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Noma-Based Energy-Efficient Wireless Powered Communications

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ABSTRACT

In this paper, we study the performance of non-orthogonal multiple access (NOMA) schemes in wireless powered communication networks (WPCN) focusing on the system energy efficiency (EE). We consider multiple energy harvesting user equipments (UEs) that operate based on harvest-then-transmit protocol. The uplink information transfer is carried out by using power-domain multiplexing, and the receiver decodes each UE's data in such a way that the UE with the best channel gain is decoded without interference. In order to determine optimal resource allocation strategies, we formulate optimization problems considering two models, namely half-duplex and asynchronous transmission, based on how downlink and uplink operations are coordinated. In both cases, we have concave-linear fractional problems, and hence Dinkelbach's method can be applied to obtain the globally optimal solutions. Thus, we first derive analytical expressions for the harvesting interval, and then we provide an algorithm to describe the complete procedure. Furthermore, we incorporate delay-limited sources and investigate the impact of statistical queuing constraints on the energy-efficient allocation of operating intervals. We formulate an optimization problem that maximizes the system effective-EE while UEs are applying NOMA scheme for uplink information transfer. Since the problem satisfies pseudo-concavity, we provide an iterative algorithm using bisection method to determine the unique solution. In the numerical results, we observe that broadcasting at higher power level is more energy efficient for WPCN with uplink NOMA. Additionally, exponential decay QoS parameter has considerable impact on the optimal solution, and in the presence of strict constraints, more time is allocated for downlink interval under half-duplex operation with uplink TDMA mode.

I. INTRODUCTION

Wireless power transfer (WPT) is considered as a promising solution to remotely energize low-power consuming devices that might be equipped with limited-size rechargeable batteries or do not have any embedded power source at all. Additionally, WPT is more convenient to perform when wired connections are not feasible or regular battery replacement is not easily accessible, e.g., for sensors implanted in human body. In principle, WPT is carried out using electromagnetic waves or radio signals, and hence the performance depends on the wireless link characteristics and receiving circuitry design. In recent years, numerous studies in the literature have provided concrete theoretical frameworks and promising numerical results on wireless power transfer and energy harvesting (see e.g., [1] - [3] and references therein).

As mentioned above, one advantage of WPT is to support wireless-powered communications. Each node, in these type of networks, harvests energy from either a dedicated wireless power source or ambient RF signals, and then transfers information uplink to the receiving node. Indeed, incorporating wireless-power transfer to support information transmission has a direct impact on optimal parameter values and resource allocation strategies. Hence, it is necessary to determine the optimal policies and analyze the

corresponding performance characteristics [4].Several studies in the literature investigated the feasibility and design of the transmission protocol, design of the receiving rectifier circuit, and downlink and uplink operation strategies of wireless-powered communication networks. The authors in [5] proposed harvest-then-transmit protocol in which an access point (AP) broadcasts wireless power to multiple users that aim to transfer information through uplink channels. In this work, the authors illustrated doubly near-far problem, i.e., sum-rate capacity maximization benefited nearby users and optimal solution encouraged to allocate more time to these users. A similar protocol was employed in [6] to operate remote devices introducing average symbol error rate as a constraint while formulating an optimization problem to determine the optimal time allocation that maximizes the throughput. Further related works were presented in [7] and [8] considering multiple users that are equipped with multiple antennas, but downlink energy broadcast and uplink information transfer operations are carried out over orthogonal time intervals. Meanwhile, deploying multiple antennas at the AP or base station (BS) provides the opportunity to carry out these operations in full-duplex mode. In [9], the authors
considered hybrid-AP that consists of two antennas to support simultaneous wireless power transfer and uplink information decoding, and incorporate the effect of self-interference as well. Each user transmitted data following the TDMA scheme, and harvested energy as long as it was not scheduled for transmission and any extra energy at the end of each block duration was stored for the next operation cycle. Similar work was presented in [10] assuming that each user harvested energy only before it started data transmission and the harvested energy was fully utilized in each frame interval. Meanwhile, impact of statistical queuing constraints, parameterized by the quality of service (QoS) exponent, on the optimal harvesting interval for wireless information and power transfer was investigated in [11] where we considered half-duplex downlink- uplink operation coordination, and formulated a convex optimization problem. However, due to the difficulty in obtaining closed-form expressions, we designed an algorithm to determine the optimal solution.

All these and related studies provide detailed analysis and interesting results considering either time/frequency- division multiplexed transmission schemes, or in general orthogonal multiple access. However, non-orthogonal multiple access (NOMA) has recently attracted much interest from both academia and industry as one of
the prominent solutions for future 5G wireless networks as it enhances spectral efficiency. As discussed in the literature, NOMA is categorized into power-domain and code-domain NOMA based on how users' data multiplexing is achieved [12], and it can be applied to both downlink and uplink operations. In principle, power-domain NOMA utilizes superposition coding (SC) at the transmitter and successive interference cancellation (SIC) at the receiver, and this allows multiple users to transmit information on the same sub- carrier channel simultaneously. The decoding order for SIC depends on the channel characteristics of the wireless link between each transmitter-receiver pair, i.e., the main idea is that information transmitted to the receiver with the strongest wireless link is decoded without interference. In [13], the authors provided the basics of power-domain NOMA scheme and discussed possible solutions to address the challenges that could be experienced while applying this technique. Similarly, the authors in [14] focused on power- domain NOMA with downlink operation,

i.e., SC at the transmitter and SIC at the receivers. Another related work was presented in [15] considering both power and channel allocation in a downlink cellular system. Meanwhile, the authors in [16] introduced and explicitly formulated the concept of power division multiple access (PDMA), and they proposed orthogonal PDMA protocol based on bit-orthogonality principle. In addition, they compared the energy efficiency of the proposed approach with conventional time/frequency division multiple access techniques. In fact, most of the above mentioned studies analyzed the throughput to characterize and compare the performances obtained using different approaches. However, in the presence of limited power resources, efficient utilization of the available energy to transfer each bit of information is also necessary. Hence, several studies in the literature considered energy efficiency as a compelling performance metric to design optimal resource allocation strategies for future wireless networks [17]. More specifically, the authors in [18] considered heterogeneous radio access networks, and characterized the system energy efficiency in a setting in which the cloud center transferred information downlink to different types of base stations using NOMA scheme. In this work, it is argued that system energy efficiency under NOMA depends on the number of base stations in each type, and a heuristic algorithm is proposed to sequentially determine the optimal number of base stations for each type. Energy efficient resource allocation for downlink NOMA system were also presented in [19] and [22]. The authors in [20] proposed a low-complexity suboptimal algorithm for sub-channel assignment and power allocation, whereas the authors in [22] took into account minimum required data rate for each user. A related work was presented in [21] considering fading MIMO channels. Additional references on the NOMA scheme can be found in the literature e.g., in [26] and [27]. Meanwhile, several studies have addressed the issue in regard to WPCN. In [23], uplink NOMA is introduced for wireless powered communications where uplink and downlink operations are carried out over non-overlapping intervals, and the authors formulated optimization problems which maximize the throughput. The authors in [25] studied the joint design of time allocation, downlink energy beamforming and receiver beamforming in wireless powered communication networks employing uplink NOMA. In this work, the formulated optimization problem focused on obtaining a solution that maximizes the sum rate capacity, but because of the non-convexity of the problem, an iterative algorithm was proposed. Similarly, joint optimization of base station transmit power and operating intervals for uplink NOMA in WPCNs was considered in [24]. Yet, despite these works, the impact of NOMA on the system energy efficiency (EE) in the presence of wireless-powered users has not been investigated, to the best of our knowledge. Hence, with this motivation, we study the energy-efficient time allocation strategies for WPCN with uplink power-domain NOMA. More specifically, we consider two scenarios, namely half duplex and asynchronous

transmission, based on the coordination of uplink and downlink operations, and we compare the performance gains achieved by these approaches with the conventional TDMA scheme.

2-INTRODUCTION TO NOMA

NOMA Description

NOMA or Non-Orthogonal Multiple Access, is an advanced multiple access technique used in wireless communication systems, particularly in 5G and beyond, to improve spectrum efficiency and user connectivity. Non-orthogonal multiple access

(NOMA) has been identified as an upcoming physical layer communication scheme and is visualized to be an essential part of 5G wireless communication systems. The benefit of NOMA is to serve multiple users at the same time/frequency/code, but with different power levels, which yields a significant spectral efficiency gain over conventional orthogonal multiple access. In NOMA, the user that has the highest effective channel gain will be treated as the highest priority in the sequence, while the user with the least channel gain will be positioned last in the queue. The remaining users will be placed in the queue in accordance with their degree of effective channel gain. One of the biggest benefits of NOMA is that it helps users that have a weak signal by allocating a higher fraction of power to it. In conventional systems that are based on orthogonal multiple access (OMA) schemes, users are unable to access a given frame once it has been allocated to a certain user. This has a negative impact upon the total system throughput. However, when NOMA is employed, users that have a strong signal are able to transmit data via a slot that has already been allocated to a user that has a weaker signal. Assigning the users to slots in this way will not have a negative impact on the performance of the weaker user that has already experienced the effect of channel fading. Furthermore, the user that has a stronger signal will avoid any interference caused by the poor signal due to the application of a successive interference cancellation (SIC) operation. As such, the efficient allocation of resources in this manner will enhance the overall data rate of the system.

review of the previous studies, while the data rate for cooperative NOMA describes the proposed system model. In the optimization of EE cooperative NOMA energy harvesting is illustrated.

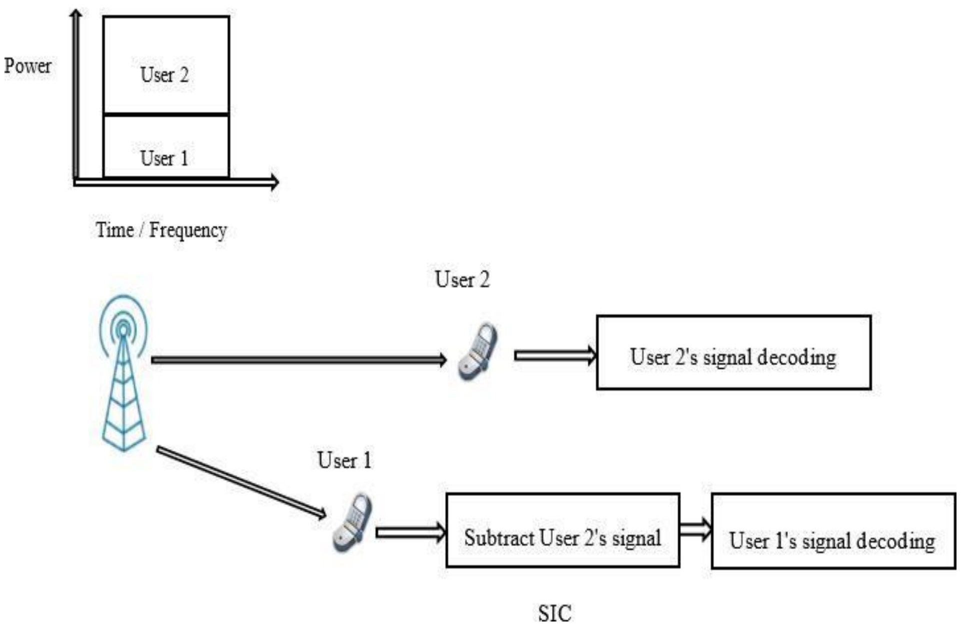

Fig 2.1: Downlink non-orthogonal multiple access (NOMA) for near and far users.

Features of NOMA Communication:

Non-Orthogonal Transmission:

Unlike traditional multiple access methods (like TDMA, FDMA, and CDMA), where resources are orthogonally divided among users, NOMA allows multiple users to share the same time, frequency, and code resources simultaneously.

NOMA's defining feature is its use of non-orthogonal transmission, where multiple users share the same time, frequency, or code resources by multiplexing their signals in the power domain.

Unlike orthogonal multiple access (OMA) schemes like TDMA or FDMA, where resources are divided exclusively among users, NOMA allows simultaneous transmission by assigning different power levels to different users based on their channel conditions.

Users with weaker channels are typically allocated more power, while those with stronger channels receive less power and use successive interference cancellation (SIC) at the receiver to decode and remove signals intended for others.

Superposition Coding:

NOMA employs superposition coding at the transmitter side, where multiple signals for different users are combined into a single transmitted signal with different power levels.

Applications

- 5G networks and beyond, for enhancing network capacity and supporting massive connectivity.
- Internet of Things (IoT), where a large number of devices need to be connected simultaneously.
- Ultra-reliable low-latency communication (URLLC) scenarios.
- NOMA communication is a key technology for modern wireless networks, addressing the increasing demand for higher data rates and connectivity in next-generation networks.

3-NOMA-ENHANCED ENERGY HARVESTING COMMUNICATION

Existing System

Before the advent of Non-Orthogonal Multiple Access (NOMA), wireless communication systems relied on various orthogonal multiple access techniques, such as Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA), and Code Division Multiple Access (CDMA). TDMA divided the time into slots, allowing each user to transmit in a specific time slot, while FDMA allocated distinct frequency bands to users to prevent interference. CDMA, on the other hand, spread each user's signal across the entire frequency band using unique codes, allowing multiple users to transmit simultaneously. Other techniques like Orthogonal Frequency Division Multiple Access (OFDMA) Here are five limitations of the older multiple access techniques compared to NOMA: Inefficient Resource Utilization: In TDMA and FDMA, resources are allocated statically, leading to underutilization when users do not fully occupy their assigned time slots or frequency bands.

Limited User Capacity: CDMA suffers from increased interference and reduced performance as the number of users increases, limiting the number of users that can be supported simultaneously.

Proposed System

Bit Error Rate (BER) performance between Non-Orthogonal Multiple Access (NOMA) and Orthogonal Multiple Access (OMA) techniques in a wireless communication system. The system uses OFDM (Orthogonal Frequency Division Multiplexing) blocks for transmission and considers two users with different distances from a base station. The code evaluates the effect of Signal-to- Noise Ratio (SNR) on the BER for both access techniques.

System Model Design

- Develop a NOMA (Non-Orthogonal Multiple Access) wireless communication framework.
- Incorporate a Wireless Power Transfer (WPT) mechanism where users harvest energy from a dedicated power transmitter.
- Divide users into strong and weak channel conditions to enable the NOMA principle:
- Weak users: Harvest power from signals.
- Strong users: Decode signals using successive interference cancellation (SIC).

4-RESULTS AND DISCUSSION

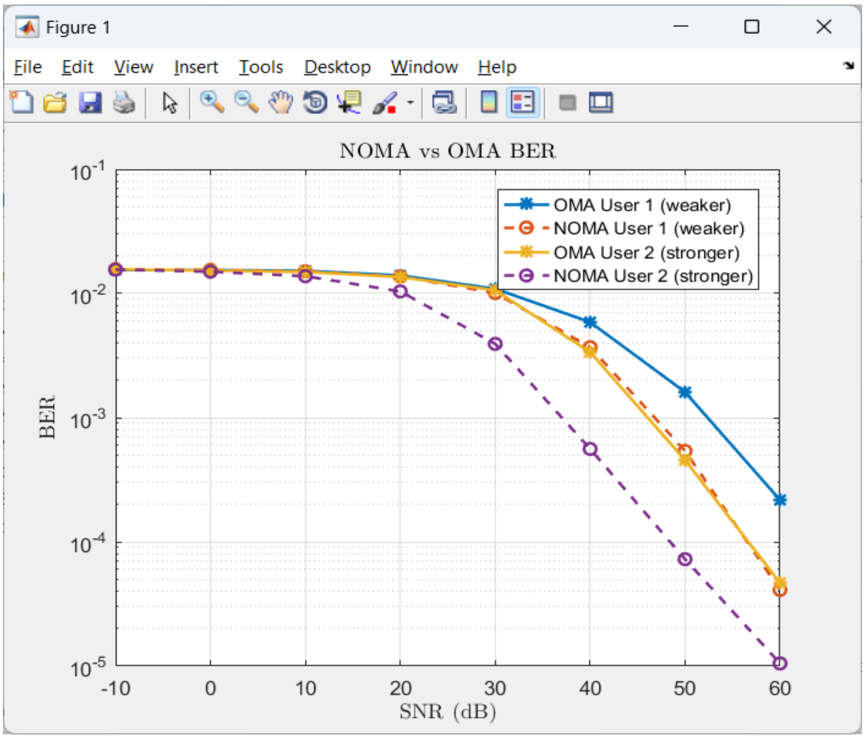

Fig 1: BER comparison for 2 users with OMA and NOMA

This Above Fig 6.1 compares the Bit Error Rate (BER) performance of Non-Orthogonal Multiple Access (NOMA) and Orthogonal Multiple Access (OMA) systems for a two-user scenario using Orthogonal Frequency Division Multiplexing (OFDM) blocks. The script begins by defining the parameters such as user distances from the base station, the number of symbols, subcarriers, cyclic prefix length, channel length, and Signal-to-Noise Ratio (SNR) range. It then initializes arrays to store the channel responses, user data, and signals for both NOMA and OMA simulations.

In the NOMA simulation, the code performs the superposition of the signals for two users with different power allocation factors, followed by transmission through a Rayleigh fading channel. The receiver employs Successive Interference Cancellation (SIC) to decode the signals, separating the stronger signal from the weaker one to reduce interference. The BER for each user across varying SNR levels is computed by comparing the transmitted and received symbols and is averaged over multiple blocks to obtain accurate results.

For the OMA simulation, the code handles each user's signal separately with dedicated resources, eliminating the need for SIC. The signals undergo similar processes, including BPSK modulation, channel modeling, and noise addition. The BER is calculated for each user independently. Finally, the script plots the BER versus SNR for both NOMA and OMA, showcasing the performance difference between the two multiple access schemes, with NOMA expected to offer better spectral efficiency and performance in certain conditions.

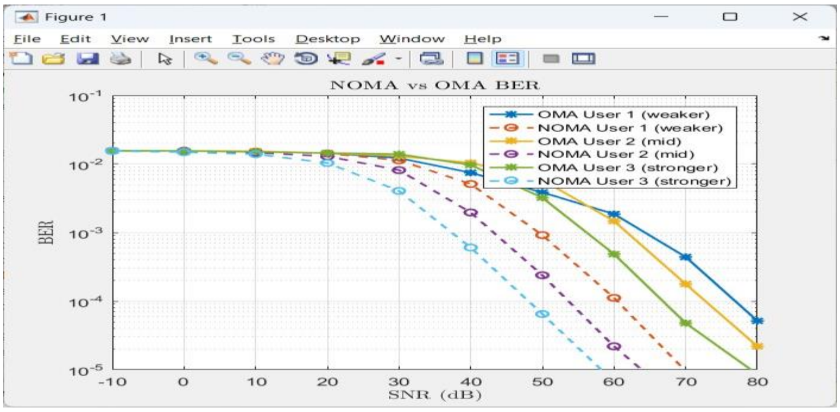

Fig2: BER comparison for 3 users with OMA and NOMA

From the above fig 6.2 simulation provide a comprehensive comparison between Non-Orthogonal Multiple Access (NOMA) and Orthogonal Multiple Access (OMA) in terms of Bit Error Rate (BER) across different Signal-to-Noise Ratio (SNR) levels for a three-user scenario using OFDM blocks. The analysis highlights the BER performance for users positioned at different distances from the base station, thereby reflecting the influence of path loss and interference on system performance.

In the NOMA scenario, users are assigned different power levels, with the user closest to the base station (stronger user) receiving the least power, while the user furthest (weaker user) receives the most. The simulation implements Successive Interference Cancellation (SIC) at the receivers, where each user decodes and cancels the signals of other users starting from the strongest to the weakest, before decoding their own signal. This technique significantly enhances the performance of users, particularly the weaker ones, by allowing them to decode their signals with reduced interference.

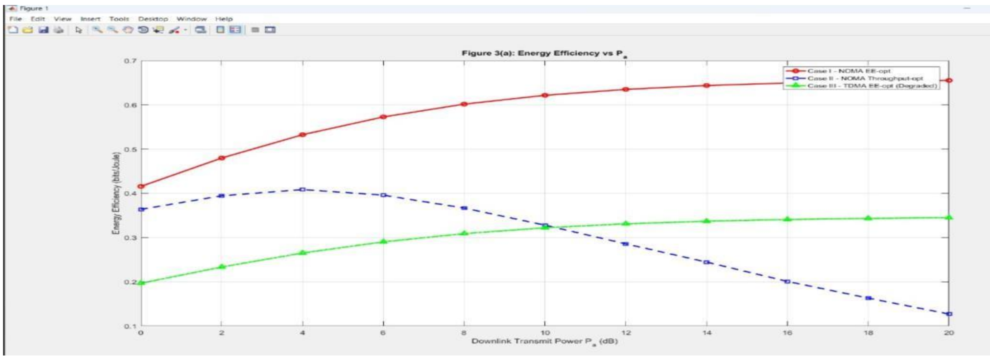

Fig 3: Average energy efficiency vs. Pa

Figure 6.3 presents a detailed comparison of energy efficiency performance for three distinct transmission strategies—EE-optimized NOMA (Case I), throughput-optimized NOMA (Case II), and EE-optimized

TDMA (Case III)—as a function of the downlink transmit power Pa, measured in decibels (dB). Energy efficiency, defined in bits per Joule, serves as a key metric to evaluate how effectively each system utilizes its energy resources for data transmission. In Case I, the red curve demonstrates that energy efficiency consistently improves with increasing Pa, ultimately reaching a saturation point at higher power levels. This trend indicates that optimizing NOMA for energy efficiency enables the system to maximize the number of bits transmitted per unit of energy consumed, making it the most efficient among the three cases. In Case II, the blue dashed curve, representing throughput-optimized NOMA, initially shows an increase in energy efficiency with rising Pa; however, after a certain threshold (around 6 dB), the efficiency declines. This decline results from a mismatch between the rising energy expenditure and the relatively slower growth in throughput, underscoring the trade-off that exists when prioritizing throughput over energy efficiency. In contrast, Case III, depicted by the green curve for a degraded TDMA system, shows a slow but steady increase in energy efficiency that remains consistently lower than both NOMA-based approaches. This is attributed to poorer channel conditions, reduced energy harvesting capability, and higher circuit power consumption in the TDMA scenario. Overall, the figure clearly highlights the superiority of NOMA when carefully optimized for energy efficiency, as it delivers substantial performance gains compared to both traditional TDMA and throughput-centric NOMA, especially in energy-constrained wireless-powered communication networks. Expanding further, the performance trends observed in Figure 3(a) provide valuable insights into the design and selection of access schemes for wireless-powered communication systems, where energy constraints and sustainability are critical considerations. The superiority of Case I—energy- efficient NOMA—is not only evident in its higher energy efficiency values but also in its scalability with increasing transmit power. This is primarily due to NOMA's ability to serve multiple users simultaneously on the same frequency band via power-domain multiplexing, which, when coupled with optimized time allocation and harvesting strategies, allows the system to better utilize the harvested energy. The adoption of successive interference cancellation (SIC) at the receiver end further enhances the decoding process, allowing stronger users to cancel interference from weaker users and improve overall data throughput without compromising energy efficiency.

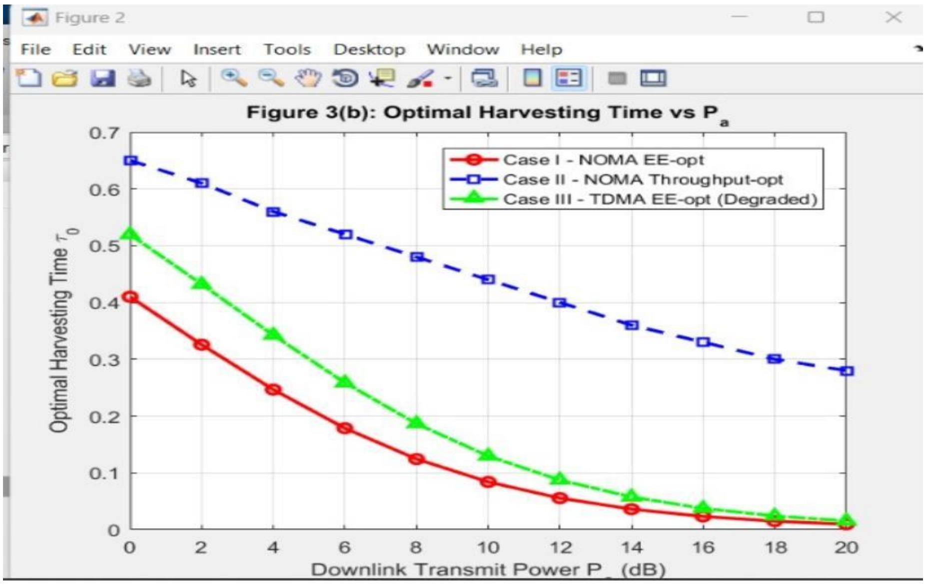

Fig 4: Optimal harvesting time vs. Pa

Figure 6.4 illustrates the relationship between downlink transmit power Pa (in dB) and the optimal harvesting time τ0 in wireless-powered communication networks for three different cases: Case I (NOMA energy efficiency-optimized), Case II (NOMA throughput-optimized), and Case III (TDMA energy efficiency-optimized with degraded parameters). The optimal harvesting time τ0 represents the fraction of time allocated to energy harvesting before data transmission begins. This parameter is crucial in wireless- powered systems, where devices must first harvest energy from a downlink signal before they can transmit any data.

As shown in the graph, for all three cases, the optimal harvesting time decreases as the downlink transmit power Pa increases. This is because higher transmit power allows devices to harvest sufficient energy in a shorter time, thereby allocating more time for data transmission. Among the three schemes, Case I (NOMA EE-opt), shown in red, consistently maintains the lowest harvesting time across the entire power range. This indicates that the EE-optimized NOMA scheme is able to harvest energy more efficiently and switch to data transmission faster, reflecting its superior resource utilization and optimal balance between energy harvesting and throughput.

On the other hand, Case II (NOMA throughput-opt), shown in blue, requires the highest harvesting time. This is because this scheme prioritizes maximizing throughput, often resulting in suboptimal energy consumption, and thus needs a longer duration to accumulate sufficient energy before transmission. Case III (TDMA EE-opt, degraded), shown in green, lies between the other two, with moderate harvesting times that gradually decrease but remain consistently higher than the energy-efficient NOMA scheme. This reflects the limitations of the TDMA structure and the degraded channel conditions assumed in this case.

5-CONCLUSION

we have comprehensively explored energy efficiency (EE) as a fundamental performance metric in the design and analysis of wireless-powered communication networks that utilize uplink Non-Orthogonal Multiple Access (NOMA). Our focus was centered on understanding how uplink NOMA, when paired with energy harvesting at the user end, influences the overall system performance under different operational constraints. Specifically, we investigated two critical transmission strategies—half-duplex mode and asynchronous downlink-uplink operation—which represent practical communication scenarios in real-world systems. For both cases, we formulated the corresponding optimization problems with the primary objective of maximizing the system's energy efficiency, defined as the number of bits successfully transmitted per unit of energy consumed

To solve the optimization problems, we leveraged the concave-linear fractional structure of the EE formulations, which allowed us to apply Dinkelbach's iterative method, a well-known approach for solving nonlinear fractional programming problems. This enabled us to derive closed-form expressions for optimal transmission and energy harvesting time allocations under the half-duplex model. Furthermore, we proposed a structured algorithm to determine the globally optimal solution efficiently, significantly reducing computational complexity. In contrast, for the asynchronous mode, due to the increased complexity and interdependence of system parameters, deriving closed-form solutions was intractable. Hence, we employed numerical optimization techniques to approximate the optimal harvesting and transmission schedules, ensuring reliable performance insights even in analytically challenging settings.

The simulation results provided a range of valuable insights. One of the key observations was that increasing the downlink transmit power (Pa) led to a marked improvement in energy efficiency. This can be attributed to the fact that higher transmit power results in greater harvested energy at the user devices, enabling more reliable and faster uplink transmissions with reduced transmission durations. On the other hand, circuit power consumption, both in the downlink and uplink, had a negative impact on EE, especially in low-gain channel conditions. However, this effect varied depending on the underlying channel statistics, suggesting that channel-aware power management strategies are essential for maintaining high EE.

Another significant outcome was the observed dependence of optimal time allocations (for both energy harvesting and data transmission) on system parameters such as QoS exponents (θ\theta), channel gains, and circuit power levels. Particularly, under more stringent delay constraints (i.e., higher values of the QoS exponent), the achievable throughput dropped due to limited transmission flexibility, resulting in degraded energy efficiency.

This trend was consistent across both operational modes, reaffirming the critical trade-off between latency and EE in delay-sensitive applications like real-time monitoring or ultra-reliable low-latency communications (URLLC).

The analysis also highlighted the superiority of NOMA over traditional TDMA schemes in scenarios involving simultaneous multi-user transmissions, especially in the context of limited energy and spectrum resources. NOMA's ability to superimpose signals and exploit power domain multiplexing proved to be particularly beneficial for energy-constrained devices in harvested-powered settings, delivering higher EE and requiring shorter energy harvesting durations compared to TDMA.

Overall, this work not only provides a detailed mathematical and simulation-based understanding of how NOMA enhances EE in energy-harvesting wireless networks but also offers practical design guidelines for optimizing transmission policies. These insights have the potential to inform future developments in green wireless technologies, where sustainable energy use, latency awareness, and spectral efficiency must be jointly optimized. Future work can extend this analysis to multi-antenna systems (MIMO), user mobility scenarios, and imperfect channel state information, further bridging the gap between theoretical research and real-world deployment of energy-efficient, intelligent communication systems.

REFERENCES

1. L. Xie, Y. Shi, Y. T. Hou, and A. Lou, "Wireless power transfer and applications to sensor networks, *IEEE Wireless Commun.*, vol. 20, no. 4, pp. 140–145, Aug. 2013.
2. S. Ulukus, A. Yener, E. Erkip, O. Simeone, M. Zorzi, P. Grover, and K. Huang, "Energy harvesting wireless communications: A review of recent advances, *IEEE J. Sel. Areas Commun.*, vol. 33, no. 3, pp. 360–381, Mar. 2015.
3. C. Zhong, X. Chen, Z. Zhang, G. K. Karagiannidis, "Wireless-powered communications: performance analysis and optimization," *IEEE Trans. Commun.*, vol. 63, no. 12, pp. 1-1, Dec. 2015.
4. H. Ju, R. Zhang, "Throughput maximization in wireless powered communication networks," *IEEE Trans. on Wireless Commun.*, vol. 13, no. 1, pp. 418–428, Jan, 2014.
5. F. Zhao, L. Wei, and H. Chen, "Optimal time allocation for wireless information and power transfer in wireless powered communication systems," DOI: 10.1109/TVT.2015.2416272
6. D. Hwang, D. I. Kim, and T. J. Lee, "Throughput maximization for multiuser MIMO wireless powered communication networks," DOI:10.1109/TVT.2015.2453206.
7. H. Lee, K. J. Lee, H. B. Kong, and I. Lee, "Sum rate maximization for multi-user MIMO wireless powered communication networks," DOI: 10.1109/TVT.2016.2515607.
8. H. Ju, and R. Zhang, "Optimal resource allocation in full-duplex wireless-powered communication network," *IEEE Trans. Commun.*, vol. 62, no. 10, pp. 3528–3540, Oct. 2014.
9. X. Kang, C. K. Ho, and S. Sun, "Full-duplex wireless-powered communication network with energy causality," *IEEE Trans. Wireless Commun.*, vo. 14, no. 10, pp. 5539–5551, Oct. 2015.
10. T. A. Zewde, and M. C. Gursoy, "Wireless-powered communication under statistical quality of service constraints," *Proc. of IEEE International Conference on Commun. (ICC)*, Kuala Lumpur, Malaysia, 2016.
11. L. Dai, B. Wang, Y. Yuan, S. Han, C.L I, and Z. Wang, "Non-orthogonal multiple access for 5G: Solutions, challenges, opportunities, and future research trends," *IEEE Commun. Mag.*, vol. 53, no. 9, pp. 74–91, Sep. 2015.
12. S. R. Islam, N. Avazov, O. A. Dobre, and K.S. Kwak, "Power-domain non-orthogonal multiple access (NOMA) in 5G systems: potentials and challenges," https://arxiv.org/abs/1609.06261, DOI: 10.1109/COMST.2016.2621116,
13. S. N. Datta, and S. Kalyanasundaram, "Optimal power allocation and user selection in non-orthogonal multiple access systems," *Proc. of IEEE WCNC*, Apr. 2016.
14. L. Lei, D. Yuan, C. K. Ho, and S. Sun, "Power and channel allocation for non-orthogonal multiple access in 5G systems: tractability and computation," IEEE Trans. Commun., pp. 8580 - 8594, vol. 15, no. 12, Dec. 2016.
15. W. Han, Y. Zhang, X. Wang, J. Li, M. Sheng, and X. Ma, "Orthogonal power division multiple access: A green communication prespective," IEEE Jour. Sel. Area Commun., vol. 34, no. 12, pp. 3828–3842, Dec. 2016.
16. S. Buzzi, C. L. I, T. E. Klein, H. V. Poor, C. Yang, and A. Zappone, "Survey of energy-efficient techniques for 5G networks and challenges ahead," IEEE J. Sel. Areas Commun., vol. 34, no. 4, pp. 697–709, 2016.
17. Q. T. Vien, T. A. Le, B. Barn, C. V. Phan,

"Optimising energy efficiency of non-orthogonal multiple access for wireless backhaul in heterogenous cloud radio access network," IET Commun., 2016.

18. H. Q. Tran, P. Q. Truong, C. V. Phan, Q. T. Vien, "On the energy efficiency of NOMA for wireless backhaul in multi-tier heterogenous CRAN," Proc. of Intern. Conf. Recent Advances in SigTelCom, 2017.

19. F. Fang, H. Zhang, J. Cheng, V. C.M. Leung, "Energy-efficient resource allocation for downlink non-orthogonal multiple access network," IEEE Tran. Commun., vol. 64, no. 9, pp. 3722-3732, Sep. 2016.

20. Q. Sun, S. Han, C.L. I, Z. Pan, "Energy efficiency optimization for fading MIMO non-orthogonal multiple access system, "Proc. IEEE ICC, 2015.

21. Y. Zhang, H. M. Wang, T. X. Zheng, and Q. Yang, "Energy-efficient transmission design in non-orthogonal multiple access," IEEE Trans. Vehicular Technology, Jun. 2016.

22. P. D. Diamantoulakis, K. N. Pappi, Z. Ding, and G. K. Karagiannidis, "Wireless powered communications with non-orthogonal multiple access," IEEE Trans. Wireless Commun., pp. 8422 - 8436, vol. 15, no. 12, Dec. 2016.

23. H. Chingoska, Z. Hadzi-Velkov, I. Nikoloska, and N. Zlatanov, "Resource allocation in wireless powered communication networks with non-orthogonal multiple access," IEEE Wireless Commun. Letts., pp. 684 - 687, vo. 5, no. 6, Dec. 2016.

24. Y. Yaun, Z. Ding, "The application of non-orthogonal multiple access in wireless powered communication networks," Proc. IEEE SPAWC, pp. 1-5, Jul. 2016.

25. Z. Ding, X. Lei, and G. K. Karagiannidis, "A Survey on Non-Orthogonal Multiple Access for 5G Networks: Research Challenges and Future Trends, IEEE J. Sel. Areas Commun., pp. 2181 - 2195, vol. 35, no. 10, 2017.

26.] L. Song, Y. Li, Z. Ding, and H. V. Poor, "Resource Management in Non-orthogonal Multiple Access Networks for 5G and Beyond," IEEE Networks, vol. 31, n. 4, pp. 8-14, 2017.

27. *C*.S. Chang and T. Zajic, "Effective bandwidths of departure processes from queues with time varying capacities," Proc. IEEE Infocom., pp. 1001-1009, 1995.

28. D. Wu and R. Negi "Effective capacity: a wireless link model for support of quality of service," IEEE Trans. Wireless Commun., vol.2, no. 4, pp.630-643. July 2003.

29. Zappone, and E. Jorswieck, "Energy efficiency in wireless networks via fractional programming theory," Foundations and Trends in Communications and Information Theory, vol. 11, no. 3-4, pp. 185-396, 2015.

30. C. P. Simon and L. Blume, Mathematics for Economists, W. W. Norton & Company Inc., New York, NY, 1994.

31. S. Boyd and L. Vandenberghe, Convex Optimization, Cambridge University Press, 2004