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Enhancement of outage probability for down link cooperative non-orthogonal multiple access in fifth-generation network

Mohamed Hassan[1], Manwinder Singh[1], Khalid Hamid[2], Imadeldin Elsayed Elmutasim[3]
[1]Department of Wireless Communication, Lovely Professional University, Phagwara, India
[2]Department of Electronics and Communication, University of Science and Technology, Omdurman, Sudan
[3]Department Electrical and Electronic Engineering, University Malaysia Pahang, Pahang, Malaysia

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ABSTRACT

Future wireless networks are expected to face several issues, but cooperative non-orthogonal multiple access (C-NOMA) is a promising technology that could help solve them by providing unprecedented levels of connection and system capacity. In this regard, the influence of the power location coefficient (PLC) for remote users adopting multiple-input-multiple-output (MIMO) and massive MIMO has been explored to provide effective performance. The goal of this study is to design fifth-generation (5G) downlink (DL) NOMA power domain (PD) networks with a variety of distances and PLCs for remote users and then to compare their outage probability (OP) performance versus signal to noise ratio (SNR). As a novel approach to improving OP performance rate and mitigating the influence of the PLC for remote users, DL C-NOMA is combined with 16×16, 32×23, and 64×64 MIMO and 128×128, 256×256, and 512×512 massive MIMO. The results were obtained that the 64×64 MIMO improves the OP for the remote user by 65.0E-03, while the 512×512 massive MIMO achieved an improvement that reaches 1.0E-06 for the PLC of 0.8 at SNR of 14 dB. The Rayleigh fading channels and MATLAB simulation tools were utilized to carry out the study work.

Corresponding Author:

Manwinder Singh
Department of Wireless Communication, Lovely Professional University India
Jalandhar-Delhi, G.T. Road, Phagwara, Punjab-144411, India
Email: manwinder.25231@lpu.co.in

1. INTRODUCTION

Non-orthogonal multiple access (NOMA) promises to be an indispensable technology in next-generation mobile networks to improve spectral efficiency as it considers one of the most interesting wireless network technologies in the future [1]–[5]. Unlike more conventional orthogonal multiple access methods such as time division multiple access (TDMA), essentially, the goal of NOMA is to allow several users to share the same frequency band while operating at different power rates [6]. The NOMA method exploits a different element in the power field [7]–[10].

The first user in the NOMA will decode the other user's message from the superposition after encoding the incoming signal. This process is referred to as successive interference cancellation (SIC). If the SIC is used, the information provided by the remote user is decoded by the near user and gives a sound to the distinguish process, regardless of the data of the remote user must be decrypted by the close user [11]–[13]. The strategy is required because the nearby user has access to the data of the remote user and can assist the latter by relaying it.

If the connection between the remote user and the base station (BS) is weak, retransmitting data from a nearby user can be a flexible workaround. To rephrase, the first communication would originate from the base station, while the second copy would be relayed by a nearby user. Thus, the potential for downtime for distant users should be mitigated. Cooperation in communication and relaying is made possible by NOMA technology because the nearby user may see the data sent by the faraway user [14]–[16].

One advantage of cooperative communication is that when two links are connected, they both send the same message even if one link is down, while the likelihood of both links failing at the same time is low [14], [15]. Combining NOMA with the various forms of multiple-input-multiple-output (MIMO) communication is one of the most effective ways to achieve high spectrum efficiency, which makes it an important element in the design of cellular communication systems. By placing a large number of antennas and making use of the space field for multiple users, massive MIMO is a crucial fifth-generation (5G) enabler that can minimize system latency and give amazing communication benefits [16], [17]. cooperative (C-NOMA) technology combined with massive MIMO yields greater spectrum and conductivity gains [17].

The performance of a near-far relay C-NOMA system is explored using a Rayleigh fading channel, perfect and imperfect channel state information, and SIC, albeit only for a single user [18]. The usage of a half-duplex MIMO C-NOMA system with just a partial grasp of the channel state, as well as outage probability (OP) over Nakagami-m fading channels, is explored in [19]. The results, on the other hand, showed that the power allocation coefficients (PLCs) of users who were physically close to the BS were all assigned the same value.

We highlight that all existing solutions have a limited number of users and rely on a single relay to forward messages from one user to another. Observe that while NOMA systems execute overlapping in the power domain (PD), the power always needs to be allocated to all users. Given that the correlation coefficients for power assignments are not expected to be equal, constructing practical C-NOMA networks requires careful consideration of both relay choice and power distribution. This motivates us to analyze the performance of downlink (DL) networks using both conventional non-overlapping multi-access (NOMA) PD and downlink (DL) C-NOMA PD. We just consider the case of two users here, ignoring any interference from other NOMA users for clarity. Here is a quick rundown of our most significant contributions:

- The OPs for the 2 users' NOMA and C-NOMA systems are generally represented in closed form by theoretical analysis with varying distances and PLCs. However, the simulation demonstrates that the derived OP expressions are more exact than those in [19].
- This paper proposes an opportunistic suboptimal relay selection technique that considers both users. The simulation findings show that the C-NOMA with the proposed effective relay selection scheme provides a considerable performance boost over the OMA scheme with novel closed-form equations for outage probability (OP) that have been generated.
- The results of the cooperative NOMA system with 16×16, 32×23, and 64×64 MIMO were compared to our previous results and optimization calculations, and the OP and effect PLC were studied.
- C-NOMA combined with 128×128, 256×256, and 512×512 massive MIMO, enhancing OP's effective rate of performance calculation and reducing the impact of the PLC on remote users.

The remaining sections of the paper are as: in section 2, we present the relevant work. In section 3, the envisioned model of the system is discussed. In section 4, we will go over the simulation and its settings. includes both findings and analysis. Future research is addressed in section 6 to round out the paper.

2. RELATED WORK

Before developing a 5G network architecture to achieve system objectives, it is important to gain a thorough understanding of the relevant performance characteristics. Many reports stress the importance of bettering transmission conditions. A new dynamically coordinated direct and relay detection system (DD-CDRT) is described in [20] to improve the dependability of transmissions. Digital data aids theoretical analysis and demonstrates how it works, and it makes use of all accessible side information to prevent user intervention. Dropout performance was negatively affected by the low signal to noise ratio (SNR), thus researchers in [21] created a new NOMA protocol that users may employ in their DL networks to improve their channel gain those utilizing the system can tell the source to switch between NOMA direct and NOMA cooperative transmission modes from a distance. An efficient resource utilization method based on NOMA's cooperative relay selection mechanism is the major point [22]. A wide variety of research [23] focused on NOMA, a strategy in which the BS sends out signals to two receivers simultaneously, accumulates OP formulae for two users (local and distant), and prioritizes the relay role of the local user. Although addressing the impact of a relay when using a direct link as discussed in [24], it is still preferable to improve the received signal. In [25], NOMA collaboration with wireless data and power transfer radio is tested, although the BS required more consideration for route relaying while transferring data to 2 users. To examine the OP, another study [26] assessed the efficiency of a DL NOMA network under Nakagami-m fading conditions. The model may aid in the advancement of NOMA systems, and the outcome showed maximum throughput as a function of varying parameters.

3. SYSTEM MODEL

Figure 1 depicts a DL C-NOMA network with 2 NOMA users and a BS, one of whom has a powerful channel while the other has a weak channel due to their respective distances from the BS $d1$, and $d2$ and PLCs (α_n, α_f). A comparison of C-NOMA, MIMO-C-NOMA, and massive-MIMO-C-NOMA networks, with an emphasis on the key distinctions between the two types of networks, is shown in Figure 2. C-NOMA uses a two-way transmission scheme. After determining the entire Rayleigh fading channel for each user, the first location is known as the direct position transmission, and the second location is known as the relay position.

Each user is given access to a total of Rayleigh fading channels by

$$h_{rN} = \sum_{r=1}^{N} h_{rN} \tag{1}$$

$$h_{nN} = \sum_{n=1}^{N} h_{nN} \tag{2}$$

where r stands for the remote user, n stands for the near user and the number of transmit antennas, is denoted by the symbol N. N=1 for NOMA and C-NOMA, N=16, 32, 64 for MIMO C-NOMA, and N=128, 256 for massive-MIMO C-NOMA.

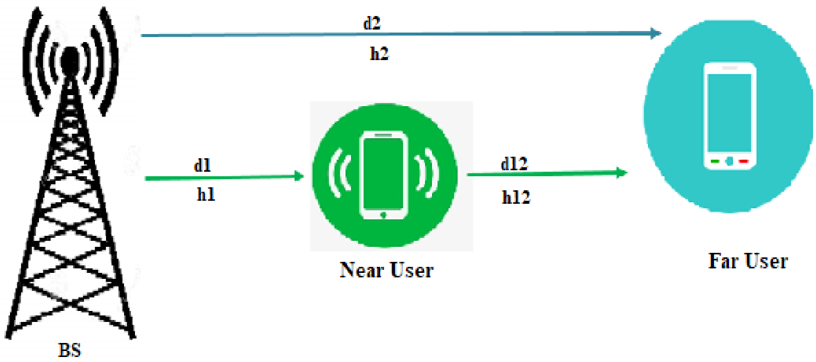


Figure 1. Shows DL transmit for C-NOMA scheme

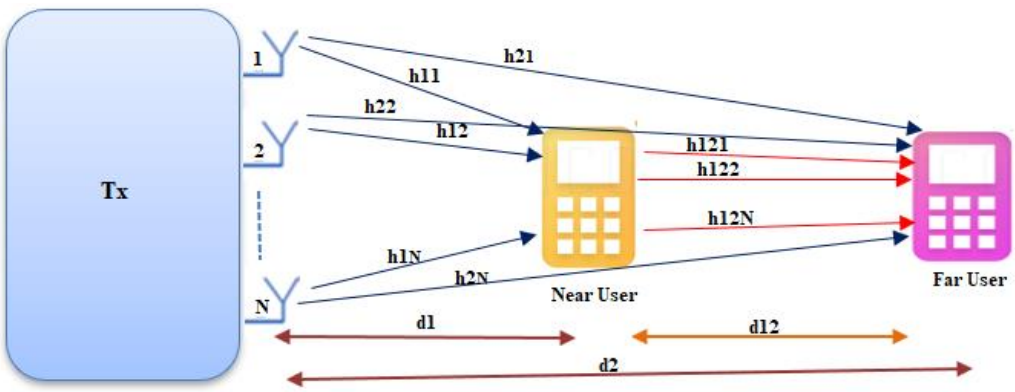


Figure 2. Shows the C-NOMA network's downlink transmission using N×N with MIMO and massive MIMO

3.1. Position for direct transmission

In the direct transmission position (x_r), the BS uses NOMA to send data to nearby (x_n) and distant (x_r) users. Before proceeding to decode its data, the near user utilizes SIC to decode the data of the distant user. The remote user is exclusively responsible for direct decoding. The following are the likely data rates for near and far away users after the direct position transmission.

$$R_n = \frac{1}{2} log_2(1 + \alpha_n \rho |h_{nN}|^2) \quad (3)$$

$$R_{\mathrm{r},1} = \frac{1}{2} \log_2 \left(1 + \frac{\alpha_{\mathrm{f}} \rho |h_{\mathrm{rN}}|^2}{\alpha_{\mathrm{n}} \rho |h_{\mathrm{rN}}|^2 \ +1}\right) \quad (4)$$

3.2. Position for relaying

Since the nearby user already has the remote user's data after decrypting it during the previous period, all the relay user has to do is transfer it to the remote user during the relay period. At the end of a relay slot, the maximum throughput available to a distant user is,

$$R_{\mathrm{r},2} = \frac{1}{2} \log_2(1 + \alpha_{\mathrm{n}} \rho |h_{\mathrm{n\ rN}}|^2) \quad (5)$$

$h_{\ nrN}$ denotes the channel between the nearby and remote users.

3.3. Diversity combining

Two sets of identical data obtained via two different channels and separated by two time periods are available to the remote user. Users in faraway locations can employ a diversity-combining strategy. Select the version with the highest SNR, for instance, using selection combining. When options are combined, a remote user can expect a rate of

$$R_{\mathrm{r}} = \frac{1}{2} \log_2 \left(1 + \ \max\left(\frac{\alpha_{\mathrm{r}} \rho |h_{\mathrm{rN}}|^2}{\alpha_{\mathrm{n}} \rho |h_{\mathrm{rN}}|^2 \ +1}, \rho |h_{\mathrm{n\ rN}}|^2\right)\right) \quad (6)$$

The maximum number of remote users that can be supported without employing cooperative relaying.

$$R_{\mathrm{f,noncoop}} = \log_2 \left(1 + \frac{\alpha_{\mathrm{r}} \rho |h_{\mathrm{rN}}|^2}{\alpha_{\mathrm{n}} \rho |h_{\mathrm{rN}}|^2 \ +1}\right) \quad (7)$$

4. SIMULATION

The system parameters in the model simulation have been implemented using the MATLAB software program after generating channel gain and calculating the OP for the remote user (NOMA, C-NOMA, MIMO-C-NOMA and massive MIMO-C-NOMA) against SNR. Table 1 shows the holistic range of the parameters has been applied to carry out the endless intrinsic potential which could pave to contributing to the domain.

Table 1. Parameters of the simulation

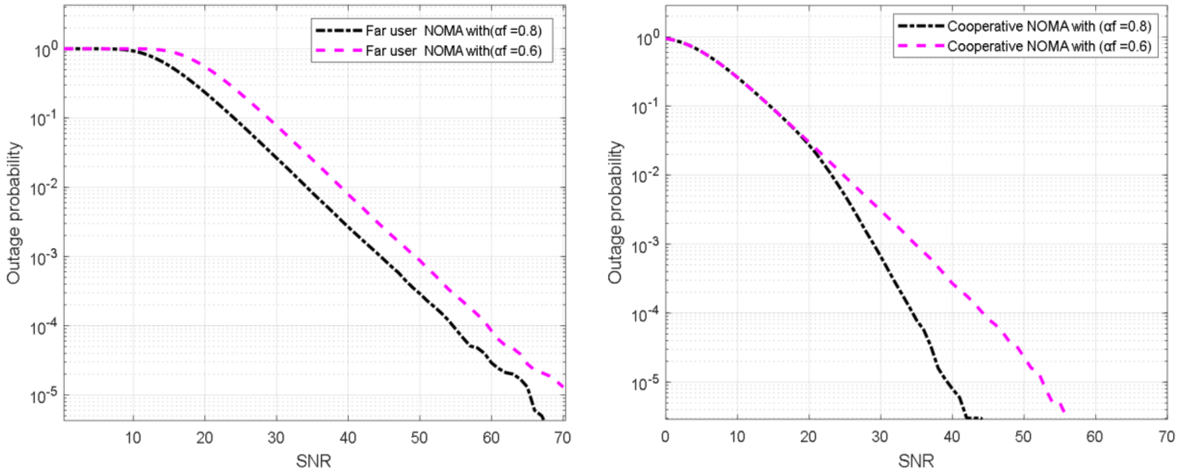
Parameters	Values
Distances	$d_1 = \frac{1}{2} d_2$
PLCs	α_f 0.9, 0.8, 0.7, 0.6
	α_n 0.1, 0.2, 0.3, 0.4
Path loss exponent	4
The number of bits assigned to each symbol	10^6
Type of fading	Rayleigh fading
Noise	AWGA
SNR	0 to 70 dB
Diversity technique	Selection combining
MIMO	16×16, 32×32 and 64×64
Massive-MIMO	128×128 and 256×256

5. RESULTS AND DISCUSSION

To analyze the NOMA OP, a heavy simulation was done to accomplish the extensive study objectives. The next various figures clarify the OP in the face of SNR. The wide study conditions have been used to cover much more aspects and potential of the upcoming telecommunication domain techniques.

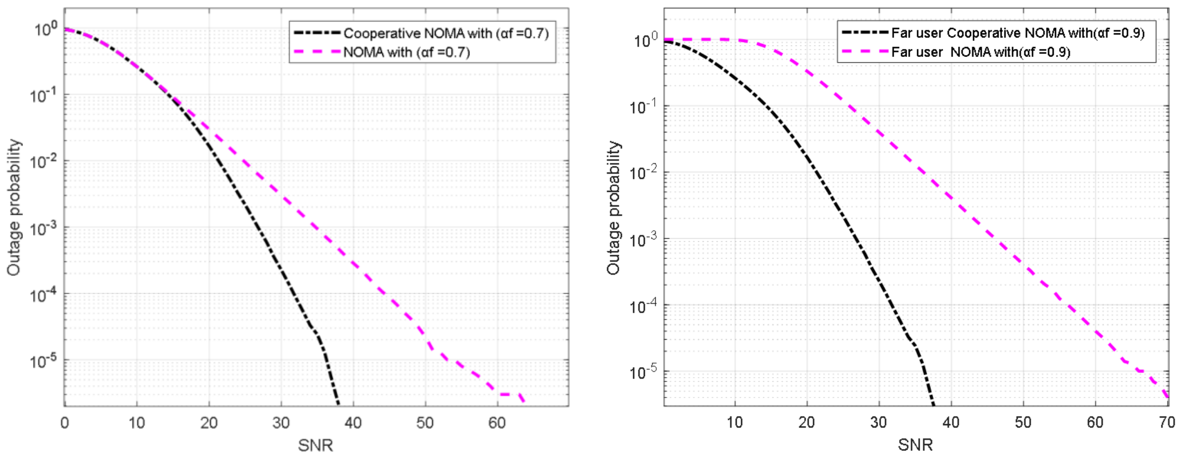
As illustrated in Figure 3(a), the OP decreases with increasing SNR for 2 remote DL NOMA PD users in separate networks with PLCs of 0.8 and 0.6. Since the DL 5G NOMA OP for users with PLCs of 0.8 is lower at an SNR of 25 dB, it is superior to the OP for users with PLCs of 0.6 and to those discovered in [8]. The DL C-NOMA PD OP vs. SNR is shown in Figure 3(b) for the 0.8 and 0.6 PLCs, respectively. It was discovered that as SNR increased, OP decreased. According to the findings, in DL C-NOMA, OP performance rates of far users are equivalent with PLCs of 0.8 and 0.6 until the SNR approaches 10 dB. According to the analysis, the level of performance obtained is 25% greater than that obtained by Ding *et al.* [2].

Figures 4(a) and 4(b) show two scenarios of far-user DL (5G C-NOMA and NOMA) PD and PLCs of 0.7 and 0.9, where the OP is plotted against the SNR. DL C-NOMA users achieve an OP performance at the PLC of 0.7, which is 37.0E-03 better than the NOMA user, and a DL C-NOMA user achieves an OP performance rate at the PLC of 0.9, which is 1.0E-06 better than the NOMA user, with an SNR ratio of 40 dB. According to the data, DL C-NOMA performs better than NOMA in terms of OP performance rates, and rising PLCs degrade OP performance rates. The reason for this is that there is less interference between users when they are further apart in terms of their PLC. Statistics show that this level of performance is 20% higher than that of [17].



(a) (b)

Figure 3. Illustrates the DL OP against SNR for two remote users (a) with NOMA and (b) with C-NOMA with different PLCs (0.8, 0.6)



(a) (b)

Figure 4. Shows the DL OP against SNR for two remote users with NOMA and C-NOMA with different PLCs (a) PLC=0.7 for two remote users and (b) PLC=0.9 for remote users

Figure 5 depicts four different C-NOMA far users using 16×16 MIMO C-NOMA, 32×32 MIMO C-NOMA, and 64×64 MIMO C-NOMA and their respective OP vs SNR at 0.8 PLCs. While the far user 64×64 MIMO C-NOMA OP rate is 91.0E-04, the far user 32×32 MIMO C-NOMA OP rate is 12.0E-04, the user 16×16 MIMO C-NOMA OP rate is 51.0E-03, and the user 5G C-NOMA OP rate is 0.04 at the SNR of 25 dB. In comparison to C-NOMA, which is used by the poorest user, 64×64 MIMO C-NOMA improves OP by 309.0E-04 percentage points. The MIMO approach improves overall OP performance, with values attained that is 5% greater than those observed in [22].

The OP versus SNR at 0.8 power sites for four remote users in 128×128, 256×256, and 512×512 C-NOMAs is shown in Figure 6. An SNR of 14 dB yields an OP of 1.0E-06 for distant user 512×512 massive MIMO C-NOMA, 79.0E-05 for user 256×256 massive-MIMO C-NOMA, 12.0E-05 for user 128×128 massive-MIMO C-NOMA, and 0.4 for user C-NOMA. 512×512 massive-MIMO-C-NOMA provides an improvement of 3999.0E-04 between the best and worst users. The achieved performance is shown to be 20% higher than [27], [28], proving that the huge MIMO strategy is successful in improving OP's performance.

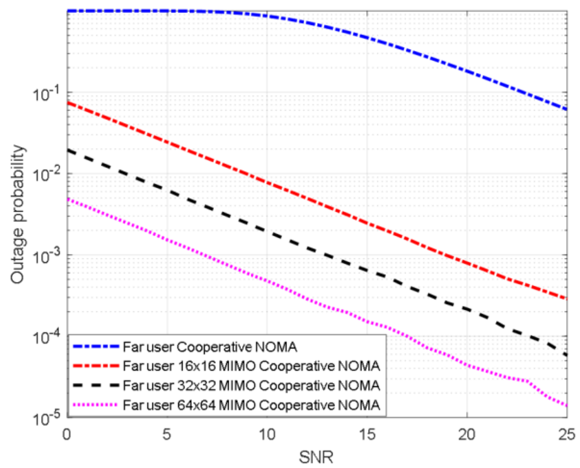


Figure 5. DL OP against SNR for C-NOMA for far users with and without the different MIMO scheme

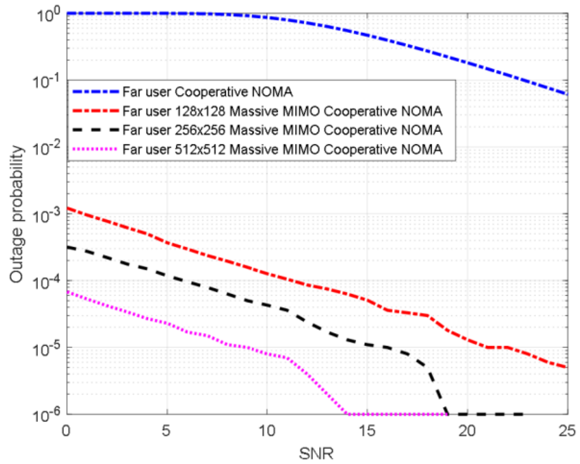


Figure 6. DL OP against SNR for C-NOMA remote users with and without different massive MIMO technique

6. CONCLUSION

The findings give away to the remote user with cooperative NOMA to obtain the lowest OP when compared with NOMA technique because it gets two separate copies of the identical message; one is from the base station, while the other is from a nearby user functioning as a relay. According to the discovery, the decrease in the PLC of the remote user increases the OP in C-NOMA and NOMA. Due to the decrease in the PLC for the remote user, building up the PLC for the near user leads to raising the interference between them.

The work investigated the NOMA technology in terms of OP to improve performance, particularly the 5G C-NOMA DL when integrated with the MIMO and massive MIMO techniques. The results reveal that when the NOMA cooperative method is integrated with 64×64 MIMO for the remote user, the OP improves by 309.0E-04 at the SNR of 25 dB, however, when the system is combined with 512×512 massive MIMO, the OP enhances by 3999.0E-04 at SNR of 14 dB and 0.8 PLC. Hence the best massive MIMO improves the OP of C-NOMA by 369E-03 when the camper with the best MIMO. Future research will investigate how well NOMA and cognitive radio integrate on the 5G network.

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BIOGRAPHIES OF AUTHORS

Mohamed Hassan received a B.Sc. degree in electrical engineering from the University of Science and Technology, Sudan, the M.Sc. degree in Communication and Networking from Al-Neelain University in Sudan. He is the Ph.D. student at Lovely Professional University, Phagwara-Jalandhar, Punjab, India. He published in 3 international journals and presented 5 papers at international conferences. He can be contacted at email: mhbe4321@gmail.com.

Manwinder Singh received the B.Tech, M.Tech, and Ph.D. Degree in Electronics and Communication Engineering from IKG-Punjab Technical University, Jalandhar, Punjab, India in 2005, 2010, and 2019 respectively. He is a Professor in the Department of Electronics and Communication Engineering at Lovely Professional University, Phagwara-Jalandhar, Punjab, India. He published in 60 international journals and presented 15 papers at national and international conferences. His research interests are in the broad area of Pervasive Wireless Communication and networks. Dr. Manwinder has published and presented more than 70 technical papers in International Journals and conferences and authored 06 book chapters with Wiley, Tylor Francis, and CRC publishing houses. He is a life member of the Indian Society for Technical Education (I.S.T.E.) and Editorial Board of many international journals of repute. His current area of interest includes cognitive radios networks, massive MIMO, AI, ML, smart farming, smart healthcare, 5G, and IoT. He can be contacted at email: manwinder.25231@lpu.co.in.

Khalid Hamid Bilal received the B.Sc. degree in communication and Control from the University of Gezira, Sudan, the M.Sc. degree in Communication and Information systems from the University of Khartoum, Sudan and the Ph.D. degree in Communication and information from Omdurman Islamic University, Sudan He used to hold several administrative posts with Department of Communication System Engineering, University of Science and Technology, Sudan (UST), from 2000 to Now, including the Head of Department, from 2007 to now. He is currently a Professor with the Department of Communication System Engineering, University of Science and Technology, Sudan (UST). He has supervised and co-supervised more than 100 masters and 20 Ph.D. students. He has authored or coauthored more than 150 publications: In IEEE Conference and different journals. His research interests include wireless communication. He can be contacted at email: khalid@ust.edu.sd and khalidhamidk9@gmail.com.

Imadeldin Elsayed Elmutasim received the B.S. degree in Electrical and Electronics engineering from (UST), Khartoum Sudan, the M.S. degree in Communication engineering from (OIU), Khartoum Sudan, and the Ph.D. in Communication engineering at University Malaysia Pahang (UMP), Pahang Malaysia. From 2013 up to 2020 working as a telecommunication engineer in Qatar state. His area of research interest is Microwave link design, Wireless channel modelling, RF propagation measurement and modelling in tropical and desert. In addition to that, he implemented various Fiber Optics transmission projects. He has authored and co-authored more than 35 publications and revised up to 120 articles from reputed journals as well as IEEE conferences abroad. He got two grand initiatives fellow program in Germany and USA under research statements in different areas. He can be contacted at email: emadcts@yahoo.com.