Energy Efficiency Performance For Next Generation Wireless Communications

2022 International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA) | 978-1-6654-6835-0/22/$31.00 ©2022 IEEE | DOI: 10.1109/HORA55278.2022.9800054

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Abstract

The growth demand in wireless communication and its application leads to a great effort should be into researcher's consideration to meet the future requirement of wireless network architecture. It's expected that the traffic will reaches multiple of hundreds than this in nowadays and to increase the capacity of the network with high and efficient energy efficiency. This can be reached by the use of small cell configuration like micro and pico cells, and use massive MIMO (Massive Multiple-input Multiple-output) with low-cost components which are prone to hardware impairments. This configuration leads to high energy efficiency for large number of base stations and user density. This article focuses in simulating an area covered by random deployment of small cells to serve hundreds of users in the simulation area. The results show that the (Energy efficiency) decreases as the SINR values increases, which is why it is important to specify a target SINR; otherwise the energy efficiency maximizing operation point might be very spectrally inefficient, and the efficient energy can be greatly improved by increasing the base station density, meaning that small cells are a promising solution for maximal energy efficiency deployment.

Keywords: *EE,5G, Massive MIMO, small cells*

I. INTRODUCTION

It is known in clearly view that the demand of wireless communication has become the main issue to consider in any modern wireless network like 5G. It is estimated that the traffic volume in 5G networks will reach tens of Exabyte's per month. This requires the capacity provided by 5G networks to be 1000 times higher than in present cellular systems[1]. This is can be performed by using several techniques like using massive multiple-input multiple-output (MIMO) system, or by enhancing the antenna beamforming, or using the mm Wave technology, or using the concept of micro-cells and pico-cells [2]. All these techniques are used to enhance the performance of 5G network, but the question is, what is the energy efficiency obtained by these techniques?

The increase of network capacity has a limitation comes from the require to make the system energy efficient which this can be called the tradeoff between energy efficiency and spectral efficiency[3]. Energy efficiency has become a primary concern in the design and operation of wireless communication systems. Indeed, while for more than a century communication networks have been mainly designed with the aim of optimizing performance metrics such as the data-rate, throughput, latency, etc., in the last decade energy efficiency has also become important due to economic, operational, and environmental concerns (Buzzi et al. 2016). The design of the next generation (5G) of wireless networks will thus necessarily have to consider energy efficiency as one of its key issues[4][5].

To overcome the challenges come from the energy efficiency requirement in 5G, ultra-dense networks (UDNs) have been considered as one of key technologies to satisfy the demand of huge transmission rate in 5G cellular networks [6]. UDNs are mainly used to reduce the coverage area of single small cell base station (SBS) and further improve the transmission rate of the whole networks. In multi-user MIMO systems, one main challenge is the increased complexity and energy consumption of the signal processing to mitigate the interferences between multiple cochannel users [7]. To achieve energy efficient transmission, the multi-user MIMO system with very large antenna arrays at each base station (known as "massive MIMO" system) has been advocated recently. In contrast to the conventional MIMO system, massive MIMO is less prone to hardware impairments problems and weakness. The key result is that, with very large antenna arrays at each base station, both the intracell and intercell interferences can be substantially reduced [8].

The first challenge that current networks face is the work to maximize the capacity by improving the transmit powers regardless the huge growth of the number of connected devices. Using more and more energy to increase the communication capacity will result in unacceptable operating costs because it is not a practical operation to perform in every network. The present wireless communication systems are simple and not 3 used to serve a huge capacity system due to the huge number of devices in the system [9][10]. To use

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the concept of increasing the transmit power, the question here is how to scale up the transmit power in base stations and what is the amount of this scaling. The second challenge that Due to the very large array dimensions, massive MIMO relies heavily on the availability of cheap and power efficient base-band hardware. [11][12]. These impairments may in turn have a negative impact on the overall system performance. Another challenge that 5G system faces is the interference between large numbers of base stations in the cell, where this challenge can be overcome by using small cells concept. But also here the use of small cell concept increases the mobility of the system due to users moving [13][14].

This article aims to make a full overview and a practical simulation for the use of small cells deployment in 5G network to simulate the effect of changing user density and BS density on the EE with simulate the energy efficiency of ultra-dense 5G network with the use of random way point (RWP) mobility model and examine hardware impairments and their impact on massive MIMO with analyze and discuss the network capacity and energy efficiency for UDNs and how the network density affects the EE [15], [16] .

Summarizes the problem statement and limitation of The first challenge that current networks face is the work to maximize the capacity by improving the transmit powers regardless the huge growth of the number of connected devices. Using more and more energy to increase the communication capacity will result in unacceptable operating costs because it is not a practical operation to perform in every network [17]. The present wireless communication systems are simple and not used to serve a huge capacity system due to the huge number of devices in the system [18]. To use the concept of increasing the transmit power, the question here is how to scale up the transmit power in base stations and what is the amount of this scaling. The second challenge that Due to the very large array dimensions, massive MIMO relies heavily on the availability of cheap and power efficient base-band hardware. [19]

A. *Ultra Dense Networks (UDN$_s$) Generations*

The major aim for the densification of microcell BSs in the third generation (3G) cellular networks is mainly to improve the rate of transmission in partial areas (such as the deployment of macrocell BSs in the urban areas) [20]. Recent advances have seen the development of frequency reuse and sectorized BS technologies for microcell densification in a bid to solve the issue of adjacent macrocell BS interferences, where the macrocell BS density is about 4-5 BS/km2. [21][22] Microcell BSs such as hotspot BSs and femtocell BSs have been deployed in the 4G cellular networks to achieve high speed data transmission in specified areas; this network has a microcell BSs density of approximately 8-10 BS/km2. However, all the aforementioned BSs are connected directly via gateways and fiber links or broadband Internet is used to forward all backhaul traffics. [23]The aim of BSs densification in the 3G and 4G cellular networks is to improve the rate of wireless transmission in specified regionsfor cellular networks[24] as showing in the figure 1 .

The massive MIMO antennas in 5G cellular networks are integrated into BSs and wireless traffics at the Gbits level are transmitted via hundreds of antennas. When the transmission power of a 5G BS is constrained to the transmission power level of 4G BS[25], the transmission power of every 5G BS antenna must be reduced by 10-20 times with respect to the transmission power of every 4G BS antenna.[26][27] Consequently, there must be a decrease in the radius of the 5G BS by one magnitude with respect to the decrease in the transmission power of every antenna

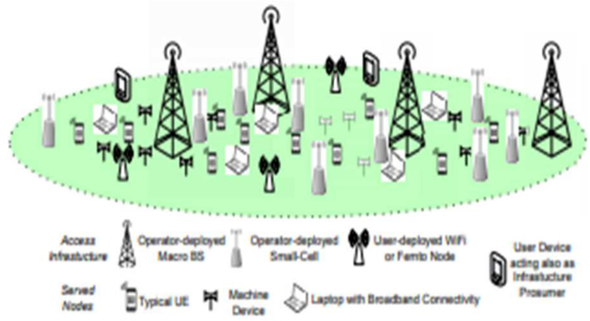

Figure. 1. An ultra-dense network infrastructure [9]

The millimeter wave communication technology is another potential 5G cellular networks key technology which is expected to offer several MHz of bandwidth for wireless communications [28]. However, the transmission of this technology must be restricted to 100 m due to the degradation in the propagation of millimeter wave in the atmosphere. Based on these two technologies, small cell networks have been proposed for 5G cellular networks and to achieve seamless coverage, it is expected that the density of 5G BS will come up to 40-50 BS/km2; thus, the 5G cellular network is expected to be an ultra-dense cellular network [29][28].

II. HARDWARE IMPAIRMENT EFFECT ON ENERGY EFFICIENCY

The information-theoretic capacity is not the only parameter that limits the spectral efficiency in wireless communications; it is also influenced by practical issues such as the channel estimation accuracy, propagation environment, signal processing complexity, Therefore, future studies should aim at improving the spectral efficiency in wireless communications to meet the increasing demand for wireless communication. A new network framework which can increase the spectral efficiency and address the issues from the practical perspective has been recently proposed [30]. This framework, known as large-scale multiple-input multiple-output (MIMO) or “massive MIMO” is based on having several antennas at the BS and exploiting channel reciprocity in time-division duplex (TDD) mode. Some of the key features of this framework are: i) mitigation of propagation losses by a large array gain due to coherent beamforming; ii) no channel estimation errors impact in the large-dimensional space; iii) easy mitigation of inter-user interference by the high beamforming resolution; iv) low-complexity signal processing algorithms are asymptotically optimal.

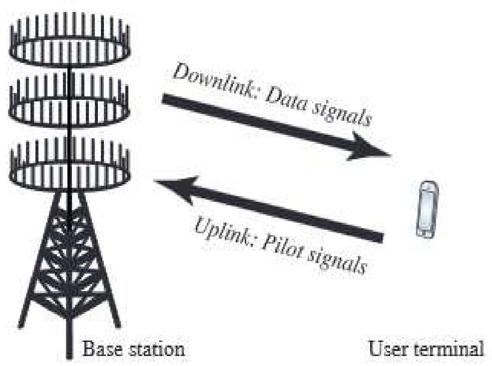

Figure. 2. a large-scale MIMO system [3]

However, such inexpensive hardware components are susceptible to impairments such as amplifier non-linarites, phase noise, and I/Q-imbalance which are encountered in any physical transceiver implementation. The high-power regime capacity can be fundamentally restricted by transceiver impairments while little is known about the effect in the large-antenna regime.

III. METHODOLOGY

The overall system description is that the system consists of random deployed antennas of BSs located on a two-dimension plane R2 follow two independent homogeneous Poisson point processes (HPPP) ɸm and ɸs with intensity λB_s. It is real that the density of the small cell base station is larger than that of the macro cells where λB_s > λB_m. It is also assumed that BSs transmit signal on different and disjoint spectrums so that there is no cross tier interference between signals on the UDNs system. The proposed area and cells of this study is shown 24 The simulation starts to assume that the base station and user unit have single antenna and use the orthogonal frequency division multiplexing (OFDM) technology adopted for 5G UDNs. Because of the usage of OFDM technology, there is no intercell interference in UDNs. And then, it starts to simulate massive MIMO configuration for the BSs.The downlink interference comes from other BSs on the plane R2. The user mobility is assumed as RWP model. The wireless channels in UDNs are assumed to be governed by Rayleigh distributions and the transmit power of BSs is denoted as Ps. According to the disjoint working spectrums of BSs, there is no cross tier interference in UDNs. So the received interference of a moving units is expressed as:

$$I_{rm} = \sum_{i\in\emptyset_m/b_{m0}} p_m h_{im} R_{im}^{-\alpha} \qquad (1)$$

where b_{m0} is the associated BS with moving units, R_{im} is the distance between a interfering BS and $U_{t,m}$, h_{im} is an exponential random variable with expectation μ = 1 and α represents the path loss exponent. The received interference of the downlink channel between a static units and the associated BS is:

$$I_{rs} = \sum_{i\in\emptyset_s/b_{s0}} p_s h_{is} R_{is}^{-\alpha} \qquad (2)$$

where R_{is} denotes the distance between a interfering BS and the static TU $U_{t,s}$.

The methodology of this study to simulate the EE for single antenna on the BS and single user served from the BS. The simulation performed under several number of SNR to evaluates its effect on the EE and under changing the value of α. The performance metric for this project is the energy efficiency (EE) which is considered as an appropriate and meaningful metric which plays a very important role in identifying the gain achieved by implementing energy efficient strategies in wireless cellular networks. The energy efficiency of UDNs is defined as follow

$$\varpi \frac{C_{Total}}{E} \qquad (3)$$

where ϖ is the network EE, C total is the total network capacity, E represents the total energy consumption in the UDN. 26 In UDNs, two types of power consumption are considered, the first type is BS transmit power consumption Ps_trans = PsλuSps_c (T, λB_s, α), and the second type is the BS operating power consumption Ps_opr = aPs_trans + bs with a = 7.84, bs = 7.15W and the table below is illustrating the Simulation parameters.and we used matalab simulator to present our results.

Table 1. Simulation parameters and values.

Parameter	Value
Area of the simulation	3 × 3 km2
User density	1-105 per square kilometer
Transmit power of BS	0.05W
Path loss exponent	3 , 4
Fading	1
Variance of gaussian noise	0.001
Bandwidth of single channel	100 KHz
Base station density	1-104 per square kilometer
Level of hardware impairments	0 – 0.2
SINR	1 , 3 , 7
Number of antennas	10 , 91

IV. SIMULATION RESULT

the simulation results obtained from the simulation of applying random deployment of ultra-dense networks in order to evaluate the performance of the energy efficiency of the 5G UDN. Figure 1 shows the energy efficiency with varying number of small cells to determine the effect of changing number of small cells on the 5G network especially on the EE. In our work here, the comparison between using the two main configuration of 5G network to enhance the EE value is obtained. For the first configuration, a small cell configuration of radius varied from 15 m to 50 m is simulated. The small cells numbers depend on the radius use and varied from 20 to 100 cells. Three different SINR γ constraints (1, 3, 7) are considered which are corresponding to the target SINR. In all three values, the EE is computed using the lower bound on the average SE

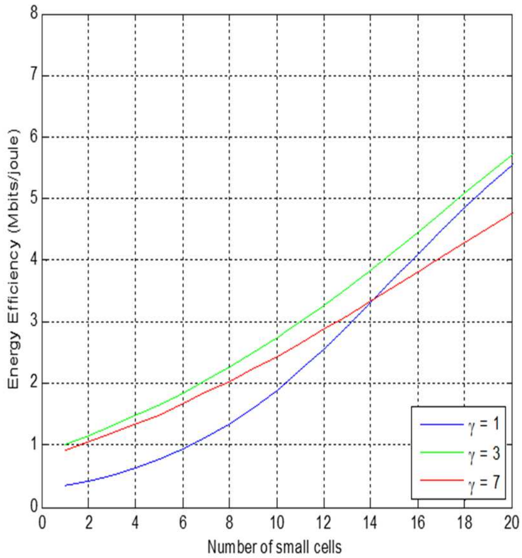

Figure 4. Energy efficiency for few number of small cells.

The simulation process for the effect of number of small cells on EE starts from Figure4. The first observation from this figure that the EE value increased as the number of cells increase. EE measures the number of bits transmitted every joule of energy consumed. This is logically true because in small cells deployment, the radius of cell is small so the frequency and energy can be reused and the user can be served from different BS from different cells and needs low energy to serve due to the small cells radius. At the beginning of the simulation for few number of cells, the EE values reaches 1 Mbits/joule at SNR equals 3 dB and 7 dB while it reaches less than 500 kbits/joule for SNR equals 1 dB. Figure 4 also shows that the EE value enhanced and reaches 5.5 Mbits/joule at SNR equals 1 dB when using 20 small cells. The value of EE enhancement is 11 times at cells equals 20 than the EE value at cells equals 2 Figure 5. Shows the results of EE enhancement when increasing number of small cells which means decreasing the cell radius. The figure shows the same concept of enhancing the EE value by increasing the number of small cells. EE at SNR equals 1 dB reaches 11 Mbits/joule at 50 cells used in the network with an enhancement equals 100% than at using 20 cells. The EE values reaches a saturation region which means that increasing number of cells does not affect the EE which is shown in Figure 6.

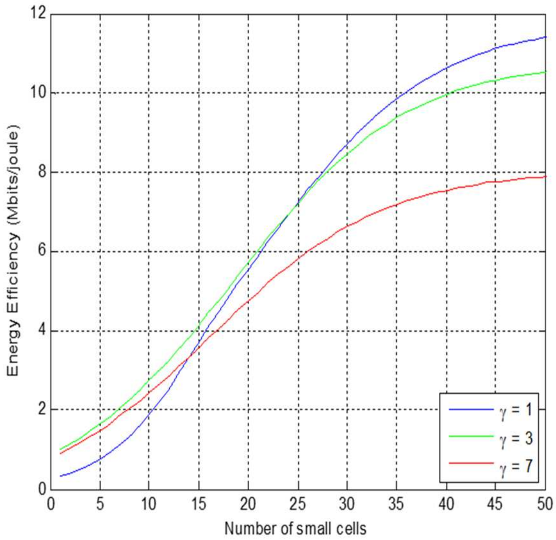

Figure 5. Energy efficiency when number of small cells reaches 50.

There are several things to note from Figure 6; the first thing is the possibility of improving the EE by increasing the BS density; this implies that small cells are a potential solution for optimal EE deployment. Meanwhile, the figure showed that the gain from this BS density enhancement resides in the range of λ = 10 to λ = 100 BS/km2, roughly corresponding to the average inter-base stations distance which is about 100 – 315 m. This is relatively large compared to the modern urban scenarios. In other words, EE maximization based on letting λ reaches high numbers is expected to give representative results in most practical small-cell deployments. EE from the simulation results shows that the EE value reaches a saturation value which means a maximum value. This value when using 100 small cells equals to that obtained from figure 3, when using massive MIMO configuration with 91 antenna used. The simulation results in figure 4 shows that increasing the small cells over 50 cells does not affect the EE value which means that using 50 small cells equals on EE performance the use of 91 antennas as a massive MIMO configuration. The second observation from Figure 3 is a decrease in the EE as the SINR values increases; this is why there is a need to specify the target SINR; else, there will be an inefficient EE maximizing operation point

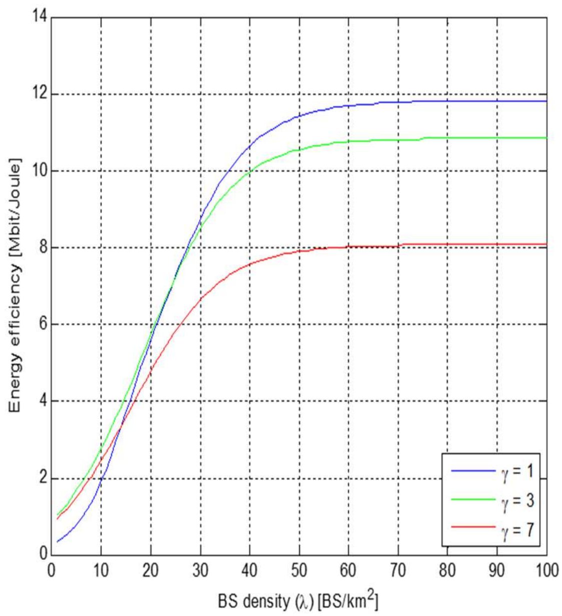

Figure 6. Energy efficiency as a function of cells density.

A. *The Effect of Level of Hardware Impairments on The EE of 5G Small Cells*

In this section, the effect of transceiver hardware impairments on the EE performance is shown in figure 6,. This figure shows the EE as a function of hardware impairment ϵ. It is clearly shown that the EE decreases with ϵ since the desired signal power decays as (1 - ϵ2). The loss is marginal for SINR equals 1, but it can be relatively large when increases. Figure 7 shows that the hardware impairments greatly affect the channel capacity in the high SNR while their impact is nothing in low SNR values. It is clear in figuire5 where the EE loss due to hardware impairments is negligible for ϵ less than 0.1 for SINR equals 1 and 3. For SNR equals 7 dB, the EE value decreases by 33% from the EE value obtained at 3 dB at the same value of hardware impairment.

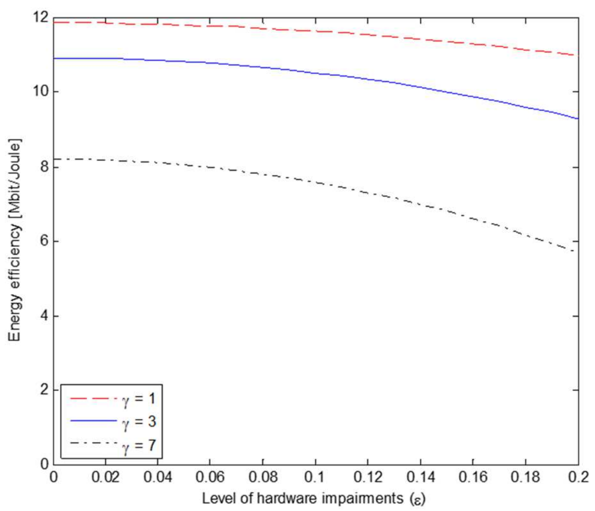

Figure 7. Energy efficiency when number of small cells reaches 50.

Figure 8 shows the effect of changing path loss coefficient on the energy efficiency. The performance of the EE with respect to the level of hardware impairments is the same when α equals 4 or 3. Figure 6 shows that the effect of changing α appears clearly on the low SNR while its effect is decreases on the high values. When SNR equals 1, the EE decreases nearly 4 Mbits/joule while for SNR equals 7, it decreases only 2 Mbits/joule which is a decrease by 25% for both values.

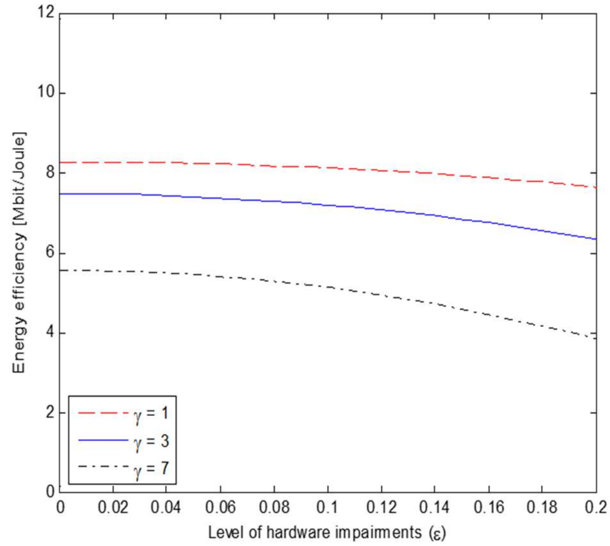

Figure 8. Energy efficiency as a function of level of hardware impairments (α=3).

Finally, figure 7 and figure 8 showed the EE of wireless backhaul networks, with respect to the path loss coefficient in considering different small cell radius. With a small cells radius of less than or equal to 50 m, there will be an increase in the EE of the path loss coefficient in wireless backhaul networks, but when the radius is more than 50 m, there will be a decrease in the EE of wireless backhaul networks while the path loss coefficient will increase.
This result is mainly because the Shannon capacity theory stipulates that an increase in the path loss coefficients can minimally affect the wireless capacity when the small cells radius is below or equal to 50 m.

V. Conclusion

Recently, UDNs gained tremendous interest from many researchers and mobile operators. They have been proposed for correlative deployment along with the macro cells and small cell, thereby forming a layer of HetNets to increase both the coverage and capacity of wireless networks. The goal of this project is to make a full overview and a practical simulation for the use of small cells deployment in 5G network to simulate the effect of changing user density and BS density on the EE. Studies have proven small cells to offer high EE, but this EE improvement quickly saturates with the BS density. The use of multiple antennas and operating in a "massive MIMO" configuration has been suggested to maximize the EE.

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