
저자 (Authors)	Kyuhuk Chung
출처 (Source)	전기전자학회논문지 23(1) , 2019.3, 314-317(4 pages) Journal of IKEEE 23(1) , 2019.3, 314-317(4 pages)
발행처 (Publisher)	한국전기전자학회 Institute of Korean Electrical and Electronics Engineers
URL	http://www.dbpia.co.kr/journal/articleDetail?nodeId=NODE07999420
APA Style	Kyuhuk Chung (2019). Performance Analysis of NOMA with Symmetric Superposition Coding. 전기전자학회논문지, 23(1), 314-317
이용정보 (Accessed)	홍익대학교 203.249.80.*** 2019/08/05 15:47 (KST)

저작권 안내

DBpia에서 제공되는 모든 저작물의 저작권은 원저작자에게 있으며, 누리미디어는 각 저작물의 내용을 보증하거나 책임을 지지 않습니다. 그리고 DBpia에서 제공되는 저작물은 DBpia와 구독계약을 체결한 기관소속 이용자 혹은 해당 저작물의 개별 구매자가 비영리적으로만 이용할 수 있습니다. 그러므로 이에 위반하여 DBpia에서 제공되는 저작물을 복제, 전송 등의 방법으로 무단 이용하는 경우 관련 법령에 따라 민, 형사상의 책임을 질 수 있습니다.

Copyright Information

Copyright of all literary works provided by DBpia belongs to the copyright holder(s) and Nurimedia does not guarantee contents of the literary work or assume responsibility for the same. In addition, the literary works provided by DBpia may only be used by the users affiliated to the institutions which executed a subscription agreement with DBpia or the individual purchasers of the literary work(s) for non-commercial purposes. Therefore, any person who illegally uses the literary works provided by DBpia by means of reproduction or transmission shall assume civil and criminal responsibility according to applicable laws and regulations.

Performance Analysis of NOMA with Symmetric Superposition Coding

Kyuhyuk Chung^{*}★

Abstract

Recently, the symmetric superposition coding (SSC) [3] is proposed for a solution for the error propagation (EP) due to the non-perfect successive interference cancellation (SIC) in non-orthogonal multiple access (NOMA). We analyze the performance of NOMA with the SSC. It is shown that the performance of the SSC NOMA is the same as that of NOMA with the normal superposition coding (NSC) for the power allocation factor less than 20%, the SSC NOMA performance is better than the NSC NOMA performance up to the power allocation factor 80%, and the SSC NOMA performs worse than the NSC NOMA for the power allocation factor greater than 80%. As a result, the SSC should be used with consideration of the power allocation.

Key words : Non-orthogonal multiple access, successive interference cancellation, power allocation, maximum likelihood, binary phase shift keying

I . Introduction

Non-orthogonal multiple access (NOMA) is the superposition based multi-user access technique for the fifth generation (5G) mobile networks, to provide high system capacity and low latency [1], [2]. In NOMA, the performance is greatly dependent on the successive interference cancellation (SIC). Recently, the symmetric superposition coding (SSC) [3] is proposed for a solution for the error propagation (EP). However, in [3], only the simulation results are presented without the derivation of analytical expressions. In this paper, the SSC NOMA is compared to NOMA with the normal superposition coding (NSC). The paper is organized as follows. Section II defines the system model. In Section III, the performance of the SSC NOMA is derived. In Section IV, the

results are presented and discussed. The paper is concluded in Section V.

II . System and Channel Model

Assume that the total transmit power is P , the power allocation factor is α with $0 \leq \alpha \leq 1$, and the channel gains are h_1 and h_2 with $|h_1| > |h_2|$. Then αP and $(1 - \alpha)P$ are allocated to the user-1 signal s_1 and the user-2 signal s_2 , with unit power. The superimposed signal is expressed by

$$x = \sqrt{\alpha P} s_1 + \sqrt{(1 - \alpha)P} s_2 \quad (1)$$

Before the SIC is performed on the user-1 with the better channel condition, the received signals of the user-1 and the user-2 are represented as

$$r_1 = |h_1| \sqrt{\alpha P} s_1 + (|h_1| \sqrt{(1 - \alpha)P} s_2 + n_1) \quad (2)$$

* Dept. of Software Science, Dankook University

★ Corresponding author

E-mail : khchung@dankook.ac.kr, Tel : +82-32-8005-3237

Manuscript received Mar. 5, 2019; revised Mar. 20, 2019; accepted Mar. 21, 2019.

This is an Open-Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/3.0>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

$$r_2 = |h_2| \sqrt{(1-\alpha)P} s_2 + (|h_2| \sqrt{\alpha P} s_1 + n_2)$$

where n_1 and $n_2 \sim N(0, N_0/2)$ are additive white Gaussian noise (AWGN) with zero mean and variance $N_0/2$ and N_0 is one-sided power spectral density. In the standard NOMA, the SIC is performed only on the user-1. Let the information bits for the user-1 and the user-2 be $b_1, b_2 \in \{0, 1\}$ with the binary phase shift keying (BPSK) modulation $s_1, s_2 \in \{+1, -1\}$. Normal superposition coding (NSC) is given by

$$\begin{cases} s_1(b_1=0) = +1 & s_2(b_2=0) = +1 \\ s_1(b_1=1) = -1 & s_2(b_2=1) = -1 \end{cases} \quad (3)$$

However, symmetric superposition coding (SSC) is represented as

$$\begin{cases} s_1(b_1=0, b_2=0) = +1 & s_1(b_1=0, b_2=1) = -1 \\ s_1(b_1=1, b_2=0) = -1 & s_1(b_1=1, b_2=1) = +1 \\ s_2(b_2=0) = +1 \\ s_2(b_2=1) = -1 \end{cases} \quad (4)$$

III. SSC NOMA Performance

In the SSC NOMA, it is interesting that if no power is allocated to the user-2 ($\alpha = 1$), then the user-1 cannot receive any information from the base station. However, if there exists the inter user-1 interference, the user-1 can receive the information for $\alpha < 0.5$. In effect, the perfect SIC is achieved for $\alpha < 0.5$. This effective perfect SIC is achieved by the maximum likelihood (ML) decoding of the user-1, not by decoding of the inter user-1 interference and subtracting the inter user-1 interference signal from the received signal, i.e., not by the standard SIC. So the ML decoding of the user-1 is required. Now, we derive the ML receiver for the SSC NOMA. The likelihoods are expressed as

$$\begin{aligned} p_{R_1|B_1}(r_1|b_1=0) &= \frac{1}{2} p_{R_1|B_1, B_2}(r_1|b_2=0, b_1=0) \\ &+ \frac{1}{2} p_{R_1|B_1, B_2}(r_1|b_2=1, b_1=0) \end{aligned} \quad (5)$$

$$\begin{aligned} &+ \frac{1}{2} \frac{1}{\sqrt{\pi N_0}} e^{-\frac{(r_1 - |h_1| \sqrt{\alpha P} - |h_1| \sqrt{(1-\alpha)P})^2}{N_0}} \\ &= \frac{1}{2} \frac{1}{\sqrt{\pi N_0}} e^{-\frac{(r_1 + |h_1| \sqrt{\alpha P} + |h_1| \sqrt{(1-\alpha)P})^2}{N_0}} \end{aligned}$$

and

$$\begin{aligned} p_{R_1|B_1}(r_1|b_1=1) &= \frac{1}{2} p_{R_1|B_1, B_2}(r_1|b_2=0, b_1=1) \\ &+ \frac{1}{2} p_{R_1|B_1, B_2}(r_1|b_2=1, b_1=1) \\ &+ \frac{1}{2} \frac{1}{\sqrt{\pi N_0}} e^{-\frac{(r_1 + |h_1| \sqrt{\alpha P} - |h_1| \sqrt{(1-\alpha)P})^2}{N_0}} \\ &= \frac{1}{2} \frac{1}{\sqrt{\pi N_0}} e^{-\frac{(r_1 - |h_1| \sqrt{\alpha P} + |h_1| \sqrt{(1-\alpha)P})^2}{N_0}} \end{aligned} \quad (6)$$

where $p_X(x)$ is the probability density function (PDF). The ML detection is made as

$$\hat{b}_1 = \underset{b_1 \in \{0, 1\}}{\operatorname{argmax}} p_{R_1|B_1}(r_1|b_1) \quad (7)$$

The equal likelihood equation is given by

$$p_{R_1|B_1}(r_1|b_1=0) = p_{R_1|B_1}(r_1|b_1=1) \quad (8)$$

For $\alpha < 0.5$, the equal likelihood equation has the two decision boundaries as follows; The first approximate decision boundary, $r_1 \simeq |h_1| \sqrt{(1-\alpha)P}$, is obtained from

$$\begin{aligned} \frac{1}{2} \frac{1}{\sqrt{\pi N_0}} e^{-\frac{(r_1 + |h_1| \sqrt{\alpha P} - |h_1| \sqrt{(1-\alpha)P})^2}{N_0}} &= \\ \frac{1}{2} \frac{1}{\sqrt{\pi N_0}} e^{-\frac{(r_1 - |h_1| \sqrt{\alpha P} + |h_1| \sqrt{(1-\alpha)P})^2}{N_0}} & \end{aligned} \quad (9)$$

where we use the following observation, at $r_1 = |h_1| \sqrt{(1-\alpha)P}$, for $\alpha < 0.5$,

$$\begin{aligned} \frac{1}{2} \frac{1}{\sqrt{\pi N_0}} e^{-\frac{(r_1 - |h_1| \sqrt{\alpha P} + |h_1| \sqrt{(1-\alpha)P})^2}{N_0}} &\simeq 0 \\ \frac{1}{2} \frac{1}{\sqrt{\pi N_0}} e^{-\frac{(r_1 + |h_1| \sqrt{\alpha P} - |h_1| \sqrt{(1-\alpha)P})^2}{N_0}} &\simeq 0 \end{aligned} \quad (10)$$

Similarly, the second approximate decision boundary, $r_1 \simeq -|h_1| \sqrt{(1-\alpha)P}$, is obtained. The decision region for $s_1 = +1$ is given by

$$r_1 < -|h_1| \sqrt{(1-\alpha)P}, |h_1| \sqrt{(1-\alpha)P} < r_1 \quad (11)$$

if $\alpha < 0.5$

For $\alpha > 0.5$, we similarly derive the decision region for $s_1 = +1$, as

$$r_1 < -|h_1| \sqrt{\alpha P}, |h_1| \sqrt{\alpha P} < r_1 \quad \text{if } \alpha < 0.5 \quad (12)$$

Then the probability of errors for the user-1 with the SSC ML decoding is given by, for $\alpha < 0.5$,

$$P_e^{(1; SSC ML)} \simeq Q \left(\frac{|h_1| \sqrt{\alpha P}}{\sqrt{N_0/2}} \right) - \frac{1}{2} Q \left(\frac{|h_1| \sqrt{P} (2\sqrt{(1-\alpha)} + \sqrt{\alpha})}{\sqrt{N_0/2}} \right) + \frac{1}{2} Q \left(\frac{|h_1| \sqrt{P} (2\sqrt{(1-\alpha)} - \sqrt{\alpha})}{\sqrt{N_0/2}} \right) \quad (13)$$

and for $\alpha > 0.5$,

$$P_e^{(1; SSC ML)} \simeq Q \left(\frac{|h_1| \sqrt{(1-\alpha)P}}{\sqrt{N_0/2}} \right) - \frac{1}{2} Q \left(\frac{|h_1| \sqrt{P} (2\sqrt{\alpha} + \sqrt{(1-\alpha)})}{\sqrt{N_0/2}} \right) + \frac{1}{2} Q \left(\frac{|h_1| \sqrt{P} (2\sqrt{\alpha} - \sqrt{(1-\alpha)})}{\sqrt{N_0/2}} \right) \quad (14)$$

For comparison, we present the probability of errors for the user-1 with the NSC ML decoding in [4] as follows, for $\alpha > 0.5$,

$$P_e^{(1; NSC ML)} \simeq \frac{1}{2} Q \left(\frac{|h_1| \sqrt{P} (\sqrt{\alpha} - \sqrt{(1-\alpha)})}{\sqrt{N_0/2}} \right) + \frac{1}{2} Q \left(\frac{|h_1| \sqrt{P} (\sqrt{\alpha} + \sqrt{(1-\alpha)})}{\sqrt{N_0/2}} \right) \quad (15)$$

and for $\alpha < 0.5$,

$$P_e^{(1; NSC ML)} \simeq Q \left(\frac{|h_1| \sqrt{\alpha P}}{\sqrt{N_0/2}} \right) \quad (16)$$

$$+ \frac{1}{2} Q \left(\frac{|h_1| \sqrt{P} (\sqrt{(1-\alpha)} + \sqrt{\alpha})}{\sqrt{N_0/2}} \right) - \frac{1}{2} Q \left(\frac{|h_1| \sqrt{P} (\sqrt{(1-\alpha)} - \sqrt{\alpha})}{\sqrt{N_0/2}} \right) - \frac{1}{2} Q \left(\frac{|h_1| \sqrt{P} (2\sqrt{(1-\alpha)} + \sqrt{\alpha})}{\sqrt{N_0/2}} \right) + \frac{1}{2} Q \left(\frac{|h_1| \sqrt{P} (2\sqrt{(1-\alpha)} - \sqrt{\alpha})}{\sqrt{N_0/2}} \right)$$

IV. Results and Discussions

Assume that the channel gain is $|h_1| = 2.5$. The total transmit signal power to one-sided power spectral density ratio is $P/N_0 = 20$. The probabilities of errors with the NSC ML and SSC ML for the user-1 are shown in Fig. 1, with different power allocations, $0 \leq \alpha \leq 1$. As shown in Fig. 1, the performance of the SSC NOMA is the same as that of NOMA with the NSC for the power allocation factor less than 20%, the SSC NOMA performance is better than the NSC NOMA performance up to the power allocation factor 80%, and the SSC NOMA performs worse than the NSC NOMA for the power allocation factor greater than 80%. Note that effectively, the perfect SIC in the SSC NOMA is achieved for $\alpha < 0.5$.

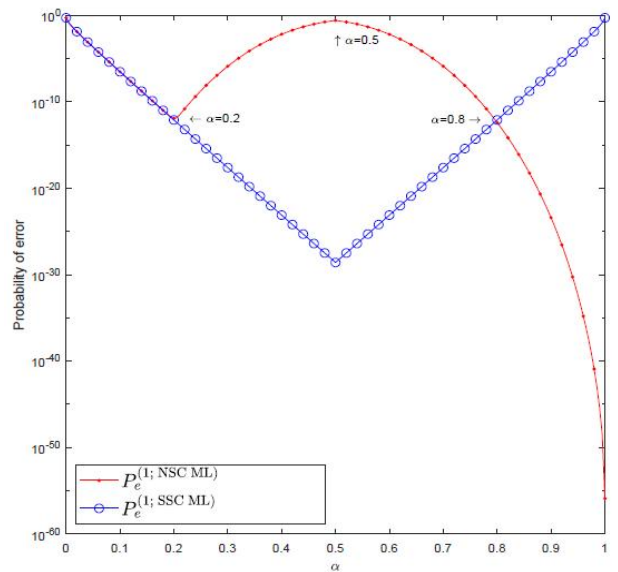


Fig. 1. Probabilities of errors with the NSC ML and SSC ML for the user-1.

V. Conclusion

We analyzed the performance of NOMA with the SSC. It was shown that the performance of the SSC NOMA is better or worse than that of NOMA with the NSC, according to the power allocation factor. In result, the SSC should be used with consideration of the power allocation.

References

- [1] Y. Saito, Y. Kishiyama, A. Benjebbour, T. Nakamura, A. Li, and K. Higuchi, "Non-orthogonal multiple access (NOMA) for cellular future radio access," in *Proc. IEEE 77th Vehicular Technology Conference (VTC Spring)*, pp. 1–5. 2013.
DOI: 10.1109/VTCSpring.2013.6692652
- [2] Z. Ding, P. Fan, and H. V. Poor, "Impact of user pairing on 5G nonorthogonal multiple-access downlink transmissions," *IEEE Trans. Veh. Technol.*, vol. 65, no. 8, pp. 6010–6023, 2016.
DOI: 10.1109/TVT.2015.2480766
- [3] H. Li, Z. Huang, Y. Xiao, S. Zhan, and Y. Ji, "Solution for error propagation in a NOMA-based VLC network: symmetric superposition coding," *Opt. Exp.*, vol. 25, no. 24, pp. 29856–29863, 2017.
DOI: 10.1364/OE.25.029856
- [4] K. Chung (in press Mar. 2019), "Performance analysis on non-SIC ML receiver for NOMA strong channel user," *J. KICS*, vol. 44, no. 3. Accepted for publication.