

Research Paper Presentation

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July 4, 2021

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

- ➊ **BackCom:** Backscatter Communication
- ➋ **BN:** Backscatter Node
- ➌ **BER:** Bit Error Rate
- ➍ **NOMA:** Non-Orthogonal Multiple Access
- ➎ **BSPK:** Binary Phase Shift Keying
- ➏ **AWGN:** Additive White Gaussian Noise
- ➐ **SIC:** Successive Interference Cancellation

System Model

Figure

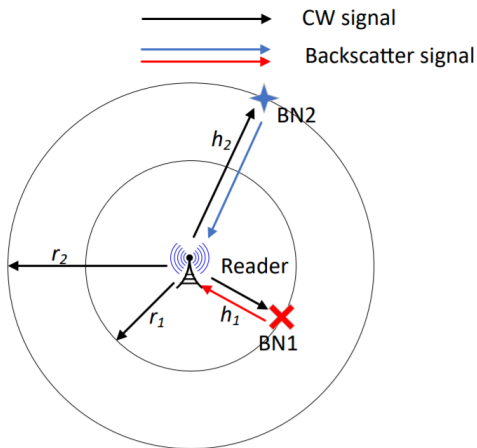


Fig. 1. Illustration of uplink NOMA-BackCom system

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 BN i

w is the AWGN with 0 mean and N_0 variance

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

System Model

Figure

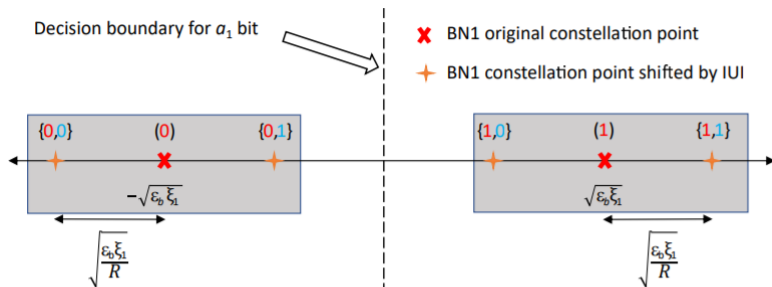


Fig. 2. The received signal space diagram for u_1 (red color and blue color represent u_1 and u_2 BPSK bit, respectively)

System Model

BER for User 1

Probability that the bit read from the first BN has error

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

where $\operatorname{erfc}()$ 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,

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

System Model

BER for User 2

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

$$\begin{aligned} P_2 = & \frac{1}{4} \left(2 \operatorname{erfc} \left(\sqrt{\frac{(\epsilon_b \xi_1) / R}{N_0}} \right) - \operatorname{erfc} \left(\frac{\sqrt{\epsilon_b \xi_1} + \sqrt{(\epsilon_b \xi_1) / R}}{\sqrt{N_0}} \right) \right. \\ & + \operatorname{erfc} \left(\frac{2 \sqrt{\epsilon_b \xi_1} + \sqrt{(\epsilon_b \xi_1) / R}}{\sqrt{N_0}} \right) + \operatorname{erfc} \left(\frac{\sqrt{\epsilon_b \xi_1} - \sqrt{(\epsilon_b \xi_1) / R}}{\sqrt{N_0}} \right) \\ & \left. - \operatorname{erfc} \left(\frac{2 \sqrt{\epsilon_b \xi_1} - \sqrt{(\epsilon_b \xi_1) / R}}{\sqrt{N_0}} \right) \right) \end{aligned}$$

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Simulation Result

Simulation 1: BER vs SNR

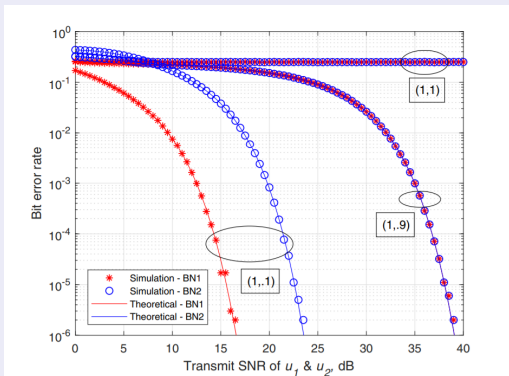


Fig. 7. BER plots of BN1 and BN2 for three reflection coefficient pairs (ξ_1, ξ_2)

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

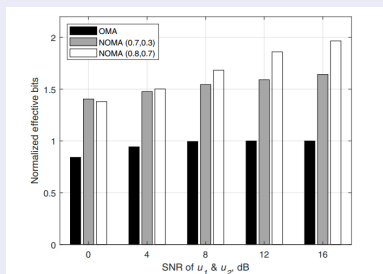


Fig. 8. Comparison of normalized effective bits transmitted in NOMA for two reflection coefficient pairs (ξ_1, ξ_2) and OMA

- 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

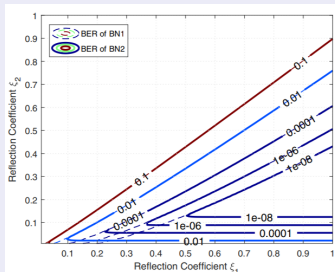


Fig. 9. BER contour plot by varying ξ_1 and ξ_2 values

- 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: ξ_2 vs range

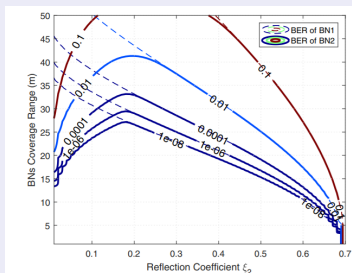


Fig. 10. BER contour plot of BackCom coverage range versus ξ_2

- 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: ξ_2 vs range

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