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Green Communications: Techniques and Challenges

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Abstract

Green technology has drawn a huge amount of attention with the development of the modern world. Similarly with the development in communication technology the industries and researchers are focusing to make this communication as green as possible. In cellular technology the evolution of 5G is the next step to fulfil the user demands and it will be available to the users in 2020. This will increase the energy consumption by which will result in excess emission of co2. In this paper different techniques for the green communication technology and some challenges are discussed. These techniques include device-to-device communication (D2D), massive Multiple-Input Multiple-Output (MIMO) systems, heterogeneous networks (HetNets) and Green Internet of Things (IoT).

Keywords: Green Communication, D2D, massive MIMO, HetNets and IoT.

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1. Introduction

Communication technology plays an important role in everyday life. Most of the real world tasks are controlled by machines and computers. All this is possible due to advancement in information and communication technology. In wireless communication, data rate is increasing drastically due to advancement and development in the electronic and communication technology at a massive scale. Researchers have shown a critical concern that this huge development of these systems will cause the data traffic to increase drastically [1]. The current generation of mobile communication, that is 4G, is now becoming congested and facing issues like capacity, bandwidth shortage, interference and slower data rates. 5G, that would be operational by 2020, is considered as the best possible solution to these issues [2]. It is expected that the 5G will have capacity and bandwidth of 1000 times greater than the 4G. Also, 5G networks would be able to serve an enormous number of devices. During the past few years, there is a huge increase in connected devices and with the advent of 5G, this will surge. Number of mobile users alone is expected to reach the mark of 5.01 billion by 2019, as shown in Figure 1. Higher data rates and fast speed internet will be a basic requirement for these connected devices [4].

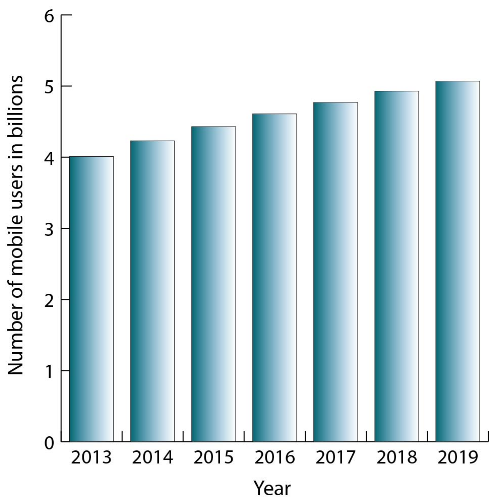

Figure 1. Estimate of mobile phone users worldwide (reproduced from [3]).

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A large amount of transmit power would be required to support all these devices resulting in a huge amount of energy consumption. This would result in the emission of greenhouse gases. Figure 2 shows the estimated footprint of CO_2 for cellular networks and devices until 2020 [5]. It is evident that a large amount of carbon dioxide would be produced by these connected devices, which will increase, by millions of tons of fold in future [6]. As one of the reasons for the global warming, CO_2 emissions should be taken seriously to make our future safer [7].

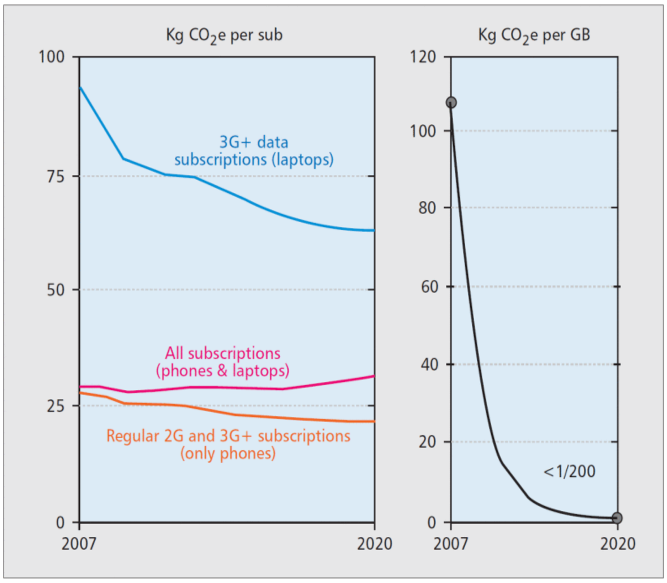

Figure 2. Carbon footprint until 2020 [4].

Though, the CO_2 contribution to the environment by the telecommunication industry is 2%, which is smaller as compared to the other industries, it can increase if necessary precautions are not taken.

Along with the environment, the CO_2 emissions caused by radio networks have also a drastic effect on human health [8]. The Federal Communication Commission (FCC) has set a threshold for the surface area radiations and limited the transmitted power for handheld devices to ensure safety of the human users from electromagnetic exposure. Specific Absorption Rate (SAR) is used as a metric to analyse the human tissue exposure to the radio signal. A system with higher SAR value will be harmful to both human health and the environment [9].

Energy efficiency is also important to ensure extended battery life for the wireless devices. As the mobile users are increasing day by day, the battery of these devices should be efficient for prolong operation. A number of studies are being carried out in this direction improving battery technology for mobile phones but also for electric vehicles [10]-[11]. But the advancement and development in this area of research is much slower than its use. Therefore, energy efficient communication and the production of reusable devices are investable.

The energy efficient devices and the control of power consumption in cellular networks are one of the key features of green communication. Resource allocation is one of the techniques to control the power consumption and to make the network energy efficient but it has its own drawbacks. Some of the resource allocation techniques are reviewed in [12]-[14]. Network planning can also be used to control the power consumption. A reduced number of base stations could result in reduced levels of CO_2 emission but it can impact the cellular coverage, particularly in 5G where networks would be much denser [15].

Energy efficiency in cellular networks can also be achieved by the renewable energy resources. The consumption of fuel causes a large amount of CO_2 emissions that is an ultimate threat to the environment. Moreover, the oil resources are decreasing drastically. Energy harvesting is a method to make the cellular networks energy efficient [16]. It is possible to power the remote devices through energy harvesting but it also needs incorporation of hardware to support energy conversion from ambient sources such as solar and radio frequency making the control on power consumption difficult [17].

Hence, there is an urgent need for the green communication that is a discipline of greater interest with the on-going evolution in the information and communication technologies. The researchers and industries are doing their best to find the most feasible solutions and techniques for the green communication. A lot of work has already been done in this field. This paper presents a review on four key techniques employed in the field of 5G communications namely Device-to-Device communication (D2D), massive MIMO (Multiple Input Multiple Output), Heterogeneous Networks (HetNets) and Green Internet of Things (IoT). The rest of the paper is organized as follows: Section I gives a brief introduction of the green technology and green communication. In Section II, use of D2D, massive MIMO, HetNets and Green IoT in green communications are critically discussed. Some of the challenges are discussed in Section III while conclusions are drawn in Section IV.

2. Techniques

The evolution of 5G has a strong urge for the green communication. Some of the techniques for green communication used in 5G are discussed below.

2.1. Device-to-Device Communication

D2D communication is a radio access technology that provides users the ability to communicate directly between them when they are in close proximity, without traversing traffic through the network infrastructure as illustrated in Figure 3.

The Device-to-Device communication is studied in [8]. The D2D communication is a strong candidate for 5G cellular networks. Spectral efficiency and energy efficiency of the network can be increased through this technique. It also offers advantages of reduction in latency and reliable link through the direct communication. In D2D communication, the users communicate directly, which causes offloading of the data traffic at base stations. It allows the base stations to go in the sleep mode that will save large amount of power. In return, less energy will be consumed resulting in reduced levels of CO_2 emission. Energy efficiency comes into play for both wired and wireless networks [18].

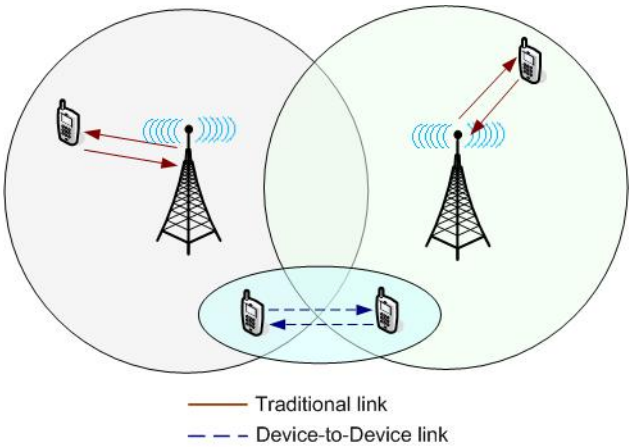

Figure 3. Device-to-device communication.

In wireless communication, the base stations have to transmit a large amount of power by consuming a lot of energy when the users are at the edges of the cells. The D2D communication is the best choice for such a scenario making the system energy efficient. There are three modes of operation in D2D communication, that are cellular, dedicated and reuse mode. The overall efficiency of the network can be increased by selecting the most appropriate mode. In [19], switching mode techniques are discussed to make the D2D communications and overall network energy efficient.

2.2. Massive MIMO

Multiuser Multiple Input Multiple Output (MIMO) systems are on rise. In such systems, a base station having multiple antennas simultaneously serves a number of users having single-antenna equipment. The multiplexing gain can be shared by all users in such scenarios, as illustrated in Figure 4.

A massive MIMO technique for energy efficient 5G cellular networks is studied in [20]. As compared to MIMO, in massive MIMO more antennas are used which makes it strong candidate for energy efficient systems. The massive MIMO has several advantages like good energy efficiency, robustness, enhanced throughput, latency reduction and high capacity gains [21]. Massive MIMO can be integrated in three different ways: network massive MIMO, single massive MIMO and distributed massive MIMO. The selection of these techniques is based on the network requirement in terms of power control and energy consumption. In a multi-cell massive MIMO, the transmitted power is controlled by taking power constraints at the base station and spectral efficiency constraints at the user end into account [8]. The pilot contamination and scaling laws of energy efficiency are also used in multi-cell massive MIMO by considering the maximum ratio transmission and zero forcing beamforming. The spectral efficiency is maximized by giving a suitable amount of power to pilot signals.

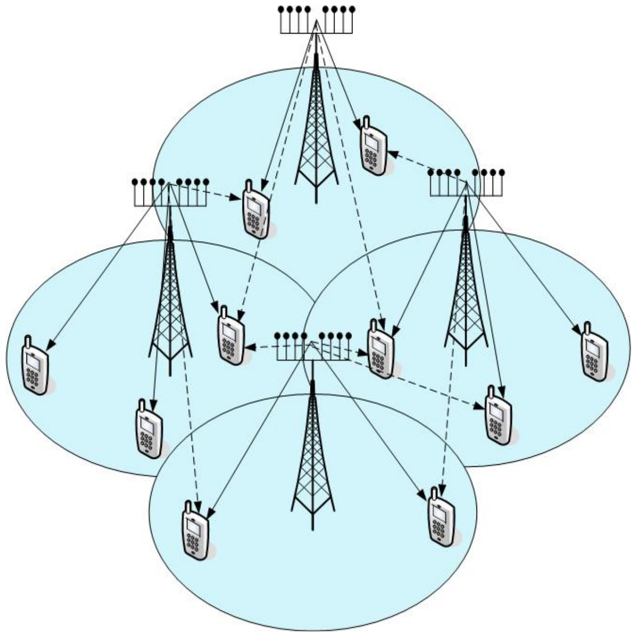

Figure 4. Massive MIMO system.

In massive MIMO, the selection of antenna plays an important role. To control the power consumption at the base stations, the antennas should be energy efficient. Overall system architecture simplification in massive MIMO can also be used to reduce the power consumption. Reconfigurable antennas are also a solution for this this problem. Another technique that can be used in massive MIMO for energy efficiency is antenna muting [22]. Muting the antenna in no load or light load conditions can save about 50% of the power. If an antenna has two or more ports, in the condition of light load or no load, only one port could be kept turned on by turning off the rest of the ports. This would not affect the overall system performance and will save a considerable amount of energy.

2.3. Heterogeneous Networks

A heterogeneous access network consists of a macrocell and several small cells (e.g., microcells, picocells, and femtocells). A backhaul network is created by connecting the base station to the core network through wired, wireless or mixed architecture as shown in Figure 5.

The heterogeneous network technique for green 5G communications is studied in [23]. In a heterogeneous network, there is a large number of micro, pico, and femto small power cells and very few large power cells. This kind of mixed wireless system brings the end users closer to the network by increasing signal to interference noise ratio (SINR). This technique gives a robust link and good quality of service. In HetNet, the frequency reuse can reduce the bandwidth issues.

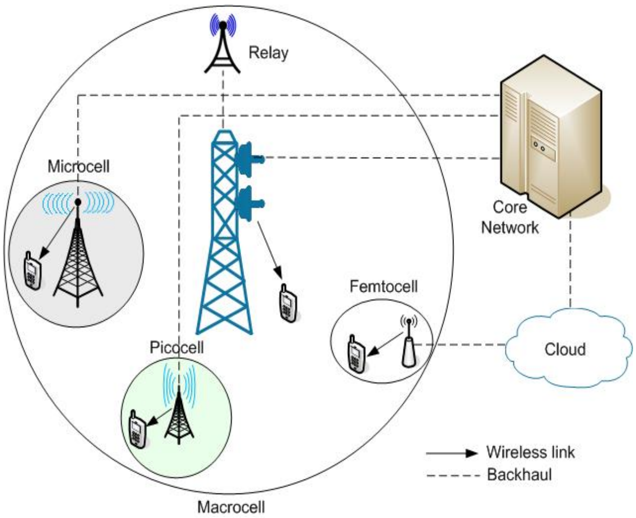

Figure 5. Network Architecture of a 5G HetNet.

The power consumption in HetNet can be controlled by putting the small cells in sleep mode when there is a low load or no load [24]. In [23], the optimization and analytical technique is used to control the power consumption in access and backhaul networks to make the overall system efficient.

2.4. Green Internet of Things

The Green Internet of Things is another potential dimension of 5G green communications that is aimed to provide integration of a number of fields, as illustrated in Figure 6. Energy efficiency in IoT is studied in [25]. To facilitate the reduction in greenhouse effect, the Green IoT plays an important role by employing energy efficient procedures. Wireless Sensor Networks are the key element for the Internet of Things. To achieve energy efficiency, each node in Wireless Sensor Networks should be operated with controlled power consumption that is not an easy task [8]. In [26], an energy saving technique is introduced in which the data from the near nodes is collected slowly while it is acquired quickly from the far off nodes. This technique results in approximately 19% of energy saving. Sleep modes method is used in this technique.

The energy efficiency in the IoT can be enhanced by switching the redundant and irrelevant nodes to sleep mode [27]. For 5G Internet of Things communication, an energy efficiency enhancement technique is discussed in [28]. Cellular partition zooming and pre-catching mechanism are combined in this scheme for enhanced energy efficiency. This technique has its advantages for both wired and wireless networks. For energy efficient Wireless Sensor Networks, the particle swarm optimization technique is proposed in [29]. Through this method, 1 dBm of power can be saved. The Internet of Things can be combined with various other techniques for energy efficiency but in conjunction with D2D, the IoT are more reliable and energy efficient [30]-[31].

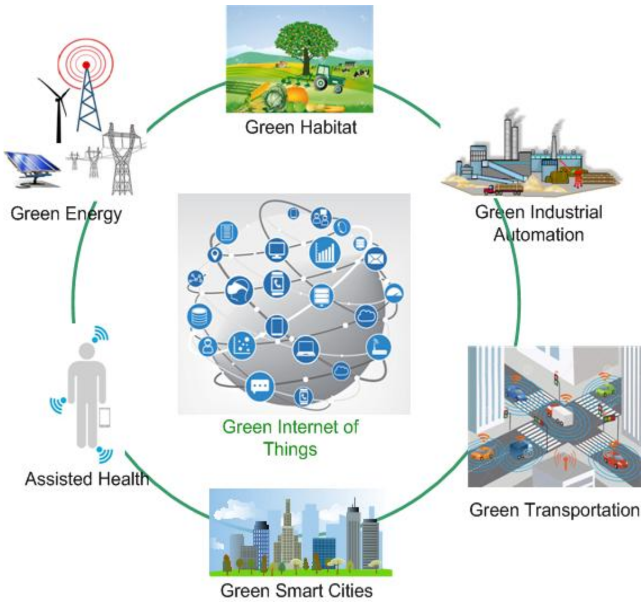

Figure 6. Green Internet of Things.

3. Challenges

With huge benefits, green communications come at a price. Some of the key issues that might slow the deployment of green solutions are as follows:

3.1. Cost

Although green communications is poised to have less energy consumption and hence, save money, requirement of new infrastructure such as in heterogeneous networks, is often associated with much higher costs than the existing techniques. Similarly, incorporation of energy-efficient schemes in devices may require higher computational power and result in increasing their price.

3.2. Spectrum Efficiency

Spectrum efficiency, which is defined as the throughput of the system, is another important issue that needs careful consideration. According to the Shannon's capacity formula, the transmission rate is directly proportional to the amount of available transmit power and bandwidth [32]. Controlling the transmission power to make the communication green would impact the data rate. Therefore, efficient characterization of this trade-off considering practical hardware constraints is key to the success of such solutions.

3.3. Bandwidth

Bandwidth requirements are another tradeoff for the green communications. Shannon's capacity formula puts the bandwidth in direct relationship to the transmission rate for given amounts of transmit power. Energy consumption can be reduced by expanding the bandwidth for a given data transmission rate [32]. However, bandwidth expansion does require changes in terms of new schemes and their integration with existing networks. A detailed analysis of this aspect is therefore, necessary for the success of green communications.

In the previous section, different techniques for green communication are studied and discussed that try to deal with these issues to some extent. However, these issues are still open for further research and innovative hybrid solutions. Moreover, the reviewed methods have their shortcomings, which need to be addressed. Without solving these issues, the implementation and practice of the green communication techniques would not be feasible. For example, the sleep mode and active mode of the base stations should be given special attention. It is imperative to specify the active period of the base station when the data traffic becomes high. The energy consumption will occur during base station mode transition. Because of IoT there could be machine type communication for which it is very challenging to implement the base station sleep mode.

Massive MIMO is the best energy efficient technique for 5G cellular communications [33]. But in massive MIMO a large amount of antennas are used which increase the power consumption. So the selection of antenna is quite challenging. Moreover massive MIMO require complex architecture. A huge amount of power is also consumed in multiplexing and de-multiplexing unit. It also increases the overall system cost. Energy harvesting techniques are also used to make cellular networks energy efficient but they are not reliable. In case of solar energy, the required amount of power cannot be generated during cloudy weather. As the energy cannot be encrypted so the energy state of devices in a cellular network is open to security attacks. This is also a challenging task for the researchers and the industries.

4. Conclusions

The demand for green communications is increasing drastically with the development in information and communication technologies. Green communications not only reduces the energy requirements but it also helps to reduce the emission of CO_2 that is a threat to environment and human health. Different green communication techniques including Device-to-Device communication (D2D), massive MIMO, Heterogeneous Networks (HetNeTs) and Green Internet of Things (IoT) for 5G cellular networks are studied and discussed in this paper. Their advantages and drawbacks are highlighted considering different inherent challenges. It is recommended that a combination of D2D and IoT could serve as a more appropriate technique for the energy efficiency needs of the 5G systems. Though the existing studies deal with a number of issues, challenges of infrastructure/device cost, spectral efficiency and bandwidth requirements still are the bottlenecks and further research is needed to address these open issues effectively. Network security and secure power optimization is also an aspect that needs to be considered for future green communications due to enhanced level of device connectivity and data sharing.

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