Tikrit Journal of Engineering Sciences (2023) 30 (4): 102-117
DOI: http://doi.org/10.25130/tjes.30.4.11

IRAQI Academic Scientific Journals

College of Engineering

ISSN: 1813-162X (Print); 2312-7589 (Online)

Tikrit Journal of Engineering Sciences

available online at: http://www.tj-es.com

TJES Tikrit Journal of Engineering Sciences

Performance Analysis of Cooperative NOMA for Different Power Allocation Strategies

Shatha Hellan Saeed*, *Ibrahim Khalil Sileh*

Electrical Department, Engineering College, Tikrit University, Tikrit, Iraq.

Keywords:

AF; C-NOMA; Fixed; Fractional; Generalized.

ARTICLE INFO

Article history:

Received	09 June	2023
Received in revised form	30 July	2023
Accepted	15 Aug.	2023
Final Proofreading	19 Nov.	2023
Available online	01 Dec.	2023

Citation: Saeed SH, Sileh IK. **Performance Analysis of Cooperative NOMA for Different Power Allocation Strategies**. *Tikrit Journal of Engineering Sciences* 2023; **30**(4): 102-117.
http://doi.org/10.25130/tjes.30.4.11

Corresponding author:

Ibrahim Khalil Sileh

Electrical Department, Engineering College, Tikrit University, Tikrit, Iraq.

Abstract: Cooperative None Orthogonal Multiple Access (C-NOMA) is a promising approach for 5G and beyond communication networks. Users will benefit from the full bandwidth of the channel without time constraints. NOMA's features are incomplete without efficient power allocation that ensures power distribution among users fairly. Integrating power management (allocation) with Cooperative-NOMA (C-NOMA) may improve the system metrics. In addition, a physical layer security (PLS) is added to make the process of sending and receiving safe, and the system works in an integrated manner, preventing any interrupting or eavesdropping inside or outside the network. This paper demonstrates the user and channel performance of C-NOMA with Amplify-and-forward (AF) and Decode-and-forward (DF) approaches. The analysis is performed by varying the power allocation techniques to derive the best system configurations. The simulation results confirmed the analytic findings and showed that the proposed system outperforms orthogonal multiple access (OMA), conventional NOMA, and conventional cooperative NOMA, enhancing the performance metrics in terms of throughput, sum rate, and outage probability. The bit-error-rate (BER) of the far user can be identical to that of the near user if power allocation is properly set. All techniques excelled except for the fixed power allocation, which had the same BER. The Channel capacity and outage probability were also considered. A slight variation in the channel capacity in all the experiments for different numbers of users was found. The generalized power allocation for AF and DF models had the optimum channel capacity close to 14 bps/Hz. Moreover, far users always had a higher outage probability than near users and channels, and generalized power allocation was the highest outage probability technique when the transmit power was close to (4 dB).

تحليل الاداء للإرسال المتعدد غير المتعامد التعاوني للاستراتيجيات المختلفة لتخصيص الطاقة

شذى هيلان سعيد، ابراهيم خليل صالح
قسم الهندسة الكهربائية، كلية الهندسة، جامعة تكريت، تكريت-العراق.

الخلاصة
يعد الوصول المتعدد غير المتعامد التعاوني (C-NOMA) نهجا واعدا لشبكة الاتصالات في الجيل الخامس وما بعدها. سيستفيد المستخدم من النطاق الترددي بشكل كامل دون التقيد بقيود زمنية. لا تكتمل ميزات NOMAبدون تخصيص فعال للطاقة يضمن توزيع الطاقة بين المستخدمين بشكل عادل. تندمج تخصيص الطاقة مع (C-NOMA)يقوم بتحسين معاملات النظام. فضلا عن ذلك , تمت إضافة طبقة الامان المادية لجعل عملية الارسال والاستلام امنة وعمل النظام بطريقة متكاملة ومنع اي مقاطعة او تنصت داخل الشبكة او خارجها . يوضح هذا البحث اداء المستخدم والقناة في CNOMA باستخدام نهج التضخيم واعادة الارسال (Amplify and forward) ونهج فك التشفير واعادة الارسال (Decode and forward). ويتم اجراء التحليل من خلال تغيير تقنيات تخصيص القدرة لاشتقاق أفضل تكوينات النظام. نتائج المحاكاة تؤكد النتائج التحليلية وتبين ان النظام المقترح يتفوق على الوصول المتعدد المتعامد (OMA) ونظام (NOMA) التقليدي وانظمة (NOMA) التعاونية التقليدية وعززت مقاييس الاداء من حيث الانتاجية ومعدل البيانات واحتمال الانقطاع. معدل خطأ البيانات (BER) للمستخدمين البعيدين يمكن ان يكون متطابقا مع ذلك في المستخدم القريب اذا كان هناك تخصيص قدرة بشكل صحيح وملائم وامتازت جميع التقنيات باستثناء تقنية توزيع القدرة الثابت لها نفس معدل الخطأ في البتات (BER) وتم دراسة سعة القناة واحتمالية الانقطاع بشكل صحيح ووجد أن هناك اختلاف طفيف في سعة القناة في جميع التقنيات لعدد من المستخدمين حيث امتازت تقنية التوزيع المعمم بأن لها اكبر سعة قناة تقترب من ١٤ بت في الثانية /هرتز في كل من بروتوكولات AF /DF. هناك احتمالية انقطاع للمستخدمين البعيدين رائدة عن قرب المستخدمين والقناة، ويمكن القول أن تخصيص الطاقة المعمم له احتمالية الانقطاع الأعلى عندما تقترب قدرة الارسال المخصصة الى ٤ ديسي بيل.

الكلمات الدالة: برتوكول التضخيم واعادة الارسال، الوصول المتعدد غير المتعامد التعاوني، الثابتة، التفاضلية، المعممة.

1.INTRODUCTION

Fifth-generation (5G) networks have attracted numerous studies and significant development in response to the recent exponential rise of mobile data traffic over gradually constrained capacity and spectrum [1]. The need for dependable, high-speed data transfer has increased dramatically in recent years, making the development of a quick and spectrally efficient wireless communication system necessary [2]. To overcome these limitations, NOMA has recently been proposed [3, 4] as a potential solution for significant performance improvement and effective spectrum usage. Contrary to orthogonal multiple access (OMA) systems, which only support users in the designated spectrum resources, NOMA techniques support an undetermined quantity of users throughout the same spectrum, time, and frequency resources over a single wireless channel [5, 6]. NOMA's performance can be greatly enhanced [7], providing greater spectrum efficiency than alternative OMA methods by carefully choosing user data rates and power allocations. Non-orthogonal multiple access is in contrast with (OMA). For users with various channel conditions, NOMA offers a more favorable trade-off between system throughput and fairness. Cooperative communications have benefited from the NOMA use since it essentially increases the base station's coverage area while reducing the likelihood of interruptions and achieving diversity gain without using additional antennas [8]. The NOMA systems usage in concert with cooperative tactics to boost performance is even more intriguing. Vaezi et al. [9] and Dai et al. [10], the user with strong channel conditions acts as a cooperative relay relaying signals to users with poor channel conditions, promoting fairness in signal distribution. Ding [11] and Liu [12] focused on various relay selection methods while discussing the relay selection results. Ahmed et al. [13] and Ali et al. [14] investigated the AF relay performance during a cooperative NOMA downlink interruption. Two well-known cooperative relaying algorithms, amplify forward (AF) and decode forward (DF), were examined for the relaying networks in [15, 16]. Ding et al. [17] found that the cooperative NOMA plan offered advantages over the OMA system. The information-carrying signal faces security challenges because the open and broadcasting nature of wireless communication severely undermines the requirement for security [18, 19]. A hostile person, i.e., eavesdroppers and jammers, can easily exploit and manipulate wireless data sent between authorized users because anyone within hearing range can listen in and perhaps get information [20]. The main critical challenges of the Internet of Things (IoT) are security and protection. Several methods have been applied to protect the IoT [21]. Up until recently, wireless communications were protected using cryptographic techniques. The effectiveness of these methods depends on how computationally complex they are; however, as technology and computer power advance, decrypting encrypted messages becomes simpler. The addition of physical layer security (PLS) offers a more advanced approach that goes above and beyond [22, 23]. PLS tries to take advantage of the random noise present in the communication channels to prevent eavesdroppers from intercepting messages that are provided without using an encryption technique. Based on the secrecy capacity, which explains the distinction between the wiretap channel's and the intended channel's capacities. PLS is still practical at bigger volumes since eavesdroppers cannot tell what data is being sent [24]. Cooperative NOMA PLS investigations are still uncommon because most references concentrate on PLS based on the NOMA system [25]. PLS security in a single-input single-output (SISO) system was examined by [26]. Transmitted power was examined to satisfy users' quality of service requirements in a NOMA network with one transmitter, numerous users, and one eavesdropper. To gain an optimal power distribution scheme, the suggested method's secret total rate was enhanced. PLS of NOMA transmission has been investigated in large-scale networks with an eavesdropper and one source linking to several randomly distributed consumers [13]. The user pair technique and the outage probability were used to examine secrecy performance and diversity. The numerical outcomes demonstrate that changing the protected zone or the user zone can enhance secrecy performance [14], which was expanded on in this work, carried out trials with a single antenna under various conditions. According to the analytical findings, a user with bad channel conditions can regulate the secrecy diversity in a situation with a single antenna. The secrecy outage probability study for the multiple-antenna scenario shows that the transmit antenna count has no effect on the eavesdropper channel condition. Do and Nguyen [27], a novel downlink cooperative communication technique that combines NOMA with AF relaying at the relay is chosen to help the BS educate the NOMA users. As numerical findings show, the outage probability of both strong and weak users is reduced due to the proposed strategies. Kaba [28] proposed a fractional power allocation for NOMA downlink and uplink. The simulation results showed that the outage probability, BER, and sum-rate capacity depend on the user channel gain and fractional power allocation of total power to the user; in downlink NOMA decoding of the weaker user first is optimum and in uplink NOMA decoding of the stronger user first is improved outage probability and BER. Lv and Ji [29] proposed a power allocation strategy to enhance the networks' performance in secrecy outages and used Monte Carlo simulations to confirm the studies. The simulation results showed the security advantages of using the MCC and ST schemes to prevent eavesdropping, which benefited the practical CR-NOMA systems design with TAS. Demand for wireless communication may need to deliver as much as 1000 times the capacity relative to current levels. Meeting this demand is a challenging task. Since conventional frequencies, such as microwaves, are insufficient. A new problem with data transmission has arisen due to the development of computers and data technology. Recently, Cooperative- NOMA has been proposed as an emerging remedy for significant performance improvement and effective spectrum utilization in specifically allotted spectrum resources. The choice of users' data rates and power management considerably impacted the NOMA's performance, which increased spectral efficiency and data rate compared to previous OMA methods. This aim is not done properly until proper management allocates capacity effectively. This work differs from earlier works that used the AF/DF protocol to check all metrics represented by BER, outage probability, and channel capacity using different power allocation methods; such as Fixed power allocation (FPA), Generalized power allocation (GPA), Water Filling power allocation (WFPA), and Fractional power allocation (FRPA); and find the best system configuration to be optimal allocate power to the users in different nodes number and distance from the base station with algorithm of protection to share secret keys efficiently between the sender and the users. This paper is organized as follows: Section 2 discusses the proposed system model. Section 3 presents the performance metrics. Sections 4 and 5 conclude the discussion of the results.

2. MODEL ESTABLISHMENT

To evaluate the cooperative NOMA performance in wireless communication, numerous metrics, i.e., bit-error-rate (BER), outage probability (P_{out}), and channel capacity, were studied under varying channel environments using MATLAB 2018 software. Two models were established with two and three nodes Fig. 1. It is worth noticing that all nodes/users in both proposed scenarios are unequally placed from the base station and unequally in the power transmits value. To study the different power allocation techniques' impact on the cooperative NOMA system, the following techniques were selected: Fixed, Fractional (FR), Generalized (GL), and Water falling (WF). Thus, the NOMA approach is applied for each power allocation type, Amplify-and-forward (AF) and Decode-and-forward (DF). First, in AF-Cooperative NOMA, the relay node, upon reception of the transmitter's data, amplifies the signal and retransmit it to the next destination node. On the other hand, DF-Cooperative NOMA decodes the signal/data upon reception and retransmits it to the destination as non-encrypted data. The cooperative approaches, i.e., AF and DF, will be applied in each power allocation scheme. The configurations of those topologies are illustrated in Table 1.

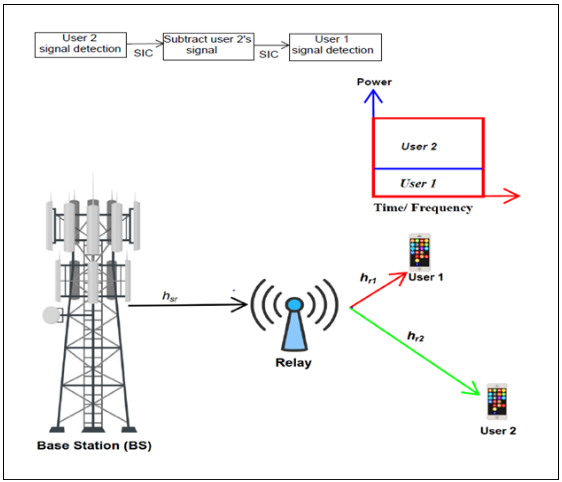

Fig.1 Co-NOMA Proposed Topologies with PLS.

Table 1 Model Configurations.

Particle	Details
Number of nodes	(2), (3)
Nodes placing from base station (scenario 1)	1000 m, 500 m
Nodes placing from BS(2)	1000 m, 400m and 500
The value of power allocated For near and far users	In FPA near user 0,35 Far user 0,65, the rest calculated by power equations
Power allocation	Fixed, FR, GL, WF
Cooperative schemes	AF, DF
Channel condition	AWGN +Rayleigh Fading.
Modulation	BPSK
SNR	(0-30 dB)

3. PERFORMANCE METRICS

3.1.BER

The most widely used performance statistic in a communication system is the Bit Error Rate (BER). In a communication system, information is conveyed as bits. During the communication procedure, bit mistakes happen. The average rate at which these bit mistakes occur during communication is known as BER [30]:

$$\text{BER}=\frac{number\ of\ error\ bits}{Total\ number\ of\ transmitted\ \ bits} \tag{1}$$

3.2.SNR

The ratio of the received signal strength to the unwanted signal strength within a frequency band is known as the signal-to-noise ratio. As long as this ratio is acceptable, the signal can be filtered to remove noise.

$$\text{SNR}=10\log_{10}\frac{signal\ power}{noise\ power}\ \text{dB} \tag{2}$$

3.3.Channel Capacity

The maximum speed at which data can be transmitted across a channel is

$$\text{Channel capacity }=\text{B}\log_2(1+SNR) \tag{3}$$

where **B** is bandwidth in Hz.

3.4.Outage Probability

The Outage probability is the probability that the information rate is less than the required threshold information rate. It is the probability that an outage will occur within a specified period. The Outage probability= 1- P_r ($\gamma_n > \gamma_{th}$) and SNR threshold $\gamma_{th1}=2^{2R_1}-1$, and $R_1=\frac{P_1}{P_2}$.

where $\gamma_n and\ \gamma_{th}$ are the received SNR and the threshold SNR, respectively.

For DF- NOMA

the superposition coded NOMA signal communicated by the BS is

$$\text{X}=\sqrt{P}(\sqrt{\alpha_1}\ \ x_1+\sqrt{\alpha_2}\ \ x_2) \tag{4}$$

where P is the total power, α_1 and α_2 are the power coefficient for U1 and U2, respectively. $x_{(1,2)}$ is the individual information of each user. At user 1, the received signal is calculated as below:

$$Y_1=h_1\text{X}+w_1$$
$$Y_1=h_1\sqrt{P}\sqrt{\alpha_1}\,x_1+h_1\sqrt{P}\sqrt{\alpha_2}\,x_2+w_1 \tag{5}$$

where h_1 is the channel fading between the relay and the U1. The signal to noise ratio for the user 1.

$$\gamma_1=\frac{|h_1|^2\ P\ \alpha_1}{|h_1|^2P\ \alpha_2+\sigma^2} \tag{6}$$

and its achievable capacity rate is

$$R_1=\log_2(1+\gamma_1)=\log_2(1+\frac{|h_1|^2\ P\ \alpha_1}{|h_1|^2P\ \alpha_2+\sigma^2}) \tag{7}$$

The outage probability for user 1 occurs when

$$\gamma_1>\gamma_{th1}$$

R_1 unity without noise $R_1=\frac{P_1}{P_2}$

SNR threshold $\gamma_{th1}=2^{2R_1}-1$

$$OP_1=1-\Pr(\gamma_1>\gamma_{th1})=1-P_r(\frac{|h_1|^2\ P\ \alpha_1}{|h_1|^2P\ \alpha_2+\sigma^2}>\gamma_{th1}) \tag{8}$$

Similarly, the X copy received at the far user after propagating through channel h_2 is:

$$Y_2=h_2\ \text{X}+w_2$$
$$=h_2\sqrt{P}\sqrt{\alpha_1}\ \ x_1+h_2\sqrt{P}\sqrt{\alpha_2}\ \ x_2+w_2 \tag{9}$$

where h_2 is the channel fading between the relay and the U2. The signal to noise ratio at user 2 for decoding the user 1 signal (before SIC) is:

$$\gamma_{1,2}=\frac{|h_2|^2P\ \alpha_1}{|h_2|^2P\ \alpha_2+\sigma^2} \tag{10}$$

and its achievable capacity rate is:

$$R_{1,2}=\log_2(1+\gamma_{1,2})=\log_2(1+\frac{|h_2|^2P\ \alpha_1}{|h_2|^2P\ \alpha_2+\sigma^2}) \tag{11}$$

after canceling the user 1's signal using SIC, the signal to noise ratio at user 2 for decoding its own signal is:

$$\gamma_2=\frac{|h_2|^2\ P\ \alpha_2}{\sigma^2} \tag{12}$$

and its achievable capacity rate is:

$$R_2=\log_2(1+\frac{|h_2|^2P\ \alpha_2}{\sigma^2}) \tag{13}$$

The outage probability of user 2 occurs when $\gamma_2>\gamma_{th2}$,

$\gamma_{th2}=2^{2R_2}-1$,When $R_2=\frac{\rho_2}{\rho_1}$

$$OP_2 = 1\text{-}\ P_r\ (\gamma_2\ > \gamma_{th2}) = 1\text{-}\ p_r\ \left(\frac{|h_2|^2\ P\ \alpha_2}{\sigma^2}\ > \gamma_{th2}\right) \quad \textbf{(14)}$$

For AF- NOMA

$R_{relay}=h_{sr}(\sqrt{\alpha_1 . P} x_1+\sqrt{\alpha_2 . P}\ x_2)+ w_r$ (first time slot) this is called direct decoding and will be neglected.

$\alpha_1 + \alpha_2 = 1$, $\alpha_2 > \alpha_1$

Amplify factor $\beta = \frac{1}{\sqrt{p_r|h_r|^2+\sigma^2}}$

In second time slots after relay amplifies the signal and forward it to the destination. The received signal at user 1:

$$Y_1\ = \beta\ \sqrt{P}[h_1(\sqrt{\alpha_1}\ x_1+\sqrt{\alpha_2}\ x_2]+w_1$$

$$Y_1\ = \beta h_1\sqrt{p\alpha_1}\ x_1+ \beta h_2\sqrt{p\alpha_2}x_2+w_1 \quad \textbf{(15)}$$

The received signal at user 2:

$$Y_2 = \beta\sqrt{P}[h_2(\sqrt{\alpha_1}\ x_1+\sqrt{\alpha_2}\ x_2)\ ]+w_2$$

$$Y_2= \beta h_2\sqrt{p\alpha_2}\ x_1+\beta h_2\sqrt{p\alpha_2}x_2\ +w_2 \quad \textbf{(16)}$$

$$\gamma_1\ = \frac{\beta^2|h_1|^2p\ \alpha_1}{\beta^2|h_2|^2p\alpha_2+\sigma^2}\ ,\ \gamma_{1,2}=\frac{\beta^2|h_2|^2\ p\alpha_1}{\beta^2|h_2|^2p\alpha_2+\sigma^2}\ ,\ \gamma_2=\frac{\beta^2|h_2|^2p\ \alpha_2}{\sigma^2} \quad \textbf{(17)}$$

Achievable rate:

$$R_1\ = \log_2(\ 1 + \gamma_1) = \log_2(\ 1 + \frac{\beta^2|h_1|^2p\ \alpha_1}{\beta^2|h_2|^2p\alpha_2+\sigma^2}) \quad \textbf{(18)}$$

$$R_{1,2} = \log_2(\ 1 + \gamma_{1,2}) = \log_2(\ 1 + \frac{\beta^2|h_2|^2\ p\alpha_1}{\beta^2|h_2|^2p\alpha_2+\sigma^2}) \quad \textbf{(19)}$$

$$R_2\ =\ \log_2(1 +\ \gamma_2) =\ \log_2(\ 1 + \frac{\beta^2|h_2|^2p\ \alpha_2}{\sigma^2}) \quad \textbf{(20)}$$

SNR threshold $\gamma_{th1}= 2^{2R_1} - 1$, and $\gamma_{th2} =2^{2R_2} - 1$

The outage probability of U_1 occurs when $\gamma_1\ > \gamma_{th1}$

$$O_{P1} = 1\text{-}\ P_r\ (\gamma_1\ \geq\ \gamma_{th1})$$

$$O_{p1} = 1\text{-}\ p_r\ [\frac{\beta^2\alpha_1\rho^2|h_1|^2}{\alpha_2\rho^2|h_1|^2\ \beta^2+1} \geq \gamma_{th1}] \quad \textbf{(21)}$$

The outage probability of user 2 occurs when $\gamma_2 > \gamma_{th2}$

$O_{P2} = 1\text{-}\ P_r(J_1, J_2)$

where $J_1\ = \frac{\beta^2\alpha_1\rho^2|h_1|^2}{\beta^2\rho^2|h_1|^2\alpha_2+1} \geq \gamma_{th1}$, $J_2 = \frac{\beta^2\alpha_1\rho^2|h_2|^2}{\beta^2p^2\alpha_2|h_2|^2+1} \geq \gamma_{th2}$

The total equation is :

$$O_{P2}=1\text{-}P_r\ (\frac{\beta^2\alpha_1\rho^2|h_2|^2}{\beta^2p^2\alpha_2|h_2|^2+1} \geq \gamma_{th2}\ ,\frac{\beta^2\alpha_1\rho^2|h_1|^2}{\beta^2\rho^2|h_1|^2\alpha_2+1} \geq \gamma_{th1}) \quad \textbf{(22)}$$

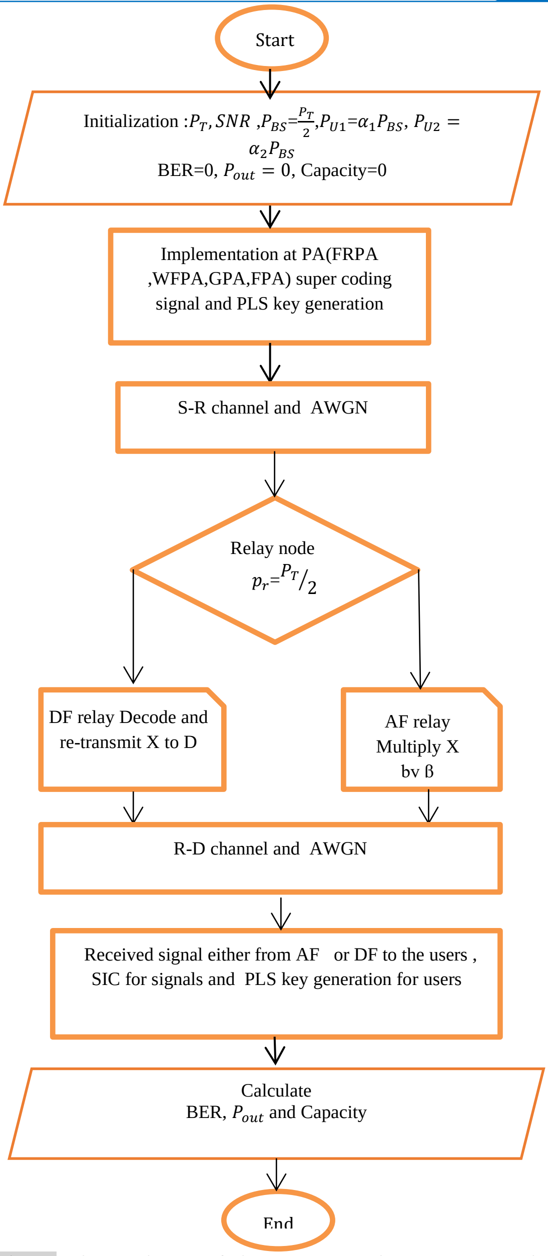

Fig.2 Flow Chart of the Proposed System Model.

4. RESULTS AND DISCUSSION

4.1.AF- NOMA

In this section, the amplify-and-forward cooperative NOMA performance is discussed. Three performance metrics were extracted, i.e., bit-error rate, channel capacity, and outage probability. The metrics were analyzed with the proposed power allocation techniques, as demonstrated below.

4.1.1.Fixed Power Allocation

In fixed power allocation, the system performance is realized when a different number of nodes are deployed. The BER for the two-node system was 0.05 and reduced as SNR increased. Thus, with a three-node system, it is realized that the far user had the highest BER as transmit power increased. The near user maintained the lowest BER as the transmit power increased due to fixed power allocation allotted a maximum portion of power for the far user. The remaining amount of power was shared between the middle and near users. Therefore, the middle user placed in the mid-point received more power than the near user to maintain variation between users' power so that particular user's data can be successfully decoded, see Fig. 3 (a) and (b). On the other hand, channel quality was also studied by monitoring two metrics, i.e., channel capacity and outage probability. The channel capacity increased with the transmit power. The same is valid with all users. The far user's channel capacity was the peak, and the mid and far users had lower channel capacities. As three users existed, the channel capacity increased as more power was required to transmit three users; hence, the channel capacity dropped for all users if the transmitted power increased above 57 dB m, see Fig. 3 (c) and (d). Eventually, the outage probability represents the probability that the far users fall into was out of coverage area. For the two-node system, the far user had a higher outage probability than the near user. So, in the case of the three-node system, comparing mid and far users' outage probability, the far user also had a higher outage probability than the middle user, see Fig. 3 (d) and (e).

4.1.2.Fractional Power Allocation

In fractional power allocation, the BER for a two-node system decreased when SNR increased. The far user had the highest BER, while the near user had the lowest. It is realized that in this kind of power allocation, the nodes/users drew evenly distributed BER values, which means both users had almost similar behaviors in combating the noise. In the three-node system, the far user had its most significant portion of the power, followed by the mid and near users, see Fig. 4 (a) and (b). For low transmitted power, e.g., (0-5dB), the channel capacity of the mid-user increased to its peak. The channel capacity was relatively lower than the fixed power allocation scenario, see Fig. 4 (c) and (d). Both users had almost similar outage probability when the transmitted power was 40 dB m. The three nodes system drew similar behaviors, however, with outage probability at higher transmitted power than the system of two users, see Fig. 4 (d) and (e).

4.1.3.Generalized Power Allocation

The BER was found for the two-node system. Both nodes drew similar behaviors when noise increased, which is, in this case, both near and far users almost having similar BER with respect to the SNR values. The power of users was slightly lower than the corresponding in previous scenarios, see Fig. 5 (a) and (b). The channel capacity maximized in this case, i.e., 14 bps/Hz. However, the channel capacity dropped at higher transmitted power, i.e., 70 dB m, see Fig. 5 (c) and (d). The far users (for the two-node system) and mid and far users (for the three-node system) drew higher outage probability than the near user at higher transmitted power. Notably, the far user's outage probability was more significant than the close and middle users, see Fig. 5 (e) and (f).

4.1.4.Water Falling Power Allocation

The BER curves for near and far users are almost identical, meaning that in this scenario, both users almost responded to the noise. The power of the far user was slightly maximized at this stage, which can be observed in the three nodes system, note Fig. 6 (a) and (b). The channel capacity was maximized at 14 bps/Hz. However, the channel capacity dropped at higher transmitted power, i.e., 70 dB m, as shown in Fig. 6 (c) and (d). Both near and far users (for two nodes system) and mid and far users (for three nodes system) drew high outage probability at higher transmitted power, i.e., 40 dB m and 65 dB m for two nodes and three nodes system, respectively, see Fig. 6 (e) and (f).

4.2.DF-NOMA

4.2.1.Fixed Power Allocation

The BER for close and remote users was refined compared to AF-Fixed-NOMA. Also, it was found that the near user BER was refined to have a closer value to the far and mid users, see Fig. 7 (a) and (b). The Channel capacity for the two-node system was slightly lower here, and for the three-node system, it was higher than the AF-Fixed-NOMA scenario, see Fig. 7 (c) and (d). The outage probability for the two-node system was higher with the far user and lower with the near user. While in the three-node system, the mid-user had a lower outage probability even when the transmitted power increased, see Fig. 7 (e) and (f).

4.2.2.Fractional Power Allocation

The BER for close and remote users differed from the AF-Fractional-NOMA case. The BER was generally higher than that in AF-Fractional-NOMA; the BER of the near user was almost close to the BER of the mid-user, see Fig. 8 (a) and (b). The channel capacity was lower than AF-Fractional-NOMA, see Fig. 8 (c) and (d). The outage probability of the far user was more significant than that of the near user. Similarly, in the three-node system, the far user showed higher outage probability than the mid user, see Fig. 8 (e) and (f).

4.2.3.Generalized Power Allocation

The BER of both near and far users had closer values, implying that both users had similar behaviors to noise. On the other hand, The BER of near, mid, and far users showed up to 5 dB m of transmitted power, note Fig. 9 (a) and (b). The channel capacity in this case was higher than that in AF-Generalized-NOMA appearing in both two-node and three-node systems, as shown in Fig. 9 (c) and (d). There was a considerable difference between the outage probability of the near and far users, which was very high in the two-node system. On the other hand, the outage probability of the far user was slightly higher than the mid-user. Both values were identical at 56 dB m of transmitted power, see Fig. 9 (e) and (f).

4.2.4. Water Falling Power Allocation

The BER of the far user led that of the near user up to 12 dB SNR, and both were identical in high SNR for the two-node system. For the three-node system, the BER was almost identical for near, far, and mid users, see Fig. 10 (a) and (b). The channel capacity in this case was almost similar to that in FA-Generalized-NOMA appearing in both two-node and three-node systems, as shown in Fig.10 (c) and (d). The outage probability of the far user was higher than that of the near user in the two-node system. However, in the three-node system, the mid-user outage probability decreased beyond the transmitted power of 52 dB m, see Fig. 10 (e) and (f).

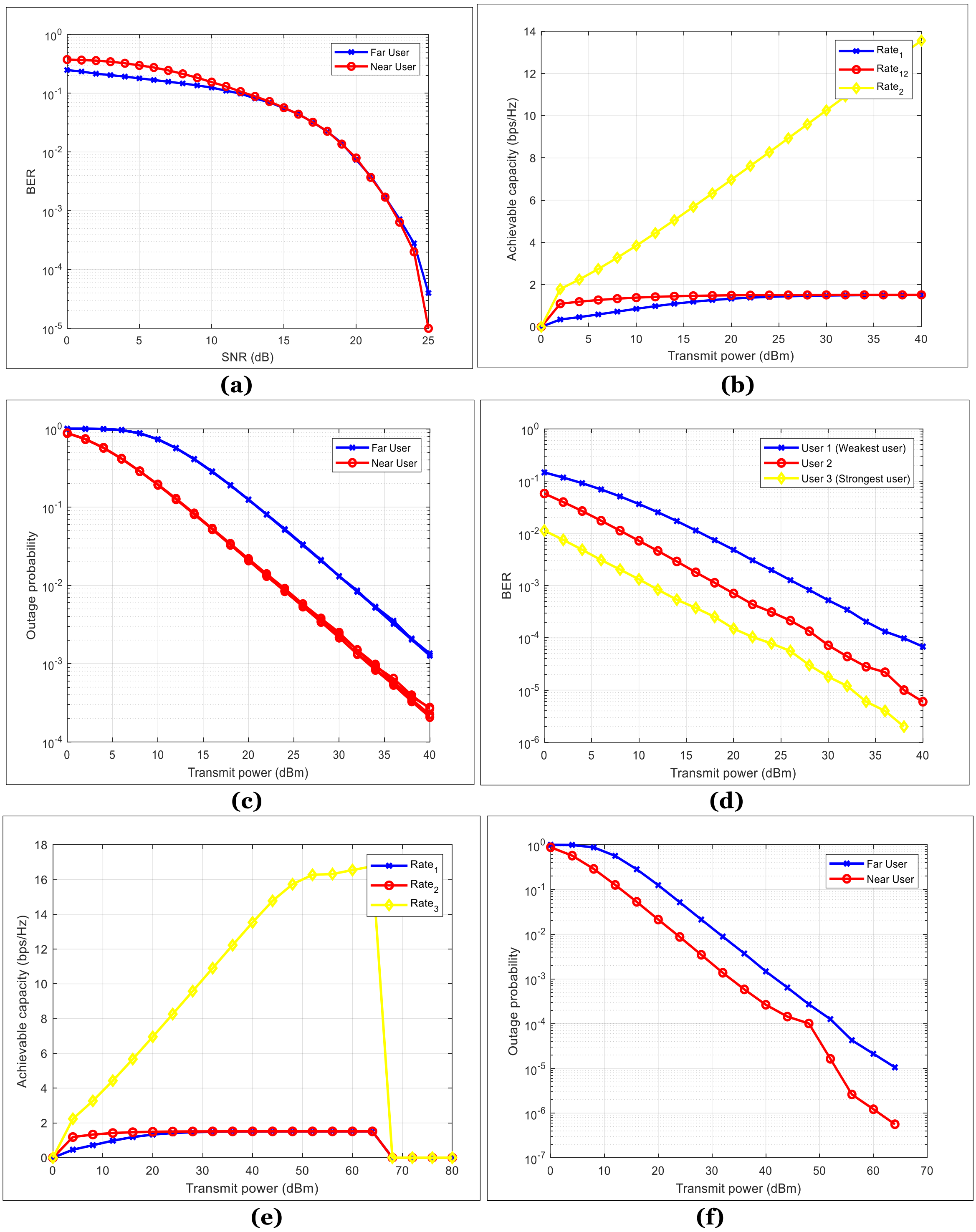

Fig.3 AF-Fixed-NOMA Two Nodes (a, c, and e) and Three Nodes (b, d, and f) System Performance.

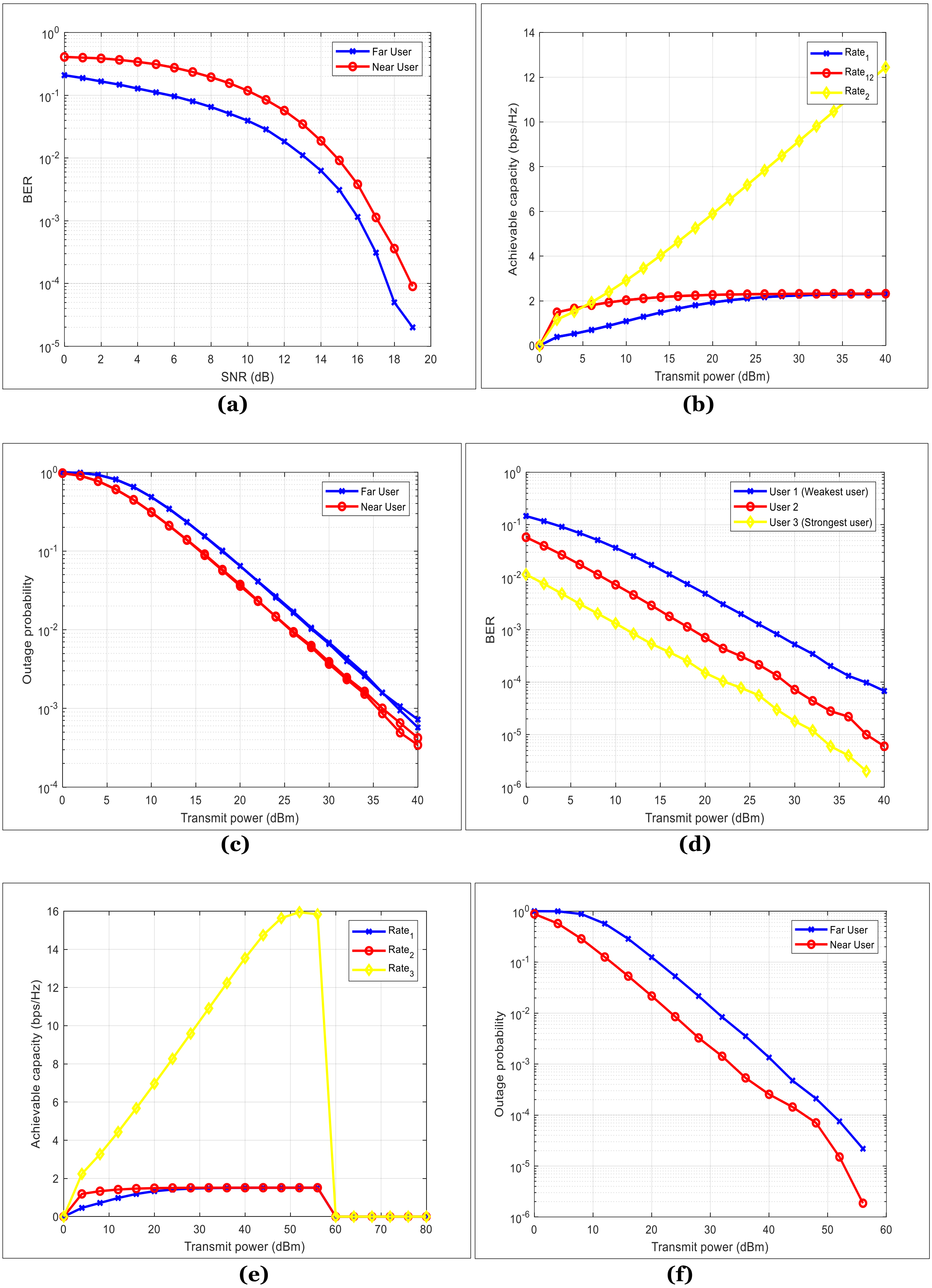

Fig. 4 AF-Fractional-NOMA Two Nodes (a, c, and e) and Three Nodes (b, d, and f) System Performance.

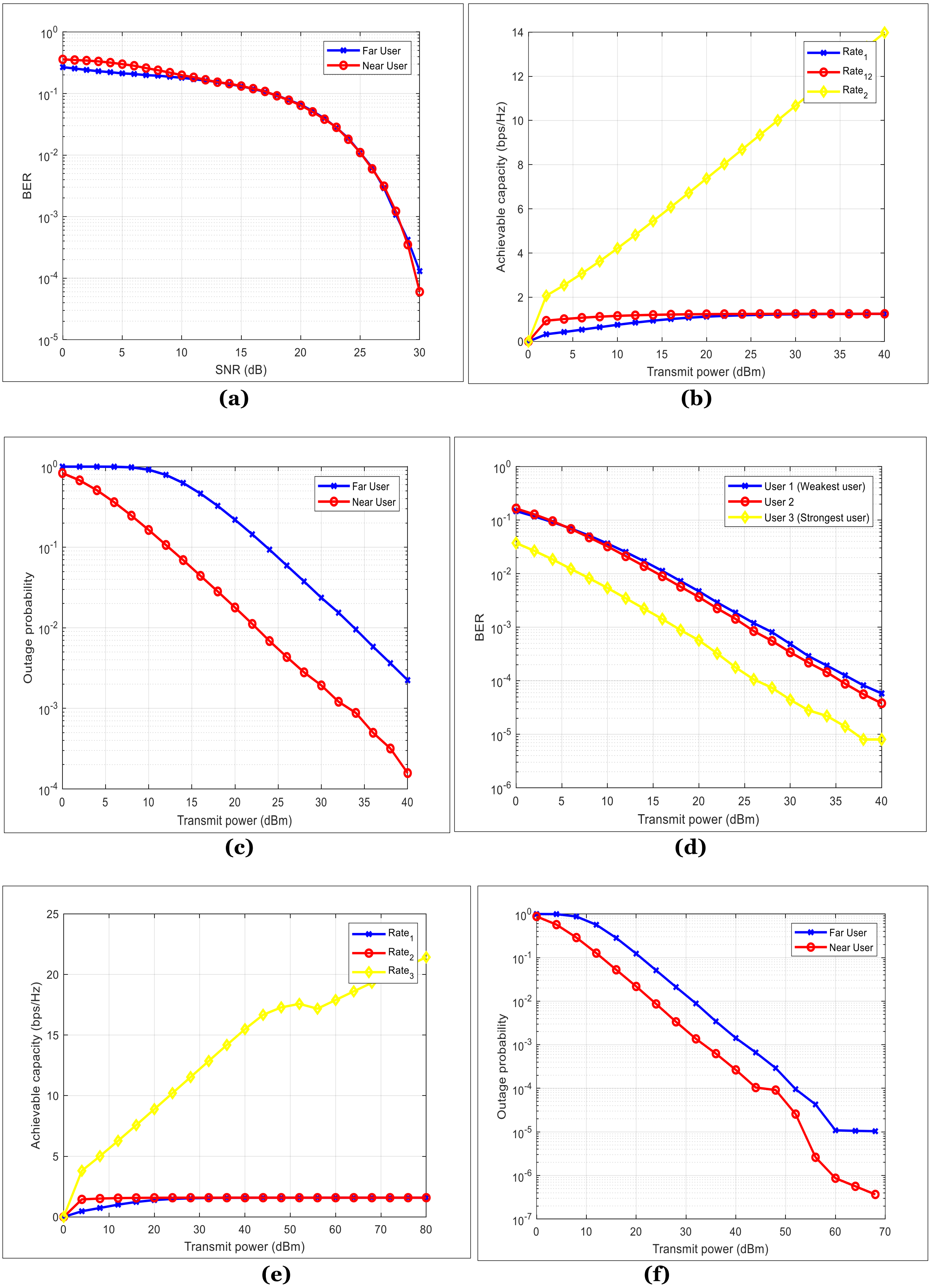

Fig. 5 AF-Generalized-NOMA Two Nodes (a, c, and e) and Three Nodes (b, d, and f) System Performance.

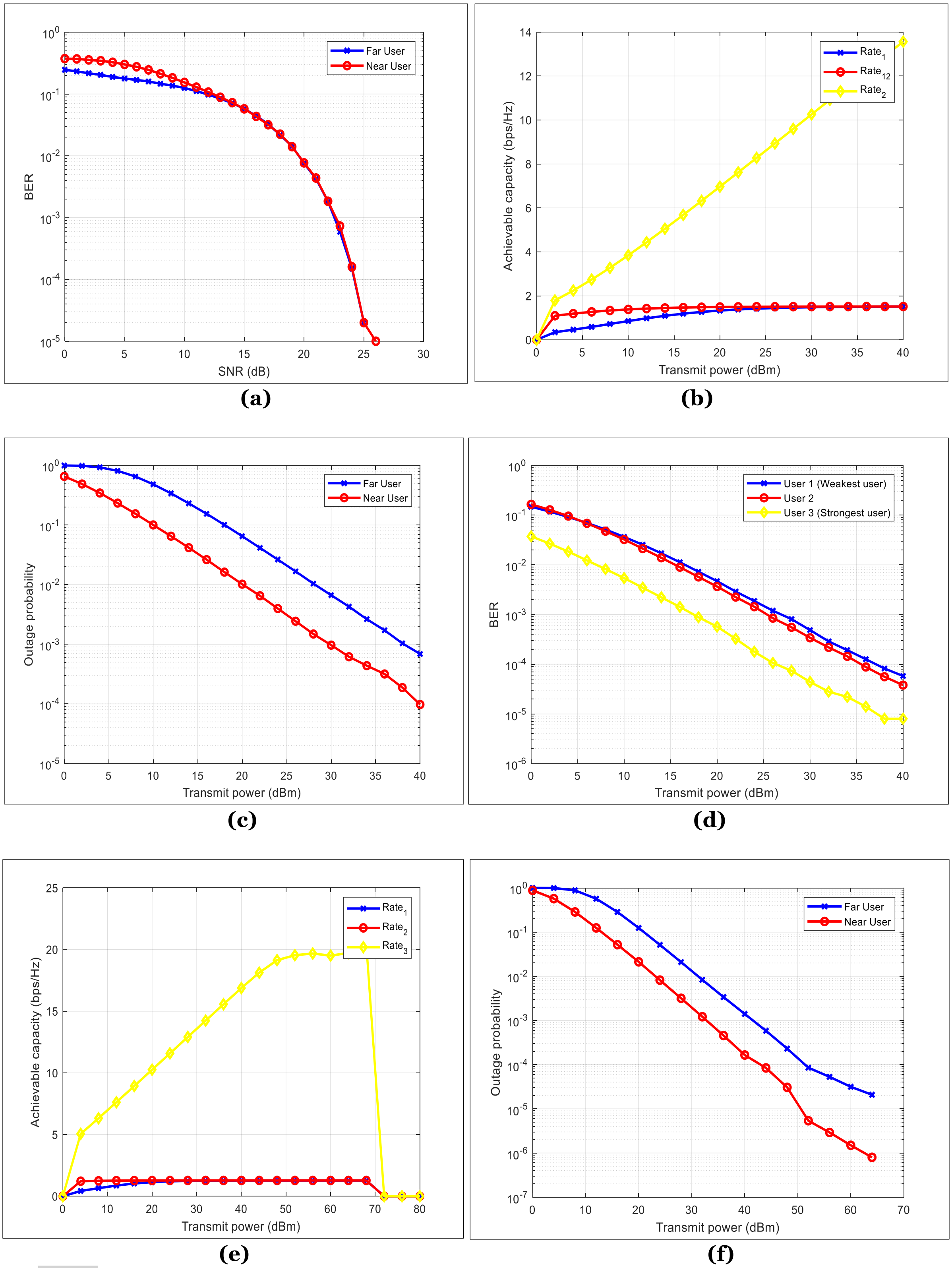

Fig. 6 AF-Water Falling-NOMA Two Nodes (a, c, and e) and Three Nodes (b, d, and f) System Performance.

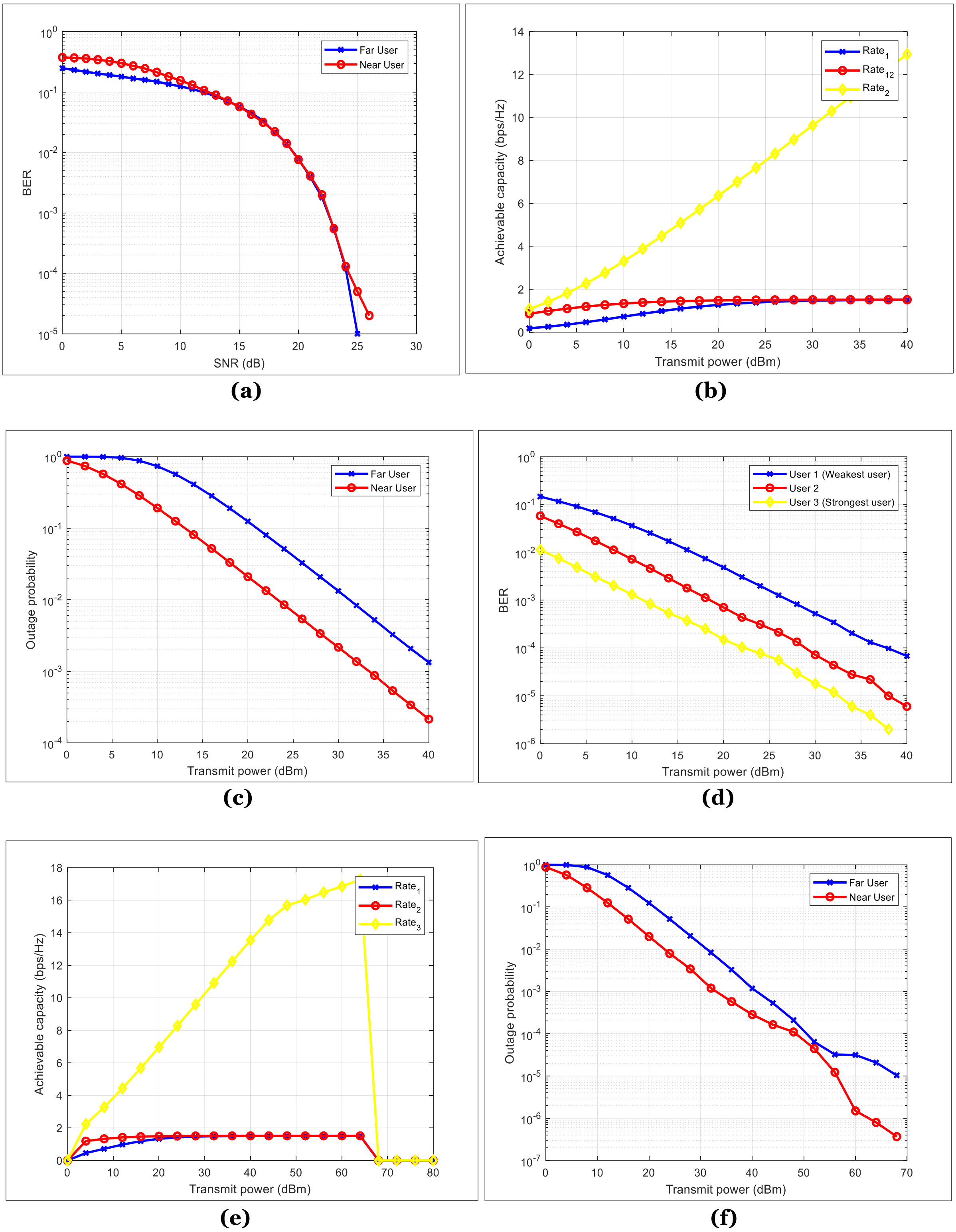

Fig.7 DF-Fixed-NOMA Two Nodes (a, c, and e) and Three Nodes (b, d, and f) System Performance.

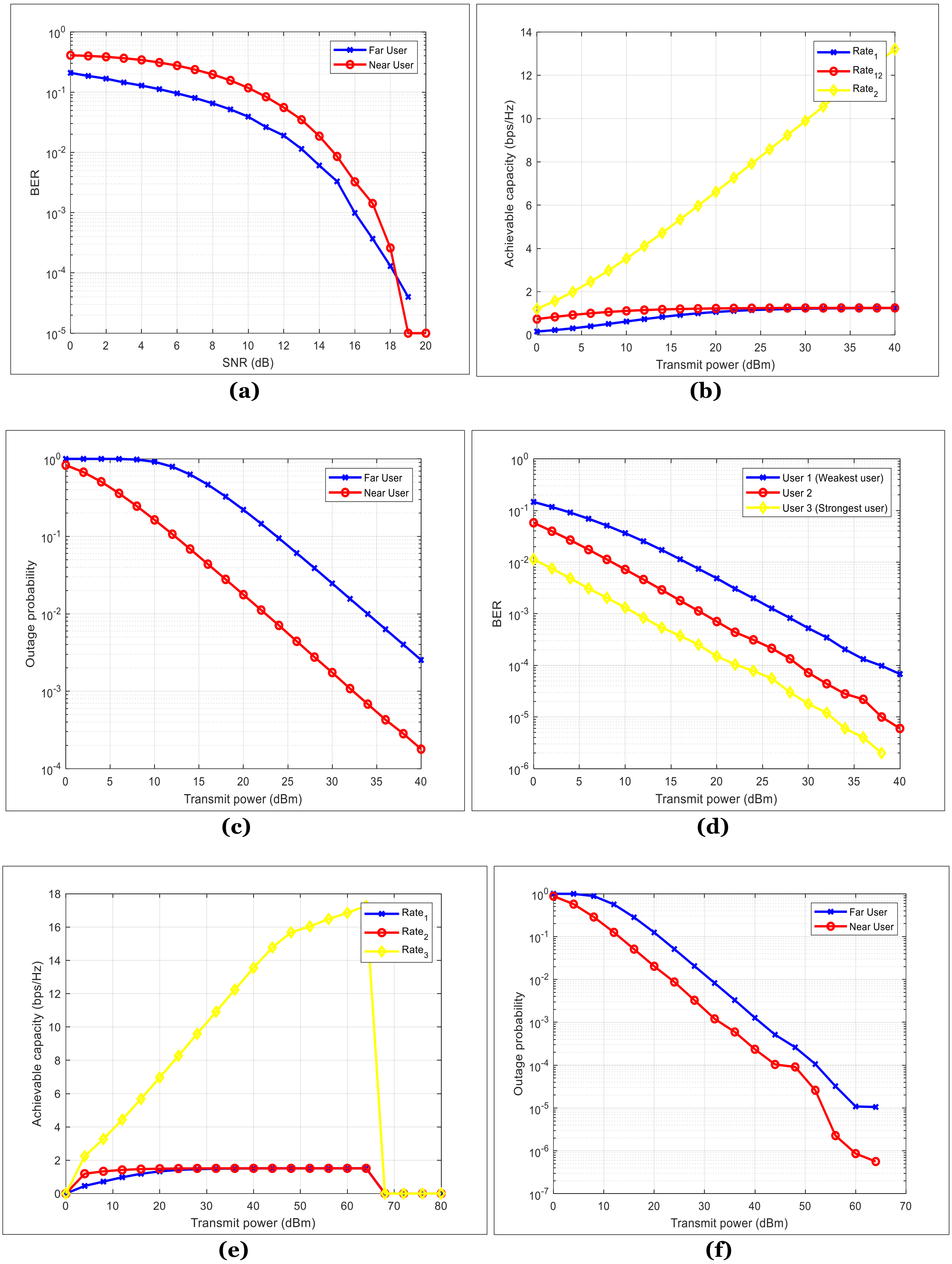

Fig. 8 DF-Fractional-NOMA two nodes (a, c, and e) and three nodes (b, d, and f) system performance.

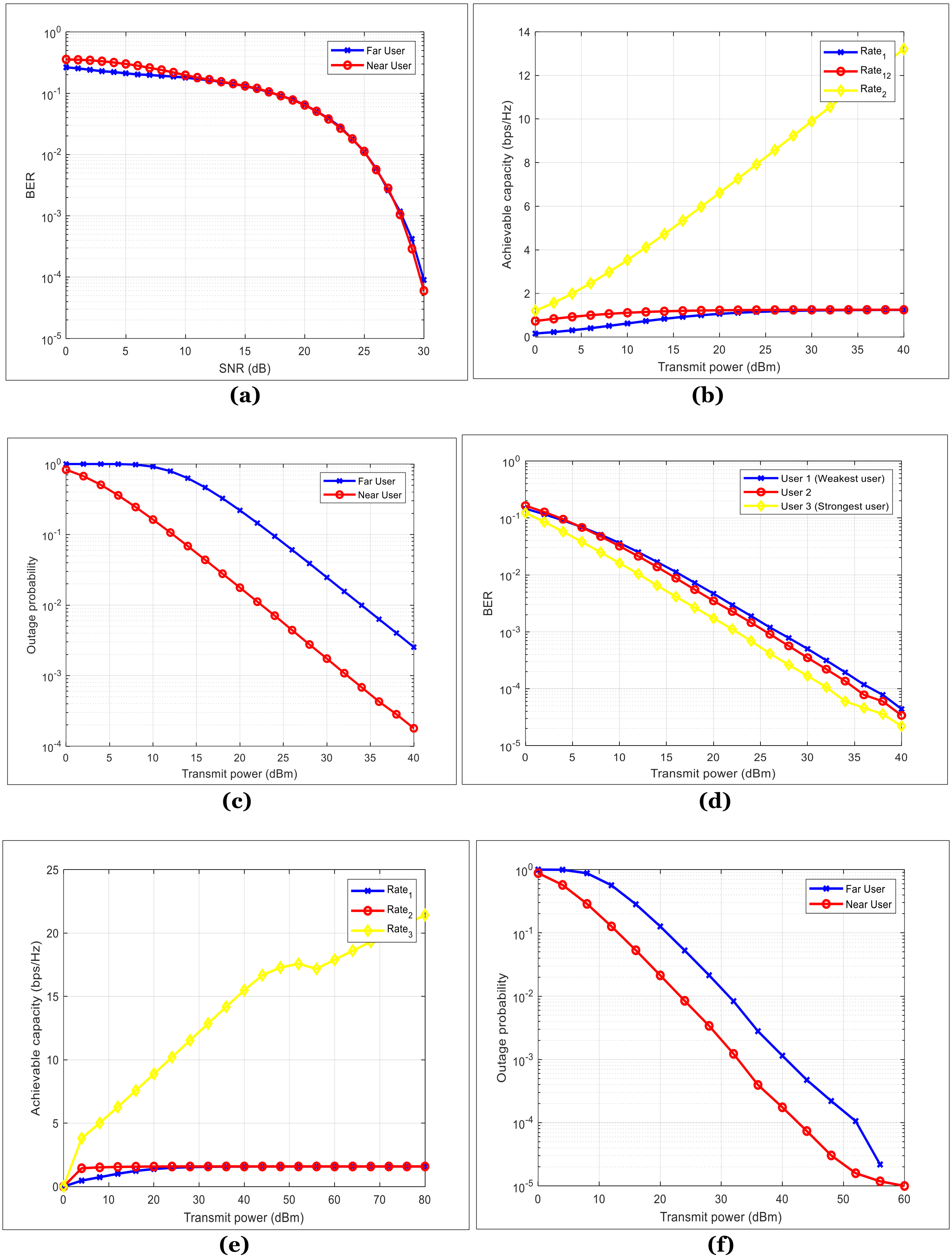

Fig. 9 DF-Generalized-NOMA Two Nodes (a, c, and e) and Three Nodes (b, d, and f) System Performance.

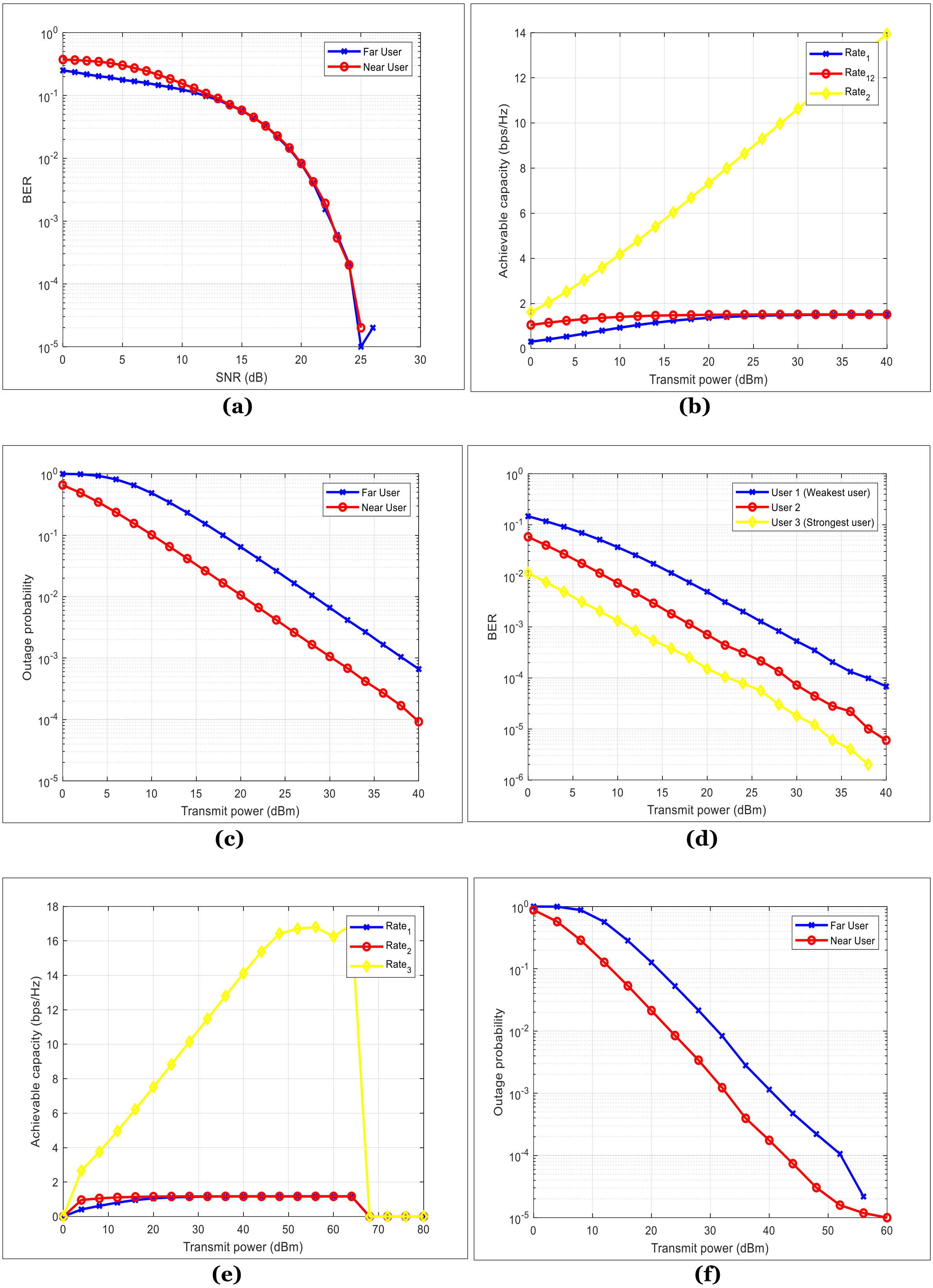

Fig. 10 DF-Water Falling-NOMA Two Nodes (a, c, and e) and Three Nodes (b, d, and f) System Performance.

5. CONCLUSIONS

The cooperative NOMA was analyzed using four techniques of power allocation. For every power allocation, two models were built, i.e., two-node and three-node systems. The following points are concluded:

BER: both near and far users drew almost similar BER responses for various SNRs in both AF and DF models for all studied power allocations except the fixed power allocation. In fixed power allocation, the far user showed higher BER. The water-falling technique stabilized the BER response only in high SNR. Channel capacity: The generalized power allocation for AF and DF models had an optimum channel capacity close to 14 bps/Hz. Outage probability presents the probability that the user is isolated from the network (out-of-coverage). The generalized power allocation showed the maximum outage probability over all power-sharing techniques in both AF and DF models. So, for good noise immunity fixed, the generalized and water-falling power allocation outperformed. Also, for good channel performance, the generalized led in terms of channel capacity was 14.1 bps/Hz for the far user. In terms of outage probability, all the power allocations showed higher outage probability for the far users, and generalized power allocation was the highest outage probability technique. Practically, using the DF protocol was better than the AF protocol because the AF protocol amplified the noise while amplifying the signal and resending it to the users. However, the simulation results in the proposed system showed a significant similarity between the AF/DF protocols because of the use of a protection algorithm on the users' side from any interrupting and interference. Also, the simulation results showed the difference between strategies used for power allocation. Table 2 indicates which techniques are better in terms of performance metrics and shows the different responses for the performance metrics under different strategies of power allocations for both AF/ DF protocols.

Table 2 Comparing Metrics Performance between Different Strategies of Power Allocation.

Performance	FPA	FRPA	GPA	WFPA
BER	High just in far user	High in far and near users	High in far and near users	stabilized in higher S SNR
Achievable Rate	Lease	Lease	Optimal	Lease
Outage probability	Lease	Lease	Higher	Lease

REFERENCES

[1] Papadias CB, Ratnarajah T, Slock DTM. **Spectrum Sharing: The Next Frontier in Wireless Networks**, New York; Wiley 2020.

[2] Shahab MM, Hardan SM, Hammoodi AS. **A New Transmission and Reception Algorithms for Improving the Performance of SISO/MIMO-OFDM Wireless Communication System**. *Tikrit Journal of Engineering Sciences* 2021; **28**(3):146-158.

[3] Papageorgiou GK, Voulgaris K, Ntougias K, Ntaikos DK, Butt MM, Galiotto C, Papadias CB. **Advanced Dynamic Spectrum 5G Mobile Networks Employing Licensed Shared Access**. *IEEE Communications Magazine* 2020; **58**(7):21–27.

[4] Gupta A, Jha RK. **A Survey of 5G Network: Architecture and Emerging Technologies**. *IEEE Access* 2015; **3**:1206-1232.

[5] Agiwal M, Roy A, Saxena N. **Next Generation 5G Wireless Networks: A Comprehensive Survey**. *IEEE Communications Surveys & Tutorials* 2016; **18**(3):1617-1655.

[6] Dai L, Wang B, Yuan Y, Han S, Chih-lin I, Wang Z. **Non-Orthogonal Multiple Access for 5G: Solutions, Challenges, Opportunities, and Future Research Trends**. *IEEE Communications Magazine* 2015; **53**(9):74-81.

[7] Islam S M R, Avazov N, Dobre OA, Kwak K. **Power-Domain Non-Orthogonal Multiple Access (NOMA) in 5G Systems: Potentials and Challenges**. *IEEE Communications Surveys & Tutorials* 2017; **19**(2):721–742.

[8] Ding Z, Peng M, Poor HV. **Cooperative Non-Orthogonal Multiple Access in 5G Systems**. *IEEE Communications Letters* 2015; **19**(8):1462–1465.

[9] Vaezi M, Schober R, Ding Z, Poor HV. **Non-Orthogonal Multiple Access: Common Myths and Critical Questions**. *IEEE Wireless Communications* 2019; **26**(5):174-180.

[10] Dai L, Wang B, Ding Z, Wang Z, Chen S, Hanzo L. **A Survey of Non-Orthogonal Multiple Access for 5G**. *IEEE Communications Surveys & Tutorials 2018*; **20**(3):2294–2323.

[11] Ding Z, Liu Y, Choi J, Sun Q, Elkashlan M, Chih-Lin I, Poor HV. **Application of Non-Orthogonal Multiple Access in LTE and 5G Networks**. *IEEE Communications Magazine* 2017;**55**(2): 185–191.

[12] Liu Y, Qin Z, Elkashlan M, Ding Z, Nallanathan A, Hanzo L. **Non-**

Orthogonal Multiple Access for 5G and Beyond. *Proceedings of the IEEE* 2017; **105**(12) :2347–2381.

[13] Ahmed QZ, Park K-H, Alouini M-S, Aïssa S. **Linear Transceiver Design for Non-Orthogonal Amplify-and-Forward Protocol Using a Bit Error Rate Criterion**. *IEEE Transactions on Wireless Communications* 2014; **13**(4) :1844-1853.

[14] Ali MS, Tabassum H, Hossain E. **Dynamic User Clustering and Power Allocation for Uplink and Downlink Non-Orthogonal Multiple Access (NOMA) Systems**. *IEEE Access* 2016; **4**:6325-6343.

[15] Do DT, Nguyen HS, Voznak M, Nguyen TS. **Wireless Powered Relaying Networks under Imperfect Channel State Information: System Performance and Optimal Policy for Instantaneous Rate.** *Radio Engineering* 2017; **26**(3):869-877.

[16] Zeng J, Sun J, Song Y, Mei J, Lv T, Zhou S. **Resource Allocation in Multi-Carrier Multiplexed NOMA Cooperative System.** *Sensors* 2022; **22**(16):6023, (1-19).

[17] Ding Z, Lei X, Karagiannidis GK, Schober R, Yuan J, Bhargava VK. **A Survey on Non-Orthogonal Multiple Access for 5G Networks: Research Challenges and Future Trends**. *IEEE Journal on Selected Areas in Communications* 2017; **35**(10):2181-2195.

[18] Makki B, Chitti K, Behravan A, Alouini M-S. **A Survey of NOMA: Current Status and Open Research Challenges**. *IEEE Open Journal of the Communications Society* 2020; **1**:179-189

[19] De Sena AS, Lima FRM, da Costa DB, Ding Z, Nardelli PH, Dias US, Papadias CB. **Massive MIMO-NOMA Networks with Imperfect SIC: Design and Fairness Enhancement**. *IEEE Transactions on Wireless Communications* 2020; **19**(9) :6100-6115.

[20] Khan F, Filippou MC, Sellathurai M. **Cooperative Communication Techniques for Spectrum Sharing**. *Spectrum Sharing: The Next Frontier in Wireless Networks* 2020; **20**:147-167.

[21] Mahmood MS, Al Dabagh NB. **Improving Iot Security Using Lightweight Based Deep Learning Protection Model**. *Tikrit Journal of Engineering Sciences* 2023; **30**(1):119-129.

[22] Khan FA, Masouros C, Ratnarajah T. **Interference-Driven Linear Precoding in Multiuser MISO Downlink Cognitive Radio Network**. *IEEE Transactions on Vehicular Technology* 2012; **61**(6):2531-2543.

[23] Dai L, Wang B, Peng M, Chen S, Hanzo L. **Hybrid Precoding-Based Millimeter-Wave Massive MIMO-NOMA with Simultaneous Wireless Information and Power Transfer**. *IEEE Journal on Selected Areas in Communications* 2019; **37**(1):131–141.

[24] Alluhaibi O, Ahmed QZ, Kampert E, Higgins MD, Wang J. **Revisiting the Energy-Efficient Hybrid DA Pre-Coding and Combining Design for Mm-Wave Systems**. *IEEE Transactions on Green Communications and Networking* 2020; **4**(2):340-354.

[25] Vaezi M, Baduge GAA, Liu Y, Arafa A, Fang F, Ding Z. **Interplay between NOMA and other Emerging Technologies: A Survey**. *IEEE Transactions on Cognitive Communications and Networking* 2019; **5**(4):900-919.

[26] Moltafet M, Yamchi NM, Javan MR, Azmi P. **Comparison Study between PD-NOMA and SCMA**. *IEEE Transactions on Vehicular Technology* 2017; **67**(2) :1830-1834.

[27] Do DT, Nguyen TT **. Fixed Power Allocation for Outage Performance Analysis on AF-Assisted Cooperative NOMA**. *Journal of Communications* 2019; **14**(7):560–565.

[28] Kaba VB**. Fractional Power Allocation Scheme for NOMA.** *International Journal of Engineering Research and Technology* 2020; **13**(4) :130–134.

[29] Lv S, Ji J **. Secrecy Outage Performance and Power Allocation for Three Secondary Users CR-NOMA Networks with Transmit Antenna Selection**. *Electronics* 2023; **12**(8):1896, (1-20).

[30] Hussein T, Haburi SI **. BER Performance for Downlink NOMA .** *Wasit Journal of Engineering Sciences* 2022; **10**(2):216–222 .