International Journal Of Engineering Research And Development
e- ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 16, Issue 6 (June 2020), PP. 37-55

A Survey and an Outlook of Requirements, Challenges and Technologies for Development and Deployment of the 5G Networks

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Abstract: *The huge and rapid increase in the number of mobile devices, massive volume of data, and higher data rate are stimulating to rethink thecurrent generation of the cellular mobile communication. The next generation (5G) cellular networks are expectedto meet top-level requirements. Four unique features broadly characterize the 5G networks: ubiquitous connectivity,extremely low latency, network energy efficiency and very high-speed data transfer. The 5G networks would provide novel architectures and technologiesbeyond state-of-the-art architectures and technologies. In this paper, theobjective is to investigate and discuss critical limitations of the fourth generation (4G) cellular networks andcorresponding new features of 5G networks. We identify challenges in 5G networks, new technologies for 5G networks, andpresent a comparative study of the proposed architectures that can be classified on the basis of energy-efficiency, networkhierarchy, and network types. Interestingly, the implementation issues, e.g., interference, QoS, load balancing, densification, handoff, cloud base communication, security-privacy,channel access and energy harvestingare hugely effect the realization of 5G networks.*

Keywords:*5G, Cloud radio access networks; cognitive radio networks; D2D communication; energy efficiency; heterogeneous network; privacy; security; IOT; latency; Massive MIMO.*

Date of Submission: 20-06-2020 Date of Acceptance: 07-07-2020

I. INTRODUCTION

The evolution of the cellular network generations is influenced essentially by continuous growth in wireless user devices, data usage, and the need for a better quality of service (QoS).By 2020, the 5G network is expected to support 50 billion connected devices and 212 billion connected sensors as well as enable access to 44 zettabytes (ZB) of data. This will range from smartphones and tablets to smartwatches, cars, machinery, appliances, and remote monitoring devices. All of these will generate a massive amount of useful data that can be analyzed [1].Inshort, the increase of 3D (Device, Data traffic, and Data transfer rate) stimulates the development of 5G networks.

Specifically, the 5G of the cellular networks will highlight and address the following three distinctviews:(a) network-operator-centric by providing an energy-efficient, scalable, low-cost,secure communication infrastructure, programmable anduniformly-monitored,(b)service-provider-centricby providing connected intelligent transportation systems, road-sideservice units, sensors, and mission critical tracking/monitoringservicesand (c)user-centricby providing device connectivity, uninterrupted communication services, and a smoothconsumer experience.

There are noticeable features of 5G network that are expected to serve a broad range of applications and services.Therefore, 5G networks are recognized to realize the four main features as below:

o Ubiquitous connectivity: In future, many types of devices will connect ubiquitously by using Internet of Things(IoT) technology and provide an uninterrupted userexperience. In fact, the user-centric view will be realized by ubiquitous connectivity.

o High-speed Gigabit connection: The extremely low latency property could be achieved using a high-speed connection for fast datatransmission and reception, which will be of the several of Gigabits/s to users and machines [2].

o Extremely low latency: The 5G networks will support life-critical systems, real-time applications and services with very small delay tolerance. Hence, it is predicted that 5G networks will realize very low latency of the order of one millisecond [2]. In fact, the service-provider-centric view will be realized by the zero latency.The zero latency property of 5G networks would help to achieve real-time data without any delay, which would help to manage and operate industrial functions quickly while preserving energy.

- Network energy efficiency:Network energy efficiency is one of the main key capability of IMT-2020 and expected to be increased 100times from 1000 mW/Mbps/sec in IMT-2000 to 10 mW/Mbps/sec in IMT-2020[3].

A few more key features of 5G networks are enrolled and compared to the fourth generation (4G) of the cellular networks[2, 4]: (a)1000 timeshigher mobile data volume per area, (b)10-100 timesnumber of connected devices, (c) 10-100 timeshigherdata rate, (d) 1 millisecond latency, (e) 100% coverage and availability, (f) tenth energy consumption as compared tothe year 2010, (g) real-time information processing and transmission,(h) reduce network management operation expenses,and(i) seamless integration with the current wireless technologies. The main key capability of IMT-2020 is shown in figure 1.

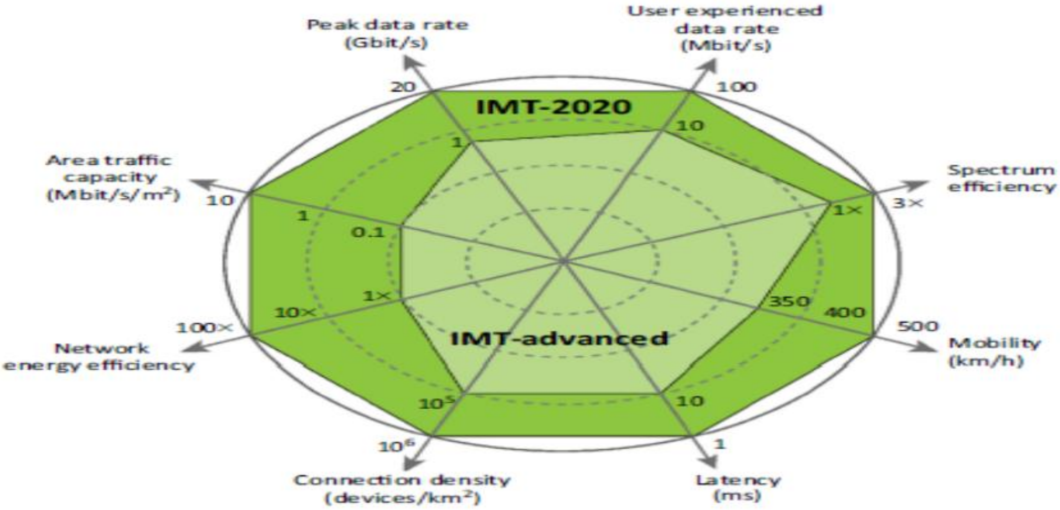

Fig.1. Key capabilities of IMT-2020[2].

The revolutionary scope and the consequent advantages of the envisioned 5G networks demand new architectures and technologies. They include energy-efficient heterogeneous frameworks, cloud-based communication including software-defined networks (SDN)and network function virtualization (NFV), dense-deployment, massive multiple-input and multiple-output (mMIMO), multi-radio access technology (M-RAT) architectures, mmWave (30–300 GHz)and backhaul connections,full duplex radio, self-interference cancellation (SIC), machine-to-machine (M2M) communications, device-to-device (D2D) communications, access protocols, cognitive networks for accessing licensed, unlicensed, and shared frequency bands,security-privacy protocols for communication and data transfer. Interestingly, the 5G networks will not be just enhancement of 4G networks in terms of additional capacity; they will encompass a system architecture visualization, and redesigning at every communication layer [5].

It will allow for an optimized and more dynamic usage of all distributed resources, and the convergence of fixed, mobile and broadcast services.5G will also support multi-tenancy models, enabling operators and other players to cooperate in new ways. 5G infrastructures will be also much more spectral efficient. The increased spectral efficiency will make 5G systems to consume a very less energy where 4G mobile networks consumes today for delivering the same amount of transmitted data. 5G will reduce service creation time and will provide the facility of integration of various players delivering parts of a service. Finally, 5G systems will also be hardware efficient. The ultra-efficient 5G hardware will be very flexible, energy aware, and interworking in very heterogeneous environments. The cost of 5G infrastructure will be reduced dramatically due to increased efficiency. Currently, the industry standards are evolved about the expected designs and architectures for 5G networks.

In this paper, we will review the vision of the 5G networks, advantages, proposed architectures and implementation issues.Section 2 presents the crucial limitations of current cellular networks. In Section 3, the requirements of 5G networks are presented and discussed. Section 4 presents challenges in the development of 5G networks.Section 5 addresses the currently proposed architectures for 5G networks, e.g., multi-tier, cognitive radio based, cloud-based, device proximity based, and energy-efficient architectures. Section 6 presents issues regarding interference, handoff, QOs, load balancing, channel access, and security-privacy of the network. Section 7 presents several Methodologies and Technologies involved in 5G Networks.Future work are defined in Section 8. Finally, we conclude the paper in Section 9.

II. LIMITATIONS OF THE CONVENTIONAL CELLULAR NETWORKS

The previous generations of mobile networks including 4G are not substantial enough to support massively connected devices with low latency and significant spectralefficiency, which will be crucial in the future communication and computing. In this section, we discuss some of the crucial aspectsin which conventional cellular networks became too late in progress, thereby motivating the evolution of 5G networks.

Latency. When a UE receives an access to the candidate BS, it takes several hundreds of milliseconds in the current cellular networks, and hence, they are unable to support the zero latency property and this represent a big problem for real time applications.

No support for heterogeneous wireless networks. The heterogeneous wireless networks (HetNets) are composed of wireless networks with diverse access technologies, e.g., the 3G, 4G, wireless local area networks (WLAN), Wi-Fi, and Bluetooth. The HetNets are already standardized in 4G; however, the basic architecture was not intended to support them.

Furthermore, the current cellular networks allow a UE to have a DL channel and a UL channel must be associated with a single BS that prevents the maximum utilization of HetNets. In HetNets, a UE may select its UL and DL channels from two different BSs belonging to two different wireless networks for performance improvement.

Inefficient utilization of processing capabilities of a base-station. In the current cellular networks, the processing power ofa base-station (BS) can only be used by its associated UEs, and they are designed to support peak time traffic. However, theprocessing power of a BS can be shared across a large geographical area when it is lightly loaded. For example: (a) during theday hours, BSs in business areas are over-loaded, while BSs in residential areas are almost idle, and vice versa [6], and (b)BSs in residential areas are overloaded in holidays or weekends while BSs in business areas are almost idle [7]. However,the almost idle BSs consume an identical amount of power as overloaded BSs; therefore, the overall cost of the networkincreases due to the inefficient consumed power.

No support for bursty data traffic. There are several mobile applications that send massive messages of huge load to their servers and occasionally request for very high data transfer rate for a very short duration. Such types of data transmission consume more battery life of (mobile) user equipment (UEs) with increasing bursty data in the network, and hence, may affect the core network [8]. However, only one type of signaling/control mechanism is designed for all types of the traffic in the current networks, creating high overhead for bursty traffic [9].

Co-channel interference. A typical cellular network uses two separate channels, one as a transmission path from a BS to UE, called downlink (DL), and the reverse path, called uplink (UL). The allocation of two different channels for a UE isnot an efficient utilization of the frequency band. However, if both the channels operate at an identical frequency, i.e., a fullduplex wireless radio, then a high level of co-channel interference (the interference between the signals using an identicalfrequency) in DL and UL channels is a major issue in 4G networks [10]. It also prevents the network densification, i.e., thedeployment of many BSs in a geographical area.

Limitation of the available spectrum. Operators will need more spectrum for 5G, not least because its benefits are fully achieved in new millimetre wave frequencies, with extremely wide bands [11]. Here, the ultra-high peak rates and low latency are most likely to be used by operators to add new levels of capacity and throughput for enhanced mobile broadband, especially as a way of offloading congested 4G networks (and for new special use cases). However, there is also broad interest in deploying 5G technology in new mid bands (3.5–6GHz) and existing, legacy mid bands (1,800–2,600 MHz) as a way of achieving national 5G coverage as rapidly as possible.

Operators will need to develop their spectrum strategies based on their own particular business focus, and the frequencies available to them, today and in the future. Utilizing legacy spectrum in combination with new bands enables operators to serve a wider variety of use cases more efficiently and, in many cases, more quickly; the whole can be greater than the sum of the parts.

No separation of outdoor and indoor users. The current cellular networks have a single BS installed preferably near the center of the cell and interacts with all the UEs irrespective of the indoor or outdoor location of the UEs; while UEs stay indoors and outdoors for approximately 80% and 20% of the time, respectively. Furthermore, the communication between an indoor UE and an outside BS is not efficient in terms of data transfer rate, spectral efficiency, and energy-efficiency, due to the high attenuation of signals passing through walls and other attenuated materials of the building [12].

III. REQUIREMENTS OF 5G NETWORKS

A massive growing number of UEs and the corresponding increase in the bandwidth requirement for the huge amount of data transmission certainly necessitates the novel enhancement to the current technology. In this section, we highlight the requirements of the future 5G networks.

Massive data streaming and high data rate. A huge growth in a number of wireless devices will of course result in a higher amount of data trading (e.g., videos, audio, Web browsing, social-media data, gaming, real-time signals, multimedia, bursty data, andphotos) that will be 100-times more as compared to the current situation and would overburden the current network. Thus, it is mandatory to have matching data transfer capabilities in terms of new architectures, methods, technologies, and data distribution of indoor and outdoor users [13, 14].

Ubiquitous connectivity. Ubiquitous connectivity requires UEs to support a variety of radios, RATs, and frequency bands due to theglobal non-identical operating bands. In addition, the major market split between frequency division duplex (FDM)versus time division duplex (TDM) so that UEs are required to support different duplex options. Hence,5G networks are envisioned for seamless connectivity of UEs over HetNets [15].

Massive increase in device scalability. A rapid growth of smart phones, gaming consoles, high-resolution TVs, home appliances, laptops, connected transportation systems, video surveillance systems, robots, cameras, sensors, and wearable devices (watches and glasses) is expected to continue exponentially in the near future. Therefore, the 5G networks are perceived tosupport massively connected devices [12, 16].

Zero latency. The future mobile cellular networks are expected to support numerous real-time applications, the tactileInternet, and services with varying levels of quality of service (QoS) (in terms of bandwidth, latency, jitter, packetloss, and packet delay) and QoE (in terms of users' and network-providers' service satisfaction versus feedback). Hence, 5Gnetworks are envisioned to achieve real-time and delay-bound services with the optimal QoS and QoE experiences [16].

Spectrum utilization. The two different channels (one for a DL and another for a UL) seem redundant from the point of view of the spectrum utilization [17]. In addition, the currently allocated spectrums have their significant portions under-utilized. Hence, it is necessary to develop an access control method that can enhance the efficiency of spectrum utilization.

Furthermore, the spectrum utilization and efficiency have already been reached to the maximum. It definitely requires new spectrum broadening (above 3 GHz) along with novel spectrum utilization techniques [18].

IV. CHALLENGES IN THE DEVELOPMENT OF 5G NETWORKS

To achieve the vision of 5G networks, there are several challenges will be handled in that context, as mentioned below and the proposed solutions will introduce and discuss during the next sections:

Data rate and Network Capacity Expansion. The deployment of more BSs (densification) in a geographicalarea, use of the higher frequency bands, and link improvement might support the network capacity expansion, billions of UEs, high data rate, high volume of data, and efficient backhaul data transfer to the core network. However, the implementation of these solutions is a difficult task in terms of economy and energy intake. Hence, the network capacity is required to be significantly increased, keeping the energy consumption and cost under rigid control.**Scalability and Flexibility**. These are the extremeoutstanding features of the future mobile communication. The future cellularinfrastructures and methodologies must be designed to work in HetNets. Moreover, a massive number of potential users mightrequest simultaneously for a set of services. Therefore, 5G networks must be powerful enough to support a scalable and flexible userdemand across the coverage area [19].

Handling Interference. Handling interference among communicating devices is a well-known challenge in the wireless communication. Due to a growing number of UEs, technologies (e.g., HetNets, CRNs, full duplex, and D2D communication) and applications, the interference will also increase in 5G networks, and the state-of-the-art technique may not perform well in the future cellular networks [14]. In 5G networks, a UE may receive interference from multiple macrocell base-stations (MBSs), various UEs, and small-cell base-stations (SBSs). Hence, it is required to develop an efficient techniques of avoidingnetwork overload, reliable techniques for perfect interference detection and decoding, interference management techniquefor channel allocation, power control, cell association, and load balancing.

Low Latency and High Reliability. Low latency and high reliability are critical in several real-time applications, e.g., messagetransmission by robots monitoring patients, life safety systems, cloud-based gaming, nuclear reactors, drones, andconnected transportation systems. However, it is challenging to have extremely low latency and reliable delivery of data over alarge scale network without increasing the network infrastructure cost, as it requires the development of techniques providingfast connections, quick handovers, and high data transfer rate.

Optimization of Network Performance. The performance parameters, e.g., peak data rate, coverage area, spectralefficiency,latency, QoS, QoE, ease of connectivity, energy-efficiency, reliability, fairness of users, and implementationcomplexity are crucial for a cellular network [12]. Hence, a general framework for 5G networks should substantiallyoptimize these parameters. However, there are some tradeoffs among all parameters, for example; which further emphasize the need ofa joint optimization algorithm.

High Mobility and Handoff. The 5G wireless UEs are meant for maintaining an active service connection while frequently moving from one cell to another or from one RAT (e.g., 3G, 4G, 5G, Wi-Fi, Bluetooth, and WLAN) to another. The mobility adaptation for the wireless services should not back-off even at a very high speed as a UE inside a moving vehicle. Moreover, during a particular interval, many UEs move from one place to another; for example, moving to offices from residential areas in the morning. As a result, 5G networks are envisioned to use the spectrum in the best manner and to adapt with the pace of the device movement.

Self-Organizing and Self-Healing Infrastructures. In the Self-Organizing Networks (SONs) with the ability of self-configuration, self-optimization, and self-healing, the amount of required manual work is minimized in order to reduce the operation cost. The specific requirements and use cases for SONs have been summarized and discussed in standards and industry organizations [20]. In SONs, there are multiple use cases for network optimization such as capacity and coverage optimization as well as mobility load balancing.

A self-healing infrastructure finds a failed macrocell or small-cell (i.e., a cell that is unable to work because of hardware failures, software failures, or misconfigurations) with the help of neighboring cells and provides a way for communication to the affected users by adjusting the transmission power and operating channels in the neighboringcells [21]. The design of a self-healing network demands on the frequent communication among cells; hence, it brings in the following challenges, as: (a) develop an efficient algorithm that can detect and reconfigure a failed cell with insignificant communication and computational overheads in the minimal detection time, and (b) reconfiguration of a failed cell should notlead to degradation of nearby cells' services.

Quality of Services. QoS guarantee in 5G networks has inherent difficulties, e.g., node mobility, multi-hop communication, resource allocation, and lack of central coordination. In addition, in 5G networks, a huge amount of bursty and multimedia data, multi-RATs, and low latency bound for different applications and services are major obstacles in achieving the desired QoS.Hence, it is challenging to design fast and efficient algorithms to maintain real-time QoS without overloading a BS [8, 22].

Environment Friendly and Energy Efficient. The ICT sector is responsible for approximately 3% of theworld energy consumption and 2 % of the equivalent CO2emissions, while almost 60% of the cellular networksenergy is spent at the operation of Base Station (BSs) [3]. In addition to that,the exponential growth of wireless data traffic calls for anultra-dense deployment of the wireless access componentsof next generation mobile networks, which in turn willyield a huge power consumption increase. Thus, it is required to develop energy-efficient communication systems, hardware, and technologies, thereby the ratio between the network throughput and energy consumption is fair.

Energy efficiency is defined as the number of bits that can be transmitted per Joule of energy, where energy is measured across the whole network. Every practicable effort must be made to gain energy without degrading efficiency, but the technology should allow native flexibility for the operator to configure trade-off between the performance and the energy [23].

Privacy and Security of the Network and UEs. The promising features of 5G networks bring in hard challenges in the design of security and privacy oriented 5G networks. For example, a massive number of new types of social devices may generatedifferent types of attacks like impersonation, denial-of-services (DoS), eavesdropping,replay, man-in-the-middle, and repudiation attacks [49]. Also, the transfer of a huge volume of data in secure and high speed manners is critical while preventing malicious files to penetrate. In addition, the network densification needs to be secure and requires fast-secure handoff of UEs.

Beyond privacy, honesty and availability, cyber-physical system security, and some other new security concepts in this area, need to address reliability of information, integrity of remote platforms, contextual correctness, proof of ownership and similar topics. Security mechanisms will be required to deploy for the existence of and support for highly limited devices such as sensors in parallel to the high-security solutions mentioned before. At the same time customized security at the service and device level should be visualized. To provide differentiated security services on request, 5G might consider dynamic control and data plane support for different security system creations. Security guarantees are needed for the dynamic composition of the 5G infrastructure within the system. beyond the mutual validation and creation of a secured channel, we will need to search through into topics of infrastructure or system integrity and operational security affirmation.

EconomicImpacts. A revolutionary change in the future mobile communication techniques would have strongeconomicimpacts in terms of deployment and motivation for user participation. It is critical to provide an entirely new infrastructurewith massive number of small cells for entire coveragedue to economical extension. Therefore, the cost of deployment, operation,maintenance and, management of an infrastructuremust be affordable from the perspective of network operators, regulating authorities, andgovernments. Hence, 5G networks need to be developed in such a way that users and network operators get comfortable and convincing advantages for both.

V. ARCHITECTURES FOR THE 5G MOBILE NETWORKS

In this section, we will study the proposed architectures for 5G networks, namely heterogeneous network, CRN-based, D2D communicationbased, energy efficient and the cloud-based architectures. These proposed 5G architectures will be explained with the associated advantages,disadvantages, and the challenges that are needed to be resolved.

5.1 Heterogeneous Networks Architectures

Several two-tier architectures have been proposed for 5G networks, where a MBS stays in the top-tier and SBSs work in the lower tier underthe supervision of the MBS. A macrocell covers all the small-cells of different types, e.g., microcell, picocelland femtocell (see table. 1), and both the tiers share an identical frequency band.

The small-cell enhances the coverage and services of a macrocell, and the advantages of small-cells are mentioned at the end of this section. In addition, D2D communication and CRN-based communication enhance a 2-tier architecture to a multi-tier architecture; see Figure 2. Note that in this section, we restrict on the deployment of small-cells under the cover of a macrocell.

Table.1: Relation between Cell type, Cell Coverage (Cell Radius) and Output Power

Cell Type	**Cell Radius**	**Output Power**	**No. of Users**	**Location**
Macro cell	**8km-30km**	**10W-50W**	**2000**	**Outdoor**
Micro cell	**200m-2km**	**1W-10W**	**100-2000**	**Outdoor/Indoor**
Pico cell	**100m-200m**	**0.25W-1W**	**30-100**	**Outdoor/Indoor**
Femtocell	**10m-100m**	**1mW-0.25W**	**1-30**	**Indoor**

For separating indoor and outdoor users, a MBS holds large antenna arrays with some antenna elements distributed around the macrocell and connected to the MBS using optical fibers. A SBS and large antenna arrays are deployed in each building for communicating with the MBS. All UEs inside a building can have a connection to another UE either through the SBS or by using Wi-Fi, mmWave, or VLC. Thus, the separation of users results in less load on a MBS. In [12] suggested to use a mobile small-cell that is located inside a vehicle to allow communication among internal UEs, while large antenna arrays are located outside the vehicle to communicate with a MBS. Thus, all the UEs inside a vehicle (or a building) appear to be a single unit with respect to the corresponding MBS, and clearly, the SBS appears as a MBS to all these UEs.

In [24], a two-tier architecture is deployed as a process of network densification that is a combination of two densifications (increasing the number of antennas per MBS andUE, and increasing the density of BSs) and spectral aggregation (using higher frequency bands greater than3 GHz).

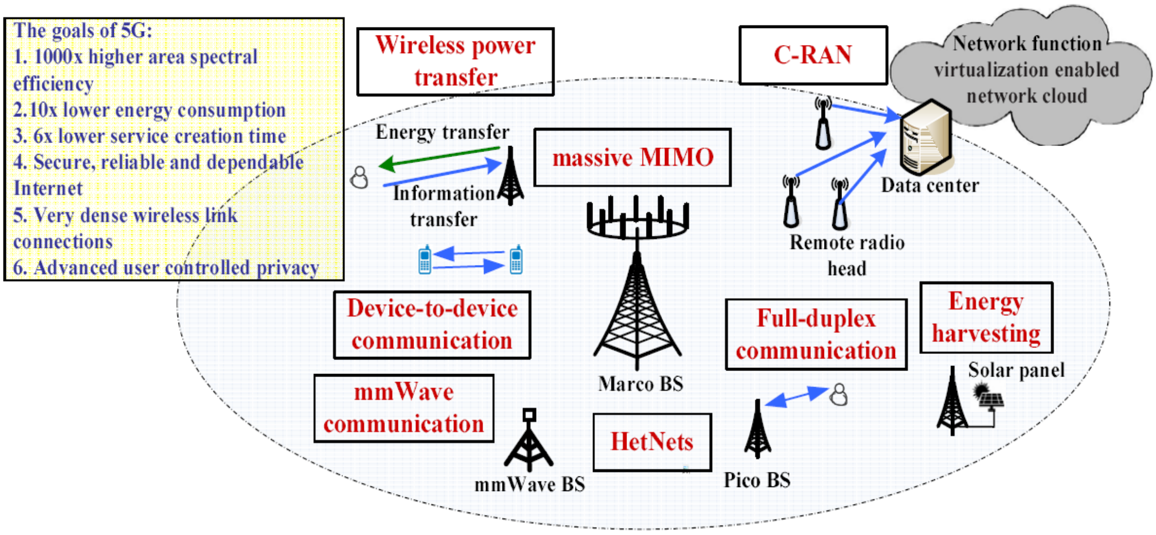

Fig.2: Enabling technologies and Goals of 5G networks.

A tradeoff between the transmission power of a macrocell and the coverage areaof small-cells is presented in [24]; i.e., on the one hand, if the transmission power of a macrocell is high, then many adjacentUEs to a small-cell may find themselves in the service area of the macrocell, and hence, it will decrease the coverage area ofthat small-cell. On the other hand, if the transmission power of a macrocell is low, then the coverage area of the small-cell willincrease. Therefore, cell coverage expansion (i.e., a biased handoff in the favor of small-cells) is carried out to serve more UEs bysmall-cells to which they are closer. Moreover, SBSs, deployed in offices or homes, can be used to serve outdoor users, e.g.,pedestrians and low-mobility vehicles, in their neighborhoods, and the approach is called indoor-to-outdoor user service [24].

A multi-tier architecture consisting of several types of small-cells, relays, and D2Dcommunication for serving users with different QoS requirements in spectrum-efficient and energy-efficient manners are presented in [14].Interestingly, all of these architectures consider that UEs automatically discover a SBS. A centralized system in which a MBS supports UEs to have connections to particular SBSs are proposed in [25], thereby interference between UEsand SBSs is reduced. However, this approach overloads the MBS.

Advantage of the deployment of small-cells.

- High data rate and efficient spectrum use: The small distance between a SBS and UEs (served by the sameSBS) leads to a higher data rate and a better indoor coverage. Also, the spectrum efficiency increases due to fewer UEs indirect communication with a MBS [22].
- Energy saving: The use of small-cells reduces the energy consumption of the network and UEs due to low signaling overhead and limited coverage area [5].
- Cost saving: It is more economical to install a SBS without heavy planning as compared to a MBS, and also operational-management cost is much lower thancost associated with a MBS.
- The plug-and-play utility of small-cells increases the on-demand network capacity [8].
- Less congestion to a MBS: SBSs offload UEs from a MBS so that the MBS is lightly loaded and less congested, and hence,improve the system capacity.
- Easy handoff: Mobile small-cells also follow the advantages of small-cells. Moreover, they provide an attractive solutionto highly mobile UEs by reducing handoff time overheads, since a mobile small-cell is capable to do the handoff on behalfof all related UEs [24].

Disadvantage of small-cells.

Despite various noted benefits as mentioned above, there are a few realistic issues suchas implementation cost and operational reliability. The small-cells impose an initial cost to the infrastructure, but lessthan the cost associated with a MBS. Moreover, a frequent authentication is mandatory due to frequent handoff operations.Furthermore, an updating of any small-cell would definitely result in frequent topological updates.

5.1.1Heterogeneous Networks architectures with self-healing property

An automatic detection and recovery of a failed cell is an important issue in densely deployed multi-tier architectures. Three approaches for designing a self-healing architecture are provided in [21]such as below:

a. Distributed approach: Each SBS detects failed small-cells in neighborhoods by measuring and analyzing users' handoff behavior and the neighboring small-cells' signals. Consequently, on detecting a failed cell, a SBS might increase the transmission power in order to incorporate users of the failed cell. However, the approach might work inefficiently in case those users are dispersed.

b. Centralized approach: A dedicated server is responsible for detecting a failed cell by measuring and analyzing abnormalbehavior of users, e.g., received signal strengths (RSSs) at users and handoff by several users at any time from a particularcell. The server collects global information and reconfigures the failed cell. However, the approach suffers with a highcommunication overhead and a high computational cost.

c. Hybrid approach: This approach combines the benefits of both the previous approaches, and therefore,minimizes the drawback. Essentially, two steps are utilized, namely distributed trigger and cooperative detection. Inthe distributed trigger, each SBS collects information about users' behavior. Subsequently, a trigger message is sentto a dedicated server in case the received information grows below a certain threshold. Hence, it does not requirecommunication among small-cells. In the cooperative detection, the dedicated server takes the final decision based onthe information received from several small-cells, resulting in a higher accuracy and lower latency.

5.1.2 Backhaul data transfer from small-cells

Data transfer from a SBS to the core network is a challenging task, and in general, there may be three approaches to transfer data to the core network, as follows:

a. Wired optical fiber: by establishing a wired optical fiber link from each SBS to a MBS; however, it is expensive and time-consuming.

b. Wireless point-to-point (PTP): by using directional antennas in line-of-sight (LOS) environments; hence, it provides high capacity PTP links at a significantly lower cost.

c. Wireless point-to-multipoint (PTMP): by deploying a PTMP-BS at a MBS that communicates with SBSs and transfers data to the core network.

Two architectures (centralized and distributed) based on the wireless PTMP approach are presented in [5]. In the centralized architecture, all SBSs send data using mmWave to a MBS that eventually aggregates the received data and forwards the same to the core network using fiber. In thedistributed architecture, all small-cells cooperatively forward data using mmWave to a specified SBS that transfers data to the core network using fiber without the explicit involvement of a MBS.

5.2 Cognitive Radio Network based Architectures

A cognitive radio network (CRN) is a collection of cognitive radio nodes (or processors), called secondary users (SUs)that exploit the existing spectrum opportunistically. The SUs have the efficiency, intelligence, reliability,and adaptively property for scanning and operating on multiple heterogeneous channels (or frequency bands) in the absenceof the licensed user(s), termed as primary user(s) (PUs), of the respective bands [26]. Each PU has a hightransmit power, fixed bandwidth,and high reliability; however, the SUs work on a broad range of bandwidth with low transmit power and lowreliability.A CRN in 5G networks is used for designing multi-tier architectures, removing interference among cells, and minimizingenergy consumption in the network [13, 27].Note that a CRN can be used to support D2D communication and mitigate interferences caused by D2D communication.

5.2.1 CRN-based architectures for 5G networks

Two types of CRN-based architectures for 5G networks are presented in [13], as: (1) non-cooperative and (2)cooperative CRNs.

The non-cooperative CRN: it establishes a multi-RATs system, having two separate radio interfaces thatoperate at the licensed and temporary unoccupied channels by PUs, called cognitive channels. The SUs work only oncognitive channels and form a CRN, which overlays on the existing licensed cellular network. The two networks can beintegrated in the upper layers while must be separated in the physical layer. This architecture can be used in different manners,as: (a) the cognitive and licensed channels are used by users near a MBS and users far away from the MBS, respectively,(b) the cognitive and licensed channels are used for relaxed QoS and strict QoS, respectively.

The cooperative CRN: it usesonly a licensed channel, where SUs access the channel in an opportunistic fashion when the PU of the channel is absent. Thisarchitecture can be used in different manners, as: (a) a SBS communicates with a MBS using the licensed channel and providesservice to its UEs via an opportunistic access to the licensed frequency band, (b) a licensed channel is used to serve UEs by aSBS and the opportunistic access to the licensed channel is used to transfer backhaul data to the MBS.

In short, the cooperative CRN [13] provides a real expectation of incorporating CRNs in 5G networks, where a SBS worksas a SU, which scans activities of a macrocell and works on temporarily unoccupied frequency bands by a PU to provide services to their UEs with minimally disrupting macrocell activities.

5.2.2 Interference Management using CRNs

An approach for avoiding inter-tier interference by integrating a cognitive technique at a SBS are provided in [28].The cognitive technique consists of three components, as: (a) a cognitive module, which senses the environment andcollects information about spectrum holes, collision probability, QoS requirements, macrocell activities, and channel gains,(b) a cognitive engine, which analyzes and stores the collected information for estimating available resources, and (c) aself-configuration module, which uses the stored information for dynamically optimizing several parameters for efficienthandoff, interference, and power management. Further, the channel allocation to a small-cell is done in a manner to avoidinter-tier and intra-tier interferences, based on spectrum sharing scheme, which avoids collisions by notassigning an identical channel to neighboring small-cells.

In [27] suggested an approach for mitigating inter-tier interference based on spectrum sensing, spectrum sharing,and cognitive relay, where links between a MBS and its UEs are considered as PUs and links between a SBS and its UEs areconsidered as SUs.

Cognitive techniques are used for detecting interference from a MBS to a SBS and vice versa, and a pathloss estimation algorithm is provided for detecting interference from a small-cell's UEs to a macrocell's UEs. After detectinginter-tier interference, a small-cell shares spectrum with a macrocell using either overlay spectrum sharing scheme (i.e., SUsutilize unoccupied channels, and it is applicable when a MBS and a SBS's UEs are very close or no interference is required bya macrocell's UEs) or underlay spectrum sharing scheme (i.e., SUs and PUs transmit on an identical channel while restrictingtransmit power of SUs, and hence, resulting in a higher spectrum utilization).

Advantages of CRNs in 5G networks.

- Increase network capacity: The spectrum holes can be exploited for supporting a higher data transfer rate and enhancingbandwidth utilization.

o Minimizing interference: By implementing a CRN at small-cells, cognitive small-cells can avoid interference very efficiently by not selecting identical channels as the channels of neighboring small-cells.

5.3 Device-to-Device Communication Architectures

Device-to-Device (D2D) communication allows close proximity UEs to communicate with each other on a licensed cellularbandwidth without involving a MBS or with a very controlled involvement of a MBS. UE that is not involved in D2D communication and communicates to a MBS is termed a cellular user equipment (C-UE).In this section, we will review D2D communication networks in short.

Challenges in D2D communication.

Interference management: UEs involved in D2D communication, say D-UEs, create (orface) interferenceto (or from)other UEs, orto (or from) a BS, based on the selection of a DL or UL channel, respectively. There are many types ofinterferences in DL and UL channels are investigated in [29]. A simple solution may exist by implementing CRNs in D2D communication, as: D-UEs areconsidered as SUs and C-UEs are considered as PUs that should not be interfered. Consequently, any mechanism ofCRNs can be implemented in D2D communication for interference cancellation.

Delay-sensitive processing: Audio, video streaming, and online gaming, which are natural in close proximity UEs, require real-time and delay-sensitive processing. Hence, it is required to consider delay-sensitive and real-time processing in D2D communication.Solutions based on channel state information (CSI) and QoS are provided in [30].

Resource allocation: When UEs involved in D2D communication, it is required to allocate a sufficient amount of resources,particularly bandwidth and channels. However, the allocation of optimum resources to D-UEs must be carried outin a fashion that C-UEs do not have interference from D-UEs, and D-UEs can also communicate and exchange dataefficiently [29].

D2D communication types.D2D communication can be done in the following four ways [31], as follows:

1. Device relaying with operator controlled link establishment (DR-OC): A UE at the edge of a cell or in a poor coveragearea can communicate with a MBS by relaying its information via other UEs, which are within the stronger coverage areaand not at the edge.
2. Device relaying with device controlled link establishment (DR-DC): Source and destination UEs communicate through arelay without involving a MBS, and they are also responsible for link establishment.
3. Direct D2D communication with operator controlled link establishment (DC-OC): Source and destination UEs communicate directly with each other without involving a MBS, but they are supported by the MBS for link establishment.
4. Direct D2D communication with device controlled link establishment (DC-DC): Source and destination UEs communicatedirectly with each other without involving a MBS, and they are also responsible for link establishment.

Note that DR-OC and DC-OC involve a MBS for resource allocation and call setup, and hence, prevent interference among devices to some extent.

Resource allocation methods. Now, we will review an architecture and some methods for resource allocation in D2D communication.

Social-Aware D2D Architecture: D2D communication is very efficient for close proximity UEs. Theproposedarchitecturehas four major components [32]. This architecture allocating more spectrum and energy resources to UEs with strong ties to improve spectral efficiency, decrease content duplication, increase the network throughput and reduce congestion of the network.

Channel Allocation Methods**:** Two cooperative channel allocation methods, frame-by-frame and slot-by-slot, are givenin [33]. Both methods improve the efficiency of frequency division multiplexing andincrease the network throughput.

A 2-phase service-aware resource allocation scheme,called SARA, is proposed [35]. In the first phase, resources are allocated on-demand to meet different servicerequirements of D-UEs, and in the second phase, the remaining resources are allocated to D-UEs such that thesystem throughput increases.

A delay-aware and dynamic power control mechanism are provided that adapts the transmit power of D-UEsbased on instantaneous values of CSI, and hence, finds the urgency of the data flow [30]. The dynamic power control selects apower control policy so that the long-term average delay and the long-term average power cost of all the flows diminish.

Advantages of D2D Communication. D2D communication results in link reliability among D-UEs, a higher data rate toD-UEs, instant communication, an easy way for peer-to-peer file sharing, local voice services, local video streaming, localonline gaming, an improved spectral efficiency, decreased power consumption of D-UEs, and the traffic offload from a MBS.

5.4 Energy-Efficient Architectures for 5G Networks

Energy efficiency is also an important factor in circuit design, such as power amplifiers and analog front-ends in microwave and millimeter frequency ranges, DSP-based optical transceivers for access and backhaul networks, and ultra-low power wireless sensors gathering surrounding energy, such as solar energy, thermal energy, vibration energy and electromagnetic energy. Also, wireless power transfer technologies and optimization of sleep mode switching present some exciting substitute to battery-less sensor operation for M2M and D2D communications. For such a great revolution in the network infrastructure parallel evolution of the connected objects (machines, terminals, drones, robots, etc.) in terms of wireless connectivity, computational power, memory capacity, battery lifetime and, cost are very important and required.

Researchers have proposed a few ways of reducing energy in the infrastructure. A joint optimization of energy-efficiency and spectral-efficiency is considered and a user-centric 5G network is suggested in [9] so that UEs are allowed to select UL and DL channels from different BSs depending on the load, channel conditions, services and application requirements. In a similar manner, decoupling of signaling and data is useful for energy saving; for example, a MBS may become a signaling BS while SBSs may serve all data requests. Thus, when there is no data traffic in a SBS, it can be turned off. A similar approach for decoupling of signaling and data is presented in [25]. However, a UE gets connected to a SBS according to instructions by a MBS, and hence, it results in less energy consumption at UEs' side due to less interference, faster small-cells' discovery, and MBS-assisted handover.

An energy-efficient C-RAN architecture in a manner that RRHs serve almost a same number of UEs are provided in [35]. They also present an interference management approach so that the power consumption of SBSs and MBSs can be decreased. The association of a UE cannot be done based on entirely a DL channel or a UL channel, and a UE must consider both the channels at the time of association with a BS [35,9].

5.5 Cloud-based ArchitecturesMobility management

Cloud computing infrastructure provides on-demand, easy, andscalable access to a shared pool of configurable resources, withoutworrying about the management of resources. The inclusion of thecloud in the mobile cellular communication can provide its benefits tothe communication system. In this section, a detailed review of cloud-basedarchitectures or cloud-based radio access networks (C-RANs) for 5Gnetworksis given in [36].

The basic idea behind any C-RAN isto execute most of the functions of a MBS in the cloud, and hence,divide the functionality of a MBS into a control layer and a datalayer (see Figure 3). The functions of the control and the data layersare executed in a cloud and in a MBS, respectively. Thus, a C-RANprovides a dynamic service allocation scheme for scaling the networkwithout installing costly network devices.

Specifically, a MBS has two main components, as: (a) a basebandunit (BBU) for implementing baseband processing using basebandprocessors, and (b) a remote radio head (RRH) for performing radiofunctions. In most of the C-RANs, BBUs are placed in the cloud andRRHs stay in MBSs. Thus, a C-RAN provides an easily scalable andflexible architecture.

Challenges in the deployment of a C-RAN.

- Real-time performance: Since C-RANs will be used instead of a MBS that provides all the services to users, it is requiredto transfer and process all the data in the cloud as fast as a MBS can do; otherwise, it is hard to find solutions to real-timeproblems using a C-RAN.
- Security: The resources of the cloud are shared among several users and never be under the control of a single authority.Hence, a malicious user may easily access the control layer of a C-RAN, resulting in a more severe problem.
- An efficient fronthaul data transfer technique: A flexible cloudification of the functions of a MBS comes at the cost of efficient fronthaul data transfer from RRHs to BBUs. The fast and efficient data transfer to the cloud has consistent impact on the performance of a C-RAN [37].
- Reliability: The cloud provider does not ensure any guarantee of failure-free executions of their hardware and software.Thus, it is hard to simulate an error-free MBS using a C-RAN.
- Manageability: It is clear that any cloud user, which poses an additional challenge in manageability of C-RANs, may access a non-secure C-RAN. Further, the dynamic allocation of the cloud resources at a specific time interval is a criticalissue; otherwise, a C-RAN may face additional latency [36].Now, we will see twomain C-RAN architectures in brief.

2-layered C-RAN architectures. Two C-RAN architectures based on the division of functionalitiesof a MBS are provided in [38], as: (a) full centralized C-RAN, where a BBU and all the other higher level functionalities of a MBS are locatedin the cloud while a RRH is only located in the MBS, and (b) partially centralized C-RAN, where a RRH and some of thefunctionalities of a BBU are located in the MBS while all the remaining functions of the BBU and higher level functionalitiesof the MBS are located in the cloud. Thus,the use of only two layers, namely a control layer and adata layer for implementing C-RANs, as follows:

1. Data layer: It contains heterogeneous physical resources (e.g., radio interface equipment) and performs signal processingtasks (e.g., channel decoding, demultiplexing, and fast Fourier transformation).
2. Control layer: It performs baseband processing and resource management (application delivery, QoS, real-timecommunication, seamless mobility, security, network management, regulation, and power control); see Figure 3.

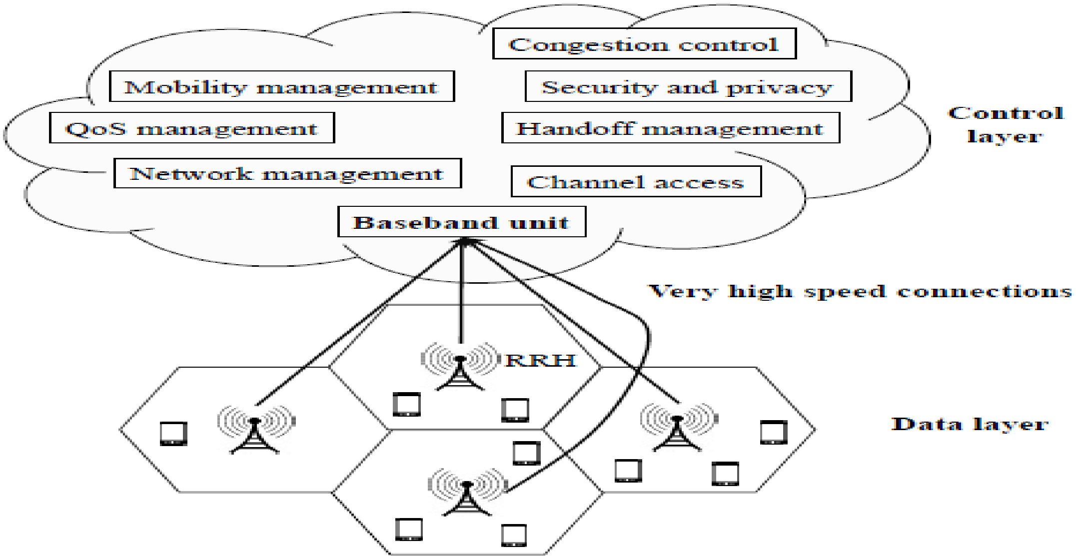

Fig. 3: A basic cloud-based architecture for 5G networks.

In [37] introduced RAN-as-a-service (RANaaS) concept, having the control and the data layers. However, in RANaaS, a cloud provides flexible and on-demand RAN functionalities (such as network management, congestion control, radio resource management, medium access control, and physical layer management), according to the network requirements and characteristics, unlike [38]. Hence, there is no need to split functionalities in advance to the control and the data layers, as a result RANaaS provides more elasticity and flexibility.

However, in order to achieve real-time performance, a RRHexecuting latency-critical applications may connect to a nearby small cloud while other RRHs that are not abide toreal-time applications may connect to a far larger cloud [16].

3-layered C-RAN architectures. The full-centralized C-RAN architecture [38] has some disadvantages, as: continuousexchange of raw baseband samples between the data and the control layers, and the control layer is usually far away from thedata layer resulting in a processing delay.

In order to remove these disadvantages, convergence of cloud and cellular systems (CONCERT) are proposed in [19].In this architecture, one more layer, called a software-defined service layer, is introduced at the top of the control layer. Thefunctioning of the layers in CONCERT is as follows:

1. Data layer: is identical to the full centralized C-RAN’s data layer, having RRHs with less powerful computationalresources for application level computations.
2. Control layer: works just as a logically centralized entity. The control layer coordinates with the data layer resources andpresents them as virtual resources to the software-defined service layer. The control layer provides a few services as: radiointerfacing management, wired networking management, and location-aware computing management to the data layer.
3. Software-defined services layer: works as a virtual BS and provides services (e.g., application delivery, QoS, real-timecommunication, seamless mobility, security, network management, regulation, and power control) to the data layer.

C-RAN architecture and RANaaS are enhanced [6], by moving the whole RAN to a cloud. Theproposed architecture also has three layers, where the data layer and the control layer are same to the respective layers ofC-RAN. The third layer, called a service layer, executes in the cloud and provides some more functionalities thanthe software-defined services layer of [37], e.g., traffic management, the cell configuration, interference control, allocation offunctional components to the physical elements, and video streaming services.

All-software-defined network using three types of hierarchical network controllers are proposed in [38], namelyMBS controller, RAN controller, and network controller, where except the MBS controller all the others can be executed inthe cloud, as follows:

1. MBS controller: usually stays nearby UEs, and performs wireless resource management and packet creation.
2. RAN controller: stays at the top of MBS controllers, and performs connectivity, RAT selection, handoff, QoS, policies,mobility management.
3. Network controller: stays at the top of RAN controllers, ensures end-to-end QoS, and establishes application-aware routes.

Advantages of C-RANs in 5G networks. C-RANs provide a variety of services as a software, power efficient, flexible, andscalable architecture for the future cellular communication. Here, we enroll some advantages of C-RANs, as follows:

- An easy network management: C-RANs facilitate on-demand installation of virtual resources and execute cloud-basedresources that dynamically manage interference, traffic, load balance, mobility, and do coordinated signal processing [37].
- Save energy of UEs and a MBS: C-RANs offload data-intensive computations from a MBS and may store data of UEs and MBSs. Consequently, C-RANs allow UEs and MBSs to offload their energy-consuming tasks to a nearby cloud, which saves energy of MBSs and UEs.
- Improved spectrum utilization: a C-RAN enables sharing of CSI, traffic data, control information of mobile services among participating MBSs, and hence, results in increased cooperation among MBSs and reduced interference [6].
- Save cost: It is very costly and time-consuming to deploy and install a MBS to increase the network capacity. However,the deployment of C-RANs involves less cost, while it provides usual services like a MBS. As a result, operators arerequired to only deploy, install, and operate RRHs in MBSs.

VI. Implementation Issues in 5G Networks

This section will introduce issues regarding the interference, handoff, QoS, load balancing, channel access management,privacy and security in the context of 5G networks.

6.1 Interference Management in 5G Networks

In this section, we will review sometechniques/methods for interference management in 5G networks.

UE-side interference is handled by using a new type of receiver equipment, called an advanced receiver,which detects, decodes, and removes interference from receiving signals [10]. In addition, the network-side interference is managedby a joint scheduling, which selects each UE according to the resources needed (e.g., frequency, time,transmission rate, andschemes of multiple cells) for its association with a BS. Hence, the joint scheduling, which can be implemented in a centralizedor distributed manner, requires a coordination mechanism among the neighboring cells.

Distributed cell access and power control (DCAPC) schemes for handling interference inmulti-tier architectures are proposed in [14]. DCAPC involves: (a) cell association (CA), which regards dynamic values of resources, traffic, distance to a MBS, and available channels at a MBS for selecting a MBS with the optimum values of the parameters; (b) prioritized power control (PPC), which assumes that UEs working under aSBS have a low-priority than UEs working under a MBS, and hence, low-priority UEs set their power so that the resultinginterference must not exceed a certain threshold; and (c) hybrid of thefirst two approaches (CA and PPC) allows a UE toconnect simultaneously with multiple BSs for a UL and DL channel based on criteria of PPC and CA.

In [17] suggested to use self-interference cancellation (SIC) in small-cells' networks. As we have seen that SBSsrequire methods to transfer backhaul data to a MBS, the use of SIC can eliminate the need of such methodsand result in self-backhauled small-cells (SSCs). SSCs use SIC for providing services and backhaul data transfer, and they gain almost the same performance as having a small-cell connected with a wired optical fiber. It works as: inthe DL channel, a SBS may receive from a MBS and simultaneously transmit to UEs. In the UL channel, a SBS may receivefrom UEs and simultaneously transmit data to the MBS. Therefore, a small-cell can completely remove the need of a separatebackhaul data transfer method, resulting in reduced cost.

In [9] suggested that the measurement of inter-user interference channel, and then, the allocation of UL andDL channels by a MBS could mitigate inter-user UL-to-DL interference in a single-cell full duplex radio network. However, inthe case of a multi-cell full duplex radio network, interference mitigation becomes more complex, because of the existence ofinterference in UL and DL channels between multi-cells' UEs that work on identical frequency and time.

6.2 Handoff Management in 5G Networks

Handoff provides a way to UEs connected to a BS to move to another BS without disconnecting their sessions.

Challenges in the handoff process in 5G networks. The handoff management in 5G networks has inherent challengesassociated with the current cellular networks, e.g., minimum latency, improved routing, security, and less uncertainty ofhaving no services. The network densification, very high mobility, the zero latency, and accessing multi-RATs make handoffmanagement in 5G networks harder. Also, the current cellular networks do not provide an efficient load balancing for a BS atthe time of handoff. Three types of handoffs are presented in the context of 5G networks, as follows:

1. Intra-macrocell handoff: refers to handoff between small-cells that are working under a single MBS.
2. Inter-macrocell handoff: refers to handoff between macrocells. It may also lead to handoff between two small-cells thatare working under different MBSs. Note that if the handover between small-cells of two different MBSs is not doneproperly, then the inter-macrocell handoff also fails.
3. Multi-RATs handoff: refers to handoff of a UE from a RAT to other RAT.A handoff mechanism for highly mobile users are provided in [25], where a UE sends some parameters (e.g. QoS,signal-to-interference ratio (SIR), and time to handoff) in a measurement report to the current MBS. SIR is considered asa primary factor for finding a situation for an initiation of the handoff. The Gray system model predicts the currentmeasurement report from the previousmeasurement report. The predicted value is used for the final decision for the handoverprocess. A handoff mechanism supported by a MBS are proposed in [25]. The MBS collects several parameters fromUEs, and if the MBS finds the values of the received parameters below a threshold, then it finds a new SBS or MBS for handoffand informs to the UEs.

For handoff over different RATs, a handoff procedure is proposed in [39], so that a UE can select the most suitableRAT without any performance loss. A UE collects RSS or quality from thecurrent MBS, and then, it initiates handoff if quality is below a threshold. The UE collects several parameters (e.g., transmittedpower, the cell's traffic load, and UE requested spectral efficiency) from adjacent BSs, and then, selects the most suitable BS.

An authenticated handoff procedure for C-RANs and multi-tier 5G networks are provided in [40]. The control layerholds an authentication handover module (AHM) for monitoring and predicting the future location of UEs (based on thecurrent location) and preparing relevant cells before UEs' arrival in that. UEs sends ID, the physical layer's attributes, location, speed, and direction to the control layer in a securemanner for the handoff process. The proposed approach reduces the risk of impersonation and man-in-the-middle attacks.

6.3 QoS Management in 5G Networks

In this section, we will review some techniques/methodsfor QoS management in 5G networks.

In [22] provided a mechanism for different delay-bounded QoS for various types of services, applications, andusers having diverse requirements, called heterogeneous statistical delay-bounded QoS provisioning (HSP). HSP maximizesthe aggregate effective capacity of different types of 5G architectures. HSPalgorithm claims better performance over other approaches; however, it imposes new challenges in terms of the assignment ofdifferent resources for different links under the cover of delay-bounded QoS requirements.

The deployment of a quality management element (QME) in the cloud for monitoring inter-UEsand inter-layer (the control and the data layers in C-RANs) QoS are proposed in [8]. RRUs send wireless information (e.g., CSI, reference signalreceived quality, and resource block utilization) to the QME. Consequently, the QME executes service control algorithms (tomanage QoS and some other activities like traffic offloading and customized scheduling), and then, sends scheduling strategiesto the RRUs to achieve a desired level of QoS.

A routing algorithm for multi-hop D2D communicationare provided in [41]. The algorithm takes into account differentQoS for each link so that it can achieve better performance than max-min routing algorithms. The algorithm increases flowuntil it provides the desired QoS or reaches the maximum capacity of the link. Since the algorithm considers individual links,there is a high probability that some of the channels will serve multiple-links with the desired QoS. A QoS-aware and energy-efficient resource allocation algorithm for DL channelsare providedin [42], where UEs are allocated an identical powerin one case and non-identical power in the second case. The algorithm maximizes energy-efficiency while minimizes transmitpower.

6.4 Load balancing management in 5G Networks

Load balancing means allocation of resources to a cell such that all the users meet their demands. Load balancing has attracted much attention as a promising solution for higher resource utilization, improved system performance and decreased operational cost. It is an effective method for balancing the traffic and alleviating the congestion among heterogeneous networks in the upcoming 5G networks.

The unprecedented increase in the mobile data traffic volume, as well as the need for network coverage expansion are major concerns for mobile operators. Hence, it is becoming important to be able to offload data from the mobile network to the Wi-Fi network. Today 20% of data is landing on Wi-Fi in outdoor environment while 60% of data is landing in Wi-Fi in indoor environments. In highly populated areas, even an 80% of data is landing in Wi-Fi networks. Therefore, the offloading from an eNodeB to Wi-Fi AP can lead to be able to load balance the overloaded commercial eNodeBs [43].In [14] provided a technique forcell association based on dynamic resources and traffic in a cell. In a fast movingvehicle, e.g., a train, it is very hard to allocate resources without any service interruption at all.

6.5 Channel Access Control Management in 5G Network

Channel access protocols allow several UEs to share a transmission channel without any collision while utilizing the maximumchannel capacity.

Challenges in channel access control management in 5G networks. Channel access control management in 5G networksfaces inherent challenges associated with the current cellular networks, e.g., synchronization, fairness, adaptive rate control,resource reservation, real-time traffic support, scalability, throughput, and delay. In addition, providing the currently availablebest channel in 5G networks is subject to additional challenges, such as: high mobility of UEs, working at the higher frequencies greater than 3GHz, different RATs, dense networks, high QoS, high link reliability, and the zero latency for applications and services.

A frame-based medium access control protocol for mmWave-based small-cells are proposed in [44]. It consists of two phases, as: (a) scheduling phase, when a SBS collects the traffic demands from the supported UEsand computes a schedule for data transmission, and (b) transmission phase, when the UEs start concurrent transmissionsfollowing the schedule. A schedule, which is computed using a graph-edge coloring algorithm, consists of a sequence oftopologies and a sequence of time intervals for indicating how long each topology should sustain.

MAC protocols for UEs of small-cells and macrocells are provided in [45]. Two types of MAC protocols for SBS'sUEs are suggested, as: contention-based random channel access (CRCA), where UEs randomly access the channel and sendmessages if the channel is available, and reservation-based channel access (RCA), which uses time division multiple access.

For macrocells' UEs, they provided a MAC protocol for CRN-based 5G networks, where SUs sense a licensed channel untilit is free or the residual energy of SUs exceeds a predetermined threshold, for saving their battery. Further, they evaluated atradeoff between the network throughput and sensing overhead.

Two CRN-based channel access techniques for cognitive SBSs are suggested in [46], one of them is similar to CRCA [45] and the other works identically as RCA [45] for increasing opportunistic spectrum access performance. A multi-user sparse code multiple access (MU-SCMA) for increasing DL's spectralefficiency are provided in [47]. MU-SCMA does not require the complete CSI, and hence, provides high data rate and the robustness to mobility. It also provided an uplink contention based SCMA for massive connectivity, data transmission with lowsignaling overhead, low delay, and diverse traffic connectivity requirements.

6.6 Privacy and Security Management in 5G Networks

In this section, we present security and privacy related challenges and a discussion of security and privacy protocols in thecontext of 5G networks.

Challenges in security and privacy in 5G networks. Authentication is a vital issue in any network. Due to the zero latencyguarantee of 5G networks, authentication of UEs and network devices is very challenging, since the current authenticationmechanisms use an authentication server that takes hundreds of milliseconds delay in a preliminary authentication phase [40].

A fast and frequent handover of UEs over small-cells requires for a robust, efficient, and secure handoff process for transferringcontext information [40]. Security to multi-RATs selection is also challenging, since each RAT has its own challenges andcertain methods to provide security; clearly, there is a need to provide overlapped security solutions across the various types ofRATs. C-RANs also inherit all the challenges associated with the cloud computing and wireless networks. In addition, severalother challenges (e.g., authorization and access control of UEs, availability of the network, confidentiality of communicationand data transfer, integrity of communication and data transmission, accounting and auditing of a task, low computationcomplexity, and communication cost) require sophisticated solutions to make a secure 5G network. The security and latencyare correlated as a higher level of security and privacy results in increased latencies. Therefore, the communication satisfyingthe zero latency is burdensome when combined with secure and privacy-preserving 5G networks.

Monitoring is suggested for securing the network and detecting intruders [48]. However, monitoring a large numberof UEs (by a trusted authority) is hard task.In [49] focused on the physical layer security, which is independent of computational complexity and easily handlesany number of devices. The physical layer security protocol considers locations of UEs and provides the best way for UEsfor securely selecting a MBS or a SBS without overloading the network. A method for secureand private D2D communications, called close access are provided in [31], where D-UEs have a list of other trusted D-UEs devices, and all suchUEs can communicate directly using an encryption scheme while the remaining UEs not in the list utilize a MBS-assistedcommunication. An encryption based video sharing scheme and a policy-based scheme that can prevent DoS and spoofing attacks are presented in [50].

VII. METHODOLOGIES AND TECHNOLOGIES FOR 5G NETWORKS

We have reviewed some of the methodologies and technologies in the previoussections, such as: D2D communication,multi-tier heterogeneous deployment or dense-deployment techniques, C-RANs, CRNs, and Energy efficient of communication systems in 5Gin Section 5 and techniques related to interference, QoS, handoff,channel access, load balancing,privacy and security management in 5G Networks in Section 6. This section will briefly describe some techniques that are mentioned but not explained in earlier sections.

Self-Interference Cancellation (SIC). When a full duplex radio receives signals from another radio, it also receivesinterference signals by its own transmission, resulting in self-interference. Hence, a full duplex radio has to implementtechniques to cancel self-interference. SIC techniques are classified into passive and active cancellations as in [51]. The implementation of SIC has many advantages whichenables seamless global roaming, high-throughput services, andlow-latency applications in a cost effective manner [17].

Massive MIMO. Massive multiple-inputmultiple-output (mMIMO) proposes utilizing avery high number of antennas to multiplex messagesfor several devices on each time-frequencyresource, focusing the radiated energy towardthe intended directions while minimizing intraandintercell interference. Hence, expensive equipment are mounted on a MBS [52]. A mMIMO system relies on spatial multiplexing, which in turn relies on the channel knowledge at MBS, on both UL and DL channels. A mMIMO system reduces latency and energy, simplifies the MAC layer, shows robustness against intentional jamming, and increases the capacity due to spatial multiplexing.

Massive MIMO mayrequire major architectural changes, particularlyin the design of macro base stations, and it mayalso lead to new types of deployments.

Network Function Virtualization (NFV). NFV implements network functions such as network address translation,domain name service,firewalls, intrusion detection, the traffic load management, and caching through software running oncommodity servers. However, the conventional networks implement these functions on dedicated and application specificservers. Hence, NFV decreases the burden on network operators by not updating dedicatedservers/hardware, thereby savescost.

Software-Defined Networking (SDN). SDN architectures [53] partition network control functions and data forwardingfunctions, thereby the network control functions are programmable, and the network infrastructure handles applications andnetwork services. SDN architectures can be divided into three parts, as: (a) the software controller: holds network controlfunctions such as the network manager, APIs, network operating system, and maintaining the global view of the network;(b) the southbound part: provides an interface and a protocol between the controller and SDN-enable infrastructure, whereOpenFlow [54] is the most famous protocol that provides communication between the controller and the southbound part; (c)the northbound part: provides an interface between SDN applications and the controller [55]. Note that SDN, NFV, and C-RANs offload functionalities to software running on commodity servers. However,SDN separates network control functions from data forwarding functions, while NFV implements network functions insoftware. Besides that, C-RANs integrate both SDN and NFV to meet the flexibility and scalability requirements inthe future mobile networks.

Security and Privacy. The security and privacy issues in 5G may be easily highlighted when recognizing the key supporting technology in 5G. As defined in the above in this section, mMIMO antennas, SDN, NFV and cloud networking are the key facilitation and transformative developments concerned to previous generations. SDN, NFV and cloud infrastructure have rich literature in terms of security and these have been used in wired networks [54]. Now, we only highlight the key technologies in terms of security for 5G, e.g., Security in massive MIMO, Security in SDN, Security in NFV and Security in Cloud Applications.

Since it is expected that the huge number of devices shall be connected with upcoming 5G network which includes massive number of Internet of Things (IoT) devices so these shall introduce new security issues and challenges for the 5G network. Currently three communication protocols are widely used which are based on cryptographic algorithms. The communication protocols are; IEEE 802.15.4, standard IPv6 over low-power Wireless Personal Area Networks (6LoWPAN) Standard, and Constrained Application Protocol. With the introduction of quantum computing and massive capacity of the network these protocols shall not be secured for communication. Following are the briefly defined recommended techniques for the strong security of the 5G network.

a. Security using software

Security functions implemented in software being able to be deployed in any network perimeter based on necessity, shall provide many opportunities to strengthen the network security. A number of firewall applications such as Flow Guard and OpenFlow firewall software can be Considered as the basic step towards softwarized security for Softwarized and virtualized networks [54].

b. Artificial Intelligent (AI)-based Security

The monitoring and analysis of massive devices on network shall require self-adaptive intelligence system and such type of systems shall employ innovative algorithms and techniques of artificial intelligence, consequently, cyber-security may become one of the best application areas for AI. Security services such as authentication and access control need to be proactively carried out within the time constraints in order to meet the main service requirements such as service migration from one edge node to another. In doing so, AI shall play a critical role to timely identify the terminal actions and requirements to avoid serviceinterruptions. Apart from this we can also use security automation and Blockchain security perspective techniques in order toenhance security.

Millimeter Waves (mmWave). The current wireless bandwidth is not able to support a huge number of UEs in 5G networks.

It is believed that 5G access networks for some services will require very wide adjacent carrier bandwidths from several hundred MHz up to several GHz, to be provided at a very high overall system capacity. To support the requirements for wide adjacent bandwidths, carrier frequencies above 6 GHz need to be considered. Wide contiguous bandwidth can be obtained with higher carrier frequencies that can provide for very high overall system capacity [56]. Now the effective user range will be relatively short, therefore there is a possibility of very efficient frequency reuse over a given geography.

Hence, researchers are looking at 30 GHz to 300 GHz frequency bands, where mmWave communication is proposed for achieving high-speed data transfer. The current research focuses on 28 GHz band, 38 GHz band, 60 GHz band, and the E-band (71–76 GHz and 81–86 GHz) [11].

With higher carrier frequency the propagation conditions become more in demand than at the traditionally used lower frequencies for wireless services. However, the path loss and diffraction loss both become more severe, the water vapors and oxygen consume mm-wave energy. The oxygen particle absorbs electromagnetic energy at around 60 Gigahertz, therefore atmospheric effects must be accounted for, and the use of directional antennas becomes necessary. The result will be relatively short links which to some degree basically depends on line-of-sight paths. In fact, this can be considered as benefit rather than a drawback, in order to provide high capacity, cell sizes are becoming smaller in dense urban settings (e.g. of the order of hundreds of meters). Furthermore, advances in technology like 3D beam-forming and massive MIMO techniques will achieve their full potential when taking advantage of the short wave-lengths, which come with high frequency bands.

Downlink and Uplink Decoupling (DUD). In the current cellular networks, a UE is associated with a BS based on thereceived signal power in its DL channel, and then, uses the same BS for UL channel transmission [57]. DUD allows a UE toselect a DL channel and a UL channel from two different BSs, based on the link quality, the cell load, and the cell backhaulcapacity. Therefore, a UE may have the DL channel connected through a BS and the UL channel connected through a different BS, resulting in a user-centric 5G architecture and improving the capacity of UL channels, which is a prime concern.

Visual Light Communication (VLC). VLC is a high-speed data transfer medium for short range LOS optical links inthe future cellular networks. The light-emitting diodes (LEDs) provide VLC using amplitude modulation at higherfrequencies and achieve higher data rates while keeping the LED’s primary illumination function unaffected. VLC can beused for outdoor applications, where high power laser-based equipment provides transmission links, and for indoor application,where LEDs provide short distance transmission links. VLC is an energy-efficient technology, works on a wider range ofunregulated frequency bands, shows high spatial reuse, and inherits security due to LOS. However, VLC is sensitive tosunlight and not able to work for a long range without LOS, and hence, limited coverage [58].

Green Communication and Energy Harvesting Networks

Recent developments in energy harvesting technologieshave made the vision of self-sustaining devices andBSs potentially possible. As such, energy harvesting ishighly desirable both for improving the energy efficiency of networksand for prolonging the battery life [59].

The deployment of renewable energy sources to supplementthe conventional power grid for powering BSs absolutely supports the trend of green communication. However, theinterrupted nature of renewable energy sources requires arethinking of the traditional user association rules designedfor traditional cellular networks relying on constant gridpower supply. The existing research contributions regardinguser association for renewable energy powered networks aimfor maximizing the exploitation of renewable energy, whilemaintaining the QoS guarantees. On the other hand, the smartgrid, as one of the use cases envisioned for 5G networks [60],has paved the way for energy cooperation in networks. Energycooperation between BSs allows the BSs that have excessiveharvested renewable energy to support other BSs that have anenergy deficit via renewable energy transfer. According to the specific sources of the harvestedenergy, energy harvesting networks may be categorizedas follows:-

a. BSs and users may harvest renewable energy fromthe environment, such as solar energy or wind energy.

b. Alternatively, BSs and users can harvest energy fromambient radio signals, relying on RF energy harvesting.

In this context, both the renewable energy harvestedby the BSs and the RF energy harvested by the users willsimultaneously play a crucial role in determining the userassociation, where the user association algorithm should becarefully redesigned for suitable QoS provision and energyconsumption reduction.

Fast caching. Caching is a way for storing temporary data for reducing data access from slow memory or the network. Ina network, content caching is popular and answers the request while responding in place of the application servers as aproxy, thereby reducing the amount of hits that are directly sent to the ultimate backend server. UEs will have enoughmemory in the future, and they can work as a cache for any other UE, since a small amount of popular data requires to becached. A caching mechanism based content centric networking (CCN) are provided in [61], assuming 5G networkswill include CCN-capable gateways, routers, and MBSs. CCN provides in-network data storage, also known as universalcaching, at every node in the network. The cached data is uniquely identified at each node. Accordingly, a user can request fora particular content from the content cache of any device within the network, or the request is forwarded to the actual sourceof content storage.

Machine-to-Machine (M2M) communication. M2M communication refers to the communication between (network) devices (e.g., sensors/monitoring-devices with a cloud) without human intervention. Some examples of M2M communication are intelligent transport systems, health measurement, monitoring of buildings, gas and oil pipelines, intelligent retail systems, and security and safety systems. However, the development of M2M communication involves several challenges to be handled in the future, as follows: connectivity of massive devices, bursty data, the zero latency, scalability in terms of supporting devices, technologies and diverse applications, fast and reliable delivery of messages, and cost of devices. In addition, the development of efficient algorithms for location, time, group, priority, and multi-hop data transmission management for M2M communication is needed [15].

VIII. FUTURE WORK

- The deployment of small-cells results in several types of interferences, as: intra-tier and inter-tier interference. Hence, it is also required to develop models to handle these interferences.
- Current cellular networks are not energy-efficient as they consume energy in circuits, cooling systems, and also radiate in air. Hence, an energy-efficient deployment of a CRN in a cellular network is of utmost importance and needs more investigations.
- In D2D communication, D-UEs may take helps from other UEs as relay nodes; hence, it is required to communicate and transfer data in secure and privacy-preserving manners. Consequently, the designing of energy-efficient and trust-making protocols is an open issue.Also, in the current design of D2D communication, UEs can do either D2D communication or communication to a BS. Hence, there is a need to design a system that allows a UE to engage the two types of communication modes simultaneously.
- Handoff mechanisms are yet to be explored. It will be interesting to find solutions to extremely dense HetNets.Furthermore, the handoff process may also create interference to other UEs; hence, it is required to develop algorithms while considering different types of interferences in 5G networks and a tradeoff between the number of handoffs and the level of interference in the network.
- The 5G networks are supposed to satisfy the highest level of QoS. The tactile Internet requires the best QoS, especially, latency of the order of 1 millisecond for senses of human perception. However, the current architectures do not support efficient tactile Internet services.In future, it would be a promising area as to encode senses, exchange data satisfying the zero latency, and enable the user to receive the sensation.
- The current security and privacy solutions to 5G networks are not strong efficient and unable to handle massive connections. We can clearly visualize a potential scope for developing secure data transmission, end-to-end security, secure and private storage, threats resistant UEs, and valid network and software access.

IX. CONCLUSIONS

This paper has discussed outstanding features, requirements, challenges and technologies involved in the development of the 5G of cellular mobile communication that is expected to provide very high-speed data transfer and ubiquitousconnectivity among various types of devices. It has reviewed some architectures for 5G networks based on the inclusion ofsmall-cells, CRN, D2D communication, and cloud-based radio access networks. We findout that energy consumption by the infrastructure is going to be a major concern in 5G networks, and hence, reviewedenergy-efficient architectures. We figured out several open issues, which may drive the future inventions and research, in allthe architectures.

The development of new architectures is not only a concern in 5G networks; there will be a need for manipulating otherimplementation issues in the context of users, e.g., interference cancellation, handoff management, QoS guarantee, channelaccessing, privacy and security management and in the context of infrastructures, e.g., load balancing. During our clarification through paper, we have also highlighted a number of challenges in the implementation of 5G networks and the key technological components of 5G, e.g., full duplex radios, dense-deployment techniques, SIC, DUD, mmWave, mMIMO, NFV, SDN, fast caching, VLC, M2M andGreen Communication and Energy Harvesting Networks. Our discussion concluded with a concept that the design of 5G infrastructure is still under progress and some open issues need to be investigated.
However, all the existing architectures and implementations of 5G networks are far from achieving the zero latency.Therefore, it is paramount desired that the latest real-time and ultra-reliable network configurations must be enhanced to alatency free environment.

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