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Energy-Efficient and Enhancement Methods For 5G Technology

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Abstract*— *With the evolution of communication technology, .a corresponding requirement for optimization in energy consumption is also growing. With the..emergence of 5G technology the importance of energy efficiency (EE) for wireless networks has been realized .even more. The major concern is to improve EE without compromising on user experience. So, in this paper, we address various energy issues and provide an analysis of various techniques which will be adopted in. the 5G networks to improve the energy efficiency of the devices. We have focused our attention on the following areas to improve the energy efficiency which include EE improvement using radio access techniques like Simultaneous wireless energy and power transfer, EE improvement by use of Small Cells and Massive MIMO, EE improvement by using relays and D2D communication.

I. INTRODUCTION

With the evolution of communication technology, a corresponding requirement for optimization in energy consumption is also growing. According to a survey the mobile operators are amongst the top energy consumers as well as their consumption is growing at a very fast rate especially with the deployment of 4G technology. The base station (BS) consumes a large part of the energy. Generating a large amount of electricity bill. Thus, not only from the operator's but also from the consumer's point of view, obtaining energy efficiency (EE) has significant economic benefits. It also has great ecological benefits and represents social responsibility in fighting. Climate change. So, there is an urgent need to purse energy efficiency along with optimal capacity and spectral efficiency when designing a wireless network. This paper briefly presents the evolution of mobile networks and concentrate on 5G advantages and its challenges.

The fifth telecommunication generation, 5G, is about to be implemented in Europe. This technology is very promising regarding its application to the many verticals, and will enable the emergence of innovations. Nevertheless, in a time when it has become important to minimize energy consumption as much as possible, the energy efficiency of 5G is a major concern. Approaches and solutions for making 5G as energy-efficient as predicted – more than 90% more energy-efficient than LTE – have been widely discussed in the literature. One of the main solutions highlighted in most of the studies on this subject is the possibility to put base stations in "sleep mode" – since base stations consume 80% of the energy used to transmit data20. Other solutions include spatial multiplexing, beamforming, improved battery life, reduction of energy consumption by auxiliary equipment, and increased hardware efficiency.

With the evolution of communication technology, a corresponding requirement for optimization in energy consumption is also growing. According to a survey the mobile operators are amongst the top energy consumers as well as their consumption is growing at a very fast rate especially with the deployment of 4G technology. The base station (BS) consumes a large part of the energy generating a large amount of electricity bill. Thus, not only from the operator's but also from the consumer's point of view, obtaining energy efficiency (EE) has significant economic benefits. It also has great ecological benefits and represents social responsibility in fighting climate change. So, there is an urgent need to purse energy efficiency along with optimal capacity and spectral efficiency when designing a wireless network.

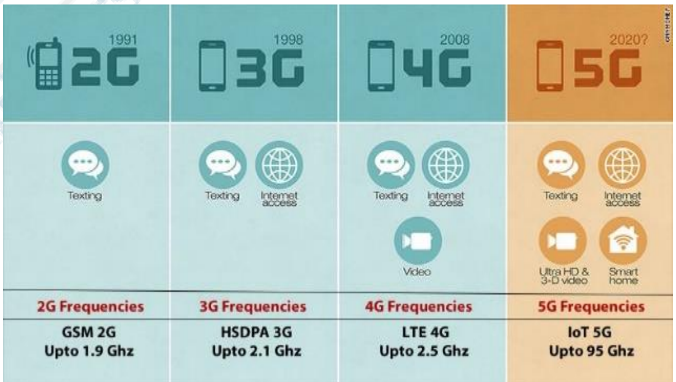

Fig. 1. All generation capacity

5G supports significantly faster mobile broadband speeds and lower latencies than previous generations while also enabling the full potential of the Internet of Things. From connecting vehicles and transforming healthcare to building smart cities and providing fiber-over-the-air, 5G is at the heart of the future of communications. 5G is also essential for preserving the future of the most popular applications – like streaming video – by ensuring that growing usage can be sustained.

II. REASONS TO CHOOSE 5G-NR OVER LTE

Always – on signal support

LTE (**Long Term Evolution**): was designed to support always on signals be it any condition or situation, leading to a lot of wastage of resources and required continuous evaluation. For Example: System information broadcast, signals for detection of base station, reference signals for channel estimation etc.

NR **(New Radio)**: Always-on transmissions are minimized in order to enable higher network energy performance and higher achievable data rates, causing reduced interference to other cells.

- **Assigned spectrum**

LTE: Just introduced support for licensed spectra at 3.5 GHz and unlicensed spectra at 5 GHz.

NR: It's first release supports licensed-spectrum operation from below 1 GHz up to 52.6 GHz and planning is ongoing for extension to unlicensed spectra.

- **Flexibility support for time/frequency resources**

LTE: has majorly supported fix timing/frequency for transmission in certain situations. For Ex: Uplink Synchronous HARQ protocol, where a retransmission occurs at a fixed point in time after the initial transmission.

NR: believes in configurable time/frequency resources. It avoids having transmission on fixed resources.

- **Channel estimation**

LTE: dependent on cell-specific reference signals for channel estimation, which are always transmitted.

NR: For channel estimation, NR doesn't include cell-specific reference signals, instead relies on user specific demodulation reference signals, which are not transmitted unless there is data to transmit, thereby improving energy performance of the network.

- **Dynamic uplink downlink allocation**

LTE: Uplink and downlink allocation does not change over time. Even though a later feature called eIMTA allowed some dynamics in UL DL allocation.

NR: Supports dynamic TDD, which means dynamic assignment and reassignment of time domain resources between UL and DL directions.

- **Device and Network Processing time**

LTE: Better than 3G but not enough considering future requirements under highly dense environment for certain applications

NR: Processing times are much shorter in NR for both device and network. For Example: A device must respond with an HARQ ACK within a slot or even lesser (depending on device capabilities) after receiving a downlink data transmission.

- **Low Latency Support**

LTE: Requires MAC and RLC layers to know the amount to data to transmit before any processing takes place, which makes it difficult to support very low latency.

NR: This is one of the most important characteristics of NR. Let me explain this support by giving 2 examples below:

1. Header structures in MAC and RLC have been chosen to enable processing without knowing the amount of data to transmit, which is especially important in the UL direction as the device may only have a few OFDM symbols after receiving the UL grant until the transmission should take place.
2. By locating the reference signals and downlink control signaling carrying scheduling information at the beginning of transmission and not using time domain interleaving across OFDM symbols, a device can start processing the received data immediately without prior buffering, thereby minimizing the decoding delay.

- **Error Correcting Codes**

LTE: uses Turbo coding for data, which are the best solution at the lower code rate (For example: 1/6, 1/3, 1/2).

NR: uses LDPC (Low density Parity check) coding in order to support higher data rate as it offers lower complexity at higher coding rates as compared to LTE. They perform better at higher code rates (For Example: 3/4, 5/6, 7/8)

- **Time Frequency Structure of Downlink control channels**

LTE: Less flexible as it needs full carrier bandwidth

NR: Has more flexible time frequency structure of downlink control channels where PDCCH's are transmitted in one or more control resource sets (CORESETS) which can be configured to occupy only part of the carrier bandwidth.

- **Service Data Application Protocol layer**

LTE: Not present

NR: Introduced to handle new Quality of service requirements when connecting to 5G core network. SDAP is responsible for mapping QoS bearers to radio bearers according to their quality-of-service requirements.

Comparison between Mobile Phone Generations.

Table 1.. Comparison between different generations

Mobile Generation	**GSM(2G)**	**CDMA(3G)**	**LTE(4G)**	**5G**
Refers to	Second generation	Third generation	2010	2020
Features	It uses digital signals. It provides services such as text messages etc.	It provides faster communication. It has large capacities and broadband capabilities. It send/receive large email messages	provides additional services. It provides mobile ultrabroadband Internet access.	Interactive multimedia, voice, internet and others services are supported by 5G. It is more effective and attractive as compare to other generation.
Band width	200 KHz	5 MHz	20 MHz	Up to 100 MHz
Data rate	14.4 Kbps	3.1 Mbps	100 Mbps	20 Gbps- 100 Gbps
Latency	700 ms	< 200 ms	< 30 ms	About 1 ms
Modulation Technique	GMSK	QPSK, 16QAM	QPSK, 16 QAM and 64 QAM	256 QAM
Applications	Voice and Slow data rate communication	Advanced applications (various services like data services access to (television/video)	high rate data Applications, wearable devices	device-to-device, machine-to machine, internet of Things ,2-way gaming, virtual reality glasses, cloud-based computing and other technologies
Multiplexing	TDMA	W-CDMA	OFDMA and MIMO	OFDM, NOMA, FBMC and Massive MIMO
Standards	GSM, EDGE, GPRS	UMTS, CDMA2000, HSPDA, EVDO	LTE advanced, IEEE 802.16 (WiMAX)	CDMA, BDMA
Technology	Digital cellular	code division multiple access, universal mobile Telecommunications system	Long-Term evolution advanced, Wi-Fi	Multi- radio Access technology, Wi-Fi, Wi-Gig

- **RRC States**

LTE: Supported only 2 states: Idle and Connected

NR: Supports a 3rd state also called the RRC_INACTIVE, which is introduced to reduce the signalling load and the associated delay in moving from idle-to-active transition. In this state, RRC context is kept in both the device and the gNB.

- **Massive MIMO**

LTE: used normal MIMO and the maximum number of antennas in MIMO is 8 (DL) * 8(UL) using spatial multiplexing by UE Category 8

NR: Uses the concept of MIMO with an antenna array system using massive number of antennas, which can go up to 256(DL) * 32(UL).

Key Performance Indicators along with other differences:

LTE:

- Peak Data Rate (With LTE-A): Downlink (1 Gbits/s), Uplink (.5 Gbits/s)
- Peak Spectral Efficiency: Downlink (30 bps/Hz) – with 8-layer spatial multiplexing, Uplink (15 bps/Hz) – with 4-layer spatial multiplexing
- Control Plane Latency: <100ms
- User Plane Latency: <10ms
- Mobility (With LTE-A): Device speeds up to 500 Km/h
- Max Supported Bandwidth: 20 MHz
- Waveform: CP-OFDM for DL, SC-FDMA for UL
- Maximum number of subcarriers: 1200
- Slot-Length: 7 symbols in 500us
- *NR*:
- Peak Data Rate: Downlink (20 Gbits/s), Uplink (10 Gbits/s)
- Peak Spectral Efficiency: Downlink (30 bps/Hz), Uplink (15 bps/Hz)
- Control Plane Latency: <10ms
- User Plane Latency: <0.2ms for URLLC
- Mobility: Device speeds up to 500 Km/h
- Max Supported Bandwidth: 100 MHz in Frequency Range1 (400 MHz to 6 GHz) and up to 400 MHz in Frequency Range2(24.25 GHz to 52.6 GHz)
- Waveform: CP-OFDM for DL, CP-OFDM and DFT-s- OFDM for UL
- Maximum number of subcarriers: 3300
- Slot-Length: 14 symbols (duration depends on subcarrier spacing), 2,4 and 7 symbols for mini-slot

5G wireless technology is meant to deliver higher multi-Gbps peak data speeds, **ultra-low latency, more reliability, massive network capacity, increased availability**, and a more uniform user experience to more users. Higher performance and improved efficiency empower new user experiences and connects new industries.

- **Main advantages**

The headline features of this fifth generation of communications technology are super-fast data rates, ultra-low latency with only a one millisecond delay between devices communicating with one another, and vastly increased network capacity. As a result, 5G offers advantages for IIoT that other wireless communication technologies do not. Dritan Kaleshi, head of 5G technology at Digital Catapult, explained: “Firstly, 5G is secure by design, meaning the network operations themselves are secure,” he says. “It’s a managed network as compared to other kinds of wireless networks in use.”

There is a higher guarantee of the reliability and the timeliness of communications through the network, he added. Finally: “5G offers a networking system that has the capability to support multiple types of devices – such as high-quality inspection cameras and micro switch sensors – that are all transmitting data simultaneously.

“Taken together, all of these features provide the support for IIoT to move away from purely sensing networks, which it is mostly used for today, towards actuation. In other words, to close the loop for the control systems.”

For example, 5G can enable predictive maintenance, which requires large numbers of sensors and high network availability to allow for real-time feedback of what is happening in an industrial setting. In a project carried out by the Worcestershire 5G Consortium, this has already successfully been trialled at the Worcester Bosch factory.

This is just one-use case; there is a wide range of others that 5G can address. But the biggest barrier is getting manufacturers on board with 5G because there is an initial scepticism. To understand what these barriers are, Kaleshi, with Digital Catapult’s 5G in Manufacturing Working Group, produced a research paper last July called “Made in 5G,” which outlines the main challenges to 5G adoption.

“As part of this research we carried out workshops with manufacturers to understand their views of adopting 5G in order to support their digital transformation. One of the key things that came through was that there was little awareness of the capabilities of 5G technology,” said Kaleshi.

This prompted Digital Catapult to create a programme that could showcase 5G’s capabilities through real-life examples in a bid to incentivise companies to adopt 5G. Launched together with Ericsson at the end of 2019, the Industrial 5G Accelerator programme will work with manufacturing companies to produce test cases proving 5G’s potential in boosting productivity and increasing efficiency.

Advanced 5G features such as end-to-end network slicing and mobile edge computing help support the needs of industry vertical sectors. Network slicing allows services to be precisely tailored to the needs of an organisation in terms of required quality of service, speed, security, latency etc. Edge computing brings compute capabilities closer to consumers and enterprise end users which can enable very low latencies and customised local services.

How much spectrum does 5G need?

The 3GPP’s 5G New Radio (NR) specification includes traditional mobile bands as well as newer, wider bands designed for 5G. It supports channel bandwidths ranging from 5 MHz to 100 MHz for bands below 6 GHz, and channel sizes from 50 MHz to 400 MHz in bands above 24 GHz. The full capabilities are best realised through the widest channel sizes in new 5G bands. 5G supports carrier aggregation to enable very high speeds, however, making spectrum available in the largest contiguous blocks possible supports faster, lower latency and greener 5G services.3 The

ITU's minimum technical requirements to meet the IMT-2020 criteria1 – and thus the fastest speeds – specify at least 100 MHz of bandwidth per operator. They also specify support for up to 1 GHz per operator in bands above 6 GHz such as mm Wave bands

Recent research shows significantly more spectrum will be needed to help 5G services scale in the 2025-2030 timeframe. For example, it has been estimated that an additional 1-2 GHz of mid-band 5G spectrum could be needed to help ensure mobile networks are capable of delivering the IMT-2020 target of 100 Mbps per user in densely populated urban areas and to support FWA more widely. This is in addition to initial 5G mid-bands (e.g. 400 MHz in 3.3-3.8 GHz) and assumes other mid-bands formerly used for 2G, 3G and 4G services are upgraded to 5G.

The energy efficiency was not given significant consideration until 3G. According to a study on 2G and 3G power consumption for a 15-minute time window, GSM consumes an average of 1.08kW to 1.20kW. Whereas, UMTS average power consumption for the same 15-minute time window was around 0.19kW to 0.22kW.

According to another study, 5G power consumption at peak hours is 1200W to 1400W, which is 300% to 350% greater than of 4G the power consumption varies significantly between peak and off-peak hours. To address this issue, researchers proposed to put the base station radios in sleep mode as the majority of the electricity consumption was due to base stations and RF transceivers (76% of total power consumption).

Optimization of energy in 5G

Considering the energy constraints and versatile network requirements, traditional approaches are not enough for network optimization. In this regard, machine learning techniques are being used to let the system learn intelligently from data and optimize the overall operation of the network. For example, virtualization technology improves energy efficiency and resource utilization and can result in up to 50% of energy-saving

To make the upcoming 5G networks energy efficient, various techniques can be adopted. These techniques can be classified under three categories which are using energy efficient architectures or energy efficient resource allocation or using radio technologies which are energy efficient. The following techniques are available:

1.Energy-Efficient Architectures:
- *Optimization of cell size: large vs small cell deployment*
- *Overlay source: microcell, Pico cell or femtocell*
- *Relay and cooperative communications*

2. Energy-Efficient Resource Management:
- *Joint power and resource allocation*
- *SISO vs. MIMO with packet scheduling*

3. Energy-Efficient Radio Technologies:
- *Heterogeneous network deployment (multi-RAT)*
- *SWIPT*

These techniques have been discussed further for power optimization along with their integration with 5G network.

III. 1.MACHINE LEARNING OVERVIEW

The engineering of developing intelligent programs (artificial intelligence) started in the 1950s. Machine Learning (which does not need any categorical programming to learn) started evolving in the mid-1980s and matured over time. Machine learning is the sub-field of Artificial Intelligence (A.I) and is further sub-categorized into Supervised, Unsupervised, and Reinforced Learning. Deep Learning is also a sub-field of machine learning which evolved in 2010 and can be classified as supervised, unsupervised, and reinforced. Recently, machine learning based approaches has been applied to many research fields for solving problems like resource management & allocation, power allocation, cell sleeping, pre-coding. In this section, we look at different machine learning approaches used for the energy efficient wireless network. A brief discussion on the benefits of applying machine learning based over the conventional approaches for improving energy efficiency in the 5G and beyond network is also presented. To achieve energy-efficient virtualization and network optimization, machine learning can further improve energy-efficiency through load sharing and consolidation. Likewise, energy consumption in the data centers, which consume most of the energy, can be minimized by intelligent resource allocation and management through machine learning approaches.

IV. COMPARISON WITH TRADITIONAL APPROACHES

The new wireless technology-based model needs high data rates and diverse applications that challenge traditional technology in learning and decision-making processes. Some of the M.L advantages over traditional approaches are as below:

- Machine learning can learn from its data, whereas the traditional techniques are mostly hard coded.
- Particularly in large scale problems, learning speed significantly improves.
- In conventional approaches, a new set of instructions needs to be coded for every new function.
- Machine learning has autonomous decision-making capability.
- Software development every-time for new applications is a costly project. Besides its benefits, there are also some of the drawbacks associated with machine learning related to training. Machine learning integration for large scale processing, security, and how the application-level implementation is possible for research theories.

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The goal of connecting billions of devices is non-sustainable in terms of both economic and environmental concerns. The rate at which network design demand is increasing, it will eventually lead to 1000 times more power consumption than today's network resource allocation, network planning and deployment, energy harvesting & transfer, and hardware solutions are the broad categories that can increase energy efficiency.

V. MACHINE LEARNING APPROACHES FOR ENERGY EFFICIENCY

Machine learning is further divided into supervised learning, reinforced learning, and unsupervised learning. There is also further classification on these techniques to be best utilized for particular problems. Machine learning techniques discussed in this paper are also presented. Supervised learning is the best approach for channel-related problems such as channel estimation, its detection, and learning its behavior to take future predictions. This is because supervised learning produces the output from the collected data based on forgoing experiences. However, for the networks where the raised problems are unknown, reinforced learning is best to use, such as resource allocation and management. Reinforced learning has the potential to adjust its strategy to obtain the required results. It learns from the results systematically and improves the decisions further. Unsupervised learning is slightly different from supervised learning as it is better utilized for clustering and spectrum sensing problems in wireless networks. It functions on its own to learn the network and solve the problem and thus solve more complex problems compared to supervised learning. depicts machine learning classification and learning approaches that are frequently used in 5G enabling technologies and energy efficiency problems. to, resource allocation, network planning and deployment, energy harvesting & transfer, and hardware solutions are the broad categories that can increase energy efficiency.

According to the Shannon formula, with the increase in bandwidth, the energy consumption factor also rises. Massive MIMO is a promising technology to deal with efficiency concepts in terms of both spectrum and energy. Multiple antennas attached to a BS can either sleep or turn off mode to increase energy efficiency. In, the authors worked on the trade-off between spectral efficiency and energy efficiency. The proposed work presented resource allocation to increase energy efficiency using the benefits of the Rayleigh fading channel model for massive MIMO. Authors in worked not only on energy efficiency as well as on end to end delay. Besides spectrum efficiency, increase in bandwidth, deploying small cells, D2D/M2M communication, and ultra-dense networks, energy efficiency is another interlinked challenge that needs to be addressed. However, 5G is promising to decrease energy consumption by 90%. According to, energy efficiency can be calculated as a ratio between the energy consumption of a system and Joules per bit capacity, which is an energy consumption ratio.

Several machine learning approaches can be applied to improve the energy efficiency of 5G networks. In supervised learning, the model is trained on a set labeled data to predict optimal solutions. An example of a supervised learning application is massive MIMO for energy efficiency, in which channel estimation and detection are considered a problem because of a high number of antennas. Unlike supervised learning, unsupervised learning works on unlabeled input and is suitable for clustering and dimensionality reduction. For example, unsupervised learning can be used to cluster BS with similar behaviors for energy-efficient operation in varying load conditions. The use of reinforced learning approaches for energy-efficient solutions is suitable when little or no prior data is required for processing

VI. MASSIVE MIMO

Among several metrics, bandwidth efficiency is one of the important factors to be chosen for the next-generation network. The rapid increase in carbon emission and the growing power demand of communication networks resulted in enhanced energy efficiency metrics. For this, MIMO became significant due to energy-efficient capability and enhanced throughput. In massive MIMO, the concept of numerous base station deployment is the same as TDD operations like conventional MIMO. However, it does not require additional power for the transmission and bandwidth. Multiple Input Multiple Output (MIMO) is not a new concept. It has been deployed in 4G with one BS support to eight antenna ports. Although it is an old concept, it was not deployed fully as conventional BS was considered more cost-effective and MIMO more complicated. As MIMO concept enters into 5G, a larger number of antennas can be deployed, which is referred to as massive MIMO. Massive MIMO gives many advantages over MIMO such as increased throughput, enhanced spectral efficiency, increased signal to noise ratio, increased capacity, reduced latency, increased data rate, and energy efficiency. Despite the earlier mentioned massive MIMO benefits, antennas placement is still an issue in massive MIMO. The basic rule to place an antenna with spacing is half the signal wavelength to provide no-correlation among antennas. Massive MIMO, with hundreds of channels at one BS, leads to increased spatial diversity. However, channel hardening results when the faded channel behaves as a non-fading channel. The random interference is still there in massive MIMO, but it has little effect on communication. One way to achieve zero correlation is by decreasing the wavelength; the higher the frequencies, the lower are the chances for correlation. Transferring more bits per Hertz bandwidth makes the network more spectrum efficient. However, another challenge is to make the network more energy efficient. This can be somehow possible with spatial modulation. Massive

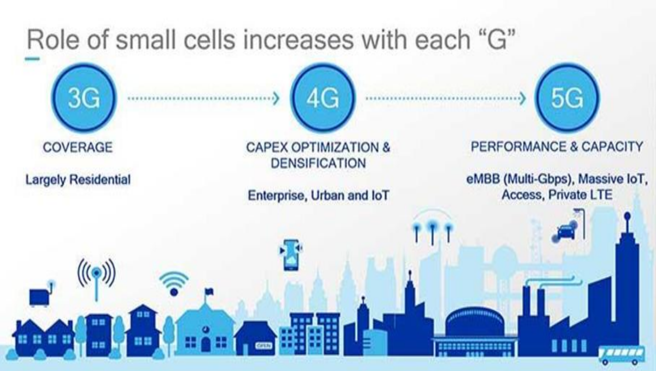
MIMO is much better than MIMO in higher bandwidth, enhanced energy efficiency, and spatial freedom. However, the pilot contamination problem occurs because of inter-user interference using the same reference signal and is an inherent problem. Because of the frequency limitation, the cells are bound to use the same frequencies blocks. The orthogonal pilot sequences lead to pilot contamination. The pilot contamination issue can occur in both ordinary BS and massive MIMO. However, it still gathered more attention in the case of massive MIMO because of the reuse of pilots. As the channel difference between conventional MIMO and massive MIMO is significant, a pilot contamination problem in any BS is reduced by switching among different pilots (among large pilot sequences). In the case of massive MIMO, due to more active terminals and more reuse of pilots (as pilots do channels estimation), it is challenging to avoid pilot contamination. Whereas in conventional MIMO, it can be overcome as more the terminals, higher will be pilot contamination. Regular Pilot (RP) and Superimposed Pilot (SP) are the two most frequently used methods to suppress pilot contamination. In RP, data and pilot sequences are transferred in a fragmented way while adjusting the pilot's sequence. In contrast, SP is an old concept, where data symbols and pilot together instead of placing them in time or frequency. The superimposed pilot has also been advocated for real-time implementation through simulation in. The proposed work advocates that the superimposed pilot has shown better results in hybrid systems. Uplink MIMO provides significant power saving because of the higher array gain. This is possible because of the coherent signal integration. In contrast, in the downlink, the beams are focused on a particular direction for users. Cell-free massive MIMO is a new concept. A large number of access points are deployed in a distributed manner to serve numerous users. These access points (AP) work in the same TDD and consist of single or numerous antennas. This concept gives high energy efficiency and spectral efficiency because of less intruder interference even with furnishing many users at the same time-frequency because of the less distance among antennas. The cell-free massive MIMO concept is similar to small cell deployment; the more significant difference is the deployment of many AP vs. single AP. Massive cell-free MIMO's energy efficiency factor depends on power allocation and consumption, channel estimation, and the selection of best access points. Although massive MIMO has matured, supporting both multi-user and massive MIMO. Several researches are being carried into spectral efficiency, pilot contamination/decontamination, power allocation factor, and energy efficiency. A deep learning-based approach is used in to let the system learn from its user equipment location to allocate downlink power. A massive MIMO network is considered on TDD for both user equipment and base station operations. The initial optimal powers are calculated using the Monte Carlo method, and the training part is done offline. The deep learning approach is used to let the network allocate power based on user location. It is proved that max production strategy for neural network is more advantageous in complex calculations than conventional approaches. When used together for power allocation, max-min and maximum production approach showed incompetence, which is then addressed through a different neural network using the LSTM layer. Although the simulation provided promising energy efficient power allocation results, the massive MIMO scenario considered is not significant to prove its efficiency for the real-time environment. However, deep learning is a promising tool to solve the real-time high computational problem as they can learn iteratively from the environment. Another work proposed on pre-coding integrates deep neural networks because of its capability to reduce the computational complexity. It utilizes structural information through the training stage. Distributed massive MIMO is also considered an energy-efficient way to allocate resources. Compared to conventional massive MIMO, its throughput, energy efficiency, and channel modelling in a complex environment are noticeable. Also, the beamforming in massive MIMO results in improved energy efficiency on the targeted coverage area.

VII. ULTRA DENSE NETWORK/DENSE SMALL CELL

Ultra-dense networks were required to fulfil the needs of those areas that are highly packed and require more cell deployment. There are three ways to enhance the capacity of the network (a) by enhancing the spectrum efficiency (b) broadening the bandwidth, and (c) by deploying more cells. The concept of dense deployment is found back in 4G, stuffing the same area with many cells. However, the cost factor and interference among those macro cells surfaced, which has more diminishing returns. The better idea was to move towards cells that provide more coverage to end-users and less deployment cost. Small cells (Pico cells, femtocells) provide coverage closer to the end-users and require less power, with almost 90% more capacity. Small cell deployment does not entirely negate the need for macro cell as its coverage area is too small compared to macro cells, which is why macro cells are still required to cover a large area. Ultra-dense small cell network extends the coverage on the benefits of low power consumption and deployment cost. Apart from coverage area frequency reuse is also another factor of small cells. Small cells are divided into four types: (a) Pico cells are mainly used to increase the capacity up to 100m and can be deployed indoors and outdoors. (b) Femtocells are also a type of small cell with the same characteristics as Pico cells, except the coverage is 10-30m. (c) Relays are the macro extension and need proper planning for indoor and outdoor deployment to reduce interference. Its coverage area is a little larger than of femtocells (up to

100m). (d) RRHs can only be deployed outdoor but with proper planning, as this is normally connected with BS through a wired connection or microwave links. The provided coverage is around up to 100m. The consumed power of small cells is same for all approximately 100mW (indoor) and 0.25W to 2W(outdoor). Deploying small cells and making the area dense does not solve all the problems. Some new issues like interference and more energy consumption also arise. To resolve such issues, the integration of different techniques is required for challenges to be addressed. Capacity is not imperatively dependent on dense deployment on cells, many other factors like interference, frequent handoffs, excessive energy consumption, and mobility.

The focus of 5G is to use higher frequency ranges, and hence ultra-dense networks are considered an efficient feasible solution. It benefits in utilizing frequencies more productively, deploying small base cells densely (to cater to exploding traffic demands), and better energy consumption. Therefore, the need for an energy efficient network became indispensable. A three-layer learning solution is provided for dense small cell networks in, macro base stations and small base stations are deployed where power grid feed energy is used to Macro Base stations (MBSs) and energy harvesting techniques like solar cell provide power to Small Base stations (SBSs). SBS also has the feature of on/off to save energy. The proposed first layer takes decision locally at SBS by making the best use of resources. It is composed of the heuristically accelerated reinforcement learning approach. The second layer takes decisions at MBS and is made up of a multilayer feedback neural network and is also responsible for the energy factor. This approach gave promising results in terms of radio resource management for self-organizing networks and energy efficiency.



VIII. BEAM FORMING

Beamforming Overview. Beamforming is **used with phased array antennae systems to focus the wireless signal in a chosen direction**, normally towards a specific receiving device. This results in an improved signal at the user equipment (UE), and also less interference between the signals of individual UE. Beamforming is a technique that focuses a wireless signal towards a specific receiving device, rather than having the signal spread in all directions from a broadcast antenna, as it normally would. The resulting more direct connection is faster and more reliable than it would be without beamforming. Digital beamforming (MU-MIMO) is used in LTE Advanced Pro (transmission modes 7,8, and 9) and in 5G NR. Digital beamforming **improves the cell capacity** as the same PRBs (frequency/time resources) can be used to transmit data simultaneously for multiple users.

Benefits of beamforming

in massive MIMO systems Beamforming is a process formulated to produce the radiated beam patterns of the antennas by completely building up the processed signals in the direction of the desired terminals and cancelling beams of interfering signals. This can be accomplished using a finite impulse response (FIR) filter. FIR filters are beneficial in that their weights can be varied adaptively and applied to obtain the optimum beamforming. The application of beamforming in massive MIMO systems has the following advantages: enhanced energy efficiency, improved spectral efficiency, increased system security, and applicability for mm-wave bands. Enhanced energy efficiency The lower power requirements of beamforming antennas for transmitting signals to the intended user and cost reductions result in the lower power consumption and amplifier costs of massive MIMO systems. Massive MIMO systems are assisted by beamforming processes to reduce the power consumption of the entire system by computing the optimal quantity of antenna elements that meet several essential criteria for manipulating energy-efficient massive MIMO systems. For each specified power consumption of each BS, the overall energy efficiency is relatively unaffected by the number of working antenna elements in the cell; thus, a common number of working antennas can be implemented for the entire cells in the system to obtain high cost-effectiveness and overall energy efficiency. To meet the terminal throughput requirements, optimization processes for beamforming techniques, such as power control, must be considered to reduce the power consumption uplink and downlink signals.

Full duplex

Today's mobile users want faster data speeds and more reliable service. The next generation of wireless networks—5G—promises to deliver that, and much more. Right now, though, 5G is still in the planning stages, and companies and industry groups are working together to figure out exactly what it will be. But they all agree on one matter: As the number of mobile users and their demand for data rises, 5G must handle far more traffic at much higher speeds than the base stations that make up today's cellular networks.

To achieve this, wireless engineers are designing a suite of brand-new technologies. Together, these technologies will deliver data with less than a millisecond of delay (compared to about 70 ms on today's 4G networks) and bring peak

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download speeds of 20 gigabits per second (compared to 1 Gb/s on 4G) to users.

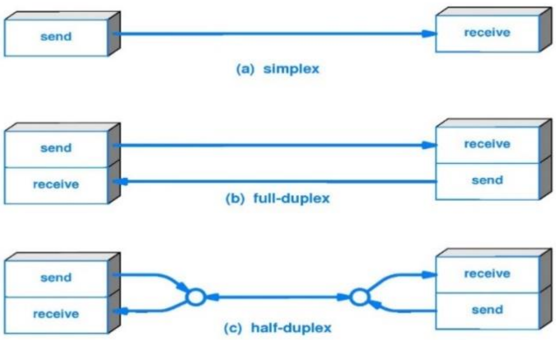
At the moment, it's not yet clear which technologies will do the most for 5G in the long run, but a few early favorites have emerged. The front-runners include millimeter waves, small cells, massive MIMO, full duplex, and beamforming.

Today's base stations and cellphones rely on transceivers that must take turns if transmitting and receiving information over the same frequency, or operate on different frequencies if a user wishes to transmit and receive information at the same time.

With 5G, a transceiver will be able to transmit and receive data at the same time, on the same frequency. This technology is known as full duplex, and it could double the capacity of wireless networks at their most fundamental physical layer: Picture two people talking at the same time but still able to understand one another—which means their conversation could take half as long and their next discussion could start sooner.

Some militaries already use full duplex technology that relies on bulky equipment. To achieve full duplex in personal devices, researchers must design a circuit that can route incoming and outgoing signals so they don't collide while an antenna is transmitting and receiving data at the same time.

This is especially hard because of the tendency of radio waves to travel both forward and backward on the same frequency—a principle known as reciprocity. But recently, experts have assembled silicon transistors that act like high-speed switches to halt the backward roll of these waves, enabling them to transmit and receive signals on the same frequency at once.



One drawback to full duplex is that it also creates more signal interference, through a pesky echo. When a transmitter emits a signal, that signal is much closer to the device's antenna and therefore more powerful than any signal it receives. Expecting an antenna to both speak and listen at the same time is possible only with special echo-canceling technology.

With full duplex and other 5G technologies, engineers hope to build the wireless network that future smartphone users, VR gamers, and autonomous cars will rely on every day. Already, researchers and companies have set high expectations for 5G by promising ultralow latency and record-breaking data speeds for consumers. If they can solve the remaining challenges, and figure out how to make all these systems work together, ultrafast 5G service could reach consumers in the next five years.

3.MM wave

As the frequency spectrum under 6 GHz is highly utilized, it appears that millimeter wave is the best candidate to respond to the huge requirements in terms of network capacity and from Gigabit broadband applications.

5G can be implemented in low-band, mid-band or high-band millimeter-wave 24 GHz up to 40 GHz. Low-band 5G uses a similar frequency range to 4G cell phones, 600–850 MHz, giving download speeds a little higher than 4G: 30–250 megabits per second (Mbit/s). Low-band cell towers have a range and coverage area similar to 4G towers. Some regions are not implementing the low band, making this the minimum service level. High-band 5G uses frequencies of 25–39 GHz, near the bottom of the millimeter wave band, although higher frequencies may be used in the future. It often achieves download speeds in the gigabit-per-second (Gbit/s) range, comparable to cable internet. However, millimeter waves (mm Wave or mm W) have a more limited range, requiring many small cells.

Millimeter-wave atmospheric loss: this parameter accounts for the level of millimeter electromagnetic energy absorbed by gases like oxygen or attenuated by rain or foliage. In this study, we assume a constant value of 3.2 dB for the atmospheric loss at 60 GHz [20]. This parameter introduces an additional attenuation at millimeter waves that must be accounted for since it increases the path loss and therefore reduces the range of the cell.

IX. CONCLUSION

5G is a diverse network that will enable a variety of services with the help of several enabling technologies. The main drivers are virtualization, softwarization, new RANs, and backhaul strategies. All the enablers for 5G will help deliver extremely low latency rates, provide high throughput, and support massive connectivity simultaneously. Furthermore, the need for increased network capacity, geographical coverage, and increasing traffic demands require network densification. All such improvements to support diverse use cases will eventually lead to more energy consumption compared to past generations. This is not sustainable from an environmental and business perspective. The need for the energy-efficient network is adopted worldwide because of both economic and environmental concerns. A lot of research has been done on improving energy efficiency in the 5G networks from the past few years. Due to the autonomous decision-making capabilities and benefit of learning from its environment, there has been growing interest in using machine learning techniques to solve energy efficiency at various 5G network levels. In this paper, we surveyed the state-of-the-art literature to address the energy efficiency issue in the 5G network and the need for intelligent learning. For this purpose, we proposed a taxonomy where we categorized the 5G network into three main parts: access, edge, and the core. The enabling technologies under the provided taxonomy are discussed by addressing machine learning importance in improving energy efficiency. In conclusion, machine learning holds the ability to mitigate energy efficiency issues and improve performance in future networks and under unpredictable network conditions. If appropriately implemented, machine learning has the potential to optimize the operation of a 5G network while at the same time, improving energy efficiency. However, there are still several open challenges that need to be addressed to build highly energy-efficient networks. For this, we highlighted prosome of the key challenges that need to be thoroughly investigated and provided future research direction for the same.

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