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Performance evaluation of wireless data traffic in mm wave massive MIMO communication

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Article Info	ABSTRACT
	Due to the evaluation of mobile devices and applications in the current decade, a new direction for wireless networks has emerged. The general consensus about the future 5G network is that the following should be taken into account; the purpose of thousand-fold system capacity, hundredfold energy efficiency, lower latency, and smooth connectivity. The massive multiple-input multiple-output (MIMO), as well as the Millimeter wave (mm Wave) have been considered in the ultra-dense cellular network (UDN), because they are viewed as the emergent solution for the next generations of communication. This article focuses on evaluating and discussing the performance of mm Wave massive MIMO for ultra-dense network, which is one of the major technologies for the 5G wireless network. More so, the energy efficiencies of two kinds of architectures for wireless backhaul networks were investigated and compared in this article. The results of the simulation revealed some points that should be considered during the deployment of small cells in the two architectures UDN with backhaul network capacity and backhaul energy efficiency, that the changing the frequency bands in Distribution approach gives the same energy efficiency reached to 600 Mb/s at 15 nodes while the Conventional approach results reached less than 100 Mb/s at the same number of nodes.

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1. INTRODUCTION

It is expected that in the next decade, there will be a research boom in the area of fifth generation wireless cellular networks. More so, there is an emergence of many potential transmission technologies which are capable of handling 1000 times volume of wireless traffic in future wireless communications [1]. The millimeter-wave massive MIMO is perceived as a promising technique and 5G transmission technology, because it offers gigabit-per-second data rates. It demonstrates the potentials of providing significant enhancement in energy and spectral efficiencies, as well as increasing the capacity of mobile networks. Another major technology that is often featured in the list of 5G enablers is the small cell network, and the deployment of these small cell base stations only requires low power, it is self-organizing and cost efficient [2, 3]

The main aim of using small cells is to improve the energy efficiency and throughput of cellular networks. The small cells have become attractive to mobile operators that are involved in the development of wireless transmission systems, because there is need for the next generation wireless networks to support higher volumes of data (one thousand times higher mobile data rate volume per area) with lower energy consumption, and this can only be achieved through the use of small cells that enhance the overlaying of a small geographical

location of outdoor/indoor applications by the wireless transmission systems. The ultra-dense network (UDN) has been proposed as a major system architecture that can be used to achieve an aggressive version of 5G; this is because the UDN is capable of facilitating green communications, providing seamless coverage, and enabling Gbps user experience [4, 5]. When the transmission power of the 5G base stations is constrained at the same level of 4G base station transmission power, then it becomes necessary for the antennas transmission power at 5G BS to be declined ten to twenty times compared with each antenna transmission power at 4G BS and mm wave communication technology is explored for application in cellular networks, and this communication technology is capable to offering over 100 MHz frequency bandwidths as present in Figure 1 [6, 7].
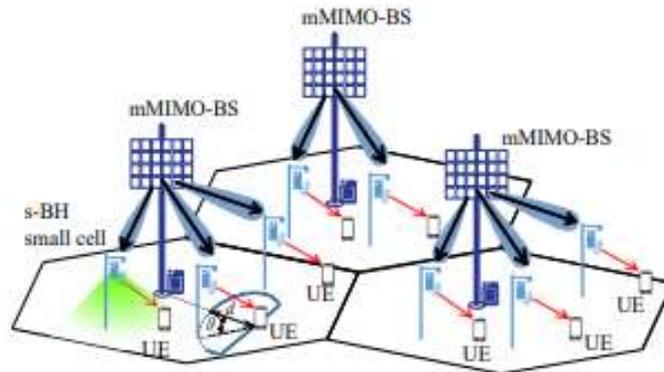
Figure 1. MmWave massive MIMO based wireless backhaul for 5G UDN

Huge path losses can be recompensed using antenna arrays that are highly directional. In UDN, it is the macro-cell base stations (BSs) that are responsible for controlling the allocation of resources, user scheduling, and supporting high-mobility users; these macro-cell BSs are often characterized by huge coverage. Despite the benefits offered by the two architectures deploying small cells in UDN, there are some limitations that are associated with these architectures and they include (1). Densification for small cells and connectivity with mm Wave massive MIMO with integrated access and backhaul for two architectures in ultra-dense cellular networks, (2) Transmission of power in the downlink, (3) lack of a method of optimizing the throughput of the uplink, downlink, and the overall system in ultra-dense cellular networks and, (4) The energy consumption of the system and how to optimize the dissipated energy and energy efficiency in the system. The contributions of this article are in three areas; (1) investigation of 5G concepts, features, the deployment of small cells in Ultra-dense network (UDN) in 5G networks, and design requirement when using mm Wave with massive MIMO for the improvement of link reliability; (2)development and simulation of mm Waves massive MIMO backhauling for two architectures (Conventional approach and distribution approach), taking account of LOS channels between small cells; (3)analysis and discussion of the changes that occur in the energy efficiency, spectral efficiency, and the capacity of a backhaul link over number of small cells.

Ultra-Dense Network for small cells. It is expected that the coverage of cell site will become smaller than what is obtainable today (i.e., micro or macro cell) because the use of higher RAN frequencies is employed by 5G. Increasing the capacity of cell site by 1000 times is not achievable. Thus, the deployment of dense small cell is the merely efficacious method of facilitating one thousand times extra capacity in network of 5G network. Due to the inherently of dense small cells deployed in grid, 5G backhaul will be confronted by the following challenges:

1. The reuse of frequency will be highly limited by denser backhaul link caused by denser small cell grid. With this, there will be need for better use of wireless backhaul spectrum, some set of new requirements for the syncronization of cell site. As forecasted, more precised requirements will be required by 5G network than LTE-A (i.e., 1.5 µs to approx. 0.5 µs).

Massive MIMO UDN. Multiple input multiple-output wireless systems have been incorporate into current standards, and are now used globally. In recent times, massive MIMO systems, which are equipped with tens or even hundreds of antennas, have emerged as improved MIMO technique designed to meet the growing traffic demand of 5G wireless communication networks. Massive MIMO (MM) is a multi-user MIMO technology involving the servicing of K single-antenna user equipment (UEs) on the same time-frequency resource by a base station (BS) equipped with a relatively large number M of antennas. Basically, the massive MIMO is specifically tailored for use in a cellular network, whereby a set of single

antenna co-channel users are served by a large number Nt of antennas [8-10]. In this process, the channel becomes near-deterministic because the BS-UE radio links become nearly orthogonal to each other. This is attributed to the asymptotic disappearance of intra cell interference, fast fading and irrelevant noise from the M engine. Favorable propagation is capable of yielding significant EE gains, because it allows the realization of multiple orders of multiplexing and array gains [11-13]

Millimeter Wave in UDN. By means of Mm Wave communication, high bandwidth is offered, there by increasing the data rate. The frequency band of the millimeter wave (mm Wave) is 30 ˜ 300 GHz, corresponding to wavelengths from 10 to 1 mm. As a result of the physical properties possessed by the mm Wave, it is able to effectively solve several problems associated with high-speed broadband wireless access [14-16]. UDN involves the dense deployment of small cells in hotspots like shopping malls, office buildings, etc. However, the deployment of these small cells requires high data rate so that traffic can be offloaded from macro cells, since the large majority of traffic demand comes from these hotspots. More so, it is important for the operator to pay attention to cost of deployment and power efficiency as they are crucial [17, 18] However, the following reasons make the mm Wave more appropriate for backhaul in UDN: High Capacity and Inexpensive: [19-21] the potential Gigahertz transmission bandwidth can be achieved by means of the large amount of underutilized mm Wave including unlicensed V-band (57 67GHz) and lightly licensed .E-band (71-76GHz and 81- 86GHz) (the specific regulation may vary from country to country) and Immunity to Interference: rain attenuation causes the E-band's transmission distance comfort zone to be up to several kilometers, while oxygen and rain attenuation causes the V-band to be about 500-700m [22-25]. The high path loss makes the mm Wave to be a more suitable candidate for UDN, where minimal inter-cell interference and improved frequency reuses are expected. It is important to note that when mm Wave is utilized in UDN, rain attenuation is minor issue.

2.   SYSTEM MODEL
2.1. Conventional approach
One of the key solutions for the fifth generation wireless network with regards to massive MIMO (Large-Scale MIMO) millimeter wave communication technologies, is the small cells. The scenario of small cell is an inevitable solution for the future 5G wireless network. The usual architecture of cellular network is a kind of tree grid architecture in which the base station managers in the core network monitor each macro cell base station, and the given gateway forwards the backhaul traffic to the core network. In the first backhaul solution, it is assumed that the macrocell base station is situated within the center of the macrocell, and it is assumed that the small cells are distributed homogenously within the macrocell. In the massive MIMO, the Main base station simultaneously uses an antenna with a few hundred base station antennas. Here, the combination of huge available bandwidth (in millimeter Wave frequency bands) and high antenna gains that can be achieved with massive MIMO antenna arrays enables the exploitation of spatial domain DoF for the formation of high-resolution beamas as presented in Figure 2. This in turn enhances better spectral efficiency, compactness, increased reliability, and inclusive system capacity. The configuration of all the small cells base stations is done using the same transmission power and coverage. In conventional cellular networks that require the deployment of microcells, a hybrid architecture is provided so as to enhance the deployment of hotspots and microcells such as picocells, femtocells.

2.2. Distribution approach
Due to the high demand of the millimeter wave communication technologies alongside the massive multi input output antenna, there is need for the densification of small cells in the 5G wireless networks. Nevertheless, it is so tricky for the broadband internet or the fiber link to forward the backhaul traffic of each small cell base station, given challenges associated with the location and cost of deployment in urban areas. When this was compared with the central approach, it was observed that there are no main base stations through which all backhaul traffic from small cells can be combined. In addition to this, all backhaul traffic is relayed to certain small cells base stations asmensioned in Figure 3 . It is assumed that all the small cells base stations are distributed homogenously within a specific spot. In order to enable the reception of the wireless backhaul data traffic from the small cells in the macrocell, the configuration of the gateway is done at the macrocell base stations which often have sufficient space for the installation of massive MIMO millimeter wave antennas. In the distribution architecture of ultra-dense cellular networks, the deployment of multiple gateways allows flexibility in terms of forwarding the backhaul traffic into the core network. Here, the deployment of gateways is done at multiple small cell base stations in accordance to the requirement of backhaul traffic and geography scenarios. The adjacent SBSs employs the use of millimeter wave communications to relay the backhaul traffic of a SBS. All backhaul traffic from adjacent SBSs will be cooperatively forwarded to a specified SBS which is connected to the core network by FTTC links as mentioned.
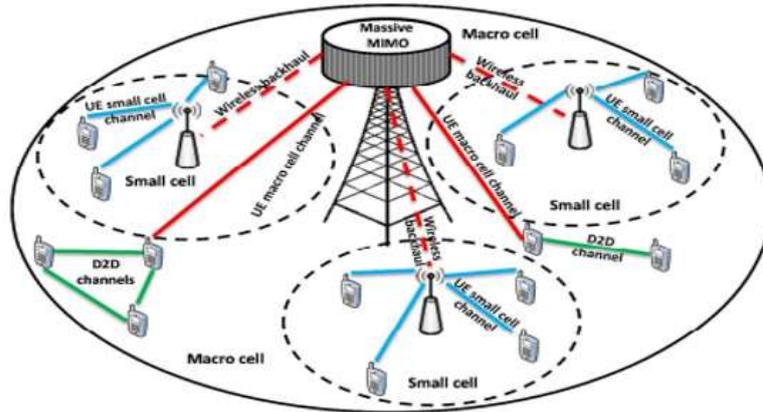
Figure 2. Logical architecture of central-ultra-dense networks
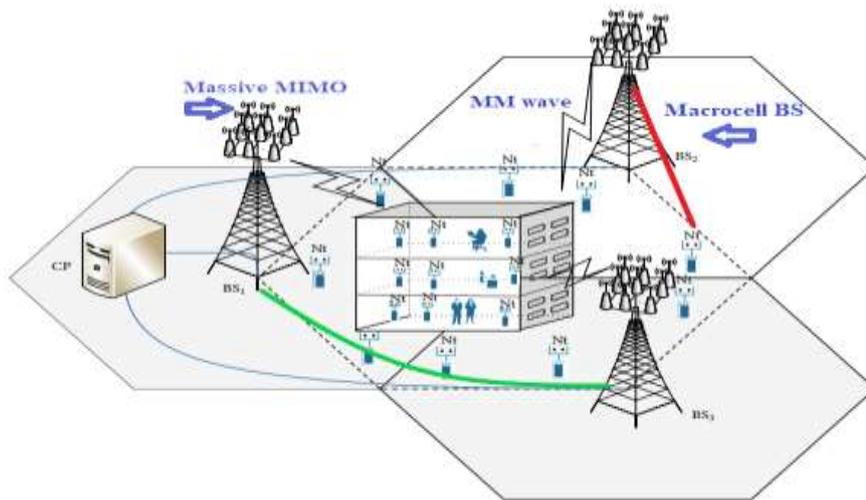
Figure 3. Logical architecture of distribution-ultra-dense networks

3.   METHODOLOGY

The simulation starts to simulate the energy efficiency of both configurations under changing the mmwave frequency band to determine the effect of changing frequency bands on 5G backhauling. The effect of changing the number of users is also simulated. The performance evaluation of the two proposed system considers LOS communication between nodes. If the system is considered LOS, all communication between nodes is LOS. This can improve the system capacity. There are two performance metrics used in this paper, the first one is the energy efficiency (EE), the second one is the capacity of wireless backhaul (C). The description of these parameters is as follows:

3.1. Capacity with deployed small cells

Capacity is a measure of how many information bits per time unit can be transferred without error over a given channel. $C = B \, log_2 \, (1 + \gamma)$. We are focusing on t the channels between deployed transmitters and receivers, their respective capacities

$$C = B \, log_2 \, (1 + \gamma) \tag{1}$$

Instead the SNR, we adding a so called interference margin. This term describes how much the experienced noise increases due to interference.

$N = Noise$
$\gamma = 2 \, C/B - 1$,
$\gamma dB = 10 log_{10} \, (2) \frac{C}{B} dB$, $\gamma dB = P_r - N - I_m nB$ \hfill (2)

$$PL = \frac{P_t}{P_r} \tag{3}$$

$\therefore n = parameter , \therefore P_t = ransmit\ power , \therefore P_r = receive\ power$

From (2) and (3), where transmitter G_t and receiver G_r is antenna gains, we get

$$P_r(n) = P_t - PL(dn) + G_t + G_r \tag{4}$$

$$C = (B, n) = B\ log_2 \left(1 + \gamma + (B, n)\right) = B\ log_2 \left(1 + 10^{\gamma dB)^{(n,B}/_{10}}\right)$$

3.2. Energy Efficiency

Expect for the backhaul network capacity, the backhaul energy efficiency is another key constrain parameter which restrict the densification of 5G ultra-dense cellular networks. Energy efficiency definition function: P = transmit power, SNR, the energy will be

$$E(P) = T(\mu p + P_{c)}\ [Joule] \tag{5}$$

P_c depend on P or R $\quad \therefore R = connection\ rate , \therefore p = power$

From (1) the model of energy efficiency

$$E = (P, R) = T(\mu p + \sum_{n=2}^{N} C_n P^n = P_c(P, R)\ [Joule]$$

$\sum_{n=2}^{N} C_n P^n$ = Transfer Amplifier $T = TW log_2(1 + \gamma)$ $\therefore w = communication\ bandwidth$
$TR(1 - e^{-\gamma})$, $TR(1 - P_{out}(\gamma))$, We include general function of efficiency $Tf(\gamma)$

$$EE = \frac{Tf(\gamma)}{T(\mu p = P_{c)}} = \frac{f(\gamma)}{\mu p + P_c}\ [bit/Joule]$$

Table 1 sammurized the parameters used in this comparitive study. There are two operators in the scenario as mentioned above named by C and EE to perform together a cognetive network. The number of samall cells is 15 and energy efficiency is 28 used and changed to 50 and EE 38 GHz to also make a comparison between the effect of using the two types on the performance metrics under study.the channel type is LOS. The carrier frequency used is the 38 GHz to satisfy the 5G requirement and mmwave concept.

Table 1. Simulation parameters and values

Parameters	Values
Carrier backhaul frequency	2.3, 38, 73 GHz
Number of nodes	50
Transmission antenna o/p power	45.4 dBm
Advanced element transmission antenna gain	24 dBi
Advance element receiver antenna gain	24 dBi
Noise figure	9 dB
Number of subscriber	10,15,25
Bandwidth	20 MHz
Spectrum efficiency	15,20,30 bit/Hz

4. RESULTS AND ANALYSIS

This section gives the simulation results of the performance evaluation of the two architectures proposed that mentioned in figure 2 and 3. It consists of two sections that are transact with all performance metric mentioned in section 3 in order to make a full overview of the small cell deployment in UDN systems. Here, Figure 4 shows Conventional approach, the energy efficiency backhaul of ultra-dense networks was analyzed, considering the small cell (radio access nodes) base radio station number. In addition, the small cell BS operating power, the linear function of the radio access nodes, and BS backhaul transmission power were also considered. Firstly, it was observed that, an increase occurred in the energy efficiency due to the increase in the number of radio access nodes base station. Secondly, the raise in the number of frequency bands with made the number of small cells fixed, thereby reducing the energy efficiency of wireless backhaul networks. It was clear that a real gap exists between the three bands. The highest EE values with 50 nodes is 6 Mb/s under 38 GHz and 9 Mb/s under 73 GHz.
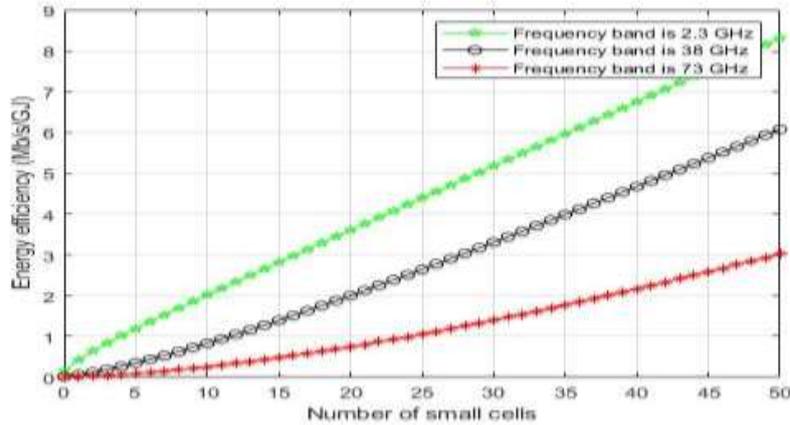
Figure 4. Energy efficiency of conventional approach with 50 nodes only

Figure 5 as an increase occurs in the number of small cells in the distribution approach, a significant increase occurs in the energy efficiency of backhaul networks. It can be observed from this figure that in the distribution approach, the energy efficiency of the three Millimeter wave frequency bands is about the same especially at 2.3GHz, and 38 GHz, and approaches 5000 Mb/s at 50 nodes. It can also be observed that the lowest value for energy efficiency backhaul was about 4200 Mb/s through 73 GHz. The energy efficiency of the 73 GHz band is lower than that of others, because of the decrease that occurs in the efficiency of energy due to the increase in frequency that results from the high atmospheric attenuation as the frequency band raise. The gases that are present in the atmosphere, absorb the high frequency signals. In addition to this, they have a short range, and as such experience high attenuation that results in the reduction of the received power, thereby reducing the energy efficiency.
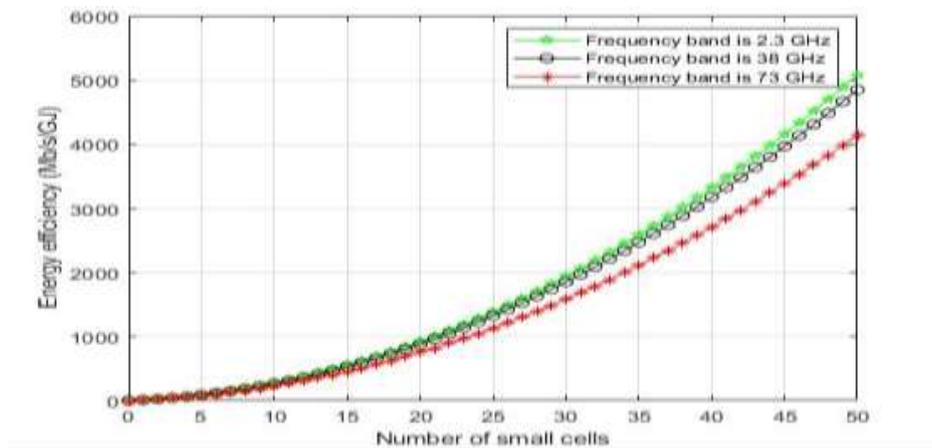
Figure 5. Energy efficiency of distribution approach with 50 nodes only

Figure 6, the performance analysis of using different number of users (subscribers) is studied. The aim of this is to present a discussion on the performance of the two different architectures in terms of energy efficiency. From the simulation results presented in Figure 6, it can be observed that as distance increase with fixed number of network users, a decrease occurs in the energy efficiency of wireless backhaul networks. The efficiency of energy is dependent on the number of users. As the number subscribers reduces with a fixed distance of area, an increase occurs in the energy efficiency of backhaul networks. The result presented in this figure, shows the value of energy efficiency of 3000 Mb/s was achieved when number of users is 10 subscribers and the distance only 50 meters, then when the number of subscribers increased to 25 with the same number of distance, the energy efficiency became 500Mb/s.
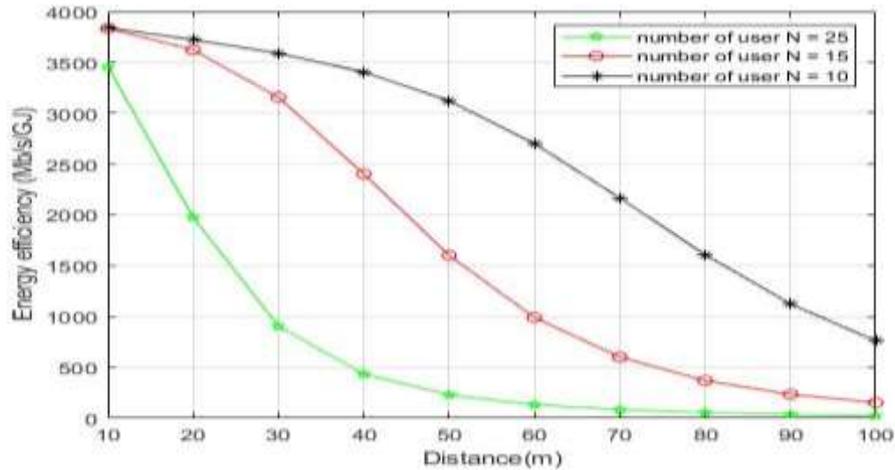
Figure 6. Variation of energy efficiency versus number of users in conventional approach

In this Figure 7, the correlation between the energy efficiency of wireless backhaul networks and distance with number of users in Conventional architecture is highlighted. It can be clearly seen that the number of users with fixed distance results in the decrease in the energy efficiency. The simulation performance performed under 100 meters. The results showed that the highest value of energy efficiency at 110 Mb/s with 30 meters was achieved for 25 subscribers.
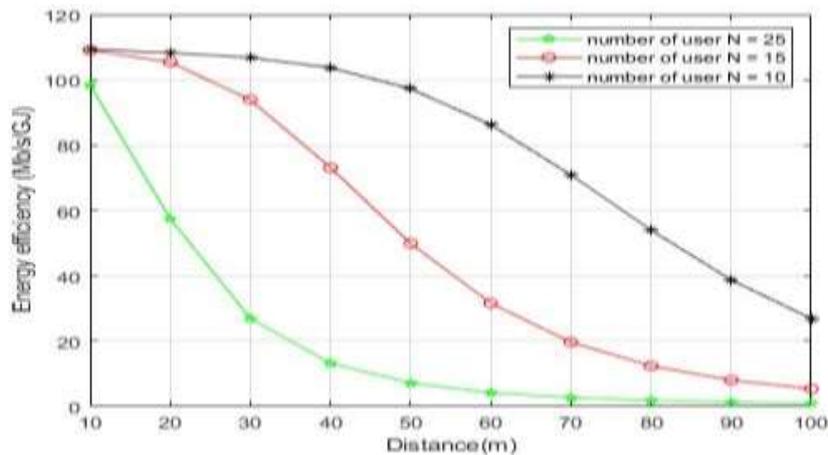
Figure 7. Variation of energy efficiency versus number of users in distribution approach

From the Figure 8 and Figure 9, it can be observed that the capacity of the wireless backhaul networks is affected by the number of small cells in the architecture, considering the three different spectrum efficiency (15, 20, 30) bit/Hz. As an increase occurs in the number of small cells within the Conventional architecture, an increase also occurs in the backhaul capacity. The figure clearly shows that with 50 Sbs, the highest value of which was obtained was about 27 Gbps when the spectrum efficiency was 30 bit/Hz. Also, with the same number of SBs, and with 15 bit/Hz the obtained capacity was 3Gbps. This shows that the role of the spectrum efficiency in the central architecture is crucial, and as such, cannot be underestimated. On the other hand, the Figure 9 shows that for distribution architecture, an exponential increase occurs in the backhaul capacity when there is an increase in the number of small cells. Also, with a fixed amount of small cells, an increase occurs in the backhaul capacity as the spectrum efficiency of small cells increases. It was observed that the highest value reached to 3500 Gbps. This implies the presence of spectrum efficiency gaps in 15, 20, 30 bit/Hz.
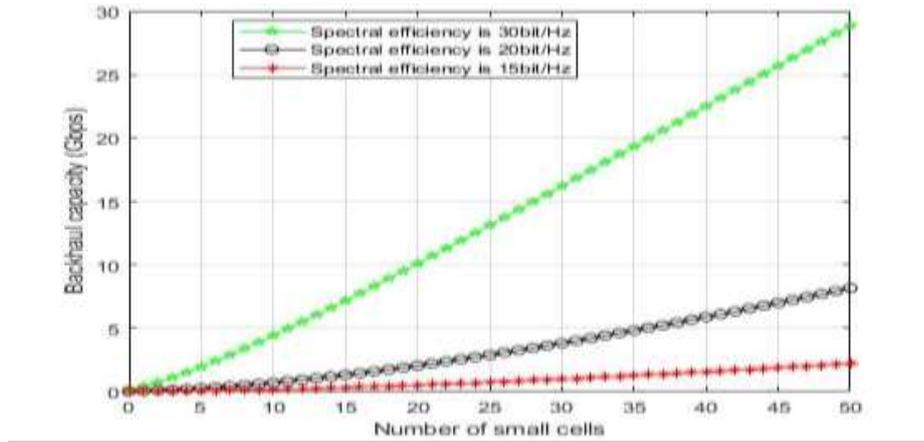
Figure 8. The backhaul network capacity aginst the number of small cell for conventional approach
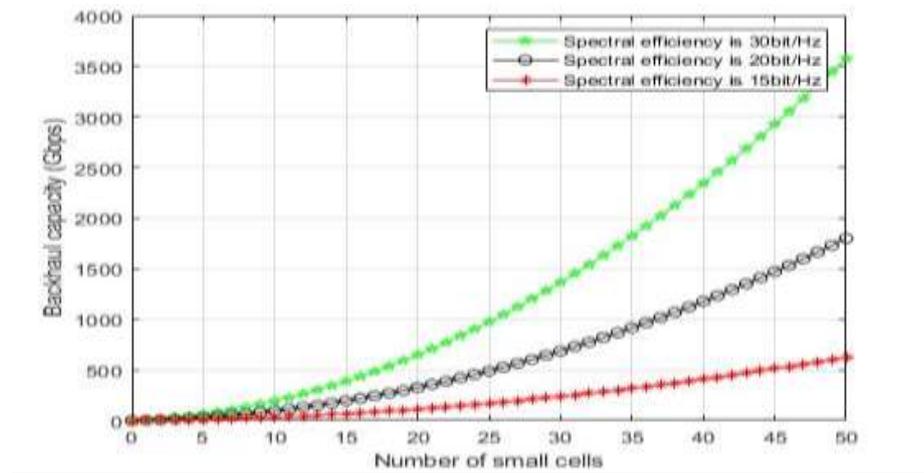
Figure 9. The backhaul network capacity aginst the number of small cell for distribution approach

5.   CONCLUSION

In this article, the Massive MIMO, millimeter wave communications, and small cells technologies were considered for the realization of Gigabit transference rate in (5G) networks. In addition, the performance of distributed and Conventional architecture used with small cell communication technologies and millimeter wave (mm) massive MIMO antennas in ultra-dense cellular networks, was evaluated and discussed. A comparison between the energy efficiency of wireless backhaul networks and that of other network architectures was carried out. Basically, the use of these two architectures is widely employed in the development of fifth generation systems with the aim of increasing the capacity and the energy efficiency of the entire system. Based on the results, the energy efficiency of the distribution approach is higher as compared to that of the Conventional approach in 5G mobile networks. With high bandwidth, the capacity of the mobile networks is significantly increased.

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