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A Survey of 5G Network: Architecture and Emerging Technologies

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ABSTRACT In the near future, i.e., beyond 4G, some of the prime objectives or demands that need to be addressed are increased capacity, improved data rate, decreased latency, and better quality of service. To meet these demands, drastic improvements need to be made in cellular network architecture. This paper presents the results of a detailed survey on the fifth generation (5G) cellular network architecture and some of the key emerging technologies that are helpful in improving the architecture and meeting the demands of users. In this detailed survey, the prime focus is on the 5G cellular network architecture, massive multiple input multiple output technology, and device-to-device communication (D2D). Along with this, some of the emerging technologies that are addressed in this paper include interference management, spectrum sharing with cognitive radio, ultra-dense networks, multi-radio access technology association, full duplex radios, millimeter wave solutions for 5G cellular networks, and cloud technologies for 5G radio access networks and software defined networks. In this paper, a general probable 5G cellular network architecture is proposed, which shows that D2D, small cell access points, network cloud, and the Internet of Things can be a part of 5G cellular network architecture. A detailed survey is included regarding current research projects being conducted in different countries by research groups and institutions that are working on 5G technologies.

INDEX TERMS 5G, cloud, D2D, massive MIMO, mm-wave, relay, small-cell.

I. INTRODUCTION

Today and in the recent future, to fulfill the presumptions and challenges of the near future, the wireless based networks of today will have to advance in various ways. Recent technology constituent like high-speed packet access (HSPA) and long-term evolution (LTE) will be launched as a segment of the advancement of current wireless based technologies. Nevertheless, auxiliary components may also constitute future new wireless based technologies, which may adjunct the evolved technologies. Specimen of these new technology components are different ways of accessing spectrum and considerably higher frequency ranges, the instigation of massive antenna configurations, direct device-to-device communication, and ultra-dense deployments [1].

Since its initiation in the late 1970s, mobile wireless communication has come across from analog voice calls to current modern technologies adept of providing high quality mobile broadband services with end-user data rates of several megabits per second over wide areas and tens, or even hundreds, of megabits per second locally. The extensive improvements in terms of potentiality of mobile communication networks, along with the initiation of new types of mobile devices such as smart phones and tablets, have produced an eruption of new applications which will be used in cases for mobile connectivity and a resultant exponential growth in network traffic. This paper presents our view on the future of wireless communication for 2020 and beyond. In this paper, we describe the key challenges that will be encountered by future wireless communication while enabling the networked society. Along with this, some technology routes that may be taken to fulfill these challenges [1].

The imagination of our future is a networked society with unbounded access to information and sharing of data which is accessible everywhere and every time for everyone and everything. To realize this imagination, new technology components need to be examined for the evolution of existing wireless based technologies. Present wireless based technologies, like the 3rd Generation Partnership Project (3GPP) LTE technology, HSPA and Wi-Fi, will be incorporating new technology components that will be helping to meet the needs of the future. Nevertheless, there may be certain scenarios that cannot be adequately addressed along with the evolution of ongoing existing technologies. The instigation of completely new wireless based technologies will complement the current technologies which are needed for the long term realization of the networked society [2].

The remainder of the paper is organized as follows: In Section II, we present the evolution of wireless technologies. Section III gives the detailed description of the proposed general 5G cellular network architecture. Section IV comprises of the detailed explanation of the emerging technologies for 5G wireless networks. We conclude our paper in Section V. A list of current research projects based on 5G technologies is shown in the appendix.

II. EVOLUTION OF WIRELESS TECHNOLOGIES

G. Marconi, an Italian inventor, unlocks the path of recent day wireless communications by communicating the letter 'S' along a distance of 3Km in the form of three dot Morse code with the help of electromagnetic waves. After this inception, wireless communications have become an important part of present day society. Since satellite communication, television and radio transmission has advanced to pervasive mobile telephone, wireless communications has transformed the style in which society runs. The evolution of wireless begins here [2] and is shown in Fig. 1. It shows the evolving generations of wireless technologies in terms of data rate, mobility, coverage and spectral efficiency. As the wireless technologies are growing, the data rate, mobility, coverage and spectral efficiency increases. It also shows that the 1G and 2G technologies use circuit switching while 2.5G and 3G uses both circuit and packet switching and the next generations from 3.5G to now i.e. 5G are using packet switching. Along with these factors, it also differentiate between licensed spectrum and unlicensed spectrum. All the evolving generations use the licensed spectrum while the WiFi, Bluetooth and WiMAX are using the unlicensed spectrum. An overview about the evolving wireless technologies is below:

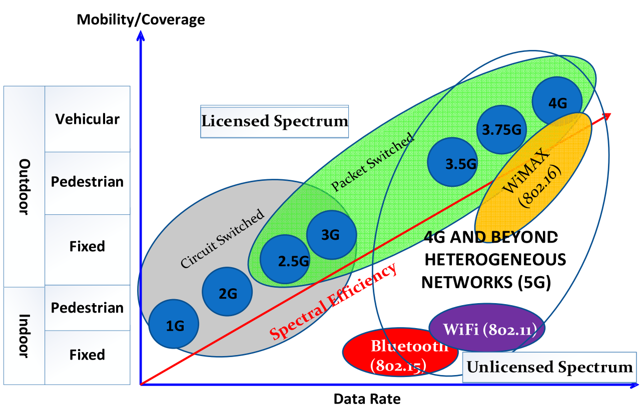

FIGURE 1. Evolution of wireless technologies.

A. 1G

The 1st generation was announced in initial 1980's. It has a data rate up to 2.4kbps. Major subscribers were Advanced Mobile Phone System (AMPS), Nordic Mobile Telephone (NMT), and Total Access Communication System (TACS). It has a lot of disadvantages like below par capacity, reckless handoff, inferior voice associations, and with no security, since voice calls were stored and played in radio towers due to which vulnerability of these calls from unwanted eavesdropping by third party increases [7].

B. 2G

The 2nd generation was introduced in late 1990's. Digital technology is used in 2nd generation mobile telephones. Global Systems for Mobile communications (GSM) was the first 2nd generation system, chiefly used for voice communication and having a data rate up to 64kbps. 2G mobile handset battery lasts longer because of the radio signals having low power. It also provides services like Short Message Service (SMS) and e-mail. Vital eminent technologies were GSM, Code Division Multiple Access (CDMA), and IS-95 [3], [7].

C. 2.5G

It generally subscribes a 2nd generation cellular system merged with General Packet Radio Services (GPRS) and other amenities doesn't commonly endow in 2G or 1G networks. A 2.5G system generally uses 2G system frameworks, but it applies packet switching along with circuit switching. It can assist data rate up to 144kbps. The main 2.5G technologies were GPRS, Enhanced Data Rate for GSM Evolution (EDGE), and Code Division Multiple Access (CDMA) 2000 [3], [7].

D. 3G

The 3rd generation was established in late 2000. It imparts transmission rate up to 2Mbps. Third generation (3G) systems merge high speed mobile access to services based on Internet Protocol (IP). Aside from transmission rate, unconventional improvement was made for maintaining QoS. Additional amenities like global roaming and improved voice quality made 3G as a remarkable generation. The major disadvantage for 3G handsets is that, they require more power than most 2G models. Along with this 3G network plans are more expensive than 2G [3], [7]. Since 3G involves the introduction and utilization of Wideband Code Division Multiple Access (WCDMA), Universal Mobile Telecommunications Systems (UMTS) and Code Division Multiple Access (CDMA) 2000 technologies, the evolving technologies like High Speed Uplink/Downlink Packet Access (HSUPA/HSDPA) and Evolution-Data Optimized (EVDO) has made an intermediate wireless generation between 3G and 4G named as 3.5G with improved data rate of 5-30 Mbps [3].

E. 3.75G

Long-Term Evolution technology (LTE) and Fixed Worldwide Interoperability for Microwave Access (WIMAX) is the future of mobile data services. LTE and Fixed WIMAX has the potential to supplement the capacity of the network and provides a substantial number of users the facility to access a broad range of high speed services like on demand video, peer to peer file sharing and composite Web services.

Along with this, a supplementary spectrum is accessible which accredit operators manage their network very compliantly and offers better coverage with improved performance for less cost [4]–[7].

F. 4G

4G is generally referred as the descendant of the 3G and 2G standards. 3rd Generation Partnership Project (3GPP) is presently standardizing Long Term Evolution (LTE) Advanced as forthcoming 4G standard along with Mobile Worldwide Interoperability for Microwave Access (WIMAX). A 4G system improves the prevailing communication networks by imparting a complete and reliable solution based on IP. Amenities like voice, data and multimedia will be imparted to subscribers on every time and everywhere basis and at quite higher data rates as related to earlier generations. Applications that are being made to use a 4G network are Multimedia Messaging Service (MMS), Digital Video Broadcasting (DVB), and video chat, High Definition TV content and mobile TV [2], [4]–[6].

G. 5G

With an exponential increase in the demand of the users, 4G will now be easily replaced with 5G with an advanced access technology named Beam Division Multiple Access (BDMA) and Non- and quasi-orthogonal or Filter Bank multi carrier (FBMC) multiple access. The concept behind BDMA technique is explained by considering the case of the base station communicating with the mobile stations. In this communication, an orthogonal beam is allocated to each mobile station and BDMA technique will divide that antenna beam according to locations of the mobile stations for giving multiple accesses to the mobile stations, which correspondingly increase the capacity of the system [8]. An idea to shift towards 5G is based on current drifts, it is commonly assumed that 5G cellular networks must address six challenges that are not effectively addressed by 4G i.e. higher capacity, higher data rate, lower End to End latency, massive device connectivity, reduced cost and consistent Quality of Experience provisioning [22], [23]. These challenges are concisely shown in Fig. 2 along with some potential facilitators to address them. An overview of the challenges, facilitators, and corresponding design fundamentals for 5G is shown in Fig. 2 [20]. Recently introduced IEEE 802.11ac, 802.11ad and 802.11af standards are very helpful and act as a building blocks in the road towards 5G [9]–[13]. The technical comparison between these standards is shown in table 1 and the detailed comparison of wireless generations is shown in table 2.

III. 5G CELLULAR NETWORK ARCHITECTURE

To contemplate 5G network in the market now, it is evident that the multiple access techniques in the network are almost at a still and requires sudden improvement. Current technologies like OFDMA will work at least for next 50 years. Moreover, there is no need to have a change in the wireless setup which had come about from 1G to 4G. Alternatively, there could be only the addition of an application or amelioration done at the fundamental network to please user requirements. This will provoke the package providers to drift for a 5G network as early as 4G is commercially set up [8]. To meet the demands of the user and to overcome the challenges that has been put forward in the 5G system, a drastic change in the strategy of designing the 5G wireless cellular architecture is needed. A general observation of the researchers has shown in [14] that most of the wireless users stay inside for approximately 80 percent of time and outside for approximately 20 percent of the time. In present wireless cellular architecture, for a mobile user to communicate whether inside or outside, an outside base station present in the middle of a cell helps in communication. So for inside users to communicate with the outside base station, the signals will have to travel through the walls of the indoors, and this will result in very high penetration loss, which correspondingly costs with reduced spectral efficiency, data rate, and energy efficiency of wireless communications. To overcome this challenge, a new idea or designing technique that has come in to existence for scheming the 5G cellular architecture is to distinct outside and inside setups [8]. With this designing technique, the penetration loss through the walls of the building will be slightly reduced. This idea will be supported with the help of massive MIMO technology [15], in which geographically dispersed array of antenna's are deployed which have tens or hundreds of antenna units. Since present MIMO systems are using either two or four antennas, but the idea of massive MIMO systems has come up with the idea of utilizing the advantages of large array antenna elements in terms of huge capacity gains.

To build or construct a large massive MIMO network, firstly the outside base stations will be fitted with large antenna arrays and among them some are dispersed around the hexagonal cell and linked to the base station through optical fiber cables, aided with massive MIMO technologies. The mobile users present outside are usually fitted with a certain number of antenna units but with cooperation a large virtual antenna array can be constructed, which together with antenna arrays of base station form virtual massive MIMO links. Secondly, every building will be installed with large antenna arrays from outside, to communicate with outdoor base stations with the help of line of sight components. The wireless access points inside the building are connected with the large antenna arrays through cables for communicating with indoor users. This will significantly improves the energy efficiency, cell average throughput, data rate, and spectral efficiency of the cellular system but at the expense of increased infrastructure cost. With the introduction of such an architecture, the inside users will only have to connect or communicate with inside wireless access points while larger antenna arrays remained installed outside the buildings [8]. For indoor communication, certain technologies like WiFi, Small cell, ultra wideband, millimeter wave communications [16], and visible light communications [17]

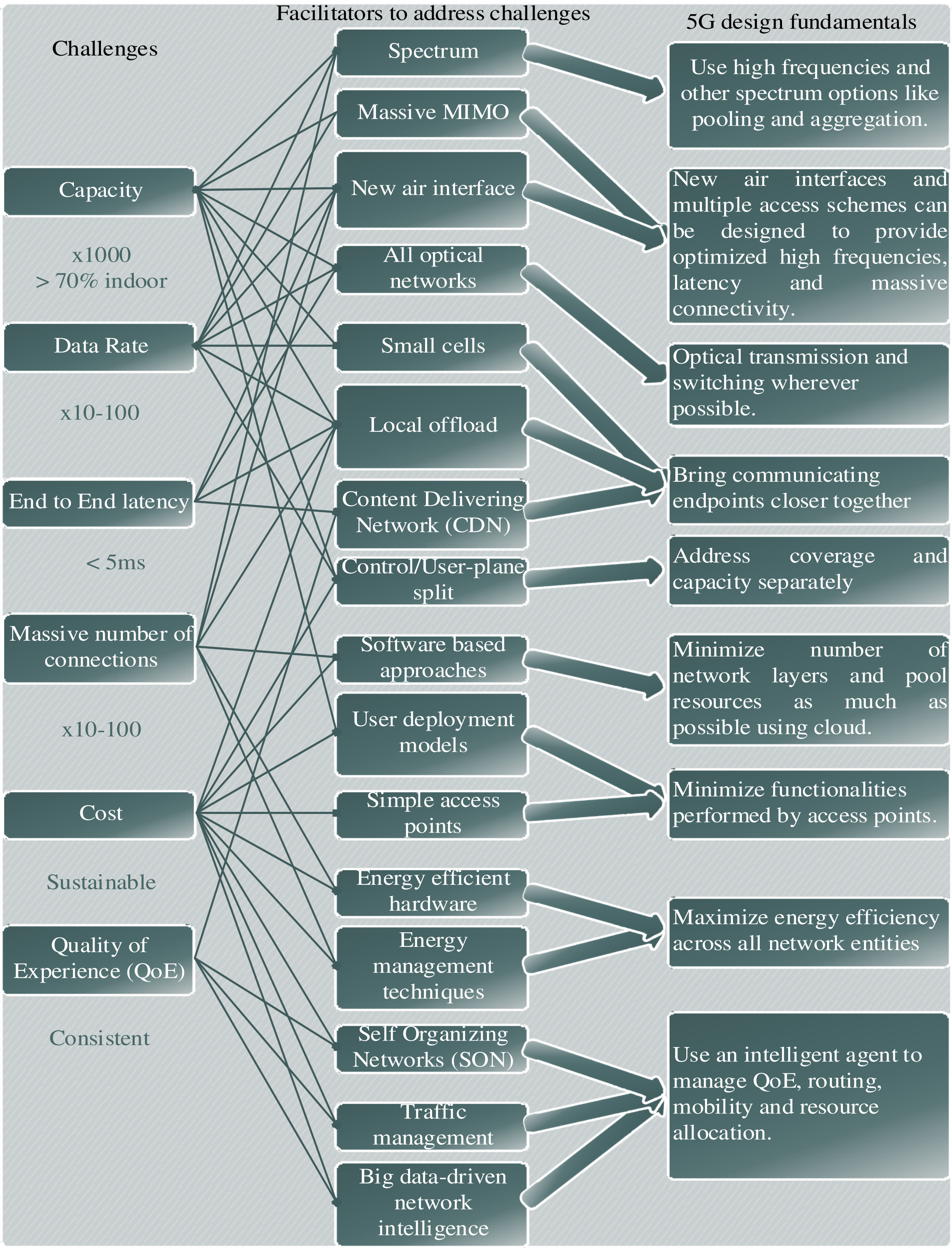

FIGURE 2. 5G challenge, facilitators, and design fundamental [20].

are useful for small range communications having large data rates. But technologies like millimeter wave and visible light communication are utilizing higher frequencies which are not conventionally used for cellular communications. But it is not an efficient idea to use these high frequency waves for outside and long distance applications because these waves

TABLE 1. Technical comparison between recent 802.11 standards.

Technical Specifications	802.11an	802.11ac	802.11ad	802.11af
Frequency	2.4, 4.9, 5GHz	5 GHz	60 GHz	0.47-0.71 GHz
Modulation scheme	OFDM	OFDM	OFDM, single carrier, low-power single carrier	OFDM
Channel bandwidth	20, 40 MHz	20, 40, 80 MHz (160 MHz optional)	2 GHz	5, 10, 20, 40 MHz
Nominal data rate, single stream	Up to 150 Mbps (1x1, 40 MHz)	Up to 433 Mbps (1x1, 80 MHz) Up to 867 Mbps (1x1, 160 MHz)	4.6 Gbps	54 Mbps
Aggregate nominal data rate, multiple streams	Up to 600 Mbps (4x4, 40 MHz)	Up to 1.73 Gbps (4x4, 80 MHz) Up to 3.47 Gbps (4x4, 160 MHz)	7 Gbps	
Spectral Efficiency	15 bps/Hz (4x4, 40 MHz)	21.665 bps/Hz (4x4, 80 MHz)	1 bps/Hz (2GHz)	NA
EIRP	22-36 dBm	22-29 dBm	1-10dBm	16-20 dBm
Range	12-70 m indoor	12-35 m indoor	60 m indoor, 100m outdoor	< 100m indoor < 5km outdoor
Through Walls	Y	Y	Y	Y
Non-Line-of-Sight	Y	Y	Y	Y
World-Wide Availability	Y	Y (Limited in china)	Y	Y

will not infiltrate from dense materials efficiently and can easily be dispersed by rain droplets, gases, and flora. Though, millimeter waves and visible light communications technologies can enhance the transmission data rate for indoor setups because they have come up with large bandwidth. Along with the introduction of new spectrum, which is not being conventionally used for wireless communication, there is one more method to solve the spectrum shortage problem by improving the spectrum utilization of current radio spectra through cognitive radio (CR) networks [18].

Since the 5G cellular architecture is heterogeneous, so it must include macrocells, microcells, small cells, and relays. A mobile small cell concept is an integral part of 5G wireless cellular network and partially comprises of mobile relay and small cell concepts [19]. It is being introduced to put up high mobility users, which are inside the automobiles and high speed trains. Mobile small cells are positioned inside the moving automobiles to communicate with the users inside the automobile, while the massive MIMO unit consisting of large antenna arrays is placed outside the automobile to communicate with the outside base station. According to user's opinion, a mobile small cell is realized as a regular base station and its allied users are all observed as a single unit to the base station which proves the above idea of splitting indoor and outdoor setups. Mobile small cell users [19] have a high data rate for data rate services with considerably reduced signaling overhead, as shown in [8]. As the 5G wireless cellular network architecture consists of only two logical layers: a radio network and a network cloud. Different types of components performing different functions are constituting the radio network. The network function virtualization (NFV) cloud consists of a User plane entity (UPE) and a Control plane entity (CPE) that perform higher layer functionalities related to the User and Control plane, respectively. Special network functionality as a service (XaaS) will provide service as per need, resource pooling is one of the examples. XaaS is the connection between a radio network and a network cloud [20].

The 5G cellular network architecture is explained in [8] and [20]. It has equal importance in terms of front end and backhaul network respectively. In this paper, a general 5G cellular network architecture has been proposed as shown in Fig. 3. It describes the interconnectivity among the different emerging technologies like Massive MIMO network, Cognitive Radio network, mobile and static small-cell networks. This proposed architecture also explains the role of network function virtualization (NFV) cloud in the 5G cellular network architecture. The concept of Device to Device (D2D) communication, small cell access points and Internet of things (IoT) has also been incorporated in this proposed 5G cellular network architecture. In general, this proposed 5G cellular network architecture may provide a good platform for future 5G standardization network.

But there are several issues that need to be addressed in order to realize the wireless network architecture in particular, and 5G networks in general. Some of these issues are summarized in Table. 3 [20].

IV. EMERGING TECHNOLOGIES FOR 5G WIRELESS NETWORKS

It is expected that mobile and wireless traffic volume will increase a thousand-fold over the next decade which will be driven by the expected 50 billion connected devices connected to the cloud by 2020 and all need to access and share data, anywhere and anytime. With a rapid increase in the number of connected devices, some challenges appear which will be responded by increasing capacity and by improving energy efficiency, cost and spectrum utilization as well as providing

TABLE 2. Evolution of wireless technologies.

Generations	Access Technology	Data Rate	Frequency Band	Bandwidth	Forward Error Correction	Switching	Applications
1G	Advanced Mobile Phone Service (AMPS) (Frequency Division Multiple Access (FDMA))	2.4 kbps	800 MHz	30 KHz	NA	Circuit	Voice
2G	Global Systems for Mobile communications (GSM) (Time Division Multiple Access (TDMA))	10 kbps	850/900/1800/1900 MHz	200 KHz	NA	Circuit	Voice + Data
	Code Division Multiple Access (CDMA)	10 kbps		1.25 MHz			
2.5G	General Packet Radio Service (GPRS)	50 kbps		200 KHz		Circuit/ Packet	
	Enhanced Data Rate for GSM Evolution (EDGE)	200 kbps		200 KHz			
3G	Wideband Code Division Multiple Access (WCDMA) / Universal Mobile Telecommunications Systems (UMTS)	384 kbps	800/850/900/ 1800/1900/ 2100 MHz	5 MHz	Turbo Codes	Circuit/ Packet	Voice + Data + Video calling
	Code Division Multiple Access (CDMA) 2000	384 kbps		1.25 MHz		Circuit/ Packet	
3.5G	High Speed Uplink / Downlink Packet Access (HSUPA / HSDPA)	5-30 Mbps		5 MHz		Packet	
	Evolution-Data Optimized (EVDO)	5-30 Mbps		1.25 MHz		Packet	
3.75G	Long Term Evolution (LTE) (Orthogonal / Single Carrier Frequency Division Multiple Access) (OFDMA / SC-FDMA)	100-200 Mbps	1.8GHz, 2.6GHz	1.4MHz to 20 MHz	Concatenated codes	Packet	Online gaming + High Definition Television
	Worldwide Interoperability for Microwave Access (WIMAX)(Scalable Orthogonal Frequency Division Multiple Access(SOFDMA)) — Fixed WIMAX	100-200 Mbps	3.5GHz and 5.8GHz initially	3.5MHz and 7MHz in 3.5GHz band; 10MHz in 5.8GHz band			
4G	Long Term Evolution Advanced (LTE-A) (Orthogonal / Single Carrier Frequency Division Multiple Access) (OFDMA / SC-FDMA)	DL 3Gbps UL 1.5Gbps	1.8GHz, 2.6GHz	1.4MHz to 20 MHz	Turbo codes	Packet	Online gaming + High Definition Television
	Worldwide Interoperability for Microwave Access (WIMAX)(Scalable Orthogonal Frequency Division Multiple Access(SOFDMA)) — Mobile WIMAX	100-200 Mbps	2.3GHz, 2.5GHz, and 3.5GHz initially	3.5MHz, 7MHz, 5MHz, 10MHz, and 8.75MHz initially			
5G	Beam Division Multiple Access (BDMA) and Non- and quasi-orthogonal or Filter Bank multi carrier (FBMC) multiple access	10-50 Gbps (expected)	1.8, 2.6 GHz and expected 30-300 GHz	60 GHz	Low Density Parity Check Codes (LDPC)	Packet	Ultra High definition video + Virtual Reality applications

better scalability for handling the increasing number of the connected devices. For the vision of all-communicating world relative to today's network, the overall technical aim is to provide a system idea that supports [21]:

- 1000 times increased data volume per area
- 10 to 100 times increased number of connected devices
- 10 to 100 times increased typical user data rate
- 10 times extended battery life for low power Massive Machine Communication (MMC) devices
- 5 times reduced End-to-End (E2E) latency

In this paper, we will cover a wide area of technologies with a lot of technical challenges arises due to a variety of applications and requirements of the user. To provide a common connected platform for a variety of applications and requirements for 5G, we will research the below technology components [21]:

- **Radio-links**, includes the development of new transmission waveforms and new approaches of multiple access control and radio resource management.
- **Multi-node and multi-antenna transmissions**, includes designing of multi-antenna transmission/reception technologies based on massive antenna configurations and developing advanced inter-node coordination schemes and multi-hop technologies.

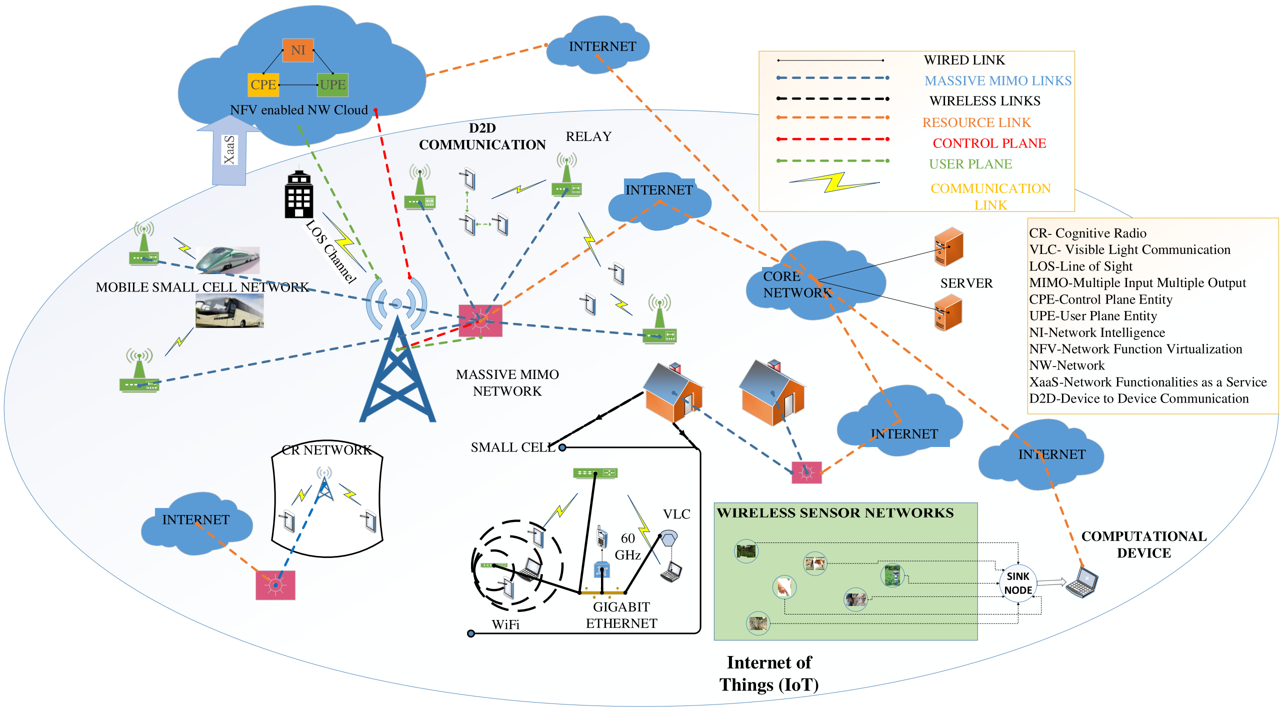

FIGURE 3. A general 5G cellular network architecture.

- **Network dimension**, includes considering the demand, traffic and mobility management, and novel approaches for efficient interference management in complex heterogeneous deployments.
- **Spectrum usage**, includes considering extended spectrum band of operation, as well as operation in new spectrum regimes to provide a complete system concept for new spectrum regimes that carefully addresses the needs of each usage scenario.

Now the topics which will integrate a subset of the technology components and provides the solution of some of the goals which are identified earlier are [21]:

- **Device-to-Device (D2D) communications** refers to direct communication between devices allowing local exchange of user plane traffic without going through a network infrastructure.
- **Massive Machine Communications (MMC)** will form the basis of the Internet of Things with a wide range of application fields including the automotive industry, public safety, emergency services and medical field.
- **Moving Networks (MN)** will enhance and extend linking together potentially large populations of jointly moving communication devices.
- **Ultra-dense Networks (UDN)** will be the main driver whose goals are to increase capacity, increase energy efficiency of radio links, and enable better exploitation of under-utilized spectrum.
- **Ultra-reliable Networks (URN)** will enable high degrees of availability.

In this section, we identify several technologies, ranked in perceived importance, which will be crucial in future wireless standards.

A. MASSIVE MIMO

Massive MIMO is an evolving technology that has been upgraded from the current MIMO technology. The Massive MIMO system uses arrays of antenna containing few hundred antennas which are at the same time in one time, frequency slot serving many tens of user terminals. The main objective of Massive MIMO technology is to extract all the benefits of MIMO but on a larger scale. In general, massive MIMO is an evolving technology of Next generation networks, which is energy efficient, robust, and secure and spectrum efficient [24].

Massive MIMO depends on spatial multiplexing, which further depends on the base station to have channel state information, both on the uplink as well as on the downlink. In case of downlink, it is not easy, but in case of uplink, it is easy, as the terminals send pilots. On the basis of pilots, the channel response of each terminal is estimated. In conventional MIMO systems, the base station sends the pilot waveforms to the terminals and based on these, the terminal estimate the channel, quantize it and feedback them to the base station. This process is not viable for massive MIMO systems, especially in high mobility conditions because of two reasons. Firstly the downlink pilots from the base station must be orthogonal among the antennas, due to which the requirement of time, frequency slots for the downlink pilots increases with the increase in the number

TABLE 3. Small cell setup options and concern [20].

	Operator-setup	User-setup
Licensed Spectrum	*Positives* • Operator controlled Cell sites. • Easier to provide Quality of experience • Realization of advanced resource allocation (RA) techniques turn out to be easier *Negatives* • Increased cost based on equipment, setup and operation • Limited spectrum • Spectrum license fees *Concern* • Backhaul provisioning	*Positives* • Reduced cost based on equipment, setup and operation *Negatives* • For later service customer sustenance, added operational cost is required *Concern* • Monitoring issues • Public or private access control • Ensuring Quality of experience • Effect of various backhaul types on advanced resource allocation techniques • Provisioning of over the air security
Unlicensed spectrum	*Positives* • Operator controlled Cell sites • Operators have extra spectrum for exploitation *Negatives* • Increased cost based on equipment, setup and operation • Lack of Quality of experience agreements *Concern* • Mechanisms to guarantee impartial performance • Concurrence with Wi-Fi, Bluetooth, etc. • Backhaul provisioning	*Positives* • Reduced cost based on equipment, setup and operation *Negatives* • Lack of Quality of experience agreements *Concern* • Access control • Mechanisms to guarantee impartial performance • Concurrence with Wi-Fi, Bluetooth, etc. • Effect of various backhaul types on advanced resource allocation techniques • Provisioning of over-the-air security

of antennas. So Massive MIMO systems would now require a large number of similar slots as compared to the conventional MIMO system. Secondly, as the number of base station antennas increases the number of the channel estimates also increases for each terminal which in turn needed hundred times more uplink slots to feedback the channel responses to the base station. A general solution to this problem is to work in Time Division Duplexing (TDD) mode and depend on the reciprocity amid the uplink and downlink channels [25].

Massive MIMO technology depends on phase coherent signals from all the antennas at the base station, but the computational processing of these signals is simple. Below are certain positives of a massive MIMO system [24]:

1) MASSIVE MIMO HAS THE CAPABILITY THAT IT CAN IMPROVE THE RADIATED ENERGY EFFICIENCY BY 100 TIMES AND AT THE SAME TIME, INCREASES THE CAPACITY OF THE ORDER OF 10 OR MORE

The positive of increase in capacity is because of the spatial multiplexing technique used in Massive MIMO systems. Regarding the improvement in the radiated energy efficiency, it is because of the increase in the number of antennas, the energy can now be concentrated in small regions in the space. It is based on the principle of coherent superposition of wave fronts. After transmitting the shaped signals from the antennas, the base station has no role to play by confirming that all the wave fronts that have been emitted from the antennas possibly will add constructively at the intended terminal's locations and destructively elsewhere. Zero forcing is used to suppress the remaining interference between the terminals, but at the expense of increased transmitted power [24].

The desirability of maximum ratio combining (MRC) is more as related to Zero forcing (ZF) because of its computational ease i.e. received signals are multiplied by their conjugate channel responses and due to the reason that it is executed in a dispersed mode, autonomously at every antenna element. Though ZF also works equally well for an orthodox MIMO system which MRC normally does not. The main reason behind the efficient use of the MRC with massive MIMO involving large number of base station antennas, the channel responses allied with different terminals tend to be almost orthogonal.

With the use of MRC receiver, we are operating in a noise restricted system. MRC in Massive MIMO system will scale down the power to an extent possible deprived of really upsetting the overall spectral efficiency and multiuser interference, but the effects of hardware deficiencies are likely to be overcome by the thermal noise. But the intention behind the overall 10 times higher spectral efficiency as compared to conventional MIMO is because 10 times more terminals are served concurrently in the same time frequency resource [26].

2) MASSIVE MIMO SYSTEMS CAN BE PUT TOGETHER WITH THE HELP OF LOW POWER AND LESS COSTLY COMPONENTS

Massive MIMO has come up with a change with respect to concept, schemes and execution. Massive MIMO systems use hundreds of less expensive amplifiers in respect to expensive ultra-linear 50 Watt amplifiers because earlier are having an output power in the milliwatt range, which is much better than the latter which are generally being used in conventional systems. It is dissimilar to conventional array schemes, as it will use only a little antenna's that are being fed from high power amplifiers but having a notable impact. The most significant improvement is about the removal of a large number of expensive and massive items like large coaxial cables [24].

With the use of a large number of antennas in massive MIMO technology the noise, fading and hardware deficits will be averaged because signals from a large number of antennas are combined together in the free space. It condenses the limits on precision and linearity of every single amplifier and radio frequency chain and altogether what matters is their collective action. This will increase the robustness of massive MIMO against fading and failure of one of the antenna elements.

A massive MIMO system has degrees of freedom in excess. For example, with 100 antennas, 10 terminals are showing presence while the remaining 90 degrees of freedom are still available. These available degrees of freedom can be exploited by using them for signal shaping which will be hardware friendly. Specifically, each antenna with the use of very cheap and power proficient radio frequency amplifiers can transmit signals having small peak to average ratio [27] and constant envelope [28] at a modest price of increased total radiated power. With the help of constant envelope multiuser precoding, the signals transmitted from each antenna are neither being formed in terms of beam nor by weighing of a symbol. Rather, a wave field is created and sampled with respect to the location of the terminals and they can see precisely the signals what we intended to make them see. Massive MIMO has a vital property which makes it possible. The massive MIMO channel has large null spaces in which nearly everything can be engaged without disturbing the terminals. Precisely modules can be placed into this null space that makes the transmitted waveforms fulfill the preferred envelope restraints. Nevertheless, the operative channels amid the base station and every terminal, can be proceeded without the involvement of PSK type modulation and can take any signal constellation as input [24].

The considerable improvement in the energy efficiency facilitates massive MIMO systems to work two steps of lower magnitude than with existing technology on the total output RF power. This is important because the cellular base stations are consuming a lot of power and it is an area of concern. In addition, if base stations that consume less power could be driven by renewable resources like solar or wind and therefore it is helpful to deploy base stations to the places where electricity is not available. Along with this, the increased concerns of electromagnetic exposure will be considerably less.

3) MASSIVE MIMO PERMITS A SUBSTANTIAL DECREASE IN LATENCY ON THE AIR INTERFACE

Latency is the prime area of concern in the next generation networks. In wireless communication, the main cause of latency is fading. This phenomenon occurs amid the base station and terminal, i.e. when the signal is transmitted from the base station, it travels through different multiple paths because of the phenomenon's like scattering, reflection and diffraction before it reaches the terminal. When the signal through these multiple paths reaches the terminal it will interfere either constructively or destructively, and the case when following waves from these multiple paths interfere destructively, the received signal strength reduces to a considerable low point. If the terminal is caught in a fading dip, then it has to wait for the transmission channel to change until any data can be received. Massive MIMO, due to a large number of antennas and with the idea of beam forming can avoid fading dips and now latency cannot be further decreased [24].

4) MASSIVE MIMO MAKES THE MULTIPLE ACCESS LAYER SIMPLE

With the arrival of Massive MIMO, the channel strengthens and now frequency domain scheduling is not enough. OFDM provides, each subcarrier in a massive MIMO system with considerably the same channel gain due to which each and every terminal can be provided with complete bandwidth, which reduces most of the physical layer control signaling terminated [24].

5) MASSIVE MIMO INCREASES THE STRENGTH EQUALLY AGAINST UNINTENDED MAN MADE INTERFERENCE AND INTENDED JAMMING

Jamming of the wireless systems of the civilian is a prime area of concern and poses a serious threat to cyber security. Owing to limited bandwidth, the distribution of information over frequency just is not possible. Massive MIMO offers the methods of improving robustness of wireless communications with the help of multiple antennas. It provides with an excess of degrees of freedom that can be useful for canceling the signals from intended jammers. If massive MIMO systems use joint channel estimation and decoding instead of uplink pilots for channel estimation, then the problem from the intended jammers is considerably reduced [24].

The advantages of massive MIMO systems can be reviewed from an information theoretic point of view. Massive MIMO systems can obtain the promising multiplexing gain of massive point to point MIMO systems, while eliminating problems due to unfavorable propagation environments [29].

Let us study a massive MIMO system having L cells, where every cell has K attended single antenna users and one base station with N antennas. $h_{i,k,l,n}$ represent the channel coefficient from the k-th user in the l-th cell to the n-th antenna of the i-th base station, which is equivalent to a complex small scale fading factor time an amplitude factor that interprets for geometric attenuation and large-scale fading:

$$h_{i,k,l,n} = g_{i,k,l,n}\sqrt{d_{i,k,l}} \tag{1}$$

Where $g_{i,k,l,n}$ and $d_{i,k,l}$ represent complex small scale fading and large scale fading coefficients, respectively. The small scale fading coefficients are implicit to be diverse for diverse users or for diverse antennas at every base station though the large scale fading coefficients are the same for diverse antennas at the same base station, but are user dependent. Then, the channel matrix from all K users in the l-th cell to the i-th base station can be expressed as

$$H_{i,l} = \begin{pmatrix} h_{i,1,l,1} & \cdots & h_{i,K,l,1} \\ \vdots & \ddots & \vdots \\ h_{i,1,l,N} & \cdots & h_{i,K,l,N} \end{pmatrix} = G_{i,l}D_{i,l}^{1/2} \tag{2}$$

Where

$$G_{i,l} = \begin{pmatrix} g_{i,1,l,1} & \cdots & g_{i,K,l,1} \\ \vdots & \ddots & \vdots \\ g_{i,1,l,N} & \cdots & g_{i.K,l,N} \end{pmatrix} \tag{3}$$

$$D_{i,c} = \begin{pmatrix} d_{i,1,l} & \cdots & \cdots \\ \vdots & \ddots & \vdots \\ \cdots & \cdots & d_{i.K,l} \end{pmatrix} \tag{4}$$

Let us study a single cell (L = 1) massive MIMO system with K singled antenna users and a base station with N antennas. For ease, the cell and the base station indices are plunged when single cell systems are deliberated [29].

a: UPLINK

The received signal vector at a single base station for uplink signal transmission is denoted as $y_u \in C^{N*1}$, can be stated as:

$$y_u = \sqrt{\rho_u}Hx_u + n_u \tag{5}$$

where $x_u \in C^{K*1}$ is the signal vector from all users, $H \in C^{N*K}$ is the uplink channel matrix defined in (2) by reducing the cell and the base station indices, $n_u \in C^{N*1}$ is a zero mean noise vector with complex Gaussian distribution and identity covariance matrix, and ρ_u is the uplink transmit power. The transmitted symbol from the k-th user, x_k^u, is the k-th element of $x_u = [x_1^u, \ldots, x_K^u]^T$ with $[|x_k^u|^2] = 1$.

The column channel vectors from diverse users are asymptotically orthogonal as the number of antennas at the base station, N, grows to infinity by supposing that the small scale fading coefficients for diverse users is independent [30]. Then, we have

$$H^H H = D^{1/2}G^H GD^{1/2} \approx ND^{1/2}I_K D^{1/2} = ND \tag{6}$$

An exhaustive debate about this result can be seen in [31]. Centered on the result in (6), the overall achievable rate of all users come to be

$$\begin{aligned} C &= \log_2 det(I + \rho_u H^H H) \\ &\approx \log_2 det\,(I + N\rho_u D) \\ &= \sum_{k=1}^{K} \log_2\,(1 + N\rho_u d_k)\,\frac{bits/s}{Hz} \end{aligned} \tag{7}$$

Capacity in (7) can be achieved at the base station by simple MF processing. When MF processing is used, the base station processes the signal vector by multiplying the conjugate transpose of the channel, as

$$\begin{aligned} H^H y_u &= H^H\left(\sqrt{\rho_u}Hx_u + n_u\right) \\ &\approx N\sqrt{\rho_u}Dx_u + H^H n_u \end{aligned} \tag{8}$$

where (6) is used. Note that the channel vectors are asymptotically orthogonal when the number of antennas at the base station grows to infinity. So, H^H does not shade the noise. Since D is a diagonal matrix, the MF processing splits the signals from diverse users into diverse streams and there is asymptotically no inter user interference. So now the signal transmission can be treated as a SISO channel transmission for each user. From (8), the signal to noise ratio (SNR) for the k-th user is $N\rho_u d_k$. Subsequently, the attainable rate by using MF is similar as the limit in (7), which indicates that simple MF processing at the base station is best when the number of antennas at the base station, N, grows to infinity.

b: DOWNLINK

$y_d \in C^{K*1}$ can be denoted as the received signal vector at all K users. Massive MIMO works properly in time division duplexing (TDD) mode as discussed in [29], where the downlink channel is the transpose of the uplink channel matrix. Then, the received signal vector can be expressed as

$$y_d = \sqrt{\rho_d}H^T x_d + n_d \tag{9}$$

where $x_d \in C^{N*1}$ is the signal vector transmitted by the base station, $n_d \in C^{K*1}$ is an additive noise and ρ_d is the transmit power of the downlink. Let us assume, $E[|x_d|^2] = 1$ for normalizing transmitting power.

As discussed in [29], the base station usually has channel state information equivalent to all users based on uplink pilot transmission. So, it is likely for the base station to do power allocation for maximizing the sum transmission rate. The sum capacity of the system with power allocation is [32]

$$\begin{aligned} C &= \max_p \log_2 \det(I_N + \rho_d HPH^H) \\ &\approx \max_p \log_2 \det\,(I_K + \rho_d NPD)\,\frac{bits/s}{Hz} \end{aligned} \tag{10}$$

where (6) is used and P is a positive diagonal matrix with the power allocations $(p_1, \ldots.., p_k)$ as its diagonal elements and $\sum_{k=1}^{K} p_k = 1$

If the MF precoder is used, the transmitted signal vector is

$$x_d = H * D^{-1/2}P^{1/2}s_d \tag{11}$$

where $s_d \in C^{K*1}$ is the source information vector. Then, the received signal vector at all K users is

$$y_d = \sqrt{\rho_d} H^T H * D^{-1/2} P^{1/2} s_d + n_d \approx \sqrt{\rho_d} N D^{1/2} P^{1/2} s_d + n_d \tag{12}$$

where the second line of (12) is for the case when the number of antennas at the base station, N, grows to infinity, and (6) is used. Since P and D are both diagonal matrices so the signal transmission from the base station to every user can be treated as if initiating from a SISO transmission which thus inhibited the inter user interference. The overall attainable data rate in (12) can be maximized by proper choice of the power allocation as in (10), which validates that the capacity can be attained using the simple MF precoder.

According to the auspicious propagation assumption of (6), the simple MF precoder or detector can attain the capacity of a massive MIMO system when the number of antennas at the base station, N, is much larger than the number of users, K, and grows to infinity, i.e., $N \gg K$ and $N \to \infty$. Another scenario assumption is that both the number of antennas at the base station and the number of users grows large while their ratio is bounded, i.e., N/K = c as N, $K \to \infty$, where c is a constant, are different [35].

The main area of concern in today's wireless cellular network is on energy efficiency and power optimization. So a lot of researchers are working on to increase the energy efficiency and optimizing the power. The work done on power optimization in [33] has been realized and shown in Fig. 4.

Fig. 4 clearly shows that if we increase the number of antennas at the base station as well as on the small cell access point, the total power per subcarrier decreases to 10 fold as compare to the case of no antenna at small cell access point.

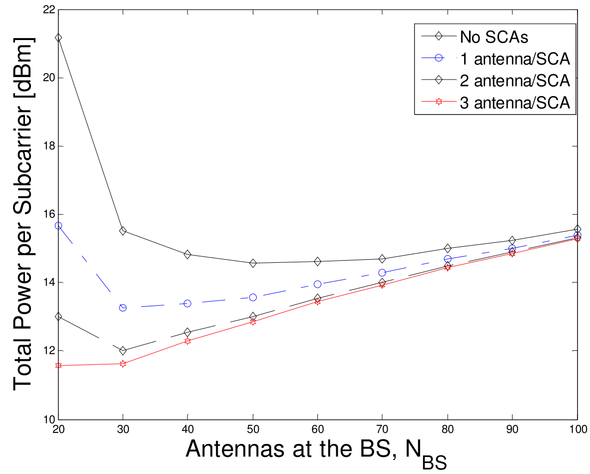

FIGURE 4. Average total power consumption in the scenario containing small cell access points.

However, there are saturation points where extra hardware will not decrease the total power anymore.

With the introduction of the concept of small cell access point, it will fulfill the need of self organizing network (SON) technology for minimizing human intervention in the networking processes as given in [36] and [37]. While a brief summary of the work done on the massive MIMO technology to increase the energy efficiency and optimizing the power of the wireless cellular network is shown in Table 4.

B. INTERFERENCE MANAGEMENT

For efficient utilization of limited resources, reuse is one of the concept that is being used by many specifications of cellular wireless communication systems. Along with this, for improved traffic capacity and user throughput

TABLE 4. Effect of massive MIMO technology on energy efficiency of the wireless cellular network.

Reference	Objectives	Observations
[33]	Improving the cellular energy efficiency by densifying the network topology for higher spatial reuse by using two densification approaches, namely massive multiple input multiple output (MIMO) base stations and small cell access points.	By adding more hardware, power consumption can be considerably decreased, as the dynamic part is decreased, which results in less propagation losses and improved energy efficiency. Improvement in energy efficiency can be achieved by implementing a network topology combining massive MIMO and by installing a few single antenna small cell access points in areas with active users with little additional hardware
[34]	Effect on Energy Efficiency (EE) of a massive MIMO system with respect to • the number of antennas at the base station (BS) i.e. M • the number of active user equipment's (UEs) i.e. K • transmit power • area throughput For different linear processing schemes like • zero-forcing (ZF) • maximum ratio transmission /combining (MRT/MRC) • minimum mean squared error (MMSE) processing)	Energy Efficiency (EE) values for different linear processing schemes and with different values of M,K • ZF processing M = 165 and K = 104, EE = 30.7 Mbit/J. • MMSE processing M = 145 and K = 95, EE = 30.3 Mbit/J. • MRT/MRC processing M = 81 and K = 77, EE = 9.86 Mbit/J. It is observed that • For maximum energy efficiency as a function of the number of base station antennas, at high SNRs MMSE and ZF are almost equal • For all the considered processing schemes, the best energy efficient approach is to increase the radio frequency power with M • There is concurrently an 8-fold progress in area, throughput for ZF and MMSE processing as compared to MRT/MRC

densification of the network is one of the key aspect. So with the introduction of reuse and densification concept, there will be an additional enhancement in terms of efficient load sharing between macro cells and local access networks. But all these advantages have come up with a problem that the density and load of the network have increased considerably and correspondingly receiver terminals in the network suffer from increased co-channel interference, mainly at the boundaries of cells. Thus co-channel interference poses a threat which is inhibiting the further improvement of 4G cellular systems. Hence the need for efficient interference management schemes is vital. Below are the two interference management techniques [38]:

1) ADVANCED RECEIVER

Modern day and growing cellular system, interference grow as a big threat, so to mitigate or manage interference, an appropriate interference management technique is the need of the hour. Advanced interference management at the receiver, or an advanced receiver is the technique which will somewhat help in interference management. It will detect and even try to decode the symbols of the interference signal within the modulation constellation, coding scheme, channel, and resource allocation. Then based on the detector output, the interference signals can be reconstructed and cancelled from the received signal so as to improve the anticipated signal decoding performance [38].

Advanced receivers not only limits to inter cell interference at the cell boundaries, but also intra cell interference as in the case of massive MIMO. According to LTE-Advanced Release 10, every base station transmitter has been equipped with up to eight antennas which will call for intra cell interference, as the number of antenna's increases. [38].

2) JOINT SCHEDULING

In LTE standard, Releases 8 and 9, interference randomization through scrambling of transmitting signals is the only interference management strategies that were considered and there were no advanced co-channel interference management strategies. But in 3GPP LTE-Advanced, Release 10 and 11, through probability readings, it was realized that there was a space for additional performance improvement at the cell edges with the help of synchronized transmission among multiple transmitters dispersed over different cell sites [38].

For calibrating the development, some typical coordinated multipoint schemes, like to coordinate scheduling, coordinated beam forming, dynamic point selection, and joint transmission, were normally conferred [38].

In the article [38], joint scheduling is broadly used to refer advanced interference management of cellular systems and link variation from the network side. But as in coordinated multipoint schemes, the transmission rates and schemes of multiple cells are not autonomously determined. In the case of fast network distribution and interoperability, advanced interference management schemes by joint scheduling from the network side need to be stated in detail in the 5G systems, without separating it entirely as an employment issue. For attracting maximum coordination, the user equipment and network side, advanced interference management must be deliberated instantaneously [38].

C. SPECTRUM SHARING

To apprehend the performance targets of future mobile broadband systems [22], [39], there is a need of considerably more spectrum and wider bandwidths as compared to the current available spectrum for realizing the performance. So to overcome this difficulty, spectrum will be made available under horizontal or vertical spectrum sharing systems.

The significance of spectrum sharing is probable to increase, dedicated licensed spectrum access is expected to remain the baseline approach for mobile broadband which provides reliability and investment certainty for cellular mobile broadband systems. Network components using joint spectrum are likely to play a balancing role [40].

There are mainly two spectrum sharing techniques that enable mobile broadband systems to share spectrum and are classified as distributed solutions and centralized solutions [40]. In a distributed solution the systems coordinate amid each other on an equal basis while in a centralized solution each system coordinates discretely with a central unit and the systems do not directly interact with each other.

1) DISTRIBUTED SPECTRUM SHARING TECHNIQUES

Distributed spectrum sharing techniques is more efficient as it can take place in a local framework. Its principle is to only manage those transmissions that really create interference amid systems. Distributed coordination can be entirely included into standards and thus they can work without the need for commercial contracts between operators [40].

The management of horizontal spectrum sharing happens through the clear exchange of messages unswervingly between the sharing systems through a distinct interface in a peer to peer coexistence protocol. This protocol describes the performance of the nodes on the receiving of certain messages or taking place of certain events. An example of this is explained in [41].

The systems frequently transmit generally understood signals that will show presence, activity factor and the time when they will transmit in a coexistence beacon based solutions. The information that is available openly can be used by the other systems to adjust their spectrum access performance for providing fair spectrum sharing. Coexistence beacons are possibly the solution for both, horizontal and vertical sharing setups. An example of its implementation is the 802.22.1 standard [42].

MAC behavior based schemes uses a MAC protocol which is designed to allow horizontal spectrum sharing. Bluetooth using frequency hopping and WLAN systems using request to send/clear to send functionality are some of the examples. For an even horizontal coexistence with Wi-Fi systems, a Wi-Fi coexistence mode is adapted. The MAC protocol may leave silent periods for Wi-Fi systems to operate and use a listen before talk method which allows Wi-Fi systems to gain access to the channel.

In Spectrum sensing and dynamic frequency selection, operating frequency range is dynamically selected on the basis of measurement results like energy detection or feature detection. To detect the aforementioned coexistence beacons, feature detection is highly useful. Due to a hidden node problem, this method is not considered as a very dependable method [40].

2) CENTRALIZED SPECTRUM SHARING TECHNIQUES

The Centralized spectrum sharing technique is useful for the systems that have granularity of spectrum sharing on a higher level than the actual radio resource allocation granularity. This technique has some restraints, as it is conservative and possibly separate users on orthogonal resources without complete information on whether they would actually interfere or not. While the benefits are in terms of reliability, certainty and control.

Geo-location database method is an example of a centralized sharing technique which involves the querying of a database to obtain information about the resources available at a particular location [43]. This is the required classical vertical sharing solution for accessing the locally unused TV bands [44].

The spectrum broker approach is one of the example of a centralized sharing technique in which horizontally sharing systems negotiate with a central resource management unit for getting short term grants to use spectrum resources on a limited basis [45].

Both the Geo-location database and the spectrum broker approach may additionally support horizontal sharing between unlicensed systems [40].

However, along with the two above spectrum sharing techniques most easily usable spectrum bands have also been allocated, but various studies have revealed that these bands are significantly underutilized. These concerns have driven the researchers to innovate a new radio technology which will encounter with the upcoming demands both in terms of spectrum efficiency and performance of certain applications. To encounter the demand of the future, a disruptive technology revolution that will empower the future wireless world is Cognitive Radio. Cognitive radios are completely programmable wireless devices and has an extensive adaptation property for achieving better network and application performance. It can sense the environment and dynamically performs adaptation in the networking protocols, spectrum utilization methods, channel access methods and transmission waveform used. It is expected that cognitive radio technology will soon arise as a general purpose programmable radio. Similar to the role of microprocessors in the computation, cognitive radio will also serve as a universal platform for wireless system expansion. But the task of successfully building and large scale deployment of cognitive radio networks to dynamically improve spectrum use is an intricate task. It is an area of concern that the academic researchers and the industry in this area has reached a point of fading returns. Its future will now depend on the multi institutional research teams that are working on a new approach with real world experimental deployments of cognitive radio networks [46].

D. DEVICE TO DEVICE COMMUNICATION SYSTEM

Device to Device Communication system can be explained by visualizing a two level 5G cellular network and named them as macro cell level and device level. The macro cell level comprises of the base station to device communications as in an orthodox cellular system. The device level comprises of device to device communications. If a device links the cellular network through a base station, then it will be operating in the macro cell level and if a device links directly to another device or apprehends its transmission through the support of other devices, then it will be on the device level. In these types of systems, the base stations will persist to attend the devices as usual. But in the congested areas and at the cell edges, an ad hoc mesh network is created and devices will be permitted to communicate with each other [47].

In the insight of device level communications, the base station either have full or partial control over the resource allocation amid source, destination, and relaying devices, or not have any control. Thus, we can describe the subsequent four main types of device-level communications (Figs. 5-8) [47]:

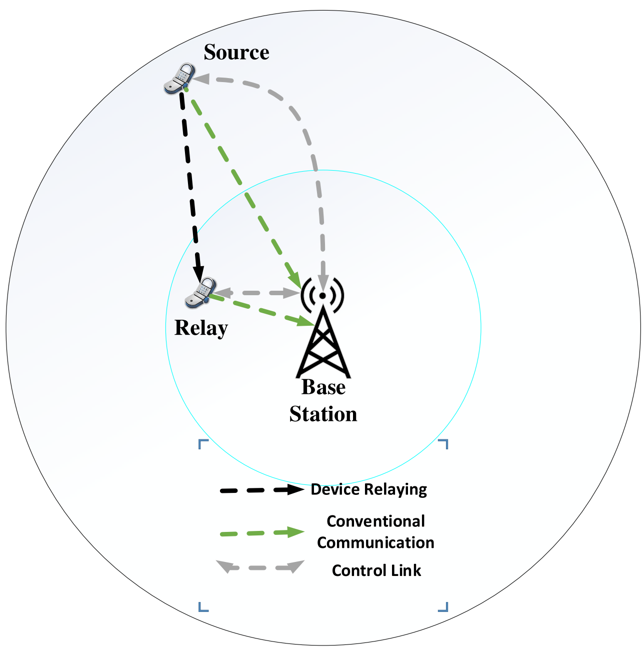

FIGURE 5. Device relaying communication with base station controlled link formation.

1) DEVICE RELAYING WITH BASE STATION CONTROLLED LINK FORMATION

This type of communication is applicable for a device which is at the edge of a cell, i.e. in the coverage area which

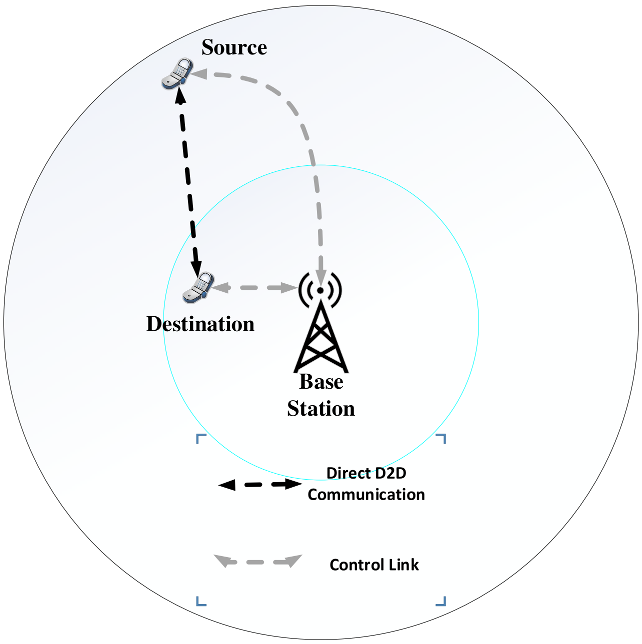

FIGURE 6. **Direct device to device communication with base station controlled link formation.**

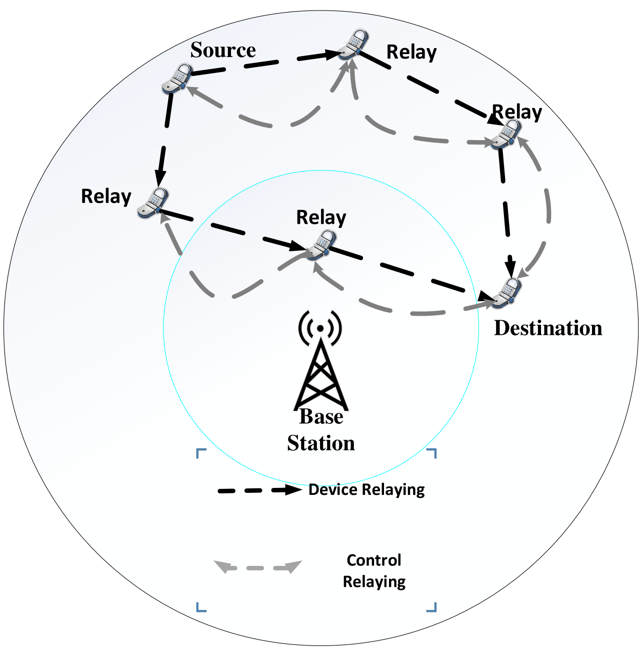

FIGURE 7. **Device relaying communication with device controlled link formation.**

have poor signal strength. In this type of communication, the devices will communicate with the base station by relaying their information through other devices.

This type of communication will be helpful for the device to attain a higher quality of service and respective increased battery life. For partial or full control link formation, the base station communicates with the relaying devices.

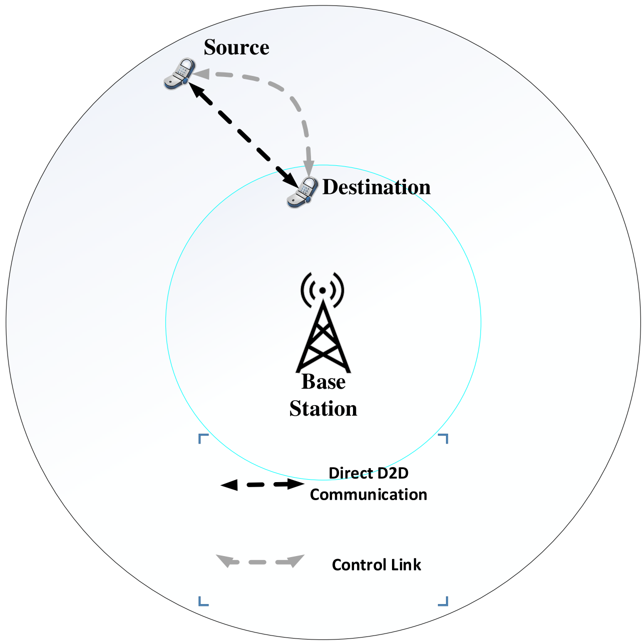

FIGURE 8. **Direct device to device communication with device controlled link formation.**

2) DIRECT DEVICE TO DEVICE COMMUNICATION WITH BASE STATION CONTROLLED LINK FORMATION

In this type of communication, the source and destination devices are exchanging data with each other without the involvement of a base station, but they are supported by the base station for link formation.

3) DEVICE RELAYING WITH DEVICE CONTROLLED LINK FORMATION

In this type of communication, a base station is neither involved in link formation nor for communication purpose. So, source and destination devices are totally responsible for synchronizing communication using relays amid each other.

4) DIRECT DEVICE TO DEVICE COMMUNICATION WITH DEVICE CONTROLLED LINK FORMATION

In this type of communication, the source and destination devices have direct communication with each other and the link formation is controlled itself by the devices without any assistance from the base station. Hence, the resource should be utilized by the source and destination devices in a way to certify limited interference with other devices in the same level and the macro cell level.

For a substantial advancement in excess of traditional cellular system architecture, a dualistic cellular system should be designed. For introducing the concept of device to device communication, some technical issues needs to be addressed like security and interference management issues [47].

As in device to device communication, the routing of user data is through the devices of the other users, so the main area of concern is about security because the privacy need to be maintained. Closed access will ensure their security for the devices that want to operate in the device level.

In closed access, a device has a list of certain reliable devices, like the users in the close vicinity or office to whom you are familiar with, otherwise the users that have been legitimated through a reliable party like an association, can unswervingly communicate with each other, sustaining a level of discretion, whereas the devices not on this list need to use the macro cell level to communicate with it. Also to prevent divulging of their information to other devices in a group, one can set an appropriate encryption amongst one another. Instead of this, in open access, each device can turn in to relay for other devices deprived of any limits. Meanwhile, in such an instance security is an open research problem. Security problems in device to device communication contain the empathy of possible attacks, threats, and weakness of the system. To discourse security problems in open access device to device, the research on the security problems of machine to machine communication [48]–[52] can be utilized.

Second technical issue of a dualistic system that need to be addressed is of interference management. In device relaying communication with the base station controller and direct device to device communication with base station controlled, the base station can execute the resource allocation and call setup process. So, the base station, to a certain degree can ease the problem of interference management by using centralized methods. But in device relaying communication with device controller and direct device to device communication with device controller, resource allocation between devices will not be supervised by the centralized unit. Devices will unavoidably effect macro cell users because they are working in the same licensed band. So to confirm the nominal effect on the performance of prevailing macro cell base stations, a dualistic network needs to be considered that involves different interference management techniques and resource allocation schemes. In addition to the interference amid the macro cell and device levels, interference amid users at the device level is also of prime concern. For performing the resource allocation in this type of communication, different algorithms as shown in table 4 and methods like resource pooling [53], non-cooperative game [54] or bargaining game, admission control and power allocation [55], cluster partitioning, and relay selection [56] can be engaged.

In device relaying communication with the base station controller, as shown in Fig. 5, since the base station is one of the communicating units, so the aforementioned challenges can be addressed with the help of the base station like authenticating the relaying devices through encryption for maintaining adequate privacy of the information of the devices [57]. The challenge of spectrum allocation amid the relaying devices to prevent them from interfering with other devices will also be managed by the base station.

In direct device to device communication with base station controlled, shown in Fig. 6, the devices communicate directly with each other, but the base station controls the formation of links between them. Precisely, the work of the base station is to authenticate the access, control the connection formation, resource allocation, and also deals with financial interaction amid devices. Basically the base station has complete control over the device to device connections, like connection setup and maintenance, and resource allocation. Since device to device connections share the cellular licensed band in the device level with the regular cellular connections in the macro cell level. So for assigning resources to every device to device connection, the network can either assign resources in an identical manner as a regular cellular connection or in the form of a dedicated resource pool to all devices to device connections [47].

In device relaying communication with device controller and direct device to device communication with device controller, there is no base station to control the communication amid devices. As shown in Figs. 7 and 8, several devices are communicating with each other by using supportive or non-supportive communication by playing the role of relays for the other devices. Since there is no centralized supervision of the relaying, so distributed methods will be used for processes like connection setup, interference management, and resource allocation. In this type of communication, two devices need to find each other and the neighboring relays first by periodically broadcasting their identity information. This will aware the other devices of their presence and then they will decide whether or not to start a device to device direct or device relaying communication [53].

Now to know the effect of relay's, let us study a system model for relay aided device to device communication [58] as shown in Fig. 9. For studying it, let us consider that the cellular user equipment eNodeB links are unfavorable for direct communication and need the assistance of relays. The device to device user equipment's are also supported by the relay nodes due to long distance or poor link condition between peers.

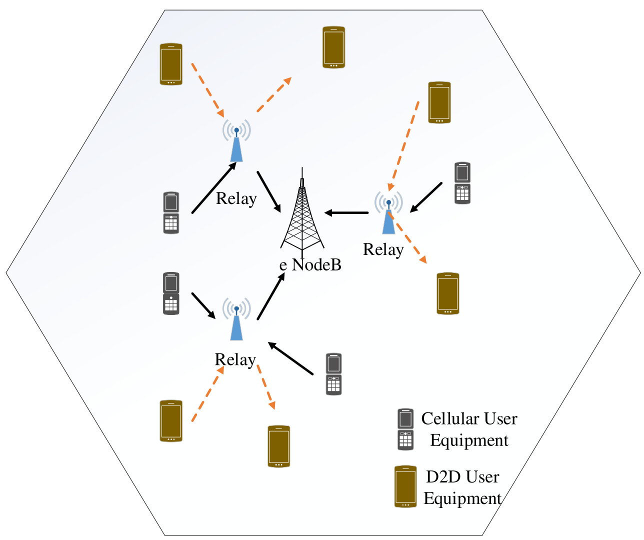

FIGURE 9. A single cell with multiple relay nodes.

a: NETWORK MODEL

Let us consider a device to device enabled cellular network with multiple relays as shown in Fig. 9. A relay node in

4G (LTE-Advanced) is connected between the radio access network and both the cellular and devices to the device user equipment's through a donor eNodeB with a wireless connection. Let $\mathcal{L} = \{1, 2, \ldots, L\}$ represents the set of fixed location relays [57] in the network. The system bandwidth is divided into N resource blocks denoted by $\mathcal{N} = \{1, 2, \ldots, N\}$. Relay node can be used for scheduling and resource allocation for the device to device user equipment's, when the link condition between two devices to device user equipment's is too poor for direct communication. In addition, the direct communication between two devices to the device user equipment's also requires the aid of a relay node. Both cellular and device to device user equipment's assisted by relay ℓ are denoted by u_ℓ. The set of user equipment's assisted by relay ℓ is $\mathcal{U}_\ell$ such that $\mathcal{U}_\ell \subseteq \{\mathcal{C} \cup \mathcal{D}\}, \forall \ell \in \mathcal{L}, \bigcup_\ell \mathcal{U}_\ell = \{\mathcal{C} \cup \mathcal{D}\}$, and $\bigcap_\ell \mathcal{U}_\ell = \emptyset$. In the second step of communication, there could be multiple relays communicating to their related device to device user equipment's. According to our assumed system model, relays are useful for scheduling and resource allocation for the user equipment's to reduce the computational load at the eNodeB [58].

b: RADIO PROPAGATION MODEL

For realizing and exhibiting the propagation channel, distance dependent path loss and shadow fading are considered and assumed that the channel is experiencing Rayleigh fading. Particularly, 3GPP propagation environment presented in [60] is considered. For example, link between user equipment and relay or between relays and device to device follows the following path loss equation

$$PL_{u_l,l}(l)_{[dB]} = 103.8 + 20.9 \log(l) + L_{su} + 10 \log(\zeta) \quad (13)$$

Where l is the distance between user equipment and relay in kilometer, L_{su} is interpreted as shadow fading and is demonstrated as a log normal random variable, and ζ is an exponentially distributed random variable which denotes the rayleigh fading channel power gain. In the same way, the path loss equation for the relay and eNodeB link is expressed as

$$PL_{l.\text{eNodeB}}(l)_{[dB]} = 100.7 + 23.5 \log(l) + L_{sr} + 10 \log(\zeta) \quad (14)$$

Where L_{sr} is a log normal random variable accounting for shadow fading. Hence, given the distance l, the link gain between any pair of network nodes i, j can be calculated as $10^{-(PL_{i,j}(l)/10)}$.

c: REALIZABLE DATA RATE

$h_{i,j}^{(n)}$ can be denoted as the direct link gain between node i and j over resource block n. The interference link gain between relay (user equipment) i and a user equipment (relay) j over resource block n is denoted by $g_{i,j}^{(n)}$ where user equipment (relay) j is not associated with relay (user equipment) i. The unit power SINR for the link between user equipment $u_l \in \mathcal{U}_l$ and relay l using resource block n in the first hop is given by

$$\gamma_{u_l,l,1}^{(n)} = \frac{h_{u_l,l}^{(n)}}{\sum_{\forall u_j \in \mathcal{U}_j, j \neq l, j \in \mathcal{L}} P_{u_j,j}^{(n)} g_{u_j,l}^{(n)} + \sigma^2} \quad (15)$$

The unit power SINR for the link between relay l and eNodeB for cellular user equipment u_l (i.e.,$u_l \in \{\mathcal{C} \cap \mathcal{U}_l$) in the second hop is as follows:

$$\gamma_{l,u_l,2}^{(n)} = \frac{h_{l,\text{eNodeB}}^{(n)}}{\sum_{\forall u_j \in \{\mathcal{D} \cap \mathcal{U}_j\}, j \neq l, j \in \mathcal{L}} P_{j,u_j}^{(n)} g_{j,\text{eNodeB}}^{(n)} + \sigma^2} \quad (16)$$

In the same way, the unit power SINR for the link between relay l and receiving device to device user equipment for the device to device user equipment's u_l (i.e., $u_l \in \{\mathcal{D} \cap \mathcal{U}_l$) in the second hop can be written as

$$\gamma_{l,u_l,2}^{(n)} = \frac{h_{l,u_l}^{(n)}}{\sum_{\forall u_j \in \mathcal{U}_j, j \neq l, j \in \mathcal{L}} P_{j,u_j}^{(n)} g_{j,u_l}^{(n)} + \sigma^2} \quad (17)$$

In (15)–(17), $P_{i,j}^{(n)}$ is the transmit power in the link between i and j over resource block n, $\sigma^2 = N_0 B_{RB}$, where B_{RB} is bandwidth of an resource block, and N_0 denote thermal noise. $h_{l,\text{eNodeB}}^{(n)}$ is the gain in the relay and eNodeB link and $h_{l,u_l}^{(n)}$ is the gain in the link between relay l and receiving device to device user equipment corresponding to the device to device transmitter user equipment's u_l.

The attainable data rate for u_l in the first hop can be expressed as

$$r_{u_l,1}^{(n)} = B_{RB} \log_2 (1 + P_{u_l,l}^{(n)} \gamma_{u_l,l,1}^{(n)})$$

In the same way, the attainable data rate in the second hop is given by

$$r_{u_l,2}^{(n)} = B_{RB} \log_2 (1 + P_{l,u_l}^{(n)} \gamma_{l,u_l,2}^{(n)})$$

Since we are considering a two hop communication approach, the end to end data rate for u_l on resource block n is the half of the minimum attainable data rate over two hops, i.e.,

$$R_{u_l}^{(n)} = \frac{1}{2} \min\{r_{u_l,1}^{(n)}, r_{u_l,2}^{(n)}\} \quad (18)$$

The ongoing problem in device to device communication is about Resource allocation. So a lot of researchers are working on to propose an optimal resource allocation algorithm. Table 5 will provide a brief summary on the proposed algorithms.

E. ULTRA DENSE NETWORKS

To meet the increasing traffic demands due to the increased number of users, densification of the infrastructure will be the prior aspect of 5G communications. But for achieving ultra-dense, heterogeneous networks will play an important role. With the introduction of moving networks and ad-hoc social networks, the heterogeneous networks are becoming more dynamic. Though dense and dynamic heterogeneous

TABLE 5. Summary of proposed algorithms for optimal resource allocation in device to device communication.

Reference	Algorithm	Description	Objective	Solution
[61]	Heuristic algorithm for the light load scenario	This algorithm is valid only for the cellular mode and dedicated mode with reusing of the channels of cellular users is not allowed, and thus resolve the problem in the light load scenario.	Maximization of the overall system throughput while ensuring the signal to noise and interference ratio of both devices to device and cellular links.	For maximizing throughput, low complexity algorithms are developed according to different network loads which execute very closely to the equivalent prime algorithms
[61]	Heuristic algorithm for the medium load scenario	In this algorithm, a device to device pair may choose any one among the three modes which will increase the system capacity, energy efficiency and bandwidth utilization rate.		
[62]	IPPO (Inverse Popularity Pairing Order) algorithm	This algorithm will maximize the total throughput while reducing the complexity problem for a large number of potential partners, which generally occurs in the traditional Kuhn-Munkres (KM) algorithm	Maximization of the well-defined performance metrics of all devices to device links and Cellular user equipment's after effective pairing under power and Quality of Service restraints.	An Inverse Popularity Pairing Order algorithm is proposed to reduce the computation complexity without foregoing much performance over the traditional KM algorithm
[63]	Iterative Resource Allocation Algorithm	This algorithm is for energy efficient resource allocation for device to device communications by using the properties of nonlinear fractional programming.	Observing the tradeoff between energy efficiency (EE) and spectral efficiency (SE) in device to device Communications for cellular networks with uplink channel reuse.	The tradeoff explains that the increasing transmission power beyond the power for prime energy efficiency brings little spectral efficiency improvement but with substantial energy efficiency loss.
[58]	Allocation of Resource Block and transmission power using message passing	A message passing technique is used for the resource allocation problem in which each user equipment sends and receives information messages to/from the relay node in an iterative method with an aim of attaining a prime allocation.	Examining the performance of the network supported device to device communication where device to device traffic is conceded over relay nodes	Observation about the proposed method has revealed that after a distant margin, relaying of device to device traffic improves system performance and delivers a better data rate to the device to the device user equipment's at the expense of a little increase in end to end delay.
[64]	Implementation of Distributed information theoretic link scheduling (ITLinQ)	Information theoretic link scheduling (ITLinQ), is a new spectrum sharing mechanism which at each time schedules those links that form an information theoretic independent set (ITISs), which indicates the sets of links for which simultaneous communication and treating the interference from each other as the noise is information theoretically optimal	Considering the problem of spectrum sharing in device to device communication systems.	Distributed ITLinQ outpaces similar spectrum sharing mechanisms, such as FlashLinQ, while keeping the complexity at the same level.
[65]	Coalition Formation Algorithm for the Spectrum Sharing Problem	A distributed coalition formation algorithm based on the Pareto order and the merge and split rule.	For the improvement of the energy efficiency of wireless users, a joint mode selection is modeled and spectrum sharing as a coalition formation game. A coalition formation algorithm is projected to jointly solve the mode selection and spectrum sharing in a device to device system.	The algorithm is proven to be of convergence and stability.

networks will give rise to new challenges in terms of interference, mobility and backhauling. To overcome these challenges, there arises a requirement of designing new network layer functionalities for maximizing the performance farther from the design of the existing physical layer.

In present networks like Long Term Evolution (LTE), there exists interference mitigation techniques like enhanced Inter-Cell Interference Coordination and autonomous component carrier selection. But these techniques are applicable only to nomadic and dense small cell deployments and have limited flexibility. So for 5G networks, the interference mitigation techniques should be more flexible and open to the variations as changes in the traffic and deployment are expected to occur more rapidly than existing networks [66].

With the introduction of smart wireless devices, the interaction between these devices and with the environment are destined to increase. To meet the challenges that have arisen because of the increasing density of nodes and interchanging connectivity options, there arises a need of the user independent algorithms. So future smart devices are designed in such a way that with the help of the context information, they will learn and decide how to manage the connectivity. Contextual information possibly will be the approaching service profile, battery position of a device or a complete data acquired through either in built sensors, cloud servers or serving base station. For example, to enable faster initialization of direct Device-to-Device communications and native multicast group making, context information about the social networking will be very helpful as it will decrease the signaling overhead in the network. Context information can also provide sustenance for the network to decrease energy consumption in base stations because of the switching of cells by improving the mobility and traffic management procedures and local handover strictures [66].

In short, future smart devices and small cell networks will be capable of providing the best wireless connectivity with minimum interference and less power consumption. Along with this, they should be rapidly adaptable to the changing requirements of devices and radio access network.

F. MULTI RADIO ACCESS TECHNOLOGY ASSOCIATION

As we are heading towards 5G, the networks are becoming more heterogeneous. The main aspect that has attracted many, is the integration among different radio access technologies. A distinctive 5G aided device should be manufactured whose radios not only support a new 5G standard like millimeter wave frequencies, but also 3G, various releases of 4G LTE, numerous types of WiFi, and possibly direct device to device communication, all across the different spectral bands [67]. So, defining of standards and utilization of spectrum to which base station or users will be a really intricate job for the network [68].

Defining of the optimal user association is the prime area of concern which depends on the signal to interference and noise ratio from every single user to every single base station, the selections of other users in the network, the load at every single base station, and the prerequisite to apply the same base station and standard in both uplink and downlink for simplifying the operation of control channels for resource allocation and feedback [69], [70]. So, certain procedures must be implemented to overcome these issues.

To increase edge rates by as much as 500%, a simple, apparently highly suboptimal association method centered on aggressive but static biasing towards small cells and blanking about half of the macrocell transmissions has been shown in [71]. The combined problem of user association and resource allocation in two tier heterogeneous networks, with adaptive tuning of the biasing and blanking in each cell, is considered in [69], [70], and [72]–[77]. A model of hotspot traffic shows that the optimal cell association is done by rate ratio bias, instead of power level bias [73]–[75]. An active model of cell range extension as shown in [79], the traffic arrives as a Poisson process in time and at the possible arrival rates, for which a steadying scheduling policy subsists. With massive MIMO at the base stations, user association and load balancing in a heterogeneous networks, is considered in [79]. An exciting game theoretic approach is used in [80] for the problem of radio access technology selection, in which union to Nash equilibria and the Pareto-efficiency of these equilibria are deliberated [67].

In conclusion, there is a vast scope for modeling, exploring and optimizing base station-user associations in 5G [81].

G. FULL DUPLEX RADIOS

For a long duration of communication period, it is assumed in the wireless system design that radios have to operate in half duplex mode. It means that it will not transmit and receive simultaneously on the same channel. Many scholars, academics and researchers at different universities and research groups have tried to undermine this assumption by proposing many designs to build in-band full-duplex radios.

But the realization to build full duplex radio has a lot of implications. The cellular networks will have to reduce their spectrum demands to half as only a single channel is used for achieving the same performance. As in LTE, for both uplink and downlink, it uses equal width separate channels for empowering radios to realize full duplex.

For communicating in the full duplex mode, the self-interference results from its own transmission to the received signal has to be completely removed. Let us consider the case of WiFi signals which are transmitting at 20dBm (100mW) average power with the noise floor of around −90dBm. So the transmit self-interference need to be canceled by 110dB (20dBm-(−90dBm)) to achieve the similar level as of the noise floor and reduce it to insignificant. If any residual self-interference is not completely canceled, then it will acts as noise to the received signal, which in turn reduces SNR and subsequently throughput [82].

H. A MILLIMETER WAVE SOLUTION FOR 5G CELLULAR NETWORK

The Wireless industry has been growing day by day and in spite of the efforts by the industrial researchers for creating the proficient wireless technologies, the wireless industry continuously facing the overpowering capacity demands from its current technologies. Recent innovations in computing and communications and the arrival of smart handsets along with the need to access the internet poses new anxieties in front of the wireless industry. These demands and anxieties will grow in the approaching years for 4G LTE and indicates that at some point around 2020, there will arise a problem of congestion in wireless networks. It will be must for the research industry to implement new technologies and architectures for meeting the increasing demands of the users. The ongoing work plans a wireless future in which data rates increase to the multi gigabit per second range. These high data rates can be attainable with the help of steerable antennas and the millimeter wave spectrum and at the same time will support mobile communications and backhaul networks [83].

Recent researches have put forward that mm-wave frequencies of 2.6 GHz radio spectrum possibly will supplement the presently saturated 700 MHz band for wireless communications [84]. Feasibility of millimeter wave wireless communications is supported by the fact that the use of high gain, steerable antennas at the mobile and base station and cost effective CMOS technology can now operate well into the millimeter wave frequency bands [85]–[87]. Additionally, with the use of millimeter wave carrier frequencies, larger bandwidth allocations will come up with higher data transfer rates and service providers that are presently using 20 MHz channels for 4G customers will now significantly expand the channel bandwidths [87]. With the increase in bandwidth, capacity will also get increased, while the latency will get decreased, which give rise to better internet based access and applications like real time streaming. Since the wavelength of millimeter wave frequencies are very small, so it will utilize polarization and different spatial processing techniques like massive MIMO and adaptive beamforming [15]. With the significant increase in bandwidth, the data links to densely populated areas will now handle greater capacity than present 4G networks. Likewise the base stations are constantly reducing the coverage areas of the cell for spatial reuse, cooperative MIMO, relays and interference mitigation between base stations. Since the base stations are abundant and more densely dispersed in urban areas, which will reduce the cost per base station. Spectrum distributions of over 1 GHz of bandwidth are currently being utilized in the 28 GHz and 38 GHz bands.

By far as for the concern of building a prototype, the antenna is essentially being positioned in very close vicinity to the 28 GHz Radio Frequency Integrated Circuit and the front end module because there will be high signal attenuation at 28 GHz. Realizing the antenna array directly on the printed circuit board of the 5G cellular device will minimize the insertion loss between the antenna and Radio Frequency Integrated Circuit. This infers that an employment of the Radio Frequency blocks in the 5G architecture before the intermediate frequency stage will be reliant on the placement of the 28 GHz antenna array in the cellular phone. Taking this concept into a thought, a minimum set of two 28 GHz antenna arrays is proposed for millimeter wave 5G cellular applications in [88], the two antenna arrays are employed in the top and bottom part of the cellular device. The 28 GHz antenna array configuration for 5G cellular mobile terminals and its comparison with the 4G standard is given in table 6.

TABLE 6. 28 GHz antenna array configuration for 5G cellular mobile terminals and its comparison with the 4G standard.

Cellular standards	4G	5G [88]
Antenna type	Sub wavelength antennas	Phased array antennas
Radiation patterns	Omnidirectional	Directional fan-beam
Diversity and MIMO	Yes	Yes
Polarization	Single and constant	Multiple and reconfigurable

The millimeter wave spectrum is under-utilized and is left idle until present years. The main reason behind the under-utilization is its unsuitability for cellular communications because of unfriendly channel conditions like path loss effect, absorption due to atmosphere and rain, small diffraction and penetration about obstacles and through objects respectively.

There is one more reason of unsuitability is due to strong phase noise and excessive apparatus costs. But the prevailing reason is that the large unlicensed band around 60 GHz [89], were appropriate primarily for very short range transmission [90]. So, the emphasis had been given to both fixed wireless applications in the 28, 38, 71–76 and 81–86 GHz and WiFi with the 802.11ad standard in the 60 GHz band. Semiconductors are also evolving, as their costs and power consumption values are decreasing rapidly due to the growth of the abovementioned short range standards. The main propagation issues regarding millimeter wave propagation for 5G cellular communication are [67]:

1) PATH LOSS

The free space path loss is dependent on the carrier frequency, as the size of the antennas is kept constant which is measured by the wavelength $\lambda = c/f_c$, where f_c is the carrier frequency. Now as the carrier frequency increases, the size of the antennas got reduced and their effective aperture increases with the factor of $\frac{\lambda^2}{4\pi}$, while the free space path loss between a transmitter and a receiver antenna grows with f_c^2. So, if we increase the carrier frequency f_c from 3 to 30 GHz, it will correspondingly add 20 dB of power loss irrespective of the transmitter-receiver distance. But for increased frequency, if the antenna aperture at one end of the link is kept constant, then the free-space path loss remains unchanged. Additionally, if both the transmitter and receiver antenna apertures are kept constant, then the free space path loss decreases with f_c^2 [67].

2) BLOCKING

Microwave signals are less prone to blockages but it deteriorates due to diffraction. In the contrary, millimeter wave signals suffer less diffraction than the microwave signals and exhibit specular propagation, which makes them much more vulnerable to blockages. This will fallout as nearly bimodal channel subject to the existence or lack of Line of Sight. Recent studies in [84] and [91] reveals that, with the increase in the transmitter and receiver distance the path loss increases to 20 dB/decade under Line of sight propagation, but descents to 40 dB/decade plus an added blocking loss of 15–40 dB for non-line of sight [67].

So due to the presence of blockages, the set connection will promptly shift from usable to unusable which will results in large scale impediments that cannot be avoided with typical small scale diversity countermeasures.

3) ATMOSPHERIC AND RAIN ABSORPTION

Within the unlicensed 60-GHz band, the absorption due to rain and air particularly the 15 dB/km oxygen absorption are more perceptible. But these absorptions are insignificant for the urban cellular deployments, where base station spacing's might be on the order of 200 m. But actually, these type of absorptions are useful as it will efficiently increase the segregation of each cell by further attenuating the background interference from more distant base stations [67].

So from the above explanation, it is inferred that the propagation losses for millimeter wave frequencies are resolvable, but only by steering the beam energy with the help of large antenna arrays and then collect it coherently. But for practical viability, the concept of narrow beam communication is fresh for cellular communications and poses problems like:

a: LINK ACQUISITION

The main problem that the narrow beams are facing is in establishing links amid users and base stations for both initial access and handoff. The user and base stations will have to locate each other by scanning lots of angular positions where the possibility of a narrow beam is high. This problem poses an important research challenge predominantly in the perspective of high mobility [67].

b: NEED OF NEW TRANSCEIVER ARCHITECTURES

Wireless millimeter wave systems have gone through significant improvement but still there are some hardware issues which will affect the designing of the communication systems. The analog to digital and digital to analog converters needed for large bandwidths are the prime cause of power consumption. A prime reason of power consumption is because of the use of large antenna arrays. Along with these, high receiver sensitivities are needed to deal with the path loss because it is not feasible that each antenna will be provided with normal fully digital beam formers [67].

I. CLOUD TECHNOLOGIES FOR FLEXIBLE 5G RADIO ACCESS NETWORKS

1) MOBILE CLOUD COMPUTING

In the recent years, mobile cloud computing has earned a lot of admiration as it is a coalition of many computing fields. It offers computing, storage, services, and applications over the Internet. It also reduces cost, disconnect services from the existing technology, and offers flexibility in terms of resource provisioning. So mobile cloud computing can be defined as an incorporation of cloud computing technology with mobile devices. This integration will make the mobile devices resource full in terms of computational power, memory, storage, energy, and context awareness [92]. Mobile cloud computing can also be explained with different concepts of the mobile cloud [93].

In the first method, let us consider that the other mobile devices will also act as resource providers as in [95]. So the combined resources of the numerous mobile devices and other available stationary devices in the local area will be exploited as shown in Fig. 10. This method supports user mobility and identifies the potential of mobile clouds to perform collective sensing.

The cloudlet concept proposed in [96] is the second method of mobile cloud computing. This method is explained

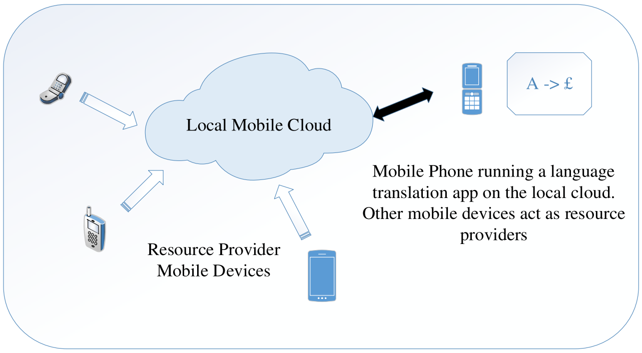

FIGURE 10. Virtual resource cloud made up of mobile devices in the vicinity.

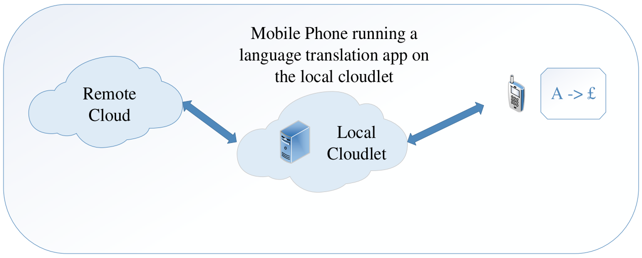

FIGURE 11. A cloudlet enabling mobile devices to bypass latency and bandwidth issues while benefitting from its resources.

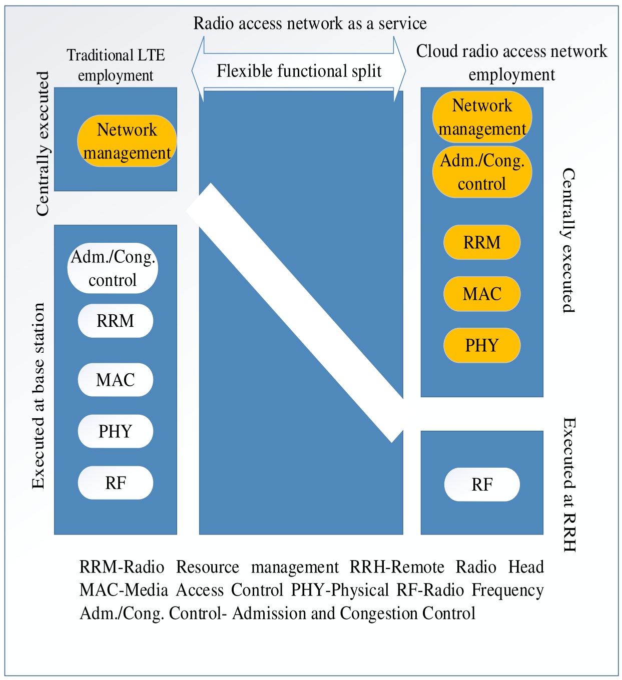

FIGURE 12. Flexible functional split [103].

in Fig. 11, where a local cloudlet encompassed by numerous multi core computers with connectivity to the remote cloud servers is used by the mobile device to relieve from its workload. Plug Computers having form factor, diversity and low power consumption can be considered as good contenders for cloudlet servers. But these computers are ideal for small scale

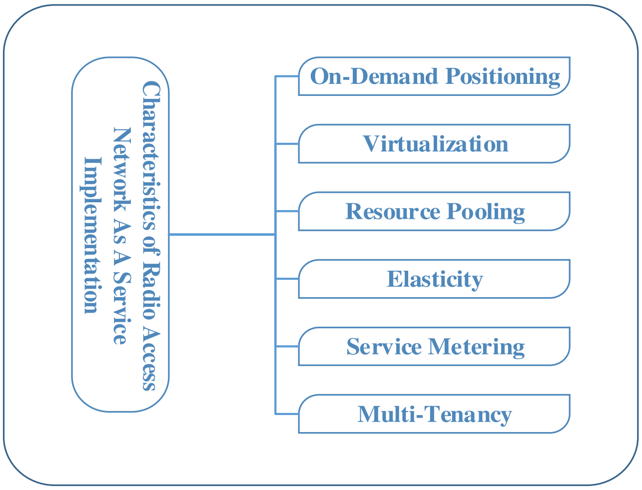

FIGURE 13. Characteristics of a radio access network as a service implementation.

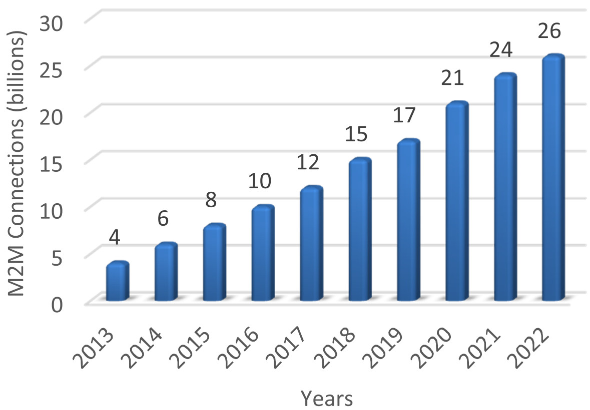

FIGURE 14. Number of Machine to Machine (M2M) connections in mobile [105].

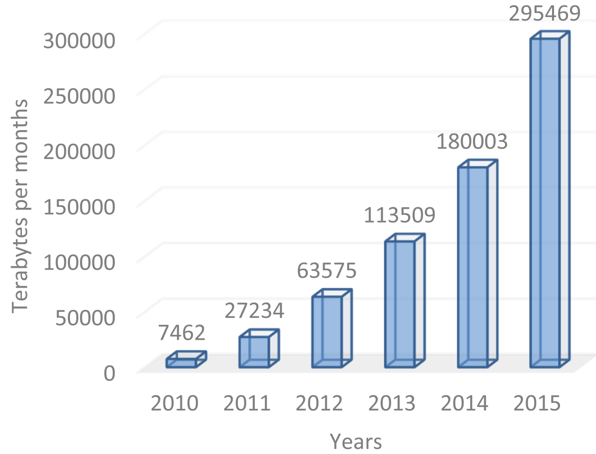

FIGURE 15. Machine to Machine traffic to increase 40-fold from 2010 to 2015.

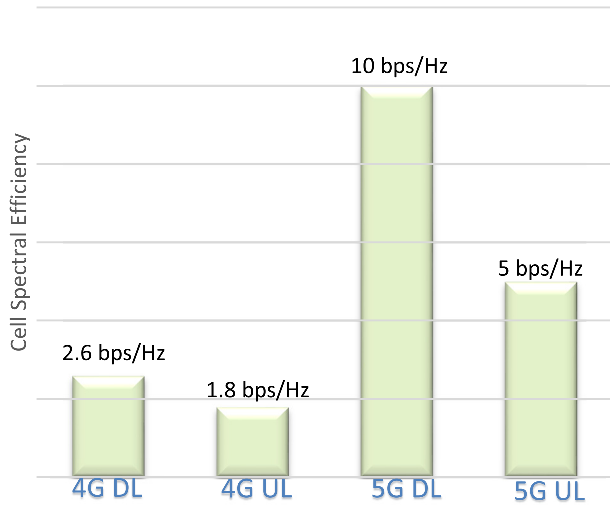

FIGURE 16. Cell spectral efficiency in 5G networks [105].

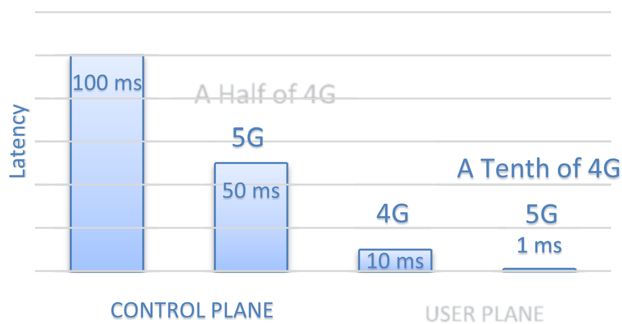

FIGURE 17. Demand to delay in control and user planes for 4G/5G networks [105].

servers installed in the public organization because they have the similar general architecture as a normal computer and are less powerful, smaller, and less costly. Hence, these cloudlets should be installed in public areas like restaurants so that mobile devices can connect directly with the cloudlet instead of a remote cloud server to remove latency and bandwidth problems [93].

Mobile cloud computing follows the basic concepts of cloud computing. There are some specific requirements that need to be encountered in a cloud like adaptability, scalability, availability and self-awareness as discussed in [94].

So mobile cloud computing should also fulfill these requirements. For example, a mobile computing cloud should be cognizant of its availability and dynamically plug themselves in, depending on the requirements and workload. An appropriate technique of self pretentious one's own quality is desirable for mobile users to proficiently take advantage of the cloud, as the internal status and the external environment is subject to change. Others facets like mobility, low connectivity and limited source of power also needed to be considered [93].

2) RADIO ACCESS NETWORK AS A SERVICE

Centralization is the prime objective of 5G mobile networks because processing and management will need to be flexible and adapted to the actual service requirements. This will lead to a compromise between the decentralized today's network and fully centralized cloud radio access network. This compromise is addressed by the radio access network as a

TABLE 7. 5G related activities in Europe [109].

Research Project / Institutions / Research Groups	Research area	HTTP location
5GNOW (5th Generation Non-Orthogonal Waveforms for asynchronous signaling) [110,111]	Non-orthogonal waveforms	http://www.5gnow.eu/
5G PPP (5G Infrastructure Public Private Partnership)	Next generation of communication networks, ubiquitous super-fast connectivity	http://5g-ppp.eu/
COMBO (COnvergence of fixed and Mobile BrOadband access/aggregation networks)	Fixed / Mobile Converged (FMC) broadband access / aggregation networks	http://www.ict-combo.eu/
iJOIN (Interworking and JOINt Design of an Open Access and Backhaul Network [112]	RAN-as-a-Service, radio access based upon small cells, and a heterogeneous backhaul	http://www.ict-ijoin.eu/
MAMMOET (MAssive MiMO for Efficient Transmission)	Massive MIMO	http://www.mammoet-project.eu/
METIS (Mobile and wireless communications Enablers for Twenty-twenty (2020) Information Society) [113-116]	Provide a holistic framework 5G system concept	https://www.metis2020.com/
MCN (Mobile Cloud Networking)	Mobile Network, Decentralized Computing, Smart Storage	http://www.mobile-cloud-networking.eu/site/
MOTO (Mobile Opportunistic Traffic Offloading)	traffic offloading architecture	http://www.ict-ras.eu/index.php/ras-projects/moto
PHYLAWS (PHYsical Layer Wireless Security) [115]	Security approaches for handsets and communications nodes	http://www.phylaws-ict.org/
TROPIC (Traffic Optimization by the Integration of Information and Control)	Femtocell networking and cloud computing	http://www.ict-tropic.eu/
5GrEEn [116]	Environmentally friendly 5G mobile network	https://www.eitictlabs.eu/news-events/news/article/toward-green-5g-mobile-networks-5green-new-project-launched/#allView
University of Edinburgh	Indoor wireless communications capacity	www.ed.ac.uk/
University of Surrey 5G Innovation Centre (5GIC)	Lowering network costs, Anticipating user data needs to pre-allocate resources, Dense small cells, Device-to-device communication, Spectrum sensing (for unlicensed spectrum)	http://www.surrey.ac.uk/5gic/

service concept, which partly centralizes functionalities of the radio access network depending on the needs and characteristics of the network. The Radio access network as a service is an application of the software as a service paradigm [97], so every function may be packed and distributed in the form of a service within a cloud platform. This will cause increased data storage and processing capabilities, as provided by a cloud platform accommodated in data centers. The design of radio access network as a service based on cloud enables flexibility and adaptability from different perceptions. Recent advances in Cloud radio access network is given in [98]–[102].

There is a flexible functional split of the radio protocol stacks as shown in Fig. 12 is present in the central element of radio access network as a service between the central radio access network as a service platform and the local radio access points. With the introduction of this functional split, degrees of freedom increases.

The left side demonstrates a traditional LTE employment in which all functionalities up to admission/congestion control are locally employed at the base station. The right side illustrates the cloud radio access network approach in which only the radio front-end is locally employed, and all the rest functionality is centralized. But radio access network as a service does not fully centralize all radio access network functionalities [103].

Functional split realization poses a serious challenge for the radio access network. Theoretically, the functional split occur on every protocol layer or on the interface amid each layer. Present architecture involves restraints on the functions between discrete protocol layers. So with a restrained backhaul, most of the radio protocol stack and radio resource management will accomplished locally, while functions with less restrained requirements like bearer management and load balancing are placed in the radio access network as a service platform. So when a high capacity backhaul is available, lower-layer functions like PHY and MAC are shifted for a higher degree of centralization into the radio access network as a service platform [103].

The following list as shown in Fig. 13 condenses major characteristics of a radio access network as a service implementation similar to the basic characteristics of a cloud computing platform and is explained in [103].

3) JOINT RADIO ACCESS NETWORK BACKHAUL OPERATION

The main reliability factor of 5G wireless networks is densely spread small cell layer which necessitates to be connected to the radio access network as a service platform. Though,

TABLE 8. 5G related activities in America [109].

Research Project / Institutions / Research Groups	Research area	HTTP location
Berkeley SWARM Lab	Third layer of information acquisition, synchrony to the Cloud, pervasive wireless networking, novel ultra-low power technologies.	https://swarmlab.eecs.berkeley.edu/letter-executive-director#overlay-context=node/5/panel_content
Berkeley Wireless Research Center (BWRC)	Radio Frequency (RF) and Millimeter Wave (mmWave) technology, Advanced Spectrum Utilization, Energy Efficient Systems and other Integrated Wireless Systems and Applications	http://bwrc.eecs.berkeley.edu/
Broadband Wireless Access & Applications Center (BWAC)	Opportunistic spectrum access and allocation technologies, Millimeter wave wireless, Wireless cyber security, Cognitive sensor networks of heterogeneous devices, Image and video compression technologies, IC and low-power design for broadband access/applications	https://bwac.arizona.edu/
Center for Wireless Systems and Applications (CWSA) at Purdue University	Devices and materials, Low power electronics, Communications, Networking, Multimedia traffic, Security	http://cwsaweb.ecn.purdue.edu/
ChoiceNet Project	Architectural design for the Internet of the near future	https://code.renci.org/gf/project/choicenet/
Clean Slate Project at Stanford University for research on Software-Defined Networking (SDN)	OpenFlow, Software Defined Networking, and the Programmable Open Mobile Internet	http://cleanslate.stanford.edu/
eXpressive Internet Architecture (XIA) Project	Internet Architecture	http://www.cs.cmu.edu/~xia/
Intel Strategic Research Alliance (ISRA)	Enabling new spectrum, improving spectral efficiency and spectral reuse, intelligent use of multiple radio access technologies, and use of context awareness to improve quality of service and wireless device power efficiency.	https://www.intel-university-collaboration.net/focused-research
Joint University of Texas, Austin and Stanford Research on 5G Wireless	New architectures for dense access infrastructure	http://www.ece.utexas.edu/news/profs-de-veciana-shakkottai-and-collaborators-received-nsf-grant-work-5g-wireless-networks
Mobility First Project	Architecture centered on mobility	http://mobilityfirst.winlab.rutgers.edu/
Named Data Network (NDN) Project	Named Data Networking (NDN) architecture	http://named-data.net
NEBULA Project	Cloud computing data centers	http://nebula-fia.org
NSF Communications & Information Foundation (CIF)	secure and reliable communications	http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503300&org=CISE
NSF Computer & Network Systems (CNS)	enterprise, core, and optical networks; peer-to-peer and application-level networks; wireless, mobile, and cellular networks; networks for physical infrastructures; and sensor networks	http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503307&org=CISE
NSF Extreme Densification of Wireless Networks	Network densification	http://www.nsf.gov/awardsearch/showAward?AWD_ID=1343383&HistoricalAwards=false
NSF Future Internet Architectures (FIA) Program	Named Data Network (NDN), Mobility First, Nebula, Expressive Internet Architecture (XIA), ChoiceNet	http://www.nets-fia.net/
NSF Grant for Evaluation of 60 GHz Band Communications	Millimeter wave picocells	....
Polytechnic Institute of New York University (NYU-Poly) Program	Smart and more cost effective wireless infrastructure	http://engineering.nyu.edu/
Qualcomm Institute	Robust wireless communication, multimedia communication systems, and devices for next-generation communication, wireless health	http://csro.calit2.net/proposals.html
UCSD Center for Wireless Communications	Low-power circuitry, smart antennas, communication theory, communication networks, and multimedia applications	http://cwc.ucsd.edu/research/focusareas.php
Wireless@MIT Center	Spectrum and connectivity, mobile applications, security and privacy and low power systems	http://wireless.csail.mit.edu
Wireless @ Virginia Tech	Cognitive Radio Networks, Digital Signal Processing, Social Networks, Autonomous Sensor, Communication, Antennas, Very Large Scale Integration	http://wireless.vt.edu

the need of deployment of small cells is in the places where the line of sight centered microwave solutions are either hard or too costly to deploy for backhaul. Hence, the need to connect small cells at diverse locations made backhaul network a critical part of the infrastructure. In particular, there is a need of flexible centralization for dynamic adaptation of network routes. The degree of radio access network centralization depends on available backhaul resources.

So there is a need of a refined transport network design that can convey the data headed towards the central unit free of the degree of centralization. This is an important necessity for maximum flexibility when the introduction of the new functionalities to the network is taking place.

But the complications increases in routing and classification of data packets according to their quality of service. On the other hand, software defined network provides quicker reaction to link/node letdowns, higher utilization of the accessible resources, and faster deployment of new updates with ease. These advantages have come up with a centralized control example, which streamlines the arrangement and management, but with increased computational efforts, as algorithmic complexity increases [103]. Also for spectrum utilization, software defined radio (SDR) and software defined networks (SDN) are the optimum solution and the study in [104] revealed that the co-existence of SDR and SDN is essential, and the optimal results can be attained only by co-existence and joint compliments.

J. TRENDS AND QUALITY OF SERVICE MANAGEMENT IN 5G

5G technologies are likely to appear in the market in 2020. It is expected to significantly improve customers Quality of Service in the context of increasing growth of data volume in mobile networks and the growth of wireless devices with variety of services provided. Some general trends related to 5G can be explained in terms of machine to machine traffic and number of machine to machine connections in mobile [105].

Based on the projections as shown in Fig. 14, in 2018 the number of machine to machine (M2M) connections in the networks of mobile operators will surpass 15 billion [108], which is 2 times more than the present rate, and in 2022 mobile operators will have more than 26 billion machine to machine connections.

At the same time the stake of machine to machine connections of the total number of connections in the mobile operator's networks will rise from the present 5% to 15% in 2018 and to 22% in 2022 [105].

A key trend relates to mobility, as broadband mobile usage, with more than 2.4 billion users globally (as of June 2012) is expected to be dominant over the coming years. For data traffic and machine to machine communications, an expected 40-fold increase between 2010 and 2015 is shown in Fig. 15 and a 1000 fold increase is predicted over a decade. This level of growth force the network operators to provide global broadband access to all types of heterogeneous and modified Internet based services and applications [105].

While the Quality of Service management in 5G can be realized in terms of cell spectral efficiency and latency.

Demand to the cell's spectral efficiency in 5G networks for diverse transmission channels are shown in Fig. 16. Increased spectral efficiency of 5G networks can be attained using non-orthogonal access methods in radio access networks and by using non-orthogonal signals [107]. Comparison of these demands with the same demands to 4G networks shows the progress of spectral efficiency by 3-5 times [105].

Assessment of demands to delay in control and user planes for signaling traffic and user traffic respectively is shown in Fig. 17. This figure depicts that the demands to 5G networks will be twice more firm for traffic in the user plane and 10 times more firm in the subscriber traffic plane [106].

V. CONCLUSION

In this paper, a detailed survey has been done on the performance requirements of 5G wireless cellular communication systems that have been defined in terms of capacity, data rate, spectral efficiency, latency, energy efficiency, and Quality of service. A 5G wireless network architecture has been explained in this paper with massive MIMO technology, network function virtualization (NFV) cloud and device to device communication. Certain short range communication technologies, like WiFi, Small cell, Visible light communication, and millimeter wave communication technologies, has been explained, which provides a promising future in terms of better quality and increased data rate for inside users and at the equivalent time reduces the pressure from the outside base stations. Some key emerging technologies have also been discussed that can be used in 5G wireless systems to fulfill the probable performance desires, like massive MIMO and Device to Device communication in particular and interference management, spectrum sharing with cognitive radio, ultra dense networks, multi radio access technology, full duplex radios, millimeter wave communication and Cloud Technologies in general with radio access networks and software defined networks. This paper may be giving a good platform to motivate the researchers for better outcome of different types of problems in next generation networks.

APPENDIX

A list of current research projects based on 5G technologies are given in Table 7, 8 and 9.

TABLE 9. 5G related activities in Asia [109].

Research Project / Research Groups	Research area	HTTP location
IMT-2020 PROMOTION GROUP	5G research and development	http://www.imt-2020.cn/en/introduction
MOST (MINISTRY OF SCIENCE & TECHNOLOGY) 863-5G PROJECT	Radio-access-network (RAN) architecture, Massive MIMO	http://www.most.gov.cn/eng/programmes1/

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