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UAV-assisted NOMA-based network with alamouti space-time block coding

Alamouti uzay-zaman blok kodlamalı iha-yardımlı NOMA-tabanlı haberleşme ağı

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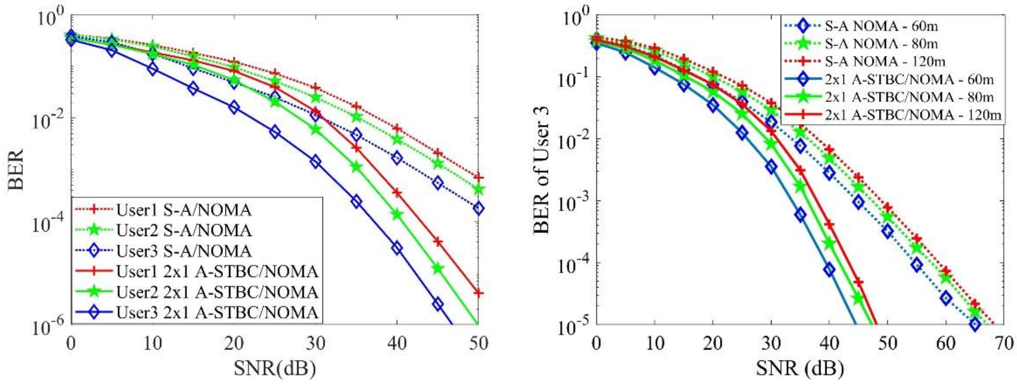
UAV-Assisted NOMA-Based Network with Alamouti Space-Time Block Coding

Highlights

- *Improving the performance of the system in terms of bit error rate and energy.*
- *Reducing the effects of environmental disruptive factors such as path loss on performance.*
- *Increasing the flying time of the UAV.*
- *Achieving the full diversity gain.*

Graphical Abstract

In this study, the error performance of the system has been improved when A-STBC technique is used in the UAV-Assisted downlink NOMA-Based network. Also, high SNR gain was obtained by using the A-STBC technique and increasing the diversity in the network. The effect of path loss on the performance has been minimized and full diversity gain has been achieved.



Figures. *BER curves for constant and variable heights compared to conventional system (S-A NOMA) when using A-STBC technique in UAV-Assisted downlink NOMA-Based network.*

Aim

By using the A-STBC technique and increasing the diversity in the network, it has aimed to minimize the effect of path loss on performance, improve error performance, provide a considerable SNR gain and achieve full diversity gain.

Design & Methodology

A good infrastructure was established by conducting detailed literature research. Simulation results have been obtained for various scenarios in the computer environment.

Originality

To the best of our knowledge, there is no such study based on performance analysis of A-STBC technique in the UAV-Assisted NOMA communication network.

Findings

The use of the A-STBC technique in the transmitter and the increase of diversity in the network provide a high SNR gain in UAV-Assisted NOMA-Based networks. UAVs that will be widely used in next-generation communication systems have some restrictions such as energy (flight time) and height. Using Space-Time Block coding techniques and multiple antennas could seem to be some of the effective solutions to such restrictions.

Conclusion

When the A-STBC technique is used in the UAV-assisted downlink NOMA-based network, error performances for each user in the coverage area have improved considerably compared to the traditional system. Also, as well as the use of Alamouti Space-Time Block Coding, it has been observed that the increase in diversity in the system provides a high SNR gain. Also, it has been observed that full diversity gain can be achieved when the A-STBC technique is used in the UAV-Assisted downlink NOMA-Based communication system.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

UAV-Assisted NOMA-Based Network with Alamouti Space-Time Block Coding

Research Article / Araştırma Makalesi

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ABSTRACT

In this study, a 3-user system was considered in the Unmanned Aerial Vehicle-Assisted (UAV-Assisted) Non-Orthogonal Multiple Access-Based (NOMA-Based) communication network. In the network, UAV communicates with users on the ground via two antennas using the Alamouti Space-Time Block Coding (A-STBC) technique. It is considered that there are two separate scenarios where user links are designed with one antenna and two antenna systems. In the study, Monte-Carlo simulations were carried out to understand the effects of using the A-STBC technique in UAV-Assisted NOMA-Based communication networks and increased antenna diversity in receiver and transmitter in the network to the performance of the system. For the benchmark, the downlink NOMA network was used, where the receivers and the UAV are designed with a single antenna. In the simulation results, with the A-STBC technique in the system and increase in diversity, the effects of Path Loss (PL) and environmental factors on error performance were examined. Especially in high Signal to Noise Ratio (SNR) values, it has been observed that the effects of these destructive factors on error performance are highly minimized. Also, the use of A-STBC technique and the increase in diversity in the system provided considerable SNR gain. Moreover, it has been observed that full diversity gain can be achieved when the A-STBC technique is used in the UAV-Assisted downlink NOMA-Based communication system.

Keywords:Non-orthogonal multiple access, unmanned aerial vehicles, A-STBC, diversity, bit error rate.

Alamouti Uzay-Zaman Blok Kodlamalı İHA-Yardımlı NOMA-Tabanlı Haberleşme Ağı

ÖZ

Bu çalışmada İnsansız Hava Aracı (İHA) yardımıyla oluşturulmuş aşağı yönde Dikgen Olmayan Çoklu Erişim (DOÇE) temelli ve 3 kullanıcılı bir sistem ağı düşünülmüştür. Ağda İHA yerdeki kullanıcıların her biri ile Alamouti Uzay-Zaman Blok Kodlama (A-UZBK) tekniğini kullanarak 2 anten üzerinden haberleşmektedir. Ayrıca kullanıcıların tek antenli ve iki antenli olarak tasarlandığı düşünülen 2 farklı haberleşme senaryosu üzerinde durulmuştur. Bu çalışmada A-UZBK tekniğinin İHA destekli aşağı yönde DOÇE temelli haberleşme ağlarında kullanımının ve ağda bulunan yerdeki alıcılarda ve vericide anten çeşitlemesinin artmasının sistemin performansına etkilerini anlamak amacıyla simülasyonlar gerçekleştirilmiştir. Önerilen haberleşme sisteminin performansını kıyaslamak amacıyla, İHA ve yerdeki kullanıcıların tek anten olarak tasarlandığı bir aşağı yönde DOÇE ağı kullanılmıştır. Yapılan Monte-Carlo simülasyon sonuçlarında, sistemde A-UZBK tekniğinin kullanılması ve çeşitlemenin arttırılmasıyla birlikte Yol Kaybı (YK) ve çevresel faktörlerden kaynaklı bozucu etkenlerin hata performansı üzerine etkileri incelenmiştir. Özellikle yüksek Sinyal-Gürültü Oranı (SGO) değerlerinde bu bozucu etkenlerin hata performansı üzerine etkilerinin oldukça minimize edildiği gözlemlenmiştir. Ayrıca, sistemde A-UZBK tekniği kullanımı ve çeşitlemenin artması, oldukça iyi seviyede SNR kazancı sağlamıştır. Dahası, İHA-Destekli aşağı yönde NOMA-Tabanlı iletişim sisteminde A-STBC tekniği kullanıldığında tam çeşitleme kazancının elde edilebileceği gözlemlenmiştir.

Anahtar Kelimeler:Dikgen olmayan çoklu erişim, insansız hava araçları, A-UZBK, çeşitleme, bit hata oranı.

1. INTRODUCTION

The need for continuous and ubiquitous communication that increases rapidly with the developing technology causes the ground communication network to be overloaded. Since the number of devices that will need wireless communication networks in 5G and Beyond 5G (B5G) communication is more than the ground communication network's capacity that can support, researchers have concentrated their studies in the field of Unmanned Aerial Vehicle (UAV) communication. UAV-Based communication brings many advantages to the network compared to the ground communication network. These advantages can be stated as being much more affordable in terms of cost and maintenance, higher possibility of establishing a Line of Sight (LoS) communication between the receiver and the transmitter due to its high altitude, higher coverage area, high mobility, and fast deployment [1-2].

Non-Orthogonal Multiple Access (NOMA) techniques are a popular researched topic for next-generation communications. With the increase in the number of

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devices that require wireless communication, today's communication techniques are inadequate in meeting the high capacity and data rate needs in communication networks. Because of this, NOMA is a potential solution to meet emerging requirements in communication networks. Standard Orthogonal Multiple Access (OMA) systems cannot provide the required capacity / spectral efficiency and high data rate for a communication network. Since user information in NOMA is sent continuously using a single packet with Superposition Coding (SC), the system's delay is minimal [3-4].

UAV-Based communication networks with the NOMA technique are used to meet the high capacity and data rate need in the next generation communication network [5-6]. It is possible to obtain a high-performance system using NOMA and UAV Base Station features into the communication network together [6-7]. The use of NOMA in UAV-Based communication network systems is one of the most suitable technologies to meet the requirements of 5G and beyond radio communication technologies. Studies have been shown that maximum fairness and data rate have been achieved by using NOMA in UAV-Enabled communication [7]. Additionally, in [8], the authors have used DBS (Drone Base Station) to increase the performance of Cell-Edge Users (CEU) in the cellular communication network. In [9], the authors designed an n-user network created with the help of UAV in a NOMA-Based communication network. For each user on this network, they obtained outage performance analysis in mathematically closed form.

Orthogonal STBC (OSTBC) techniques are used in communication systems to benefit from the transmit diversity. High reliability, capacity, and diversity gain are aimed at the communication network using the Alamouti Space-Time Block Coding (A-STBC) technique [10]. Combining the A-STBC technique and NOMA provides more reliable communication, low latency, and high data rate in the system. The number of studies based on performance analysis in A-STBC/NOMA network in the literature is minimal [11-13]. Also, in [14], the authors analyzed the network's Outage Probability for practical challenges such as CEE (Channel Estimation Error) FBD (Feedback Delay) on the downlink NOMA network using the OSTBC technique with code lengths 2 and 3.

i. Motivation and Contribution

When we examined the literature, we saw that there are very few studies based on performance analysis on communication using the A-STBC technique in the UAV-Based communication network. The only research in the literature based on A-STBC in the UAV-Based communication network is about channel estimation within a simple MIMO (Multiple Input Multiple Output) structure [15]. Additionally, to the best our knowledge, there is no study based on performance analysis of the using A-STBC technique in the UAV-Based NOMA communication network. This motivated us, and therefore, in this study, we examined the effects of using A-STBC techniques in a UAV-Assisted downlink NOMA-Based communication network with 3-user.

Communication is provided with a UAV to users on the ground. In the proposed system, while the UAV was designed with two antennas, simulations were carried out for two different situations. The ground users utilize one and two antennas (2x1-MISO, Multiple Input Single Output and 2x2-MIMO A-STBC technique) for our approach. The BER performance analysis of the users within the coverage area has been compared when communication was established using the A-STBC technique in the UAV-Assisted NOMA-Based communication network with Monte Carlo simulations. Also, for the benchmark, simulations have been conducted for the downlink NOMA network where the receivers and the UAV are designed with single antenna (S-A NOMA). Then, the BER values of the S-A NOMA, 2x1 MISO A-STBC / NOMA, and 2x2 MIMO A-STBC / NOMA scenarios are given comparatively. In this way, we tried to understand the benefits of the use of Alamouti-Space Time Block Coding technique and increase in diversity in UAV-Assisted downlink NOMA-Based networks. In other words, we aimed to provide the literature a study examining the effects of use of the A-STBC technique and increase diversity on performance of UAV-Assisted downlink NOMA-Based networks.

ii. Paper Organization

Section II of this paper defines the proposed system model. In section III, simulation results are given. The results obtained in the study and the implications about the use of the A-STBC technique in the proposed system are presented in section IV. Also, future studies on the subject are given in section V.

2. SYSTEM MODEL

The UAV-Based downlink NOMA network considered in Figure 1 is shown. It is assumed that there are 3 users in the network, and both UAV and users are assumed to be fixed. The UAV is equipped with two antennas to enable communication with the users on the ground. The analyses are made on two different situations, considering that the users are designed as one antenna and two antennas.

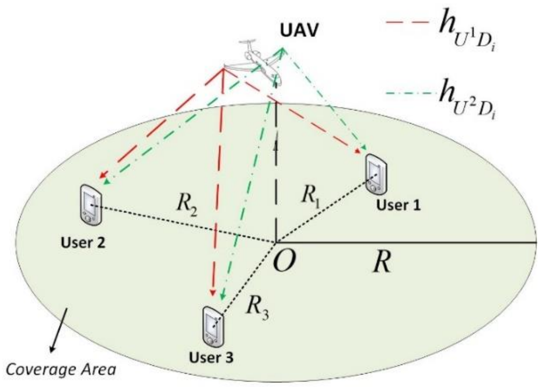

Figure 1. Proposed System model

In the system considered as shown in Figure 1, the UAV is thought to be at a height equal to the distance A from the ground and be stationary. It is also considered that the first, second, and third users' distances to the center of coverage (R_1, R_2, and R_3) do not change with time. It has also been assumed that the power distribution is homogeneous within the coverage area (shadowing effects ignored). Figure 1, the $h_{U^k D_i}$ shows the small scale flat fading channel coefficient expression between the kth transmitter antenna and the i'th user for $k \in \{1,2\}$ and $i \in \{1,2,3\}$. Considering the case that the users on the ground are designed with two antennas, $h_{U^k D_{iz}}$ is used to show the channel coefficients between the UAV and the users on the ground. In this expression, $z \in \{1,2\}$ denotes the antenna index for users. UAV uses the NOMA technique to communicate with users on the ground. In addition, it combines users' symbols and sends superimposed symbols to all users using the Alamouti Space-Time Block Coding method over two antennas [10].

While doing Downlink Aerial-Terrestrial link modeling, it is assumed that the signal received at the receiver on the ground contains three groups of components. These three components are LOS (direct incoming signals), NLOS (signals caused by strong reflections) signals that change probabilistically with environmental parameters. These components are called Large scale fading components. Also, small scale fading components, which cause multipath fading in high scattering environments, are components of the signal in the receiver [16-17]. In this study, the LOS and NLOS channel model, which is affected by environmental parameters, building density, the distance between the UAV and the receiver, and the elevation of the ground user, is considered as the large scale fading of the channels between the UAV and ground users. [18]. In Equation (1), the LOS connection possibility is given for the i'th user. X and Y values in this equation are parameters that change depending on environmental conditions [17]. θ_i shows the elevation angle for the i'th user. Therefore, $\theta_i = arctan\left(\frac{A}{R_i}\right)$ can be written. In addition, the NLOS connection probability for the i'th user can be defined as $P_r(NLOS)_i = 1 - P_r(LOS)_i$.

$$P_r(LOS)_i = \frac{1}{1+Xexp[-Y(\theta_i - X)]} \tag{1}$$

The LOS and NLOS connection model used after these definitions can be expressed as in (2).

$$F_i = \begin{cases} \frac{P_s}{2} d_{UM_i}^{-\varsigma} & LOS\ link \\ \zeta \frac{P_s}{2} d_{UM_i}^{-\varsigma} & NLOS\ link \end{cases} \tag{2}$$

In (2), F_i shows the PL caused by LOS and NLOS links. Here, P_s, ζ, ς ve d_{UM_i} terms represent respectively the total UAV transmitter power, the additional attenuation factor originating from the NLOS connection, the path loss exponent, and the distance between the UAV and the i'th user. For the sake of simplicity, in this study, the distance between any antenna of the UAV and the i'th user is considered the same. Here, it can be written as $d_{UM_i} = \sqrt{A^2 + R_i^2}$. According to these expressions, large scale fading for i'th user can be written (3).

$$PL_{tot,i} = \frac{P_s}{2} PL_i d_{UM_i}^{-\varsigma} \tag{3}$$

In order to reduce the complexity, $PL_i = P_r(LOS)_i + \zeta P_r(NLOS)_i$ is taken. Besides, in this study, it is assumed that the small scale flat fading channel coefficient $h_{U^k D_i}$ between the UAV and i'th user follows identical independent (i.i.d.) Rayleigh distribution.

As mentioned before, UAV sends users' data over two antennas using Alamouti Space-Time Block Coding technique together with the NOMA access technique. The Alamouti generator matrix is given in (4). The expressions s_1 and s_2 in this generator matrix represent superimposed symbols combined in UAV. Here, it can be expressed as $s_1 = \sum_{i=1}^{3} \sqrt{a_i P_s/2}\, x_{i1}$, $s_2 = \sum_{i=1}^{3} \sqrt{a_i P_s/2}\, x_{i2}$. Within the combined signal expressions, a_i indicates the power allocation parameter associated with the ith user. The x_{i1} and x_{i2} expressions denote the first and second symbols with unit energy for ith user, $(\,.\,)^*$ symbol represents a conjugate operator.

$$\boldsymbol{G} = \begin{bmatrix} s_1 & s_2 \\ -{s_2}^* & {s_1}^* \end{bmatrix} \tag{4}$$

Under the above assumptions, there are two-antennas at UAV and single-antenna users in the system, that is, considering the system as a 2x1-MISO system, the signal expressions received at the time $t = 1$ and $t = 2$ at the i'th user can be given as in (5)

$$\begin{bmatrix} r_{i1} \\ r_{i2} \end{bmatrix} = PL_{tot,i}\, \boldsymbol{G}\, [h_{U^1 D_i} \quad h_{U^2 D_i}]^T + [n_{i1} \quad n_{i2}]^T \tag{5}$$

where $[\,.\,]^T$ describes transpose of the matrix. n_{i1} and n_{i2} show zero mean Additive White Gaussian Noise (AWGN) at time $t = 1$ and $t = 2$ for i'th user respectively. Also, distribution is assumed as follows, $n_{i1} \sim CN(0, \sigma_1^2)$, $n_{i2} \sim CN(0, \sigma_2^2)$. For the sake of simplicity $\sigma_1^2 = \sigma_2^2 = \sigma^2$ is used in this form. For the network that uses 2x1-MISO A-STBC and NOMA techniques together in the system by extracting the antenna indexes, the equivalent noisy single input single output signal expression in the i'th user is shown in (6).

$$\tilde{\boldsymbol{r}}_i = PL_{tot,i}\, \boldsymbol{G} \left\| h_{UD_i} \right\|_F^2 + \tilde{\boldsymbol{n}}_i \tag{6}$$

The expressions $\|.\|_F$ and $\tilde{\boldsymbol{n}}_i$ in (6) show the Frobenius norm of the matrix and equivalent complex additive gaussian noise, respectively. Here $\tilde{\boldsymbol{n}}_i$ has distribution as $\tilde{\boldsymbol{n}}_i \sim CN\left(0, \left\| h_{UD_i} \right\|_F^2 \sigma^2\right)$ [19].

If it is assumed that the UAV and ground users in the system are designed with two antennas, the system is 2x2-MIMO, the received signal expressions of the i-th user can be given as in (7) [10].

$$\begin{bmatrix} r_{i1} & r_{i3} \\ r_{i2} & r_{i4} \end{bmatrix} = PL_{tot,i}\,\boldsymbol{G} \begin{bmatrix} h_{U^1D_{i1}} & h_{U^1D_{i2}} \\ h_{U^2D_{i1}} & h_{U^2D_{i2}} \end{bmatrix} + \begin{bmatrix} n_{i1} & n_{i3} \\ n_{i2} & n_{i4} \end{bmatrix} \quad (7)$$

In (7), r_{i1} and r_{i2} express the signal values received at the first and second antennas of the i*th* user respectively at the time $t = 1$, and the r_{i3} and r_{i4} expressions indicate the signal values received at the first and second antennas of the i*th* user respectively at the time $t = 2$. Likewise, n_{i1}, n_{i2}, n_{i3} and n_{i4} expressions are i.i.d complex zero mean Gaussian noise expressions in the *ith* user at times. For the sake of simplicity, it is assumed that all of them have the same mean and variance. The equivalent single input and single output signal expression of (7) can be written as in (6). As the channel matrix changes in (7), the PDF of the SNR in the receiver and the variance of Gaussian noise will also be changed in the system.

Since the system is considered as NOMA based network, the channel gains of the users play an important role. It is well known that, in the NOMA network, the transmitter allocates power to users in accordance with the channel gain parameters of the users. Also, the data of all users are superimposed on the transmitter part. Firstly, the superimposed signal is sent to all users. Then the user has low channel gain, that is, less power allocated, decodes the data of the users allocated more power, and then extracts these signals from the combined signal. Finally, it determines its data, if there is a less powerful signal, that is, if it is not the user with the best channel gain, it perceives those symbols as interference. This process is called the Successive Interference Cancellation (SIC) process, and all users on the network perform the SIC process according to their channel gains and allocated power. Besides, it is accepted that there is no error propagation while the users perform the SIC operation. This is called perfect SIC. Our Monte-Carlo simulations were performed for the perfect SIC case.

In this study, it is considered that the communication channels between UAV and users in the UAV-assisted NOMA-based network are feedback channels. Furthermore, it has been assumed that the channel coefficients of the communication channels between users and the UAV are perfectly estimated for the UAV to effectively allocate power to users. In other words, the channel gain parameters, which are perfectly estimated at the receiver, are sent to the UAV via feedback channels. UAV allocates power to each user according to these channel coefficients. We assume that users' channel gains are sorted in decreasing order, $\|h_{UD_1}\|_F^2 \leq \|h_{UD_2}\|_F^2 \leq \|h_{SU}\|_F^2$. Accordingly, the relationship between power parameters allocated to users by UAV is $\alpha_1 > \alpha_2 > \alpha_3$.

Under all these assumptions, Monte-Carlo simulations were performed and the performance of the proposed system was examined. For the benchmark, simulations have been conducted for the downlink NOMA network where the receivers and the UAV are designed with single antennas (S-A NOMA). Firstly, the performance of 2x1-MISO-NOMA and S-A NOMA networks were compared in order to examine the effects of A-STBC technique on the performance of the network. Afterward, the performances of the 2x1-MISO and 2x2-MIMO networks were compared, and the extra effects of the increase of diversity in the system on the performance as well as the use of the A-STBC technique were examined.

3. RESULTS AND DISCUSSIONS

In this section, Monte-Carlo simulation results of proposed system are presented. The parameters and values used in the simulations are given in Table 1. Firstly, the performance of the UAV-Assisted downlink NOMA-Based 2x1-MISO network using the A-STBC technique was compared with the case where there is no antenna diversity in the network (S-A NOMA). Then, the system considered as 2x1-MISO was compared with the performance of the second communication scenario, which is considered as 2x2-MIMO. Also, to better understand the effects of both the antenna diversity and the space-time block coding method on the performance in the UAV-Assisted downlink NOMA-Based network, simulation results are given for a fixed user (3rd user) for the situation where the UAV is at different heights. We should also say that the SNR expressions in the figures express the ratio of the power of the symbols of the users to the noise power in dB. A higher SNR value means that the UAV will send symbols with higher energy.

Figure 2, shows the BER curves of the traditional system (S-A NOMA) where there is no diversity in the receiver and transmitter and the 2x1-MISO communication system where UAV uses the A-STBC technique for communication. Here, it is seen that the use of the A-STBC technique provides considerably good SNR gain when looking at the same BER values compared to the conventional system. Especially at high SNR values, it has been observed that the SNR gain increases considerably for each user. It has also been observed that the diversity order has doubled.

Figure 3 shows the comparison of the performances of 2x1-MISO and 2x2-MIMO networks when the A-STBC technique is used for communication with each ground user. It is observed that antenna diversity in the receiver, especially at high SNR values, increases the diversity order of the system approximately 2 times compared to the diversity only transmitter side (2x1-MISO). Also, the 2x2-MIMO A-STBC system provides considerable SNR gain compared to the 2x1-MISO A-STBC system at high SNR values (especially for 2nd and 3rd users !).

Table 1. Simulation parameters.

Parameters	***Values***
Fixed Height of UAV $\boldsymbol{A}$	30 m
Variable Height of UAV $[\boldsymbol{A_1}, \boldsymbol{A_2}, \boldsymbol{A_3}]$	[60,80,120] m
Path Loss Exponent $\boldsymbol{\varepsilon}$	3
Additional Attenuation Factor $\boldsymbol{\zeta}$	20dB
Number of Users	3
Power Allocation Coefficient $[\boldsymbol{\alpha_1}, \boldsymbol{\alpha_2}, \boldsymbol{\alpha_3}]$	[0.7,0.2,0.1]
Coverage Radius $\boldsymbol{R}$	100 m
Distance Between Users and Center of Coverage Area $[\boldsymbol{R}_1, \boldsymbol{R_2}, \boldsymbol{R_3}]$	[70,35,20] m
Modulation Type	QPSK
Environment Parameter X	9.61
Environment Parameter Y	0.16

Figure 4 and Figure 5 show the performances of 2x1-MISO A-STBC/NOMA and S-A NOMA networks for situations where the UAV is at different heights. Figure 4 shows the performance of the third user for cases where the system is 2x1-MISO A-STBC/NOMA or S-A NOMA, and the UAV is 60-80 and 120 meters above the ground. By looking at the same BER value at high SNR values, using the A-STBC technique provide a very good SNR gain compared to the traditional system. Even if the height of the UAV is increased, it is seen that the communication scenario considered as 2x1-MISO A-STBC/NOMA gives better results than the scenario considered as S-A A-STBC/NOMA.

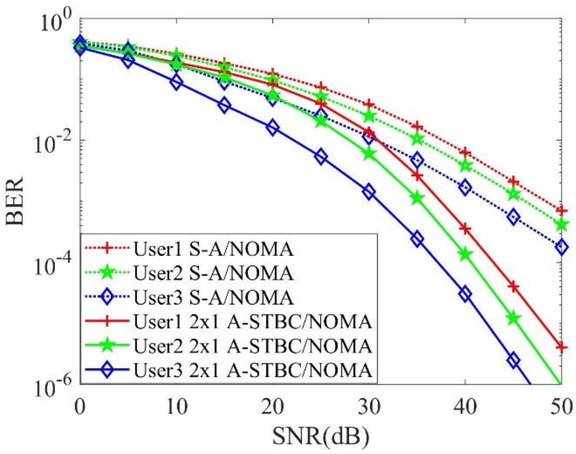

Figure 2. BER curves for S-A NOMA and 2x1-MISO A-STBC/NOMA cases for fixed height of UAV (30 m).

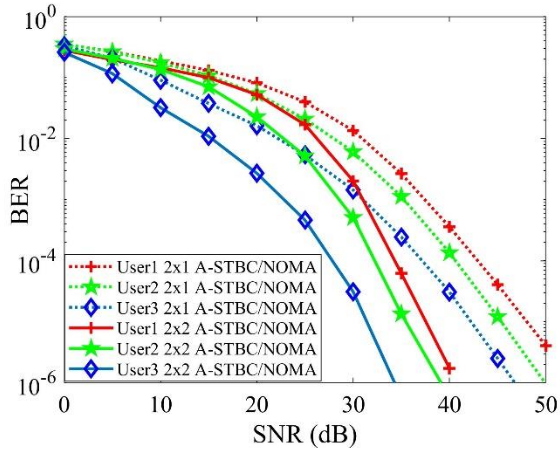

Figure 3. BER curves for 2x1-MISO and 2x2-MIMO A-STBC/NOMA cases for fixed height of UAV (30 m).

In Figure 5, the performances of the communication scenarios considered as 2x1-MISO and 2x2-MIMO A-STBC/NOMA are given for different height values for the UAV. Especially, the performance of the system, which is considered as 2x2-MIMO, improves considerably at high SNR values. In addition, even if the height of the UAV is increased, it is seen that the communication scenario considered as 2x2-MIMO A-STBC gives better results at high SNR values than the scenario considered as 2x1-MISO A-STBC. In other words, the use of the Alamouti Space-Time Block Coding technique to communicate in the UAV-Assisted downlink NOMA-Based communication network and increasing the antenna diversity minimizes the effects of disruptive factors such as path loss due to height on error performance. Besides, it has been observed that increasing the antenna diversity in the network along with the use of A-STBC further reduces the impacts of such disruptive factors on performance.

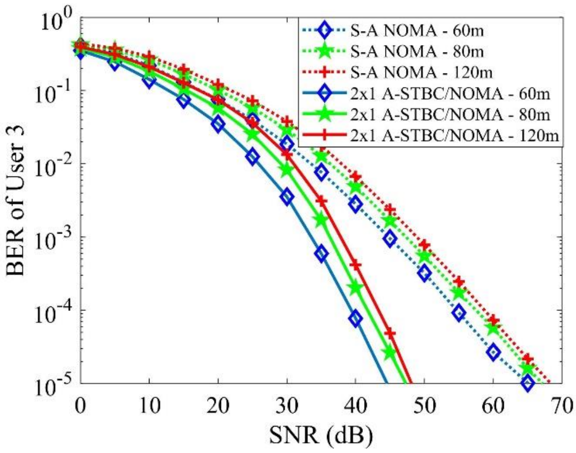

Figure 4. 3rd user's BER curves for S-A NOMA and 2x1-MISO A-STBC/NOMA cases at variable height of UAV.

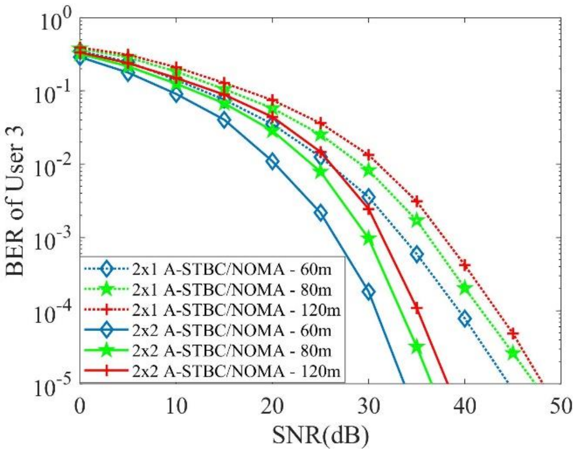

Figure 5. 3rd user's BER curves for 2x1-MISO and 2x2-MIMO A-STBC/NOMA cases at variable height of UAV.

Finally, in Figure 6, In order to better observe the SNR gains, all three scenarios are shown together for a fixed BER value reached by the 3rd user.

In order to better understand what the effects of the use of the A-STBC technique and increasing the antenna diversity will be on the error performance of the network, the SNR gain values reached by 3rd user, relative to S-A NOMA and fixed BER value, are given numerically in Table 2. As can be seen from Table 2 and Figure 2-6, increasing the diversity in the network and using the Space-Time Block Coding technique significantly improves the performance of the system.

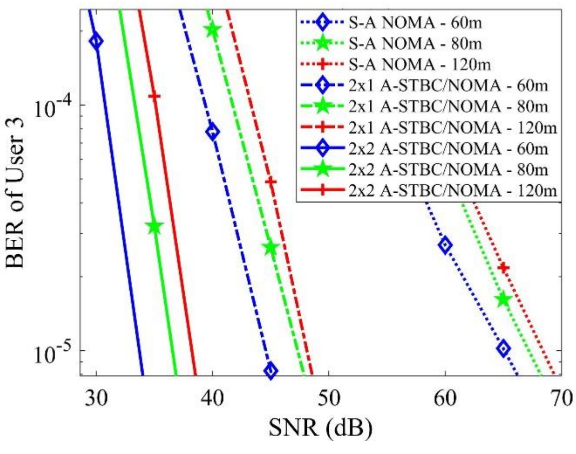

Figure 6. BER curves for all scenarios of the 3rd user at 10^{-5} BER.

4. CONCLUSIONS

In this study, performance analysis of a UAV-Assisted multi-antenna downlink NOMA network using A-STBC technique in two different scenarios was obtained by Monte-Carlo simulations. According to the simulation results, increasing the diversity and using the A-STBC coding technique in the system offers a very effective solution for destructive effects. When compared to the conventional system, the error performance for each user is significantly improved in both 2x1-MISO and 2x2-MIMO A-STBC systems at high SNR values. In this way, much lower BER values have achieved at lower SNR values (see Table 2). Here, a lower SNR value means sending lower energy symbols from UAV to ground users. As a result, considering the energy (battery)-size limitation of UAVs, it is expected to provide less energy consumption and increase the UAV's flying time. In addition, when looking at Table 2 and Figure 4-6, it is observed that the use of the A-STBC technique in the system, as well as the increase in diversity, minimizes the effect of disruptive factors such as path loss on performance. Also, looking at Table 2, it is observed that the proposed system model provides a very high SNR gain compared to the traditional system.

As a result, when both at the transmitter and receiver or only at the transmitter was increased diversity in a UAV-Assisted NOMA network, it is observed that the network improves the system in terms of performance when communication is provided using the A-STBC technique. Also, it has been observed that the use of the A-STBC technique in UAV-Assisted downlink NOMA-Based networks created minimizes the distorting effects of UAV on the performance in the network. In addition to all these gains, it has been observed that when the A-STBC technique is used in the system, the diversity order of the 2x1-MISO A-STBC/NOMA network is doubled compared to the traditional system. Also, the diversity order of the 2x2-MIMO A-STBC/NOMA network increases approximately four times compared to the S-A NOMA. This shows that full diversity gain can be achieved when the A-STBC technique is used in UAV-Assisted downlink NOMA-Based networks.

Table 2. Table of SNR gain values for the 3rd user in different height and communication scenarios relative to S-A NOMA at the 10^{-5} BER value.

Height of UAV	**S-A NOMA** (SNR values at 10^{-5})	**SNR gains relative to S-A NOMA**	
		2x1 A-STBC NOMA	2x2 A-STBC NOMA
60 m	65.55 dB	19.81 dB	31.16 dB
80 m	68.01 dB	19.52 dB	30.7 dB
120 m	69.81 dB	20.68 dB	30.86 dB

5. FUTURE WORKS

In this study, the effects of the use of the A-STBC technique and the increased diversity on the network were investigated via simulations. In order to perform a more detailed performance analysis of the use of the A-STBC technique in UAV-assisted downlink NOMA-based networks, detailed mathematical studies were planned under different communication channel designs.

DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and legal-special permission.

AUTHORS' CONTRIBUTIONS

Tayfun YILMAZ: Performed all simulations and analyze all results. Wrote the manuscript and directed the study.

Ahmet Aytug AYRANCI: Performed some simulations. Wrote the manuscript.

Emre BACANLI: Performed some simulations. Wrote the manuscript.

Hacı ILHAN: Performed some simulations. Wrote the manuscript and directed the study.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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