International Journal of Electrical and Computer Engineering (IJECE)
Vol. 13, No. 2, April 2023, pp. 1654~1668
ISSN: 2088-8708, DOI: 10.11591/ijece.v13i2.pp1654-1668

Energy-efficient non-orthogonal multiple access for wireless communication system

Muhamad Firdaus Darus[1], Fakrulradzi Idris[2], Norlezah Hashim[3]
[1]Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer, Universiti Teknikal Malaysia Melaka (UTeM), Durian Tunggal, Malaysia
[2]Centre for Telecommunication Research and Innovation, Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer, Universiti Teknikal Malaysia Melaka (UTeM), Durian Tunggal, Malaysia
[3]Centre for Telecommunication Research and Innovation, Fakulti Teknologi Kejuruteraan Elektrik dan Elektronik, Universiti Teknikal Malaysia Melaka (UTeM), Durian Tunggal, Malaysia

Article Info

Article history:

Received Mar 11, 2022
Revised Oct 9, 2022
Accepted Oct 21, 2022

Keywords:

Algorithm
Energy efficiency
Internet of things
Non-orthogonal multiple access
Reinforcement learning

ABSTRACT

Non-orthogonal multiple access (NOMA) has been recognized as a potential solution for enhancing the throughput of next-generation wireless communications. NOMA is a potential option for 5G networks due to its superiority in providing better spectrum efficiency (SE) compared to orthogonal multiple access (OMA). From the perspective of green communication, energy efficiency (EE) has become a new performance indicator. A systematic literature review is conducted to investigate the available energy efficient approach researchers have employed in NOMA. We identified 19 subcategories related to EE in NOMA out of 108 publications where 92 publications are from the IEEE website. To help the reader comprehend, a summary for each category is explained and elaborated in detail. From the literature review, it had been observed that NOMA can enhance the EE of wireless communication systems. At the end of this survey, future research particularly in machine learning algorithms such as reinforcement learning (RL) and deep reinforcement learning (DRL) for NOMA are also discussed.

Corresponding Author:

Fakrulradzi Idris
Centre for Telecommunication Research and Innovation, Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer, Universiti Teknikal Malaysia Melaka (UTeM)
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
Email: fakrulradzi@utem.edu.my

1. INTRODUCTION

Multiple access used in 4G wireless networks is called orthogonal frequency division multiple access (OFDMA). This technique has received widespread adoption to increase the data rate. The estimated need for mobile traffic data volume will be a thousand times larger in 2020 and beyond. Therefore, non-orthogonal multiple access (NOMA) has become a promising technique to get around the limitations of orthogonal multiple access (OMA) since it provides extra resource utilization in either the code domain or power domain. The main concept behind NOMA is to serve numerous customers at varying power levels in the same time slot or frequency. Due to its superiority in offering improved spectral efficiency (SE) and facilitating vast connections, NOMA is now viewed as a possible choice for 5G networks. As a result, NOMA has received a lot of attention in recent industry standards. The core concept of NOMA is to serve numerous users [1] with varying power levels on the same resource block. NOMA can also reduce latency with high reliability and enable massive connectivity. NOMA has proved its effectiveness over OMA in existing research work [2]–[4].

The comparison of SE and energy efficiency (EE) in [5] showed that NOMA is better than OFDMA. Using superposition coding (SC) at the transmitters, NOMA provides power resources to multiplexed consumers. Successive interference cancellation (SIC) is used by the receivers to take advantage of the channel differences between users.

The demand for users in communication sectors will greatly raise electricity costs for network operation as well as bring adverse effects on the environment because of CO_2 emissions. Because of that, green communications need to be applicable to reduce the carbon footprint caused by the networking sector. Resultantly, green communication can be adapted to the networking system by applying energy efficient approaches [6]. Various algorithms have been developed by many researchers for enhancing the EE of NOMA systems.

This provides a motivation to perform a systematic literature review to look on how the preceding research associated with the improvement or comparison of EE algorithms in their works. This review targets to find the research gap for any improvement in EE in the future. This review will bring advantages to several readers. For researchers constructing a new set of rules for the EE of NOMA, this evaluation can emerge as a guiding principle for selecting appropriate approaches. Based on this systematic literature review findings, we additionally offer a few pointers for future works.

2. PROPOSED METHOD

The systematic literature review was conducted by referring to the guidelines found in [7]. The findings have been published on the IEEE, Wiley, MDPI, Hindawi, and Scopus websites. The search returned 5,522 papers for IEEE. For Wiley's website, 665 articles have been given as the search result. The MDPI website search returned us with 1,439 results. As for the IET, 541 articles have been found in the search results. We searched Scopus database, where the website returns 1,116 publications related to NOMA. Hindawi is another popular open-access publisher whose website returns 238 publications.

2.1. Fundamental research

The search was conducted using the keyword: "NOMA, Non-Orthogonal Multiple Access, Non-Orthogonal Multiple Access and Energy Efficiency." The publications were included in our samples if the content met two criteria. First, the content reflects the work relevant to the NOMA field; second, the content should discuss the development of EE algorithms. If any of the requirements are not met or redundant, articles are removed from this literature review. Based on this method, we have found a total of 108 publications. 92 publications are from IEEE; 2 publications from Wiley's website; 4 publications from MDPI; 5 articles from the IET; 4 articles from Scopus; and finally, 1 publication from the Hindawi website. The summary of the search strategies is listed in Figure 1.

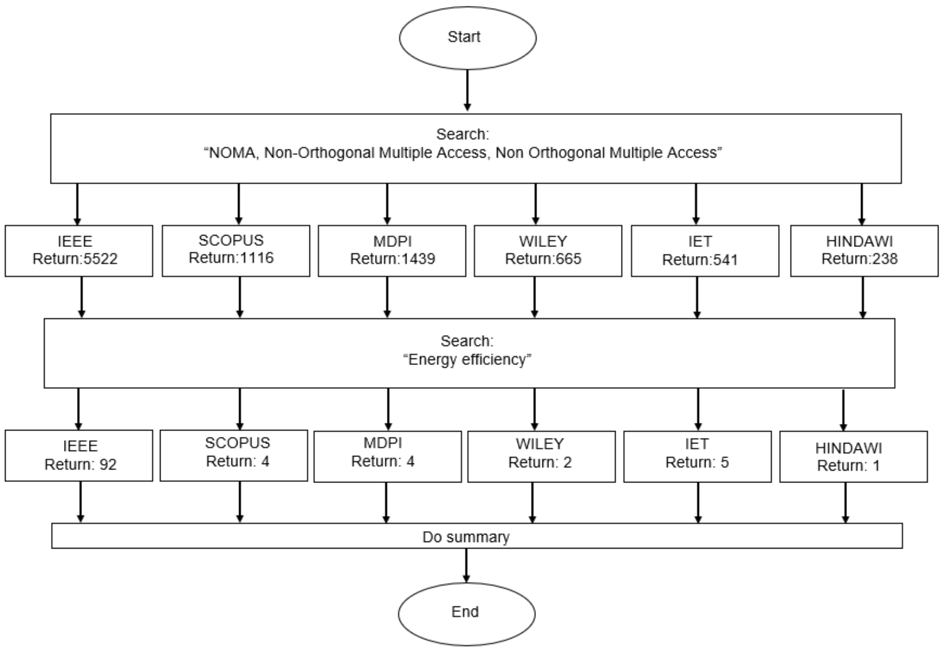

Figure 1. Flowchart of searching strategy

3. METHOD
3.1. Search terminology
It should be noted that NOMA and EE are the focus of this work. We can arrange the 108 publications into 19 different subcategories. The NOMA variants that emphasize EE are heterogeneous networks (Het-Nets), device-to-device (D2D), cognitive radio, cooperative communication, mobile edge, simultaneous wireless information and power transfer (SWIPT), backscatter, machine-to-machine (M2M), multiple-input multiple-output (MIMO), massive MIMO, ultra-dense, user pairing, coordinated multi-point (CoMP), mmWave, full duplex, visible light communication (VLC), terahertz, unmanned aerial vehicle (UAV), and internet of things (IoT). Figure 2 shows the graphical view of subcategories in NOMA.

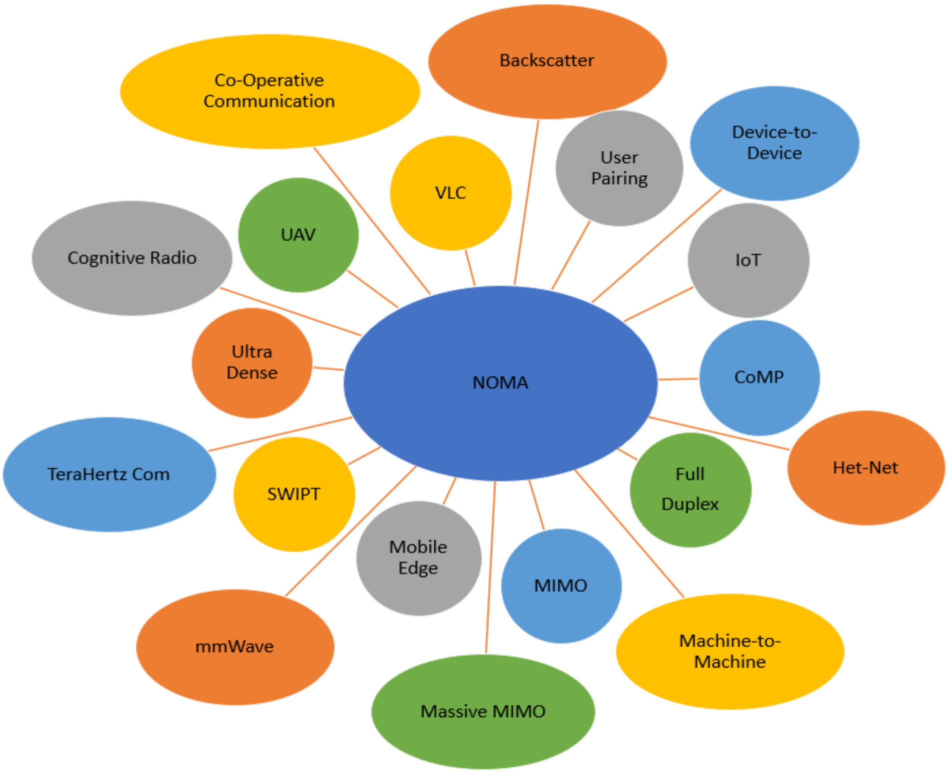

Figure 2. Subcategories of EE in NOMA

3.1.1. Heterogeneous networks
Heterogeneous networks are well known for improving user coverage and capacity in an extremely crowded network where the network allows the connection of various devices with different access technologies. EE approach for NOMA has been studied in several papers and the results obtained can improve the overall network. Xiang and Chen [8] adapted fractional transmit power allocation (FTPA) and fixed power allocation (FPA) in their work and were able to prove the performance of NOMA exceeds OFDMA, however, in terms of user fairness FPA exceeds FTPA. An improved version of the algorithm using convex relation and dual decomposition techniques via the Lagrangian approach is suggested by Fang [9]. Simulation results show the proposed algorithm managed to obtain high EE [10], [11]. However, the author did not consider joint optimization of both small cell and microcell users which will result in improving the entire system EE. Zhang *et al.* [12] and Xu *et al.* [13] use Lagrange dual method for achieving EE in NOMA where they considered energy harvesting, cross-tier interference, and imperfect channel state information (CSI) for cell association.

In terms of imperfect CSI, Zhang *et al.* [14] solved the resource optimization problem with the help of convex optimization to enhance the EE of the system. The greedy algorithm with sequential convex programming is another way to achieve fair EE [15]. Li and J. Gui [16] and Zhang *et al.* [17] obtained the closed-form power allocation solution with sectorization and Karush-Kuhn-Tucker (KKT) method, while Long *et al.* [18] applied successive convex approximation method for power allocation across subchannel proved better result than OMA system. Area SE had been considered in [19] which focused on EE enhancement by investigating base station (BS) density optimal. Nguyen [20] simulated the effects of EE for NOMA under imperfect SIC and the author found out EE is significantly decreasing when the Het-Net network becomes larger due to imperfect SIC implementation. Then, Khan *et al.* [21] proposed a new sequential quadratic programming for enhancing EE for NOMA beyond 5G. Finally, in their paper, Gharagezlou *et al.* [22] implemented an iteration algorithm for determining the maximal number of cells.

3.1.2. Device to device communications

In a traditional network, communication needs a certain network infrastructure to get through before reaching the receiver. However, D2D communication [1], [23]–[25] based on radio technology allows the user to communicate with each other directly without BS. Diallo *et al.* [5] achieved high EE by applying joint power allocation and selection scheme by content fetching mode of Lagrange dual method and a heuristic algorithm while geometric water filling (GWF) method was used in [26]. In contrast, He *et al.* [27] came out with analyses of EE and quality of experience (QoE) performance for the user with different NOMA systems and with different numbers of users. Then, the EE is maximized for NOMA D2D network when channel state information is imprecise, wireless information, and power transfer techniques are explored in [28] but the EE decreases as the distances increase.

3.1.3. Cognitive radio

Cognitive radio (CR) provides a network that can detect the status of the channel whether it is in use or not. It can cover dynamic spectrum sharing to achieve higher SE. CR networks also improve satellite communication and have a power-saving protocol. The issue of EE has been a controversial and much-disputed subject within the field of CR with poor channel performance for direct transmission. Therefore, to optimize the system for enhancing EE, Wang *et al.* [29] apply CR with SWIPT to overcome the problem. However, the outcome met limited battery capacity and affected the system performance. In contrast, the multiuser system in [30] applied multiple antenna technique designs that increase the number of users and the EE. For that reason, increasing antenna units using UAV operation as secondary transmitters show the decreasing latency by the decreasing number of transmission bits [31]. Case studies have been investigated for limitation of energy, where Wang and Men [32] designed a system for transmitting energy in broadcast specifically for the secondary users and NOMA technique also starts from the secondary user. However, there was a decrease in EE led by secondary users broadcasting radio frequency. Because of that, Zhao *et al.* [33] maximize the security of EE for secondary users and make sure it meets the quality of service (QoS) with no direct link between two pair of secondary users. Another major investigation was conducted by Kumar and Kumar [34], where capacity can affect the system. Hence, over On-Off Power Splitting method show the system is more effective compared to the previous [35]. Moreover, optimizing EE using gaming methods was proposed in [34].

3.1.4. Cooperative communication

Cooperative communication is the network that devices support each other for transmission and connection stabilization, where the user with a strong connection will role as a relay for the transmission between the supported user and the base station [36], [37]. The connection will be established by another user and supports the weak user to connect to the base station [38]. A cooperative communication system is designed for stronger users to support weak users but in [39] system has been set to direct the signal from the base station to the near user and the far user will get support by relay. The relay system plays an important role in the cooperative communication system network. Therefore, Liu *et al.* [40] designed a cooperative relaying system transmission for the source node and relay node by joint transmit power to achieve EE. In contrast to earlier findings, the cooperative relaying system in [41] applies a delay trade-off function. However, the system needs to consume more energy to compensate for the delay under higher arrival rates. Other than that, more power is needed for a worse channel to guarantee QoS for resource allocation in hardware impairments [42].

More energy-consuming will affect the EE of the system. Thus, the idea of minimizing the total energy consumption by applying a stochastic learning algorithm in the mobile edge computing network had been carried out by Qian *et al.* [43]. Similarly, Lan *et al.* [44] uses a half-duplex energy relay to send a signal but energy consumption for transmitting the pilot channel at the source and relay needs to be estimated manually. The present findings seem to outperform the half-duplex cooperative NOMA by applying a full duplex for the cooperative NOMA system [45]. These results agree with the findings by Yuan *et al.* [46], who uses a full-duplex that focuses on the cell-edge for cell center responsive relay. This design needs more power allocation to overcome the negative effect for far users. Then, the design of a hybrid system in-band full-duplex (IBFD) and two-way cognitive transmission was carried out in [47] and managed to achieve higher EE. Issues that emerged from this finding are that the feasible region shrinks and affects the EE to decline. The study found that in [48] system of full-duplex cooperative NOMA systems with SWIPT can enhance the EE for the system, however, the limitation for the system for each cluster only can be set for two users only.

3.1.5. Mobile edge

Wireless devices can outsource their processes to BSs located at the network edge due to mobile edge computing (MEC). By optimizing energy consumption obviously, EE can be improved. The drawback of this work, it is limited to two users only for each group [49]. Li *et al.* [50] applied reconfigurable intelligent surface (RIS) phase shift to minimize energy consumption. Li *et al.* [51] also focuses on minimizing energy by focusing on wireless energy transfer with Online Energy Consumption Minimization (OECM) algorithm. Still on minimizing energy, Zeng [52] focused on offloading part and followed by Qian [43], who enhanced the secrecy of the edge-computing device computation offloading part but there are eavesdropping attacks. Therefore, Wu *et al.* [53] improved by discovering that full offloading was not a good option for assuring the security of system connection, compute tasks offloading security and improved user connectivity. According to our earlier observations, minimizing energy had been applied to the system for EE. However, the greedy algorithm was used in [54] by allocating frequency block but the limited battery capacity affects the result as the time taken to get the results was longer.

Then, effects on task offloading, transmission time allocation, and transmit power optimization were studied in [55] but the amount of overhead in the uplink transmission decreases the signaling quality. Other than that, EE was achieved in MEC network where the system edge user applied NOMA to offload the tasks to the edge access point [56]. However, each NOMA group's system function can only use one subchannel at a time, and each subchannel can only support one NOMA group. Therefore, Han [57] investigates energy-efficient allocation of resources in MEC NOMA-enabled heterogeneous for wider link connection but due to limited computing capacity at devices, the entire task must offload to the MEC server for each user in the system. Due to that, the latency of connection increases; and it affects the system quality to decrease. Thus, designing a system to satisfy the latency part was done [58] by using an offloading algorithm based on an alternating direction method of multipliers able to improve the system latency and enhanced the EE for the system. Overall, the research on MEC topics in NOMA has improved a lot lately.

3.1.6. Simultaneous wireless information and power transfer

Simultaneous wireless information and power transfer is a wireless communication technology that allows user to receive data while simultaneously collecting energy from a signal. SWIPT is one method that offers a good connection for multiple users that can enhance the EE, by gathering info and power transfer while optimizing EE for the system. A dual-layer iterative resource allocation algorithm was developed where the restrictions on the maximum budget for transmitting power, the minimum data rate, and the minimum amount of energy captured per endpoint were studied [59]. The results agreed with the findings from [60] that overcome the EE optimizing problem from the previous research. Then, by designing the system with a power splitting ratio and power allocation method; Andrawes *et al.* [61] used a Genetic algorithm to optimize EE in the system. A different technique was used by Zhang *et al.* [62], who maximized the sum achievable user rate in NOMA user cluster with non-convex quadratic programming. Other than that, a system for wider area coverage has been designed in [63] that combines energy harvesting in a CR network where this research limits the transmission rate achievable to maximize the EE. However, the interference constraint in the CR network can severely limit the transmission rate achievable.

There is a major concern about the limitations caused by far distances meeting high signal disturbance. One possible method is by designing a system that set near user directs connect to the base station and far user attaches to relay with full-duplex connection [39]. Besides, the area coverage can also be designed for heterogeneous architecture like in [64] which focuses on the small cell network, while Budhiraja *et al.* [65] applied femtocell design and the result shows less interference because of the segmentized area. A broader perspective has been applied by another researcher, where a hybrid pre-coding SWIPT for mmWave with a massive MIMO method has been applied to achieve better EE of the system [66]. Other than that, a system being designed by Nguyen *et al.* [67] uses a hybrid system to improve EE by using SWIPT with multiple input with single output (MISO) method in a non-linear energy harvesting circuit model. Based on the result, the hybrid system achieved better EE than the conventional SWIPT.

3.1.7. Backscatter

Another communication method is backscatter which allows devices to communicate without an active radio frequency component. Communication by backscatter in communication helps a lot in making faster connections and data transmission. NOMA system with backscatter method can achieve good EE by applying reflection coefficient transmit power from BS to user, followed by QoS requirement [68]. Therefore, a system with unused energy will affect EE performance. The unused energy in [69] will be a surplus to the power for other user’s information recovery. Other than that, applying ambient backscatter to the system also can help enhance the EE in the system. Because of that, ambient backscatter with CR was applied to set a better EE in the system [70]. However, it is limited to the high region only due to outage probability and ergodic capacity corresponding to delay-limited transmission, and delay-tolerant modes will affect the EE of the system. Despite that, Zhuang *et al.* [71] proposed ambient backscatter with an intelligent reflecting surface shows better performance of EE for the system.

3.1.8. Machine-to-machine

Machine-to-machine (M2M) is a technology that enables networked devices to exchange information and carry out tasks without the need for human interaction. Optimizing energy consumption for achieving better EE in the system for M2M with NOMA network was proposed in [72]. Therefore, to perform a better system of NOMA, Selvam and Kumar [73] introduced a novel method called the rider optimization technique that managed to show a better result of EE compared to the basic NOMA system. These results are consistent with those of other studies that suggested minimizing energy related to energy harvesting [74]. Yang *et al.* [75] also focus on the same research but in the uplink phase.

Following the present results, another method can be implemented in the system like in [76] using a trade-off situation in the system which focus on power allocation more than other function. The present findings seem to be consistent with the result, for that reason; Li and Gui [16] seems to play with a hybrid method of time division multiple access (TDMA) with NOMA in cellular which focuses on the improved time-sharing scheme while EE of the system keeps in good condition. When the EE of the system can be maintained well in condition, the coverage of the system needs to improvise better for security by having a machine-type communication gateway (MTCGs). In contrast to earlier findings, Sobhi-Givi *et al.* [77] maximizes EE and studies for the minimal spectrum for an indoor environment through mmWave-NOMA applied to small cell user (SCU) and MTC devices. This will help for the communication and the building part while keeping the connection between the outdoor part and with indoor in good condition.

3.1.9. Multiple-input-multiple-output

Multiple-input multiple-output is a wireless method that uses several transmitters and receivers to send more data simultaneously [34]. It is a well-known wireless communication technology for sending and receiving several data signals over the same channel at the same time. Zeng *et al.* [78] grouped users into clusters with satisfying minimum rate requirements for a MIMO system. However, the EE for the system will be affected when more users are requesting services lower than the minimum rate, while the minimum rate is applied to the weak user in the system using fading MIMO for power consumption constraint [79]. The energy harvesting part affected the EE in the system of the NOMA network; therefore, power splitting and minimum setup for energy harvesting in power allocation show better results [80]. This investigation, differ from transmission system like through-beam space like in [81] that fundamentally serve one user only but, in this research, the MIMO with NOMA break the limit. These findings show a better result for EE but need to be aware of the number of users is less than the number of radio-frequency chains. Besides that, the limitation of users with the increased number of antenna transmitters was studied in [82].

3.1.10. Massive MIMO

Previous research findings show how massive MIMO takes advantage by providing more efficient sensing techniques for serving large coverage that is practically better for NOMA architecture and enhances EE of the system designed right away [83]. To obtain the EE of the NOMA system, optimal power allocation for each user is needed for better results. Therefore, Gharagezlou *et al.* [84] applied a power allocation scheme with a new algorithm standard interference function (SIF) able to prove better results of EE than the benchmark scheme, while Wang *et al.* [85] investigated resource allocation and energy harvesting for achieving EE of the system. However, the drawback of this system is there is a lot of power loss occurring in the system due to the increase in the number of antennas.

While previous studies have reported power loss due to the number of antennas, Wang and Lv [86] proposed a wireless power transfer system with an enabled multicell network but results show decreasing performance as the distance between BS to devices increases. Thus, to overcome the disadvantage, a higher transmit power to the base station is allocated to all devices. Other than that, there is an awareness raised about the limited capacity of backhaul links that can affect EE performance. Due to that problem, Tan *et al.* [87] designed a system for EE NOMA in massive MIMO for multicast and unicast with the SWIPT method. Preliminary work on maximizing EE for massive MIMO congruently focuses to achieve better EE. However, Hao *et al.* [88] applied MIMO with NOMA on mmWave transmission with QoS requirement. In this particular work, only the SE has improved due to the increases of radio frequency chain, while the EE is decreasing as the phase shifter consumes more circuit power. To determine the effects, Zeng *et al.* [89] applied the same system to the uplink phase and the result shows a consistent pattern with downlink NOMA but unfortunately, OMA shows better results. Unlike before, a more complex system performed for the system under the Poisson process was carried out in [90] but the more complex scheme was difficult to tractable with the high number of antennas in mMIMO method. Last but not least, Mandawaria *et al.* [91] proposed an idea to optimize global EE by using a fractional function of sum-product for optimizing variables by fixing the maximum relay of transmit power for the system function.

3.1.11. Ultra-dense

Ultra-dense (UD) network is referred to as a system where the capacity of a network is close to the maximum number of links connections. Which mean compact or crowded user in one area. Each node is connected and the user fully covers around coverage [92]. The use of quantitative case studies is being focused on UD situation to achieve EE due to the high number of users in a close area. Therefore, allocation of power for the user subject to achieve EE can be done by using FPA and FTPA [8]. While applying the Stackelberg game for the joint backhaul and the relay, adopting the Decode and Forward protocol for power allocation access was introduced in [93] for optimizing EE performance.

3.1.12. User pairing

When the user meets the dense condition, there will be part of the user with a strong signal and there will be a weak signal. Therefore, the user pairing can help these weak signal users to connect with the base station. However, to get EE, NOMA system needs to focus on the power allocation for the user in the design system. For that reason, Xu *et al.* [94] designed a NOMA network system with mmWave transmission for multi-user pairing to allocate power. Applying an iterative algorithm based on coordinate descent will achieve power allocation optimally.

Considered quantitative measures by enhancing coverage signal area for a huge number of users to connect with the base station, therefore; Chai *et al.* [95] formulated resource allocation for mobile broadband users and massive machine-type communication (mMTC) by focusing on enhancing EE for the system but first need to group the user to each transmission group. Nguyen *et al.* [67] improvised the design by suggesting NOMA system for user pairing hybrid of multiple users for multiple input with single output applied with SWIPT. These circuit models use novel hybrid user pairing (HUP) that set pairing for the user over random and conventional multiuser.

3.1.13. Coordinated multi-point

Coordinated multi-point a networking method that enables many BSs to deliver data to a single user simultaneously by coordinating their transmissions. This offers enhanced service for cell-edge users and improves the users’ reception. Rayati *et al.* [96] derived the closed-form approximation (CFA) of EE for the uplink phase with MIMO and power consumption model (PCM), while Liu *et al.* [97] focuses on the downlink phase but eventually, the result shows the unchanged EE because the excess transmits power is no longer to be used after achieving the maximum EE. In a nutshell, CoMP is best to use for a small number of users for easy setup of coordinates.

3.1.14. Millimeter wave

Millimeter wave (mmWave) communication technologies have inspired a lot of interest as an approach to handle the future 5G network’s capacity requirements. The mmWave systems work with frequencies between from 30 to 300 GHz, with a total bandwidth of roughly 250 GHz. The range of mmWave is only 300 to 500 feet, making it difficult to penetrate buildings.

The mmWave shows the transmission for a larger area, where NOMA network can achieve higher EE. EE is derived from improving the throughput and reliability of the mmWave NOMA downlink multi-relay system [98]. Referring to limited spectral resources, the carrier frequency will be reused by neighbor’s calls. Meanwhile, EE is maximized using analog beamforming for the uplink phase able to show the same result [99]. However, a power allocation strategy needs to be implemented to get good results. Hybrid precoding structures used in [100] are able to enhance the overall result. Other than that, some of the problems can be solved by pairing the user in terms of their channel difference and correlation like show in [101] while in [102] show enhances EE based on the sum of throughput. The function to reduce interference between different clusters by using an algorithm based on coordinate descent was proposed in [94]. Rahmati *et al.* [103] are more interested to design a system where signal transmission is done by UAV. Grouping users into clusters through mmWave signal with NOMA by presenting three precoding schemes shows an improvement in signal strength for all users [104]. One of the possible applications of green energy communication for energy harvesting is a system that serves each beam only to support one user for the same radio resource [46].

3.1.15. Full duplex

The term full duplex (FD) explains the simultaneous transmission and receipt of data over a single channel. An FD device has simultaneous bi-directional network data transfer capabilities. The user devices can transmit and receive simultaneously.

Gupta *et al.* [105] applied the function of the amplify-forward relay for transmitting power to maximize EE in the system. The type of power applied is only static power for each node. While the work in [106] focuses on the minimum required target rate of cell-edge users in maximizing the EE. Hence, the system targets the cell-edge user by setting the near user as a relay to support the connection between the cell-edge user with the base station. Consequently, rather than setting up the user as a relay to support one user only, another researcher focuses on reducing energy consumption with MEC for a single relay applied to multi-user cooperation [107]. Because of that, the system needs top performance of central processing unit (CPU) capability and high energy requirement for relay due to the increased task. Thus, Liu and Mo [108] uses one-dimensional search and path-following-based algorithms for user communication. The previous researcher studied the system for the base station to user connection and the receiver part needs to improve for signal receiving in a good performance. There was a degradation of performance in the system due to the signal-to-interference-noise ratio (SINR) problem. However, by cooperating NOMA system with FD the system achieved a higher EE [106].

3.1.16. Visible light communication

Visible light communication is using visible light for data transmission between 400 and 800 THz and a range of distances of about 780 to 375 nm. VLC systems work at optical frequencies in contrast to radio frequency (RF) communication systems and do not produce any electromagnetic interference. There is no special communication device on the transmitter part, but the receiver part needs special devices such as a light detector such as a photocell. VLC commonly is used in an indoor communication coverage area.

To achieve EE for VLC system, findings show that most of the researchers controlled the energy consumption of the system. Thus, Zhang *et al.* [109] reduces energy consumption by minimizing the emitting power (EP) with maintaining the stability of QoS in the system. Other than that, the NOMA-VLC system adopted a low complexity QoS that focused on a power allocation strategy to achieve EE [110]. Besides that, the hybrid design of VLC with radio frequency wireless system by applying line of sight (LOS) proves to maximize the EE for the system [111]. However, the limitation was in the LOS itself which will affect the EE performance. Consequently, VLC system had been applied with a deep neural network able to set the system in the best condition for achieving better EE performance compared to traditionally NOMA and OMA [112].

3.1.17. Terahertz

Terahertz is a complementary technology for wireless communication from high speed to fiber-optic speed. The presented findings were about the investigation of EE with power optimization because energy consumption is one of the main factors affecting the EE of the system [113]. Therefore, solving subchannel assignments with power optimization can decrease energy consumption as wireless service has increased. Terahertz frequency is suffering in the atmospheric air caused by absorption and the signal will be attenuated. These results agree with the findings of other studies [114] which designed a system with power optimization by applying MIMO method to show better performance of results. The present studies draw our attention to distinctive categories of maximization EE often observed in NOMA systems by drawing on the concept of hybrid precoding that can decrease the power consumption and set the multiple users into clusters that help to set the convergence faster [115]. Thus, the result shows better in terms of time to solve because the user clustering makes the system functions better.

3.1.18. Unmanned aerial vehicle

Unmanned aerial vehicle is a class of aircraft that contains sensors, target designators, or communication equipment which can be controlled remotely without the onboard presence of pilots. Mobility, maneuverability, cheap cost, and LOS communication are all qualities of UAVs, making them a possible choice for future wireless communication networks.

Sabuj *et al.* [31] analyses the EE performance of services for mMTC and NOMA-based cognitive ultra-reliable and low-latency communications (URLLCs). However, system throughput steadily declines as distances increase and the perfect EE is at 200m. This finding supports previous research on system performance in optimization with imperfect CSI between the UAV and users [116]. Nonetheless, due to the power of each UAV being limited, it is essential to achieve greater EE by saving transmit power. Sohail *et al.* [117] use a pointed design system for maximizing information bits per unit of energy consumption between UAV with BS. Nevertheless, Najmeddin *et al.* [118] uses Lagrangian optimization and gradient descent methods to enhance the EE for NOMA. With this technique, the lesser wireless power transfer time will be needed from UAV to charge energy receivers when using NOMA.

Another possibility to improve EE on UAV is by proposing a system spatial NOMA which is a combination method of NOMA and spatial modulation, yet it is important to consider the EE performance in a low power situation due to the energy-carrying capacity and rising energy consumption [119]. Conversely, throughput fairness being investigated in [120] with time-sharing NOMA able to maximize the EE and in [121] by applying fixed PA and random PA schemes framework of power resource. Lastly, a system was designed to achieve EE by minimizing the power consumption in the network and focusing on the deadline constraints for the computation task of each UE [122].

3.1.19. Internet of things

The Internet of things refers to the use of the Internet to facilitate communication with things that refer to devices. IoT devices also can connect through the cloud and rapidly growing network of connected objects in real-time. IoT architecture is a system of numerous elements and Layers are identified to monitor a system's consistency through protocols and gateways. With IoT, data can be exchanged without limit or distance and time because it can be updated in real-time. Application in IoT has been considered in a lot of research works [123]–[125]

The EE of an IoT system is a major concern of interest among researchers. The use of mobile edge computing to transfer their processing demands to adjacent edge servers (ESs) has attracted increasing attention in IoT applications [126]. The results provided managed to minimize the total energy consumption compared to conventional OFDMA based offloading schemes. Olatinwo and Joubert [127] present a novel approach to allocating resources in IoT water quality monitoring using a sensor network (IoTSN) for a more sustainable application. A meta-heuristic method is used to define an EE optimization question and the result was compared with a non-meta-heuristic algorithm. The proposed system significantly outperforms the contemporary system in terms of EE. A polynomial complexity power allocation (PA) algorithm is explored in [128] and the average system EE loss is only less than 2% while Xu and Liang [129] proposed a more effective particle swarm optimization algorithm, however; the algorithm complexity is high.

Increased activation in IoT is concerned about latency that affects the data received on time and it also affected the EE of the system design. Therefore, Liu *et al.* [130] shows the importance of EE maximization by focusing on offloading part along with concurrently meeting the IoT device's maximum tolerated delay requirements using matching and sequential convex programming algorithms. Chen *et al.* [131] proposed optimal power allocation (OPA) for light fidelity (LiFi) to optimize EE of both downlink and uplink, an IoT communication system that is bidirectional has been enabled. A fractional non-convex optimization is formulated to maximize the EE in MIMO NOMA heterogeneous cellular network (HCN) with IoT for wireless communication systems [132]. However, only to reduce the complexity of the decoding, two users are considered for each pair. Khan *et al.* [70] proposed an EE for ambient backscatter communication (AmBC) enabled NOMA IoV network where the data show that the proposed AmBC-enabled NOMA IoV is preferable to the existing IoV architecture.

4. RESULT AND DISCUSSION

The literature works on energy-efficient NOMA scheme and its variations for 5G communications are enormous due to advantages over OMA. To understand fully its impact, new problems and future research direction must be considered. In NOMA, optimum power distribution among users is entirely dependent on the availability of efficient algorithms that deliver the best performance with the least number of resources. Power allocation, which is the core part of the NOMA scheme need to be designed not only to meet the 5G criteria of very high data rates and minimal latency, but also to enhance the overall EE of wireless communication system.

Another prospective research subject is the evaluation of NOMA performance in the presence of IoT. The performance shows the user connection, and EE can be achieved higher in NOMA-IoT. On this occasion, reinforcement learning (RL) is a part of M2M language communication that will keep providing the best value for the new environment. There have been numerous studies conducted to investigate the implementation of RL in many applications. For instance, Rayati *et al.* [96] prove that by using RL can improve the operation of the energy systems for smart grid and energy hub. This is followed by Bi *et al.* [133], who concentrate on smaller scale microgrids that protect the environment and optimize the grid structure using deep reinforcement learning (DRL). Increasing demand for EE by using RL has been reviewed in [134] where RL models for smart home energy management are proposed.

Previous research showed RL in NOMA has been investigated by focusing on maximizing the sum rate but not EE [135], [136]. In another research but not NOMA related, RL has been implemented in IoT applications where Ashiquzzaman *et al.* [137] create ultra-durable and energy efficient IoT for sensor calibration to decrease consumption and increase device efficiency. Nevertheless, Wang *et al.* [138] recently concluded applying RL for UAVs can improve communication quality under jamming attacks. We found out there is a lack of studies on maximizing the energy efficiencies of NOMA in IoT-based applications. In the future, we would like to encourage researchers to consider using RL or other deep learning methods in NOMA IoT-based applications for EE maximization.

5. CONCLUSION

In this paper, 19 different NOMA variants emphasizing EE namely Het-Nets, D2D, cognitive radio, cooperative communication, mobile edge, SWIPT, backscatter, M2M, MIMO, massive MIMO, ultra-dense, user pairing, CoMP, mmWave, full duplex, VLC, Terahertz, UAV, and IoT are explored. Out of this variant, most research has been found on Het-Nets and cooperative communication topics. Finally, future research using RL and DRL for NOMA is also highlighted.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Faculty of Electronics and Computer Engineering (FKEKK) and Faculty of Electrical and Electronic Engineering Technology (FTKEE), Universiti Teknikal Malaysia Melaka (UTeM); and those who give energetic and full support in carrying out this research. This work was supported by the ministry of higher education (MoHE) Malaysia through the fundamental research grant scheme (FRGS) under Grant FRGS/1/2020/TK0/UTEM/03/11.

REFERENCES

[1] I. Budhiraja, N. Kumar, S. Tyagi, Q.-V. Pham, and S. Tanwar, "Energy efficient mode selection scheme for wireless powered D2D communications with NOMA underlaying UAV," in *IEEE INFOCOM 2020 - IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS)*, Jul. 2020, pp. 877–882, doi: 10.1109/INFOCOMWKSHPS50562.2020.9162839.

[2] M.-S. Van Nguyen, P. H. Dang, and N. D. Nguyen, "Exploiting user grouping and energy harvesting in downlink cellular system," *Bulletin of Electrical Engineering and Informatics (BEEI)*, vol. 11, no. 2, pp. 870–877, Apr. 2022, doi: 10.11591/eei.v11i2.2982.

[3] A.-T. Le, D.-T. Do, and M. Munochiveyi, "Outage performance of downlink NOMA-aided small cell network with wireless power transfer," *Bulletin of Electrical Engineering and Informatics (BEEI)*, vol. 10, no. 5, pp. 2686–2695, Oct. 2021, doi: 10.11591/eei.v10i5.3015.

[4] T.-T. Nguyen and D.-T. Do, "Performance gap of two users in downlink full-duplex cooperative NOMA," *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 19, no. 6, pp. 1795–1802, Dec. 2021, doi: 10.12928/telkomnika.v19i6.19034.

[5] E. M. Diallo, R. Chai, and T. Ahmad, "Energy efficient resource allocation and mode selection for content fetching in cellular D2D networks," in *2021 Wireless Telecommunications Symposium (WTS)*, Apr. 2021, pp. 1–8, doi: 10.1109/WTS51064.2021.9433685.

[6] R. Ruby, S. Zhong, D. W. K. Ng, K. Wu, and V. C. M. Leung, "Enhanced energy-efficient downlink resource allocation in green non-orthogonal multiple access systems," *Computer Communications*, vol. 139, pp. 78–90, May 2019, doi: 10.1016/j.comcom.2019.03.010.

[7] N. Tariq, R. A. Hamzah, T. F. Ng, S. L. Wang, and H. Ibrahim, "Quality assessment methods to evaluate the performance of edge detection algorithms for digital image: A systematic literature review," *IEEE Access*, vol. 9, pp. 87763–87776, 2021, doi: 10.1109/ACCESS.2021.3089210.

[8] L. Xiang and H. Chen, "Energy-efficient and fair power allocation approach for NOMA in ultra-dense heterogeneous networks," in *2017 International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery (CyberC)*, Oct. 2017, pp. 89–94, doi: 10.1109/CyberC.2017.54.

[9] F. Fang, J. Cheng, Z. Ding, and H. V. Poor, "Energy efficient resource optimization for a downlink NOMA heterogeneous small-cell network," in *2018 IEEE 10th Sensor Array and Multichannel Signal Processing Workshop (SAM)*, Jul. 2018, pp. 51–55, doi: 10.1109/SAM.2018.8448840.

[10] Q. Vien, T. A. Le, B. Barn, and C. V Phan, "Optimizing energy efficiency of non-orthogonal multiple access for wireless backhaul in heterogeneous cloud radio access network," *IET Communications*, vol. 10, no. 18, pp. 2516–2524, Dec. 2016, doi: 10.1049/iet-com.2016.0247.

[11] S. Zhang, N. Zhang, G. Kang, and Z. Liu, "Energy and spectrum efficient power allocation with NOMA in downlink HetNets," *Physical Communication*, vol. 31, pp. 121–132, Dec. 2018, doi: 10.1016/j.phycom.2018.09.006.

[12] H. Zhang, M. Feng, K. Long, G. K. Karagiannidis, and V. C. M. Leung, "Energy-efficient resource allocation in NOMA heterogeneous networks with energy harvesting," in *2018 IEEE Global Communications Conference (GLOBECOM)*, Dec. 2018, pp. 206–212, doi: 10.1109/GLOCOM.2018.8647140.

[13] Y. Xu, R. Q. Hu, and Y. Qian, "Robust max-min fairness energy efficiency in NOMA-based heterogeneous networks," in *ICC 2020 - 2020 IEEE International Conference on Communications (ICC)*, Jun. 2020, pp. 1–6, doi: 10.1109/ICC40277.2020.9149205.

[14] H. Zhang, F. Fang, J. Cheng, K. Long, W. Wang, and V. C. M. Leung, "Energy-efficient resource allocation in NOMA heterogeneous networks," *IEEE Wireless Communications*, vol. 25, no. 2, pp. 48–53, Apr. 2018, doi: 10.1109/MWC.2018.1700074.

[15] Z. J. Ali, N. K. Noordin, A. Sali, and F. Hashim, "Fair energy-efficient resource allocation for downlink NOMA heterogeneous networks," *IEEE Access*, vol. 8, pp. 200129–200145, 2020, doi: 10.1109/ACCESS.2020.3035212.

[16] Z. Li and J. Gui, "Energy-efficient resource allocation with hybrid TDMA–NOMA for cellular-enabled machine-to-machine communications," *IEEE Access*, vol. 7, pp. 105800–105815, 2019, doi: 10.1109/ACCESS.2019.2931657.

[17] G. Zhang, C. Wu, Y. Xu, and Z. Wang, “Robust energy efficiency optimization for SWIPT-enabled heterogeneous NOMA networks,” in *2019 11th International Conference on Wireless Communications and Signal Processing (WCSP)*, Oct. 2019, pp. 1–5, doi: 10.1109/WCSP.2019.8927984.

[18] K. Long, W. Li, M. Jiang, and J. Lu, “Non-cooperative game-based power allocation for energy-efficient NOMA heterogeneous network,” *IEEE Access*, vol. 8, pp. 49596–49609, 2020, doi: 10.1109/ACCESS.2020.2980191.

[19] L. Xiang, H. Chen, and F. Zhao, “Area spectral efficiency and energy efficiency tradeoff in ultradense heterogeneous networks,” *Wireless Communications and Mobile Computing*, vol. 2017, pp. 1–8, 2017, doi: 10.1155/2017/4390197.

[20] T.-D. Nguyen, V.-C. Phan, and P. Q. Truong, “Energy efficient performance analysis of NOMA for wireless down-link in heterogeneous networks under imperfect SIC,” in *2019 International Conference on System Science and Engineering (ICSSE)*, Jul. 2019, pp. 255–260, doi: 10.1109/ICSSE.2019.8823337.

[21] W. U. Khan, X. Li, A. Ihsan, Z. Ali, B. M. Elhalawany, and G. A. S. Sidhu, “Energy efficiency maximization for beyond 5G NOMA-enabled heterogeneous networks,” *Peer-to-Peer Networking and Applications*, vol. 14, no. 5, pp. 3250–3264, Sep. 2021, doi: 10.1007/s12083-021-01176-5.

[22] A. S. Gharagezlou, J. Pourrostam, M. Nangir and M. M. Safari, “Energy efficient power allocation in massive MIMO NOMA systems based on SIF using cell division technique,” *2020 2nd Global Power, Energy and Communication Conference (GPECOM)*, 2020, pp. 356-361, doi: 10.1109/GPECOM49333.2020.9247920.

[23] M. Najimi, “Energy-efficient resource allocation in D2D communications for energy harvesting-enabled NOMA-based cellular networks,” *International Journal of Communication Systems*, vol. 33, no. 2, Jan. 2020, doi: 10.1002/dac.4184.

[24] F. Idris, J. Tang, and D. K. C. So, “Resource and energy efficient device to device communications in downlink cellular system,” in *2018 IEEE Wireless Communications and Networking Conference (WCNC)*, Apr. 2018, pp. 1–6, doi: 10.1109/WCNC.2018.8377382.

[25] F. Idris, J. Tang, and D. K. C. So, “Energy efficient device to device communication by resource efficiency optimization,” in *2017 IEEE 85th Vehicular Technology Conference (VTC Spring)*, Jun. 2017, pp. 1–5, doi: 10.1109/VTCSpring.2017.8108255.

[26] M. S. Al-kahtani, L. Ferdouse, and L. Karim, “Energy efficient power domain non-orthogonal multiple access based cellular device-to-device communication for 5G networks,” *Electronics*, vol. 9, no. 2, Feb. 2020, doi: 10.3390/electronics9020237.

[27] S. He, W. Wang, and K. Sohraby, “QoE-centric multimedia relay in energy efficient NOMA wireless communications,” in *ICC 2019 - 2019 IEEE International Conference on Communications (ICC)*, May 2019, pp. 1–6, doi: 10.1109/ICC.2019.8761993.

[28] Y. Xu, Z. Liu, Z. Yang, and C. Huang, “Energy-efficient resource allocation with imperfect CSI in NOMA-based D2D networks with SWIPT,” in *2021 IEEE Wireless Communications and Networking Conference (WCNC)*, Mar. 2021, pp. 1–6, doi: 10.1109/WCNC49053.2021.9417316.

[29] X. Wang, Z. Na, K. Lam, X. Liu, Z. Gao, F. Li and L. Wang, “Energy efficiency optimization for NOMA-based cognitive radio with energy harvesting,” *IEEE Access*, vol. 7, pp. 139172–139180, 2019, doi: 10.1109/ACCESS.2019.2940698.

[30] Y. Zhang, Q. Yang, T.-X. Zheng, H.-M. Wang, Y. Ju, and Y. Meng, “Energy efficiency optimization in cognitive radio inspired non-orthogonal multiple access,” in *2016 IEEE 27th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*, Sep. 2016, pp. 1–6, doi: 10.1109/PIMRC.2016.7794658.

[31] S. R. Sabuj, A. Ahmed, Y. Cho, K.-J. Lee, and H.-S. Jo, “Cognitive UAV-aided URLLC and mMTC services: Analyzing energy efficiency and latency,” *IEEE Access*, vol. 9, pp. 5011–5027, 2021, doi: 10.1109/ACCESS.2020.3048436.

[32] D. Wang and S. Men, “Secure energy efficiency for NOMA based cognitive radio networks with nonlinear energy harvesting,” *IEEE Access*, vol. 6, pp. 62707–62716, 2018, doi: 10.1109/ACCESS.2018.2876970.

[33] W. Zhao, R. She, and H. Bao, “Security energy efficiency maximization for two-way relay assisted cognitive radio NOMA network with self-interference harvesting,” *IEEE Access*, vol. 7, pp. 74401–74411, 2019, doi: 10.1109/ACCESS.2019.2920710.

[34] A. Kumar and K. Kumar, “Energy-efficient resource optimization using game theory in hybrid NOMA assisted cognitive radio networks,” *Physical Communication*, vol. 47, Aug. 2021, doi: 10.1016/j.phycom.2021.101382.

[35] Z. Wang and Q. Zhu, “Energy efficiency optimization algorithm of CR-NOMA system based on SWIPT,” *Mathematical Problems in Engineering*, vol. 2020, pp. 1–13, Jun. 2020, doi: 10.1155/2020/6207989.

[36] Y. Zhang, J. He, S. Guo, and F. Wang, “Energy efficiency maximisation in wireless powered networks with cooperative non-orthogonal multiple access,” *IET Communications*, vol. 12, no. 18, pp. 2374–2383, Nov. 2018, doi: 10.1049/iet-com.2018.5056.

[37] C. E. Garcia, M. R. Camana, and I. Koo, “Secrecy energy efficiency maximization in an underlying cognitive radio–NOMA system with a cooperative relay and an energy-harvesting user,” *Applied Sciences*, vol. 10, no. 10, May 2020, doi: 10.3390/app10103630.

[38] N. Zhou, J. Hu, and J. Hou, “Research on energy efficiency of NOMA–SWIPT cooperative relay network using GS-DinkelBach algorithm,” *Sensors*, vol. 21, no. 17, Aug. 2021, doi: 10.3390/s21175720.

[39] H. Huang and M. Zhu, “Energy efficiency maximization design for full-duplex cooperative NOMA systems with SWIPT,” *IEEE Access*, vol. 7, pp. 20442–20451, 2019, doi: 10.1109/ACCESS.2019.2896252.

[40] Q. Liu, T. Lv, and Z. Lin, “Energy-efficient transmission design in cooperative relaying systems using NOMA,” *IEEE Communications Letters*, vol. 22, no. 3, pp. 594–597, Mar. 2018, doi: 10.1109/LCOMM.2018.2790379.

[41] B. Ning, W. Hao, A. Zhang, J. Zhang, and G. Gui, “Energy efficiency–delay tradeoff for a cooperative NOMA system,” *IEEE Communications Letters*, vol. 23, no. 4, pp. 732–735, Apr. 2019, doi: 10.1109/LCOMM.2019.2900320.

[42] Z. Fan, H. Zhang, Z. Wang, X. Wan, and X. Lin, “Energy efficient resource allocation of cooperative non-orthogonal multiple access with hardware impairments,” in *2019 IEEE 20th International Conference on High Performance Switching and Routing (HPSR)*, May 2019, pp. 1–5, doi: 10.1109/HPSR.2019.8808098.

[43] L. Qian, W. Wu, W. Lu, Y. Wu, B. Lin, and T. Q. S. Quek, “Secrecy-based energy-efficient mobile edge computing via cooperative non-orthogonal multiple access transmission,” *IEEE Transactions on Communications*, vol. 69, no. 7, pp. 4659–4677, Jul. 2021, doi: 10.1109/TCOMM.2021.3070620.

[44] X. Lan, Y. Zhang, Q. Chen, and L. Cai, “Energy efficient buffer-aided transmission scheme in wireless powered cooperative NOMA relay network,” *IEEE Transactions on Communications*, vol. 68, no. 3, pp. 1432–1447, Mar. 2020, doi: 10.1109/TCOMM.2019.2959336.

[45] G. Liu, X. Chen, Z. Ding, Z. Ma, and F. R. Yu, “Hybrid half-duplex/full-duplex cooperative non-orthogonal multiple access with transmit power adaptation,” *IEEE Transactions on Wireless Communications*, vol. 17, no. 1, pp. 506–519, Jan. 2018, doi: 10.1109/TWC.2017.2767601.

[46] Y. Yuan, Y. Xu, Z. Yang, P. Xu, and Z. Ding, “Energy efficiency optimization in full-duplex user-aided cooperative SWIPT NOMA systems,” *IEEE Transactions on Communications*, vol. 67, no. 8, pp. 5753–5767, Aug. 2019, doi: 10.1109/TCOMM.2019.2914386.

[47] R. Tang, J. Cheng, and Z. Cao, “Energy-efficient power allocation for cooperative NOMA systems with IBFD-enabled two-way

cognitive transmission," *IEEE Communications Letters*, vol. 23, no. 6, pp. 1101–1104, Jun. 2019, doi: 10.1109/LCOMM.2019.2913424.
[48] X. Yin, W. Wu, H. Dai, P. Li, and B. Wang, "Energy-efficient transceiver design for full-duplex cooperative NOMA systems with SWIPT," in *2018 10th International Conference on Wireless Communications and Signal Processing (WCSP)*, Oct. 2018, pp. 1–6, doi: 10.1109/WCSP.2018.8555913.
[49] Z. Yang, J. Hou, and M. Shikh-Bahaei, "Energy efficient resource allocation for mobile-edge computation networks with NOMA," in *2018 IEEE Globecom Workshops (GC Wkshps)*, Dec. 2018, pp. 1–7, doi: 10.1109/GLOCOMW.2018.8644143.
[50] Z. Li *et al.*, "Energy efficient reconfigurable intelligent surface enabled mobile edge computing networks with NOMA," *IEEE Transactions on Cognitive Communications and Networking*, vol. 7, no. 2, pp. 427–440, Jun. 2021, doi: 10.1109/TCCN.2021.3068750.
[51] C. Li, J. Tang, Y. Zhang, X. Yan, and Y. Luo, "Energy efficient computation offloading for nonorthogonal multiple access assisted mobile edge computing with energy harvesting devices," *Computer Networks*, vol. 164, Dec. 2019, doi: 10.1016/j.comnet.2019.106890.
[52] M. Zeng and V. Fodor, "Energy-efficient resource allocation for NOMA-assisted mobile edge computing," in *2018 IEEE 29th Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC)*, Sep. 2018, pp. 1794–1799, doi: 10.1109/PIMRC.2018.8580984.
[53] W. Wu, F. Zhou, R. Q. Hu, and B. Wang, "Energy-efficient resource allocation for secure NOMA-enabled mobile edge computing networks," *IEEE Transactions on Communications*, vol. 68, no. 1, pp. 493–505, Jan. 2020, doi: 10.1109/TCOMM.2019.2949994.
[54] L. Zhang *et al.*, "Energy-efficient non-orthogonal multiple access for downlink communication in mobile edge computing systems," *IEEE Transactions on Mobile Computing*, p. 1, 2021, doi: 10.1109/TMC.2021.3083660.
[55] Y. Pan, M. Chen, Z. Yang, N. Huang, and M. Shikh-Bahaei, "Energy-efficient NOMA-based mobile edge computing offloading," *IEEE Communications Letters*, vol. 23, no. 2, pp. 310–313, Feb. 2019, doi: 10.1109/LCOMM.2018.2882846.
[56] X. Cao, C. Liu, and M. Peng, "Energy-efficient mobile edge computing in NOMA-based wireless networks: A game theory approach," in *ICC 2020 - 2020 IEEE International Conference on Communications (ICC)*, Jun. 2020, pp. 1–6, doi: 10.1109/ICC40277.2020.9149056.
[57] Q. Han, G. Zheng, and C. Xu, "Energy-efficient resource allocation for mobile edge computing in NOMA-enabled small cell networks," in *2020 IEEE 20th International Conference on Communication Technology (ICCT)*, Oct. 2020, pp. 415–419, doi: 10.1109/ICCT50939.2020.9295762.
[58] M. Hua, H. Tian, W. Ni, and S. Fan, "Energy efficient task offloading in NOMA-based mobile edge computing system," in *2019 IEEE 30th Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC)*, Sep. 2019, pp. 1–7, doi: 10.1109/PIMRC.2019.8904347.
[59] J. Tang *et al.*, "Energy efficiency optimization for NOMA with SWIPT," *IEEE Journal of Selected Topics in Signal Processing*, vol. 13, no. 3, pp. 452–466, Jun. 2019, doi: 10.1109/JSTSP.2019.2898114.
[60] J. Tang, J. Luo, D. So, E. Alsusa, K.-K. Wong, and N. Zhao, "Energy-efficient resource allocation in SWIPT enabled NOMA systems," in *2018 IEEE Global Communications Conference (GLOBECOM)*, Dec. 2018, pp. 1–7, doi: 10.1109/GLOCOM.2018.8647573.
[61] A. Andrawes, R. Nordin, and N. F. Abdullah, "Energy-efficient downlink for non-orthogonal multiple access with SWIPT under constrained throughput," *Energies*, vol. 13, no. 1, Dec. 2019, doi: 10.3390/en13010107.
[62] Z. Zhang, H. Qu, J. Zhao, and W. Wang, "Energy efficient transmission design of cooperative NOMA with SWIPT network," in *2019 IEEE 4th International Conference on Signal and Image Processing (ICSIP)*, Jul. 2019, pp. 566–572, doi: 10.1109/SIPROCESS.2019.8868752.
[63] W. Zhao, R. She, and H. Bao, "Energy efficiency maximization for two-way relay assisted CR-NOMA system based on SWIPT," *IEEE Access*, vol. 7, pp. 72062–72071, 2019, doi: 10.1109/ACCESS.2019.2919965.
[64] H. Zhang, M. Feng, K. Long, G. K. Karagiannidis, V. C. M. Leung, and H. V. Poor, "Energy efficient resource management in SWIPT enabled heterogeneous networks with NOMA," *IEEE Transactions on Wireless Communications*, vol. 19, no. 2, pp. 835–845, Feb. 2020, doi: 10.1109/TWC.2019.2948874.
[65] I. Budhiraja, N. Kumar, S. Tyagi, S. Tanwar, and M. Guizani, "An energy-efficient resource allocation scheme for SWIPT-NOMA based femtocells users with imperfect CSI," *IEEE Transactions on Vehicular Technology*, vol. 69, no. 7, pp. 7790–7805, Jul. 2020, doi: 10.1109/TVT.2020.2991466.
[66] A. N. Uwaechia and N. M. Mahyuddin, "Spectrum and energy efficiency optimization for hybrid precoding-based SWIPT-enabled mmWave mMIMO-NOMA systems," *IEEE Access*, vol. 8, pp. 139994–140007, 2020, doi: 10.1109/ACCESS.2020.3013305.
[67] T.-V. Nguyen, V.-D. Nguyen, D. B. da Costa, and B. An, "Hybrid user pairing for spectral and energy efficiencies in multiuser MISO-NOMA networks with SWIPT," *IEEE Transactions on Communications*, vol. 68, no. 8, pp. 4874–4890, Aug. 2020, doi: 10.1109/TCOMM.2020.2994204.
[68] Y. Xu, Z. Qin, G. Gui, H. Gacanin, H. Sari, and F. Adachi, "Energy efficiency maximization in NOMA enabled backscatter communications with QoS guarantee," *IEEE Wireless Communications Letters*, vol. 10, no. 2, pp. 353–357, Feb. 2021, doi: 10.1109/LWC.2020.3031042.
[69] W. Chen, H. Ding, S. Wang, D. B. da Costa, F. Gong, and P. H. Juliano Nardelli, "Backscatter cooperation in NOMA communications systems," *IEEE Transactions on Wireless Communications*, vol. 20, no. 6, pp. 3458–3474, Jun. 2021, doi: 10.1109/TWC.2021.3050600.
[70] W. U. Khan, M. A. Javed, T. N. Nguyen, S. Khan, and B. M. Elhalawany, "Energy-efficient resource allocation for 6G backscatter-enabled NOMA IoV networks," *IEEE Transactions on Intelligent Transportation Systems*, vol. 23, no. 7, pp. 9775–9785, Jul. 2022, doi: 10.1109/TITS.2021.3110942.
[71] Y. Zhuang, X. Li, H. Ji, and H. Zhang, "Exploiting intelligent reflecting surface for energy efficiency in ambient backscatter communication-enabled NOMA networks," *IEEE Transactions on Green Communications and Networking*, vol. 6, no. 1, pp. 163–174, Mar. 2022, doi: 10.1109/TGCN.2022.3144465.
[72] S. Zhang and G. Kang, "User association and power control for energy efficiency maximization in M2M-enabled uplink heterogeneous networks with NOMA," *Sensors*, vol. 19, no. 23, Dec. 2019, doi: 10.3390/s19235307.
[73] K. Selvam and K. Kumar, "A novel energy-efficient resource allocation algorithm for non-orthogonal multiple access (NOMA) based M2M communication," in *2020 7th International Conference on Signal Processing and Integrated Networks (SPIN)*, Feb. 2020, pp. 776–780, doi: 10.1109/SPIN48934.2020.9071332.
[74] Z. Yang, Y. Pan, W. Xu, R. Guan, Y. Wang, and M. Chen, "Energy efficient resource allocation for machine-to-machine communications with NOMA and energy harvesting," in *2017 IEEE Conference on Computer Communications Workshops*

(INFOCOM WKSHPS), May 2017, pp. 145–150, doi: 10.1109/INFCOMW.2017.8116367.
[75] Z. Yang, W. Xu, H. Xu, J. Shi, and M. Chen, "Energy efficient non-orthogonal multiple access for machine-to-machine communications," *IEEE Communications Letters*, vol. 21, no. 4, pp. 817–820, Apr. 2017, doi: 10.1109/LCOMM.2016.2641423.
[76] K. Selvam and K. Kumar, "Energy and spectrum efficiency trade-off of non-orthogonal multiple access (NOMA) over OFDMA for machine-to-machine communication," in *2019 Fifth International Conference on Science Technology Engineering and Mathematics (ICONSTEM)*, Mar. 2019, pp. 523–528, doi: 10.1109/ICONSTEM.2019.8918884.
[77] S. Sobhi-Givi, M. G. Shayesteh, and H. Kalbkhani, "Energy-efficient power allocation and user selection for mmWave-NOMA transmission in M2M communications underlaying cellular heterogeneous networks," *IEEE Transactions on Vehicular Technology*, vol. 69, no. 9, pp. 9866–9881, Sep. 2020, doi: 10.1109/TVT.2020.3003062.
[78] M. Zeng, A. Yadav, O. A. Dobre, and H. V. Poor, "Energy-efficient power allocation for MIMO-NOMA with multiple users in a cluster," *IEEE Access*, vol. 6, pp. 5170–5181, 2018, doi: 10.1109/ACCESS.2017.2779855.
[79] Q. Sun, I. Chin-Lin, S. Han, and Z. Pan, "On the ergodic capacity and energy efficiency for fading MIMO NOMA systems," *Journal of Signal Processing Systems*, vol. 83, no. 2, pp. 165–175, May 2016, doi: 10.1007/s11265-015-1076-3.
[80] L. Chen, B. Hu, G. Xu, and S. Chen, "Energy-efficient power allocation and splitting for mmWave beamspace MIMO-NOMA With SWIPT," *IEEE Sensors Journal*, vol. 21, no. 14, pp. 16381–16394, Jul. 2021, doi: 10.1109/JSEN.2021.3076517.
[81] B. Wang, L. Dai, Z. Wang, N. Ge, and S. Zhou, "Spectrum and energy-efficient beamspace MIMO-NOMA for millimeter-wave communications using lens antenna array," *IEEE Journal on Selected Areas in Communications*, vol. 35, no. 10, pp. 2370–2382, Oct. 2017, doi: 10.1109/JSAC.2017.2725878.
[82] M. Zhang *et al.*, "Energy efficiency optimization for secure transmission in a MIMO-NOMA system," in *2020 IEEE Wireless Communications and Networking Conference (WCNC)*, May 2020, pp. 1–6, doi: 10.1109/WCNC45663.2020.9120741.
[83] Y. Wang, Z. Tian, and X. Cheng, "Enabling technologies for spectrum and energy efficient NOMA-MmWave-MaMIMO systems," *IEEE Wireless Communications*, vol. 27, no. 5, pp. 53–59, Oct. 2020, doi: 10.1109/MWC.001.2000055.
[84] A. S. Gharagezlou, J. Pourrostam, M. Nangir, and M. M. Safari, "Energy efficient power allocation in massive MIMO NOMA systems based on SIF using cell division technique," in *2020 2nd Global Power, Energy and Communication Conference (GPECOM)*, Oct. 2020, pp. 356–361, doi: 10.1109/GPECOM49333.2020.9247920.
[85] Z. Wang, T. Lv, and W. Li, "Energy efficiency maximization in massive MIMO-NOMA networks with non-linear energy harvesting," in *2021 IEEE Wireless Communications and Networking Conference (WCNC)*, Mar. 2021, pp. 1–6, doi: 10.1109/WCNC49053.2021.9417389.
[86] Z. Wang and T. Lv, "Energy-efficient and distributed resource allocation for WPT enabled multicell massive MIMO-NOMA networks," in *2020 IEEE 31st Annual International Symposium on Personal, Indoor and Mobile Radio Communications*, Aug. 2020, pp. 1–6, doi: 10.1109/PIMRC48278.2020.9217065.
[87] F. Tan, P. Wu, Y.-C. Wu, and M. Xia, "Energy-efficient non-orthogonal multicast and unicast transmission of cell-free massive MIMO systems with SWIPT," *IEEE Journal on Selected Areas in Communications*, vol. 39, no. 4, pp. 949–968, Apr. 2021, doi: 10.1109/JSAC.2020.3020110.
[88] W. Hao, M. Zeng, Z. Chu, and S. Yang, "Energy-efficient power allocation in millimeter wave massive MIMO with non-orthogonal multiple access," *IEEE Wireless Communications Letters*, vol. 6, no. 6, pp. 782–785, Dec. 2017, doi: 10.1109/LWC.2017.2741493.
[89] M. Zeng, W. Hao, O. A. Dobre, and H. V. Poor, "Energy-efficient power allocation in uplink mmWave massive MIMO with NOMA," *IEEE Transactions on Vehicular Technology*, vol. 68, no. 3, pp. 3000–3004, Mar. 2019, doi: 10.1109/TVT.2019.2891062.
[90] S. Kusaladharma, W.-P. Zhu, W. Ajib, and G. A. Aruma Baduge, "Rate and energy efficiency improvements of massive MIMO-based stochastic cellular networks with NOMA," *IEEE Transactions on Green Communications and Networking*, vol. 5, no. 3, pp. 1467–1481, Sep. 2021, doi: 10.1109/TGCN.2021.3083205.
[91] V. Mandawaria, E. Sharma, and R. Budhiraja, "Energy-efficient massive MIMO multi-relay NOMA systems With CSI Errors," *IEEE Transactions on Communications*, vol. 68, no. 12, pp. 7410–7428, Dec. 2020, doi: 10.1109/TCOMM.2020.3019316.
[92] L. Zhang *et al.*, "Resource allocation for energy efficient user association in user-centric ultra-dense networks integrating NOMA and beamforming," *AEU - International Journal of Electronics and Communications*, vol. 124, Sep. 2020, doi: 10.1016/j.aeue.2020.153270.
[93] A. Khodmi, S. Ben Rejeb, N. Agoulmine, and Z. Choukair, "Energy-efficient power allocation and user-channel assignment for NOMA heterogeneous ultra-dense network," in *2020 IEEE 31st Annual International Symposium on Personal, Indoor and Mobile Radio Communications*, Aug. 2020, pp. 1–7, doi: 10.1109/PIMRC48278.2020.9217254.
[94] F. Xu, X. Yu, M. Li, and B. Wen, "Energy-efficient power allocation scheme for hybrid precoding mmWave-NOMA system with multi-user pairing," in *2019 IEEE International Conference on Communications Workshops (ICC Workshops)*, May 2019, pp. 1–5, doi: 10.1109/ICCW.2019.8756772.
[95] R. Chai, P. Ma, and F. Zou, "5G multi-service scenarios-oriented resource allocation and NOMA pairing scheme for energy efficiency maximization," in *2020 International Conference on Wireless Communications and Signal Processing (WCSP)*, Oct. 2020, pp. 1159–1164, doi: 10.1109/WCSP49889.2020.9299819.
[96] M. Rayati, A. Sheikhi, and A. M. Ranjbar, "Applying reinforcement learning method to optimize an energy hub operation in the smart grid," in *2015 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT)*, Feb. 2015, pp. 1–5, doi: 10.1109/ISGT.2015.7131906.
[97] Z. Liu, G. Kang, L. Lei, N. Zhang, and S. Zhang, "Power allocation for energy efficiency maximization in downlink CoMP systems with NOMA," in *2017 IEEE Wireless Communications and Networking Conference (WCNC)*, Mar. 2017, pp. 1–6, doi: 10.1109/WCNC.2017.7925860.
[98] Y. He, J. Jiao, Z. Chen, S. Wu, W. Wu, and Q. Zhang, "Energy efficient mmWave NOMA downlink multi-relay system for ITSN," in *2020 IEEE 92nd Vehicular Technology Conference (VTC2020-Fall)*, Nov. 2020, pp. 1–5, doi: 10.1109/VTC2020-Fall49728.2020.9348587.
[99] M. Zeng, W. Hao, A. Yadav, N.-P. Nguyen, O. A. Dobre, and H. V. Poor, "Energy-efficient joint power control and receiver design for uplink mmWave-NOMA," in *2020 IEEE International Conference on Communications Workshops (ICC Workshops)*, Jun. 2020, pp. 1–5, doi: 10.1109/ICCWorkshops49005.2020.9145398.
[100] X. Qi, G. Xie, and Y. Liu, "Energy-efficient power allocation in multi-user mmWave-NOMA systems with finite resolution analog precoding," *IEEE Transactions on Vehicular Technology*, vol. 71, no. 4, pp. 3750–3759, Apr. 2022, doi: 10.1109/TVT.2021.3080387.
[101] X. Yu, F. Xu, K. Yu, and X. Dang, "Power allocation for energy efficiency optimization in multi-user mmWave-NOMA system with hybrid precoding," *IEEE Access*, vol. 7, pp. 109083–109093, 2019, doi: 10.1109/ACCESS.2019.2933328.

[102] I. Ganesan, R. J. S. Jayakumar, S. priya Murugan, and D. B. Muneeswaran, "Joint energy-efficient user scheduling and power allocation scheme for a millimeter-wave-NOMA system," *International Journal of Communication Systems*, vol. 34, no. 12, Aug. 2021, doi: 10.1002/dac.4901.

[103] A. Rahmati, S. Hosseinalipour, Y. Yapici, I. Guvenc, H. Dai, and A. Bhuyan, "Energy-efficient beamforming and power control for uplink NOMA in mmWave UAV networks," in *GLOBECOM 2020 - 2020 IEEE Global Communications Conference*, Dec. 2020, pp. 1–6, doi: 10.1109/GLOBECOM42002.2020.9348114.

[104] X. Pang, J. Tang, N. Zhao, X. Zhang, and Y. Qian, "Energy-efficient design for mmWave-enabled NOMA-UAV networks," *Science China Information Sciences*, vol. 64, no. 4, Apr. 2021, doi: 10.1007/s11432-020-2985-8.

[105] A. Gupta, S. Biswas, K. Singh, T. Ratnarajah, and M. Sellathurai, "An energy-efficient approach towards power allocation in non-orthogonal multiple access full-Duplex AF relay systems," in *2018 IEEE 19th International Workshop on Signal Processing Advances in Wireless Communications (SPAWC)*, Jun. 2018, pp. 1–5, doi: 10.1109/SPAWC.2018.8445898.

[106] Z. Wei, X. Zhu, S. Sun, J. Wang, and L. Hanzo, "Energy-efficient full-duplex cooperative nonorthogonal multiple access," *IEEE Transactions on Vehicular Technology*, vol. 67, no. 10, pp. 10123–10128, Oct. 2018, doi: 10.1109/TVT.2018.2864545.

[107] C. Chen, X. Li, H. Ji, and H. Zhang, "Energy-efficient mobile edge computing system based on full-duplex energy harvesting relay network," in *GLOBECOM 2020 - 2020 IEEE Global Communications Conference*, Dec. 2020, pp. 1–6, doi: 10.1109/GLOBECOM42002.2020.9348248.

[108] X. Liu and J. Mo, "Spectral-energy efficiency maximization for wireless powered low-latency NOMA systems with full-duplex relaying," *EURASIP Journal on Wireless Communications and Networking*, vol. 2019, no. 1, Dec. 2019, doi: 10.1186/s13638-019-1516-z.

[109] L. Zhang, F. Fang, and Z. Wu, "Energy efficient power allocation for OFDM-NOMA visible Light communication systems with statistical channel state information," in *2021 15th International Symposium on Medical Information and Communication Technology (ISMICT)*, Apr. 2021, pp. 110–115, doi: 10.1109/ISMICT51748.2021.9434931.

[110] C. Chen, S. Fu, X. Jian, M. Liu, and X. Deng, "Energy-efficient NOMA with QoS-guaranteed power allocation for multi-user VLC," in *2021 IEEE 16th Conference on Industrial Electronics and Applications (ICIEA)*, Aug. 2021, pp. 1305–1310, doi: 10.1109/ICIEA51954.2021.9516247.

[111] A. al Hammadi, S. Muhaidat, P. C. Sofotasios, and M. al Qutayri, "A robust and energy efficient NOMA-enabled hybrid VLC/RF wireless network," in *2019 IEEE Wireless Communications and Networking Conference (WCNC)*, Apr. 2019, pp. 1–6, doi: 10.1109/WCNC.2019.8885577.

[112] K. G. Rallis, V. K. Papanikolaou, P. D. Diamantoulakis, M.-A. Khalighi, and G. K. Karagiannidis, "Energy efficiency maximization in cooperative hybrid VLC/RF networks with NOMA," in *2021 17th International Symposium on Wireless Communication Systems (ISWCS)*, Sep. 2021, pp. 1–6, doi: 10.1109/ISWCS49558.2021.9562202.

[113] H. Zhang, Y. Duan, K. Long, and V. C. M. Leung, "Energy efficient resource allocation in terahertz downlink NOMA systems," *IEEE Transactions on Communications*, vol. 69, no. 2, pp. 1375–1384, Feb. 2021, doi: 10.1109/TCOMM.2020.3037597.

[114] H. Zhang, H. 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, doi: 10.1109/JSAC.2020.3000888.

[115] H. Zhang, H. Zhang, W. Liu, K. Long, J. Dong, and V. C. M. Leung, "Energy efficient user clustering and hybrid precoding for terahertz MIMO-NOMA systems," in *ICC 2020 - 2020 IEEE International Conference on Communications (ICC)*, Jun. 2020, pp. 1–5, doi: 10.1109/ICC40277.2020.9149188.

[116] H. Zhang, J. Zhang, and K. Long, "Energy efficiency optimization for NOMA UAV network with imperfect CSI," *IEEE Journal on Selected Areas in Communications*, vol. 38, no. 12, pp. 2798–2809, Dec. 2020, doi: 10.1109/JSAC.2020.3005489.

[117] M. F. Sohail, C. Y. Leow, and S. Won, "Energy-efficient non-orthogonal multiple access for UAV communication system," *IEEE Transactions on Vehicular Technology*, vol. 68, no. 11, pp. 10834–10845, Nov. 2019, doi: 10.1109/TVT.2019.2939186.

[118] S. Najmeddin, S. Aissa, and S. Tahar, "Energy-efficient resource allocation for UAV-enabled information and power transfer with NOMA," in *GLOBECOM 2020 - 2020 IEEE Global Communications Conference*, Dec. 2020, pp. 1–6, doi: 10.1109/GLOBECOM42002.2020.9348068.

[119] M. Jia, Q. Gao, Q. Guo, and X. Gu, "Energy-efficiency power allocation design for UAV-assisted spatial NOMA," *IEEE Internet of Things Journal*, vol. 8, no. 20, pp. 15205–15215, Oct. 2021, doi: 10.1109/JIOT.2020.3044090.

[120] A. Masaracchia, L. D. Nguyen, T. Q. Duong, C. Yin, O. A. Dobre, and E. Garcia-Palacios, "Energy-efficient and throughput fair resource allocation for TS-NOMA UAV-assisted communications," *IEEE Transactions on Communications*, vol. 68, no. 11, pp. 7156–7169, Nov. 2020, doi: 10.1109/TCOMM.2020.3014939.

[121] A. Masaracchia, L. D. Nguyen, C. Yin, O. A. Dobre, and E. Garcia-Palacios, "The concept of time sharing NOMA into UAV-enabled communications: An energy-efficient approach," in *2020 4th International Conference on Recent Advances in Signal Processing, Telecommunications & Computing (SigTelCom)*, Aug. 2020, pp. 61–65, doi: 10.1109/SigTelCom49868.2020.9199023.

[122] Y. Yang and M. Cenk Gursoy, "Energy efficiency optimization in UAV-assisted communications and edge computing," in *2020 IEEE 21st International Workshop on Signal Processing Advances in Wireless Communications (SPAWC)*, May 2020, pp. 1–5, doi: 10.1109/SPAWC48557.2020.9154211.

[123] N. Hashim, N. F. A. M. Azmi, F. Idris, and N. Rahim, "Smartphone activated door lock using Wi-Fi," *ARPN Journal of Engineering and Applied Sciences*, vol. 11, no. 5, pp. 3309–3312, 2016.

[124] N. Hashim, N. Norddin, F. Idris, S. N. I. Mohd Yusoff, and M. Zahari, "IoT blood pressure monitoring system," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 19, no. 3, pp. 1384–1390, Sep. 2020, doi: 10.11591/ijeecs.v19.i3.pp1384-1390.

[125] N. Hashim, F. Idris, A. F. Kadmin, and S. S. J. Sidek, "Automatic traffic light controller for emergency vehicle using peripheral interface controller," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 9, no. 3, pp. 1788–1794, Jun. 2019, doi: 10.11591/ijece.v9i3.pp1788-1794.

[126] Y. Wu, B. Shi, L. P. Qian, F. Hou, J. Cai, and X. S. Shen, "Energy-efficient multi-task multi-access computation offloading via NOMA transmission for IoTs," *IEEE Transactions on Industrial Informatics*, vol. 16, no. 7, pp. 4811–4822, Jul. 2020, doi: 10.1109/TII.2019.2944839.

[127] S. O. Olatinwo and T.-H. Joubert, "Energy efficiency maximization in a wireless powered IoT sensor network for water quality monitoring," *Computer Networks*, vol. 176, Jul. 2020, doi: 10.1016/j.comnet.2020.107237.

[128] G. Wu, W. Zheng, Y. Li, and M. Zhou, "Energy-efficient power allocation for IoT devices in CR-NOMA networks," *China Communications*, vol. 18, no. 4, pp. 166–181, Apr. 2021, doi: 10.23919/JCC.2021.04.013.

[129] J. Xu and Z. Liang, "Energy efficiency optimization of NOMA IoT communication for 5G," *Mobile Networks and Applications*, vol. 27, no. 3, pp. 862–873, Jun. 2022, doi: 10.1007/s11036-021-01815-4.

[130] B. Liu, C. Liu, and M. Peng, "Resource allocation for energy-efficient MEC in NOMA-enabled massive IoT networks," *IEEE Journal on Selected Areas in Communications*, vol. 39, no. 4, pp. 1015–1027, Apr. 2021, doi: 10.1109/JSAC.2020.3018809.

[131] C. Chen, S. Fu, X. Jian, M. Liu, X. Deng, and Z. Ding, "NOMA for energy-efficient LiFi-enabled bidirectional IoT communication," *IEEE Transactions on Communications*, vol. 69, no. 3, pp. 1693–1706, Mar. 2021, doi: 10.1109/TCOMM.2021.3051912.

[132] S. Chinnadurai and D. Yoon, "Energy efficient MIMO-NOMA HCN with IoT for wireless communication systems," in *2018 International Conference on Information and Communication Technology Convergence (ICTC)*, Oct. 2018, pp. 856–859, doi: 10.1109/ICTC.2018.8539610.

[133] W. Bi, Y. Shu, W. Dong, and Q. Yang, "Real-time energy management of microgrid using reinforcement learning," in *2020 19th International Symposium on Distributed Computing and Applications for Business Engineering and Science (DCABES)*, Oct. 2020, pp. 38–41, doi: 10.1109/DCABES50732.2020.00019.

[134] H. Zhang, D. Wu, and B. Boulet, "A review of recent advances on reinforcement learning for smart home energy management," in *2020 IEEE Electric Power and Energy Conference (EPEC)*, Nov. 2020, pp. 1–6, doi: 10.1109/EPEC48502.2020.9320042.

[135] F. Jiang, Z. Gu, C. Sun, and R. Ma, "Dynamic user pairing and power allocation for NOMA with deep reinforcement learning," in *2021 IEEE Wireless Communications and Networking Conference (WCNC)*, Mar. 2021, pp. 1–6, doi: 10.1109/WCNC49053.2021.9417564.

[136] S. K. Mahmud, Y. Liu, Y. Chen, and K. K. Chai, "Adaptive reinforcement learning framework for NOMA-UAV networks," *IEEE Communications Letters*, vol. 25, no. 9, pp. 2943–2947, Sep. 2021, doi: 10.1109/LCOMM.2021.3093385.

[137] A. Ashiquzzaman, H. Lee, T.-W. Um, and J. Kim, "Energy-efficient IoT sensor calibration with deep reinforcement learning," *IEEE Access*, vol. 8, pp. 97045–97055, 2020, doi: 10.1109/ACCESS.2020.2992853.

[138] W. Wang, Z. Lv, X. Lu, Y. Zhang, and L. Xiao, "Distributed reinforcement learning based framework for energy-efficient UAV relay against jamming," *Intelligent and Converged Networks*, vol. 2, no. 2, pp. 150–162, Jun. 2021, doi: 10.23919/ICN.2021.0010.

BIOGRAPHIES OF AUTHORS

Muhamad Firdaus Darus received the B.Eng. degree in electronic engineering from Universiti Teknikal Malaysia Melaka (UTeM), in 2019 respectively. He is currently pursuing a Master of Science in electronic engineering. His research interests are related to telecommunication, the internet of things (IoT), non-orthogonal multiple access (NOMA), and energy efficiency. He can be contacted at M022020004@student.utem.edu.my.

Fakrulradzi Idris received the B.Eng. and the M.Eng. degrees from Universiti Teknologi Malaysia in 2007 and 2008 respectively. He received his Ph.D. degree from The University of Manchester, U.K in 2018. He is a senior lecturer in Faculty of Electronics and Computer Engineering (FKEKK), Universiti Teknikal Malaysia Melaka (UTeM). His research interests include device-to-device (D2D) communications, non-orthogonal multiple access (NOMA) and 5G networks. He can be contacted at fakrulradzi@utem.edu.my.

Norlezah Hashim obtained her first degree in 2006 from the University of Malaya (UM) and her master's degree from Universiti Teknologi Malaysia (UTM) in 2014. She is currently serving UTEM as a lecturer in the Faculty of Electrical and Electronic Engineering Technology (FTKEE). The pervasiveness of bringing high-speed mobile internet and IoT brings to light her work on 5G and beyond, focusing on non-orthogonal multiple access (NOMA). Other than that, her current publications are based on wireless communication and LoRa technology. She can be contacted at norlezah@utem.edu.my.