Key Open Research Issues For Implementing Femtocell in 5G Networks

Sultan Alotaibi[1†] and Saud S. Alotaibi[2††],

College of Computer and Information Systems, Umm Al-Qura University, Makkah, 24381 Saudi Arabia

Summary
When aiming to enhance coverage and capacity while simultaneously offering high-quality services to mobile customers at an affordable cost, femtocells have emerged as a viable option (Quality of Service). The objectives and limitations of femtocell implementation in the 5G network have been discussed in this article. 5G wireless system characteristics have also been explored. Furthermore, femtocell network implementation criteria have been added. Numerous research has been done on femtocells and their uses in traffic modeling and implementation for 5G networks. As a follow-up, the most pressing research issues for 5G femtocell deployment were presented and reviewed.
Keywords:
5G, Femtocell, Small Cells, IoT.

1. Introduction

A major driver of the 5G New Radio (NR) system is the need for massive amounts of data, which has increased in recent years as a result of the growth of data-hungry applications for smart phones. Examples of popular consumer-facing AR and VR applications include games and audio and video streaming services. Furthermore, high-definition smartphone screens have raised demand for more data storage. G global video data traffic will exceed 75% of total mobile data in 2024, up from 60% in 2018 [1]. 5G is anticipated to increase data volume by 1,000 times, reduce latency by five times, boost communication with other devices 100-fold, raise the total of the data rate (10 Gbps peak data rate), increase battery performance by 10%, and improve reliability by 100% [2][3]. New services and user experiences may be enabled by this network, which connects people and machines. It will enable mission-critical control applications through low-latency communication channels such as vehicle-to-vehicle (V2V) communications and the massive IoT device network. Among the essential technologies described in the 5G protocol are massive MIMO, mmWave transmissions, ultra-dense networks (UDNs), and multi-tier HetNets [4].

Massive MIMO technology is more efficient in terms of spectral and energy efficiency than SISO [5] [6]. Small antennas at the base station (BS) or user equipment (UE) improve capacity linearly (UE). It was developed to service several UEs in the same time-frequency resource while improving spectral efficiency (SE). It may also enhance energy economy by beamforming the signal from the antenna to the user, reducing interference and improving data connection dependability [7] [8]. In order to meet 5G requirements, current ultrahigh frequency (UHF) wireless network designs will have to be modified [9]. Exploring the use of higher frequency spectral from 3 GHz to 300 GHz may help solve spectrum shortages. Except for 57 GHz to 64 GHz and 164 GHz to 200 GHz, there are vast frequency ranges that might be used. Due to the fact that transmissions at such frequencies may be absorbed by oxygen and water vapor, these bands are not appropriate for wireless communication [10]. As well as terahertz (THz) frequency ranges from 300 GHz to 3 THz, which may handle future applications with exceptionally high data rates [11] [12]. Working in higher frequency bands implies using mmWave, and mmWave radio networking is fundamentally different from conventional wireless networks. mmWave transmissions exhibit high levels of signal penetration and blocking effects [13] [14], resulting in a greater emphasis on the effects of reflection, scattering, and line-of sight (LOS) propagation [15], and [16] than for other types of signals.

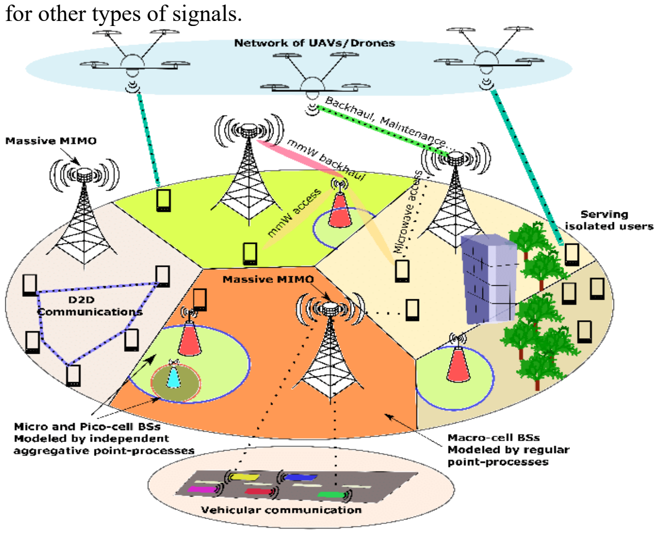


Fig. 1 Architecture of multi-tier HetNets [17].

In order to reduce the distance between users and mmWave access points, a small-cell network is the best approach. These small-cell networks will be able to boost network capacity by deploying in a highly concentrated way [18], [19].Densification of small-cell networks allows more users to be serviced on the same spectrum, increasing SE. The overall power consumption of the UEs may be decreased by communicating with neighbouring small cells via low power transmission. The small-cell network was initially suggested in Long-Term Evolution Release 9 for usage in smaller coverage areas such as residences, workplaces, and retail malls [20] [21]. There are three types of small-cell

Manuscript received April 5, 2022
Manuscript revised April 20, 2022
https://doi.org/10.22937/IJCSNS.2022.22.4.86

networks: femtocells, picocells, and relay nodes (RNs). A femtocell is the smallest unit commonly put inside for residential usage and operated independently from a macrocell network. A femtocell network typically has a coverage radius of 10-30 meters and uses less than 100 mWatts of power to transmit. Mobile network operators (MNOs) install pico cell networks to increase outdoor coverage of current cellular networks (consisting of macrocells and microcells). Pico cell networks are employed for interior locations such as retail malls and airports [22]. MNOs install RNs near the cell network's edge or in dead zones when macrocell signal strength is poor or nonexistent. The implementation of RNs may improve coverage and throughput while balancing traffic between users at the cell edge and cell center [23]. A HetNet is a combination of an existing macrocell network with dense small cell deployment. Figure 1 depicts the deployment of several small-cell networks as a multi-tier HetNet. In the current cellular network, small-cell networks are currently in use. However, the future 5G HetNet will have a greater density of these small cells, to the point where one femtocell network is present in every room of a building. This is required for 5G's high capacity and enormous connection. 2G, 3G, LTE-Advanced, WiFi, and Device-to-Device (D2D) communications are planned to be supported by the new HetNet. Indoor small-cell networks will employ mmWave technology, whereas outside massive MIMO networks will be used [24]. 3GPP Release 12 identified various possible 5G HetNet technologies, such as dual connectivity (DC), which enables users to connect to both macrocell and small-cell networks simultaneously utilizing the same or alternative carrier frequencies [25], [26]. The DC functionality should improve the overall HetNet data rate.

Future mobile devices will have several radio interfaces to let consumers to employ different RATs and smoothly switch between them. However, implementation is fraught with risk. The 5G HetNet RRM will be more sophisticated than the preceding LTE-A, therefore resource management will be crucial. The construction of uncoordinated femtocell networks by privately held buildings or residential properties would further affect HetNet interference control. For example, a HetNet UE may experience interference from MBSs, UEs, and SBSs at various tiers. A femtocell BSS that utilizes the same spectrum as the macrocell BSS will exacerbate this. Other major challenges include power allocation, user association, fairness, assigned capacity, and complexity.

In this study, 5G wireless network system would be described in the next section. Also, the deployment of femtocell network is discussed in the third section. The fourth section includes key significant open research issues of implementing femtocell network in 5G network.

2. The 5G Wireless Network System

Globally, wireless communication has progressed steadily but consistently over the last three decades, from 2G to 3G to 4G wireless networks as a result of a slow but persistent shift in perception. Because of the growing popularity of smart devices, all IP-based 4G-LTE networks have now become a part of everyday life for most people. The result is that many new user-oriented apps are being developed, which not only meet the needs of users, but also provide a new income stream for wireless carriers by boosting their revenue . As a result, there is an urgent need to increase the capacity of wireless communication systems. The capacity of a wireless communication system is primarily determined by bandwidth and spectrum efficiency, which are both linked to cell size. As cell sizes continue to shrink, the physical layer is approaching the Shannon capacity limit. Today, all wireless communications operate in the 300MHz to 3GHz range, which is referred to as the "sweet pot" or "beachfront spectrum," respectively [27]. However, the current spectrum is overburdened with traffic, making it a difficult obstacle to overcome. In 5G wireless networks, the new issue of high frequency bandwidth is critical because it allows for the exploration of previously unexplored frequencies in the millimeter (mm) high band frequency range spanning from three to three hundred gigahertz (GHz). Currently, several communication systems, such as military, radar, airport, radio astronomy, and others, are using the mm high frequency band to achieve more capacity and data rate than is currently available on the spectrum. The frequency bands of 57GHz – 64GHz and 164GHz – 200GHz are not appropriate for communication use due to their high frequencies. As an alternative to this, a large amount of millimeter wave band spectrum is accessible for 5G wireless communication systems [28][29].

2.1 Architecture of 5G

5G technology will support a wide range of clients, devices, and services. The need for growth has pushed the wireless industry to construct small cell networks instead of base station centric networks. Future systems will connect hubs via small, pico, and femto cell networks, as well as the first macro hexagonal coverage. Researchers are now focused on innovative approaches to create user-centric 5G wireless communication networks. The user centric network will replace the base station centric network [30], however dense 5G systems will have severe co-channel interference.

The new 5G network architecture idea of user-centric networks and small cells. Still, co-channel interference may be decreased utilizing smart antennas. Smart antennas are designed to replace omnidirectional antennas with smart beamforming directional antennas, reducing transmit power on both the user device and the base station [31].

The need for high data rates is also growing. The cloud radio access network (C-RAN) addresses some of the challenges associated with high data rates and rising demands [32]. C-RAN improves mobility, energy efficiency, system design, and coverage while lowering network implementation and operating costs [32]. It requires centralization and virtualisation. Baseband assets are aggregated at a distant central office [31]. The reduced architecture shown here is paving the way for a dense 5G organization that is adaptive, competent, and modest in its operation [33]. Cloud computing can manage the complicated control procedure.

In 5G wireless communication systems, a huge number of small cells are conveyed, giving rise to heterogeneous networks (HetNets). As an alternative to the legacy of macro cells, HetNets are made up of very small cells with minimal transmitted power. Using low power base stations increases network capacity and fills coverage gaps [34][35]. Increased efficiency and effectiveness of frequency reuse are achieved by the overlap of tiny, pico, and femto cells with currently extant macro cells. Small cells with diverse connectivity are the foundation of 5G. Directivity and small cell design are potential for 5G communication systems to increase coverage and data speeds. Changes in 5G architecture complicate the system. 5G requires more small cells and antennas. Several servers and routers must be configured and maintained. So a simpler solution is necessary to reduce system complexity. The Software Design Network (SDN) is a solution for reducing the complexity of a system's architecture. This will allow 5G networks to be more adaptable [36] [37].

2.2 Applications of 5G Networks

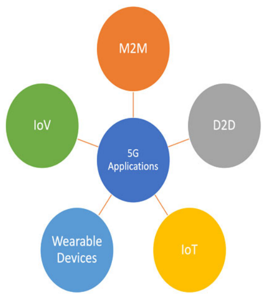


Fig. 2 5G Applications.

With advancements in software services [38] [39], 5G design is needed to provide organized solutions for a broad range of commercial and public sectors, including energy, city administration, manufacturing, farming, transportation, and medical services. 5G networks are capable of supporting large numbers of connections, as well as supporting a wide range of device types with varying service needs. Figure 2 depicts some of the 5G network's applications that will be covered in this study.

(i) Internet of Things IoT: With the Internet of Things, the goal is to link a large number of devices at the same time, which will include devices that will connect houses, smart grids, and smart transportation systems. Figure 3 depicts the Internet of Things. The Internet of Things' philosophy is "connect anything, anybody, anytime, and everywhere." In order to connect such a vast number of devices, 5G wireless networks will need to provide more capacity. The Internet of Things (IoT) provides internet connections and data interoperability for a wide range of smart items and applications [40]. Sensor businesses have had significant growth over the last decade, and statistical surveying predicts that the rate of growth will continue to increase at a fast rate in the next years. As a result of their constant operation, these sensors generate an enormous quantity of data. It is necessary to get unrefined sensor information in order to maximize the value of that information. In this course, the selection, demonstrating, reasoning, and appropriation of settings appropriate to sensor information are all essential functions to do. Context-aware computing has shown to be effective at deciphering sensor input in many situations.

(ii) D2D: Sharing information between the devices is done without the need of the cellular base station [41]. It contributes to the development of a device-centric nature for 5G technology . D2D is used in networks in order to minimize control signaling and end-to-end latency between nodes. It has advantages in terms of energy efficiency, scalability, and latency. It will also be aware of the benefits of smart mobile management. D2D correspondences were initially introduced in cell networks as a means of enhancing network performance by providing a different viewpoint. The emergence of new applications, such as those that are aware of location advertising and those that distribute information, is shown in a novel client for D2D correspondences in cell-organizational environments. The preliminary examinations revealed that D2D correspondences have favorable conditions, such as a decrease in transmission time and an increase in spectral effectiveness. Nonetheless, this correspondence mode offers difficulties in terms of resistance control overhead and conventions, both of which are now under investigation. A large amount of attention is being paid to the feasibility of D2D correspondences in LTE-A by the academic community, industry, and standardization agencies.

(iii) M2M: M2M communication is quite similar to D2D communication. These devices connect with one another directly, without the need of a cellular base station. The automated generation, processing, transport, and exchange of data across intelligent devices are the most significant characteristic. It needs less interference from humans [42]. Its objective is to integrate a large number of devices with less data, more efficient transmission, high dependability, real-time operation, and minimal latency, all while maintaining high reliability. M2M communication is also essential for the Internet of Things. Machines are supposed to be simple in multiple M2M correspondences applications, with the purpose that they may be easily implanted in real-world environments and widely distributed over a wide range of environments. The machine equipment specifications and the application-driven demands provide a variety of one-of-a-kind challenges in recognizing perfectly integrated, effective, and reliable machine-to-machine communication. Some of the most challenging challenges are machine heterogeneity, asset constraints, and maintaining high levels of Quality-of-Service (QoS).

(iv) IoV: The development of IoV is necessary for reliable traffic management and to limit the likelihood of collisions [43]. The Internet of Things (IoT), which links automobiles, plays a role in making the vehicular communication system more sophisticated. Because the Internet of Things demands large amounts of data, it is critical that it be processed and supplied with the highest level of security and safety. Wireless access in vehicular environment (WAVE) (IEEE 1609 standards) has been created as a standard for IoV by the IEEE [44]. The expansion of the Internet of Things (IoT) leads to the emergence of IoV. In the Internet of Automobiles, vehicles are linked to one another to form a vehicular ad hoc network (VANET). However, as a result of the constant topological changes, the information base store (unified/circulated) in IoV is of a spatio-temporal character, since it comprises traffic-related information that is dependent on the schedule and area from a vast number of linked vehicles. It is necessary to have vast storage capacity and computation time in order to prepare for the notion of obtained information as it grows in size, volume, and measures throughout time.

As a result, one of the most significant challenges in the Internet of Things is dealing with the massive amount of information that must be processed and then sent to its destination with the aid of a large number of middle of the road/hand-off hubs. When it comes to managing spatio-temporal information, the halfway/hand-off hubs may operate in either a helpful or a non-agreeable manner.

(v) Wearable Devices: Another possible use of 5G wireless communication technology is the use of wearable technologies [45]. Many physiological signs may be estimated by these devices when they are used in a rescue vehicle-type environment. It captures several physiological indications over an extended period of time, which aids in the understanding of the illness [46]. A paradigm change in real-time remote patient health monitoring is made possible by the use of wireless technology in conjunction with Body Area Network (BAN). Wearables are available in a variety of flavors and structures that are based on the many accessories and clothes that humans choose to wear. They are really rather little in size, but they are constantly detecting, gathering, and transmitting various physiological information in order to increase enjoyment of life. As a result of these requirements, there is a great deal of interest in increasing communication security and reducing the energy consumption of the system, which is driving new research in these areas. Additionally, there are some additional uses of 5G wireless networks, such as the financial sector, which is seeing a growth in business as well as clients, and which necessitates the use of powerful computers and data processing [47]. Future mobile networks based on 5G technology have more potential for transformation into a variety of financial services, including banking, social payments, local commerce, and others [48]. It is also a critical component of smart grids systems. Smart grids are large-scale cyber-physical systems [49], and they represent large-scale cyber-physical systems. 5G is also a foundation for home automation, enabling greater efficiency and security for all of the linked devices. This new research path in 5G wireless networks contributes to the development of a smart global network as a result of all-in-one services in 5G wireless networks.

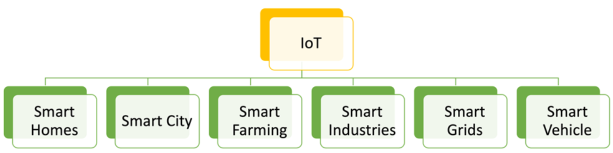


Fig. 3 Internet of Things IoT.

3. Femtocell Network in 5G

Femtocell technology is one of the most often used infrastructures in HetNet settings, and it is becoming more popular . Femtocells may be used by a variety of applications in Internet of Things settings to minimize the amount of traffic that passes through the macrocell layer, as well as to increase coverage and capacity across the network.

The Internet of Things (IoT) is an unique paradigm in which diverse things such as sensors, actuators, smart phones, and other devices are connected together and become a part of the Internet. The Internet of Things (IoT) influences every part of our everyday lives and has the ability to span a wide variety of applications such as smart environments, healthcare, transportation and logistics, futuristic, and personal and social life, among many others. These applications have the potential to dramatically enhance the quality of life of individuals in a variety of settings. The use of femtocells in the 5G network has the potential to dramatically increase the energy efficiency of the network [50]. When femtocells are deployed, more users may be packed into a given area on the same radio spectrum, resulting in higher area spectral efficiency and reduced network congestion. Furthermore, because of the reduced distance between User Equipments (UEs) and the serving macro base stations, these devices have the ability to decrease transmit power, resulting in considerable power savings for the UE when femtocells are deployed. As an example, femtocells may be employed in smart homes as a communication mechanism to monitor energy efficiency, which is particularly beneficial. In addition, femtocells may be utilized in a variety of 5G applications to ensure that communication is as efficient as possible. A femtocell-based communication mechanism in a home area network was presented by [51], and security challenges associated with the use of femtocells in the smart grid were examined by [52]. In addition, studies such as [52] and [53] have considered the use of femtocells in a home area network as a cost-effective solution for a variety of problems. Femtocells are being used in healthcare applications, which is another example of their use in IoT contexts. Paper [54] described an Internet of Things (IoT)-oriented healthcare monitoring system in which sensors gather data through an Android application and then communicate the data using a novel scheduling mechanism based on an LTE-based femtocell network to a central location. [55] address a combination of wireless body area networks, which are widely utilized in passive healthcare data gathering, with the notion of mobile cloud computing, which allows flexibility in big storage spaces and processing in healthcare monitoring systems.

It is explained in [56] what are the advantages of employing femtocells to support indoor produced Internet of Things traffic. The authors point out that sustaining the traffic created by the Internet of Things (IoT) is the most difficult task for 5G, since a significant percentage of the data is generated inside. As a result, it should be noted that femtocells can be employed in the majority of Internet of Things applications since there is a need for evolutionary communications systems. It is also envisaged that femtocells would be a critical component of 5G designs, both for human users and for the Internet of Things (IoT).

3. Femtocell Base Station Implementation Approaches

In order to deliver services to end users in a network that contains Femtocell Base Station (FBS), it is necessary to establish the right position of the FBS for a femtocell-based cellular network before the network may be operational [57]. When femtocells are deployed, the architecture of existing macro cellular networks is altered, and new design difficulties are presented as a result of these modifications. In telecommunication systems, one of the most difficult problems to solve is the issue of interference [58].

Consequently, adequate techniques and algorithms for the deployment of femtocells in the present macro cellular networks must be implemented in order to ensure their success. These approaches may be divided into three categories: random, deterministic, and hybrid.

3.1 Random Implementation of Femtocell Base Stations

When using a random deployment technique, femtocells are distributed at random locations within the service area of the larger cellular network [59]. If we consider the situation of Home Base Stations (HBSs), for example, they are randomly positioned inside the coverage area of a macrocell in order to give improved spectrum efficiency and better coverage in the regions that are not totally covered by the macrocell. The use of interference cancellation or avoidance strategies, on the other hand, is required in order to ensure that services are not affected in the area of a femtocell [58]. Femtocell positions may be decided in random deployments using either a purely random technique or by using a weighted random approach when the distribution of femtocells is not uniform. In purely random deployments, the location of femtocells can be chosen by using a simply random approach. Studies such as [60], [61], and [62] make use of a random deployment approach to get their results.

3.2 Deterministic Implementation of Femtocell Base Stations

The position of femtocells is not randomly selected in deterministic deployment, as opposed to random deployment strategy. Instead, the position of femtocells is determined based on various criteria, including path loss [63], [64], Signal-to-Interference Ratio (SIR) statistics [65] [66], controlling the power and radio resource [67], [68], a combination of path loss, SINR Grid-based deployment methodologies [69], [70] may be used to achieve these deployments. A dynamic greedy approach for deterministic placement of femtocells, for example, was presented in [71], which may be changed and optimized while taking into account the optimal coverage for peak-demanding regions. Article [63] describes the development of a model for optimizing the placement of base stations (BSs) for indoor wireless communications. A propagation model with parameters for the path loss is used, and a cost function is defined to show the coverage of the system is discussed in [64]. A model to analyze indoor wave propagation is used, with the effects of walls, roofs, and floors on the propagation taken into account by including different terms in the expression of the path loss [64]. They also looked at the prospect of employing Genetic Algorithms to optimize interior radio coverage in order to determine the positions of access points, which they found to be promising. The paper [72] covers numerous strategies for access point placement in wireless networks, including the Discrete gradient optimization algorithm, the Genetic Algorithm, and the Global optimization methodology, and proposes a novel strategy based on a Heuristic approach. A study published in [73] looks at the optimal positioning of FBSs in an indoor setting. The authors employ a femtocell route model to improve the quality of service (QoS) of associated UEs by installing the femtocell in a suggested position. Article [65] investigates the subject of determining the appropriate BS location for CDMA systems. Each mobile user is allocated to a BS based on the minimum path loss, taking into account the SIR in both the uplink and downlink directions, determined by a heuristic method . A novel hybrid approach is proposed in [74] for determining the best location of FBSs in indoor wireless communication networks while taking into account SIR statistics in both the uplink and reverse links. In [75], a mix of a heuristic algorithm and a brute force search is used to offer a novel technique for finding an ideal location for BSs from a collection of candidate BS sites in indoor CDMA networks. In the suggested technique for the placement issue, SIR limitations on both the forward and backward links are taken into account. The research study carried out in [76] investigates the most optimum sites to deploy a FBSs in an interior setting while taking SIR data into consideration. The study's main goal is to increase the system's throughput and mean capacity while keeping costs low.

The research [67], [68], and [77] explore the issue of BS placement in femtocell networks by regulating the transmitting power and radio resource management between the FBS and the outside cell-site, respectively. The research in [78] explores the topic of FBS placement in LTE networks with the goal of increasing the efficiency of automated traffic sharing algorithms by determining where they should be placed. Consideration and simulation of traditional traffic sharing algorithms in an office setting with a variety of femtocell location plans are used to assess this technique. A femtocell deployment method in multi-tier wireless cellular networks is proposed in [79] based on morphological segmentation of macrocells, heuristic levels of traffic intensity, and user distribution with the goal of meeting the network's current traffic demand. In [80], a dynamic method for transmission optimization on dense femtocell installations is developed, which defines resource allocation based on the satisfaction of femtocell users and the congestion state of the network. A femtocell deployment site was chosen for this study, and the effects of interference on incoming handover were explored. Article [81] introduces an algorithm that modifies a femtocell's coverage optimally based on user equipment's handover requests, and the range extent of the femtocell is maintained depending on whether or not a UE is authorized to use the femtocell. The research study reported in [82] presents a strategy for femtocell installations that is based on coverage adaptability. This technique makes use of information on the movement of passing and indoor users in order to optimize femtocell coverage and performance.

3.3 Hybrid Implementation of Femtocell Base Stations

Both deployment types are used in hybrid femtocell deployment, where randomly available femtocells are used as hotspots in addition to those that have been deterministically deployed at the outset based on the cellular network operational conditions, as demonstrated by the Siemens e-mobility project and other similar projects [83]. When it comes to medical scenarios, hybrid deployments of femtocells are also used in E-health monitoring systems. In these cases, femtocells are deployed deterministically inside a home or a hospital in addition to those that are randomly deployed inside an ambulance in order to transmit medical data to the hospital [84]. Most hybrid femtocell deployments account for the density of mobile users, the amount of traffic, and the coverage of their networks when designing their network models. When it comes to energy efficiency, it is also critical to maintain or improve the quality of service. For example, cross-tier interference during the deployment of femtocells has the potential to drastically decrease the system's performance. Authors of [85] investigates the resource allocation issue in both the uplink and the downlink for two-tier networks consisting of spectrum-sharing femtocells and macrocells, as well as the resource allocation problem in the uplink alone. The authors' goal is to optimize the capacity for both delay-sensitive users and delay-tolerant users while keeping in mind the quality-of-service (QoS) limitation imposed by the macrocell and the interference constraint imposed by the delay-tolerant users. Mixed-integer programming is used to simulate the issue of sub-channel and power allocation. In order to address the issue, an iterative sub-channel and power allocation method that takes into account heterogeneous services and cross-tier interference is developed that makes use of the sub-gradient updating technique.

4. Key Significant Research Issues

4.1 Control Software Defined Networking (SDN)

A viable solution to cope with the tremendous rise in mobile broad-band traffic has been identified in the form of femtocell technology, which improves spectral efficiency while expanding coverage area. However, femtocells provide a number of difficulties in terms of implementing an optimal mobility management strategy. In order to solve some of these difficulties, such as signaling overhead, greater packet loss, increased coordination and management complexity as well as increased handover delay, SDN is one of the viable solution techniques [86]. Accordingly, because of the massive increase in the volume of data traffic on communication networks, as well as the growth in the number of communication devices and new applications, the deployment of small cells such as femtocells could be a viable solution for meeting the current and future requirements of the next generation of wireless networks. However, the dense deployment of small cells causes a number of obstacles, including frequent handovers and substantial backhauling, which must be overcome. Through the separation of the control plane and data plane, SDN may give a solution to these problems [87] [88]. With the help of SDN, it is possible to gather information about user access behaviors such as access time and access point at an SDN controller that is capable of effectively allocating radio resources. Furthermore, when a loss occurs at the backhaul, the SDN controller may monitor the network behaviors and trigger the self-healing mechanisms to ensure adequate quality of service. SDN may also be utilized as a management mechanism in 5G/IoT scenarios, allowing various operators to interoperate flexibly with a large number of small cells, such as femtocells while maintaining network security [89]. To guarantee excellent quality of experience and improvements in network QoS, research into SDN management approaches would be advantageous in this context.

4.2 Spectrum Management

The deployment of femtocells in existing macrocellular networks necessitates the acquisition of additional spectrum resources. A failure to do so will result in interference with the current cellular networks [90]. In order to offer a wide variety of services while also delivering social and economic advantages, spectrum allocation is critical. As a result, many operators place a high value on making optimal use of their available spectrum. It would be helpful to do research into strategies and approaches that take into account dynamic spectrum management methods in order to prevent interference and improve the capacity performance of the network. Interference management and interference minimization are two key aspects of wireless communication systems. Frequency synchronization is another significant feature in wireless communication systems. Synchronization is also essential in order to have effective handovers between base stations in order to maintain a high degree of QoS [91]. Inter Symbol Interference (ISI) is a kind of interference that may occur in OFDMA systems when there is a timing or synchronization issue [92]. The usage of backhaul ADSL or the use of GPS inside the femtocell networks may help to solve the issue of synchronization in femtocell networks. It is necessary to do further study on time and frequency synchronization in order to design intelligent algorithms that can solve this problem.

4.3 Interference Management

In the case of a dense deployment of femtocells, interference is one of the most significant technological obstacles. Overall, interference is seen to occur in two sorts of ways: cross-tier interference (femto to macro) and co-tier interference (femto to femto) [93]. Cross-tier interference (femto to macro) may be caused by several factors. During the deployment of femtocells, interference is a critical aspect to consider since it has the ability to restrict the overall performance of the network while also affecting Quality of Service (QoS) and network capacity. The development of interference management algorithms and methods, such as interference cancellation and avoidance, is thus essential for ensuring an acceptable level of quality of service (QoS) for UEs.

4.4 Security

Securing femtocell networks is another major difficulty that must be overcome. Open access access mode is more demanding than closed access mode since everyone may join to the network, making it more difficult to provide effective security measures. This is because private information of the UEs must be secured. Numerous security concerns have been raised in relation to femtocell networks. For example, private information about a subscriber that is transferred through a backhaul Internet connection may be hacked, resulting in a violation of privacy and confidentiality laws [94]. Femtocells are similarly vulnerable to denial-of-service (DoS) attacks. In the case of the FBS, a hacker may cause the connection between the FBS and the main network to become overloaded, preventing the femtocell users from receiving services. In addition, security is required in closed access mode to restrict unauthorized users from gaining access to the network and its resources. It is critical to do substantial research in this field in order to ensure acceptable levels of security for femtocell users as a result of these security-related challenges and the growth in number of femtocell installations, which is becoming more prevalent.

Furthermore, physical layer security approaches are potential options for ensuring safe networks in the next generation of wireless communication systems, which is now under development. According to [95], physical layer security approaches are not reliant on computational complexity, demonstrating that the degree of security achieved will not be compromised even when the illegal smart objects in the 5G communication networks possess tremendous computing capabilities. Also noteworthy is the great scalability of physical layer security approaches, which is important for the 5G network since smart devices are constantly linked to nodes with varying levels of power and computing capability. SDN and NFV in 5G networks will offer a wide range of new service delivery models that need new security approaches. With network functions virtualization (NFV), network functions are no longer physically separated from one another in distinct hardware. Because of this, it is beneficial to develop and apply various methods of monitoring the allocation of software components to physical computing resources in a manner that ensures continued effective use of the available hardware and software components [96]. Aside from that, due to the high density of femtocells in 5G, key management would be challenging for users who often enter and exit the service area of the femtocells. Furthermore, in order to meet the low latency requirements of 5G, it is necessary to accelerate the authentication proces. For example, Article [97] proposes an SDN-based architecture in order to facilitate coordination amongst heterogeneous cells of varying sizes. The locations of users are anticipated and tracked via the usage of an SDN controller. Furthermore, the SDN controller samples various physical layer properties on a continuous basis in order to determine the performance of various secure context information combinations. This study's findings demonstrate that the latency performance of SDN-based authentication is superior to the latency performance achieved by standard cryptographic approaches. The authors further demonstrate that by using pre-shared secure context information through SDN, the tolerance level of the security framework may be increased. Allowing it to more effectively interact with network failures. Various current research in the fields of small cells and Internet of Things security are listed in Table XIV and compared. The primary communication infrastructures, as well as the protocols that are used, are shown in detail. Additionally, the Confidentiality, Integrity, and Availability (CIA triad) paradigm, which is used to develop information security rules, is discussed. An investigation is being conducted on the availability of mechanisms for access control, enforcing rules, auditing use, and giving the information essential to charge for services, as well as investigating the capacity to provide privacy. Finally, a summary of the difficulties discovered for each research is provided.

4.5 Cognitive Radio

It is built on Dynamic Spectrum Access (DSA), which has been shown to be a viable method in the field of communications technology. It is recommended that CR be implemented in a number of IoT-based femtocells since it has favorable effects on interference mitigation, power consumption level, and network lifespan. The FBS may be able to take use of capabilities such as spectrum sensing, detecting the unoccupied band, and increasing overall usage in order to apply spectrum allocation and process resource limits of low-end UE. CR is significant due to the fact that there is a trade-off between energy consumption and bandwidth, which means that in order to lower power consumption, we must have larger bandwidth. In other words, we need dynamic and optimum spectrum management. This is when the concept of CR comes into play. Research into CR-based structures and methodologies would also be advantageous in order to provide less costly and/or sophisticated schemes compared to the schemes described in [98] and [99], which would allow for power consumption reduction while preserving QoS. As a suitable solution to the issue of spectrum scarcity, CR networks may also be utilized to increase spectrum utilization by making effective use of the available spectrum [100]. When main radio users are not utilizing the spectrum, CR networks make use of the spectrum that has been licensed to them (e.g., when the spectrum is idle). As a result, the activity of primary radio listeners has a significant impact on the functioning of CR networks. As a result, it is critical to do research in this area in order to adequately characterize the behavior of main radio users in CR networks. Also possible is the use of occupancy measures that are done across a defined region rather than a single site in order to provide useful information regarding spectrum utilization. Consequently, research into methods and methodology for the evaluation and monitoring of spectrum occupancy would aid in the acquisition of more realistic spectrum occupancy data, which would serve as the basis for making spectrum management choices in the future. Furthermore, cognitive femtocells may be used to minimize interference in cognitive radio networks. Cognitive skills, like as learning and reasoning, may be used to femtocell devices in order to allow opportunistic exploitation of the available spectrum area. Furthermore, femtocells with CR capabilities are capable of allocating radio resources in an adaptable manner. They can also aid in the reduction of co-channel interference and the enhancement of spatial reuse [101].

4.6 Quality Management

A Quality of Service (QoS) specification may be used to assign different priority to data flows in order to ensure a given degree of performance in compliance with demands from the application. In femtocells, quality of service (QoS) assurance is considered essential, particularly when the cellular network capacity is restricted. Streaming multimedia applications that need a set data rate and are sensitive to delay, for example, fall under this category. To meet the diverse requirements of multimedia traffic in a heterogeneous traffic environment, femtocells that provide QoS assurance should be able to support a variety of application-specific QoS requirements (such as energy efficiency, end-to-end delay, dependability, delay jitter, and bandwidth consumption) with varying degrees of flexibility. When a femtocell serves a small number of UEs, it is possible to achieve significant improvements in QoS. Although femtocells have been implemented in outdoor locations and public venues such as shopping malls and airports, they have only recently been deployed in areas where a high number of users are linked with a femtocell. As a result, the available resources may not be sufficient to meet the QoS needs of each individual user. Furthermore, when femtocells are deployed in dense clusters, quality of service management becomes even more critical since each femtocell may only have a limited amount of resources available. So that each user's QoS needs are met, an optimal and efficient radio resource management system is necessary that takes a variety of aspects into consideration, such as interference and restricted radio resource availability.

4.7 Handover and Mobility Management

Since frequent handover occurs in IoT environments, femtocell mobility is a major barrier for these devices. With the constant change in UE coverage, there is a significant difficulty in terms of optimization, as well as achieving gains in energy savings and bandwidth usage, among other things. The majority of the time, users of femtocells are found in indoor locations. As a result, there is no requirement for specialized mobility management. However, in order to achieve a dense deployment of femtocells, it is important to implement mobility management and handover protocols [102]. Mobility management is one of the most challenging problems to solve in the event of dense femtocell deployment since it would be exceedingly impossible for a femtocell to keep track of all of its adjacent femtocells owing to the fact that any FBS may have a huge number of mobile neighbors that constantly modify the network architecture. In order to improve the performance in terms of energy savings and bandwidth usage, it is necessary to conduct research into an effective mobility management system.

4.8 Handover and Mobility Management

Since frequent handover occurs in IoT environments, femtocell mobility is a major barrier for these devices. With the constant change in UE coverage, there is a significant difficulty in terms of optimization, as well as achieving gains in energy savings and bandwidth usage, among other things. The majority of the time, users of femtocells are found in indoor locations. As a result, there is no requirement for specialized mobility management. However, in order to achieve a dense deployment of femtocells, it is important to implement mobility management and handover protocols [102]. Mobility management is one of the most challenging problems to solve in the event of dense femtocell deployment since it would be exceedingly impossible for a femtocell to keep track of all of its adjacent femtocells owing to the fact that any FBS may have a huge number of mobile neighbors that constantly modify the network architecture. In order to improve the performance in terms of energy savings and bandwidth usage, it is necessary to conduct research into an effective mobility management system.

4.9 Scalability

A typical HetNet consists of many macrocell sites that are layered on top of one another and several femtocells [103]. Because of this, maintaining current information on femtocells is a difficult undertaking. Scalability is one of the most important design aspects of femtocells, and it must be taken into consideration throughout the deployment and data traffic modeling processes as well. The deployment method should be scalable enough to allow it to function with increasing numbers of UEs while also ensuring that the application behaves correctly on a continuous basis. Also required is the ability to be transparently modified in response to scalability changes. It would be advantageous to do research on methods for FBS management in order to develop systems that are adaptable to a variety of transmission settings and available resources.

4.10 Traffic Modeling

The data flow and processing model has a considerable impact on the performance of femtocells, particularly in terms of energy consumption and quality of service (QoS). In order to properly represent the behavior of the network, the traffic models for femtocells as well as the systems with which they interact should be examined, defined, and verified. Through the analysis of these interactions over time, it is possible to generate profiles for various tactics such as power allocation approaches and radio resource management strategies, as well as analyze the behavior of network traffic in more depth. Furthermore, the performance of the femtocell should be evaluated using a variety of metrics, such as cell and user throughput, packet loss, call blocking/dropping probability, and so on, since an adequate data traffic model can provide realistic and accurate performance assessment.

5. Conclusion

Femtocells have shown to be a potential alternative for mobile operators looking to increase coverage and capacity while also providing high-quality services to mobile consumers at a low cost while maintaining high levels of quality of service (Quality of Service). In this article, we reviewed the aims and limits of implementing femtocell in 5G Network. Also, the characteristics of 5G wireless system has been discussed. Furthermore, the requirements of implementing femtocell networks have been introduced. The use of femtocells and their applications in traffic modeling and deployment in the 5G environment have been the subject of numerous studies in the existing literature. In addition, key open research issues of deploying femtocell in 5G networks were provided and discussed.

References

[1] *Ericsson Mobility Report*. Available: https://www.ericsson.com/en/mobility-report/reports/june-2019

[2] Jain, A. K., Acharya, R., Jakhar, S., & Mishra, T. (2018, April). Fifth generation (5G) wireless technology "Revolution in telecommunication". In *2018 second international conference on inventive communication and computational technologies (ICICCT)* (pp. 1867-1872). IEEE.

[3] *Minimum Requirements Related to Technical Performance for IMT-2020 Radio Interface(s)*, Int. Telecommun. Union (ITU). Available: http://www.itu.int/publ/R-REP/en

[4] Wong, V. W., Schober, R., Ng, D. W. K., & Wang, L. C. (Eds.). (2017). *Key technologies for 5G wireless systems*. Cambridge university press.

[5] Selinis, I., Katsaros, K., Allayioti, M., Vahid, S., & Tafazolli, R. (2018). The race to 5G era; LTE and Wi-Fi. *IEEE Access*, *6*, 56598-56636.

[6] Wu, Y., Khisti, A., Xiao, C., Caire, G., Wong, K. K., & Gao, X. (2018). A survey of physical layer security techniques for 5G wireless networks and challenges ahead. *IEEE Journal on Selected Areas in Communications*, *36*(4), 679-695.

[7] Ghosh, S., & Sen, D. (2019). An inclusive survey on array antenna design for millimeter-wave communications. *IEEE Access*, *7*, 83137-83161.

[8] Wang, J., Weitzen, J., Bayat, O., Sevindik, V., & Li, M. (2019). Interference coordination for millimeter wave communications in 5G networks for performance optimization. *EURASIP Journal on Wireless Communications and Networking*, *2019*(1), 1-16.

[9] Busari, S. A., Huq, K. M. S., Mumtaz, S., Dai, L., & Rodriguez, J. (2017). Millimeter-wave massive MIMO communication for future wireless systems: A survey. *IEEE Communications Surveys & Tutorials*, *20*(2), 836-869.

[10] Lin, Z., Du, X., Chen, H. H., Ai, B., Chen, Z., & Wu, D. (2019). Millimeter-wave propagation modeling and measurements for 5G mobile networks. *IEEE Wireless Communications*, *26*(1), 72-77.

[11] Yang, P., Xiao, Y., Xiao, M., & Li, S. (2019). 6G wireless communications: Vision and potential techniques. *IEEE network*, *33*(4), 70-75.

[12] Rappaport, T. S., Xing, Y., Kanhere, O., Ju, S., Madanayake, A., Mandal, S., ... & Trichopoulos, G. C. (2019). Wireless communications and applications above 100 GHz: Opportunities and challenges for 6G and beyond. *IEEE access*, *7*, 78729-78757.

[13] Jain, I. K., Kumar, R., & Panwar, S. S. (2019). The impact of mobile blockers on millimeter wave cellular systems. *IEEE Journal on Selected Areas in Communications*, *37*(4), 854-868.

[14] Han, K., Huang, K., & Heath, R. W. (2018). Connectivity and blockage effects in millimeter-wave air-to-everything networks. *IEEE Wireless Communications Letters*, *8*(2), 388-391.

[15] Rappaport, T. S., Xing, Y., MacCartney, G. R., Molisch, A. F., Mellios, E., & Zhang, J. (2017). Overview of millimeter wave communications for fifth-generation (5G) wireless networks—With a focus on propagation models. *IEEE Transactions on antennas and propagation*, *65*(12), 6213-6230.

[16] Rubio, L., Peñarrocha, V. M. R., Molina-García-Pardo, J. M., Juan-Llácer, L., Pascual-García, J., Reig, J., & Sanchis-Borras, C. (2019). Millimeter wave channel measurements in an intra-wagon environment. *IEEE transactions on vehicular technology*, *68*(12), 12427-12431.

[17] Hmamouche, Y., Benjillali, M., & Saoudi, S. (2018, November). Closed-form Coverage Probability under the Idle Mode Capability: A Stochastic Geometry Approach. In *2018 9th International Symposium on Signal, Image, Video and Communications (ISIVC)* (pp. 135-140). IEEE.

[18] Yang, C., Li, J., & Guizani, M. (2016). Cooperation for spectral and energy efficiency in ultra-dense small cell networks. *IEEE wireless communications*, *23*(1), 64-71.

[19] Gao, Y., Yang, S., Wu, S., Wang, M., & Song, X. (2019). Coverage probability analysis for mmWave communication network with ABSF-based interference management by stochastic geometry. *IEEE Access*, *7*, 133572-133582.

[20] Chen, J., Ge, X., & Ni, Q. (2019). Coverage and handoff analysis of 5G fractal small cell networks. *IEEE Transactions on Wireless Communications*, *18*(2), 1263-1276.

[21] ETSI, M. (2014). Overview of 3GPP Release 9 V0. 3.4. *3GPP, September*.

[22] Teng, Y., Liu, M., Yu, F. R., Leung, V. C., Song, M., & Zhang, Y. (2018). Resource allocation for ultra-dense networks: A survey, some research issues and challenges. *IEEE Communications Surveys & Tutorials*, *21*(3), 2134-2168.

[23] Zhou, K., Gui, J., & Xiong, N. (2017). Improving cellular downlink throughput by multi-hop relay-assisted outband D2D communications. *EURASIP Journal on Wireless Communications and Networking*, *2017*(1), 1-23.

[24] Huang, J., Liu, Y., Wang, C. X., Sun, J., & Xiao, H. (2018). 5G millimeter wave channel sounders, measurements, and models: Recent developments and future challenges. *IEEE Communications Magazine*, *57*(1), 138-145.

[25] Kibria, M. G., Nguyen, K., Villardi, G. P., Ishizu, K., & Kojima, F. (2018). Next generation new radio small cell enhancement: architectural options, functionality and performance aspects. *IEEE Wireless Communications*, *25*(4), 120-128.

[26] *Overview of 3GPP Release 12 V0.2.0*.

[27] Andrews, J. G., Buzzi, S., Choi, W., Hanly, S. V., Lozano, A., Soong, A. C., & Zhang, J. C. (2014). What will 5G be?. *IEEE Journal on selected areas in communications*, *32*(6), 1065-1082.

[28] Adhikari, P. (2008). Understanding millimeter wave wireless communication. *Loea Corporation*, 1-6.

[29] Khan, F., Pi, Z., & Rajagopal, S. (2012, October). Millimeter-wave mobile broadband with large scale spatial processing for 5G mobile communication. In *2012 50th annual allerton conference on communication, control, and computing (Allerton)* (pp. 1517-1523). IEEE.

[30] Boccardi, F., Heath, R. W., Lozano, A., Marzetta, T. L., & Popovski, P. (2014). Five disruptive technology directions for 5G. *IEEE communications magazine*, *52*(2), 74-80.

[31] Feng, Z., & Zhang, Z. (1999). Dynamic spatial channel assignment for smart antenna. *Wireless Personal Communications*, *11*(1), 79-87.

[32] Checko, A., Christiansen, H. L., Yan, Y., Scolari, L., Kardaras, G., Berger, M. S., & Dittmann, L. (2014). Cloud RAN for mobile networks—A technology overview. *IEEE Communications surveys & tutorials*, *17*(1), 405-426.

[33] Cvijetic, N. (2014, September). Optical network evolution for 5G mobile applications and SDN-based control. In *2014 16th International Telecommunications Network Strategy and Planning Symposium (Networks)* (pp. 1-5). IEEE.

[34] Abd El-atty, S. M., & Gharsseldien, Z. M. (2013, April). On performance of HetNet with coexisting small cell technology. In *6th Joint IFIP Wireless and Mobile Networking Conference (WMNC)* (pp. 1-8). IEEE.

[35] Huq, K. M. S., Mumtaz, S., Alam, M., Rodriguez, J., & Aguiar, R. L. (2013, August). Frequency allocation for hetnet comp: Energy efficiency analysis. In *ISWCS 2013; The Tenth International Symposium on Wireless Communication Systems* (pp. 1-5). VDE.

[36] Agyapong, P. K., Iwamura, M., Staehle, D., Kiess, W., & Benjebbour, A. (2014). Design considerations for a 5G network architecture. *IEEE Communications Magazine*, *52*(11), 65-75.

[37] Lai, C. F., Hwang, R. H., Chao, H. C., Hassan, M. M., & Alamri, A. (2015). A buffer-aware HTTP live streaming approach for SDN-enabled 5G wireless networks. *IEEE network*, *29*(1), 49-55.

[38] 5G-Infrastructure Public-Private Partnership. Available: http://5g-ppp.eu/

[39] Alcaraz-Calero, J., Belikaidis, I. P., Cano, C. J. B., Bisson, P., Bourse, D., Bredel, M., ... & Wang, Q. (2017, October). Leading innovations towards 5G: Europe's perspective in 5G infrastructure public-private partnership (5G-PPP). In *2017 IEEE 28th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)* (pp. 1-5). IEEE.

[40] Xu, B., Da Xu, L., Cai, H., Xie, C., Hu, J., & Bu, F. (2014). Ubiquitous data accessing method in IoT-based information system for emergency medical services. *IEEE Transactions on Industrial informatics*, *10*(2), 1578-1586.

[41] Gandotra, P., & Jha, R. K. (2016). Device-to-device communication in cellular networks: A survey. *Journal of Network and Computer Applications*, *71*, 99-117.

[42] Zhang, Y., Yu, R., Nekovee, M., Liu, Y., Xie, S., & Gjessing, S. (2012). Cognitive machine-to-machine communications: Visions and potentials for the smart grid. *IEEE network*, *26*(3), 6-13.

[43] Kumar, N., Misra, S., Rodrigues, J. J., & Obaidat, M. S. (2015). Coalition games for spatio-temporal big data in internet of vehicles environment: A comparative analysis. *IEEE Internet of Things Journal*, *2*(4), 310-320.

[44] Wu, X., Subramanian, S., Guha, R., White, R. G., Li, J., Lu, K. W., ... & Zhang, T. (2013). Vehicular communications using DSRC: challenges, enhancements, and evolution. *IEEE Journal on Selected Areas in Communications*, *31*(9), 399-408.

[45] Rutherford, J. J. (2010). Wearable technology. *IEEE Engineering in Medicine and Biology Magazine*, *29*(3), 19-24.

[46] Binkley, P. F. (2003). Predicting the potential of wearable technology. *IEEE engineering in medicine and biology magazine*, *22*(3), 23-27.

[47] Zhang, L., Ijaz, A., Xiao, P., Molu, M. M., & Tafazolli, R. (2017). Filtered OFDM systems, algorithms, and performance analysis for 5G and beyond. *IEEE Transactions on Communications*, *66*(3), 1205-1218.

[48] Ng, A. W., & Kwok, B. K. (2017). Emergence of Fintech and cybersecurity in a global financial centre: Strategic approach by a regulator. *Journal of Financial Regulation and Compliance*.

[49] Erol-Kantarci, M., & Mouftah, H. T. (2014). Energy-efficient information and communication infrastructures in the smart grid: A survey on interactions and open issues. *IEEE Communications Surveys & Tutorials*, *17*(1), 179-197.

[50] Al-Turjman, F. M., Imran, M., & Bakhsh, S. T. (2017). Energy efficiency perspectives of femtocells in Internet of Things: Recent advances and challenges. *IEEE Access*, *5*, 26808-26818.

[51] Bou-Harb, E., Fachkha, C., Pourzandi, M., Debbabi, M., & Assi, C. (2013). Communication security for smart grid distribution networks. *IEEE Communications Magazine*, *51*(1), 42-49.

[52] Zhang, H., Nie, Y., Cheng, J., Leung, V. C., & Nallanathan, A. (2016). Sensing time optimization and power control for energy efficient cognitive small cell with imperfect hybrid spectrum sensing. *IEEE Transactions on Wireless Communications*, *16*(2), 730-743.

[53] Fan, Z., Kulkarni, P., Gormus, S., Efthymiou, C., Kalogridis, G., Sooriyabandara, M., ... & Chin, W. H. (2012). Smart grid communications: Overview of research challenges, solutions, and standardization activities. *IEEE Communications Surveys & Tutorials*, *15*(1), 21-38.

[54] Hindia, M. N., Rahman, T. A., Ojukwu, H., Hanafi, E. B., & Fattouh, A. (2016). Enabling remote health-caring utilizing IoT concept over LTE-femtocell networks. *PloS one*, *11*(5), e0155077.

[55] Wan, J., Zou, C., Ullah, S., Lai, C. F., Zhou, M., & Wang, X. (2013). Cloud-enabled wireless body area networks for pervasive healthcare. *IEEE Network*, *27*(5), 56-61.

[56] Al-Turjman, F., Ever, E., & Zahmatkesh, H. (2018). Small cells in the forthcoming 5G/IoT: Traffic modelling and deployment overview. *IEEE Communications Surveys & Tutorials*, *21*(1), 28-65.

[57] Mahmud, S. A., Khan, G. M., Zafar, H., Ahmad, K., & Behttani, N. (2013). A survey on femtocells: Benefits deployment models and proposed solutions. *Journal of applied research and technology*, *11*(5), 733-754.

[58] Zhang, J., & de la Roche, G. (2010). Interference in the presence of femtocells.

[59] Omar, T., Abichar, Z., Kamal, A. E., Chang, J. M., & Alnuem, M. A. (2016). Fault-tolerant small cells locations planning in 4G/5G heterogeneous wireless networks. *IEEE Transactions on Vehicular Technology*, *66*(6), 5269-5283.

[60] Alexiou, A., Bouras, C., Kokkinos, V., Kontodimas, K., & Papazois, A. (2011, October). Interference behavior of integrated femto and macrocell environments. In *2011 IFIP Wireless Days (WD)* (pp. 1-5). IEEE.

[61] He, S., Lu, Z., Wen, X., Zhang, Z., Zhao, J., & Jing, W. (2015). A pricing power control scheme with statistical delay QoS provisioning in uplink of two-tier OFDMA femtocell networks. *Mobile Networks and Applications*, *20*(4), 413-423.

[62] Bouras, C., & Diles, G. (2015, November). Resource management in 5G femtocell networks. In *2015 10th International Conference on Broadband and Wireless Computing, Communication and Applications (BWCCA)* (pp. 353-358). IEEE.

[63] Ji, Z., Sarkar, T. K., & Li, B. H. (2002). Methods for optimizing the location of base stations for indoor wireless communications. *IEEE Transactions on Antennas and Propagation*, *50*(10), 1481-1483.

[64] Nagy, L. (2012). Global optimization of indoor radio coverage. *automatika*, *53*(1), 69-79.

[65] Ngadiman, Y., Chew, Y. H., & Yeo, B. S. (2005, September). A new approach for finding optimal base stations configuration for CDMA systems jointly with uplink and downlink constraints. In *2005 IEEE 16th International Symposium on Personal, Indoor and Mobile Radio Communications* (Vol. 4, pp. 2751-2755). IEEE.

[66] Talau, M., Wille, E. C., & Lopes, H. S. (2013, April). Solving the base station placement problem by means of swarm intelligence. In *2013 IEEE Symposium on Computational Intelligence for Communication Systems and Networks (CIComms)* (pp. 39-44). IEEE.

[67] Fagen, D., Vicharelli, P. A., & Weitzen, J. (2008). Automated wireless coverage optimization with controlled overlap. *IEEE Transactions on vehicular technology*, *57*(4), 2395-2403.

[68] Ashraf, I., Claussen, H., & Ho, L. T. (2010, May). Distributed radio coverage optimization in enterprise femtocell networks. In *2010 IEEE International Conference on Communications* (pp. 1-6). IEEE.

[69] Saha, R. K., & Aswakul, C. (2017). A tractable analytical model for interference characterization and minimum distance enforcement to reuse resources in three-dimensional in-building dense small cell networks. *International Journal of Communication Systems*, *30*(11), e3240.

[70] Novlan, T. D., Ganti, R. K., & Andrews, J. G. (2011, December). Coverage in two-tier cellular networks with fractional frequency reuse. In *2011 IEEE Global Telecommunications Conference-GLOBECOM 2011* (pp. 1-5). IEEE.

[71] Qutqut, M. H., Abou-zeid, H., Hassanein, H. S., Rashwan, A. M., & Al-Turjman, F. M. (2014, June). Dynamic small cell placement strategies for LTE heterogeneous networks. In *2014 IEEE Symposium on Computers and Communications (ISCC)* (pp. 1-6). IEEE.

[72] Rodd, S. F., Prof, A., & Kulkarni, A. H. (2009). Optimization algorithms for access point deployment in wireless networks. *J. Comput. Appl*, *2*(1), 2-2.

[73] Jain, A., Tawar, K., & Rathore, A. (2013, December). Optimal placement of femtocell base station for indoor environment. In *2013 International Conference on Advanced Computing and Communication Systems* (pp. 1-5). IEEE.

[74] Pujji, L. K., Sowerby, K. W., & Neve, M. J. (2013). Development of a hybrid algorithm for efficient optimisation of base station placement for indoor wireless communication systems. *Wireless personal communications*, *69*(1), 471-486.

[75] Pujji, L. K., Sowerby, K. W., & Neve, M. J. (2009, May). A new algorithm for efficient optimisation of base station placement in indoor wireless communication systems. In *2009 Seventh annual communication networks and services research conference* (pp. 425-427). IEEE.

[76] Wang, S., Guo, W., & O'Farrell, T. (2012, September). Optimising femtocell placement in an interference limited network: Theory and simulation. In *2012 IEEE Vehicular Technology Conference (VTC Fall)* (pp. 1-6). IEEE.

[77] Torregoza, J., Enkhbat, R., & Hwang, W. J. (2010). Joint power control, base station assignment, and channel assignment in cognitive femtocell networks. *EURASIP Journal on wireless communications and networking*, *2010*, 1-14.

[78] Ruiz Aviles, J. M., Toril, M., & Luna-Ramírez, S. (2015). A femtocell location strategy for improving adaptive traffic sharing in heterogeneous LTE networks. *EURASIP Journal on Wireless Communications and Networking*, *2015*(1), 1-13.

[79] Emelianova, E., Park, S., & Bahk, S. (2012, October). Deployment algorithm for femtocells in multi-tiered wireless cellular network. In *2012 International Conference on ICT Convergence (ICTC)* (pp. 131-136). IEEE.

[80] Ahmed, A. U., Islam, M. T., Ismail, M., & Ghanbarisabagh, M. (2014). Dynamic resource allocation in hybrid access femtocell network. *The Scientific World Journal*, *2014*.

[81] Jang, S., Lee, Y., Lim, J., & Hong, D. (2011, October). Self-optimization of single femto-cell coverage using handover events in LTE systems. In *The 17th Asia Pacific Conference on Communications* (pp. 28-32). IEEE.

[82] Claussen, H., Ho, L. T., & Samuel, L. G. (2008, April). Self-optimization of coverage for femtocell deployments. In *2008 Wireless Telecommunications Symposium* (pp. 278-285). IEEE.

[83] *Siemens Solutions for the E-Mobility Infrastructure Management*. Available: https://www.siemens.com

[84] Rehman, I. U., Philip, N. Y., & Istepanian, R. S. (2014, November). Performance analysis of medical video streaming over 4G and beyond small cells for indoor and moving vehicle (ambulance) scenarios. In *2014 4th International Conference on Wireless Mobile Communication and Healthcare-Transforming Healthcare Through Innovations in Mobile and Wireless Technologies (MOBIHEALTH)* (pp. 211-216). IEEE.

[85] Zhang, H., Jiang, C., Beaulieu, N. C., Chu, X., Wen, X., & Tao, M. (2014). Resource allocation in spectrum-sharing OFDMA femtocells with heterogeneous services. *IEEE Transactions on Communications*, *62*(7), 2366-2377.

[86] Elgendi, I., Munasinghe, K. S., & Jamalipour, A. (2015, December). A three-tier SDN architecture for DenseNets. In *2015 9th International Conference on Signal Processing and Communication Systems (ICSPCS)* (pp. 1-7). IEEE.

[87] Ali-Ahmad, H., Cicconetti, C., De la Oliva, A., Mancuso, V., Sama, M. R., Seite, P., & Shanmugalingam, S. (2013, November). An SDN-based network architecture for extremely dense wireless networks. In *2013 IEEE SDN for Future Networks and Services (SDN4FNS)* (pp. 1-7). IEEE.

[88] Dixit, A., Hao, F., Mukherjee, S., Lakshman, T. V., & Kompella, R. (2013). Towards an elastic distributed SDN controller. *ACM SIGCOMM computer communication review*, *43*(4), 7-12.

[89] Thyagaturu, A. S., Dashti, Y., & Reisslein, M. (2016). SDN-based smart gateways (Sm-GWs) for multi-operator small cell network management. *IEEE Transactions on Network and Service Management*, *13*(4), 740-753.

[90] Feng, M., Chen, D., Wang, Z., Jiang, T., & Qu, D. (2012, August). An improved spectrum management scheme for OFDMA femtocell networks. In *2012 1st IEEE International Conference on Communications in China (ICCC)* (pp. 132-136). IEEE.

[91] Pappalardo, I., Zanella, A., & Zorzi, M. (2016). Upper bound analysis of the handover performance in HetNets. *IEEE Communications Letters*, *21*(2), 418-421.

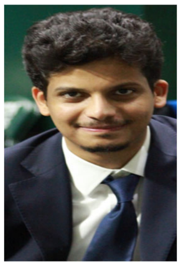
[92] Su, H., Kuang, L., & Lu, J. (2009, September). Interference avoidance in OFDMA-based femtocell network. In *2009 IEEE Youth Conference on Information, Computing and Telecommunication* (pp. 126-129). IEEE.

[93] Saquib, N., Hossain, E., Le, L. B., & Kim, D. I. (2012). Interference management in OFDMA femtocell networks: Issues and approaches. *IEEE Wireless Communications*, *19*(3), 86-95.

[94] Han, C. K., Choi, H. K., & Kim, I. H. (2009, December). Building femtocell more secure with improved proxy signature. In *GLOBECOM 2009-2009 IEEE Global Telecommunications Conference* (pp. 1-6). IEEE.

[95] Yang, N., Wang, L., Geraci, G., Elkashlan, M., Yuan, J., & Di Renzo, M. (2015). Safeguarding 5G wireless communication networks using physical layer security. *IEEE Communications Magazine*, *53*(4), 20-27.

[96] Schneider, P., & Horn, G. (2015, August). Towards 5G security. In *2015 IEEE Trustcom/BigDataSE/ISPA* (Vol. 1, pp. 1165-1170). IEEE.
[97] Duan, X., & Wang, X. (2016, May). Fast authentication in 5G HetNet through SDN enabled weighted secure-context-information transfer. In *2016 IEEE International Conference on Communications (ICC)* (pp. 1-6). IEEE.
[98] He, A., Srikanteswara, S., Bae, K. K., Newman, T. R., Reed, J. H., Tranter, W. H., ... & Verhelst, M. (2009, November). System power consumption minimization for multichannel communications using cognitive radio. In *2009 IEEE International Conference on Microwaves, Communications, Antennas and Electronics Systems* (pp. 1-5). IEEE.
[99] He, A., Srikanteswara, S., Reed, J. H., Chen, X., Tranter, W. H., Bae, K. K., & Sajadieh, M. (2008, December). Minimizing energy consumption using cognitive radio. In *2008 IEEE International Performance, Computing and Communications Conference* (pp. 372-377). IEEE.
[100] Saleem, Y., & Rehmani, M. H. (2014). Primary radio user activity models for cognitive radio networks: A survey. *Journal of Network and Computer Applications*, *43*, 1-16.
[101] Akhtar, F., Rehmani, M. H., & Reisslein, M. (2016). White space: Definitional perspectives and their role in exploiting spectrum opportunities. *Telecommunications Policy*, *40*(4), 319-331.
[102] Wang, L., Zhang, Y., & Wei, Z. (2009, April). Mobility management schemes at radio network layer for LTE femtocells. In *VTC Spring 2009-IEEE 69th Vehicular Technology Conference* (pp. 1-5). IEEE.
[103] Klessig, H., Gunzel, M., & Fettweis, G. (2014, September). Increasing the capacity of large-scale HetNets through centralized dynamic data offloading. In *2014 IEEE 80th Vehicular Technology Conference (VTC2014-Fall)* (pp. 1-7). IEEE.



Sultan Alotaibi received t the B.Sc. degree in Computer Science from Umm Al-Qura University, the M.Sc. and Ph.D. degrees from University of North Texas, USA. He is currently an Assistant Professor with the Department of Information Systems, College of Computers and Information Systems, Umm Al-Qura University, Saudi Arabia. His research interest includes wireless communication networks, LTE, LTE-A, radio resource scheduling, 5G and data quality in wireless networks.

Dr. Saud S. Alotaibi is an assistant professor of Computer Science at the Umm Al-Qura University, Makkah, Saudi Arabia. His current research interests include AI, Machine learning, Natural language processing, Neural computing IoT, Knowledge representation, Smart cities, wireless, and sensors. He received his Bachelor of Computer Science degree from King Abdul Aziz University, in 2000. Dr. Saud started his career as Assistant Lecturer in July 2001 at Umm Al-Qura University, Makkah, Saudi Arabia. He then earned his master's degree in computer science from King Fahd University, Dhahran, in May 2008. After that, he worked as a Deputy of the IT-Center for E-Government and Application Services, in January 2009, at Umm Al-Qura University. Under Dr. Charles Anderson's supervision, Saud completed his Ph.D. degree in Computer Science from Colorado State University in Fort Collins, US, in August 2015. From 2015 to 2018, Dr. Saud worked with the Deanship of Information technology to improve the IT services that are provided to the Umm Al-Qura University. Nowadays, Dr. Saud is working right now with the Computer and Information College as a vice dean for academic affairs.

.