This article has been accepted for publication in a future proceedings of this confernce, but has not been fully edited. Content may change prior to final publication. Citation information: DOI10.1109/GPECOM55404.2022.9815677, 2022 4th Global Power, Energy and Communication Conference (GPECOM)

A Cooperative SWIPT-Hybrid-NOMA Pairing Scheme considering SIC imperfection for THz Communications

1st Haider. W. Oleiwi
Department of Electronic and Electrical Engineering
Brunel University London
UB8 3PH, UK
Haider.Al-Lami@brunel.ac.uk

2nd Nagham Saeed
School of Computing and Engineering
University of West London
W5 5RF, UK
Nagham.Saeed@uwl.ac.uk

3rd H. S. Al-Raweshidy
Department of Electronic and Electrical Engineering
Brunel University London
UB8 3PH, UK
Hamed.Al-Raweshidy@brunel.ac.uk

***Abstract*— Almost all 6G non-orthogonal multiple access NOMA-based research assumes a perfect successive interference cancelation (SIC) when it comes to system analysis or planning; this assumption should be supported by advanced schemes that consider the suggested technologies and THz characteristics. The work in this paper proposes an optimized two-user pairing scheme where simultaneous wireless information and power transfer (SWIPT) is adopted with cooperative hybrid-NOMA (H-NOMA) in terahertz (THz) considering SIC imperfection. The aim is to improve the overall performance of wireless THz communication networks including wireless connectivity, resource management, scalability, and user fairness. Hence, thorough studies for a number of SWIPT-NOMA schemes were presented alongside a selection of the best H-NOMA pairing strategy for the served users. We investigated system performance according to SIC manipulation to develop a proper SWIPT-based simplified system. The results showed a remarkable improvement in energy efficiency and spectral efficiency compared to conventional work (NOMA and OMA (TDMA)) by 75%. This promising proposal has a positive impact on reducing system hardware, complexity, and cost while improving signal detection, diversity, and reliability, without the need for complicated techniques such as multiple-input multiple-output (MIMO).**

Keywords—6G, Cooperative Networks, Energy Efficiency, Hybrid-NOMA, Reliability, Imperfect SIC, Resource Management, Spectral Efficiency, SWIPT-Pairing, System complexity, THz communications.

I. INTRODUCTION

The massive increase of users, devices, and data traffic nowadays necessitates integrated wireless communication systems and technologies to adapt to the emerging requirements of 6G various applications, considering the achievement of the required levels of energy efficiency (EE) and spectral efficiency (SE) and other evaluating metrics [1]-[4]. When it comes to NOMA studies, successive interference cancelation (SIC) has commonly been considered to implement perfectly, where procedural errors might occur. Furthermore, it is extremely important to minimize the number of users per cluster as users' channel state information (CSI) acquisition has a high impact on SIC implementation, however, SIC is not only dependent on CSI, but also QoS, hybrid, or other strategies [5]. Due to the expected additional hardware and power consumption, EE is essentially considered a crucial factor in the next era of wireless communications (6G and beyond), especially with ubiquitous coverage of the massive number of devices i.e., the Internet of Everything (IoE) [6]-[11]. Moreover, energy-efficient systems are critical in 6G communications to meet green communications criteria [12]. Terahertz communications (0.1 – 10) THz represent the pillar of the next generations because of its unique characteristics and the variety of applications it supports [13], e.g., connections of backhaul-to-backhaul/fronthaul, kiosk-to-users, data center intercom, intra-device, and THz-fiber networks [14]. However, THz characteristics split its spectrum into several windows that are still under investigation to support 6G communications [15]. The existing systems have noticeable constraints to support the new needs, to this end, integrating promising techniques is recommended to build a capable wireless system that provides the supreme targeted levels of connectivity, SE, latency, data-rate, reliability, user fairness, EE, and cost-effectiveness. The recent studies have nominated non-orthogonal multiple access (NOMA) to be part of 6G systems, as it outperforms the previous orthogonal multiple access (OMA) schemes, providing better SE, capacity, user fairness, connectivity, and latency, however, decoding complexity must be considered alongside system planning [16]-[18]. NOMA technique performs superposition coding at the transmitter (Tx), merging users' signals, and then manipulating successive interference cancellation (SIC) at the receiver (Rx) to remove any interference with the user's signal. The paper concentrates specifically on the impact of imperfect SIC on SIC-dependent NOMA-based systems using a simplified scheme of SWIPT-paired clustered users equipped with single-input single-output (SISO) hybrid-NOMA (H-NOMA). NOMA dedicates power fractions to users per their CSI, target rates, or other metrics, combining all the signals in the power domain. Users' clustering depends on certain parameters of users to reduce procedural complexity, significantly with THz-NOMA communications, e.g., setting main CSI as a reference to other users within a cluster [14].

To the best of the author's knowledge, such a modified system and its metrics have not yet been investigated with THz aspects, considering SIC imperfection. This work contributes to solving the SIC-dependent detection problem by proposing an

Copyright © 2022 IEEE. Personal use of this material is permitted. Permission from IEEE must be obtained for all other uses, in any current or future media, including reprinting/republishing this material for advertising or promotional purposes, creating new collective works, for resale or redistribution to servers or lists, or reuse of any copyrighted component of this work in other works.

This article has been accepted for publication in a future proceedings of this confernce, but has not been fully edited. Content may change prior to final publication. Citation information: DOI10.1109/GPECOM55404.2022.9815677, 2022 4th Global Power, Energy and Communication Conference (GPECOM)

EH-based low-cost scalable simplified system self-powered/double-regulated mobile DF relaying, lower power-consuming elements/procedures equipped with SISO instead of MIMO to minimize SIC-based decoding complexity at the Rx while enhancing EE. Further, the presented work applies a SWIPT-pairing strategy to the proposed system to achieve the best performance by integrating the promising technologies and decreasing the cluster's users (SIC operations) that is reducing computational and procedural complexities.

The paper's remainder is organized as follows; Section (II) presents a background of the associated technologies, listing a number of related works. Section (III) demonstrates the system model, deriving the related closed forms. It discusses the gains of the proposed system with the promising technologies to utilize THz communications, overcoming the challenging SIC imperfection. Section (IV) explains the implementation of the proposed system with the adopted strategies. Section (V) includes system simulation and results discussion, explaining the outperformance of the proposed system with the contribution of adopted techniques to existing systems. Finally, section (VI) summarizes the conclusion.

II. BACKGROUND

In the SISO-NOMA scheme, the base station (BS) and nodes are equipped with one antenna, considering simultaneous CSI to specify users' sequence for successful SIC at the Rx. As a multi-user detection (MUD), SIC is critically required for signal detection. It is worth noticing that the smaller number of cluster users the simpler SIC implementation we achieve, Fig. 1 explains the SIC procedure for an nth number of iterations at the Rx where it occurs upon receiving a superposed signal from numerous users with varying amounts of power. The signal strength of the SIC receiver is ranked ascendingly, however, error propagation is an issue [19].

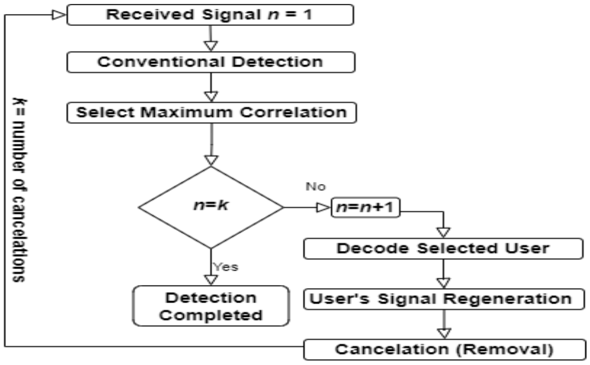

Fig. 1. SIC procedure in NOMA Rx.

H-NOMA scheme supports a variety of services more than single carrier (SC)-NOMA and OMA as a combination of these two schemes, taking full advantage of them. It is presented to overcome system constraints e.g., the potential SIC complexity with the interference of the massive number of users of SC-NOMA and resources limitation of OMA. Due to THz characteristics, researchers proposed many advanced schemes such as cooperative-NOMA. It was suggested to integrate cooperative relaying with NOMA to overcome THz issues. Cooperative-NOMA provides signal diversity, reliable connectivity, expanded coverage area, and improved SE consequently supporting users with weak (or zero) signal to noise ratio (SNR) in THz communication. Thus, integrating the energy harvesting (EH) technique with cooperative-NOMA delivers a prestigious enhancement to THz communications [20]. Cooperative networking leads to battery exhaustion of the relaying user's device (due to high computational SIC at the Rx), thus, it is reasonably required to adopt the EH technique [21]. Using EH the relaying user harvests the surrounding radiofrequency (RF) energy for retransmission. The EH power splitting protocol enables relaying user to split the power of the received signal into power harvesting (ψ) and data decoding (1-ψ) fractions to manipulate energy harvesting and information decoding simultaneously i.e., Simultaneous Wireless Information and Power Transfer (SWIPT). SWIPT improves system capacity, diversity, and reliability [22].

Recently, NOMA-based/integrated systems research considered SIC to implement perfectly, which is an impractical assumption as SIC errors occur and propagate to other signals' detection successively. THz-NOMA communications were investigated pointing out system performance and constraints by academic and industrial research. By developing an intelligent algorithm, the authors in [23] investigated clustering, precoding, and energy optimization in THz MIMO-NOMA design. Besides, the authors of [24] developed a MIMO spatial multiplexing technique based on a novel index modulation, and they investigated building high-throughput applications with high SE using MIMO. The power dedication issue is investigated in [25] using cooperative THz-MIMO-NOMA in half-duplex and full-duplex modes in order to maximize user data rates. Of late, the author's recent work in [26] proposed a similar simplified SISO system, the authors explored the effect of EH and other critical enabling approaches in increasing the performance of 6G communication systems. However, some researchers considered imperfect SIC throughout their research using NOMA-based systems. For instance, reference [27] derived a closed-form for bit error rate (BER) in the network. Transmission power optimization and reflection coefficient were studied to increase the sum rate in [28], investigating a new optimization method in [29] to enhance the system EE. In multi-cell NOMA networks, EE was intended to be increased in [30], while SE improvement was targeted in [31].

Notably, the proposed system with its integrated 6G candidate technologies has not been previously utilized under the assumption of imperfect SIC in the state-of-the-art. Based on the authors' knowledge, it achieves multiple gains sufficiently making use of all the integrated edge of technologies.

III. SYSTEM MODEL

The proposed system (shown in Fig. 2) operates in large open areas where downlink THz-NOMA small-cell with four users cluster is considered, using SISO scheme equipped with high-directional antennas. The BS superimposes signals to the served users, near users (NUs) and far users (FUs), where we assume pairing every two SWIPT-based users in a cluster, but an obstacle keeps the far two users (U1 and U2) shadowing from the BS at a given time. As a result, far users are unable to detect their signals effectively, however, the channel gains of the nearby users (U4 and U3) are sufficient. According to NOMA principles, all FUs signals must first be decoded by NUs before

SIC can be used to remove them and consequently decode NUs' data. As a result, NUs already hold copies of the FUs' data. Therefore, NUs can assist FUs in connectivity by acting as a DF relay. The energy in the NUs batteries, on the other hand, is insufficient to convey the information to the FUs. We proposed that NUs use the EH power-splitting protocol (SWIPT) to capture power from BS and RF energy surrounding them for this purpose during the next level. The entire transmission procedure is split into two parts. NUs receive the transmitted signal from BS at the first step. The power-splitting mechanism will collect a portion of NUs' received powers, while the left power will be used to decode their data. The NUs then use the captured energy to convey FUs' information to them in the second step.

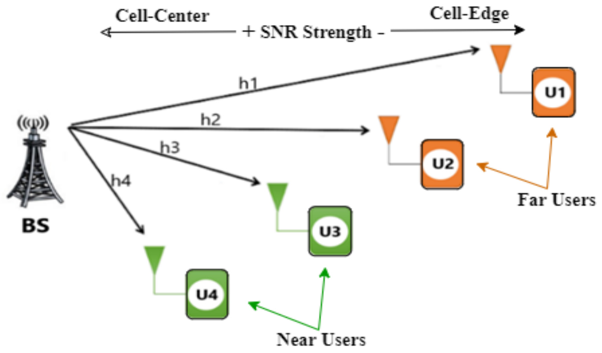

Fig. 2. SWIPT-paired H-NOMA system.

The channel model and mathematical analysis of cooperative SWIPT NOMA-THz can be found in our previous work [26].

Fig. 3 explains the concept of H-NOMA as a combination of NOMA and OMA (e.g., TDMA) schemes. It clarifies the probable pairs for the served users assumed in the proposed system model.

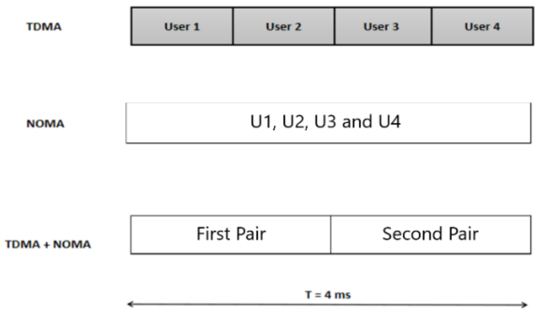

Fig. 3. Hybrid-NOMA strategies.

Based on Fig. 2 and Fig. 3, the two pairing techniques suggested are:

(1) Near-Far (N-F) pairing technique:

The N-F technique pairs BS's closest user (U4) with BS's farthest user (U1). The second closer user (U3) of BS is paired with the second farther user of BS (U2). Thus, in the first resource block, the N-F pairing method pairs U4 with U1, and in the second resource block, U3 with U2.

U4 is a NOMA near user (NU) and U1 is a NOMA far user (FU) in the first pair, but power fractions must be allotted using the constraint α4<α1. As a result, U4 must perform SIC before decoding its signal, but U1 can simply decode its signal. U3 is NOMA NU and U2 is FU in the second pair, however, power fractions must be distributed using the constraint α3<α2. As a result, U3 must execute SIC while U2 directly decodes its signal.

Within the first pair, users' achievable rates are

$$R4,nf = \frac{1}{2}log_2\left(1+\frac{P\alpha 4|h4|^2}{\sigma^2}\right) \tag{1}$$

$$R1,nf = \frac{1}{2}log_2\left(1+\frac{P\alpha 1|h1|^2}{P\alpha 4|h1|^2+\sigma^2}\right) \tag{2}$$

Similarly, for the second pair:

$$R3,nf = \frac{1}{2}log_2\left(1+\frac{P\alpha 3|h3|^2}{\sigma^2}\right) \tag{3}$$

$$R2,nf = \frac{1}{2}log_2\left(1+\frac{P\alpha 2|h2|^2}{P\alpha 3|h2|^2+\sigma^2}\right) \tag{4}$$

The sum rate is calculated as

$$Rnf = R1,nf + R2,nf + R3,nf + R4,nf \tag{5}$$

(2) Near-Near, Far-Far (N-N, F-F) pairing technique:

In this technique, the nearest user (U4) is paired with a second nearer user (U3), while the distant user (U2) is matched with a second farther user (U1). Thus, in the first resource block, the N-N, F-F pairing approach pairs U4 with U3, and in the second resource block, U2 with U1.

When compared to U3, U4 is a NOMA NU. As a result, we need to allot α4<α3. Before decoding its signal, U4 must execute SIC, whereas U3 decodes it directly. In comparison to U1, U2 is a NOMA NU within the opposite pair. As a result, we must allot α2<α1. As a result, U2 must execute SIC while U1 directly decodes its signal.

Within the first pair, users' achievable rates are

$$R4,nn = \frac{1}{2}log_2\left(1+\frac{P\alpha 4|h4|^2}{\sigma^2}\right) \tag{6}$$

$$R3,nn = \frac{1}{2}log_2\left(1+\frac{P\alpha 3|h3|^2}{P\alpha 4|h3|^2+\sigma^2}\right) \tag{7}$$

Similarly, for the second pair:

$$R2,nn = \frac{1}{2}log_2\left(1+\frac{P\alpha 2|h2|^2}{\sigma^2}\right) \tag{8}$$

$$R1,nn = \frac{1}{2}log_2\left(1+\frac{P\alpha 1|h1|^2}{P\alpha 2|h1|^2+\sigma^2}\right) \tag{9}$$

The sum rate is calculated as

$$Rnn = R1,nn + R2,nn + R3,nn + R4,nn \tag{10}$$

THz atmospheric attenuation and molecular absorption are taken into consideration in signal modeling of cooperative SWIPT H-NOMA [32]. As the path loss of the Non-Line-of-Site path (NLoS) is significantly greater than that of the Line-of-Site (LoS) path, NLoS impact may be neglected if the LoS path takes precedence [22]. Hence, THz total losses value is set very high.

Based on the Physical layer section THz for high-data-rate communications aimed for bandwidth-demanding applications such as wireless backhaul/backhaul, fronthaul/backhaul, or data center links [33]. Due to free-space effects, [34] split the THz spectrum into 69 overlapping channels with 8 bandwidths (2.16 - 69 GHz) based on THz spectral windows (252.72 – 321.84) GHz. BPSK and QPSK modulations are required in THz-SC PHY; therefore, we use the simplest scheme (BPSK) to achieve the trade-off between scale and efficiency [33].

IV. IMPLEMENTATION

The impact of the SWIPT-pairing strategy in conventional NOMA, OMA (TDMA), and H-NOMA schemes based on Fig. 3 were studied. For the four users, distant users (i.e., U1 and U2) and the near users (i.e., U3 and U4), the users' associated transmission channels (i.e., h1, h2, h3, and h4). The approach serves the farthest blocked users (or distant users in the cell edge with weak SNR).

A. *NOMA Users' Capacities*

The first system implementation examines the performance of all the served users in Fig. 2, considering them as SWIPT-based NOMA relaying users (near users). Achievable capacities of individual users will be studied when performing SIC to explore the procedural complexity and the influence of SIC imperfection on SIC-dependent signal detection.

B. *H-NOMA Vs. Other multiple-access schemes*

The second system implementation examines each possible SWIPT-pairs of users in Fig. 2 using the H-NOMA concept in Fig. 3, e.g., (N-F) and (N-N, F-F) techniques. We Investigate the feasibility of applying H-NOMA (studying the best SWIPT-pairing strategy) to the proposed system to achieve the best performance, overcoming conventional NOMA and OMA challenges. This Utilizes all the possible SWIPT pairs with the available line-of-site (LoS) users to specify the best pairing, achieving the best performance.

The simulation scenarios are as follows (parameters can be found in [26]):

The first simulation is to prove the validity of using H-NOMA instead of NOMA for the same purpose to gain the utmost benefits as compared to conventional NOMA or TDMA, comparing the sum-throughput with the mathematical analysis. Then we simulate the paper's main scenario to investigate the three possible SWIPT pairs with the blocked user (U1), using parameters' values of frequency, BW, power, and distance to compare the system performance of every pair.

Hence: 1) Transmit Power, frequency, Bandwidth, and distance are adjustable. 2) High Path loss is assumed eta = 4 (adjustable depending on the use case). the absorption coefficient is found in [25]. The simulations were implemented by the MATLAB program. Fig. 3 shows H-NOMA pairing strategies.

V. SIMULATION RESULTS

We simulate the proposed system model to prove the validity of system compatibility. All possible SWIPT pairs for the two far users (U1 and U2) are studied (i.e., pairing techniques). We examine system performance considering some factors that THz communication provides. When the far nodes' links fail to connect to the BS due to an obstruction, the proposed solution should allow them to keep communicating. We investigate how this simple and scalable system may be used to control THz transmission restrictions, demonstrating how it can increase SE, EE, reliability, and overall performance. In comparison to traditional systems, the simulation results validate the derived closed-form of the optimized system.

A. *NOMA Users' Capacities*

The first implementation shown in Fig. 4 represents the achievable rates of SWIPT-based individual users as NUs when performing SIC the farthest user is assumed as relaying user for a default far user (i.e., assumed perfect-SIC).

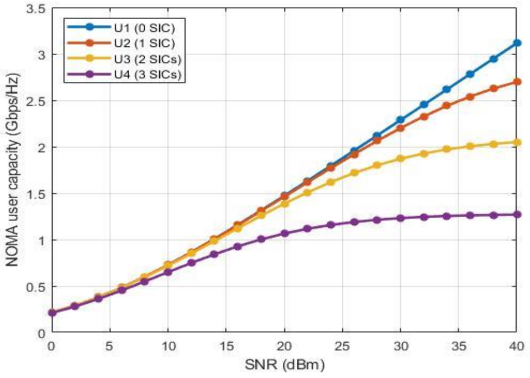

Fig. 4. NOMA Users' Capacities Vs SNR.

Fig. 4 depicts users' performance individually performing as NOMA relaying NUs. The farthest user (U1) shows the best performance as SIC is perfectly implemented (i.e., there is not any interference from other users' signals or sequential SIC errors propagated from previous SIC operations) and ultimately, SIC imperfection does not affect its capacity. However, the users U2, U3, and U4 show a gradual degradation to the rates because of the interference of the far users' remaining signal that will be considered as an additional noise to them in case of imperfect SIC. That demonstrates the detrimental impact of SIC accuracy on signal detection due to the interference of the farther users' residues with the SIC-dependent decoded signal. It clarifies the fact that achievable rates' degradation is proportional to SIC error propagation.

B. *H-NOMA Vs. Other multiple-access schemes*

In this section, we simulate H-NOMA strategies of Conventional Single-Carrier NOMA (SC-NOMA) and OMA (TDMA) in Fig. 5 to validate the idea behind using the best scheme and pairing strategy compared to other multiple-access schemes based on the scenario shown in Fig. 2 and Fig. 3.

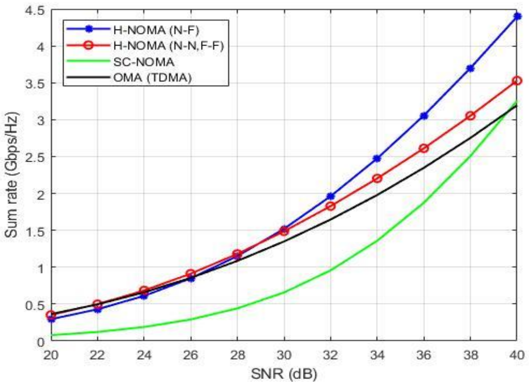

Fig. 5. System SE Vs. SNR of H-NOMA strategies, NOMA, and OMA.

According to the comparison in Fig. 5, it could be noticed that NOMA (N-F) strategy outperforms the other strategies in certain cases, meaningfully with THz. It confirms the possibility of taking full advantage of NOMA when the channel conditions difference between NUs and FUs are distinct. With (N-N, F-F) strategy, NOMA still performs better than TDMA, but without a significant improvement. The performance of SC-NOMA is not sufficient because of the interference due to the overloading of users sharing one carrier and the complex error propagating SICs, which accordingly cause interference and complexity issues. Therefore, it is not preferable to increase the number of served users within a single cluster while using a single carrier. However, the SWIPT-paired (two-user clustering) strategy shows a noticeable enhancement of SE and accordingly EE, the harvested power in the SWIPT-based NU is entirely allocated to the FU throughout the relaying stage.

VI. CONCLUSION

The deployment of promising technologies comes with a cost, especially with complex power-consuming systems. This paper started with studying the impact of the complicated SIC imperfection on such systems. It utilized the best THz H-NOMA SWIPT-paired strategy for all the served users. The results addressed the significant strategy to overcome the limitation of SC-NOMA and THz to achieve the intended objectives, adapting to the potential wireless systems of the next generations. Then, all the possible SWIPT-pairing candidate users of the cooperative THz H-NOMA were thoroughly studied. It was practically proven that the best SWIPT DF relaying user is the nearest possible user to the BS, which provides the best system performance amongst all the available users (addressed in our previous work). Moreover, the paper demonstrated the importance of adopting the proposed strategy, examining how it managed to select the SWITP-pairing for the two-user cluster. Pairing depends on the NU's location and channel condition to achieve the best system performance e.g., maximal EE and SE resulting from leveraging the promising techniques. The results stated the enhancement of overall performance as compared to the existing systems (EE with SE were enhanced by 75%), taking into consideration all the comparative metrics. This work has proven the validity of the proposed techniques for reliable THz communications, improving system performance and SIC precision.

Furthermore, the proposed system outperformed MIMO-NOMA with FD/HD with simpler, lower-cost/complexity, and higher SE/EE. In a brief contrast, MIMO-NOMA with FD/HD reached the targeted reference point (i.e., 1 Gbps) using more SNR (i.e., 60 dBm) with a data-rate of 1 Mbps using 20 dBm, whereas the proposed work reached that reference point using an SNR of 26 dBm, achieving much more data-rate (i.e., 1 Gbps) for all the users separately using only 16 dBm of SNR. That is demonstrating the value of the EH approach and low-complexed clustering as a beneficial addition to the state-of-the-art.

REFERENCES

[1] S. Han, T. Xie, and I. Chih-Lin, "Greener Physical Layer Technologies for 6G Mobile Communications," *IEEE Communication Magazine*, Vol. 58, Issue 4, pp. 68-74, May 2021.

[2] W. Jiang, B. Han, M. A. Habibi, and H. D. Schotten, "The Road Towards 6G: A Comprehensive Survey," *IEEE Open Journal of the Communications Society*, Vol. 2, pp. 334-366, Feb. 2021.

[3] M. Alsabah et al., "6G Wireless Communications Networks: A Comprehensive Survey," *IEEE Access*, Vol. 9, pp. 148191-148243, Nov. 2021.

[4] C. de Alwis et al., "Survey on 6G Frontiers: Trends, Applications, Requirements, Technologies and Future Research," *IEEE Open Journal of the Communications Society*, Vol. 2, pp. 836-886, April 2021.

[5] Y. Liu et al., "Evolution of NOMA Toward Next Generation Multiple Access (NGMA) for 6G," *IEEE Journal On Selected Areas In Communications*, Vol. 40, Issue 4, pp. 1037-1071, Jan. 2022.

[6] I. F. Akyildiz, A. Kak , and S. Nie, "6G and Beyond: The Future of Wireless Communications Systems," *IEEE Access*, Vol. 8, pp. 133995-134030, Jul. 2020.

[7] Y. Liu, F. Liu, G. Zhu, X. Wang, and Y. Jiao, "Dynamic power optimization of pilot and data for downlink OFDMA systems," *IEEE Journal of Communications and Networks*, Vol. 23, Issue 4, pp. 250-259, Aug. 2021.

[8] T. S. Rappaport et al., "Wireless Communication and Applications Above100 GHz: Opportunities and Challenges for 6G and Beyond," *IEEE Access*, Vol. 7, pp. 78729-78757, June 2019.

[9] P. Chatzimisios, D. Soldani, A. Jamalipour, A. Manzalini, and S. K. Das, "Special issue on 6G wireless systems," *IEEE Journal of Communications and Networks*, Vol. 22, No. 6, pp. 440-443, Dec. 2020.

[10] D. Darsena, G. Gelli, and F. Verde, "Design and performance analysis of multiple-relay cooperative MIMO networks," *IEEE Journal of Communications and Networks*, Vol. 21, No. 1, pp. 25-32, April 2019.

[11] Y. Sun and B. Cyr, "Sampling for data freshness optimization: Non-linear age functions," *IEEE Journal of Communications and Networks*, Vol. 21, No. 3, pp. 204-219, July 2019.

[12] G. Gur, "Expansive Networks: Exploiting Spectrum Sharing for Capacity Boost and 6G Vision," *IEEE Journal of Communications and Networks*, Vol. 22, No. 6, pp. 444-454, Dec. 2020.

[13] H. Elayan, O. Amin, B. Shihada, R. M. Shubair, M. S. Alouini, "Terahertz Band: The Last Piece of RF Spectrum Puzzle for Communication Systems," *IEEE Open Journal of the Communication Society*, Vol. 1, pp. 1-32, Jan. 2020.

[14] H. Sarieddeen, M. S. Alouini, T. Y. Al-Naffouri, "An Overview of Signal Processing Techniques for Terahertz Communications," *Proceedings of the IEEE*, Vol. 109, 10, pp. 1628-1665, Aug. 2021.

[15] H. Tataria, M. Shafi, A. F. Molisch, M. Dohler, H. Sjöland, and F. Tufvesson, "6G Wireless Systems: Vision, Requirements, Challenges, Insights, and Opportunities," *Proceedings of the IEEE*, Vol. 109, Issue 7, pp. 1166-1199, July 2021.

[16] A. Krishnamoorthy, R. Schober, "Uplink and Downlink MIMO-NOMA with Simultaneous Triangularization," *IEEE Transactions on Wireless Communications*, Vol. 20, No. 6, pp. 3381-3396, June 2021.

[17] H. W. Oleiwi, D. N. Mhawi, and N. A. Saeed, "Comparative Investigation on Different QoS Mechanisms in Multi-homed Networks," *Iraqi Journal of Industrial Research*, Vol. 9, pp. 1-10, 2022.

This article has been accepted for publication in a future proceedings of this confernce, but has not been fully edited. Content may change prior to final publication. Citation information: DOI10.1109/GPECOM55404.2022.9815677, 2022 4th Global Power, Energy and Communication Conference (GPECOM)

[18] H. W. Oleiwi, N. Saeed, and D. N. Mhawi, "An Enhanced Interface Selectivity Technique to Improve the QoS for the Multi-homed Node," *Engineering and Technology Journal*, In Press, 2022.

[19] O. Maraqa, A. S. Rajasekaran, S. Al-Ahmadi, H. Yanikomeroglu, and S. M. Sait, "A Survey of Rate-Optimal Power Domain NOMA with Enabling Technologies of Future Wireless Networks," *IEEE Communications Surveys & Tutorials*, Vol. 22, No. 4, pp. 2192-2235, Aug. 2020.

[20] M. Liaqat, K. A. Noordin, T. Abdul Latef, and K. Dimyati, "Power-domain non orthogonal multiple access (PD-NOMA) in cooperative networks: an overview," *Springer Wireless Networks*, Vol. 26, pp. 181-203, 2020.

[21] Y. Liu and M. Elkashlan, "On the application of SWIPT in NOMA networks," (chapter 6, book: Wireless information and power transfer: theory and practice, *Wiley Telecom*) (pp. 99-120).

[22] D. Tri Nhu and A. Beongku," Optimal Sum-Throughput Analysis for Downlink Cooperative SWIPT NOMA Systems," *IEEE 2nd International Conference on Recent Advances in Signal Processing, Telecommunications & Computing (SigTelCom)*, March 2018.

[23] H. Zhang, Haisen Zhang, W. Liu, K. Long, J. Dong, and V. C. M. Leung," Energy Efficient User Clustering, Hybrid Precoding and Power Optimization in Terahertz MIMO-NOMA Systems," *IEEE Journal on selected areas in communications*, Vol. 38, No. 9, pp. 2074-2085, Sep. 2020.

[24] M. Saad, N. Al Akkad, H. Hijazi, A. C. Al Ghouwayel, F. Bader and J. Palicot, "Novel MIMO Technique for Wireless Terabits Systems in sub-THz Band," *IEEE Journal Transactions on Vehicular Technology*, Vol. 2, pp.125-139, Jan. 2021.

[25] O. Elkharbotly, E. Maher, A. El-Mahdy, F. Dressler, "Optimal Power Allocation in Cooperative MIMO-NOMA with FD/HD Relaying in THz Communications," *IEEE 2020 9th IFIP International Conference on Performance Evaluation and Modeling in Wireless Networks (PEMWN)*, Dec. 2020.

[26] H. W. Oleiwi and H. Al-Raweshidy, "Cooperative SWIPT THz-NOMA / 6G Performance Analysis," *Electronics, MDPI*, Vol. 11, No. 6, pp. 873, March 2022.

[27] A. W. Nazar et al., "BER analysis of a backscatter communication system with non-orthogonal multiple access," *IEEE Transaction on Green Communication Networks*, Vol. 5, Issue 2, pp. 574-586, March 2021.

[28] W. U. Khan et al., "Backscatter-enabled NOMA for future 6G systems: A new optimization framework under imperfect SIC," IEEE Communication Letters, Vol. 25, Issue 5, pp. 1669-1672, Jan. 2021.

[29] W. U. Khan et al., "Energy-efficient resource allocation for 6G backscatter-enabled NOMA IoV networks," *IEEE Transactions on Intelligent Transportation Systems*, Early Access, pp. 1-11, Sep. 2021.

[30] M. Ahmed et al., "Backscatter sensors communication for 6G low-powered NOMA-enabled IoT networks under imperfect SIC," *arXiv preprint* arXiv:2109.12711, Sep. 2021.

[31] W. U. Khan et al., "Integration of backscatter communication with multi-cell NOMA: A spectral efficiency optimization under imperfect SIC," *arXiv preprint* arXiv:2109.11509, Sep. 2021.

[32] Z. Ding, P. Fan, and H. V. Poor, "Impact of User Pairing on 5G Nonorthogonal Multiple-Access Downlink Transmissions," *IEEE Transactions on Vehicular Technology*, Vol. 65, Issue 8, pp. 6010-6023, Aug. 2016.

[33] IEEE Std. "802.15.3d-2017 – IEEE Standard for High Data Rate Wireless Multi-Media Networks–Amendment 2: 100 Gb/s Wireless Switched Point-to-Point Physical Layer," *IEEE Standards*, Oct. 2017.

[34] Vitaly Petrov, Thomas Kurner, Iwao Hosako, "IEEE 802.15.3d: First Standardization Efforts for Sub-Terahertz Band Communications toward 6G," *IEEE Communications Magazine*, Vol. 58, Issue 11, pp. 28-33, Nov. 2020.