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Review

# Handover management over dual connectivity in 5G technology with future ultra-dense mobile heterogeneous networks: A review

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A B S T R A C T

Supporting seamless connection through user mobility is a critical challenge that must be addressed in mobile Heterogeneous Networks (HetNets). The case will become more worse in the future Ultra-Dense HetNets with the deployments of Fifth Generation (5G) and beyond mobile networks. That due to various key important factors, these factors include the use of Millimetre Waves (mmWaves), the massive growth of connected mobile equipment, overlapping network deployments, implementation of Dual Connectivity (DC), Carrier Aggregation (CA), emergence of connected drones, the massive deployment of small cells and the required for supporting high mobility speed scenarios. Consequently, this paper provides a comprehensive review of handover management in future mobile Ultra-Dense HetNets. Different mobility and handover management techniques are discussed to highlight their contribution in providing seamless connection during user mobility. Several key challenges, opportunities and prospective solutions are also examined to pinpoint key issues and determine suitable solutions that may contribute to solving mobility problems in future mobile networks. Conclusively, background studies and practical solutions are presented and discussed for future research directions.



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## 1. Introduction

The exceptional growth in the number of mobile devices and advanced applications has caused an upsurge in data traffic massively [1]. According to an Ericsson report published in June 2020, the number of mobile subscribers will reach up to 9 billion by 2025, and 88 percent of total subscribers will use mobile broadband connections [2]. Billions of other mobile devices and home appliances will also be connected to the internet. As a result, the demand for mobile data will increase a 1000 fold over the next five years [3]. For that, the spectrum gap will further rise, leading to the necessary need for opening and utilizing new spectrum bands [4,5].

Consequently, the 5G mobile technology has been introduced to increase system capacity and provide ubiquitous connectivity. Therefore, Millimetre Wave (mmWave) bands has been proposed as the most suitable and effective solution for 5G and beyond mobile networks [6–8]. This is due to the wider size of bandwidth produced by today's consumers, all parts of mobile networks must undergo a paradigm change. The Ultra-Dense Network (UDN) is one of the racetrack's major concepts. UDNs are networks with more cells than active users. In other words, the access point density is greater than the user density. This will mainly contribute to higher throughput, enhanced energy efficiency, ubiquitous connection, reduced coverage gaps in indoor and outdoor environments and enhanced Quality of Service (QoS). The deployed small cells of HetNets will connect home appliances to the internet. The Non-Standalone Access (NSA) mode of 5G and 6G will allow Dual Connectivity (DC), which operates on the New Radio (NR) and 4G Evolved Packet Core (EPC), to simultaneously access various technologies. Although the implementation of these new technology will come with several advantages, the ultra-dense HetNet is anticipated to encounter various issues that must be addressed. These challenges occur due to the emergence of new technological solutions and massive growth of mobile connections. This includes the use of mmWave, the vast growth of connected mobile equipment, the deployment of massive small cells, overlapping network deployments, implementation of DC and the emergence of connected drones [9].

The challenge of seamless handover increases after the implementation of HetNets. Handover is a switching technique that ensures seamless mobility between cells in mobile cellular networks. It is a process that enables a mobile device to switch its connection from one cell to another, and the data offloads in such a way that no interruption occurs in the ideal case. Handover decision is a critical part of mobility management in mobile networks. In future HetNet generations, the handover will drastically affect the system's performance due to the frequent switching from one cell to another. For instance, if the number of handovers between small cells increases, the overall throughput achieved by the 5G and beyond mobile networks will proportionally diminish [10]. Numerous studies have been conducted to propose several handover techniques in the literature that minimise frequent handovers, ping-pong effects, rate of handover failures, handover time, handover disruption and energy consumption.

The use of the mmWave in 5G and beyond mobile networks creates a severe problem which intensifies the handover issue. Part of the best candidate spectrum bands to be used for 5G systems are between 24 and 84 GHz, and may go up to 100 GHz for the next generation technologies [11]. Employing such spectrum bands comes with several limitations: they significantly suffer from higher path-loss and cannot penetrate walls or any other obstacles due to their short wavelength [12,13]. This will cause an increased handover rate, which may subsequently lead to a higher probability of handover failure, handover ping-pong, unnecessary handover, and interruption time and throughput degradation..

The massive growth of mobile connections is another expected challenge for future mobile networks. The number of connected mobile devices is exponentially growing. The number of IoT devices are also massively increasing. After the inclusion of numerous mobile devices, the network will require higher bandwidth and ubiquitous connection [14][1]. Various types of small cells are therefore proposed to operate in future mobile networks to enhance connection and minimise coverage gaps. The deployment of different types of cells working together collectively forms the HetNet, thereby enhancing the throughput of the overall system. However, deploying a massive number of small cells in future mobile HetNets will cause various problems such as Co-Channel Interference (CCI), frequent handovers, more unnecessary handover, higher Radio Link Failure (RLF) and backhaul provisioning due to the short coverage area and inter-cell interactions [15–18].

A big concern of the 5G and beyond mobile networks is the overlapping deployment of different network types. The computational complexity will increase when a mobile device is frequently switching from one cell to another, or from one network to another. Similarly, the use of different technology such as NR, Massive Multiple Input Multiple Output (MIMO), Cognitive Radio (CR), Carrier Aggregation (CA), etc., will also increase the complexity of future mobile networks. For instance, the CA is a key technology that simultaneously uses two or more carriers to enhance system capacity in mobile networks. However, it will also cause serious handover issues when a mobile device switches from one cell to another and from one Component Carrier (CC) to another in order to switch the primary CC [19]. This problem will further increase when frequent handovers among small cells are present.

The emergence of connected drones is an enormous progress in the development of 5G and beyond cellular networks. Connected drones can be used on-demand and in selected areas to increase mobile network coverage [20]. They can also act as access points in the air to provide wireless services. However, complexity of handover process will multiply due to the frequent switching among different access points.

The 3GPP presents a novel idea of DC in its Release-15 [21]. DC enables a mobile device to simultaneously connect with two cells. According to 3GPP specifications, a cell node is known as the evolved Node Base Station (eNB). During a DC process, the main macrocell is considered as the Master eNB (MeNB), while the small cell is registered as the Secondary eNB (SeNB) [22]. The DC enables the 5G NR to operate along with the LTE-A EPC system. The Multi-Radio Dual Connectivity (MR-DC) enables DC via two different Radio Access Technologies (RAT). The SeNB operates using the NR 5G access technology, while the MeNB uses the Evolved Universal Terrestrial Radio Access Network (E-UTRAN) technology. The two eNBs are generally connected via a non-ideal backhaul. They also operate in this case with two independent schedulers [23,24]. DC is a promising approach that enables a mobile device to simultaneously connect to both the macrocell and small cell by using two different RATs. This approach can enhance the overall throughput and spectral efficiency of the future HetNet. However, handover through DC is a serious challenge in 5G HetNets. It required to be addressed on the prior basis.

Adequate and highly efficient handover management techniques are vital to reduce complexity and mobility issues of future mobile HetNets. Several techniques and algorithms have been developed throughout the literature to address these problems. In [25], an arm-elimination based algorithm was proposed to resolve frequent handovers and ping-pong effects in HetNets. The authors simplified the proposed algorithm and analysed the performance in the case of delayed feedback. A Grey Relational Analysis (GRA) based handover technique was recommended in [26]. The analytical hierarchy process technique and the GRA method were combined to rank the available cells for the best handover target. A novel protocol for DC was also implemented in [27]. It enables a user to simultaneously connect to both the 4G and 5G wireless networks. All mentioned articles discuss either the handover techniques or DC strategies. Several potential ideas have been presented in the literature for the development of 5G and 6G HetNets. Different handovers and offloading techniques were also identified in order to improve the capacity, speed, spectral efficiency and energy efficiency of the 5G HetNet. The concept of DC, functions and challenges have also been presented. A need to examine handover and mobility management strategies over DC in future mobile HetNets still remains to be accomplished.

In this paper, different handover management algorithms and mobility management techniques for DC are investigated and studied. Briefly, the key contributions are as follows:

1. A comprehensive review is accomplished to explain the main concepts of the handover technique over DC in future ultra-dense mobile HetNets.
2. Different handover approaches are discussed, highlighting the essential aspects of future handover possibilities over DC in LTE-A, 5G and 6G mobile networks.
3. The Machine Learning (ML) based approaches and other developed strategies to solve mobility issues are examined.
4. Several expected challenges and solutions are presented and discussed for future research directions.

The rest of the article is organised as follows: Section II presents the background and preliminary concepts used in future mobile cellular networks. Section III describes the concept of DC in LTE-A and 5G core networks. Section IV highlights the challenges of future mobile HetNets. Section V presents the primary solutions from the literature review. Section VI focuses on future research directions concerning handover for next-generation wireless and beyond HetNets. Section VII summarises and concludes the paper.

## 2. Background and preliminary concepts

Various designs, techniques and technology have been recently developed to satisfy subscribers' increasing data demands for next-generation wireless networks. The key concepts include reduced cell sizes and the use of new frequencies [28]. Small cells and mmWaves are introduced to provide better coverage and higher throughput for indoor and outdoor users. The main concepts are defined in the following subsections.

### *2.1. Heterogeneous networks (HetNets)*

The term HetNet refers to a wireless network connected with various types and sizes of small cells and macrocells deployed to overlap each other. HetNets have gained much attention due to better coverage, higher throughput, improved energy efficiency and greater QoS. HetNet is considered to be an essential building block for future mobile network generations. In HetNets, small cells can be deployed at homes, offices, large shopping malls, sport stadiums, airports and other crowded areas [29,30]. These small cells consist of various types such as microcells, picocells, femtocells, etc. The network deployment plan will be an ultra-dense HetNet for the future 5G mobile communication system so as to meet high data and coverage demands.

The 5G mobile network has been launched in a few countries, changing the paradigm of cellular and wireless communication systems. The telecommunication industry always strives to improve its infrastructure to meet data traffic demands. The proposed idea is to provide wider bandwidth for the 5G mobile network, which is only possible with the use of the mmWave bands. This will lead to the deployment of multiple small cells along with macrocells for future HetNets. In 2010, the 3GPP upgraded the LTE to LTE-A and suggested the deployment of small cells underneath a macrocell in its Release-12 [31]. Developments will remain ongoing until the latest Release-17. The additional network infrastructure helps increase cellular network capacity [32]. However, some studies noted that such deployment is bound to face interference problems [33]. New cell deployment is also not cost-effective from the operator's perspective. The needed power, rental property, deployment and maintenance costs may further increase.

IoT promotes the concept that everyone and everything should be connected to the internet. This will transform our lives since smart devices will be employed everywhere, such as in homes, cities, vehicles, offices, etc. This will reduce human effort and save time. To successfully implement IoT technology, operators must provide uninterrupted internet service at all places and at all times. Small cells (such as femtocells) can play a crucial role in providing internet services, especially for indoor environments. This can mainly be achieved by employing the mmWave radio frequency. Developing an ultra-dense HetNet is an essential part of the 5G wireless network which completes the Third Generation Partnership Project (3GPP) requirements [34,35].

The typical mobile cellular communication system consists of a homogeneous network architecture where only macrocells are used to provide services to all UEs in a cellular network. In such a network, all macrocells apply almost identical transmit power, antenna patterns, Radio Access Network (RAN), modulation technique, Signal to Noise Ratio (SNR) and EPC to serve UEs across all cells [36]. Unfortunately, the typical homogeneous network will not sufficiently cover all areas, especially cell-edges, and is unable to meet the demanded data traffic of the 5G networking system.

Another suggested approach to solve this problem is to split the cells. However, this implementation will be expensive and unsuitable since numerous macrocells must be deployed within a small region [37]. Therefore, evolving LTE-A systems are adopting a more efficient and cost-effective approach by using a hierarchical cell deployment model. According to 3GPP specifications, different cell sizes can be deployed over macrocells. This type of multi-cell network architecture is called a HetNet system. Fig. 1 presents the LTE-A HetNet architecture, which consists of a combination of macrocells and small cells. The small cells are further explained in the next subsection.

The implementation of the HetNet architecture is useful for both operators and subscribers. The main reason is that this approach increases the coverage area and also improves the overall network performance in terms of throughput, spectral efficiency, cell edge performance as well as connection reliability and stability. Deploying small cells is also easy to set up and very cost-effective [38].

### *2.2. Small cells*

Mobile cellular networks play a crucial role when it comes to achieving high data rates. However, network operators are encountering several significant challenges. One such challenge is to provide full coverage, especially in dense cities with numerous tall buildings. Another challenge is the continuous and dramatic increase in data traffic demands. To overcome this problem, the size of macro cells must be reduced [39]. Unfortunately, this approach is not economical and requires massive investments. Small cells with different specifications and system settings have therefore been introduced in 4G networks to solve this issue. The use of mmWave has been proposed for 5G and 6G networks, leading to the deployment of small cells due to the high path loss characterisation of these bands.

Small cells are usually low-powered, have easy to plug-in access nodes typically designed to extend coverage, can increase capacity and further enhance spectral efficiency of wireless cellular networks [40]. Different types of small cells are deployed within a single macrocell, as shown in Fig. 2. Small cells can be situated either inside or outside of buildings. They use licensed, shared or unlicensed spectrum bands. Their coverage can range from 10 m to a few hundred metres. Small cells can be connected to the core mobile network via the Digital Subscriber Line (DSL), Fibre Link or other Microwave Link connections. They can provide broadband coverage for both indoor and outdoor subscribers. They are also seen as traffic off-loading spots in RAN to decrease congestion in macrocells and enhance users' QoS experience [41]. The typical small cells are listed as follows:

1. **Femtocell:** The femtocell is the smallest type of small cell with a radius coverage of 10 to 30 m. It can be used for homes, offices, shopping malls and subways [42]. A femtocell can be installed for scenarios where a person needs high speed broadband but cannot make phone calls within his/her indoor environment. It also provides high speed broadband connection to satisfy user demands and help the network operator reduce the burden from the traditional cellular network [43].
2. **Picocells:** The picocell covers a radius of about 20 to 200 m [44]. They are usually deployed at crowded places or venues for special occasions such as celebrations, arenas, concerts and other large gatherings. The network operators install picocells to provide better and extended coverage to end-users.
3. **Microcells:** Microcells are also small cells, but they cover more than two kilometres of area [45]. Microcells are usually deployed in remote locations such as suburban and small towns. They provide high data rates and improve the service at blind spots caused by line-of-sight problems.

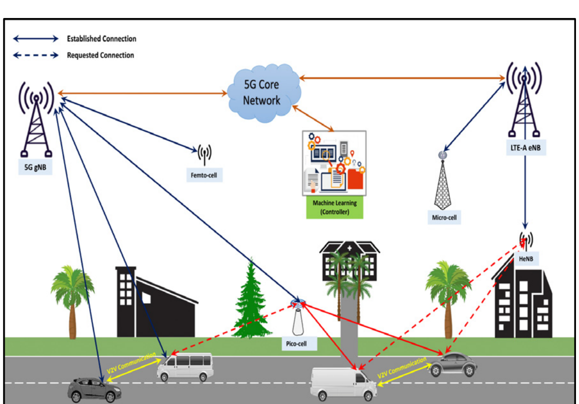


**Fig. 1.** The 5G technology and Heterogeneous Network (HetNet) architecture.

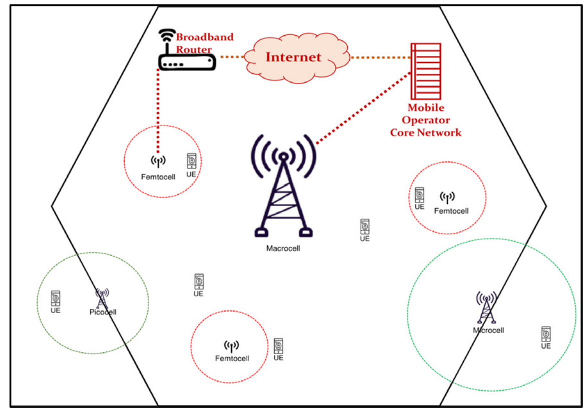


**Fig. 2.** Variety of Small Cells and deployment scenarios overlapping with Macrocell.

The deployment of small cells over macrocells is called HetNet, which is more scalable and useful for both operators and users. Due to better indoor broadband wireless coverage, the system capacity will be enhanced in a cost-effective way [46].

### *2.3. Internet of things (IoT)*

The IoT is a forthcoming technology which will be widely deployed in 5G mobile networks. The IoT concept is to interconnect all devices such as home appliances, vehicles, cameras, traffic signals and other applications [47]. To connect these devices, wireless communication plays a significant role. Due to the development of new technology and increased internet speed, millions of devices can be connected to enable interchangeable communication [48].

The main principle that stands behind the IoT ideology is connectivity. Unlike traditional internet connectivity that requires human surveillance and intervention, IoT can utilise the internet without human intervention. It can globally connect all devices to guarantee compatibility, impeccable inclusion and distinct system management of the IoT elements [49].

For better performance of the core principles of IoT networks and their applications, it is crucial to have thorough knowledge of their entities, peculiar attributes and unique properties accompanied by their validation. With the vast development of IoT's constituent domains, such as wireless sensor networks and data processing, IoT must take giant leaps to keep up with progress in revolutionising human life. By using the latest improvements in technology, IoT attempts to facilitate solutions to the biggest challenges anticipated in the next-generation wireless HetNet.

### 2.4. 5G New Radio (NR)

In 2015, the 3GPP began studying a new RAT. The NR was proposed and adopted as the new global standard for air interface. In 2017, 3GPP announced the standard specifications of NR in their Release-15 [50]. This was considered to be the new radio air interface for the 5G mobile network. Technical support was also provided in the next release of 3GPP. Two different frequency bands are used in the 5G mobile network.

1. Frequency Range-1 (FR-1): includes the frequency band ranges of 410 MHz to 7125 MHz.
2. Frequency Range-2 (FR-2): includes the frequency bands in mmWave ranges of 24 to 100 GHz.

5G NR supports subcarrier spacings ranging from 15 KHz to 240 KHz and has a total of 3300 subcarriers that can be simultaneously employed by a single channel. However, the total range of all channels cannot be wider than 400 MHz. It is important to note that the standard NR frequency can be alternatively used. This means that none of the subcarriers can be identified for any particular sub-band. The frequency bands within 6 GHz are specifically marked by different channels and noise characteristics. Thus, higher bandwidths employ higher frequency bands ranging between 15 KHz and 60 KHz. Currently, the NR frequency bands used by the 5G mobile network are below 24 GHz.

The 5G mobile network also supports flexible NR frequency bands. The approach allows the mobile equipment to switch from a lower to a higher frequency band, and vice versa when necessary. The approach can thereby achieve greater performance in IoT-based mobile networks since IoT devices usually use little energy when a small amount of data is transmitted.

### 2.5. Mobility management in 5G HetNets

Mobility management is the most researched topic in recent years. Innovative and enhanced techniques are still required to enable mobility for upcoming technology. Due to the ultra-dense HetNet, the 5G architecture requires additional mobility management provisions to ensure seamless mobility. Various technology will merge to meet the increasing demands for higher data rates in the 5G wireless network. Therefore, efficient mobility management solutions are required to ensure seamless and secure mobility in the 5G HetNet [51,52].

Several mobility management studies were conducted, suggesting many useful techniques. A widely adopted mobility method is the Centralised Mobility Management (CMM), mentioned in [53]. According to the CMM method, a centralised node acts as an anchor node and retains information, such as the Internet Protocol (IP) address, of existing and new nodes. During the mobility process, the packets are also routed via the anchor node. This method can be helpful in 4G LTE and LTE-A cellular networks, but it may pose some serious issues in the ultra-dense 5G HetNet. The number of switching may increase in the 5G HetNet due to the size of the small cells, causing extra and unnecessary mobility requests [54].

A Distributed Mobility Management (DMM) has been introduced in [55] to fix the previous CMM issue. In the DMM strategy, the role of the anchor node is enhanced to efficiently perform the UE mobility. The nearest spot acts as an anchor node in the IP-based mobility management system and controls the mobility process. Although the DMM reduces the handover delay, the unnecessary control message signals undermine the performance of the 5G wireless network.

### 2.6. Handover decision procedures in 5G HetNet

In wireless cellular communication, a handover is a vital concept where the UE can move from one cell to another without dropping the session. The efficient switching of UEs between cells is a crucial element of the handover process. Therefore, handover plays a vital role in the development of the 5G HetNet. It keeps the UE connected to the network while moving from one cell to another. It also maintains signal strength, load balance, cost efficiency and energy consumption efficiency.

The two main handover types are Hard Handover and Soft Handover. In the Hard Handover process, the UE connection to an existing cell terminates while connecting to a new cell without any delays. This is also called a break-before-connect mechanism. In the Soft Handover process, a new connection is established before the existing connection is terminated [56]. This is sometimes referred to as the connect-before-break approach.

Another two handover types are Horizontal Handover (HHO) and Vertical Handover (VHO). During the HHO process, a UE switches within the same network [57]. The VHO presents seamless UE mobility between distinctive networks [58]. The VHO has become crucial in 5G and beyond wireless networks due to the implementation of new technology.

Innovative technology such as HetNet, NR, Machine to Machine (M2M) communication and smart drones are ready to join the 5G wireless network. The increasing demand for high data rates can be fulfilled by employing the latest technology [59]. Nevertheless, frequent handovers and ping-pong effects remain to be critical challenges in the development of HetNets. Such issues can severely degrade the performance of the wireless networking system [60]. Therefore, it is essential to proactively address and establish proper handover and mobility management techniques.

Several essential handover techniques have been extracted from the literature review. A VHO based method was proposed in [61] which uses a dynamic power control mechanism to consume less power for data transmission. Wang et al. in [62] also suggested an efficient VHO scheme. Their technique was formulated using a Markov Decision Process (MDP) where VHO is performed after checking the queue length and channel condition.

Similarly, Chen et al. [63] presented a QoE-Aware Intelligent VHO scheme designed to satisfy the required QoS to a wide range of applications while allowing seamless handover in the 5G HetNet. A novel handover decision algorithm was introduced in [64] to reduce the handover failure and ping-pong effect in the ultra-dense 5G HetNet. The authors implemented a fuzzy logic system with a dynamic determination of the hysteresis margin. The results indicate that the novel scheme works better than existing schemes.

In [65–69], several algorithms were proposed to minimise the RLF, call drops and ping-pong effect. A fuzzy logic cells selection method was presented in [70]. The proposed method executes a handover process after checking the UE uplink conditions, resource block utilisation and selection criteria measurements. This method minimises the ping-pong effect and handover failure, thereby achieving higher capacity.

### 2.7. Enhanced Inter-Cell Interference Coordination (eICIC)

Utilizing Enhanced Inter-Cell Interference Coordination (eICIC) is another approach to improve network efficiency and user data rates. As a result, Inter-Cell Interference (ICI) induced by many cells' concurrent use of the same spectrum presents significant challenges. ICI degrades system throughput and network capacity, impairing cell-edge users' experiences and overall system performance. As a result, improved interference coordination solutions, particularly for user-to-cell association and resource allocation, are necessary to limit ICI's severe impact on system performance in 5G HetNets. This is to enhance QoS and increase system throughput due to the deployment of small cell overlays on macro base stations in heterogeneous cellular networks, which results in traffic load imbalance owing to the varied transmit power of various base stations in the downlink. Cell selection is a critical problem to address in the HetNet topology. The Reference Signal Received Quality (RSRQ) and the Reference Signal Received Power (RSRP) are two widely utilized cell selection strategies in LTE-A and 5G mobile networks. The comparison in the LTE-A HetNet cell selection strategy is based on movement to interference and noise ratio to RSRP and RSRQ. Cell selection using RSRP is not optimal since it takes into account the received power from each cell and does not consider the channel quality of the corresponding resources. As a result, SINR is a more appropriate requirement for downlink performance to obtain high throughput. To mitigate coverage imbalances caused by power transmission variances across two-tier networks, the Cell Range Extension (CRE) offset value is utilized. The Signal to Interference plus Noise Radio (SINR) value for each cell is determined in [71], and the cell that best serves is chosen.

$$\mathrm{I} = \arg\max\{\gamma_{\mathrm{m}}, \gamma_{\mathrm{P}} + \mathrm{CRE}\}$$

If $\gamma_m > \gamma_P + CRE$, macrocell is assigned to serve. Otherwise, smallcell is chosen as a serving cell.

## 3. 5G Dual Connectivity (DC)

DC is an innovative technique that can meet the increasing demands for high data rates in the 5G ultra-dense HetNet system. It is also the most potential technology in the development of the 5G HetNet. The progress of the 5G network is highly dependent on reliable LTE-A core EPS and NR technology. NR frequencies are expected to be implemented in the 5G network to achieve higher throughput. The current bandwidths are unable to satisfy the increasing demand for data traffic. As a result, NR can be used in the 5G mobile network to recognise the requirements of the enhanced Mobile Broadband (eMBB) traffic.

The ultra-dense deployment of small cells in the 5G HetNet creates a notable challenge, such as CCI. This occurs when two eNBs, the macrocell and small cell, operate through the same channel [72]. 3GPP presented a new concept of DC to resolve CCI challenges and increase the overall throughput of the cellular system. According to the definition of DC, a UE can simultaneously connect to two eNBs and use different access technologies [73]. The 3GPP explains various DC architectures in its Release-15, and for implementation in the 5G HetNet. The main architectures include the Standalone and Non-Standalone designs. These architectures are highlighted in the following subsections. However, this article mainly focuses on the non-Standalone architecture. In the 5G HetNet, a UE can simultaneously connect to the 5G NR access technology and the 4G LTE-A EPC. This technology is known as E-UTRAN-NR Dual Connectivity (EN-DC) [74]. The advantages of using DC include attaining higher data rates, improving reliability, increasing spectral efficiency, as well as achieving better load-balancing and compatibility with the 4G LTE-A infrastructure. The only disadvantage of using DC in the 5G HetNet is the drastic increase in the RF signal complexity. Fig. 3 presents the general application of DC. Three different scenarios are provided in the figure. In Scenario-1, the UE is only served by the macrocell since no available small cell is nearby. Scenario-2 is the perfect example of DC since the HetNet system provides double data flow to the UE. The UE is simultaneously connected to the macrocell and small cell to achieve peak data rates. However, different frequency bands will be used by both macrocells and small cells. Scenario-3 shows that UE is only served by the small cell since it is not within range of the macrocell. It is easy to see that DC is the best option to achieve higher throughput and better spectral efficiency.

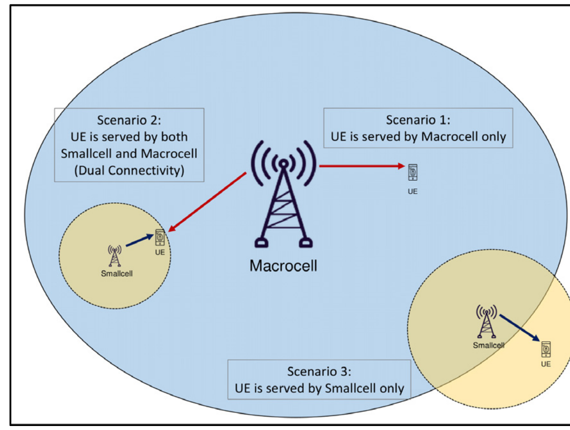


**Fig. 3.** A general concept of DC technology in the 5G HetNet.

### 3.1. 5G Non-Standalone Access architecture

Although the 3GPP's Release-15 presented different designs for the development of the 5G networking system, the most appropriate is the NSA architecture. The principal idea is to launch the 5G wireless network along with the existing 4G LTE system. The shift to 5G can be accelerated by enabling the 5G bearers in the present 4G-LTE infrastructure. The main feature of the NSA architecture is the extended form of DC, that is, EN-DC [75]. The EN-DC enables the eNB of 4G LTE-A as MeNB and the next generation Node Base Station (gNB) as Secondary gNB (SgNB) to simultaneously serve the UE and share the workload between them. The use of EN-DC is appropriate in the 5G HetNet because the MeNB operates on LTE-A EPC infrastructure, while the SgNBs can utilise NR of the 5G RAN channel.

Fig. 4 explains the potential configuration of the under-lying NSA architecture suggested for EN-DC in the 5G HetNet. The UE can be connected to an S-GW through four different configuration setups.

1. Master Cell Group (MCG) Bearer: In this configuration, information is sent to MeNB from S-GW where MeNB directly forwards the information to the UE. DC cannot be implemented since the Secondary SgNB is not involved in this process.
2. MCG Split Bearer: Bearer splitting occurs at MeNB in the MCG splitting bearer configuration. The data traffic stream is not only

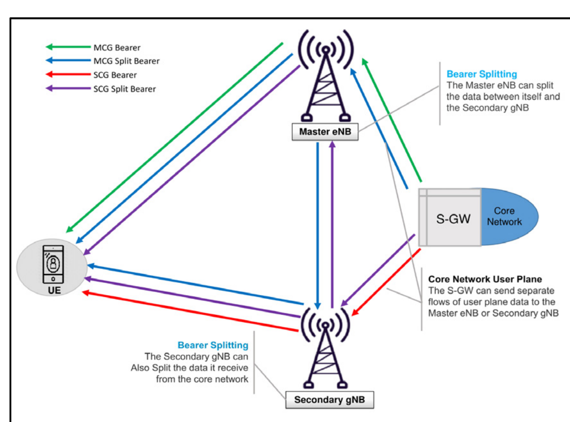


**Fig. 4.** The 5G EN-DC Non-Standalone Access (NSA) architecture.

directly sent to the UE from MeNB, but also through SgNB. The information received at MeNB can be split into two pieces: one piece is directly transferred to the UE, while the other piece is passed to the SgNB. The SgNB transmits that information to the UE.
3. Secondary Cell Group (SCG) Bearer: Similar to the MCG bearer configuration, the SCG bearer configuration does not use splitting, and the data is directly sent from S-GW to SgNB and then straight to the UE. In this particular configuration, the UE is served by the 5G NR access technology.
4. SCG Split Bearer: In this configuration, data traffic is divided into SgNB and MeNB. However, a major portion of data is transmitted by the SgNB.
5. It is clear that the highest data rates can be achieved using the splitting bearer approach. The main objective of implementing the NSA architecture is to enable DC in the 5G EN-DC and exiting LTE systems. The NSA architecture allows the next-generation 5G networking system to launch sooner alongside the existing 4G network.

### 3.2. 5G Standalone Access architecture

The 5G NR Standalone Access (SA) deployment is the first pre-defined method recently launched. The SA architecture is the main deployment scenario for 5G NR access technology. In this architecture, the UE is directly connected to the gNB, and the gNB is linked with the 5G core network. A new core network must be established instead of the LTE-A EPC network. The 5G NR SA technology must completely upgrade the 4G RAN to NR Access technology as well as the LTE-A EPC infrastructure to a new 5G core network architecture in order to start its services. Unfortunately, some areas will remain unresolved even after the launch of the 5G wireless network.

Fig. 5 explains the 5G SA architecture, a new and upgraded core networking system. The eNB is enhanced to become the gNB, and the 5G core network replaces the LTE-A EPC network. 5G SA is expected to establish a smart and intelligent architecture with NR access technology that will improve the end user's QoS. The 5G SA also has its own architecture which is not compatible with the existing LTE-A EPC network. However, it allows the flexible deployment of small cells.

### 3.3. Comparison between 5G NSA and SA architectures

This subsection gives the comparison between NSA and SA architectures of 5G. Some of the fundamental differences are explained in the following.

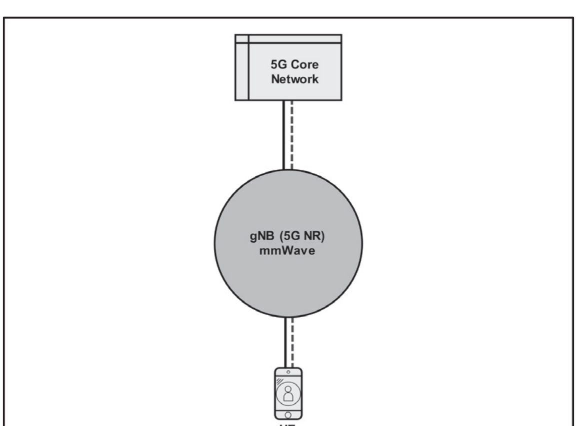


**Fig. 5.** Fifth Generation (5G) new Standalone Access (SA) architecture.

1. NSA 5G is a critical first step in a worldwide transition to 5G. By the end of 2019, the whole world's gadgets will support 5G. According to the GSMA, global 5G connections are expected to reach 1.8 billion by 2025, primarily because of the successful deployment of 5G NSA.
2. NSA 5G enables network operators to optimize the use of the LTE-A infrastructure while delivering corporations and individuals with quicker and more reliable communications than ever before, courtesy of 5G eMBB. However, eMBB is merely scratching the surface of 5G's potential.
3. The SA 5G core design offers a slew of additional features and capabilities, apart from increased bandwidth. These include Ultra-Reliable Low Latency Communications (URLCC), a critical component for applications needing a near-real-time response, such as self-driving cars, precision robotics, and machine vision. Massive IoT, which is made possible by specific machine-to-machine communication protocols, is also an essential part of SA 5G.
4. Operators need SA 5G to provide URLLC and massive IoT to corporate clients. Hence, SA allows the network to be sliced into virtual portions that can be tailored to the needs of each business while increasing operational efficiency.

### 3.4. Handover decision procedures over Dual Connectivity

The primary goal of 5G development is to achieve higher capacity and coverage gains by using DC with existing 4G LTE-A EPC networks. DC is an innovative solution that combines the existing 4G LTE-A with the next-generation 5G by leveraging the NR spectrum. This signifies that an LTE-A 20 MHz band of 4G can be simultaneously used with a three-time higher frequency band, i.e., 60 MHz NR of 5G. The split bearer mode can be applied to simultaneously employ the old frequency bands and NR. The advantage of using DC is the achievement of higher throughput at a cost-effective approach [76].

During the DC process in the 5G HetNet, two different handover scenarios can be predicted. The first is when the UE moves from the old MeNB to a new MeNB in the 4G LTE-A system. The second is when the UE switches between two small cells, i.e., from the existing SgNB to a new SgNB. Due to the ultra-dense deployment of small cells and their limited coverage area, frequent handovers and ping-pong effects are expected to occur among these small cells. In a later scenario, the MeNB remains connected while the small cells switch during movement. In the LTE-A EPC and 5G HetNet, ther RSRP plays a crucial role in the handover process. If the RSRP value of the new SgNB is higher than the connected SgNB, the handover of UE then takes place, otherwise, the connection remains the same [77].

Fig. 6 presents the handover procedure over DC in the 5G HetNet. The UE is simultaneously connected to the LTE MeNB and the 5G SgNB (smallcell-1). Once the UE moves from smallcell-1 towards smallcell-2, the MeNB sends an alert message to smallcell-2 to inform it on the arrival of UE. When the UE enters the vicinity, it starts receiving pilot signals from the new smallcell-2. The smallcell-2 will subsequently send a request signal to the MeNB to trigger the handover process. The MeNB checks the RSRP value of smallcell-2 at the UE. If the RSRP value of UE at smallcell-2 is higher than smallcell-1, the handover process begins. During this process, the UE continuously receives two streams of data traffic: one from the MeNB and the other from SgNB. Similarly, the handover procedure repeats when the UE moves from smallcell-2 to smallcell-3. The handover process is an important step to maintain DC in the 5G HetNet.

Fig. 7, as given in [78], describes the simplest handover procedure used by the 5G HetNet during the DC process. Following are steps:

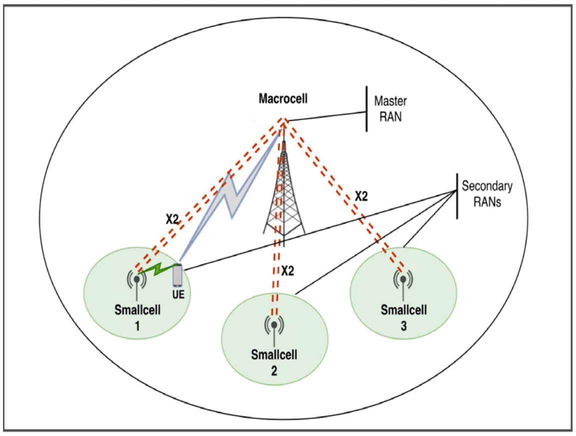


**Fig. 6.** Handover procedure over DC in a 5G HetNet.

**Step 1:** The Radio Resource Control (RRC) measurement report is generated by the UE and sent to the existing LTE MeNB.
**Step 2:** The MeNB receives the RRC report and compares the RSRP value. If the RSRP value of neighbouring SgNB is higher than the existing SgNB, it will pass to the MCG and SCG mobility management groups. According to the method used in Fig. 7, the MeNB controls the mobility of UE from one cell to another in the 5G HetNet. The following are the steps involved when handover occurs.
**Step 3:** The MCG and SCG check the parameters of neigh-boring SeNB and existing SeNB. If the neighbouring SeNB is connected with the new MeNB, then an acknowledgment request is sent to the new MeNB.
**Step 4:** A handover request message is sent to the new MeNB. All required information regarding the carrier frequency are also sent to the new MeNB.
**Step 5:** The new MeNB sends an acknowledgment message and begins the handover process.
**Step 6:** The connection reconfiguration message is sent to the UE through the old MeNB. The UE is then ready to switch both the 4 LTE-A and 5G NR links.
**Step 7:** The MCG mobility group releases the existing SgNB.
**Step 8:** The S-GW and MME switch the data traffic from the old MeNB to the new MeNB.
**Step 9:** The UE context is released by the old MeNB and shifts to the new MeNB.
**Step 10:** The existing SeNB releases the UE context and transfers it to the neighbouring SeNB.
**Step 11:** The LTE-A RRC measurement report is generated and sent to the new MeNB.
**Step 12:** The handover process is complete, and the data flow begins from the newly connected SgNB.

### 3.5. Dual Connectivity Advantages/Disadvantages

In the current 3GPP specifications, there are many ways to build NR, including moving from LTE-A networks to 5G core networks. These alternatives are classified as SA and NSA. Each technique of relocation offers several advantages and disadvantages. In the SA architecture, which includes a 5G core and a gNB, 5G services can be delivered right away. The NSA architecture, which uses the current LTE-A infrastructure, can only deliver 5G services. NSA may be a good option for businesses that want to build 5G quickly by using existing networks and cutting costs up front. If operators want to take advantage of new.

5G opportunities, the SA architecture is the best choice. Because only the SA architecture supports 5G-specific services, it is the best choice for operators. It's important for an operator to understand and use the differences between the different types of 5G bands. This way, they can use them to set up 5G in dense and urban areas that need a lot of capacity, or in metropolitan areas that need a good balance of capacity and coverage benefits and trade-offs.

Dual connectivity is one of the most advanced 5G network technologies. It makes up for some of the problems with NR deployment and gives users the benefits of two connections at the same time. On the other hand, seamless handover becomes more complicated, particularly when switching between two distinct network types [79]. Additionally, it is noted that the 3GPP began adopting the X2 interface between HeNB and gNB in Released-15 and later.

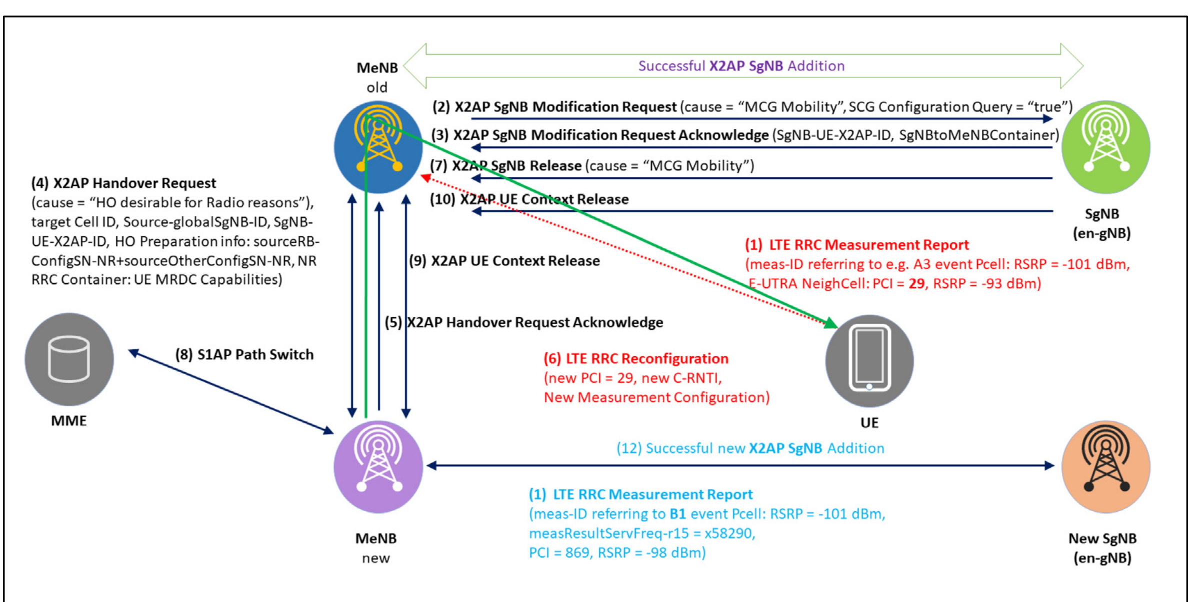


**Fig. 7.** Handover design of EN-DC connecting LTE-A and 5G [78].

## 4. DC challenges in future mobile HetNets

CA is a functionality in LTE-A which allows the UEs to simultaneously receive data from both the macrocell and small cell [80,81]. Similarly, DC enables the UE to simultaneously receive data stream from two eNBs without any issues, but using different carrier frequencies [82]. In the 5G NSA networking system, the NR is applied for short distances and assigned to gNB, while the main radio frequency is used for wider ranges by the traditional LTE-A eNBs. By using two different radio frequencies for data transmission in the 5G HetNet, the overall performance can be enhanced and the CCI is successfully reduced.

Although DC is a far better approach in the 5G HetNet and can be used to increase the system's capacity and throughput, many challenges still remain when it comes to implementation. Mobility, handover, fast switching (such as ping-pong), handover failure, reliability and security are the main issues that must be addressed. The use of mmWaves is sensitive and cannot penetrate walls. Therefore, the channel quality can be extremely vulnerable. Spectrum management and power management are the other challenges facing future wireless network generations due to the multi-bands environment utilised. The major challenges are explained in the following subsections and summarized in Table 1.

### 4.1. Ultra-Dense HetNet challenge

The ultra-dense HetNet deployment is a key technology for achieving higher capacity and ubiquitous connection for UEs in the 5G mobile wireless communication system. The distinct low-powered small cells (such as femtocells, picocells and relay nodes) are deployed at every hole and edge locations to provide better coverage. However, the ultra-dense deployment of small cells in the 5G HetNet can create several problems. For instance, if numerous small cells are deployed within a short distance, the chances of co-tier interference may increase if the same carrier frequency is used. Similarly, the UE consumes more energy while connecting to the appropriate small cell.

Another issue of the ultra-dense deployment of small cells is the ping-pong effect since the UE switches frequency from one small cell to another. The UE is expected to receive many signals from different small cells due to their short coverage area.

### 4.2. Mobility management challenge

In all mobile communication networks, mobility management between two different networks is a complicated procedure. This complexity will increase when DC is involved. DC connects the UE to two different network tiers, making mobility management even more complex. The switching of UE from one BS to another is called handover. The handover of DC in 5G HetNet is accomplished according to the RSRP value, which can be easily interrupted due to numerous factors. As a result, unnecessary handover will occur, and the system performance will drop.

Frequent handovers, ping-pongs and handover failures are serious challenges of the 5G HetNet. These issues significantly decrease the overall system performance. Hence, proper handover and mobility management techniques are required to resolve these problems. The aim of this article is to investigate and suggest handover techniques for DC in the 5G HetNet.

**Table 1**
The description of possible challenges in 5G DC HetNets.

| Challenge | Reason | Network |
|---|---|---|
| Ultra-Dense HetNet | Massive Small Cells Operate same frequency band. | 5G and 6G |
| Mobility Management | Due to small coverage areas, ping-pong effect and frequency handovers occur. | 5G and 6G |
| New Radio Spectrum | Due to higher frequency it cannot penetrate walls and other obstacles. It cover short distances. | 5G and 6G |
| Ultra-High Speed | It increases the number of frequent handovers and receive low RSRP value due to Doppler effect. | 5G and 6G |
| Security and Privacy | The DC may increase the chances of malicious nodes attacks. | 5G and beyond Networks |

### 4.3. New Radio (NR) spectrum challenge

The next-generation 5G will experience the NR spectrum, which can boost the data rate multiple times. However, there are some issues while using NR. Since NR uses a higher frequency band, it cannot travel long distances or penetrate walls and other solid materials. During the DC process, the UE may face signal drops from walls or other obstacles while moving. It may also cause several health issues due to the use of higher frequency bands.

Another problem of using NR in the 5G HetNet and the LTE-A EPC network is its frequency management during DC. The NR spectrum may increase the power distribution between LTE-A EPC and NR for uplink and downlink transmissions. An Equal Power Sharing technique is available to divide the maximum UE transmit power into two links, which is 20 dBm [83].

However, this technique may not be effective since the suggested UE power for uplink is 23 dBm in the LTE-A system. Hence, a 3 dB loss in the uplink coverage will be observed. In the NSA architecture, the LTE-A EPC acts as the MeNB and carries the control plane traffic. This 3 dB loss may impact the coverage and overall system performance.

Data splitting between MeNB and SeNB is also difficult and may increase the power consumption and processing costs. The UE has a limited battery charge, and the use of two different types of frequency bands in the uplink mode will result in extra processing. Hence, the induction of NR may consume extra power and increase processing time.

### 4.4. Ultra High-Speed challenge

The commute system has globally changed (for instance, the use of the bullet train), increasing speed in various ways. Due to the ultra-high speed railway system and modern highways, users are now traveling at greater speeds [84]. Providing wireless services and QoS to users at such speeds remains to be a challenging task.

A mobility management issue is present when users move at very high speeds in the 5G HetNet wireless network. The main problems of high speed movement include high penetration loss, frequent handovers and poor RSRP signal strength due to large Doppler spread [85].

Another challenge of high speed user movement is the application of NR. NR is a short range frequency band used by the SeNB in the 5G HetNet. Once the user starts moving fast, NR will not be applicable, and the objective of DC cannot be achieved. Similarly, the NR frequency band may further face a coverage blindness problem due to directional antennas [86].

### 4.5. Security and privacy challenges

The security of a user is the fundamental element of a wireless communication system. The growing number of IoT devices has relatively increased security threats. A robust and efficient authenticated key agreement between the UE and eNB is necessary to provide secure services in the 5G HetNet [87].

The DC may also cause security and privacy issues. The NR frequency band can be made widely available for public use as well as for private operators. During the DC mode, the UE may connect to a malicious node which can access private user data and hack important information [88]. Therefore, a good mechanism is needed to detect such malicious nodes and prevent possible attacks.

## 5. Proposed solutions in the literature

Mobility and handover management is a driving force of DC that makes it serviceable in the 5G HetNet. Numerous factors are involved when a UE switches from one BS to another such as time, location and service availability. In the literature, many techniques have been proposed to ensure seamless UE mobility in different environments and conditions.

The Self-Organized Network (SON) has been proposed as an adaptive and autonomous network model to simplify mobility management, planning, configuration and optimisation [89]. The main function of the SON is self-adjustment and self-management, striving to minimise handover failures during mobility.

Similarly, article [90] also suggested the self-healing approaches applied in Wi-Fi networks to reduce the number of handover failures. The detection of damaged and out-of-service Access Point (AP) is a suitable solution for reducing handover failures. The reason is that once faulty APs are known, they can then be avoided, and on-going connections will be attached to other APs. In the previous attempt in detecting faulty APs, the remaining energy of the serving APs can be used for other classification methods such as the K-Nearest Neighbours (KNN) and Support Vector Machine (SVM). The authors of [91] proposed a SON based algorithm that can improve system efficiency.

The novel clustering method is based on the idea that priority must be given to the same cluster cells with a higher mobility ratio. This method can solve the load balance and optimisation problems. The proposed algorithm accumulates the number of handover attempts of every cell and updates its location. In the update process, cells with high mobility interactions between each other acquire the closest location. Updated location data are fed to the K-mean algorithm to observe different clusters. The authors of [92] suggested that if the UE has a more enhanced role in the handover process, many link failures can be reduced. In the next-generation of 5G wireless networks, UEs are expected to choose the target cell to mitigate link failures. A combined prediction and classification model has been presented in [93] to avoid link failures. During the prediction phase, RSRP values of serving and strongest neighbouring BSs are fed to the Long Short-Term Memory (LSTM) model to predict future signal conditions. The classification process begins with a Feed-Forward Neural Network (FNN) trigger point, which is the point where signal conditions of serving and neighbouring BSs come within comparable range. The FNN and Network Component Analysis (NCA) algorithms are used to reduce handover failures. The system-level simulations are performed in order to verify the proposed methods. In the simulation, several handover failure scenarios were created with varying speeds and under different channel conditions. Their simulation results revealed that the LSTM classification model can reduce handover failures by up to 99%. Other methods were also noted to perform better when faulty APs are predicted in advance. All proposed methods can be applied in the 5G HetNet due to the characteristics of small cells, such as lower transmission power.

The main challenge of the 5G HetNet includes the measurement gaps between inter-RAT handover and the network switching automation [94]. The measurement gaps reduce the overall throughput of the end-user. The authors of [95] proposed a technique to classify handover failures during the measurement gap. To apply the proposed method, the handover procedure between the LTE-A serving cell and the mmWave target cell has been considered. Estimating signal conditions in the mmWave cell by the LTE-A cell simplifies the prediction of possible handover failures. Partially blind handovers have been introduced to detect such failures. They are called blind handovers since the measurement gap configuration is unnecessary. The term "partially" indicates that it will require specific measurement reports during a particular time, known as the collection period.

A survey article [96] had explained various methods to predict the UE movement pattern from historical trajectories, thereby achieving efficient mobility management in the ultra-dense HetNet. DC is suggested to decrease interruptions due to the break-before-make handover procedure. However, this solution has some problems, such as a higher complexity of measurement reports, network resource utilisation of two cells and power consumption. The suggested scheme optimises DC by adding Artificial Intelligence (AI). The mobility prediction of a user is the key component. The LSTM is a type of recurrent neural network used to determine user mobility trends in future wireless communication networks. The dataset collection is performed by the Self-Similar Least Action Human Walk (SLAW) and the SMOOTH model. The dataset includes the user's mobility pattern, capturing their location for 12 h at one-minute granularity in the simulation area of 4000 m*4000 m each day. The two-dimensional position coordinates of each user feed the three-layer LSTM network. According to the performance analysis, the proposed DC achieved more throughput than the traditional hard handover. It further possessed a BER gain higher than 60% in the low cell density. However, simulations were performed by a lower speed user profile of up to 8 m/s. When the user speed is 8 m/s, the handover prediction accuracy falls to 0.6. Therefore, this method is not suitable for high mobility wireless communication systems.

An optimisation method has been presented in [97] to enhance handover parameters in HetNets. Due to the diverse characteristics of small cells, mobility management appears to be a significantly challenging task. Instead of focusing on an individual handover trend, it was suggested that the handover behaviours of different small cells should only be observed on the bases of cell clustering. This process can detect faulty BSs and avoid wrong handovers. The K-mean algorithm is used for clustering 2000 small cells and for recording the handover KPIs, such as the number of handover attempts. The proposed method records the handover attempts every hour. Various Machine Learning algorithms were employed to investigate the handover request demands. The outcomes displayed a visible change, and the number of handovers were accurately minimised.

An SDN based method has been proposed to manage network resources by establishing a global view of the network [98]. SDN improves continuity in the handover process with different handover schemes. It checks for handover requests when an alert is received from a neighbouring cell. A smart technique was also presented in [99] using the global view of SDN throughout the network. It provides SINR values detected on different APs as a time-series data to the RNN-HM model AP, which is the best choice for handover. The last step of the RNN-HM model includes a SoftMax classifier to predict the sensibility of handover decisions to specific APs. According to the simulation analysis, nine APs and nine UEs have been used. One serves as a mobile object among the UEs. The proposed RNN-HM can perform earlier triggering to heal handover procedure in the throughput approach. The experimental results revealed that the proposed technique pulls the variation of throughput during a single handoff process at a short range. Therefore, the probability of providing higher throughput is improved. The optimisation of handover parameters is a challenging task for HetNets, especially for in-building systems such as campuses and airports where small cells provide service. Two main aspects emerge in the case of in-building systems. The unexpected signal conditions can create a severe issue on cell edges due to interference caused by outdoor macrocells. These signal conditions can create early or late handovers because of rapidly decreasing signal qualities or the attempt to decrease unnecessary handovers, respectively. Another aspect is the load. Congestion in macrocells can create a delay in the execution of handovers from the femtocell to the macrocell.

In [100], a novel algorithm has been proposed to optimise handover parameters for in-building systems by considering the load and signal conditions at cell edges. According to the algorithm's methodology, the first phase consists of a collection of data which includes the time-series data of RSRP values derived from measurement reports transmitted by users who successfully handover to another cell. The collected data is fed to the shapelets algorithm for clustering. The shapelets algorithm can identify local patterns to discriminate time series. Two clusters appear: users who receive degraded signals from small cell conditions when walking out of a building, and users who have a relatively slow signal degradation from the serving cell. After the clustering process, the handover parameters, which include the Time to Trigger (TTT) and hysteresis, are adjusted according to the clustering method's output and different loading conditions. The main objective of the proposed optimisation function is to decrease the ping-pong effect, the numerous handover rates and several handover failures. The algorithm's performance over the RSRP dataset from two hotspot areas of the University of Regina in Saskatchewan, Canada had shown that the proposed solution provides an average data rate between 25% and 65% for different loading scenarios.

The authors in [101] suggested a technique for tackling the high-speed handover issue of the 5G HetNet. This method can reduce the problem of coverage blindness, limited handover time and frequent transmission interruptions caused by the break-before-make handover. New spectrums, such as the NR bands, have been recently introduced to meet the increasing data demands in 5G communications. However, maintaining communication with NR bands is challenging due to severe path loss. To address this issue, energy-concentrated beam-forming has been suggested to extend signal propagation distance. Due to the limited coverage of directional beams, coverage blindness does occur, especially in vehicular networks. In vehicular networks, the user cannot detect the target mmWave Remote Radio Unit (mmWave-RRU) when it does not remain in the narrow active area of mmWave-RRU during the handover process. The control user-plane's decoupled network architecture is therefore adopted to heal coverage performance. This is accomplished by the separation of control and user plane while critical data is transmitted by reliable bands, the sub-6 GHz bands. User data is transmitted by the mmWave bands. With an integrated network architecture, it was suggested that the LF-RRUs, which operate in sub-6 GHz bands, can predict the user's position from collected Channel State Information (CSI) data to activate the candidate mmWave-RRUs to handover. To predict the position, a kernel-based machine learning positioning technique has been introduced. The goal of the algorithm is to decide the function which maps the CSI input data to a corresponding position data. The key idea behind 'kernel' is the redefinition of CSI data derived from different positions while considering the similarities between each other. Target mmWave-RRUs are selected with respect to the predicted position information. The second issue is providing a fast handover process due to limited time. It has been suggested that if the relationship between the status information of vehicles is determined when handover and the final handover decisions are requested, the LF-RRUs can rapidly provide handover decisions of vehicles at the time of the handover request. The concept behind this solution is an existing similarity between the mobility pattern of vehicles with finite and deterministic corners. The solution is applied using the KNN algorithm. The KNN model is trained by the status information of vehicles when the requested handover is an input feature data, and the handover decision information is a label. The last issue is transmission interruptions due to the hard handover issue. The use of Vehicle to Vehicle (V2V) links has been suggested for forwarding data. Data is forwarded during vehicle execution to infrastructure handover in order to maintain the connection. The performance of the V2V data forwarding has been analysed using three metrics: connectivity probability, the average SNR and the V2V interruption probability.

## 6. Future research directions

The next-generation wireless networks will experience extensive developments of target specifications for mobile users. DC is the promoted technology that enables the UE to simultaneously connect to multiple networks. However, it requires proper consideration during the handover process when the UE moves from one cell to another in an ultra-dense HetNet. Some of the potential future research areas are briefed in Table 2 and explained in the following subsections.

### *6.1. Software defined network (SDN)*

The Software Defined Network (SDN) concept is a solution for handling the dynamic nature of different network architectures and their increasing complexity [102]. The main management issue for diverse network architectures is the handover procedure. For instance, paper [103] presented a handover scheme based on SDN/NFV for ultra-dense 5G mobile networks. SDNs suffer from frequent unnecessary handovers. According to this study, mobile network virtualisation focuses on the virtualisation of base stations. Network function virtualisation means decoupling network functions from dedicated hardware devices to transform them into operations performed by software-based applications. Virtual base stations allow operators to accomplish procedures from different mobile network technology with a single virtual base station by performing layer 2 and layer 3 on the software-based application. The proposed handover scheme has four phases: data gathering, data processing, V-cell creation and handover execution. The data gathering phase is a collection of data by the control plane on network conditions. Collected data includes measurement reports

**Table 2.T**
The Future Enabler Technologies with their Advantages and limitations.

| Future Technology | Advantages | Limitations |
|---|---|---|
| Software Defined Network (SDN) | The BS can be controlled virtually and by software-based applications. | Lack of well-defined algorithms. |
| Machine Learning (ML) | The mobility management can be controlled by using machines. | A state-of-the-art Handover Decision Algorithms are required. |
| Optimised Load Balancing | Achieve higher throughput and better QoS. | The use of DC in a 5G Non-Standalone architecture. |
| Augmented Reality (AR) | Improving the users' perspective of the real world. | The lack of privacy in AR applications is a major limitation. |

**Table 3**
The acronyms used in this paper.

| Term | Abbreviation |
|---|---|
| 3GPP | Third Generation Partnership Project |
| 4G | Fourth Generation |
| 5G | Fifth Generation |
| AI | Artificial Intelligence |
| AP | Access Point |
| AR | Augmented Reality |
| CA | Carrier Aggregation |
| CC | Component Carrier |
| CCI | Co-Channel Interference |
| CMM | Centralized Mobility Management |
| CR | Cognitive Radio |
| CRE | Cell Range Extension |
| CSI | Channel State Information |
| DC | Dual Connectivity |
| DMM | Distributed Mobility Management |
| DSL | Digital Subscriber Link |
| EHF | Extremely High Frequency |
| eICIC | Enhanced Inter-Cell Interference Coordination |
| eMBB | enhanced Mobile Broadband |
| eNB | evolved Node Base Station |
| EN-DC | E-UTRAN-NR Dual Connectivity |
| EPC | Evolved Packet Core |
| E-UTRAN | Evolved Universal Terrestrial Radio Access Network |
| FHO | Frequent Handover |
| FNN | Feed-Forward Neural Network |
| FR-1 | Frequency Range-1 |
| FR-2 | Frequency Range-2 |
| gNB | Next generation Node Base Station |
| GRA | Grey Relational Analysis |
| HetNet | Heterogeneous Network |
| HHO | Horizontal Handover |
| ICI | Inter-Cell Interference |
| IoT | Internet of Things |
| IP | Internet Protocol |
| ITU | International Telecommunications Union |
| KNN | K Nearest Neighbours |
| LSTM | Long Short-Term Memory |
| LTE-A | Long Term Evolution Advanced |
| Term | Abbreviation |
| M2M | Machine to Machine |
| MCG | Master Cell Group |
| MDP | Markov Decision Process |
| MeNB | Master eNB |
| MIMO | Multiple Input Multiple Output |
| ML | Machine Learning |
| mmWave | Millimeter Wave |
| mmWave RRUs | mmWave Remote Radio Unit |
| MR-DC | Multi-Radio Dual Connectivity |
| NCA | Network Component Analysis |
| NR | New Radio |
| NSA | Non-Standalone |
| QoE | Quality of Energy |
| QoS | Quality of Service |
| RAN | Radio Access Network |
| RAT | Radio Access Technology |
| RLF | Radio Link Failure |
| RRC | Radio Resource Control |
| RSRP | Reference Signal Received Power |
| RSRQ | Reference Signal Received Quality |
| SA | Standalone Access |
| SCG | Secondary Cell Group |
| SDN | Software Defined Networks |
| SeNB | Secondary eNB |
| SgNB | Secondary gNB |
| SINR | Signal to Interference plus Noise Radio |
| SLAW | Self-Similar Least Action Human Walk |
| SNR | Signal to Noise Ratio |
| SON | Self-Organized Network |
| SVM | Support Vector Machine |
| TTT | Time to Trigger |
| UDN | Ultra-Dense Network |
| UE | User Equipment |
| URLCC | Ultra-Reliable Low Latency Communications |
| V2V | Vehicle to Vehicle |
| VHF | Very High Frequency |
| VHO | Vertical Handover |
| WLAN | Wireless Local Area Network |

from the mobile node, the serving base station and the candidate handover base stations. Collected data is then processed to generate QoS for each base station coverage area so that the best set of target base stations are selected for mobile users with different behaviours.

### 6.2. Machine learning (ML)

Various novel solutions and networking techniques have been proposed to reach the set goals of the 5G wireless network. However, these solutions have also brought about their own set of problems, transforming the network into one with complex management problems. For instance, HetNets have obstructed the control of different functions, such as mobility management, yet still provides better coverage. To enhance the productivity of these models, conventional reactive based models must transition to proactive data-driven models, another key essence of the 5G wireless network. In future, machine learning based algorithms will play a crucial role in many innovative 5G HetNet technology and architectures [104].

Machine learning is the most attractive technique with enormous potential for the 5G mobile network [105]. Fig. 8 displays the ML based architecture. In HetNets, machine learning based algorithms are required to accurately apply HO decisions during DC. These algorithms enable the system to automatically adjust parameters according to the UE demand and requirements. As a result, frequent HO can be efficiently reduced.

Algorithms that use machine learning techniques provide systems with the self-learning ability, enhancing performance by experiences without pre-defining their roles. Machine learning-based algorithms enable systems to actively monitor, learn and model network behaviour using data in the dynamic nature of network parameters. Machine learning-based algorithms suggest data-driven paths to model system parameters and their effects on complex systems to accomplish the necessary tasks.

### 6.3. Deep learning

Deep Learning is a subtype of AI that teaches computers to carry out tasks autonomously. It is a very promising approach that has lately attracted a lot of attention. Additionally, deep learning makes use of artificial neural networks approaches, a sophisticated

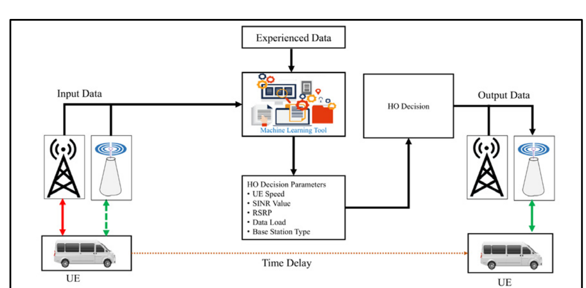


**Fig. 8.** A Machine Learning (ML) based architecture for 5G HetNet.

technology for resolving complicated issues. Deep learning is a critical component of autonomous automobiles since it enables them to identify stop signs and discriminate between pedestrians and lampposts. It enables voice control of consumer electronics such as smartphones, tablets, televisions, and hands-free speakers. Deep learning has received a lot of attention recently, and with good reason. It is achieving outcomes that were previously unattainable. Deep Learning models may attain state-of-the-art accuracy, often outperforming humans. Models are trained on a massive amount of labeled data and multilayer neural network topologies. Deep learning delivers better recognition accuracy than ever before. This enables consumer gadgets to live up to customer expectations, which is vital in safety-sensitive applications such as autonomous automobiles. When it comes to some tasks, like classifying objects in photos, deep learning has recently made progress that has made it even better than humans.

### *6.4. Optimised load balancing*

Self-optimisation and load balancing are potential techniques that can adjust radio resources in the HetNet environment of a mobile cellular network. High throughput can be achieved by switching the load from a high-density cell to a low-density cell.

Generally, Cloud Radio Access Network, Cell Types and Dynamic Handover parameters are the load balancing methods that can be used in the 5G HetNet [106]. The main objectives of using such methods are to balance data traffic and optimise QoS, latency and energy consumption in the future generation of wireless communication systems.

### *6.5. Augmented reality*

Augmented Reality (AR) is a digitally enhanced depiction of the physical world made by the use of digital visual components, audio, or other sensory stimuli provided by technology. Organizations interested in mobile computing and commercial applications are more likely to implement AR in the future of mobile networks [107]. AR is improving and becoming more common in a wide range of applications. Since its inception, marketers and technology companies have struggled to fight the perception that augmented reality is nothing more than a marketing tool. However, there is evidence that buyers are beginning to realize tangible benefits from this feature and are demanding it as part of their buying experience. Several early adopters in the retail business, for example, have developed technology geared at enhancing the consumer shopping experience. Retailers use augmented reality in catalogue apps to allow shoppers to visualize what different things would look like in different circumstances.

Aside from that, the benefits of augmented reality may extend to the healthcare business, where it might play a far more prominent role. One option would be to employ apps that enable people to examine incredibly detailed 3D images of different biological systems by hovering their mobile device over a target image. Augmented reality, for example, might be an excellent method for medical professionals to study while still in school.

According to some experts, wearable devices might be a game-changer for augmented reality. Whereas smartphones and tablets only show a tiny portion of the user's environment, smart eyewear, for example, may allow a complete connection between real and virtual realms if it advances enough to become widespread.

## 7. Conclusion

The handover management algorithms and DC techniques have been examined in this paper. The highlighted concepts are the potential candidates for the next-generation wireless HetNet. Small cells, NR and IoTs are the most prominent technology of the 5G mobile network, and are expected to improve data speed, coverage and spectral efficiency. However, handover and mobility management in an ultra-dense HetNet remain to be significant challenges. An efficient and effective handover decision algorithm is required to manage mobility and achieve the target specifications. This article highlighted the recent advancements of various handover and mobility management techniques.

The DC method can be used to improve capacity in the 5G HetNet. The UE can simultaneously connect to two different RATs. During the DC process, the macrocell is considered as the MeNB, while the small cell is considered as the SeNB. The handover process between two SeNBs is a challenging task since the MeNB and SeNB are directly connected via the X2 interface. The main challenges to resolve have been identified during the implementation of the 5G HetNet. Several important topics have also been discussed and explained for future research directions.

This paper further highlighted the acceptable solutions for HO implemented in 5G HetNets. The suggested solutions for HO mobility management are ML and SDN. Finally, this study has provided the researchers with good fundamental knowledge on mobility management, which will serve as guidance for establishing new algorithms and models to address future HetNet challenges.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Further reading

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