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Systematic Review

Non-Orthogonal Multiple Access Enabled Mobile Edge Computing in 6G Communications: A Systematic Literature Review

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Abstract: Mobile edge computing (MEC) supported by non-orthogonal multiple access (NOMA) has recently gained a lot of interest due to its improved ability to lessen power consumption and MEC offload delay. In recent decades, the need for wireless communications has increased tremendously. Fifth-generation (5G) communications will soon be widely used and offer much more functionality than a fourth generation (4G). Between 2027 and 2030, an innovative wireless communication paradigm is known as the sixth generation (6G) system is projected to be introduced with the full help of artificial intelligence (AI). Advanced system capacity, higher data rate, lower latency, advanced security, and improved quality of service (QoS) than 5G systems are a few of the main challenges to resolve with 5G. The growing need for data rates in the sixth generation (6G) communication networks are being met by extraordinary technologies such as NOMA, Soft Computing (SC), and MEC. Owing to the massive attention to the NOMA-enabled MEC, there has been a significant spike in the number of papers published in this area, while more comprehensive studies and classifications are still needed. Using the preferred reporting items for systematic reviews and meta-analysis (PRISMA) guidelines, the investigation reports a systematic literature review (SLR) of NOMA-enabled MEC. This survey also evaluates numerous pieces of literature prudently chosen over a multi-step procedure and meets the selection criteria described in the paper summarizing our review.

Keywords: 6G communication network; non-orthogonal multiple access; mobile edge computing; artificial intelligence

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1. Introduction

Researchers have thought about the 6G generation of cellular networks, which can handle significantly greater data rates and numerous future applications [1–3], while 5G networks are still in the deployment phase [4–6]. The three main application services that 5G communications focus on providing are improving mobile broadband (eMBB), supplying ultra-reliable low latency communications (URLLC), and providing massive machine-type communications (mMTC). Contrarily, 6G networks may run programs that enable augmented reality, virtual reality, linked and autonomous drones and cars, and intelligent and automated devices. Compared to the gigabit per second data rate offered by 5G networks, these networks necessitate a data throughput of up to terabit per second for all of them [7,8]. The utilization of the tera-Hz band is a crucial component of 6G networks. 5G networks currently use millimetre-wave and sub-6GHz spectrum. 6G networks offer sub-1ms latency and 99.99999% reliability, enabling universal communication and several future uses. To improve communication capacity, offer better channel estimations for effective signal transfer, and enable dependable data propagation, 6G will use full-duplex communication and other physical layer technologies [9–11]. Additionally, 6G will leverage AI to make autonomous systems possible, distributed learning techniques to boost precision, big data analytics for forecast and wise decision-making, and the realization of smart cloud, fog, and edge nodes [12–15]. For 6G networks, energy efficiency will be a significant problem [16–18]. Supporting widespread IoT applications is one of the primary causes of the need for increased power consumption [19]. Future network nodes, such as Internet of Things (IoT) gadgets and fog nodes, will have a lot of work to do, increasing power consumption [20,21]. Adopting Tera Hz communications, a short-range communications technology presents another energy-related difficulty for 6G networks. Higher data speeds are possible with the tera-Hz transmission, but it is severely attenuated because of propagation losses and molecular absorption losses [18,22]. 6G networks will prioritize energy-efficient schemes by delivering less-power communications, new energy harvesting (EH) procedures, and energy-saving computing approaches. 6G networks, which will increase connection, boost computational power, and enhance detection and location accuracy, will also enable massive IoT applications. 6G could offer tera-Hz communications, incredibly high data throughput, and extremely small latency because of its capabilities and technologies [23].

NOMA has been recommended as a substitute for traditional orthogonal multiple access (OMA) because it can improve the number of authorized individuals, bandwidth effectiveness, and reduce downtime [24,25]. NOMA's fundamental notion is to allow many individuals to transmit signals simultaneously on a particular bandwidth block. The successive interference cancellation (SIC) technique is used as a multiuser authentication strategy at the reception point to reduce disturbance [26,27]. Integrating NOMA and MEC has become a promising way to deliver efficient transmission and processing to many devices. Implementing NOMA enables multiple clients to synchronously transfer their computational operations to a machine located at the network's periphery, thereby increasing computational capability and effectiveness. A significant amount of investigation has been committed to improving MEC's efficacy in wireless connections by employing NOMA techniques. [28–30]. The developers of [28] sought to reduce system energy usage by enhancing people gathering, resource apportionment, and broadcast rules. The scholars of [29] jointly adjusted jobs and transmission periods to reduce structure interruption in NOMA-centered MEC connections. In [30], the investigators examined the employment of gadget-to-gadget approaches to improve people's cooperation and alleviate the computational load on the edge server in NOMA-centered MEC connections. The publications mentioned above [28–30] concentrated mostly on the case of individual-cell relationships, ignoring the utmost all-inclusive and interesting challenge of NOMA-centered MEC in multicell networks understudied. This study examines how the NOMA strategy can produce cost-effective MEC in multiple node connections where various clients synchronously delegate processing tasks to their corresponding SBSs. Intra- and inter-cell disturbance in multiple node connections can severely degrade the effectiveness of NOMA-centered MEC if not appropriately maintained [31–33]. Considering this concern, we propose a combination of wireless and computational power distribution techniques to improve the environmental sustainability of NOMA-centered MEC while meeting clients' utmost permissible latency requirements. In the suggested framework, the non-convex energy utilization optimization challenge is separated into subchannel distribution, allocation of electricity, and computation resource distribution problems. The researchers additionally illustrate why resolving these issues continuously can optimize energy utilisation. The mathematical outcomes demonstrate that their proposed method can improve the computational effectiveness of NOMA-centered MEC in multiple-cell connectivity.

NOMA ranks as one of the most intriguing electromagnetic transmission techniques for the forthcoming era of mobile communication. NOMA offers numerous desirable improvements across the conventional orthogonal frequency division multiple access (OFDMA) and today's de facto standard OMA innovations, such as expanded spectral efficacy, lowered delay, superior reliability, and a large interconnection. NOMA's guiding terms of reference provide many users with a single value in terms of duration, intensity, and position [34].

The numerous NOMA methodologies can be broadly classified into two major groups: power-domain NOMA and code-domain NOMA. Several approaches for access dependent on lower-density dissemination and patchy code allocation may be employed to improve the classification of code-domain NOMA. In this setting, lattice-partition has several accessibilities, multiple uses of shared-key in several utilizations, and pattern-division multiple connections strongly correlate with numerous connection strategies [34].

The latest study indicates that NOMA can be utilized in numerous sixth-generation (6G) transmission scenarios involving Machine-to-Machine (M2M) connections and the IoT. Furthermore, there is an indication that efficacy can be improved once NOMA is used with additional effective mobile communication strategies. These include shared interactions, multiple-input multiple-output (MIMO) [35], beam formation, space–time programming network of things programming, and full-duplex. Standards and Technology of NOMA have been developed for the future of American digital TV standard (ATSC 3.0) as layered-division multiplexing (LDM) and launched for the third-generation partnership project (3GPP) as multi-user superposition transmission (MUST) [34].

As a result of the fact that NOMA permits several users to use the same resource, interference occurs in such systems. Thus, current resource management and interference mitigation strategies, particularly for ultra-dense networks, need to be reconsidered owing to the inclusion of extra disturbance this new technology provides. Beamforming and the resulting difficulties (e.g., precoding) in massive-MIMO systems provide additional obstacles that must be resolved to realise these technologies' full potential. Existing channel coding, modulation, and estimation issues about the physical layer must also be updated. Cognitive, cooperative, and visible light communications are favourable paradigms under NOMA systems compared to traditional methods. Yet, the difficulties that have arisen due to the inclusion of this new technology must be resolved before reaping the advantages of these paradigms. While NOMA provides various benefits, more users' increased information sensing capability due to this approach poses a greater security and privacy risk. To develop a strong, efficient, and successful system using this method, several security issues ranging from physical to application levels must be resolved. [34].

NOMA trumps conventional orthogonal multiple access (OMA) in several ways, including:

1. It achieves superior spectral efficiency by serving multiple users simultaneously with the same frequency resource and mitigating interference through SIC.
2. It increases the number of simultaneously served users, thus supporting massive connectivity; and 3. It achieves superior spectral efficiency by doing multiple users simultaneously and with the same frequency resource, mitigating interference through SIC.

3. Due to the nature of simultaneous transmission, a user does not need to send information within a predetermined time, resulting in shorter latency;
4. NOMA can preserve the user-fairness and diversified quality of service by flexible power regulation between strong and weak users [36]. Specifically, when more power is provided to a vulnerable user, NOMA provides greater cell-edge throughput, improving the user experience.

To increase throughput, decrease latency, and conserve energy in RAN, NOMA approaches can be combined with MEC [37–39]. The authors presented the heterogeneous NOMA MEC network with numerous mobile edge server nodes providing computing for end devices [37]. The authors suggest an ideal offloading protocol that reduces latency and energy use. Similar findings were reported by Wan, Xu, Xu, and Ahmad [38]. The authors use an optimisation technique to optimise the transmit power allocation of the users, the computing resource allocation of the MEC servers, and the time allocation. According to the findings, the system has a lower total delay than OMA systems. It has been established that the NOMA MEC-based system, created by Dong, Li, Yue, and Xiang [39], increases system throughput and energy efficiency. In the model, two users cooperate with a MEC AP to communicate utilizing uplink NOMA. The NOMA MEC network performs better than other networks, as shown by the Monte-Carlo simulation with the message chain length, signal-to-noise ratio, and transmission time parameters.

1.1. The NOMA Mathematical Characterization, When Compared with OMA

NOMA, which has higher spectral efficiency than traditional orthogonal multiple access (OMA) [40,41], has recently attracted much research interest. For instance, NOMA has been suggested for downlink circumstances in systems utilizing the long-term development of the 3GPP [42,43]. NOMA has been suggested as a potential multiple-access method for future cellular communication networks [44,45]. However, the current multiple-access methods used in cellular communication networks, such as Orthogonal frequency division multiple access (OFDMA) for 4G, FDMA for 1G, time division multiple access (TDMA) for 2G, and code-division multiple access (CDMA) for 3G, are all examples of OMA methods. These methods have a limitation where spectrum resources assigned to users with poor channel conditions are not utilized effectively, which makes them less than ideal.

The idea of NOMA is put up as a solution to this problem and to further increase spectrum efficiency. NOMA is used in conjunction with superposition coding (SC) at the base station (BS) and successive interference cancellation (SIC) at the consumers to obtain the best possible reception for compromised broadcast stations [46]. In a two-user, single-input, single-output (SISO) NOMA structure, for illustration, the base station supports clients on the same channel simultaneously using the time, software, and bandwidth while overlapping transmissions with a distinct distribution of energy factors. The proximal client, who encounters robust circuit circumstances, unravels its shared communication before deriving it by deducting the other person's statement from its assessment. The far user, who has weak channel conditions, decodes its message by considering the partner's message to be noise. This approach provides both parties with complete accessibility to all resource blocks (RBs), and the nearby person can decode its data without interruption from the distant user. Hence, compared to traditional OMA techniques, the overall performance is improved.

1.2. Problem Formulation for Sound Mathematical Representations

Consider a downlink communication arrangement with one BS and K user, where each user has a single antenna. The signal at user i is received using NOMA transmission and is shown in Equation (1)

$$y = h_i x + n_i,\ i = 1,\ 2,\ \ldots,\ K, \tag{1}$$

where h_i signifies the station coefficient, and $n_i \sim N(0, N_0)$ is the additive white Gaussian noise (AWGN) at client i, $\sum_{i=1}^{K} \sqrt{P_i s_i}$ is the superposition of $s_i' s$ with power allocation policy $P = \left\{(P_1, P_2, \ldots, P_K) / \sum_{i=1}^{K} P_i = P\right\}$, s_i signifies the data envisioned to communicate to the client i, P_i signifies the power assigned to client i, and P represents the total power constraint. For effortlessness of examination, we accept that $|h_1| \geq |h_2| \geq \cdots \geq |h_K|$ and the total bandwidth is normalized to unity in this review.

In this paper, we establish the minimal rate constraint r^* In the interest of consumer impartiality. The following condition should be guaranteed by the power allocation policy mathematically as seen in Equation (2):

$$\underset{i}{min}\, r_i \geq r^*, \tag{2}$$

where r_i Is the user i possible rate in nats/sec/Hz, which is determined by Equation (3)

$$r_i = ln\left(1 + \frac{P_i |h_i|^2}{N_0 + |h_i|^2 \sum_{j=1}^{i-1} P_j}\right) \tag{3}$$

The summation in the denominator becomes zero for the exceptional case of $i = 1$, and the associated rate changes to as seen in Equation (4):

$$r_1 = ln\left(1 + \frac{P_i |h_i|^2}{N_0}\right) \tag{4}$$

The fact that the channels are ordered and the user with the stronger channel can decode the messages delivered to the user with the weaker channel indicates that r_i is possible. Consequently, the Equations (5)–(7) that follows is capable of being utilized to address the optimization challenge of enhancing the overall aggregate rate while satisfying the consumer's equitable requirement for NOMA frameworks:

$$R_N \triangleq \max_{P_i} \sum_{t=1}^{K} r_i \tag{5}$$

$$s.t. \qquad r_i = ln\left(1 + \frac{P_i |h_i|^2}{N_0 + |h_i|^2 \sum_{j=1}^{i-1} P_j}\right), \tag{6}$$

$$\sum_{t=1}^{K} P_i \leq P, \tag{7}$$

Conventional OMA structures, which include FDMA or TDMA, allocate duration/ frequency resources quasi-adaptively, giving every customer an established subchannel. To simplify designation, we refer to this kind of OMA as OMA-TYPE I in the present investigation. Therefore, the OMA-TYPE-I optimization challenge is capable of being formulated in the following Equations (8) and (9), presuming that all consumers will receive an equal volume of assets (the duration or bandwidth):

$$R_{01} \triangleq \underset{P_i}{max} \sum_{t=1}^{K} r_i \tag{8}$$

$$s.t. \qquad r_i = \frac{1}{K} ln\left(1 + \frac{K P_i |h_i|^2}{N_0}\right), \tag{9}$$

The optimization problem for jointly designing power and sub-channel allocations will be addressed because some users may encounter poor channel conditions due to significant route loss and random fading caused by sub-channel allocations that are not optimal. When the total time/frequency is divided into n sub-channels that will be shared orthogonally among K users, the following Equations (10)–(15) represents the optimization problem:

$$R_{0X} \triangleq \max_{P_{i,n},\ S_i} \sum_{t=1}^{K} \sum_{n \in S_i} r_i,\ n \tag{10}$$

$$s.t. \qquad r_i,\ n = \frac{1}{N} ln\left(1 + \frac{P_i,\ n|h_i|^2}{N_0 \frac{1}{N}}\right), \tag{11}$$

$$\sum_{n=1}^{N} \sum_{i=1}^{K} P_i,\ n \le P, \tag{12}$$

$$P_i,\ n\ \ge 0,\ \forall_i,\ n \tag{13}$$

$$\sum_{n \in S_i} r_i,\ n\ \ge\ r^*, \tag{14}$$

$$S_1,\ S_2, \ldots,\ S_K \text{ are disjoint, } P_i,\ n \text{ and } h_i,\ n$$

$$S_1,\ \cup S_2 \cup \ldots \cup\ S_K = \{1,\ 2,\ \ldots,\ N\}, \tag{15}$$

The power allotted to and the station coefficient of the client i's sub-station, correspondingly, are denoted as $P_i,\ n$ and h_i. S_i is the collection of sub-channel indexes that are allotted to client i. Be aware that the optimization issue in Equation (16) is not arched. Admittedly, it is found that by substituting the discrete solution with the following optimization problem, it might be a continuous one with an upper-bounded time/frequency allocation like this:

$$R_{02} \triangleq \max_{P_{i,n},\ \alpha_i} \sum_{t=1}^{K} r_i \tag{16}$$

$$s.t. \qquad r_i = \alpha_i ln\left(1 + \frac{P_i,\ n|h_i|^2}{\alpha_i N_0}\right), \tag{17}$$

$$\sum_{i=1} \alpha_i = 1. \tag{18}$$

The OMA system with the optimization described in Equations (16)–(18) is referred to as OMA-TYPE-II in this paper for notational simplicity. Because the energy conservation $\sum_{i=1}^{K} \alpha_i \frac{P_i}{\alpha_i} = P$ is created in TDMA throughout all user orthogonal time slots, and the effective noise power becomes $\alpha_i N_0$ in FDMA, it should be noted that the optimization difficulties in Equations (14) and (16) apply to both technologies. The definitions of the three different types of OMA systems is suggest in Equation (19)

$$R_{01}\ \le\ R_{0X}\ \le\ R_{02} \tag{19}$$

Consequently, we must demonstrate that NOMA is superior to OMA to illustrate its superiority as seen in Equation (20).

$$R_N\ \ge\ R_{02}. \tag{20}$$

However, OMA-TYPE-I and OMA-TYPE-II are considered in this research to uncover more complex aspects of these OMA systems. Also, distinct mathematical techniques must demonstrate NOMA's superiority over OMA-TYPE-I and OMA-TYPE-II.

1.3. Fundamentals of the NOMA System

The CD-NOMA and PD-NOMA systems enable manifold clients to access the same wireless resources in the coding and power domains. This creates non-orthogonality in client access. This work focuses on the PD-NOMA system, where users sharing the same resources are assigned different power levels [46,47]. PD-NOMA further supports user fairness by providing the user with a high transmission power and a low channel gain. Conversely, the greater the channel gain, the less user will get broadcast power. This indicates that clients' power coefficients are allocated among corresponding clients contrariwise proportionate fashion with their station circumstances [48]. Additionally, under the NOMA system, a single subcarrier may be allotted to several clients, and each client can collect data from manifold subcarriers.

1. NOMA's capacity to support manifold clients with the equivalent time-frequency resource makes it highly spectrum-efficient, resulting in improved spectral efficiency (SE). This, in turn, can enhance the system throughput.
2. Improved fairness for users can be achieved through the NOMA system, which allows for greater flexibility in the allocation of radio resources. By relaxing the orthogonal restraint of the OMA scheme, NOMA permits efficient resource allocation, promoting user fairness.
3. The non-orthogonal assignment of resources of the NOMA scheme implies that the available resources do not constrain the supported users or devices. With a less non-orthogonal resource allocation, NOMA can accommodate more users than OMA.
4. The NOMA technique can be considered an "add-on" to existing OMA methods as it uses a distinct power-domain dimension. As superposition coding and SIC methodology are well-established in theory and practice, NOMA can be linked to modern MA approaches. This makes NOMA compatible with different systems.
5. In the 6G connection, using OMA incurs significant latency and signalling costs due to the access grant required in the uplink. This is deemed unacceptable. As a solution, the NOMA approach can provide low transmission delay and signalling requirements.

NOMA, on the other hand, facilitates confer-free upstream dissemination, reducing dissemination delay and transmitting complexity. Additionally, serving multiple users in a NOMA network helps to minimize latency. However, the following are some drawbacks of the NOMA scheme [49]:

1. The overhead for CSI feedback is increased in the NOMA system because the base station (BS) needs to identify the top CSI to achieve the best-translating directive for the SIC scheme.
2. The SIC process increases the computational complexity of the receiver side, especially for multicarrier and multi-user systems.
3. In the NOMA system, the communication cost is heightened because the strong user needs to be aware of the energy dissemination of the feebler client to implement SIC.
4. As a result of distributing more power to the poor users, the whole system experiences increased inter-cell interference.

1.4. Resource Allocation Issue for the NOMA System

For NOMA systems, optimizing performance requires efficient resource allocation, which involves power allocation (PA), subcarrier-user assignment (SUA), or user pairing (UP). UP refers to the selection of multiplexed consumers for each subcarrier, while PA involves the allocation of the total power budget among the subcarriers and the distribution power per subcarrier among users sharing the same subcarrier. UP and PA structures aim to accomplish various performance metrics, including:

1. Increasing the overall scheme ability, thereby enhancing SE and EE.
2. Decrease the likelihood of outages.
3. Improve the data transfer rate for slow clients.
4. Improve the effectiveness of the SIC
5. Increase the fairness between users
6. Reduce energy use as much as possible.

NOMA-enabled MEC has some protocols and practices, which are discussed as follows:

1. *3GPP Standards*: The 3rd Generation Partnership Project (3GPP) is a worldwide standard-setting organization establishing mobile telephone technology protocols. NOMA-MEC is being investigated as a component of 3GPP's 6G advancement. 6G requirements for NOMA and MEC are right now being designed. For instance, 3GPP is developing a NOMA-based network layer specification for 6G, which is anticipated further to boost the wireless transmission system's efficacy and bandwidth. NOMA-MEC technological advances are additionally being investigated for the subsequent infrastructure of the 6G system.
2. *IEEE Standards*: IEEE is an accredited body that creates norms for numerous technologies. IEEE is investigating NOMA-MEC as a component of the ongoing creation of the IEEE 802.11 norm, the accepted norm for wireless local area networks (WLANs). In particular, IEEE 802.11ax(Wi-Fi 6) and IEEE 802.11be (Wi-Fi 7) are being created to facilitate NOMA-MEC, which is anticipated to boost the speed and effectiveness of WLANs.
3. *European Commission (EC) Policy Framework*: The EC has put forward guidelines for implementing networks capable of supporting 5G and, afterwards, encompassing the encouragement of periphery computing and the advancement of spectrum-use protocols. To guarantee the competitive edge of European enterprises, the regulatory structure further emphasizes the necessity to support creativity and investment in cutting-edge technologies like NOMA-MEC.
4. *National Institute of Standards and Technology*: The NIST in the United States released policies applicable to the NOMA-MEC system aimed at edge computing safety. These policies involve suggestions for safeguarding edge technology, guaranteeing safe connections within edge technology and the cloud, and protecting the confidentiality of data.

Therefore, regulatory authorities and other agencies are proactively creating NOMA MEC-related standards and policies to facilitate the sequent application of this innovation effectively and safely.

With 6G's ability to handle numerous edge applications and facilities with reduced latency and power utilization, edge computing (EC) has become an essential constituent of 5G communication [50]. Extending cloud computing facilities to the system edge fetches these facilities quicker to consumer devices [51]. Conventional EC's three main computing technologies are MEC, cloudlets, and fog computing (FC) [52–54]. MEC is considered to deliver facilities to mobile consumers despite permitting them to access regional resources. To extend the pertinency of MEC to diverse structures (e.g., immobile access expertise, Wi-Fi, etc.), the word "mobile" has been dropped since 2016. MEC has been renamed Multi-Access Edge Computing (MAEC) by the European Telecommunications Standards Institute's Industry Specification Group (ETSI ISG) to consider best the increasing concentration of MEC among non-cellular carriers [55].

MEC is a significant technology for the subsequent wave of wireless systems [56]. The fundamental knowledge behind MEC is to leverage base stations and other mobile network infrastructure as compute servers, enabling mobile operators to delegate their most crucial activities to the servers to avoid computationally costly ad delays [57,58]. Because MEC servers have more processing power than local servers, these computations can be finished faster than locally. Because local computing does not require energy, MEC suggests to offers mobile operators the advantage of longer battery life from a power consumption perspective [59–61]. MEC is vital in the wireless Internet of Things (IoT) environment, where gadgets usually have limited power and computing capabilities [62]. MEC provides an alternative to employing IoT devices for local task computing for machine learning (ML) applications that is low-latency and power-efficient [63,64].

The utilization of NOMA for MEC discharge is inspired by the need for spectrally and energy-efficient release in MEC networks [65–67]. The development of analytical findings for the successful likelihood of MEC discharge demonstrated in [68,69] that using NOMA communication may momentously decrease the interruption and energy usage of the MEC discharge. The study of the NOMA-centered MEC approach scheme founded on orthogonal frequency division multiplexing (OFDM) in [70–73] resulted in the creation of state-of-the-art joint power and subcarrier assignment techniques. There was a discussion of utilising unmanned aerial vehicles (UAVs) in NOMA-aided MEC structures [74,75], and several initiatives for cooperative MEC resource distribution and UAV trajectory schedules were established [76,77]. The security of NOMA-MEC networks was examined by [78,79] while assuming that passive eavesdroppers were present.

It is shown in [80,81] that combining MEC with NOMA may avoid time-consuming delays and use less energy. The researchers of [82] also looked at the utilization of uplink and downlink NOMA in MEC structures. The investigators produced investigative outcomes to show how effectively adopting NOMA may decrease the interruption and power usage for MEC discharge. The new emphasis on NOMA and MEC working together is an additional essential communication approach for usage in upcoming wireless networks. The authors of [83] looked at a MEC system that uses NOMA for activity and results downloading while improving communication powers, transmission, time distribution, and work divesting to decrease data consumption. Additionally, [84] combined methods to reduce the total user latency. The authors of [85] adapted multi-antenna NOMA to multi-user MEC systems and considered partial and binary offload situations.

Inspired by the advantages of NOMA, substantial studies have been devoted to improving the efficiency of MEC in wireless networks by using NOMA approaches. According to a review of the relevant works, the effectiveness of NOMA-enabled MEC has not been exhaustively examined in various manifold client 6G radiocommunication deployment scenarios. Thus, we evaluated the efficacy of NOMA-enabled MEC expertise utilizing the THz channel for 6G communication. In addition, existing work does not assess the effectiveness of NOMA-centered MEC in a 6G connection employing a THz medium, considering the varying device powers.

In this SLR paper, we compare the effectiveness of NOMA-centered MEC systems concerning various key performance parameters, such as resource allocation, power allocation, energy efficiency, dynamic resource allocation, computational efficiency, and computational offloading, for 6G communication deployment scenarios in communities.

With a focus on incorporating two concepts relating to NOMA and MEC structures and their utilization in 6G networks, we propose an SLR on NOMA-enabled MEC in this study. NOMA-MEC has emerged as an exciting innovation capable of supporting the growing need for rapid, low-latency, and reliable mobile communication connections. Yet, the implementation of NOMA-MEC connections confronts numerous tactical and technological obstacles. To establish and implement effective and sustainable NOMA-MEC relationships, it is essential to comprehend the present phase of the investigation to recognize the main difficulties and possibilities.

This investigation is an SLR that concentrates on the present situation regarding MEC connections enabled by NOMA NOMA-MEC connections are an intriguing innovation capable of meeting the rising need for fast, low-latency, and dependable 6G mobile communication systems.

Therefore, the primary objective of this SLR on NOMA-enabled MEC connections is to present an in-depth knowledge of existing present-day studies conducted in this field of study. This SLR aims to recognize NOMA-MEC connection gaps in analysis, advantages, and limitations in the current body of research. The study specifically addresses this issue by examining and responding to the following research questions in the areas that are underlined:

1. What strategies, methods, and approaches have scholars recommended to enhance the operational efficiency of NOMA-MEC connections?
2. What are the gaps in knowledge, advantages, and limitations regarding NOMA-MEC connections in the published literature?
3. What are the primary obstacles and possibilities associated with creating and implementing NOMA-MEC in 6G connections?
4. What are the prospective areas of investigation for creating and implementing NOMA-MEC connections that are economical and sustainable?

In summary, this survey aims to deliver a thorough knowledge of the present state of study on NOMA-MEC in 6G connections and to recognize the difficulties and possibilities associated with the potential creation and implementation of effective and sustainable mobile communication systems.

To address the RQs mentioned above, the SLR is conducted using a standardized and thorough PRISMA approach (Supplementary Materials). The procedure involves establishing the RQs, undertaking a planned search for pertinent literature, evaluating and choosing the research articles according to established inclusion and exclusion requirements, and then assessing the selected studies employing an established collection of data method.

Scientists, entrepreneurs, and governments concerned with creating and implementing effective and sustainable 6G mobile communication structures can benefit from the findings of this investigation.

NOMA-MEC in 6G communications can contribute in the following ways to sustainability.

1. NOMA-MEC provides cost-effective and adaptable resource distribution in 6G networks, facilitating many users' concurrent utilization of the same resources. This leads to a greater effective application of resources and may lower energy consumption, contributing to sustainability.
2. NOMA-MEC may encourage the implementation of edge computing, which allows the consideration of data closer to its origination. This may minimize the quantity of data that must be conveyed over vast distances, thereby reducing energy consumption and carbon emissions related to the transfer of information.
3. NOMA-MEC can aid in the establishment of intelligent and environmentally friendly communities. NOMA-MEC may facilitate the creation of applications such as smart transportation, smart energy management, and smart waste management that enhance the sustainability of communities by promoting the effective utilization of resources and peripheral computing.
4. NOMA-MEC in 6G connectivity can help achieve sustainability by promoting effective resource utilisation, minimizing energy consumption, promoting periphery computing, and aiding the establishment of intelligent and sustainable cities.

The rest of this paper is pre-structured; thus, Section 2 discusses the literature relating to the study. The resources and procedures employed for this survey are discussed in Section 3. Section 4 presents the findings and discussion, including answering the research questions formulated earlier in the study. The study was concluded with upcoming investigations recommended in Section 5.

2. Related Works

Numerous research studies have been conducted on NOMA, MEC, and 6G communications. To our knowledge, however, a comprehensive evaluation of the literature on NOMA-based mobile edge computing in 6G communications has not been done.

Basnayake et al. [86] completed a thorough categorization analysis of research in the power and code domains on NOMA-related energy-saving solutions. They also considered developing plans to use cutting-edge methods to increase the energy efficiency of current green NOMA programs. Finally, they determined upcoming difficulties and strategies for an energy-efficient NOMA since NOMA has been identified as a critical technology for fifth-generation wireless (5G) networks.

Reddy, Mannem, and Jamal [87] primarily investigate the implementation of NOMA structures on software-defined radio (SDR) schemes. This investigation thoroughly evaluates NOMA's origins, current developments, and potential future research areas. Mathematical analysis is presented for several successive interference cancellations (SIC) receivers, including the ideal SIC recipient, the symbol-level SIC receiver, and the codeword-level SIC receiver.

Shahraki et al. [88] thoroughly investigated 6G networks. They examined the 6G networks' utilization, essential services, enabling technology, and upcoming difficulties. They started by talking about the demand for 6G networks. The following section discusses prospective 6G demands, trends, and current 6G-related research initiatives, such as B. Touch Internet and terahertz (THz). There will also be presentations of applications, new services, important enabling technologies, and key performance metrics for 6G networks. Finally, several possibly unsolved difficulties for upcoming 6G networks are also given.

Liu et al. [89] investigated the evolution of Next Generation Multiple Access (NGMA), focusing particularly on the change from NOMA to NGMA. Specifically, the authors explore many potential candidate approaches after first addressing the essential capability restrictions of NOMA and outlining the innovative specifications for NGMA. We also offer a summary of existing investigation exertions on multi-antenna procedures for NOMA, possible upcoming utilization situations of NOMA, and the interaction amid NOMA and further upcoming physical layer approaches in light of the increased compatibility and litheness of NOMA. In addition, we talk about sophisticated mathematical techniques for NOMA communication design.

Yazid et al. [90] thoroughly analysed the most important research papers on UAV technology utilization connected to MEC-allowed or aided networks. It discusses how new IoT applications might benefit from the UAV-enabled MEC architecture and how DL and ML play a part in overcoming different restrictions like latency, task shifting, energy requirements, and security.

After reviewing these surveys, our contribution will focus on analysing resource and power allocation, latency, energy consumption, and the allocation of computing and energy-saving resources while also suggesting a more effective allocation of resources and energy. In summary, we concentrate on the present methods, unanswered issues, and future areas of study for NOMA-enabled MECs in 6G communications. Additionally, we will offer suggestions for researchers who want to do this type of research. The literature relating to this survey reviewed is abridged in Table 1.

It was deduced from the literature review that many authors did not follow the systematic literature review procedure, which involves using the PRISMA method for a thorough investigation. Hence, in this study, we have proposed to consider the SLR using the PRISMA method to analyse the articles for the study.

Table 1. summarizes the various related literature reviewed.

Authors	Objectives	Limitations
Basnayake et al. [86]	The authors completed a thorough categorization analysis of research in the power and code domains on NOMA-related energy-saving solutions. They gave a comprehensive review of the origins of NOMA.	The review was limited to only NOMA technology, and the study did consider the SLR process.
Reddy, Mannem, and Jamal [87]	The authors primarily investigate the execution of NOMA systems on software-defined radio (SDR) platforms.	The study did not consider the process of SLR.
Shahraki et al. [88]	The authors performed a thorough investigation of 6G networks. They examined the 6G networks' applications, essential services, enabling technology, and upcoming difficulties.	Their review was just limited to the 6G communication network.
Liu et al. [89]	The scholars examined the evolution of Next Generation Multiple Access (NGMA), focusing particularly on the change from Non-Orthogonal Multiple Access (NOMA) to NGMA.	They did not conduct an SLR review process or consider MEC technology in their study.
Yazid et al. [90]	The authors thoroughly analysed the important papers on UAV technology utilization connected to MEC-allowed or aided architectures.	They only considered UAV and MEC technologies and also, and they didn't follow the SLR procedure.

3. Materials and Methods

This analysis used the Preferred Reporting Items for the PRISMA technique to assess the existing evidence [91,92]. We also integrated our research with the acknowledged IT-related SLR design criteria. The following subsections summarise the procedures employed to investigate this survey, the selection criteria, information sources, search strategy, decision-making process, and content analysis.

3.1. Eligibility Criteria and Information Source

The justifications provided in the research publications and the criteria listed in Table 2 were contrasted. Relevant papers use search terms like NOMA, mobile edge computing, soft computing, and 6G in databases, including IEEE Xplore, Scopus, SpringerLink, Wiley Online Library, and Web of Science. We aim to provide you with a choice of results utilizing a range of general phrases and various search term combinations.

Table 2. Inclusion and Exclusion Standards.

Criteria	Justification
The analysis requires to be carried out on an investigative article	The study focuses on publications from peer-reviewed journals and conferences to ensure the selected publications are of exceptional eminence.
The study was required to be published as a full-length paper.	A brief article typically lacks a strong evidence and cannot cover all the specifics of the suggested solution.
The study's papers have to be written in English.	The language of communication among the researchers who carried out this SLR is English.
Publications must be pertinent to certain topics, like engineering.	The research in this article is not concentrated on any other topics.
Articles that were published between 2010 and 2022	To collect all relevant field-related data

3.2. Selection Process

The time frame for the search is January 2010 through September 2022. In this phase, 8335 records in total were extracted. The analysis eliminated 356 records after removing duplicates. After the retrieved publications' titles, abstracts, and keywords are evaluated in line with the suggestions made by the SLR framework [91,92], a total of 32 papers are selected. A forward referral was made to get more pertinent articles, which were retrieved. Once potentially relevant publications are founded on their titles, keywords, and abstracts, the full text of each journal is recovered and then further examined to decide eligibility. Forty-nine items are ultimately chosen for evaluation. Figure 1 depicts the selection procedure, which entails locating, selecting, and narrowing the list of research publications.

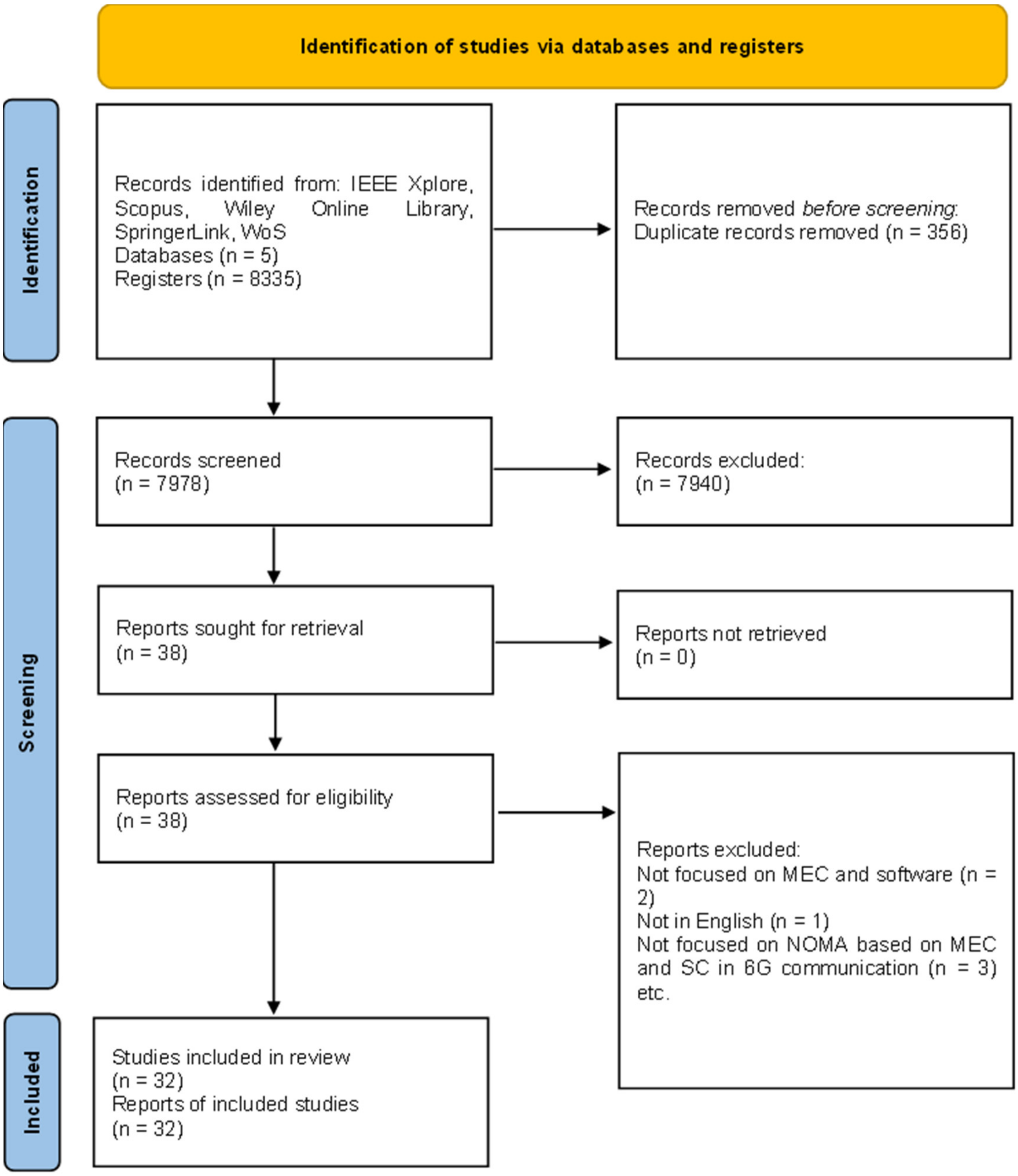

Figure 1. Systematic Review Paper Selection Process.

3.3. Data Extraction

The selection process is depicted in the Flow Diagram in Figure 1 and has considered the PRISMA standards [91]. The figure shows the many stages of the SLR, from the records identified to the final selection, including the articles included, omitted (and reasons), and additional documents discovered using alternative approaches.

We show the distribution of a few chosen works across several databases in Figure 2. Five (5) databases were searched for publications for this investigation. These include Web of Science, SpringerLink, IEEE Xplore, Scopus, and Wiley Online Library. The search term utilized in the study was "Soft Computing" OR "Mobile Edge Computing" AND "NOMA" ("6G System"). Figure 3 displays the distribution of the study's paper publications between 2010 and 2022. Table 3 shows the total number of articles initially retrieved from each of the five databases. As the number of reports increased yearly in 2019, three articles were published and 2 published in 2020. The number of published articles increased in 2021 to eight, and in 2022, nineteen articles were published, meaning more research was conducted on NOMA-enabled MEC.

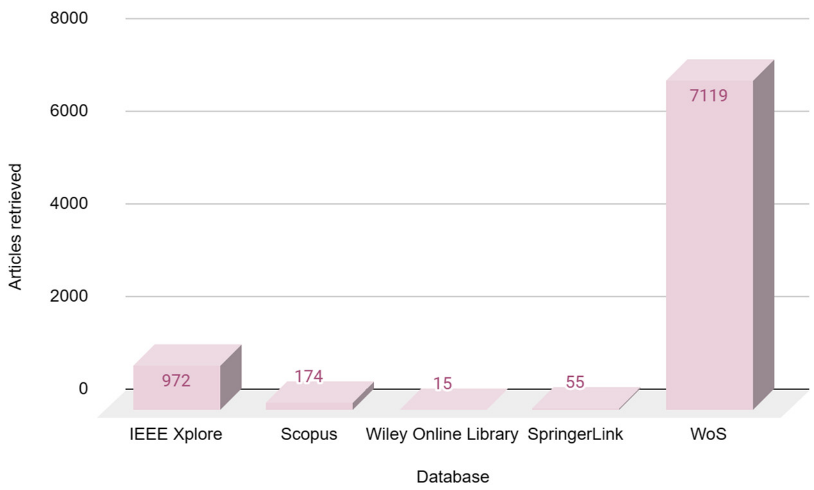

Figure 2. The database and the articles retrieved.

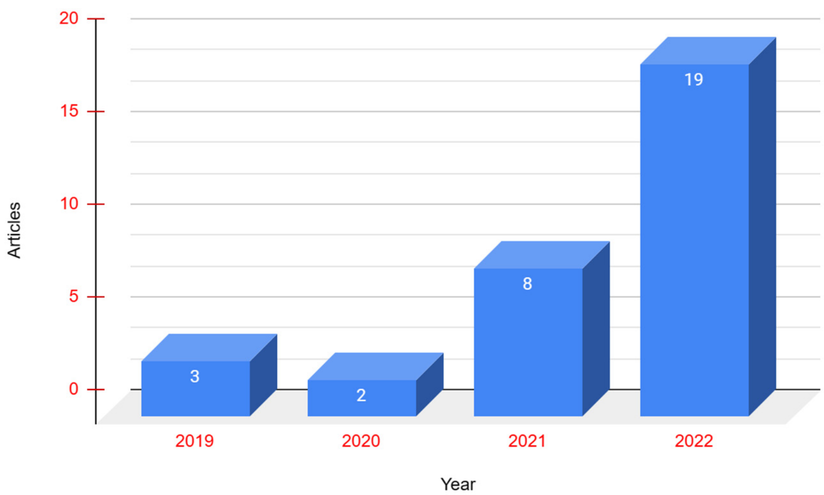

Figure 3. Number of printed documents per year.

Table 3. The database and the papers initially retrieved.

Database	Articles
IEEE	972
Scopus	174
Springer	55
Web of Science	7119
Wiley Online Library	15
Total	8335

4. Results and Discussion

The findings of the conducted systematic literature review are covered in this section. Each of the research questions was also answered in this section.

In the Web of Science database from 2010 to 2022. Figure 3 displays the annual number of published papers that can be found and retrieved using the detailed criteria. The bar graph shows a gradual rise in the frequency of publications. The years 2022 and 2021 have the highest publications, clearly showing rising attention in the domain. This inclination was sustained in 2021, observing that this evaluation covers only the first eleven calendar month of the year 2022.

Only two publication outlets were considered in this SLR: journal and conference proceedings because two or more reviewers thoroughly reviewed the articles. Figure 4 shows the publications per outlet, and it was demonstrated that there are more publications in the journal outlet than in the conference. 27 (84.4%) articles were published in the journals, while 5 (15.6%) were published in the conference proceedings.

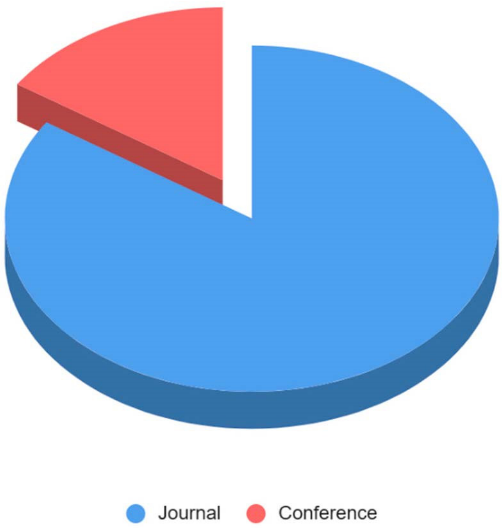

Figure 4. Publications per outlets.

Figure 5 shows the journal publishers and the articles each published. It was demonstrated that IEEE in Manhattan, NY, USA published the highest report of 17, followed by MDPI in Basel, Switzerland, with five articles and Elsevier in Amsterdam with three. Springer in Berlin/Heidelberg, Germany published two articles, while Hindawi in Cairo, Egypt; Frontiers in Lausanne, Switzerland, IOP in Bristol, England, Wiley in Hoboken, NJ, USA, and Tech Science in Henderson, NV, USA all published one.

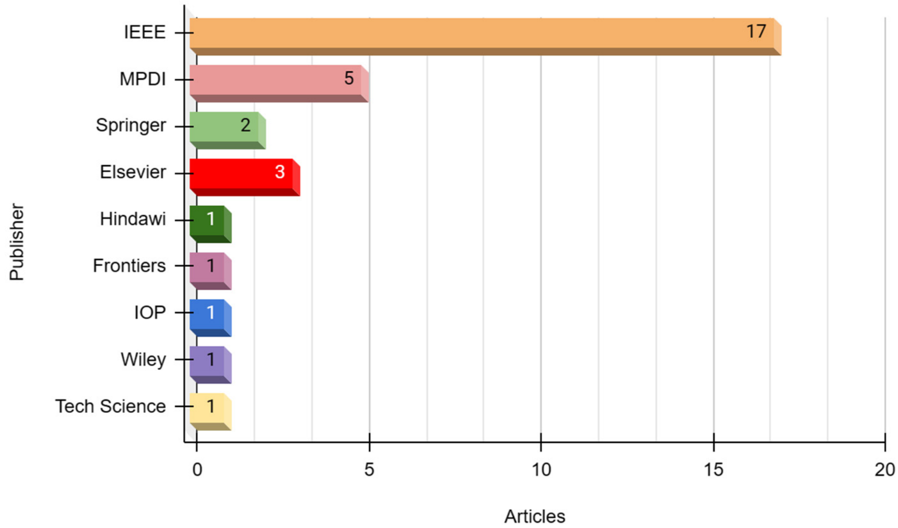

Figure 5. Publishers and Articles published.

Table 4 provides a list of the extracted articles. All techniques used were found to be deep learning technologies. It summarizes the information that was taken from the relevant studies. The first column lists the author's name, the year the paper was published, and the technology each contributor utilized. After the subject technology, the aims and contributions made by the research are described. Additionally, the table displayed responses to each research question in the final three columns on the right.

Table 4. Analysis of the retrieved and included articles.

Authors	Technology	Objectives	Contribution	RQ1	RQ2	RQ3
Noor-A-Rahim et al. [93]	6G for V2X (vehicle to everything)	This article discusses the scientific and technological advancements that could affect future 6G vehicle-to-everything (6G-V2X) telecommunications.	The authors discuss innovations like new materials, methods, and system architectures.			Yes
Ding, Schober, Poor [64]	NOMA and Multi-user MEC network	It was suggested to use a universal hybrid NOMA-MEC offloading strategy.	The authors developed a multi-objective optimization problem and a low-complexity resource allocation strategy to reduce the energy used for MEC offloading.	Yes		Yes
Jiao et al. [94]	NOMA, 6G, and Vehicular network	The authors suggest a hybrid intelligent non-orthogonal forwarding system (UN) multiple access (NOMA) for next-generation millimetre-bandwidth (mmWave) end-edge cloud vehicle systems, which principally consist of the high-throughput satellite (HTS), edge-founded station (BS), and end-vehicle nodes.	The authors introduced an expectation minimization-based power allocation approach and an iterative power allocation methodology.		Yes	Yes

Table 4. *Cont.*

Authors	Technology	Objectives	Contribution	RQ1	RQ2	RQ3
Abozariba et al. [95]	NOMA, IoT, Cellular networks	The authors of this paper offer a methodology for constructing intelligent systems that will efficiently measure and supply radio resources to IoT gadgets.	With a guaranteed bit rate (GBR) and non-GBR, the researchers' method gives IoT facility providers cost estimates to optimize their spectrum procurement and deliver the required quality of service.			Yes
Tuong et al. [96]	MEC, NOMA, 6G	The authors' goal is to make computations easier (weighted sum of consumed energy and latency)	The authors proposed the ACDQN deep reinforcement learning algorithm, which combines the benefits of actor-critic and deep Q-network approaches while being simple to implement.	Yes	Yes	
Bai et al. [97]	NOMA, Radio access network (RAN), Fog access node	NOMA is designed to disengage between clients whose data is multiplexed from various power factors within its orthogonal source. The subsequent interference suppression (SIC) detects information at fog access nodes	The investigation findings indicate that the I-FTPA outperforms the previous FPA and FTPA approaches.			Yes
Wu et al. [98]	NOMA, Medium-grain quality scalable, Video coding	The researcher suggests a multicast solution that is scalable and is influenced by soft video delivery systems.	The researchers suggest a scheme with a soft-encrypted augmented layer and a digitalized base layer. The problem of power distribution is presented as one of distortion minimization.			Yes
Li, Fang, and Ding [99]	Multi-access edge computing, NOMA, OMA, 6G	The experiment findings show that the I-FTPA outperforms the prior FPA and FTPA in terms of performance.	The authors developed a deep reinforcement learning (DRL)-based approach to deliver a user grouping strategy that is practically perfect.	Yes	Yes	
Dursun, Fang, and Ding [100]	NOMA, MIMO, MEC	The authors want to increase the spectrum proficiency, energy proficiency, and data throughput of MEC offloading by minimizing communication interruption in the MIMO-MEC.	The delay minimization issue is resolved using the generalized singular value decomposition (GSVD) approach and the Dinkelbach transform.		Yes	
Peng, Yuan & Zhang [101]	Clustered NOMA, Cell-free edge network, 6G	This research aims to provide a downlink adjustable reflector synchronized distribution system that relies on clustered NOMA for a future 6G cell-free edge network.	The findings showed that the suggested method might offer customers a higher cumulative data rate than the immediate broadcast method, the decode-and-forward (DF) method, and the relays amplify-and-forward (AF) method.		Yes	

Table 4. *Cont.*

Authors	Technology	Objectives	Contribution	RQ1	RQ2	RQ3
Jain et al. [102]	NOMA, OMA	This study compared the effectiveness of NOMA and OMA structures in a single-cell setting with randomly dispersed cellular operators while taking cooperative relays into account for increased system dependability.	The outcomes proved that the NOMA structure beats the OMA structure in performance.	Yes		
Cheng et al. [103]	Unmanned Aerial Vehicle, Edge network, intelligence, Fog computing node	They proposed a combined task and energy offloading issue under an intelligent edge network with UAV assistance and energy constraints, comprising a high-altitude platform (HAP), several UAVs, and on-ground fog computing nodes (FCNs).	To overcome the issue previously identified, the authors suggest a multiple-agent soft actor-critic (MASAC) founded solution. Numerical simulation results demonstrate the superiority of our recommended strategy compared to benchmark approaches.	Yes	Yes	
Sayyari, Pourrostam, and Ahmadi [104]	Orthogonal Frequency Division Multiplexing, NOMA	Precoding and dummy sequence insertion (DSI) techniques are recommended to overcome the earlier restrictions to reduce PAPR. A brand-new way for creating mock arrangements is also developed for the suggested strategy.	Regarding PAPR reduction and BER performance, the authors demonstrate that the suggested approach performs better than precoding and PTS-based alternatives.		Yes	
Shahjalal et al. [105]	RAN, 6G	The paper focuses on the requirements-compliant intelligent massive RAN (mRAN) architecture and essential technologies.	The researchers look at potential AI solutions for network and resource administration problems in 6G mRAN. Lastly, discuss the 6G network architecture's physical layer intelligence and edge technology research challenges.	Yes		Yes
Zhang et al. [106]	Vehicular application, MEC, vehicle users	An immediate electricity-aware contracting approach powered by MEC has been suggested for automobile systems to effectively utilize connectivity and computing capabilities, decrease electricity use, and mitigate interruptions.	Based on the computational findings, the suggested bi-level optimizing technique minimizes the entire burden by roughly 40% compared to a comparable method.		Yes	Yes
Huang et al. [107]	MIMO, NOMA, communication deep neural network (CDNN)	The authors provide a MIMO-NOMA structure for increasing total data throughput and energy proficiency based on deep learning.	The CDNN framework uses training algorithms to handle the power allocation issue to increase MIMO-data NOMA's throughput and energy efficiency.	Yes	Yes	
Douch et al. [108]	Edge computing, Multi-access edge computing, 5G	This study provides a comprehensive, in-depth, and well-organized evaluation of edge computing and its supporting technologies.	Future worries about green energy and standards were highlighted with edge computing.		Yes	Yes

Table 4. *Cont.*

Authors	Technology	Objectives	Contribution	RQ1	RQ2	RQ3
Guo and Li [109]	5G network, AI, Cloud computing, and big data	The following paper describes the health-related uses of 5G internet innovations involving telecare, virtual healthcare emergencies, and utilization of virtual automation.	This publication's authors investigate the development and health-related uses of 5G internet technologies.			Yes
Fu et al. [110]	NOMA	To lessen the average scheme's latency, the scholars use a proactive behaviour-shaping approach called suggestion in cache-assisted NOMA structures.	The study findings show that, when measured against extensive benchmark procedures, the proposed joint optimization strategy benefits from the system latency and the ratio of cache hits.		Yes	Yes
Truong et al. [111]	MEC, UAV, Deep reinforcement learning (DRL)	The scholars presented a paradigm for a MEC-improved aerial providing infrastructure in which aerial vehicles—drones, UAVs, etc.—fly in the air to provide services to remote places without terrestrial base stations.	They formulate a deep deterministic policy gradient (DDPG)-a based method called HAMEC to address the issue identified in the literature using a deep reinforcement learning (DRL) framework.	Yes		Yes
Mounir et al. [112]	NOMA, Orthogonal frequency division multiplexing,	This paper employs the most common soft limiter (SL) technique with input back-off (IBO) as a valuable regulating measure.	The feasible data rate for users, the total rate capacity, the system's fairness, and the bit error rate (BER) of each operator are all considered while analyzing the effectiveness of the OFDM-NOMA structure in the existence of nonlinear falsification in both UL and DL.			Yes
Li et al. [113]	MEC, 6G network	The authors examine a multiobjective task scheduling issue in a 6G network with MEC support.	A DAG-based task scheduling problem is addressed with the improved multiobjective cuckoo search (IMOCS) method to decrease UE execution delay and energy usage.	Yes	Yes	Yes
Chen et al. [114]	NOMA, Single in, Single out (SISO), 6G technology, reconfigurable intelligence surface (RIS)	The authors considered the handling effectiveness and ergodic capability of a cooperative NOMA of an IoT structure.	Simulation results indicate that RIS-aided NOMA has a reduced outage risk compared to conventional NOMA.	Yes	Yes	
Rahman et al. [115]	NOMA, OFDM, Bi-Directional Deep Neural Network	A DNN with bi-directional Bi-LSTM is suggested for multiple access uplink channel estimate (CE) and frequency identification of the first frequency band.	The suggested strategy is suitable for 5G wireless communication because it enhances the signal-to-noise ratio and symbol-error rate.	Yes	Yes	

Table 4. *Cont.*

Authors	Technology	Objectives	Contribution	RQ1	RQ2	RQ3
Jia et al. [116]	NOMA, 6G communication, Artificial bee colony (ABC)	The paper suggests using a genetic algorithm (GA) for UE-BS association, assigning SCs, and allocating power using an artificial bee colony (ABC) approach.	The implementation outcomes establish that the suggested power allocation structure may rapidly reach the best result and that increasing the number of operators and SCs can raise the MOS.	Yes	Yes	Yes
Wang et al. [117]	MEC, Visual reality, 6G	The authors build an offloading computing system for IoT devices on the principles of reinforcement learning.	Numerous implementation outcomes revealed that the RAPG could accomplish the optimum allocation rate between the BS and local and lower the inclusive structure interruption of job combinations with the least energy use.		Yes	Yes
Song et al. [118]	AI, Networkng systems AI (NSAI)	The researcher's objective is to present an in-depth summary of the scheme framework, essential pieces of machinery, utilization situations, obstacles, and prospects of NSAI, which can give insight into the telecoms and AI computing industries' next advancements.	They provide a cohesive structure for the intense union of computation and infrastructures, allowing for combined optimization of the network and applications/services as a single integrated system.	Yes		Yes
Jha et al. [119]	Cuckoo search (CS) and genetic algorithm (GA)	The study develops an innovative amalgam of CS and GA to increase throughput, reduce delay in heterogeneous wireless systems to their highest possible levels, and minimise handover failure probability.	The performance of the suggested method is encouraging for applications where it is necessary to regulate frequent handoffs and enhance handoff procedures to reduce core network power usage even more.	Yes	Yes	Yes
Attanasio, Corte, and Scata [120]	MEC, IoT, Smart cities	They put out a theoretical strategy to look into a more in-depth understanding of the city's structure and to reveal unobserved urban trends.	The topic of MEC node cooperation in a multi-service environment is investigated using evolutionary game theory, revealing insight into the combined effect of its dynamics and the multiplex structure on reducing the blocking likelihood of the MEC nodes.		Yes	Yes
Sadieddeen et al. [121]	NOMA, MIMO, Ultra massive	To improve channel conditions, the authors of this work offer spatial tuning techniques that modify antenna subarray topologies.	A proposed architectural design demonstrates complexity reductions and approximate bit error rate (BER) formulae.		Yes	Yes
Bhattacharya et al. [122]	5G, vehicular users, blockchain, C-V2X	The authors suggested effective 5G REC infrastructures for end users who drive vehicles (VU)	The suggested study serves as a roadmap for researchers, academics, and automotive stakeholders as they further investigate the numerous integration prospects.			Yes

Table 4. *Cont.*

Authors	Technology	Objectives	Contribution	RQ1	RQ2	RQ3
Cengiz et al. [123]	5G wireless network, NOMA, UFMC	This study attempts to provide a distinct Hartley transform (DHT) pre-coding-founded NOMA-assisted universal filter multicarrier (DHT-NOMA-UFMC) waveform structure to mitigate the excessive PAPR.	Due to power sector multiplexing on the broadband internet connection, the recommended method has a significant content gain advantage over the current 5G waveforms.			Yes

Table 4 also provides insights on the RQs examined, the methodology employed, the goals, and the contributions made from the study investigated from existing research. The breadth of technologies used by investigators in their various studies is shown in Table 4 by class for evaluated published articles.

Table 5 demonstrates the results of this investigation's three research questions (RQ). RQ1 is on DL algorithms utilized to reduce computational overhead in NOMA-enabled MEC in a 6G network. RQ2 is on approaches employed to minimize transmission delay and lower complexity; finally, RQ3 is on the taxonomy of NOMA-based MEC used to address technologies in NOMA and MEC in 6G networks. Each piece of literature demonstrates the results of each of the RQs formulated in the study. It can be deduced that most of the literature provides answers to RQ1 and RQ3.

Combining power domain NOMA with a UFMC can address the high demands of 5G technology. NOMA uses energy-domain synchronization to accommodate many customers, whereas UFMC compensates for scheduling and bandwidth discrepancies. However, the high peak-to-average power (PAPR) problem associated with the multicarrier modulations of NOMA-UFMC waveform can negatively impact it, rendering it unsuitable for the next-generation mobile and wireless networks. Hence, 6G technology will improve the NOMA power-domain multiplexing, supporting many users, and the multicarrier modulations will be utilized well.

The cellular Internet of Things (IoT) is regarded as the de facto paradigm for enhancing the systems for processing and communication. Utilizing cellular networks, cellular IoT links a sizable number of real-world and virtual things to the Internet. The newest cellular networks, such as 5G, use cutting-edge and evolutionary technology to enhance wireless network performance significantly. However, in light of the anticipated new use cases, such as holographic communication and the IoT's growing use of large smart-physical endpoints, the amount of network traffic has significantly increased, making it impossible for the present generation of mobile networks to satisfy the rising needs fully. Therefore, the next generation, 6G networks, is expected to be crucial in addressing these IoT concerns by offering uRLLC network capacity and new communication services.

Technically, it was observed from the literature reviewed and evaluated that some procedures, such as deep learning (DL), were adopted and utilized to reduce computational overhead in NOMA-enabled MEC in a 6G network. This is demonstrated in Table 6.

Table 5. Category-wise data for reviewed research articles.

Reference	Resource Allocation	Power Allocation	Energy Efficiency	Dynamic Resource Allocation	Computational Efficiency	Computation Offloading
Noor-A-Rahim [93]	Yes	No	No	No	No	No
Ding et al. [64]	Yes	No	Yes	No	No	No
Jiao et al. [94]	No	Yes	No	No	No	No
Abozariba et al. [95]	Yes	No	No	No	No	No
Tuong et al. [96]	No	No	No	No	No	Yes
Bai et al. [97]	No	Yes	No	No	No	No
Wu et al. [98]	Yes	No	No	No	No	No
Li, Fang, and Ding [99]	Yes	No	No	No	No	No
Dursun, Fang, and Ding [100]	No	No	Yes	No	No	No
Peng, Yuan & Zhang [101]	No	Yes	No	No	No	No
Jain [102]	No	No	Yes	No	No	No
Cheng et al. [103]	No	No	Yes	No	No	Yes
Sayyari, Pourrostam and Ahmadi [104]	No	No	No	No	Yes	No
Shaljalal et al. [105]	Yes	No	No	No	No	No
Zhang et al. [106]	Yes	No	No	No	No	Yes
Huang et al. [107]	No	Yes	Yes	No	No	No
Douch et al. [108]	Yes	No	No	No	No	Yes
Guo and Li [109]	No	No	No	No	No	No
Fu et al. [110]	No	Yes	No	No	No	No
Truong et al. [111]	No	No	No	No	No	Yes
Mounir et al. [112]	No	Yes	No	No	No	No
Li et al. [113]	No	No	Yes	No	No	No
Chen et al. [114]	Yes	No	No	No	No	No
Rahman et al. [115]	Yes	No	No	No	No	No
Jia et al. [116]	No	Yes	No	No	No	No
Wang et al. [117]	No	No	Yes	No	No	Yes
Song et al. [118]	No	No	No	No	No	Yes
Jha et al. [119]	No	No	Yes	No	Yes	No
Attanasio, Corte, and Scata [120]	X	No	No	No	No	No
Sadieddeen et al. [121]	No	Yes	No	No	No	No
Bhattacharya et al. [122]	No	No	No	No	No	No
Cengiz et al. [123]	Yes	No	No	No	No	No

Table 6. Summary of Literatures Reviewed and Analysed.

Authors	Methods	Contributions
Ding, Xu, Schober & Poor [64]	Iteration power allocation algorithm and PREM algorithms	The simulation results demonstrate that their suggested algorithms may approach the exhaustive search strategy and outperform the current optimum NOMA methods. In addition, they exploit the impacts of the number of moving end VNs, which may provide directions for constructing the future vehicular network.
Truong et al. [96]	Deep reinforcement learning algorithm named ACDQN	The suggested strategy is demonstrated to achieve its optimal value with a computational overhead of approximately 10%, 27% and 69% lower than existing methods.
Li, Fang, and Ding [99]	Deep reinforcement learning (DRL)	In addition, by attaining the shuttered-form approach to the matter of resource apportionment issue, we ideally reduced the offloading energy consumption. The suggested procedure was completed rapidly based on modelling findings, and the NOMA-MEC strategy performed better than the prevailing OMA schemes.
Jain et al. [102]	Signal-to-interference noise-ratio	It is shown by numerical findings that the NOMA scheme outperforms the OMA system.
Cheng et al. [103]	Soft Actor-Critic (SAC) algorithm, MASAC-based approach, and MADDPG framework	Results from numerical simulations demonstrate that our suggested strategy is superior to benchmark approaches.
Shahjalal et al. [104]	Intelligent massive RAN (mRAN) architecture	Prioritizing network intelligence, the authors provided a comprehensive evaluation of the capabilities of AI and ML techniques in network administration, assigning resources, bandwidth distribution, peripheral communication, and safety. In addition, they identified significant research difficulties and obstacles for each facet of 6G mRANs.
Huang et al. [107]	Effective communication deep neural Network	Simulation findings indicate that the suggested CDNN framework is a viable choice for improving the effectiveness of MIMO-NOMA in relation to power distribution, and thorough simulations demonstrate that it accomplishes an advanced cumulative data proportion and better energy proficiency than current solutions.
Truong et al. [111]	Deep reinforcement learning (DRL), deep deterministic policy gradient (DDPG)-based algorithm, named HAMEC	The investigational findings indicate that HAMEC performed better than benchmark systems.
Li et al. [113]	An improved multiobjective cuckoo search (IMOCS) algorithm	Simulation findings indicate that the IMOCS algorithm beats four benchmark algorithms, providing the ideal workload scheduling strategy for MEC servers in 6G networks.
Chen et al. [114]	RIS-assisted downlink in a NOMA network with p-CSI across Nakagamim fading channels without direct connection situations.	Based on experiment results without a direct link from the base, it has been observed that NOMA aided by RIS exhibits a low outage probability compared to traditional NOMA. Closed-form formulas calculated using Monte Carlo simulations indicate that the coverage probability of a remote user is higher than that of a local user.
Rahman et al. [115]	Bi-directional long short-term memory (Bi-LSTM)	In the simulated results, the efficacy of the suggested model is evaluated to that of the convolutional neural network model and conventional CE schemes like MMSE and LS. It is demonstrated that the recommended technology offers attainable performance enhancements in terms of symbol-error rate and signal-to-noise ratio, making it appropriate for 5G wireless communication and beyond.
Jia et al. [116]	Genetic algorithm (GA), SC assignment and artificial bee colony (ABC) algorithm	The implementation results indicate that the recommended power distribution procedure can swiftly unify to the most effective approach and that the MOS can be increased by boosting the range of customers and scheduling centres (SCs).

Table 6. *Cont.*

Authors	Methods	Contributions
Song et al. [118]	Networking systems of AI (NSAI)	This paper's contribution entails (1) offering an all-encompassing structure for the deep convergence of computing and communications, where the network and implementation can be collectively improved as one cohesive unit, and (2) suggesting the overall strategy and addressing open investigations in acknowledging the online-evolutionary convergence of the digital world, the natural environment, and society as a whole, towards the ubiquitous neurological systems (UBNs), which require cooperation in the functioning of the internet, the physical world, and society at large.
Jha et al. [119]	Hybrid cuckoo search (CS) and genetic algorithm (GA)	The hybrid approach presented boosts throughput by 17% and 8%, respectively, as likened to the cuckoo search and genetic algorithms employed separately. The efficiency of the suggested technique is encouraging for scenarios in which the handoff techniques must be tuned to regulate repeated handoffs to lower the power consumption of user equipment further.

4.1. Benefits of NOMA for Edge Computing

NOMA and MEC are potential technologies for the next generation of wireless networks. With the rapid development of intelligent communication, mobile edge computing is increasingly applied to future contact, can increase the computing power of an application user, and can play a crucial role in virtual reality, augmented reality, unmanned driving, and similar domains. Unlike typical cloud computing systems, mobile edge computing may supply computational power in a cloud radio access network. For example, with a mobile edge computing server integrated with a base station, a user may offload computing chores to the mobile edge computing server placed at the network's edge, which executes task computing. As the mobile edge computing server may be close to the user, a mobile edge computing network can provide the user with task computing services with low latency and energy usage. For moving edge computing, there are two modes of operation: the partial offload model and the binary offload model. In the partial offload approach, computational activities may be divided into two halves, one for local execution and the other for offloading to the mobile edge computing server. Under the binary offload approach, computational operations may be locally or completely offloaded to the mobile edge computing server. To address the ever-increasing data traffic, NOMA has been recognized as a vital technology for the upcoming generation of mobile communication networks. By employing superposition coding at the transmitter and successive interference cancellation at the receiver, NOMA can achieve higher spectral efficiency than traditional OMA techniques. If NOMA uplink, downlink transmission and mobile edge computing are integrated, latency and energy consumption may be greatly lowered by using NOMA mobile edge computation offload, a major improvement for enhancing the mobile user experience. Nonetheless, no technique or technological solution is presently developed in the prior art.

The technical configuration is as follows: To accomplish the objective mentioned above, the present invention employs the following technological solutions: The next stages constitute a technique for developing a NOMA-based mobile edge computing system:

1. establishing a system model wherein the system comprises two users and a base station equipped with a MEC server; the users and the base station are both fitted with a single antenna, and information transmission is carried out on the uplink in a NOMA mode, a wireless channel adopts a frequency non-selective quasi-static block fading model, the channel state is maintained unchanged in a selected given transmission block period, and the duration is limited, and 2. transmitting information over the upline

2. getting the signal-to-interference-and-noise ratio of user m and user n at aa base station according to a NOMA model chosen by an uplink
3. obtaining the information transmission rate condition of each user under the worst circumstance based on the safety transmission requirement;
4. defining the safety interruption probability to observe the communication effectiveness of the whole system during the transmission process; creating an expression of the transmission interruption likelihood of the entire connections based on the results of steps (2) and (3); and deducing the result.

4.2. Unresolved Issues and Future Directions

As stated in the article, NOMA-based MEC technologies have a lot of benefits, yet they also have many shortcomings, such as short battery life, high energy consumption, unfair workload offloading and resource allocation, restrictive latency constraints, and security issues. In this part, the problems associated with the unresolved issues are emphasized. Furthermore, the potential areas for future study to solve the problems presented are highlighted. This research also suggests new application scenarios that show the range of NOMA-based MEC solutions. The unresolved issues and future directions are presented in Table 7.

Table 7. Summary of research issues and future research.

Unresolved Issues	Future Directions
We are optimizing resource allocation and offloading using NOMA and MEC	NOMA-based MEC founded smart city network architecture
Pricing Tactics and the Effects of user behaviour traits	Trust, privacy, and Openness with Blockchain Technology
Increasing capacity with multipath networking and multi-layer heterogeneous architecture	Mobility solution for smart agriculture
Content delivery with NOMA-based MEC	NOMA-based MEC: Aiding and using technology in Industry 6.0
Regulatory policies and Standardization	Mobility solution for smart vehicular network

4.3. Research Challenges and Future Trends

Although the NOMA system is generally recognized as one of the most important multiple access strategies for 5G and beyond, many unresolved difficulties must be investigated to advance the NOMA system's implementation. As a consequence, this part examines prospects for resolving NOMA's research challenges and provides a short overview of some of NOMA's research concerns.

1. NOMA with faulty CSI: The present analysis of the NOMA system assumes a perfect CSI to execute multi-user SIC at the user receiver or resource distribution at the base station (BS) [124–127]. In addition, this assumption cannot be implemented practically inside the NOMA system. Thus, real-time channel estimate errors occur in NOMA systems. Therefore, the NOMA system's theoretical analysis should address channel estimation errors and incorrect CSI. Hence, improved approaches and algorithms are necessary for actual NOMA systems to get an optimum channel estimate [128–131].
2. Imperfect SIC implementation: Due to incorrect extraction and discovery, there is an increase in time and residual intrusion of previously recognized users during actual SIC operations [131–135]. This results in error propagation inside the SIC receiver (i.e., an imperfect SIC receiver) and decreases the performance of the NOMA system. So, for a successful SIC implementation, it is necessary to construct hardware devices that minimize processing complexity, reduce latency time, and improve NOMA performance. Hence, effective methods for performing the SIC process are developed in the uplink and downlink NOMA systems [136–139].

3. A heterogeneous network (HetNet) is a wireless network that uses several network topologies and operating systems [140]. Also, it has nodes with varied transmission capabilities and coverage regions. By incorporating tiny cells within the coverage of macrocells, the HetNet may reduce the energy consumption of future wireless networks and improve user QoS [31–34]. Real-time NOMA allows networks of different sorts to exchange resources. In cooperative communication, NOMA-based HetNet improves downlink coverage substantially [36–40]. In HetNets, it is recommended to employ effective heterogeneous suitable communication techniques using NOMA to reduce interference issues and accomplish spectrum splitting since there is mutual interference between numerous users and a limited spectrum resource. In light of this, several studies [41–45] must build an effective NOMA-based HetNet.
4. NOMA in millimetre wave (mm-Wave) communication: Millimeter-wave (mm-wave) communications and the NOMA technology are essential for meeting the high data rate requirements of 5G and beyond [141–144]. NOMA approaches become increasingly interesting at mmWave frequencies since the mmWave band is fundamentally suitable for multi-Gbps 5G wireless technologies. In addition, NOMA approaches may boost data transfer speeds while supporting multiple user connections [145–148] Despite its promise, the use of NOMA in mmWave communications is still in its infancy and applicable in various circumstances, including IoT and cloud-assisted vehicle systems. Hence, the NOMA in mm-wave communications proposes developing 5G technologies with high data rate wireless access [149–153].
5. Visible light communication (VLC)-based NOMA: Independent of mmWave communications, Visible Light Communication (VLC) has attracted great attention from the standpoint of excellent spectrum resources [154–157]. The VLC supports several characteristics, including a high data rate, high security, eye safety, license-free broad bandwidth, absence of electromagnetic interference, and low energy usage [158–160]. In addition, the VLC employs random data signals to power light-emitting diodes (LEDs) rather than the incandescent and fluorescent lights used by traditional light senders. Thus, the VLC is an excellent strategy for 5G networks and beyond. Moreover, the NOMA system may improve the performance of the VLC system. Hence, further study must be conducted on the NOMA VLC system to make VLC-based NOMA advantageous in many situations and places [161,162].
6. Mobile edge computing (MEC) based on NOMA is one of the 5G technology's enabling technologies [163–165]. MEC technology allows user equipment (UEs) to conduct compute-intensive tasks by creating computing capabilities at the network edge and inside wireless access networks. In addition, NOMA systems allow several UEs to share the same resources [166–168]. Consequently, combining the NOMA system with MEC technology has several advantages, including decreased energy usage, enhanced EE and SE, and a rise in corporate UEs. To solve big data processing in future 5G wireless networks, it is necessary to recommend a NOMA-based MEC in multiple studies [169–171].
7. Practical realization of more than two-user pairing: The primary characteristic of the NOMA system is that it serves multiple users with the same resource. Nevertheless, most practical studies use a two-user pairing technique to facilitate the channel gains of two-paired users at the base station and implement effective SIC at receivers. As the need for connected devices such as IoT, machine-to-machine (M2M), and massive machine-type communications increases, new ways for multi-user pairing are also essential. These methods for pairing multiple users must take full use of NOMA. Hence, multi-user pairing strategies enhance the mass connection necessary for the next wireless network.
8. Hybrid NOMA: Integrating hundreds of millions of gadgets via an underlying BS gets challenging due to restricted orthogonal substances with exceptionally reduced-latency mobile communication in situations of minimal SNR. Therefore, the NOMA strategy is inappropriate for this circumstance [171–175]. To overcome this issue, an

integrated MA that relies on a combination of NOMA and OMA approaches offers an improved approach to linking massive equipment in IoT settings, D2D and M2M connections, etc. For MA, a combination of NOMA uses both PD-NOMA and CD-NOMA. Additionally, the combined NOMA provides a higher SE than both NOMA and OMA. As a result, the hybrid NOMA can switch between NOMA and OMA modes of operation and can be utilized in various experiments [176,177].

9. Internet of Things and MIMO-NOMA: IoT, which represents the interconnection of all things, constitutes one of the main components of 6G connectivity. For cellphone IoT, the amalgamation of immense MIMO and NOMA is employed to simplify the integration of many IoT gadgets with a small radio bandwidth [178–181]. Immense MIMO-NOMA provides excellent transmission effectiveness and system adaptability to support many gadgets with a simple system architecture, which is beneficial for IoT technologies employing affordable, minimal-power, and minimal-complexity gadgets. To show the effects of MIMO-NOMA on IoT demand fulfilment, novel techniques with an optimal multiple-purpose architecture are essential [182–184].

4.4. Limitation of the Study

Owing to the consideration of just English-language research, the selected search terms, and repository restrictions, it is possible that certain relevant papers were missed regardless of the thorough search throughout databases. Valuable data can be obtained in non-peer-reviewed papers, unpublished term papers, and dissertation studies.

5. Conclusions

In this study, we took into account NOMA interoperability with MEC. We summarized the significant aspects and technologies used by the many publications featured in the survey and gave a comprehensive overview of NOMA-enabled MEC. Furthermore, we pinpoint important unresolved issues and the accompanying directions for further investigation. The combination of NOMA and MEC will be a game-changer as we approach the generation of future 6G and B6G technologies, offering a potent approach that can influence 6G and B6G's performance characteristics, including latency, connection density, data rate, energy efficiency, and mobility. In the future, we intend to provide solutions to the resolved issues presented.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15097315/s1. A database containing additional information on the PRISMA method checklist used in the systematic literature review is accessible online at [91]: Zenodo. https://doi.org/10.5281/zenodo.7867236.

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