges to find optimum values for each scenario
3. NOMA has a upper hand over OMA when it comes to BackCom