IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

Enhancing Energy Efficiency in 5G Networks

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Abstract

Wireless communication is indispensable in meeting the escalating demands for data, speed, and voice from users. To address these requirements, communication systems have been upgraded to 5G networks, which offer high data rates, capacity, and quality of service (QoS). However, as the demand for resources increases, there is a pressing need to develop energy-efficient communication techniques and establish efficient networks to minimize the impact on health and the environment. This paper focuses on the challenges and issues associated with designing low-energy communication techniques within the framework of green communication for 5G networks. The goal is to strike a balance between meeting the demands of users and maintaining ecological equilibrium. Various parameters of 5G communication are considered, including carbon dioxide emissions, energy consumption, and techniques for mitigating these problems. The paper discusses several key topics, incorporating massive MIMO (multiple input, multiple output), device-to-device (D2D) communication, heterogeneous networks, and green IoT, spectrum sharing, energy harvesting, and the challenges associated with implementing these techniques. The overarching theme is to achieve green communication by reducing energy consumption and promoting sustainability in the field of wireless communication.

Overall, this paper provides a thorough introduction of the idea of green communication and addresses

the technical aspects and challenges involved in achieving energy efficiency and environmental sustainability in 5G networks.

Keywords: MIMO, D2D, 5G, green communication, and green IOT.

I. Introduction

Cellular networks play a significant role in our daily lives, as they enable the control of various real-world tasks through computers and machines. This has been made feasible by ongoing developments in communication and information technology. With each passing day, the data rate in wireless communication is increasing rapidly, thanks to the constant improvements and developments in the field of communication and electronics. As a result of these system enhancements, there is a subsequent increase in data traffic [1]. The present generation of mobile communications, 4G, has problems with reduced data rates, interference, bandwidth shortages, congestion, and capacity restrictions [2].

The optimal solution to address these challenges is the adoption of 5G technology, which is available in India from October 1, 2022. 5G is renowned for its significantly increased capacity and bandwidth, offering hundreds of times more capacity compared to 4G. Moreover, it has the ability to provide services to a vast number of devices simultaneously [3].

In recent years, there has been a notable surge in the number of connected devices. By leveraging the capabilities of 5G technology, it becomes possible to effectively manage the potential traffic issues associated with this increase in device connectivity. For the average individual, the primary expectations from devices focus on boosting data rates and accelerating internet speeds [4]. Meeting these demands requires substantial transmit power, leading to significant energy consumption. Unfortunately, this energy consumption contributes to greenhouse gas emissions. Notably, Burning fossil fuels, primarily coal and natural gas, produces around 75% of our electricity [5]. As a consequence, connected devices are projected to contribute significantly to carbon dioxide emissions in the future, with estimates indicating a potential increase of several million ton [6]. The rate of CO_2 emissions should be regarded as an extremely concerning issue in the context of global warming, as addressing it is crucial for securing a better future [7]. While the telecommunication industry currently contributes only 2% of CO2 emissions to the environment, it is crucial to take proactive measures to prevent a significant increase in the future. The emissions from network operations, as well as the environmental impact of radio fields, have already had a substantial effect on human health [8]. Therefore, it is essential to address these issues promptly and effectively. In order to prioritize user safety from electromagnetic (EM) radiation, the FCC (Federal communications commission) has established limits for harmful radiations on the surface and has imposed restrictions on transmitting power for everyday gadgets. A statistic used to assess the degree of radio signal exposure to human tissue is called the SAR Value (Specific Absorption Rate). A higher SAR Value indicates a greater Possibility of endangering both human health and the environment [9].

Green Communication principles emphasize the crucial role of the Energy Efficiency Factor in promoting extended battery life for radio gadgets. With the increasing number of mobile subscription users, it is crucial for these devices to optimize energy consumption for everyday usage. Extensive tests, surveys, and research are being conducted to advance battery technology and explore innovative solutions for both electric vehicles and cell phones [10]-[11]. These endeavours are focused on enhancing energy efficiency and promoting sustainability in the realm of communication technology [12]. The ability to control remote devices using harvested energy such as solar power, necessitates the use of hardware equipment to convert energy from the surrounding sources [13]. As a result, there is growing need for environmentally friendly communication methods that can handle the increasing volume of data and communication advancements. To find the most practical answers and strategies for green communication, researchers and businesses are exerting enormous effort. This article provides a comprehensive review of four primary strategies employed in the realm of 5G communication.

In this paper, a comprehensive audit of four fundamental approaches are used in the field of 5G communication. The subsequent sections are structured as follows:

The first section provides a brief introduction to green communication.

The second section delves into the utilization of D2D (Device-to-Device)communication, HetNets (Heterogeneous Networks), green IoT (Internet of Things), and Massive MIMO (Multiple-Input Multiple-Output) in the context of green communication.

In the third section, various challenges pertaining to these strategies are discussed.

Finally, the fourth section presents the conclusion of the paper.

II. Techniques

The evolution of 5G technology has had a notable influence on fostering green communication. Below are several techniques employed in 5G to enable eco-friendly communication:

1.Massive MIMO: This technique is currently highly sought-after due to its numerous advantages, leading to its increasing demand. It involves using a large number of antennas at the base station, allowing it to serve a significant number of devices simultaneously with a single-antenna equipment. By utilizing a multiplexing technique, all the devices can benefit from the antenna's gain. Massive MIMO has the capability to accommodate 10-12 times more antenna slots in comparison to conventional MIMO techniques [14]. This technique offers several advantages, including improved energy consumption, expanded network coverage, enhanced throughput, reduced latency, and increased capacity gain [15]. There are three integration methods for this technique: System Massive MIMO, Single Massive MIMO, and Distributed Massive MIMO. The selection of these integration methods is based on the network's specific requirements, particularly in terms of energy and power consumption. In massive MIMO multicell scenarios, the transmitted power is regulated by considering constraints on power at both the base station and the receiver end. Additionally, spectral efficiency constraints are taken into account to optimize the system performance. The scaling rules of energy and pilot signal interference are used in multicell massive MIMO systems employing the maximum ratio transmission and zero forcing techniques. To the fullest extent possible, power is allocated to pilot signals, which are crucial for improving spectral efficiency.

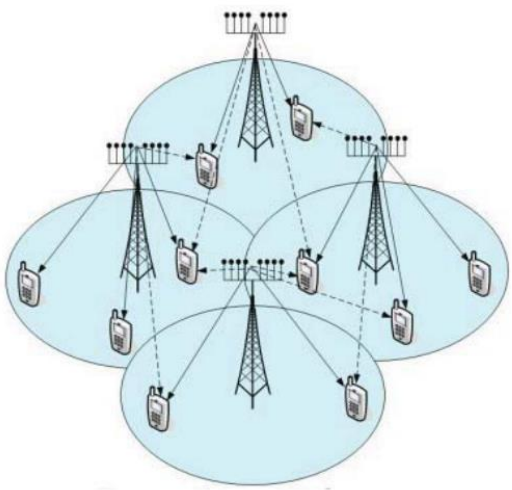

Figure: - MIMO system

The choice of antennas is important for this strategy, emphasizing the importance of energy-efficient antennas to minimize power consumption. Simplifying the overall system architecture is another approach to cut back on energy use. An effective solution in this area is provided by reconfigurable antennas. Additionally, antenna muting [16] is a different method that has been used, allowing for power savings of up to 50% by disabling or reducing the load on certain antennas. In instances of low or zero load, one port is activated while all others are deactivated, multiple ports can be utilized in the antenna [17]. This approach ensures that the system's overall performance remains unaffected while maximizing energy savings.

2. Device-to-Device Communication: D2D (Device-to-Device) technology allows devices to exchange data directly when they are in close proximity to each other. This ensures that traffic is minimized within the network infrastructure. In 5G cellular systems, D2D (Device-to-Device) communication is a key technique employed for enhancing energy efficiency. The spectral and energy efficiency of this method are both enhanced, leading to reduced latency and reliable data transmission through direct communication. When D2D technology is used by mobile users to directly connect with one another in close proximity, data offloading takes place. This enables the base station to go into sleep mode and conserve a large amount of power. This leads to lower energy consumption and subsequently reduces CO_2 emissions. The concept of energy efficiency applies to both wireless and wired systems in this context [18].

When end devices in wireless networks are situated at a cell's corners, the base station consumes a substantial amount of energy to transmit high power. In these circumstances, where conserving energy is of utmost importance, D2D communication is an advantageous option. This technique operates in three modes: cellular, reuse, and dedicated. Selecting the appropriate mode can significantly enhance the overall system efficiency. There are various integration approaches for incorporating this technique into cellular networks, which can be categorized into two types based on their spectrum resources. These integration types are as follows:

When D2D users are included into the same licensed spectrum as cellular user equipment

(CUEs), it is referred to as **"in band communication."** Overlay and underlay transmissions are two subcategories of this categorization. D2D users in the overlay technique make use of the time and frequency slots that are open for their applications. Contrarily, the underlay method enables D2D users to recycle the resources of various CUEs located within the cell. The decision between these methods depends on the particular requirements of the application.

Out band communication involves the utilization of unlicensed spectrum by D2D users, they use ISM (Industrial, Scientific, and Medical) bands for their transmissions. By using this approach, potential interference to and from other communications can be minimized, resulting in improved overall performance.

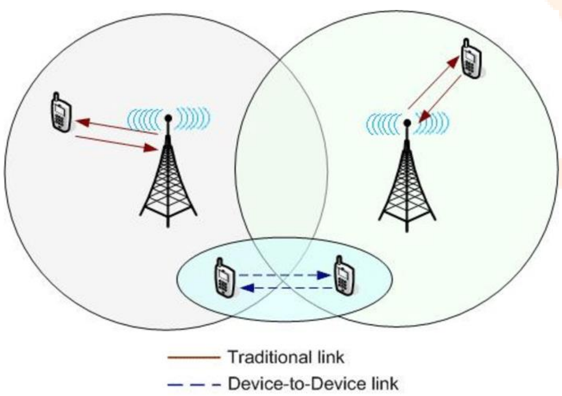

Figure: Device-to-Device communication scenario

The conceptual image up top shows how D2D users can utilize the spectrum designated for cellular customers. D2D communications are classified into two groups in terms of network control:

Network-assisted communication refers to a scenario where the central hub, typically the base station (BS), assists in managing the radio resources for device-to-device (D2D) communication. This assistance includes establishing D2D links, allocating channels, ensuring portability, and addressing security concerns.

When device-to-device (D2D) communication is unmanaged by the base station (BS), this is referred to as **autonomous communication,** similar to ad-hoc networks. In this mode, D2D communications are self-controlled and can be employed in situations where the base station is non-functional or during emergencies that render the base station inoperable.

3. Heterogeneous Networks: Macrocells and countless small cells, including microcells, picocells, and femtocells, make up heterogeneous networks. Through wired, wireless, or hybrid architectures, these cells are linked to the central network, forming a backhaul network. In [19] the study of green communication in 5G, particular attention is given to heterogeneous networks.

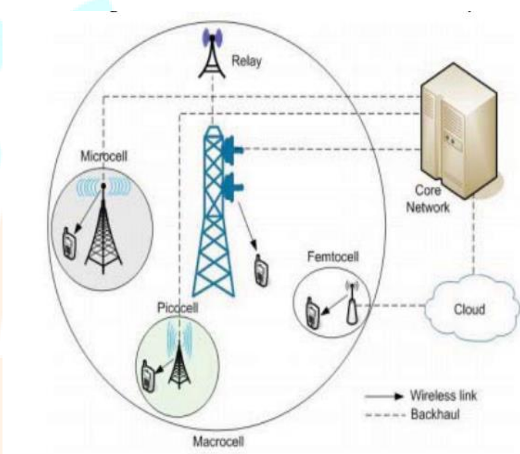

Figure: Architecture of 5G HetNet

These networks consist of numerous small power cells, enabling the network to be closer to the end users, thereby increasing the Signal Interference to Noise Ratio (SINR). This approach leads to improved Quality of Service (QoS) and robust links. Additionally, frequency reuse is employed to mitigate bandwidth concerns within the network. One can switch the smaller cells to sleep mode using this technique to reduce power consumption when there is no load or a low load [20]. Analytical techniques are employed to increase the overall network's efficiency and manage the power in the backhaul and access networks.

4. Green IOT: - The diagram below illustrates the integration of multiple platforms with the objective of implementing green communication for 5G networks.

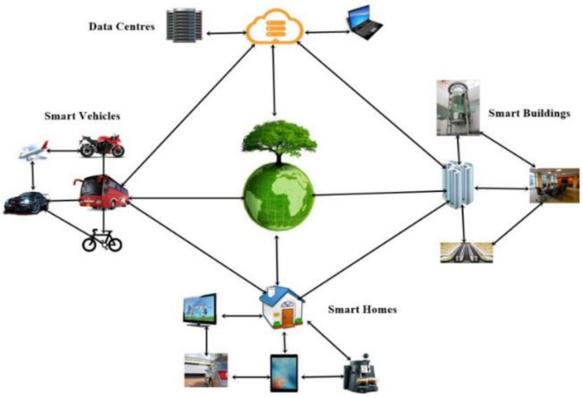

Figure: Green IOT

By employing energy-efficient procedures, a significant contribution is made towards reducing the greenhouse effect in the context of green IOT. The internet of things (IOT) relies heavily on wireless sensor networks (WSNs).

Enabling the operation of Wireless Sensor Networks (WSNs) while implementing controlled power consumption techniques is a challenging endeavor. A method for energy conservation is introduced, which involves exchanging information with nearby nodes at a slower pace while obtaining information from distant nodes more quickly. This approach leads to approximately 19% energy savings. The procedure employs a rest mode strategy wherein unnecessary and superfluous nodes are put into sleep mode, improving IoT energy efficiency. Energy efficiency enhancement techniques play a crucial role in optimizing 5G IOT communication. One such technique involves the combined utilization of cellular partition zooming and pre-caching mechanisms, which greatly improve energy efficiency. This strategy benefits both wired and wireless systems. Additionally, to increase the efficiency of wireless sensor networks and save a significant amount of electricity, the PSO (Particle Swarm Optimization) algorithm is presented. Leveraging different energy-saving mechanisms related to Device-to-Device (D2D) communication, the IOT technique proves to be consistently reliable and dependable, ultimately facilitating a more efficient deployment of 5G networks.

III. Challenges

The efficient utilization of green communication offers numerous benefits. The development of this technology is, however, being hampered by a number of problems. These difficulties consist of:

Cost: cost is significant challenge in implementing green communication solutions. Even though it is often believed that green communications use less energy and cost less, the introduction of new infrastructure, Costs are frequently higher than those of conventional systems, especially in heterogeneous networks. Additionally, energy-efficient methods being used in electronics can sometimes lead to higher power consumption, thereby increasing overall cost.

Spectrum efficiency: Analysis is necessary for effective spectrum use, which affects system throughput. According to Shannon's formula for capacity, data transmission rate is directly related to available power and bandwidth. However, limiting electricity transmission can affect data rate when aiming for green communication. Therefore, balancing hardware limitations and energy-saving techniques is necessary to achieve productive spectrum efficiency. We can cohabit with energy needs and cost considerations while maximizing resource use by finding this equilibrium.

Bandwidth: Data transfer speed is another restriction for green communication. Given a fixed level of transmit power, Shannon's capacity formula establishes a direct correlation between bandwidth and transmission rate. When the bandwidth is increased for a particular information transfer rate, energy utilization can be reduced. The need for additional alterations in terms of incorporating new systems into the current network is not required by the increase in bandwidth. For green communication to be implemented successfully, this viewpoint needs to be thoroughly examined.

These difficulties have been somewhat addressed by several green communication strategies that have been developed. The creation of novel crossover mechanisms and further research into these problems are still needed. Additionally, each of the surveyed green communication approaches has flaws that need to be fixed. The deployment and efficacy of these green technology initiatives would not be possible without finding a solution to these obstacles. Higher energy efficiency can be attained by the use of two base station operating modes, namely sleep mode and active mode. It is important to carefully determine how long the base station will be in the active mode, when data flow is often higher. It is important to note that there is some energy consumption during the transition process between these modes. However, with the incorporation of IOT, It gets even harder to develop and use sleep mode in machine-to-machine communication.

One of the most effective methods for 5G cell energy optimization is massive MIMO. This technique involves the utilization of a large number of devices, which in turn leads to increased energy consumption. Therefore, the selection of devices become a highly challenging task in the context of Massive MIMO due to increased energy consumption. Moreover, the deployment of Massive MIMO necessitates complex design due to the significant energy consumption involved in Multiplexing and Demultiplexing devices. The overall network cost is further increased by this complexity. Energy harvesting techniques are used to improve the energy efficiency of cellular networks, although they are not always trustworthy in real-world situations. Cloudy weather conditions pose a challenge for generating power through solar energy, as the required energy cannot be harnessed effectively. Moreover, the inability to encode energy leads to vulnerability in the resource condition of a cell network, making it susceptible to security attacks. Addressing these challenges becomes crucial for scientists and researchers in the field.

Results: -

LTE (Long-term evolution): -

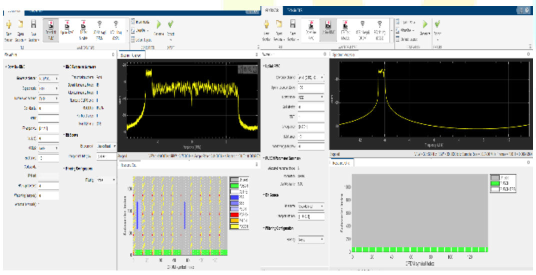

Fig: - LTE Downlink & Uplink RMC

In Long-Term Evolution (LTE) networks, there are specific reference channels used for measurement purpose in both the uplink and downlink directions. These channels are essential for performing radio measurements, estimating the quality of the radio link, and making decision related to handover and other network optimizations.

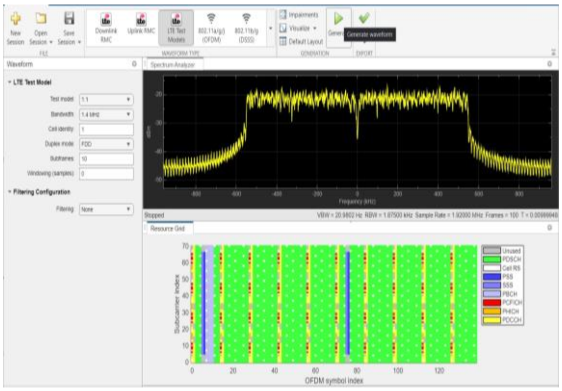

Fig: - LTE Test models

Long-Term Evolution, also known as 4G, is a wireless broadband communication technology. In the context of LTE, "test models" generally refer to different types of test scenarios used to evaluate the performance and functionality of LTE networks and devices. These test models can be used for various purposes, including: Network testing, Device testing, Protocol testing, Performance evaluation and Deployment planning. These test models are designed to replicate real-world conditions and scenarios to ensure that LTE networks and devices operate effectively and deliver seamless experience. They are an essential part of the development and testing process for LTE technology.

NR (New Radio) 5G : -

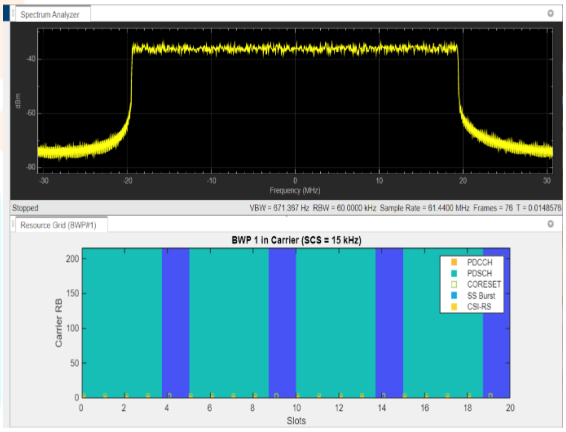

Fig :- 5G NR test models

5G NR is designed to support a wide range of services and use cases, including enhanced mobile broadband (eMBB), ultra reliable low-latency communications (URLLC), and massive machine-type communications (mMTC). To achieve these goals, 5G NR uses various waveforms and test models to access and optimise its performance under different scenarios.

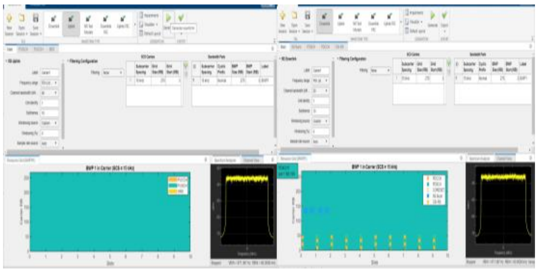

Fig :- 5G uplink & downlink waveforms

SC-FDMA, also known as Single Carrier Frequency Division Multiple Access, is the foundation of the 5G uplink waveform. SC-FDMA is the chosen uplink waveform in 5G New Radio (NR) due to its advantages in power efficiency and low peak-to-average power ratio (PAPR), which are crucial considerations for mobile devices with limited battery life and transmit power capabilities.

The 5G downlink waveform is based on a technology called orthogonal frequency division multiplexing (OFDM). The use of OFDM in the 5G enables several benefits such as, High data rates, flexibility, robustness and interference mitigation.

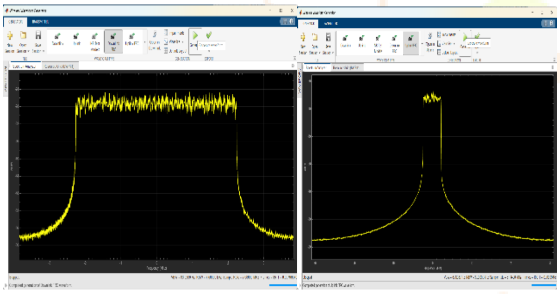

Fig:- 5G downlink & uplink FRC

5G New Radio (NR) uses several fixed reference channels to facilitate various functions in the uplink and downlink. These reference channels play a critical role in enabling synchronization, system information decoding, and channel estimation for user devices. Here are some of the key fixed reference channels in 5G: Downlink Reference Signal (DMRS), Physical Broadcast Channel (PBCH), the Physical Uplink Shared Channel (PUSCH), the Primary Uplink Control Channel (PUCCH), the Secondary Synchronization Signal (SSS), the Demodulation Reference Signal (DMRS), and the Sounding Reference Signal (SRS).

The below tabular forms shows the LTE and 5G NR simulated values: -

LTE Simulated values: -

parameter	LTE Test models	LTE Downlink RMC	LTE Uplink RMC
VBW	20.9802 HZ	41.9605 HZ	335.684 HZ
RBW	1.87500 KHZ	3.75000 KHZ	30.000 KHZ
Sample Rate	1.92000 MHZ	3.84000 MHZ	30.7200 MHZ
Frames	100	100	100
T	0.00999948	0.00999974	0.00999997

5G NR Simulated values: -

param eter	5G Uplink	5G Downl ink	5G NR Test model s	5G Down link FRC	5G Uplink FRC
VBW	671.36 7 HZ	671.36 7 HZ	671.3 67 HZ	83.92 09 HZ	671.36 7 HZ
RBW	60.000 0 KHZ	60.000 KHZ	60.00 00 KHZ	7.500 0 KHZ	60.000 0 KHZ
Sampl e Rate	61.440 0 MHZ	61.440 0 MHZ	61.44 00 MHZ	7.680 00 MHZ	61.440 MHZ
Frame s	100	100	100	100	100
T	0.0099 9943	0.0099 9935	0.014 8576	0.007 9957	0.0099 9455

Conclusion:

In line with improvements in data and bandwidth capacities, there is a rising demand for green communication technologies. Green communication not only uses less energy but also makes base station offloading easier, which lowers CO2 emissions. This reduction is crucial for preserving environmental conditions and ensuring human well-being. This paper provides a detailed overview and comparative analysis of the various green communication solutions for 5G mobile networks. The paper highlights the advantages and disadvantages of these strategies while considering various innate difficulties. It is believed that integrating IOT with Device-to-Device (D2D) communication may be a more effective strategy for meeting 5G networks' energy efficiency standards. Despite the fact that the current studies have made considerable strides in tackling problems and obstacles linked to network establishment costs, spectrum efficiency, and data transmission capacity requirements, there are still bottlenecks that need to be dealt with. To adequately address these unresolved concerns, more research is required. Additionally, the development of green communication should continue while taking system security and maintaining a secure environment into account.

References :

[1] Cisco (2016), Global Mobile Data Traffic Forecast Update, 2016-2021. Cisco Visual Networking Index. Available at: https://www.cisco.com/c/en/us/solutions/serviceprovider/visual-networkingindexvni/index.html#~stickynav=1, accessed on 08/09/2017.

[2] Andrews, J.G. et al. (2014) What Will 5G Be?. IEEE Journal on Selected Areas in Communications, 32(6):1065-1082.

[3] Mobile Phone Users Worldwide 2013-2019 (2017) Statista. Available at: https://www.statista.com/statistics/274774/forecast -ofmobile-phone-usersworldwide/, accessed on 15/08/2017.

[4] Cisco, (2016) Global Mobile Data Traffic Forecast Update, 2015 – 2020. Cisco Visual Networking Index.

[5] Fehske, A.; Fettweis, G.; Malmodin, J. and Biczok, G., The Global Footprint Of Mobile Communications: The Ecological And Economic Perspective. IEEE Communications Magazine, 49(8):55-62.

[6] Green Power for Mobile, The Global Telecom Tower ESCO M market. Available at: http://www.gsma.com/mobilefordevelopment/wpcontent/u ploads/2015, accessed on 10/09/2017.

[7] Ali, A. and Erdogan. S. (2016) The Convergence Behaviour of CO2 Emissions in Seven Regions under Multiple Structural Breaks. International Journal of Energy Economics and Policy, 2016:575-580.

[8] Gandotra, P.; Jha, R. and Jain, S. (2017), Green Communication in Next Generation Cellular Networks: A Survey. IEEE Access, PP (99):1-1.

[9] Abbasi, Q.H; Ur Rehman, M; Alomainy, A. and Qaraqe, K. (Ed.) (2016) Advances in Body-Centric Wireless Communication: Applications and Stateof-the-art. The IET (UK). ISBN: 978-1849199896.

[10] Amin, A. (2016) Energy Efficient Machine-Type Communications over Cellular Networks: A Battery Lifetime-Aware Cellular Network Design Framework. Dissertation submitted to KTH Royal Institute of Technology.

[11] Iova, O.; Theoleyre, F. and Noel, T. (2014) Improving The Network Lifetime With Energy-Balancing Routing: Application to RPL. In Proceedings of 7th IFIP Wireless and Mobile Networking Conference (WMNC), Vilamoura.

[12] Yang, H.H.; Lee, J. and Quek, T.Q.S. (2016) Heterogeneous Cellular Network With Energy HarvestingBased D2D Communication. IEEE Transactions on Wireless Communications, 15(2):1406-1419.

[13] Tabassum, H.; Hossain, E.; Ogundipe, A. and Kim, D.I. (2015) WirelessPowered Cellular Networks: Key Challenges And Solution Techniques. IEEE Communications Magazine, 53(6):63-71.

[14] Prasad, K.N.R.S.V.; Hossain, E. and Bhargava, V.K. (2017) Energy Efficiency in Massive MIMO-Based 5G Networks: Opportunities and Challenges. IEEE Wireless Communications, 24(3): 86-94.

[15] Lu, L.; Li, G.Y.; Swindlehurst, A.L.; Ashikhmin, A. and Zhang, R. (2014) An Overview of Massive MIMO: Benefits and Challenges. IEEE Journal of Selected Topics in Signal Processing, 8(5):742-758.

[16] Zhou, X.; Bai, B. and Chen, W. (2015) Antenna Selection In Energy Efficient MIMO Systems: A Survey. China Communications, 12(9):162-173.

[17] Yang, T.; Heliot, F. and Foh, C.H. (2015) A Survey Of Green Scheduling Schemes For Homogeneous and Heterogeneous Cellular Networks. IEEE Communications Magazine, 53(11):175-181.

[18] Feng, D.; Jiang, C.; Lim, G.; Cimini, L.J.; Feng, G. and Li, G.Y. (2013) A Survey Of Energy-Efficient Wireless Communications. IEEE Communications Surveys & Tutorials, 15(1):167-178.

[19] Mowla, M.M.; Ahmad, A.; Habibi, D. and Viet Phung, Q. (2017), A Green Communication Model for 5G Systems. IEEE Transactions on Green Communications and Networking, PP(99):1-1.

[20] Yang, T.; Heliot, F. and Foh, C.H. (2015) A Survey Of Green Scheduling Schemes For Homogeneous and Heterogeneous Cellular Networks. IEEE Communications Magazine, 53(11):175-181.