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# A Survey on Handover Optimization in Beyond 5G Mobile Networks: Challenges and Solutions

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**ABSTRACT** Handover (HO) management is essential in any mobile cellular network. It ensures seamless connectivity to the User Equipment (UE) while moving from a Base Station (BS) to another within the coverage area. HO optimization refers to adopting intelligent and automatic HO techniques in mobile networks. HO optimization is taking more importance in the Fifth-Generation (5G) and Beyond (B5G) systems due to the requirements and specifications that B5G targets. The requirements of the B5G, such as global connectivity, ultra-low latency, big data analytics, extreme data rate transmissions, a massive number of devices in a small area, etc., and the new technologies that will support the B5G network, such as Millimeter Wave (mmWave), Terahertz (THz) communication, Ultra-Dense Networks (UDNs), etc. All these cause new HO optimization challenges and require new solutions for HO optimization techniques. This paper comprehensively provides the HO optimization challenges and solutions in B5G. Firstly, it provides a research background and explanation for the HO in legacy. Then, it investigates the HO optimization challenges in B5G, including future research directions. After that, the paper discusses the most prominent and recent techniques and technologies solutions for HO optimization management in B5G. Finally, it highlights the potential techniques for HO optimization in B5G.

**INDEX TERMS** Handover management, mobility management, HO, HO optimization, 5G, Beyond 5G, B5G, small cells, UDNs, mmWave, THz.

## I. INTRODUCTION

The advancement of the mobile or cellular system has been extremely rapid, and vast new prospects are emerging. First-Generation (1G) and Second-Generation (2G) networks supplied voice services, while Third-Generation (3G) and Fourth-Generation (4G) networks provided broadband internet to consumers. The latest Fifth-Generation (5G) promises to offer consumers greater multi-Gbps peak data speeds, ultra-low latency, improved dependability, enormous network capacity, enhanced availability, and better consistency in user experience. The vision also includes expanding the coverage to more users that were not reachable via legacy technologies, such as in rural, remote and areas with disasters. In addition, increased performance and efficiency enable new user experiences and business linkages. Although scenario identifications for Sixth-Generation (6G) networks have not yet been accomplished, numerous studies, such as [1-7], provide studies on 6G and predict the goal of linking everything globally via almost instantaneous, dependable and inexhaustible wireless resources.

Furthermore, the 5G and 6G technological and architectural aspects that will form the future mobile systems access, networking, and management domains offer limitless possibilities for service innovation and business efficiency, with tremendous influence on numerous vertical sectors [8]. 5G and Beyond-5G (B5G) network technologies can open up multiple options for various sectors, and new value chains and business models are ushering in a paradigm shift in the traditional communications service provider industry as it transitions to the digital services [9].

Mobility management is considered one of the key functions in B5G networks since it provides smooth access to wireless networks and mobile services. It assures users' connectivity everywhere and at all times. Location and Handover (HO) management are the two major functions of mobility management. Location management allows networks to track the whereabouts of mobile nodes. On the other hand, HO management is the process through which User Equipment (UE) maintains its connection when traveling from one Access Point (AP) to another. The process of altering the UE's relationship with mobility such that the best serving Base Station (BS) is always picked is referred to as HO. The average Received Signal Strength (RSS) level is a common and easy criterion for selecting the optimal serving BS. In other words, if another BS delivers a greater RSS than the serving BS, the UE changes its affiliation, which may occur when the user departs from the serving BS and toward another BS.

HO management in B5G is a significant part of the network that must be improved. Moreover, the requirements of enabling the B5G, such as, in 6G, the ultra-high mobility of up to 1000 km/h, ultra-low latency of 10–100 µs, the ultra-high peak data rate of up 1–10 Tbps, massive of connected devices per area of $10^7$ devices/km$^2$, etc., [10, 11] requires efficient HO techniques to enable the B5G to meet its requirements. Furthermore, utilizing new technologies such as Millimeter Wave (mmWave), Terahertz (THz), and a massive number of small cells in a small area complicate the HO process, which makes the traditional HO techniques not applicable to the B5G system. In this regard, the developer and researchers have begun investigating the challenges of HO management in B5G and studied solutions that may help to address the HO issues in B5G. Several researchers, such as in [26-33], detailed in the related work section, have studied mobility management in 5G and B5G in view of different points. However, there is still a lack of studying HO's challenges and possible solutions in B5G considering innovative technologies and techniques, such as Blockchain, free cell network, and Cell-Free massive Multiple-Input-Multiple-Output (CF-mMIMO), etc.

Unlike the existing research in the literature, this survey comprehensively studies the challenges of HO in B5G that will be caused due to the new technologies and techniques to be implemented in B5G. On the other hand, this paper discusses the recent possible solutions of HO in B5G. Overall, the main contributions of this survey are summarized as follows:

- This survey first presents the background research of HO management in legacy systems and for different terminologies.
- Recent related works of this survey are also provided and summarized.
- The survey also comprehensively investigates the challenges of HO optimization in the B5G system. It explains the HO optimization issues in the most prominent B5G enabler technologies and is summarized in a table. For example, the HO challenges due to interoperability, THZ Wave, high accuracy of data transmission, CF-mMIMO, The Non-Terrestrial Network (NTN), etc. Moreover, the challenges related to HO optimization emerging from the B5G requirements are introduced. In addition, the HO optimization research directions are illustrated.
- Most HO optimization techniques solutions for B5G are discussed and explained how each technique could improve the HO optimization in B5G. Also, the potential technologies that will help in enhancing the HO optimization in B5G, such as HO techniques based on: Blockchain, Artificial Intelligent (AI) techniques, RIS (Reconfigurable Intelligent Surface), Holographic Beamforming (HBF), cell-less network, etc., are highlighted. Moreover, their impact on enhancing the HO optimization in B5G is summarized.
- This survey will help the researchers, developers, and system designers interested in HO optimization in the B5G system to identify the HO optimization issues facing the implementation of B5G. It also highlights the most recent and advanced HO optimization solutions techniques in B5G. As a result, this survey can assist researchers and developers in designing robust and seamless HO optimization algorithms for B5G networks.

The remainder of this survey is organized as follows: Section II introduces the research background, including the HO techniques in legacy systems. In Section III, the related works are presented. Moreover, the challenges of the HO in B5G are investigated in Section IV. Furthermore, Section V discusses the HO techniques and the potential solutions in B5G. Lastly, Section VI concludes this survey.

## II. RESEARCH BACKGROUND

This section provides a research background in detail. It explains HO in terms of several aspects, such as HO management and process, HO decision types, HO network types, HO schemes, HO Control Parameters (HCPs), and HO in B5G.

### A. HO MANAGEMENT

HO management is the primary function and process in any mobile wireless system. It enables the UE to be connected to the networks while it moves within the network's coverage. In addition, HO management in mobile cellular networks aims to provide a fast and seamless transition of UE between the service and the target BS.

In general, there are three stages to the HO process: commencement, preparation, and implementation. The report on the reference signals measurement by the users from nearby BS to the serving BS is included in the first stage. For example, in 4G Long Term Evolution (LTE), the signal measurement report consists of the Reference Signal Received Quality (RSRQ) and Reference Signal Received Power (RSRP), further HO processes of LTE was provided in [12]. Furthermore, the HO may be conducted following the downlink and/or uplink signal measurement reports. The

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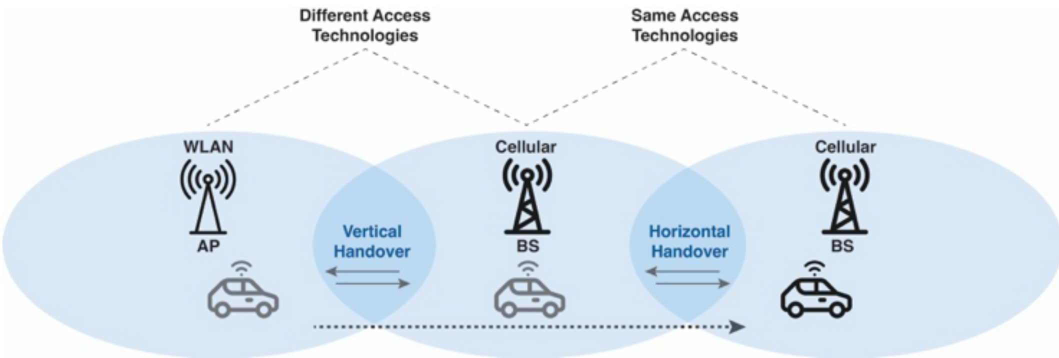


**FIGURE 1.** **Horizontal and vertical HO.**

second stage is preparation, where the signal exchange between the admission controller, the target BS, and the serving BS takes place. The admission controller determines whether or not to commence the HO based on the network-defined HO features. Once the HO requirements are fulfilled, the mobile user releases the serving BS, which then seeks to harmonize and get access to the target BS through the Random-Access Channel (RACH). When the target BS is synchronized, the UE sends a confirmation message to the network, indicating that the HO has been completed.

### B. TECHNIQUE-BASED HO CLASSIFICATION

HOs can be of two types: hard HOs and soft HOs. Both are also known as Break Before Connect (BBC) and Connect Before Break (CBB), respectively. The details can be found in [13], but they can be discussed further as follows:

**Soft HO or CBB:** CBB is a kind of HO technique where the radio connections are included and relinquished so that the user consistently keeps one link connected to the system [14]. Soft and softer HOs were presented in Code Division Multiple Access (CDMA) designs [15]. A softer HO occurs when the mobile device is associated with two sectors/ cells in the same BS [16]. A soft HO is reasonable for anticipating voice call dropping, keeping up a functioning session, and resetting a parcel session. It provides a smooth transition between the BSs. However, soft HO can only work between the BSs with the same frequency.  Moreover, it uses multiple channels simultaneously for a single mobile user, increasing network resources and reducing network capacity.

**Hard HO or BBC:** Refers to the type of process of HO in which the mobile device breaks the connection from the serving BS before connecting to the target BS [17]. Unlike the soft HO, the mobile device drops the current radio connection in the hard HO and then reconnects to a new BS. This causes communication interruption. However, hard HO can improve the network load resources by releasing the mobile user's resources and allocating them to another user. Table I compares the hard HO to the soft HO in terms of several essential characteristics.

TABLE I
HARD HO VS. SOFT HO

| Characteristic | Hard HO | Soft HO |
|---|---|---|
| HO speed | Fast | Slow |
| Reliability | High | Moderate |
| Service interruption | More | Less |
| Power consumption | High | High |
| Complexity | Low | High |
| Network resource | High | Moderate |
| Packet loss | More | Less |

### C. NETWORK-BASED HO CLASSIFICATION

There are two types of HOs in terms of networks and access technology: horizontal HO and vertical HO. The illustration provided in Figure 1 illustrates the two HO types based on the network.

**Horizontal HO** is the type of HO that occurs between the same type of access technology, such as HO, within 5G networks. Moreover, when UE moves and changes its BSs in the same networks, this type of HO is called horizontal HO.

**Vertical HO** denotes a type of HO that occurs between two different access technologies. In addition, when the connection of the UE changes between mobile cellular networks and Wireless Local Area Networks (WLAN), this is a vertical HO.

### D. HO CONTROL PARAMETERS (HCPs)

The HO decision technique comprises two HCPs: HO Margin (HOM) and Time-to-Trigger (TTT) [18]. The HOM refers to the threshold of two signals of the serving BS and target BS, which adjust with a specific value for the HO initiation decision. In addition, if the difference between two signals (serving and target) is greater than the HOM value, then the HO is initiated, and vice versa. Choosing the value of the HOM should be accurate to avoid the HO issues, such as frequent HO, unnecessary HO, connection drop, and ping-pong effect. For example, low HOM may lead to an HO Ping-Pong (HOPP) effect and unnecessary HO, while high HOM causes connection failure [19].

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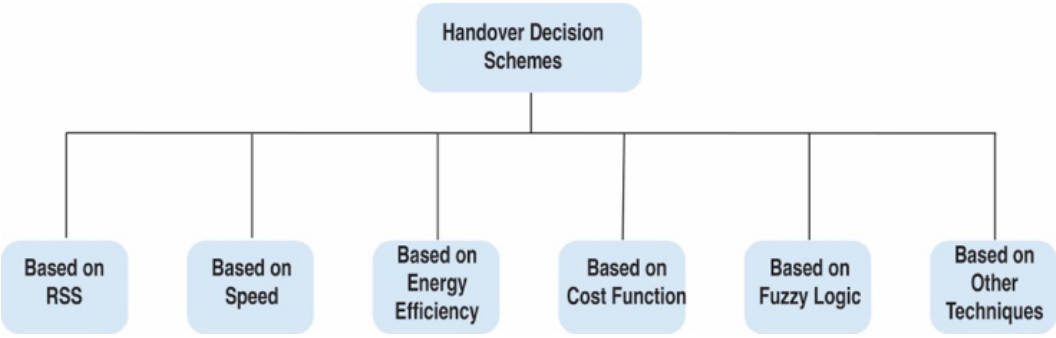


**FIGURE 2. Classification of HO decision schemes.**

The TTT represents the time it takes the mobile device with a poor signal to detect a better signal and initiate the HO. Same as the HOM, the TTT should be adjusted carefully to avoid the HO problems such as the abovementioned issues. Overall, TTT and HOM should be appropriately selected to provide optimum HO performance.

### *E. HO DECISION SCHEMES*

This subsection provides several different HO schemes and algorithms implemented in the legacy, current and B5G mobile systems. The classification can be found in Figure 2.

#### 1) RSS-BASED HO DECISION SCHEME

The HCP, HOM, is utilized here to analyze the RSS of the serving cell to the RSS of the objective cells [20]. The HO decision utilizing this technique is based on measuring the RSS of the serving BS at the mobile device. Moreover, the mobile device keeps measuring the RSS and report to the serving BS the measurement of both serving and target BSs. Considering the RSS measuring and HOM, already predefined with a particular value, the decision of HO is initiated. In addition, the RSS-based HO decision technique is simple to implement. However, this technique has several limitations, such as its sensitivity to radio interference and the mobile user's mobility. Therefore increases the ping-pong effect and unnecessary HOs [21].

#### 2) HO SCHEME BASED ON SPEED

One of the various HO decision schemes is the HO based on UE’s speed. In this scheme, the speed of the mobile device is utilized as an essential criterion to determine when the HO needs to initiate. The value of either one or both TTT and HOM is adjusted according to the level of the UE. For example, when the mobile speed is high, the value of TTT and HOM are set with low levels to avoid link failure. Furthermore, this type of HO scheme is usually combined with other HO decision factors, such as the RSS, UE’s direction factor and type of mobile data traffic, etc., such as in [22, 23]. In addition, HO based on mobile speed is typically used in high-speed mobile scenarios, such as in vehicular networks or High-Speed Rail (HSR), such as in [24, 25].

#### 3) COST FUNCTION-BASED HO SCHEME

This kind of HO decision technique is utilized to coordinate a wide scope of various HO choice parameters, for example, type of traffic, cell load, the lifetime of the battery, user speed and RSS, into one cost function. Moreover, this technique employs a cost function to analyze the quality of the current connection and prospective new connections and choose the option with the lowest cost. Several works, such as in [26-29], considered cost-function-based HO schemes.

#### 4) HO SCHEME BASED ON ENERGY EFFICIENCY

Energy efficiency-based HO technique means building the framework’s energy effectiveness using small cells. In addition, it aims to reduce energy consumption during the HO process or to switch from one BS to another. A few criteria can be set as the essential imperatives in this kind of HO choice, for example, the power consumption of the mean TX (transmitter) of the user, the UE, and the system. Energy consumption can be reduced by decreasing the number of HOs and signaling overhead. For example, many works utilized the Energy efficiency-based HO techniques, as published in [30-32].

As the power utilization of the user and the system are both emphatically reliant on the signal quality of interference, HO decision schemes based on energy efficiency are like HOs based on interference.

#### 5) HO SCHEME BASED ON FUZZY LOGIC (FL)

Fuzzy Logic (FL) promptly leads to the HO choice issue as its adaptability in characterizing parameters would oblige the dynamic nature of system conditions [33]. In a conventional HO situation, the HO choice depends on whether the signal level (RSS) falls underneath a specific limit. When looking at various systems, an increasingly adaptable methodology, for example, FL, would give greater granularity in its portrayal. FL utilizes participation capacities that enable a parameter to take two unique states simultaneously [34]. Taking the RSS model, utilizing a customary framework, a system's RSS is either above or below the limit. Furthermore, FL can depict how far a specific system’s RSS is above or below the limit by appointing it as enrollment work for the two states. For

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instance, a system with a participation capacity of 0.4 above and 0.6 underneath is less far beneath the edge than a system with a participation capacity of 0.2 above and 0.8 underneath.

#### 6) HO BASED ON OTHER TECHNIQUES

The work in [35] advocates an all-SDN (Software-Defined Networking) system design with hierarchical system control abilities to consider various evaluations of execution and intricacy in offering central system administrations and give administration separation for 5G frameworks. A dual-link soft HO plot for a split system in HSR is introduced in [36]. By sending a train relay station and two reception apparatuses in the train, the HO blackout likelihood will be decreased. In addition, the bi-throwing is received to diminish the correspondence interference time and the flagging progressions of the intra-macro scale eNodeB (eNB) HO. Simulation results demonstrate that the introduced HO plan can essentially decrease the blackout likelihood and improve the HO achievement likelihood in the HO among eNBs.

In [37], an enhanced HO technique has been developed to merge the current UE trajectory and the Home-eNB (HeNB) cell location. Additionally, a polynomial function is utilized to anticipate the future position of a user, while the cosine function, alongside separation, is utilized for the choice of a proper objective cell.

The authors in [38] present an improved HO scheme that mitigates the rate of unnecessary HO probability in LTE-Advanced (LTE-A) by decreasing the number of objective femtocells and call blocking likelihood during HO. Two parameters, which are the speed and signal level of the UE, are considered before making the HO decision. However, in these works, the effect of the call admission control scheme has not been verified for call dropping and blocking probability.

More comparisons of the different HO decision schemes in terms of the advantages and disadvantages are summarized in Table II.

TABLE II
ADVANTAGES AND DISADVANTAGES OF THE DIFFERENT HO DECISION SCHEMES

| Scheme | Advantages | Disadvantages |
|---|---|---|
| RSS-Based HO Decision Scheme | • Simple and easy to implement.<br>• It is based on RSS, which is a commonly available measurement.<br>• Low computational complexity. | • Susceptible to signal fluctuations and multipath fading.<br>• May not consider other factors like user speed, network load, or energy efficiency.<br>• May lead to frequent HOs (ping-pong effect). |
| HO Scheme Based on Speed | • Considers user mobility, which may reduce unnecessary HOs.<br>• Can adapt to different user speeds for better performance.<br>• May lead to better QoS for high-speed users. | • May not consider factors like signal strength, network load, or energy efficiency.<br>• Requires precise user speed measurements, which may be challenging to obtain.<br>• Less effective for low-speed users. |
| Cost Function-Based HO Scheme | • Considers multiple factors (e.g., signal strength, user speed, network load) in decision-making.<br>• Can be tailored to specific network requirements or user preferences.<br>• May lead to better overall network performance. | • Higher computational complexity.<br>• Requires appropriate cost functions, which may be challenging.<br>• Sensitive to parameter tuning and initial conditions. |
| HO Scheme Based on Energy Efficiency | • Focuses on energy consumption, promoting sustainable network operations.<br>• May extend battery life for mobile devices.<br>• Can help reduce network power consumption. | • May not consider factors like signal strength, user speed, or network load.<br>• Potential trade-offs between energy efficiency and QoS.<br>• May require additional monitoring and control mechanisms. |
| FL-Based HO Scheme | • Simple to implement.<br>• Handles uncertain and imprecise input information.<br>• Considers different factors for HO decisions.<br>• Can be combined with other techniques.<br>• Provides a more flexible HO decision-making process | • Requires designing fuzzy rules and membership functions precisely.<br>• Higher computational complexity, in the case of a high number of rules and membership |

### F. HO IN B5G SYSTEMS

#### 1) OVERVIEW

5G has been proposed as a solution to the rapid expansion of terminals, mobile data, current enterprises, and various phenomena and services. The rapid growth of the mobile internet and rising corporate demand should contribute to 5G's safety, reliability, lower power consumption, and low cost. Furthermore, the transmission degree would increase from 10 to 100 times, with the peak transmission degree reaching 10 Gbit/s. The one-way delay would be reduced to the ms level. Additionally, the connection device density would expand by 10 to 100 times while the traffic density would increase by

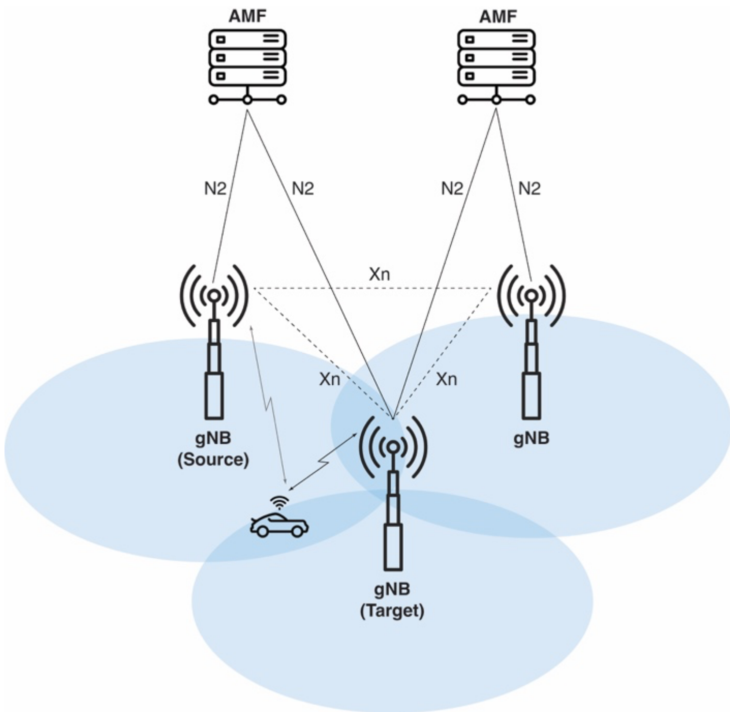


**FIGURE 3.** **HO in the B5G network with the two HO procedure types.**

1,000 times. The spectrum's efficacy would be increased by 5 to 10 times, with a guaranteed user experience speed of 500 km/h [39]. It could be concluded that 5G technology has the potential to significantly enhance communication and connectivity, resulting in a positive interactive experience among users, a significant reduction of distance between objects and individuals, and rapid identification of a connection between objects and individuals [40].

HO is a key component of radio resource management, in which the optimal execution of the HO results in a considerable increase in the overall system's efficacy and dependability, which is a critical function in modern wireless communication. In some occurrences, high bandwidth and transmission are essential in the B5G mobile communication system to accommodate various terminals. Notably, HO technology is critical for continuous responsiveness, service quality, and overall network execution.

#### 2) HO PROCEDURES IN B5G

HO procedures are used in B5G systems to switch a UE from a source Next-Generation Radio Access Network (NG-RAN) node to a target NG-RAN node. These procedures are used to maintain the connectivity of the service for the UE as it moves from one cell to another. Like the EPS (Evolved Packet System), HO methods are accessible even without a control plane link between the source and target NG-RAN nodes. Two main types of HO procedures exist in B5G systems: Xn-based and N2-based [41].

Xn-based HO uses the Xn interface between the source and target NG-RAN nodes to handle the HO. This interface is responsible for transferring UE-related information between the two gNodeB (gNB) nodes. This method allows for a smooth HO without service interruption, even without a control plane link between the source and target NG-RAN nodes.

N2-based HO uses the N2 interface between the NG-RAN and the Access and Mobility Management Function (AMF) for handling the HO. The N2 interface is responsible for the transfer of UE-related information between the NG-RAN and the AMF. This method also allows for seamless HO without interruption of service, but it is typically used when the UE is moving to a new coverage area that is managed by a different AMF.

Both the Xn-based and N2-based HO methods are used to ensure continuity of service for the UE as it moves from one gNB coverage area to another gNB coverage area. These methods are major to maintaining a high-quality user experience and support the high-mobility requirements of B5G mobile networks. Figure 3 demonstrates the HO in B5G, including the two types of HO procedures: Xn-based HO and N2-based HO.

## III. RELATED STUDIES

This section presents several recent related works that have been conducted in the same field as our study. The works are discussed and summarized in Table III.

Zaidi et al. [42] pioneered a holistic survey in 2020 on mobility challenges amidst ultra-dense mobile networks and presented an in-depth tutorial on 5G mobility techniques with pivotal mobility risks of legacy networks. The study reviewed key results from recent research and outlined the technical complexities and opportunities associated with mobility amidst emerging ultra-dense cellular networks.

Gures et al.'s comprehensive survey in 2020 [43] elaborated on 5G mobility management and its key elements (requirements, architecture, and challenges), which characterize mobility management in recent generations. Novel Radio Resource Control (RRC) inactive status, initial access, and registration and paging procedures were also highlighted. Inter-RAN HO protocols in a connected state, and integrated mmWave cells with a 5G technology were thoroughly justified through literature reviews. Lastly, specific complexities entailing HO problems, signaling overhead, power consumption, security, and latency were addressed. Optimal solutions were highlighted to fulfill the 5G mobility management prerequisites.

Ahmad et al. [44] conducted an inclusive study of the HO decision within two-tier 5G networks (eNB and HeNB) in 2020. The first part of this survey provided technical background to the HO mechanisms. Essentially, LTE-A architecture was discussed with the recently released versions. The HeNB admission control and HO procedure phases in two-tier networks and HeNB HOM intricacies were subsequently highlighted. The integration of current modern HO algorithms into Heterogenous Networks (HetNets) following primary techniques and input parameters was surveyed and classified in the second part of the survey based on the HO challenges encountered by HO decisions in two-tier networks. The primary mechanism and input parameters in each category were employed in the HO decision to justify the method's benefits and drawbacks. Notably, the representative algorithm in every category characterized its performance evaluation metrics. The aforementioned HO decision algorithms were then tabulated to present the decision parameters, key decision technology, and performance evaluation metrics. The article concluded with discussions on specific open issues involving 5G HetNets HO.

Jain et al.'s study in 2020 [45] presented a novel discussion on the functional requirements of mobility management strategies for these networks with elaborations on the extent to which the current mechanisms conceived by standardization bodies, such as IEEE (Institute of Electrical and Electronics Engineers), IETF (Internet Engineering Task Force), 3rd Generation Partnership Project (3GPP) (including the newly-defined 5G standards), ITU (International Telecommunication Union) and other academic and industrial research efforts fulfill these conditions. This was accomplished through a new qualitative evaluation that assessed every discussed mechanism following its capacity to fulfill the reliability, flexibility, and scalability criteria for future mobility management strategies. Research involving the limitations in mobility management strategy design and implementation for 5G networks and beyond was also presented. Potential mobility management alternatives and their relevant capacities were outlined to manage persisting complexities. The study was summarised with a vision for mobility management mechanisms in 5G and B5G networks.

Mollel et al.'s survey study in 2021[46] offered an extensive study on HOM in 5G networks with an emphasis on Machine Learning (ML) applications to HOM. A novel taxonomy based on the data source to be utilized in training ML algorithms was generated following two broad divisions: visual and network data. The survey, which strived to divert the empirical focus from traditional methods to visual data sources following the potentiality of incorporating them into HOM, discussed how intelligent HOM could prove insightful in emergency scenarios involving mobile clinics, ambulances, and remote hospitals. Furthermore, advanced ML-aided HOM in cellular systems under every category was reviewed with recent research and elaborations on empirical issues and future study directions.

Tanveer et al.'s survey [47] on 5G mobility management in Ultra-Dense Small Cell networks (UDSC) with Reinforcement Learning (RL) methods was published in 2022. Current surveys were first discussed before emphasizing HOM within the UDSC scenario. Likewise, this study explained how ML algorithms could facilitate multiple HO scenarios and outlined future directions and challenges involving 5G UDSC networks.

Khan et al.'s research in 2022 [48] presented a comprehensive review of HOM in future mobile ultra-dense HetNets. Various mobility and HOM methods were elaborated to underscore their contribution towards seamless connection amidst user mobility. Specific intricacies, opportunities, and possible alternatives were also investigated to highlight key complexities and ascertain appropriate solutions that may resolve mobility issues in future mobile networks.

The research in [49] examined the various forms of flat and Distributed Mobility Management based (DMM-based) IP (Internet Protocol) mobility management designs. Siddiqui et al., in 2022, identified and explored mobility management strategies for wireless networks from the viewpoint of network topologies where traffic will primarily be transferred locally at the RAN level rather than being routed over the primary network. The latest results were included in the study, along with the possible advantages of resilient mobility enablement in dynamic DMM 5G and B5G radio communication systems. Furthermore, the research thoroughly describes a wide range of recent and continuing investigations and difficulties while outlining possible prospective study directions related to the planned flat DMM-based 5G and 6G networks. This article is deemed a promising reference for designing wireless networks of 5G and B5G.

In summary, unlike the presented studies, from existing literature, which mostly focus on the existing HO challenges and omit critical expected HO optimization challenges and potential solutions of B5G networks, our survey extensively

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studies the HO optimization of B5G networks. The survey coherently discusses the challenges and solutions of the HO optimization techniques for the future mobile wireless B5G. It examines the most HO optimization challenges that may face the implementation of the B5G networks, including the HO optimization issues of the potential technologies and techniques that will be implemented in B5G networks. Additionally, it states future research directions. Concurrently, the study provides the most prominent HO optimization techniques and explores the latest potential solutions for addressing HO optimization issues within the B5G context. Table III summarizes the existing related works regarding their motivations and contributions and is classified according to their published years and system focus.

TABLE III
SUMMARY OF EXISTING RELATED WORKS

| Ref. | year | System | Motivation | Contribution |
|---|---|---|---|---|
| [42] | 2020 | UDN | • The mobility management challenges in UDN<br>• Few existing surveys are focused on ad hoc networks. | • Providing a comprehensive survey on mobility challenges in UDN.<br>• Highlighting the mobility's technical constraints and possible prospects from the perspective of UDN. |
| [43] | 2020 | 5G/ HetNets | • The importance of deploying intense small cells in 5G satisfies the demands and provides high coverage to the 5G network.<br>• The mobility challenges, such as HOF, HOPP, HOL, etc. caused by the intense small cells. | • Providing a comprehensive survey in mobility management discussing RRC, the initial access and registration procedure of UE to the network, the paging procedure, connected mode mobility management techniques, beam level mobility, and beam management.<br>• Addressing the challenges of mobility management and suggesting possible solutions for mobility management in the 5G. |
| [44] | 2020 | 5G/ HetNets | • HO management decisions challenge facing in HetNets (femtocells). | • Presenting the challenges of HO management and highlighting modern HO decision algorithms between the eNB femtocells.<br>• Providing a comprehensive study of HO procedure in LTE-A HetNets.<br>• Categorizing the recent literature in HO's decision algorithms for eNB and femtocells in terms of the main decision technique. |
| [45] | 2020 | 5G/ B5G | • The mobility management issues in 5G/B5G caused due to ultra-dense and HetNets to meet the users' data traffic requirements and ensure the QoS. | • Presenting discussion on 5G/ B5G mobility management functional requirements.<br>• Developing qualitative analysis for the legacy mobility management techniques<br>• Providing classification of the existing state-of-the-art techniques.<br>• Discussing the research mobility management challenges. And discussing the potential solution. |
| [46] | 2021 | 5G/ B5G | • ML HO management application in 5G/ B5G<br>• HO challenges in the 5G requirements | • Updating the recent status of HO management in 5G.<br>• Providing a comprehensive study on HO management in 5G, as well as a discussion on ML applications to HO management.<br>• Producing taxonomy for the source of data used in training ML algorithms<br>• Providing a revision of the state-of-the-art on ML-aided HO management |
| [47] | 2022 | 5G/ UDSC | • The capability of the ML techniques enables the 5G to meet its requirements. | • Presenting HO RL-based techniques in 5G UDSC and showing how ML techniques impact HO management. |
| [48] | 2022 | 5G/ B5G | • HO management over DC in 5G with UDN and HetNets. | • Various DC HO management techniques and mobility management strategies are examined and studied.<br>• Describing the key concepts of the DC HO approaches in future UDN and HetNets.<br>• Investigating the HO techniques based on ML and other emerging strategies to overcome mobility management issues.<br>• Presenting and discussing several expected challenges and solutions for the future research direction. |
| [49] | 2022 | 5G/ B5G | • The capability of DMM to solve the problems of unaided obstacles that destructively impact the current networks. | • Highlighting the possibilities and advantages of flat network architecture for efficient and fast traffic routing and providing the scheme's efficacy toward mobility management in B5G by outlining recent research efforts.<br>• Discussing the existing constraints, problems, and future research path for seamless mobility to meet the requirements of current and future networks. |

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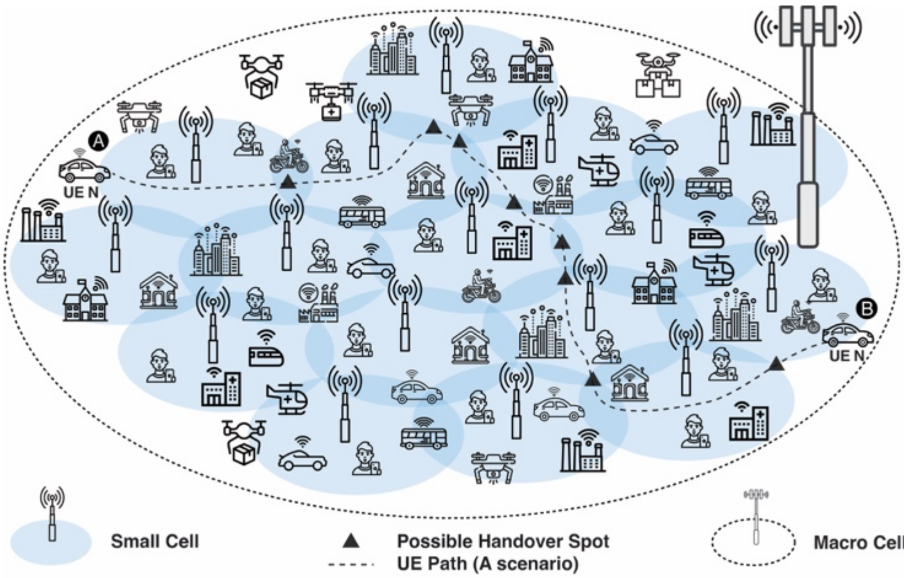


**FIGURE 4.** **A UE HO scenario in UDN.**

## IV. HO OPTIMIZATION CHALLENGES IN B5G

The challenges of the HO management in B5G are increased as new technologies are/will be designed for the B5G system to meet its requirements. This section discusses the most prominent HO optimization challenges in the B5G network by introducing different new technologies to support the network.

### A. ULTRA-DENSE NETWORK

In an Ultra-Dense Network (UDN) design, the cell's radius is smaller than the initial radius [50]. A recurring HO is also generated by a decrease in the length of the mobile terminal that remains in the cell. Provided that the moving speed of the mobile terminal amounted to 10 km/h, the cell radius speed amounted to 25 m, and the overlap length amounted to 5 m, the mobile terminal initiated the HO within 12 s, while the overlap area persisted for 4 s.

Various unresolved issues exist in the development of UDN, including many mobile node employments on the UDN and small cells, which increases the number of HOs. This occurrence results in new recurrent HOs. Also, UDNs may increase the HOPP effect that happens when the UE frequently switches back and forth of the UE between two or more cells within a short period [51]. As a result of the control traffic surge, energy and network resources are consumed at a greater rate, thereby increasing the likelihood of HO Failure (HOF). In other words, increasing the number of cells increases the HOs, which increases signaling overhead between the mobile node, serving, and target eNBs [52].

Recurrent and alternating HOs might arise from UDNs, leading to further problems, such as increased latency and total error in the HO procedure [53]. Mobility based on SDN and the current resource estimation method were proposed in [53] as solutions to the HO Latency (HOL) problem. A Markov-chain-based HO management solution for software-defined ultra-dense 5G networks was also presented, which identified the optimal eNBs and conducted virtual allocation of the eNBs to the mobile node. Compared to the conventional method, the proposed solution reduced HO errors and latency by 21% and 52%, respectively. In another study [54], a state-dependent HO selection algorithm was proposed that could notably reduce the rate of error in HO without decreasing the use of small cells and the throughput user experience.

Besides that, two intelligent HO skipping methods were proposed in [55], which enabled users to effectively skip future HO performances by considering the topological features of the network deployment. The Cooperative (CO) skipping method, in particular, is known as the BS collaboration advantage gained by the user, except for when a HO was skipped. Meanwhile, in the Non-CO (NCO) skipping method, a single BS relation was used, and a HO was skipped according to three characteristics: (a) the cell area, (b) path distance in the cell, and (c) BS distance from the cell boundary. For moderate user speed, the NCO method was shown to give the most significant average throughput.

Figure 4 illustrates a UE HO scenario in UDNs. As the figure shows, the network consists of a large number of small cells and a large number of different types of connected users. Thus, increasing the number of frequent HOs complicates the HO process and affects the overall system performance. Additionally, assuming a scenario *UE N* is moving from point *A* to point *B* through the UDN, as shown in the figure, it will occur a high number of HOs; this increases as the UE speed increases.

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### B. ULTRA-LOW LATENCY COMMUNICATION (URLLC)

Mobility execution is one of the most crucial aspects of wireless interactions, and it also applies to Ultra-Low Latency Communication (URLLC). URLLC services require high mobility, dependability, and latency [56-59]. Seamless and quick HO approaches with no delay are essential for the activation of 5G capabilities as well as various services and applications that demand a low latency connection.

The effect of HOF rate and HO Interruption Time (HIT) on reliability execution was investigated in [60]. The conditional make-before-break HO was then proposed, along with the methods for simultaneously achieving zero HIT and zero HOF rates. In particular, zero HIT could be attained through the make-before-break HO by suppressing the link from the source cell to the first or multiple downlink receptions from the chosen cell upon HO.

### C. INTEROPERABILITY

Interoperability refers to the ability of different networks, devices, access technologies, or systems to communicate and work together smoothly [61]. Furthermore, in B5G, mobile users will be connected with the different mobile wireless networks and access technologies to ensure connectivity and availability so the mobile user can move and switch between the other mobile wireless networks and access technologies freely and seamlessly. However, this increases the HO management challenges due to performing HOs between various wireless technologies [62]. Therefore, advanced HO techniques are highly required to support the mobile user to be connected when it sweeps within the different wireless network access.

### D. ULTRA HIGH MOBILITY

One of the major problems facing the advancement of B5G systems is ensuring dependable broadband wireless communications in high-speed mobility scenarios, such as HSR systems. In addition, the expected mobility speed that will be supported by the B5G system, such as in 6G, is up to 1000 km/h. The major problems for HO in high mobility systems were presented in [63]. In high-mobility scenarios, UEs often have a higher HO rate. Additionally, because UEs can quickly travel through the overlapping coverage area of two BSs, the system may not have enough time to complete the HO operation. As a result, more stringent delay control is required for HO in high-mobility systems. Moreover, fast-moving UEs might overlook the optimal HO position, increasing the chance of HOF. Furthermore, in HSR systems, HO may be required for many passengers aboard simultaneously, resulting in a group HO problem requiring a significant amount of network resources.

### E. MMWAVE

5G mobile networks use a wide range of spectrums in the mmWave bands to significantly enhance the interaction volume. There are significant differences between mmWave interactions and other current interaction systems in terms of substantial propagation loss, reactivity to blockage, and directivity. Moreover, when these features of mmWave interactions are fully utilized, they exhibit several problems [64]. In light of this situation, a thorough review of the new 5G mmWave wireless system ideas and a selection of the crucial mmWave radio propagation models developed globally to date was presented in [65].

Notably, mmWave interaction aided in the interaction of higher-frequency bands, significantly enhancing the interaction system's volume. Nevertheless, the high-band radio is only utilized within a restricted range due to low expansion around the barriers, atmosphere, rain absorption and significant path loss [66]. Following the rapid fading, a particular error in the measurement signal would be present, resulting in a lower effective rate of HO and unnecessary HO. Overall, these phenomena have a severe impact on the user interaction experience.

Accordingly, the problems associated with the HO methods for Radio-over-fiber networks at 60 GHz were discussed in [67]. In the mmWave interaction system, some problems in user mobility would lead to notable changes in channel conditions in particular. Users' movement would create a distance variation from the receiver (RX) to the TX, including the wide range of channel conditions. The limited coverage of BSs would also lead to a substantial and rapid rate of load shifts through user mobility in each BS, particularly in indoor areas [68]. As a result, careful management of HOs between cellular APs and user relations is required to achieve optimum load stability.

In general, user mobility could lead to constant HOs between the APs, while HO mechanisms could significantly impact network traffic, load stability, Quality of Service (QoS) guarantee, etc. For instance, smooth HOs are required to decrease the missing link and ping-pong, which refers to various HOs between similar pairs of APs. Nevertheless, there needs to be more research performed on the HO mechanisms for mmWave interactions in the band of 60 GHz.

### F. THZ WAVE

The core technology for 6G will be THz wave, which has an electromagnetic wave spectrum ranging from 0.1 to 10 THz with a wavelength of 30 to 3,000 microns [69]. The spectrum is in the transition region where macro-electronics and micro-photonics collide, especially between microwave (from its lower band) and infrared light (up to its higher band) [70]. Despite the fact that the frequency band (from microwave to optical wave) of THz may not be fully operated, THz communication has abundant resources of the spectrum and an ultra-high transmission rate, which provide precious broadband wireless access for future mobile networks [71]. THz communication also has a very large bandwidth range (up to 10 THz). In addition to its ability to penetrate visually non-transparent objects, THz communication also allows interactions with micro-scale objects (e.g., nanoscale network or nanonetwork) due to its scale-down antennas (the wavelength of about 1 mm for the frequency of 300 GHz). Consequently, THz wave coverage will be relatively limited, necessitating a large number of BS in a small area. Furthermore, the number of HO will be greatly increased since 6G will employ ultra mMIMO, which will affect the overall system performance. Consequently, the 6G system will experience significant challenges in terms of mobility management.

### G. FAST AND SEAMLESS HO

A fast HO refers to the process of switching the UE from one BS to another with minimal disruption to the ongoing communication. At the same time, a seamless HO is defined as a HO process that keeps the UE's connection and data connected to the network without interruption when the HO occurs [72]. Moreover, the goal of seamless HO is to ensure uninterrupted delivery of end-to-end data in the case of a connection interruption or a HO event [73].

In the B5G system, the fast and seamless HO is a major challenge because B5G requires ultra-low latency and 100% connectivity to support different service cases, which require ultra-low latency and uninterrupted connection [74, 75]. Therefore, providing seamless and fast HO techniques is crucial in B5G mobile systems.

### H. MASSIVE NUMBER OF DEVICES

The dramatically increasing number of devices connected to the Internet each year likewise increases the volume of data. Billions of devices and sensors that are expected to be connected to the Internet represent the main hurdle for 5G. Based on Huawei and Information Handling Services (IHS) forecasting analyses [76, 77], the number of connected devices will reach 75.4–100 billion devices by 2025. As such, 5G/B5G must be able to support the massive data from the immense number of connected devices and sensors and process them in an incredibly short time.

Overall, as the number of devices increased, the number of frequent HO increased, so the challenge of the HO also increased. Therefore, ensuring HO techniques that can address the problem of the increase in the number of HO is very important to meet the B5G requirements.

### I. MULTI-RADIO ACCESS

To enhance the connection density, coverage, spectrum efficiency, and traffic capacity, B5G systems are promising to employ Multi-Radio Access Technology (Multi-RAT) [78]. Multi-RAT refers to the ability of a UE to use multiple wireless communication technologies simultaneously. However, the network diversity increases the HO management's challenges, such as interference, delay, and complexity. In the scenario of the Multi-RAT network, the interference of frequency between networks may increase, affecting the signal quality and thus increasing the HO management challenges. The delay is another factor that increases the challenges in HO management in Multi-RAT networks in B5G. In other words, as the number of mobile access technology increases, the delay in HO can also increase, which leads to data communication delay. The complexity of managing HO in a Multi-RAT can be a significant challenge. With multiple networks and devices, ensuring that HO management is efficient and effective can be difficult. Overall, managing HO in a Multi-RAT network presents considerable issues, necessitating efficient and effective HO techniques.

### J. HIGH ACCURACY OF DATA TRANSMISSION

B5G has to achieve high accuracy of data transmission without any error to satisfy its requirement and vision [79]. This is a considerable challenge, especially with the mobility of users and HO management. In the case of the requirement of high data accuracy, the HO management task becomes more challenging, necessitating a fast and accurate HO decision to satisfy the data communication accuracy. Also, when the data is highly accurate, the UE keeps connected to the serving BS even when it is the cell's edge. This can increase HO frequency as the UE moves in and out of the cell, creating additional signaling overhead and reducing the overall system capacity. Therefore, this issue must be addressed efficiently to meet the demands and achieve the drawn targets of the B5G system.

### K. CARRIER AGGREGATION (CA)

Carrier Aggregation (CA) is one of the innovative techniques that can increase the data rate in the B5G system [80]. In addition, CA enables the mobile terminal to be simultaneously linked with two or more cells of the providing BS, allowing the mobile terminal, or UE, to operate at various frequencies at the same time. However, switching UE from one cell to another cell in a short time may increase the complexity of HO management and cause some difficulties during HO. One of the issues of carrier aggregation-related HO management is the requirement for coordinated HOs. For example, when a UE is connected to multiple carriers, it is critical to guarantee that HOs occur simultaneously across all carriers to maintain service continuity. If the HO is not coordinated, it can cause service disruption, especially for real-time applications like voice and live conference with video calls. Furthermore, CA can also result in higher signaling overhead, influencing total system capacity. The mobile device must exchange signaling messages with the network to perform the HO as it moves from one carrier to another. This can result in greater signaling overhead, particularly in densely populated areas, resulting in lower system capacity. These issues will be increased in the B5G system as it uses enormous cells in a small area.

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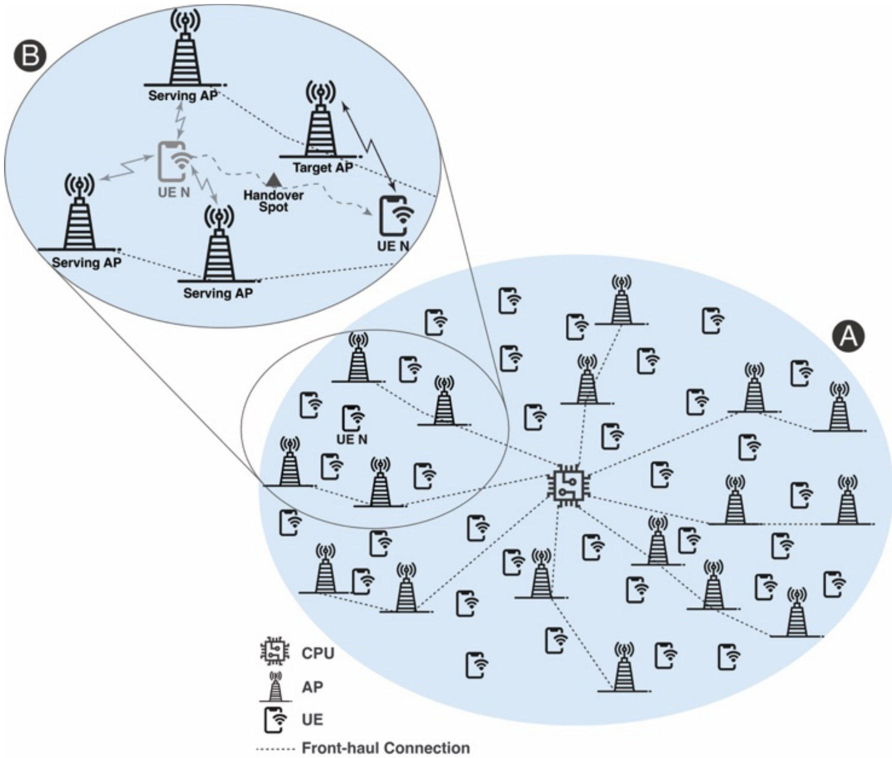


**FIGURE 5.** **HO in CF-mMIMO.**

### *L. COGNITIVE RADIO (CR)*

In wireless communication, Cognitive Radio (CR) is a technique used to utilize unused communication channels and allow the users to dynamically switch between the channels to evade the user's interference and congestion [81]. In addition, CR intelligently detects which warless channels are in use and not in use. It is considered a type of spectrum allocation management.

In the B5G network, CR is an emerging technology that aims to increase spectrum utilization and satisfy the massive data requirement by sharing the available spectrum intelligently, thus improving the QoS. However, HO management and the switch between the primary and secondary users is a critical task [82]. Therefore, developing seamless and robust HO optimization schemes that can dynamically transfer the users between the sections channels ensures a high QoS.

### *M. CELL-FREE MASSIVE MIMO (CF-mMIMO)*

mMIMO is an extension of MIMO, a method in the wireless system that consists of many antennas for sending and receiving data from/to several users simultaneously [83]. CF-mMIMO [84] is a promising technology in B5G systems. On the other hand, CF-mMIMO is a system in which a huge number of distributed APs serve a large number of user terminals coherently at the same time and same frequency band. However, as investigated in [85], the users' serving clusters must be updated very often in high mobility scenarios. This will generate a large number of signaling, which affects the throughput. Furthermore, using CF-mMIMO may increase the HOL since each user can be served by several APs, which are themselves by several Central Processing Units (CPUs).

Figure 5 (A and B) depicts the HO in CF-mMIMO. As the figure shows, each AP is connected to the CPUs, and multi-APs can serve each UE. Moreover, as the zoomed-in Figure 5 (B) illustrates, *UE N* was served by more than one AP simultaneously and handed off to another AP/APs. Furthermore, the issue of HOL increased as the speed of UE increased.

### *N. PRIVACY AND SECURITY*

Privacy and security are two of the biggest concerns in any mobile wireless communication. In the B5G network, the importance of security and privacy are significantly higher than in the legacy due to the huge value of the individuals' data that will be carried over different use cases and through the network [86, 87]. Also, because of many applications that are not tolerant of security lack, such as autonomous and health use cases [88, 89].

In B5G HO, the issue of privacy and security is the main corner that must be addressed to ensure ultra-reliability. A comprehensive study in [90] is presented on privacy and security. The study outlined a complete set of security and privacy standards for 5G HetNet HOs to prevent possible threats and attacks. The study findings and comparison show that state-of-the-art HO schemes fall short of fulfilling all security and privacy standards. Therefore, efficient HO techniques are still required to satisfy the requiems of the B5G network.

### O. NON-TERRESTRIAL COMMUNICATION NETWORK (NTN)

The NTN is an important potential system that aims to satisfy the B5G system requirements of the global connectivity and availability [91]. NTN aims to ensure connective and service availability for users anywhere and anytime [92]. Traditionally, NTN refers to the networks of satellite networks, Unmanned Aerial Vehicles (UAVs), and High-Altitude Platforms (HAPs), which are used in certain applications, such as navigation, remote sensing, TV broadcasting, and disaster management [93]. In the B5G system, the NTN and Terrestrial Network (TN) will be integrated to ensure availability, scalability, and ubiquitous wireless coverage worldwide. However, the integration of TNs with NTNs may increase the complexity of the HO process, especially in the case of Non-Geostationary-Satellite Orbit (NGSO) with moving cells, which causes cell pattern motion, thus increase the frequent HO. Furthermore, due to the high speeds of the satellites, the time that UE is connected with the satellite is very short, which increases the frequent HO [94]. Therefore, new and robust HO techniques over NGSO are required to address the frequent HO caused by the movement of NGSO satellites. Table IV summarizes the HO optimization challenges in B5G in each technology.

### P. ADDITIONAL HO CHALLENGES IN MEETING THE 6G REQUIREMENTS

6G, expected to be released in 2030, is the latest generation of mobile systems. The researchers, developers, and system designers have started to do the experiments and identify its roadmap and standards, as well as 3GPP. 6G will make the most significant changes in the mobile system ever and will change the concept of the wireless system due to the revolutionary technologies that will impact all life fields, people's life, and industry domain.

The main 6G requirements and capabilities, explained in our previous work [10], are:

- User experience data rate of up to 1–10 Gbps.
- Extremely peak data rate of larger than 1Tbps.
- Spectrum efficiency is 5 to 10 times higher than in 5G.
- Ultra-high mobility speeds of 1000 km/h.
- Extremely low latency, about 1–10 µs.
- Massive connectivity density of $10^7$ devices/ $km^2$.
- Network energy efficiency is 100 times higher than in 5G.
- Area traffic capacity of 1 $Gbps/m^2$.

To achieve these requirements, the researchers and developers need to overcome the challenges that face 6G implantation in all related fields. One of these fields is mobility management, specifically on the HO. The existing HO schemes may not be capable of being used in the 6G system. New optimization HO techniques must be developed to address the HO issues, thus satisfying the 6G requirements. Table V provides the HO management challenges each distinct 6G requirement may face.

TABLE IV
SUMMARY OF THE HO CHALLENGES IN THE B5G NETWORK

| Technology | HO Related Challenges |
|---|---|
| UDN | High number of HO<br>HOPP effect |
| URLLC | HOL<br>HOL |
| Interoperability | High number of HO<br>Different types of HO |
| High Mobility | HOF effect<br>HOL |
| mmWave | High number of HO<br>HOPP effect |
| THz Wave | High number of HO<br>HOPP effect<br>HOF effect<br>HOL |
| Fast and Seamless HO | Fast HO<br>Seamless HO |
| Massive Number of Devices | High number of HO |
| Multi-Radio Access | High number of HO<br>Different types of HO |
| High Accuracy of Data Transmission | Fast HO<br>Seamless HO<br>HOL |
| CA | HO complexity |
| CR | Frequent HO |
| CF-mMIMO | High HOL |
| Privacy and Security | HO Privacy and security<br>Cyber threats and attacks |
| NTN/ NGSO | Frequent HO |

TABLE V
SUMMARY OF THE HO CHALLENGES FACE 6G IMPLEMENTATION

| Key Capability | Value | HO Optimization Challenges |
|---|---|---|
| Peak data rate | >1Tbps | Fast HO<br>HOL |
| User experience data rate | 1–10 Gbps | Frequent HO<br>HOL |
| Spectrum efficiency | 5x–10x of 5G | Frequent HO<br>HOPP effect<br>HOF |
| Ultra-high mobility speed | >1000 km/h | HOF<br>Fast HO process<br>HOL |
| Extremely low latency | 1–10 µs. | HOL |
| Massive number of connected devices | $10^7$ devices/ $km^2$ | Frequent HO<br>HOL |
| Network energy efficiency | 100x of 5G | Energy efficiency HO technique |
| Area traffic capacity | 1 $Gbps/m^2$ | Frequent HO<br>HOL |

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### *Q. DISCUSSION AND FUTURE RESEARCH DIRECTIONS*

This subsection discusses future research directions based on the conducted study. The discussion is summarized in several points, as follows:

- **Dynamic network conditions:** In B5G networks, the environment is constantly changing due to several factors, such as the mobility of the user, network load and capacity and radio link conditions. Thus, HO optimization techniques must be adaptive and capable of working with these various dynamic conditions to preserve a high QoS and user experience.
- **Complexity:** Due to the B5G network comprising a high level of HetNets and high-density networks, designing HO optimization techniques requires a high level of complexity. This complexity poses a challenge for developing and implementing HO self-optimization techniques, as it requires advanced algorithms to fulfill the complexity of the networks.
- **Interference:** It is one of the major challenges facing the implementation of HO self-optimization techniques in B5G cellular networks. This is due to the rapid increase in the massive of connected devices, high-frequency bands, and an enormous number of small cells in a certain area. Interference can cause significant performance degradation, impacting the effectiveness of HO decisions. Therefore, developing HO optimization techniques that can ensure a seamless HO process is very important.
- **Scalability:** As B5G networks are expected to support a massive number of connected devices and high-speed data rates, it is critical that HO self-optimization techniques must be scalable to meet the demands of the networks. This requires developing scalable and efficient HO decision techniques to handle the huge volume of data associated with B5G networks.
- **Real-time performance:** HO self-optimization techniques must operate in real-time to ensure that the HO process is performed efficiently and effectively, as several applications require real-time connectivity. Thus, designing HO techniques with fast decision processes is challenging to maintain network performance.
- **Energy efficiency and sustainability:** HO optimization techniques should also consider energy efficiency and environmental impact. Developing energy-aware HO techniques can help to minimize energy consumption and extend the battery life of mobile devices. In addition, energy efficiency and sustainability are essential global issues that must be addressed to ensure sustainability everywhere.

In short, this survey suggests several solutions for HO optimization techniques. However, various issues and challenges may still open for researchers and developers in the future.

## V. HO OPTIMIZATION SOLUTIONS FOR B5G

As discussed in the previous section, many HO optimization challenges will face the B5G implementation and limit its goal and requirements unless finding solutions that can overcome these challenges. The developers and researchers have come up with several solutions, techniques and technologies to enable the requirements of B5G. This section provides the main and most recent HO optimization solutions for B5G.

### *A. CONDITIONAL HO (CHO)*

When one or more HO execution conditions are met, a Conditional HO (CHO) is proposed to be executed by the UE. The UE begins evaluating the execution condition(s) upon receiving the CHO configuration and stops once a HO is executed (legacy HO or CHO execution) [95]. CHO is a novel solution included in 3GPP Release 16 that seeks to increase a mobile terminal's mobility robustness [96]. New mobile services with minimal latency and high dependability achievement are surfacing. Although the 5G standard has been devised from the beginning to deal with these services, 5G New Radio (NR) development must continually improve mobility robustness achievement in these challenging contexts. Furthermore, CHO concentrates on lowering the number of HOFs while a user moves (for example, when an HO between cells fails or when a link fails before a HO is triggered). In CHO, instead of preparing one target cell as in the legacy case, the network prepares several potential target cells in advance. This method allows the HO order to be transmitted to the mobile terminal sooner than legacy HO when the radio circumstances are still good rather than when they start to decline.

Accordingly, the study in [97] investigated the mobility performance, disruption, and signaling overhead of CHO in 5G NR. According to the study, CHO could offer mobility robustness and outage gain, but at the same time, improper parametrization could notably increase signaling (overhead). Furthermore, optimization of Self-Organizing Networks (SON) for CHO and CHO triggering based on source quality was found to considerably enhance performance without increasing signaling. In another study, [98] examined the merits and limitations of CHO by comparing it to 5G baseline HO. The study proposed utilizing more preparations to improve CHO's robustness, resulting in significant signaling overhead. The study also proposed a revolutionary Prediction-based CHO (PCHO) strategy that employed Deep Learning (DL) technology to address CHO weaknesses and produce more intelligent preparation selections. The performance evaluation showed that PCHO could enhance the success rate of early preparation and decrease signaling overhead compared to existing CHO strategies.

The authors in [99] recommended the 'ZEro HOF with unforced and automatic time-to-execute Scaling' (ZEUS) algorithm in 2022 for seamless HO parameter optimization in CHO and the minimization of HOF to near 0 to fulfill the 5G network prerequisites, which necessitates HIT at 0 ms in

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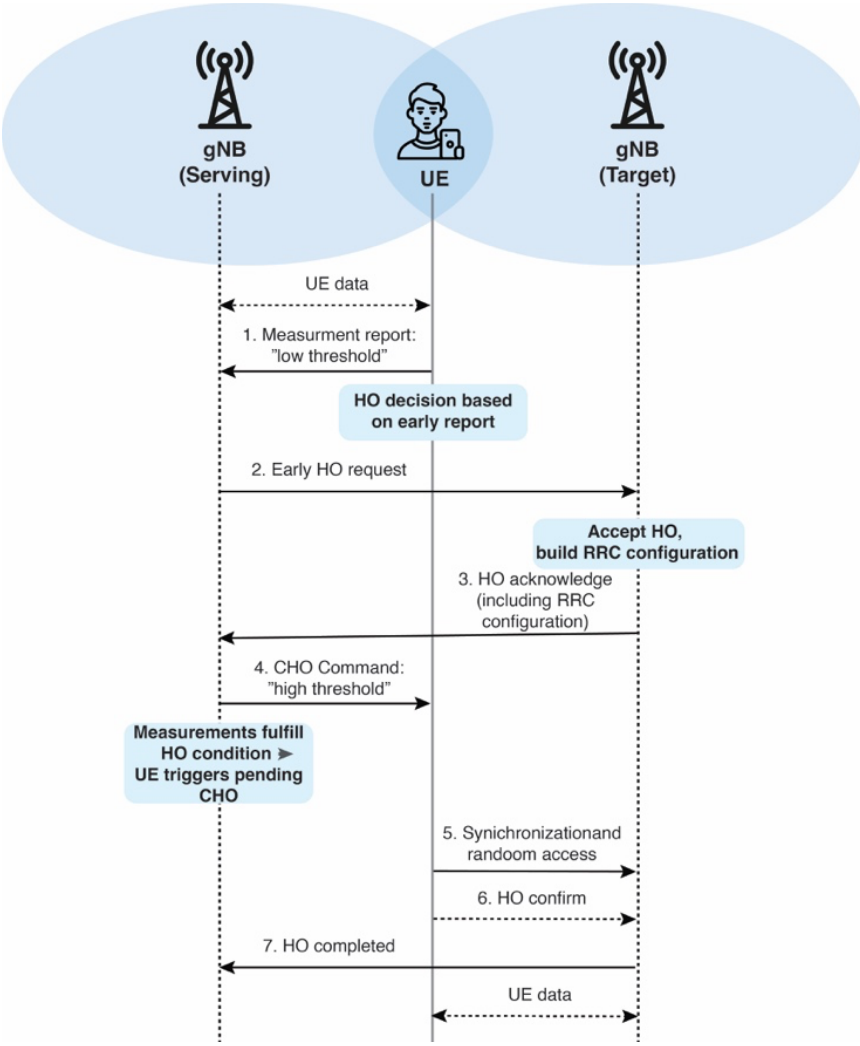


**FIGURE 6. CHO procedures.**

various scenarios. In line with the analysis and simulation outcomes, ZEUS potentially attains a '0' HOF rate without elevating the HOPP rate. Although both metrics assessed an HO algorithm following a tradeoff between them, the two metrics proved inadequate with CHO, which resolves the tradeoff. Hence, a novel integrated HO performance metric, Mobility-Aware Average Effective Spectral Efficiency (MASE), assessed the HO algorithm optimality. Following the simulation outcomes, ZEUS offered a higher MASE than LTE and other CHO variants. Figure 6 shows the CHO and stages of the CHO procedures [100].

### B. MACHINE LEARNING (ML) HO TECHNIQUES

ML is a collection of computation methods that emerged from powerful AI techniques that enable computers to self-learn, find patterns, and create models from past data without being explicitly programmed [101]. ML aims to find data collection characteristics likely to impact an outcome of interest given the input and then utilize those learned features to forecast the outcome in new circumstances [102].

By minimizing delays, computational overhead, and frequent HOs, ML techniques can significantly contribute to HO optimization and BS selection. These techniques aid in forecasting the target BS and ensuring enough resources are accessible at the target BS before HO to guarantee a smooth HO [46].

A detailed explanation of HO management in 5G systems, including a discussion on ML applications to HO management, was presented in [46]. A unique taxonomy was developed for the data source used in training ML algorithms, with two broad categories taken into account: (i) visual and (ii) network data. The current state-of-the-art in ML-aided HO management in cellular networks was thoroughly examined, including the latest studies, and the obstacles, and potential study areas, were discussed.

An example of utilizing ML is the study in [103] that proposed and explored an ML method for learning the best timing and location for HOs in 5G radio networks, as well as how to utilize the learned model to trigger HOs depending on forecasted radio circumstances. The entire solution was analyzed and compared to modern mobility methods to evaluate its efficacy in minimizing total system outages.

The following subsection discusses several important ML-based HO techniques promising to enhance HO management in mobile wireless networks, especially in future networks, B5G.

#### 1) DEEP LEARNING (DL)

DL HO technique is an important ML HO technique that improves the HO performance in the B5G networks [104]. DL can significantly help to improve the HO performance in the B5G system.

DL is anticipated to significantly improve mobility management in future networks by leveraging its ability to analyze vast amounts of data and generate effective mobility management models. This powerful AI technique will assist in developing intelligent algorithms capable of predicting user mobility patterns and adapting network resources accordingly. As a result, HO processes will be optimized, in which reducing latency and enhancing the Quality of Experience (QoE). Furthermore, DL-based HO optimization techniques will facilitate more efficient load balancing among cells and the seamless integration of HetNets, such as 5G/6G, Wi-Fi, Device-to-Device (D2D), satellite systems, etc.

In [105], the authors suggested a hybrid user mobility prediction method for HOM in mobile networks. User mobility patterns were first extracted with a mobility model using statistical models and DL algorithms. Users' future trajectories were forecasted with a Vector Autoregression (VAR) model and Gated Recurrent Unit (GRU). The number of unnecessary HO signaling messages was mitigated while the HO procedure was optimized with the derived prediction outcomes. The mobility data generated from actual users were employed in this experiment. All the simulations were conducted with an Intel core i7-6700k CPU using 4.00 GHz and 32 GB RAM (Random-Access Memory). Keras, a renowned Python library, was utilized for the simulations. Based on the simulation outcomes, the suggested VAR-GRU mobility model demonstrated minimal prediction error compared to current approaches. The HO processing and transmission costs were also examined for predictive and non-predictive scenarios. Resultantly, the HO-oriented expenditure significantly reduced post-network prediction. The processing and transmission costs in vertical HO improved by 57.14% and 28.01%, respectively.

#### 2) REINFORCEMENT LEARNING (RL)

Reinforcement is a subset of AI that can perform high HO performance [106]. It has shown its ability to provide robust HO algorithms in the B5G system.

The study in [107] recommended an autonomous mobility management control method to enhance UE mobility robustness and mitigate operational mobility management expenses. The proposed technique relies on RL to autonomously learn an optimal HO control policy through environmental interactions. The function approximation technique enabled RL for large-state and action-space processing. A linear function approximator was employed to approximate the state-action value function. Lastly, the semi-gradient state-action-reward-state-action (Sarsa) approach was updated to the approximated function and the optimal HO control policy was learned. The COST-Hata model simulated the LTE channel with the propagation models Urban Macro (UMa) and Urban Micro (UMi) from [108] incorporated for 5G channel simulation. Meanwhile, both AWGN (Additive White Gaussian Noise) and Rayleigh noise represented channel noise. Parallel to the simulation outcomes, the recommended approach could efficiently enhance UE mobility robustness of UE under varying ranges of speed and minimize unnecessary HOs and latency by approximately 20% and 58%, respectively, while attaining a near-0 HOF rate and increasing throughput by 12% compared to the conventional RSRP-based method.

In [109], the research suggested an HO scheme following a Jump Markov Linear System (JMLS), which accounts for abrupt system dynamic shifts, and Deep-RL (DRL), an AI approach to learning highly-dimensional and time-varying behaviors, to alleviate HO intricacies, maintain connectivity, and prevent unnecessary HO 5G mmWave mobile networks. Both methods were integrated to ascertain time-varying, abrupt, and incongruent shifts in mmWave link behavior by forecasting possible target link deterioration patterns. As this prediction was enhanced by meta-training methods which minimize training sample size, the JMLS-DRL platform formulated astute and flexible HO policies for 5G. The Dual Connectivity (DC) LTE mmWave model presented by New York University and the University of Padova was employed in the current study simulation [110]. The LTE BSs in the DC model managed mmWave BS. Reportedly, this HO scheme proved more reliable in target link selection compared to the Signal-to-Noise Ratio (SINR) and DRL-based HO schemes. The suggested scheme, which supports longer dew time between HOs and high sum rates by avoiding unnecessary HOs with almost half the HOs, could reduce wasteful HO to under 5% in 200 training episodes instead of the DRL-based HO counterpart, which required over 200 training episodes.

#### 3) Q-LEARNING

Q-Learning is an RL model-free algorithm that does not require an environment model, given the current state, to determine the next best action. It randomly selects this action and seeks to maximize the reward [111].

In B5G HO, the Q-Learning HO base technique is another type of AI HO technique that significantly improves the B5G HO performance, as several studies show.

The authors in [112] introduced a technique based on Q-Learning for LTE. The method selects the TTT and HOM values according to the best performance due to testing different values of HCPs. The method has been compared with other HO optimization algorithms from the literature to evaluate its performance in various scenario speeds. According to the results, the method effectively enhanced the HO optimization in several HO Key Performance Indicators (KPIs). Furthermore, the technique reduced the number of HO, increased the system throughput, and reduced the latency.

The authors in [113] proposed a novel Quality of QoE-aware Mobility Robustness Optimization (MRO) algorithm based on a multi-service scenario. In this study, optimization enhanced cell edge QoE while simultaneously elevating the successful HO probability throughout the network, unlike past methods that aimed to improve successful HO rates. Defined by the pair of HCPs (HOM and TTT), the HO trigger point was tuned per-adjacency basis in line with QoE and HOF assessments. Essentially, a performance assessment was conducted in an authentic LTE scenario, which was integrated with a dynamic LTE simulator embedded in MATLAB [114]. Resultantly, QoE-aware MRO simultaneously enhanced cell edge QoE throughout the network and the successful HO probability compared to conventional techniques.

In [115], an intelligent scheme based on the AHP-TOPSIS (Analytic Hierarchy Process-Technique For Order Of Preference By Similarity To Ideal Solution) method and Q-Learning approach is proposed for HO optimization. The proposed scheme is analyzed numerically and by simulation also, utilizing MATLAB. According to the results report, the method performs better in delay-sensitive and speed-sensitive applications. However, the method aims to improve the HO performance by reducing the HOF rate and HOPP effect in the LTE-A system caused by deploying ultra-densification and small eNBs. In addition, the method is applicable to work with the NG 5G networks. The results show that the method reduced the HOF rate and HOPP to 28% and 25%, respectively. The method outperforms the conventional method and Fuzzy Multiple-Criteria Cell Selection (FMCCS) scheme, with a reduction of 35% and 33% of HOF and HOPP, respectively.

#### 4) DATA-DRIVEN

The Data-Driven technique is another crucial HO technique that can improve HO performance.

In [116], the authors studied HO optimization in the NG networks. The study also introduced the HO optimization technique utilizing Data-Driven HO (DHO) to overcome the problem of HO management such as unnecessary HO, wrong HO, too-late HO, too-early HO, and HOPP effect. The DHO technique is composed of four main steps, which are: (a) identifying the mobility management issues, (b) designing HO KPIs, (c) estimating the HO KPI function, and (d) optimizing HCPs (TTT and HOM). To evaluate the system, the LTE-Sim was used considering LTE networks. The technique aimed to adjust the HCPs, including TTT and HOM. The simulation results showed that the DHO could reduce mobility management issues effectively.

The research in [117] developed a DHO optimization model for femtocells based on data gathered from the mobile communications network's measurement results to evaluate the association between the collected dataset features and KPIs represented as the weighted average of mobility problem ratios. The proposed DHO approach addressed mobility problems such as HO delay, early HO, erroneous target cell selection, and prevalent HO. Furthermore, KPI was improved by optimizing HO design parameters, such as TTT and HOM. The neural network multilayer perception method was used to estimate the KPI based on TTT and HOM design parameters. MATLAB was used to test and simulate the proposed model. According to the simulation findings, a KPI increase of 12 to 15.4% was achieved for 40 to 15 dBm transmission power. Following the positive results, the study concluded that the proposed DHO scheme could effectively address mobility issues.

The transmit power Tuning-Based HO Success Rate Improvement Scheme (TORIS), a new Data-Driven alternative to mitigate inter-frequency HOFs and inter-frequency HOF prediction in 5G, was introduced and assessed by [118]. Essentially, TORIS was developed through the establishment and combination of two sub-solutions. The first counterpart constitutes an AI-based model to forecast inter-frequency HOFs, which attained higher accuracy than its advanced counterparts by leveraging two techniques. A new feature set was initially created by manipulating the domain knowledge derived from in-depth drive test data evaluation. An extensive set of data augmentation approaches, such as the Chow-Liu Bayesian Network and generative adversarial network, were then exploited to resolve the class imbalance in HOF prediction model training. These approaches were further optimized with an emphasis on borderline sampling. Advanced AI model performance was also compared to predict HOFs with and without augmented data. SyntheticNET, an advanced 3GPP-compliant system-level simulator, was manipulated for the data generation [119]. This simulator was calibrated against actual network measurements for data validity. Consequently, AdaBoost demonstrated the most optimal performance for HOF prediction. The second counterpart involves a heuristic technique to tune the transmit power of serving and target BSs. Notably, TORIS focused on the primary causes of HOFs, such as low signal quality and propagation conditions, by proactively varying the TX power of the cells in anticipation of HOF, unlike the advanced HOF mitigation methods that Tune Cell Individual Offset (CIO). Overall, TORIS outperformed the advanced HOF reduction solution with a 40% to 75% reduction in HOFs.

Overall, the choice of HO management technique will depend on the specific application and requirements of the system, as well as the available data and computational resources. Essential comparisons for the different ML-based HO optimization methods are presented in Table VI.

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TABLE VI
COMPARISON OF THE DIFFERENT ML-BASED HO OPTIMIZATION TECHNIQUES

| Criterion | ML | DL | RL | Q-Learning | Data-Driven |
|---|---|---|---|---|---|
| Learning Method | Supervised/Unsupervised learning. | Neural networks, including deep architectures. | Agent-environment interaction, reward-based learning. | Special case of RL, learning by trial and error. | Analyzing and discovering patterns in existing data. |
| Complexity | Relatively low to medium. | High, due to multiple layers and complex architectures. | Medium to high, depending on the environment and learning algorithm. | Medium, depending on state and action space. | Varies based on the method used and dataset complexity. |
| Training Data | Labelled or unlabeled data. | Large amounts of labelled data. | Cumulative reward from the environment. | Q-value table or function approximator. | Large volumes of data, structured or unstructured |
| Computational Requirements | Relatively low to medium. | High, due to deep networks. | Medium to high, depending on the learning algorithm. | Medium, depending on state and action space. | Varies based on the method used and dataset complexity. |
| Applicability in HO | Analyzing HO patterns, prediction. | Complex pattern recognition, feature extraction. | Dynamic environment adaptation, optimal decision-making. | Adaptive control of the HO process. | Discovering hidden patterns, feature extraction, modeling HO behavior. |
| HO Optimization Use Case and Suitability | When a simple and fast model is required. Suitable for less complex networks | When there is a need to learn complex HO patterns. Suitable for more complex networks and large-scale applications. | When HO optimization needs to adapt to changing conditions. Suitable for highly dynamic networks. | When a discrete representation of HO optimization is sufficient. Suitable for smaller-scale network. | When large amounts of historical data are available. Suitable for networks with limited dynamics or when historical data is highly representative. |
| Adaptability to Changing Networks | Moderate, may require retraining. | Moderate to high, depending on the architecture. | High, can learn new policies as the environment changes. | High, adaptive learning based on Q-values. | Moderate, may require additional data analysis and updates. |
| Generalization & Robustness | Moderate, depending on the model. | High, due to deep architectures. | Moderate to high, depending on the learning algorithm. | Moderate, depends on state and action space representation. | Moderate, depends on data quality and model selection. |

### C. MULTI-CRITERIA DECISION SUPPORT

Multi-Criteria Decision-Making (MCDM) is a process used to evaluate and rank multiple alternatives based on multiple criteria or objectives. It helps decision-makers select the best option by considering different factors, often by assigning weights to each criterion and aggregating the scores [120]. In general, the MCDM method has two categories: (1) Multi-Objective Decision-Making (MODM) and (2) Multi-Attribute Decision-Making (MADM). Specifically, the first one manages continuous decision space, while the other deals with discrete decision space [121].

The study in [122] presented an entropy-based simple additive weighting decision-making method for multi-criteria HO in SDN-based 5G small cells to address the challenges highlighted earlier. The proposed HO method enabled the mobile node to connect with the best-suited eNB utilizing bandwidth, user density, and SINR characteristics. Furthermore, the method was contrasted with the traditional LTE HO and distributed approach considering latency, block ratio, HOF, and throughput based on the differing number of mobile users. Besides that, the HO scalability for both methods (dependent on the number of users) was also investigated. The simulation results showed that the proposed method improved HOL, blocking probability and throughput by 15%, 48%, and 22%, respectively, compared to conventional LTE HO.

In another study, [123] presented an intelligent mobility management system for HO optimization that was based on the Enhanced Multi-Objective Optimization Method by Ratio Analysis (E-MOORA) and Q-Learning technique. E-MOORA is a method that combines the modified entropy weighting approach with the Multi-Objective Optimization Method by Ratio Analysis (MOORA), which includes vector normalization. Furthermore, the E-MOORA method employed the performance parameters accordingly while selecting a HO target cell, reducing ranking abnormality. The Q-Learning technique was utilized to determine the best-triggering locations to mitigate the effect of frequent needless HOs while still satisfying user QoS requirements. When compared to other current MCDM methods, the performance analysis demonstrated a substantial enhancement concerning avoiding needless HO, Radio Link Failure (RLF), and user throughput.

### D. FUZZY LOGIC (FL)

FL is a variable processing technique that allows numerous values to be processed through the same variable and seeks to solve issues using an open, imprecise data spectrum and heuristics that allow for an array of accurate conclusions [124]. Furthermore, FL was created to solve problems by accounting for all accessible information and making the most feasible decision given the input. Recently, FL has become widely utilized in HO for 5G systems because it can significantly enhance HO performance in 5G systems, making this technique one of the best solutions for HO issues in 5G systems [125, 126].

Many studies have applied FL in their algorithms to develop HO techniques for 5G systems. For instance, [127] presented an FL-based method that utilized a user's speed and radio channel quality to self-optimize a HOM for HO decisions. The proposed algorithm's goal was to reduce the number of duplicate HOs and the HOF ratio while allowing users to reap the advantages of deploying dense small cells. The simulation results revealed that the proposed method effectively suppressed the HOPP effect and kept it at a minimal level (below 1%) in all circumstances studied. Furthermore, the HOF ratio and overall number of HOs were significantly reduced compared to previous schemes, particularly in cases with many small cells.

An auto-tuning optimization (ATO) method that adjusted the HOM and TTT based on the velocity of the UE and RSRP was presented in [128]. The proposed method mitigates the number of HOs and the HOF ratio. Simulations with a two-tier 4G and 5G systems model assessed the proposed algorithm's performances. Simulation results indicated that the proposed algorithm considerably decreased the average rates of HOPPs and HOF compared with other schemes in the state-of-the-art.

### E. PREDICTIVE HO

In mobile wireless networks, predicting the HO is a simple technique of efficiently allocating radio resources and increasing QoS. For instance, [129] presented a Line-of-Sight (LOS) blockage forecast tool for small and dense mmWave cellular networks that can eradicate needless HO and make essential HO smoother by accurately predicting the mmWave channel's LOS component blockage time and duration.

The study in [130] proposed a unique approach for choosing the best network from available networks to which a UE may be handed over to improve QoS performance. AHP acquired the aggregation of several criteria for calculating overall network ranking, which was coupled with the history of previously visited cells and regression analysis of Layer 1 (L1) and Layer 3 (L3) filtered RSS data for predicting future values. The AHP was used to determine the system properties' weights and rank the available networks based on numerous criteria MADM. Compared to the conventional AHP, the findings revealed that the developed algorithm decreased the number of HO and needless HO, as well as the threshold crossing rate and average fade time.

In another study, [131] introduced a unique algorithm based on the RSRP, RSRQ, and various UE parameters, such as movement direction and femtocell location, utilized as HO decision criteria. The proposed algorithm selected the most appropriate target femtocell from many candidates and eradicated redundant HO in femtocell-based cellular networks. MATLAB was utilized to assess the proposed network's performance in terms of user mobility in HO regions with success/failure HO Probability (HOP). The findings showed that the developed approach performed better than the usual procedure in predicting the best target femtocell AP for HO. The overall network's QoS was also improved due to a lower failure likelihood rate and nearly steady ping-pong impact.

### F. BLOCKCHAIN-BASED HO

Blockchain is one of the most recent revolution technologies that impacted life in different applications [132-134]. One of its famous applications nowadays is a cryptocurrency, such as Bitcoin [135]. It was created to allow Bitcoin users to execute safe financial transactions without using a go-between, such as a bank. Mobile service providers, corporations, telecom providers, government regulators, and infrastructure suppliers may all benefit from 5G's unique features, which can enable new business models and services that need uninterrupted interactions among numerous parties. Meanwhile, blockchain technology has emerged as a transformative, disruptive, and enabling technology that has begun to be used across various vertical industry sectors [136]. In addition, in 5G and B5G, blockchain (i) facilitates full-forward key separation for HO, (ii) provides some innate security features to complement HO security, and (iii) improves network performance for HO [137].

To enhance performance and security on 5G, the research in [137] evaluated the existing LTE system's key management system in the HO process for reference. This assessment enabled it to pinpoint the places that fundamentally threatened the efficiency and security of mobile communication. This study offered a solution to this problem by employing blockchain technology to boost throughput and security during the intra-HO phase of a 5G network. In addition to enhancing HO efficiency, PB-KDF (Parallel Blockchain Key Derivation Function) also fixes structural flaws to help 5G reach its maximum capacity. In 5G, PB-KDF with secure and quick HO would answer the large BSs densifying problem.

Similarly, [138] suggested using blockchain for key sharing and key generation to increase the security and efficiency of the HO process. A novel technique called the Blockchain Key Derivation Function (BKDF) allowed for increased protection and faster HO between the BSs. Due to the blockchain's additional element of protection, the network could securely produce the HO key and distribute it to BSs and mobile devices in the pre-HO stage, greatly decreasing the number of transactions required during the intra-HO phase. The simulation findings showed that BKDF improved network reliability, reduced intra-HO packet loss, and reduced HOL.

A summary of the different existing HO optimization techniques, from the literature, in terms of mobile systems, problems, solutions, used techniques, considered HO's KPIs, strengths and weaknesses is provided in Table VII. Additionally, Table VIII offers the strengths and weaknesses of the various HO optimization techniques in B5G.

TABLE VII
SUMMARY OF EXISTING WORKS IN HO OPTIMIZATION MANAGEMENT

| Ref. | Year | System | Problem | Solution | Technique | HO's KPIs | Strength | Weakness |
|---|---|---|---|---|---|---|---|---|
| [98] | 2020 | 5G/ mmWave | Undesired early HO preparations due to the weakness of the mmWave signal affect the CHO's robustness. | Develop a novel PCHO scheme. | CHO/ DL | Early preparation success rate, number of early preparations and total resource reservation time | High prediction accuracy. | Computational complexity due to using the DNN model. |
| [99] | 2022 | 5G | The problem of the accordance of HOF, which leads to an increase in the interruption time. | Introduce the "ZEro HOF with Unforced and automatic time-to-execute Scaling" (ZEUS) technique to optimize HO parameters easily in the CHO. | CHO/ | HOP, HOF, and HOPP | Decreasing the HOF as well as decreasing HOPP. | Further HO reliability is required. |
| [103] | 2021 | 5G | Minimize radio link failures while avoiding unnecessary HOs. | Propose an ML technique for learning the optimal time and destination for HOs. | ML | Outage | Simplicity. | No major HO KPIs (such as HOF, HOPP, etc.) are validated. |
| [105] | 2021 | Mobile Network | Problems of unnecessary HO affect the network capacity and increase the latency. | Develop VAR-the GRU mobility model, which is a hybrid user mobility prediction approach for HO management in mobile systems. | DL/ Prediction | Prediction error, HO processing cost and transmission cost | Predicts future user trajectory. | No HO's KPIs evaluated |
| [107] | 2021 | 5G UDN/ HetNets | The problem of frequent HOs and HOF is caused by small cells and HetNets. | Propose RL-based with tile coding function approximation. | RL | HO rate, HOF rate, Throughput, HOPP and HOL | Better convergence and high computational efficiency as compared to the completive approaches. | Conflict of the trade-off between HOF and HOPP. |
| [109] | 2022 | 5G/ mmWave | The problem of too early, too late, or wrong HOs is caused by utilizing mmWave, which is easily blocked. | Propose an HO scheme based on JMLS and DRL (JMLS–DRL). | DRL | Wasteful HO, and unnecessary HOs | Using fewer training episodes. | No main HO KPIs were validated. |
| [112] | 2018 | LTE | The problem of inappropriately adjusting HOM and TTT affects the HO performance. | Propose a Q-Learning optimization technique to learn the best TTT and HOM values. | Q-Learning | Throughput and number of HO. | Optimizing both HCPs (TTT and HOM). | Low HO robustness in complex network deployment scenarios. |
| [113] | 2021 | LTE | The problem of HOF impacts the QoS and QoE. | Propose a novel QoE-aware MRO algorithm considering a multi-service scenario. | Q-Learning | Too-late HO, too-early HO, successful HO, HOPP and QoE throughput. | Improve cell edge QoE while improving successful HOP. | Not suitable for applications that require extremely high throughput and ultra-reliable low-latency communications. |
| [115] | 2019 | LTE-A | The problem of optimizing the triggering time and selection of eNB impacts the QoS. | Develop a HO scheme based on the AHP-TOPSIS technique and Q-Learning. | AHP-TOPSIS Q-Learning | HOF and HOPP. | The technique provides more accuracy and low complexity. The method provides better performance for both delay-sensitive and speed-sensitive applications. | Needs further improvement in terms of energy computation. |
| [116] | 2016 | 4G | The problems of mobility management include too-late HO, too-early HO, HO to the wrong cell, HOPP and unnecessary HO that is caused due to the deployment of dense small cells and UDSCs. | Present a DHO optimization approach. | Data-Driven | Too-late HO, too-early HO, HO to the wrong cell, HOPP, and unnecessary HO. | Improves mobility performance by reducing mobility management problems, including too-early HO, too-late HO, HO to the wrong cell, unnecessary HO and HOPP. | Computational complexity. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| [117] | 2019 | Small Cells | The challenges of the HOL, early HO, wrong HO, and frequent HO that caused by the deployment of the dense cells or UDNs. | Propose a DHO optimization technique. | Data-Driven | HOL, early HO, wrong HO, and frequent HO. | Optimizes both HCPs, HOM and TTT. | Introduces additional latency in the HO decision-making process due to data processing and model training. |
| [118] | 2022 | 5G | The issues of the inter-frequency HOFs due to UDN. | Introduce a novel Data-Driven solution, which is referred to as TORIS. | Data-Driven | HOF. | Enhances the inter-frequency HO success rate by tuning the transmitter power using AI. | The approach omits the intra-frequency HOs and only focuses on inter-frequency HOs. |
| [122] | 2021 | SDN/ 5G Small Cell | The issues of HOF, HOPP, HOL and frequent HO that caused by the deployment of UDNs. | Introduce an Entropy-based simple additive weighting MCDM method HO in SDN based 5G small cells. | Multi-criteria HO | HO blocking probability, HOL, HOF and Throughput. | Provides better allocate resources within the network, improving network utilization and efficiency.<br>Uses several parameters to make the HO decision, which improves the HO optimization accuracy. | The HOF probability is still relatively high.<br>Computational Complexity. |
| [127] | 2018 | Dense Small-Cell Networks | A high number of HOs in dense small cell networks. | Self-optimization algorithm based on FL exploiting the velocity of the users and radio channel quality to adjust HOM. | FL | The number of HO, HOF, and HOPP. | It is simple and provides good HO decision-making accuracy. | The technique may suffer from computational complexity. |
| [128] | 2019 | 4G/5G HetNets | The increase in the number of HOs increases the HOPP effect and HOF due to deploying a large number of BSs. | Introduce a self-optimization method based on WFSO to adjust HOM and TTT. | FL | RLF, HOPP, and HOF. | Besides its simplicity, it offers better performance with different mobile speeds due to considering the speed as a system input. | Effaced to sensitivity to noise and interference due to considering only two parameters, speeds and RSRP. |
| [130] | 2020 | HetNets | HO Optimization in HetNets. | Present a HO algorithm that considers the history of visited cells for target selection combined with AHP. | Prediction-based/ AHP-MADM | The number of HO and HOL. | Improves the QoS performance by selecting the optimal network. | The technique may suffer from computational complexity due to combining multiple schemes. |
| [131] | 2019 | LTE/ Femtocells | The challenges of deploying a large number of femtocells which leads to an increase in the frequent initiation of an HO procedure. | Propose a novel HO algorithm utilizing RSRP, RSRQ and several UE parameters, such as moving direction and the position inside the femtocell. | Prediction-based | HOP, HOF, and number of successful HO. | The technique considers multiple parameters for the HO decision, including RSRP, RSRQ, cell capacity and bandwidth availability. | The algorithm was not compared with any other advanced HO optimization technique to show its robustness. |
| [137] | 2020 | 5G | The issues of the HOL and security in 5G network. | Introduce a novel approach to improve 5G experience by adopting blockchain. | Blockchain | HOL, Packet loss in the intra-HO phase. | Enhances the security and latency of the HO process. | Increases the computational complexity. |
| [138] | 2019 | LTE | The challenges of the HO process and security in LTE and Beyond networks. | Propose a method BKDF. | Blockchain | HOL, Packet loss in the intra-HO phase. | Improves the security of the HO process, as the technique utilizes blockchain technology. | Blockchain-based HO optimization techniques may consume more energy than traditional methods due to their computational intensity. |
| [139] | 2021 | DC | The issues of frequent HO,<br>HOL, and computational complexity in the DC. | Develop a DC-aided proactive HO and resource reservation scheme for mobile users requesting real-time service. | DC-aided | Outage probability, average network rate and average minimal rate. | Offers dynamically balanced network performance by reducing service outages and boosting throughput during heavy traffic while | The technique may suffer from interference management. |

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|---|---|---|---|---|---|---|---|---|
| | | | | | | | enhancing user fairness and minimizing outages during light traffic. | |
| [140] | 2021 | 5G/ mmWave | The weakness of the links caused by the high directivity and attenuation of mmWave signals causes frequent mmWave channel blockages, thus triggering excessive HOs. | Present a RIS-assisted HO technique by leveraging DRL. | RIS-assisted/ DRL | Prediction accuracy, number of HO and spectrum efficiency. | Reduces the HOP and achieves higher spectrum efficiency. | The technique may suffer from HOL and computational complexity. |
| [141] | 2017 | 5G/ UDN | The requirement of ubiquitous service and support the users in smart cities. | Introduce 5G converged cell-less communication networks. | Cell-less | Coverage probability and energy saving. | Reducing the HOP. | High complexity and security concerns. |

TABLE VIII
SUMMARY OF THE STRENGTHS AND WEAKNESSES OF THE DIFFERENT HO OPTIMIZATION TECHNIQUES

| Technique | Strengths | Weaknesses |
|---|---|---|
| CHO | • Simple to implement.<br>• Reduces the number of HOF. | • May not be suitable for complex scenarios.<br>• Undesired early preparations in the scenario of mmWave. |
| ML-Based HO | • Adapts to network changes.<br>• Continuously learns and improves.<br>• Can handle complex scenarios | • Requires a large dataset for training.<br>• May suffer from overfitting or model bias |
| Multi-Criteria Decision HO | • Considers multiple factors for HO decisions.<br>• Suitable for complex scenarios.<br>• Flexibility.<br>• Enhances the QoS. | • Higher computational complexity.<br>• HO decision-making overhead. |
| FL-Based HO | • Simple to implement.<br>• Handles uncertain and imprecise input information.<br>• Considers different factors for HO decisions.<br>• Can be combined with other techniques.<br>• Provides a more flexible HO decision-making process. | • Requires designing fuzzy rules and membership functions precisely.<br>• Higher computational complexity, in the case of a high number of rules and membership. |
| Predictive HO | • Simple to implement.<br>• Reduces HOL.<br>• Optimizes network resource utilization. | • Can be computationally intensive.<br>• May suffer from prediction errors.<br>• Complexity |
| Blockchain-Based HO | • Enhances security and privacy.<br>• Enhances reliability.<br>• Improves the user's experience. | • Scalability issues.<br>• Implementation complexity.<br>• Increases energy consumption. |

### G. OTHER POTENTIAL SOLUTION TECHNIQUES

In order to satisfy the requirement of the B5G network and address the issues that may occur because using the technologies, such as mmWave and THz communication, several techniques and technologies can play essential roles in improving the HO performance and QoS for the users.

The following subsections discuss several techniques that are considered potential techniques and solutions for HO management in the B5G system.

#### 1) DUAL CONNECTIVITY-AIDED (DC)

DC is a method that enables each user to connect to more than one BS at the same time [142], hence reducing HIT [143]. It has been demonstrated in [144, 145] that the HIT may be reduced to near zero using this approach.

Considering mobile consumers who demand real-time communication with minimal data rate demands, the authors in [139] developed a proactive mobility management system that uses DC to assist. A proactive HO strategy and a predictive resource reservation method comprise proactive mobility management. With the projected aggregate channel gains and the estimated list of linked BSs for each user, the predictive resource reservation method is improved to increase the transmission rate or user impartiality. By dividing cell-center and cell-edge users and selecting varying sets of linked BSs for the two classes of users, the proactive HO system attempts to prevent repeated and prolonged HOs and minimize the computing overhead. The suggested methodology undertakes better than reactive equivalents, according to simulation findings. It can substantially lower service interruptions while supporting a greater transmission rate when traffic volume is high, or it can enhance user fairness while causing fewer service interruptions when a traffic load is low.

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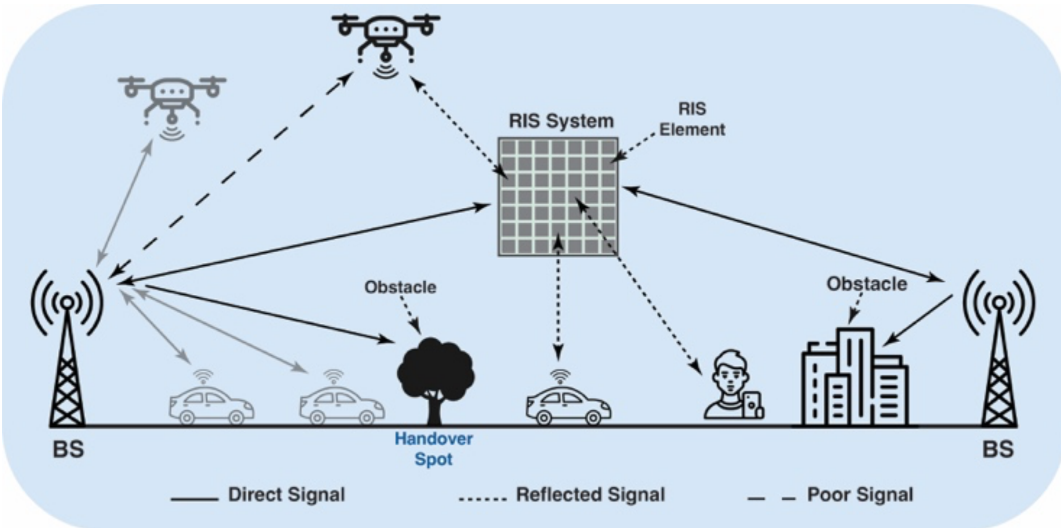


**FIGURE 7.** **RIS System.**

### 2) RIS-ASSISTED

RIS is a new concept in the wireless system which aims to extend the coverage over blockage areas [146]. RIS consists of a big surface area over a wall or a flat surface [147, 148]. It is constructed of many low-cost reflecting electronic components with programmable variables, such as traditional reflect-arrays and varactor diodes or micro-electrical-mechanical systems, the resonance frequency of which may be electrically adjusted. In HO management, using RIS has a great potential to cut down the blockages, thus minimizing the number of unnecessary HO. That is due to RIS strengthening the weak signals (mmWave or THz), which are being attenuated or blocked because of the Non-LOS (NLOS) transmission, obstacles and other environmental factors, such as rain and unclear space.

The study in [140] suggests a HO technique that uses RIS by utilizing DRL. By concurrently modifying beamformers and RIS phase shifts, the DRL agent can lower the accumulated HO costs under various channel occlusion circumstances. The RIS-assisted HO system dramatically decreases the number of HO and provides improved spectrum utilization compared to the previous systems without considering RIS. Additionally, the researcher suggests a simple technique to detect the blockage state to lessen the effects of the constrained views of the rapidly fading channels. The findings of this sensing can be used to enhance the effectiveness of model development. The efficacy of the DRL agent can be even more enhanced by integrating it with the blockage status sensing algorithm, according to numerical data.

Figure 7 demonstrates a HO scenario in the RIS system and how RIS may help to enhance the mobile cellular coverage and HO issues caused by the blockages and signal weakness.

### 3) HOLOGRAPHIC BEAMFORMING (HBF)

In general, Beamforming (BF) [149] is a method for transmitting and receiving antenna arrays using a focussed narrow beam with a very high gain. This is accomplished by focusing the power in a restricted angular range. In addition, BF enhances coverage and throughput while boosting the SINR, which may be utilized to monitor individuals. HBF [150] is a more sophisticated BF method that employs a Software-Defined Antenna (SDA). On the other hand, HBF tracks the user with a narrow coverage providing strong signals, thus will reduce the unnecessary HO, Ping-Pong effect, and HOF.

Figure 8 shows a scenario of HO in HBF and gNB BSs, the scenarios of the HO between the BSs, and how the HBF system serves each UE with a directive and narrow signal.

### 4) CELL-LESS NETWORK

The cell-less network is a promising technology that will be enabled in the B5G system. It provides seamless communication between various technologies, such as mmWave THz communication and Visible Light Communication (VLC) [151]. Moreover, in cell-less networks, the single UE can be automatically connected to any available radio network. In other words, cell-free targets avoid the HO issues, such as frequent HO, thus improving the user experience and QoS [152].

Contrary to the typical cellular network, the UE is not limited to establishing an association with a single standard BS or AP. The authors in [141] described a convergent cell-less communication network that utilizes collaborative communications to enhance the traditional HO. It can connect to several BSs or APs. This could be obtained by coordinated multipoint. Additionally, the SDN controllers are set up in 5G convergent cell-less communications systems to manage traffic and distribute resources. As a result, connectivity can

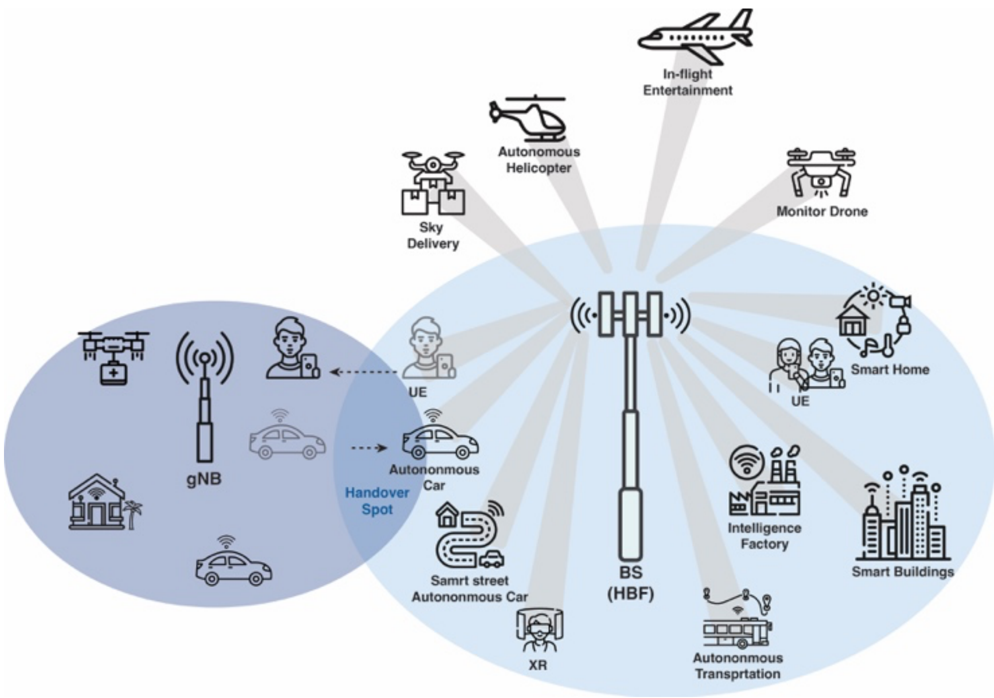


**FIGURE 8.** **HO in HBF and gNB BSs.**

be enhanced while reducing the delay brought on by the HO. The simulation findings also reveal that the suggested method increases the likelihood of coverage and both BS/AP and UE's energy usage. Table IX summarizes the impact of the potential techniques on HO optimization in B5G.

TABLE IX
IMPACT OF THE POTENTIAL TECHNOLOGIES ON HO OPTIMIZATION IN B5G

| Ref. | Technology | Impact on HO Optimization |
|---|---|---|
| [60, 139, 144, 145] | DC | Reduce: unnecessary HO, Reduce: HOPP effect, and HOF failure. |
| [140, 146] | RIS | Reduce unnecessary HO and HOF. |
| | HBF | Reduce HIT. |
| [141, 152, 153] | Cell-less network | Decrease: HO frequent, HOPP effect, HOF and HOL. |

## VI. CONCLUSION

HO management plays a significant role in mobile cellular systems, especially in 5G and forthcoming generations, B5G. Therefore, the researchers and developers must take substantial consideration in providing studies to improve the HO techniques to be suitable for the B5G system. Moreover, HO optimization is considered a crucial topic due to its importance in enabling the B5G network. Furthermore, this survey paper conducts extensive research on the challenges and solutions of HO management in B5G. It firstly presents background research for HO management for the current systems. Then it introduces the recent related studies. The survey also studies the HO optimization challenges facing implementing the B5G system. Besides, it discusses the most prominent HO optimization issues in the B5G network. Finally, candidate solutions of HO optimization techniques in B5G are provided. In the end, this survey paper will contribute to helping the researchers and developers interested in HO optimization in B5G technologies comprehend the HO optimization challenges and potential solutions, thus developing robust, seamless, and consistent HO techniques with B5G systems.

## APPENDIX

TABLE X
LIST OF ABBREVIATIONS IN ALPHABETICAL ORDER

| Acronym | Definition |
|---|---|
| 1G | First Generation |
| 2G | Second Generation |
| 3G | Third Generation |
| 3GPP | The 3rd Generation Partnership Project |
| 4G | Fourth Generation |
| 5G | Fifth Generation |
| 6G | Sixth Generation |
| AHP | Analytic Hierarchy Process |
| AI | Artificial Intelligence |
| AMF | Access And Mobility Management Function |
| AP | Access Point |
| ATO | Auto-Tuning Optimization |
| AWGN | Additive White Gaussian Noise |
| B5G | Beyond Fifth Generation |
| BBC | Break Before Connect |

| | |
|---|---|
| BCC | Break Before Connect |
| BF | Beamforming |
| BKDF | Blockchain Key Derivation Function |
| BS | Base Station |
| C-RAN | Cloud- Radio Access Network |
| CA | Carrier Aggregation |
| CBB | Connect Before Break |
| CDMA | Code-Division Multiple Access |
| Cf-MIMO | Cell-Free Multiple Input Multiple Output |
| CHO | Conditional Hanover |
| CIO | Cell Individual Offset |
| CO | Cooperative |
| CoMP | Coordinated Multiple Points |
| CPU | Central Processing Unit |
| CR | Cognitive Radio |
| CRE | Cell Range Extension |
| D2D | Device-to-Device |
| DC | Dual Connectivity |
| DHO | Data-Driven Handover |
| DL | Deep Learning |
| DMM | Distributed Mobility Management Train Relay Station |
| DRL | Deep Reinforcement Learning |
| E-MOORA | Enhanced Multi-Objective Optimization Method by Ratio Analysis |
| eNB | eNodeB |
| EPS | Evolved Packet System |
| FL | Fuzzy Logic |
| FMCCS | Fuzzy Multiple-Criteria Cell Selection |
| GB | Gigabyte |
| Gbps | GigaBit Per Second |
| GHz | Giga Hertz |
| gNB | gNodeB |
| GRU | Gated Recurrent Unit |
| HAPs | High-Altitude Platforms |
| HBF | Holographic Beamforming |
| HCPs | Handover Control Parameters |
| HeNB | Heterogenous Home-eNB |
| HetNets | Heterogenous Networks |
| HIT | Hanover Interruption Time |
| HO | Handover |
| HOF | Hanover Failure |
| HOL | Hanover Latency |
| HOM | Hanover Margin |
| HOPP | Hanover Ping-Pong |
| HSR | High-Speed Railway |
| IEEE | Institute of Electrical and Electronics Engineers |
| IETF | Internet Engineering Task Force |
| IHS | Information Handling Services |
| IP | Internet Protocol |
| ITU | International Telecommunication Union |
| JMLS | Jump Markov Linear System |
| Km/h | Kilo Metre Per Hour |
| KPI | Key Performance Indicator |
| LOS | Line-of-Sight |
| LTE | Long Term Evolution |
| LTE-A | Long Term Evolution-Advanced |
| MADM | Multi-Attribute Decision-Making |
| MASE | Mobility-Aware Average Effective Spectral Efficiency |
| MBS | |
| MCDM | Multi-Criteria Decision-Making |
| MIMO | Multiple Input Multiple Output |
| ML | Machine Learning |
| MLP | Multi-Level Perceptron |
| mMIMO | Massive Multiple-Input-Multiple-Output |
| mmWave | Millimeter Wave |
| MODM | Multi-Objective Decision-Making |
| MOORA | Multi-Objective Optimization Method by Ratio Analysis |
| MRO | Mobility Robustness Optimization |
| Multi-RAT | Multi-Radio Access Technology |
| NCO | Non-Cooperative |
| NG | Next-Generation |
| NG-RAN | Next-Generation Radio Access Network |
| NGSO | Non-Geostationary-Satellite Orbit |
| NLOS | Non-Line-of-Sight |
| NR | New Radio |
| NRN | Radio Access Network |
| NTN | Non-Terrestrial Network |
| PB-KDF | Parallel Blockchain Key Derivation Function) |
| PCHO | Prediction-Based CHO |
| QoE | Quality of Experience |
| QoS | Quality of Service |
| RACH | Random Access Channel |
| RAM | Random-Access Memory |
| RAN | Radio Access Network |
| RIS | Reconfiguration Intelligent Surface |
| RL | Reinforcement Learning |
| RLF | Radio Link Failure |
| RNC | Radio Network Controller |
| RRC | Radio Resource Control |
| RSRP | Reference Signal Received Power |
| RSRQ | Reference Signal Received Quality |
| RSS | Received Signal Strength |
| RX | Receiver |
| Sarsa | State-Action-Reward-State-Action |
| SCeNBs | Small Cells eNBs |
| SCNs | Small Cell Networks |
| SDA | Software-Defined Antenna |
| SDN | Software-Defined Networking |
| SINR | The Signal-to-Noise Ratio |
| SON | Self-Organizing Networks |
| TCP | Transmission Control Protocol |
| THz | Terahertz |
| TN | Terrestrial Network |

| | |
|---|---|
| TOPSIS | Technique For Order of Preference by Similarity to Ideal Solution |
| TORIS | Tuning-Based Handover Success Rate Improvement Scheme |
| TTT | Time-to-Trigger |
| TX | Transmitter |
| UAVs | Unmanned Aerial Vehicles |
| UDNs | Ultra-Dense Networks |
| UDSC | Ultra-Dense Small Cell Networks |
| UE | User Equipment |
| UMa | Urban Macro |
| UMi | Urban Micro |
| URLLC | Ultra-Low Latency Communication |
| VAR | Vector Autoregression |
| CF-mMIMO | Cell-Free Massive Multiple-Input-Multiple-Output |
| VLC | Visible Light Communication |
| WCDMA | Wideband Code Division Multiple Access |
| WLAN | Wireless Local Area Network |
| ZEUS | Zero HOF With Unforced and Automatic Time-to-Execute Scaling |

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