MM-wave backhauling for 5g small cells

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ABSTRACT

The high capacity requirement for meeting the high demand of wireless application usage is the main issue in researches. It's expected that the traffic will reaches multiple of hundreds than this in nowadays until 2020 and beyond. Besides, to increase the capacity of the network, a new topology of cell configuration should be deployed which is the use of small cell configuration like micro and Pico cells with such configuration topologies in order to have high data rate network. This project aims to study the performance evaluation of the use of two 5G mm wave backhauling configurations. The first one is the star topology and the second one is the mesh topology. The main difference between them is the cooperation in mesh topology between cells to transfer data. The performance metric used in this project is the energy efficiency obtained from the two configurations when changing the frequency bands and path loss coefficient. The simulation results show that the changing the frequency bands in mesh configuration gives the same energy efficiency reached to 500 Mb/s at 15 nodes while the star configuration results reached less than 100 Mb/s at the same number of nodes.

Keywords: mm-wave; small cells; LOS; NLOS; Wireless backhaul

INTRODUCTION

The high demand of wireless communications due to the high need of capacity and high data throughput makes the bandwidth of the spectrum is a main issue in wireless modern systems like 5G (Nasser and Fahmy, 2016). There are many issues that considered as challenges towards the use of mm Waves like attenuation in the free space propagation, penetration and indoor propagations and the backhauling between nodes of the network (Robson 2012). The high data backhaul traffic still big challenging and many communication mediums are proposed like fiber optic, and wireless communication.

Figure 2.1 shows the legacy base stations (BSs) of macro layer operate typically in mm wave frequency band and cover the wider geographical area but at limited capacity towards user equipment's (UEs) (Maccartney et al. 2015. Small-cell layer coverage is provided by mm Wave Access Points.

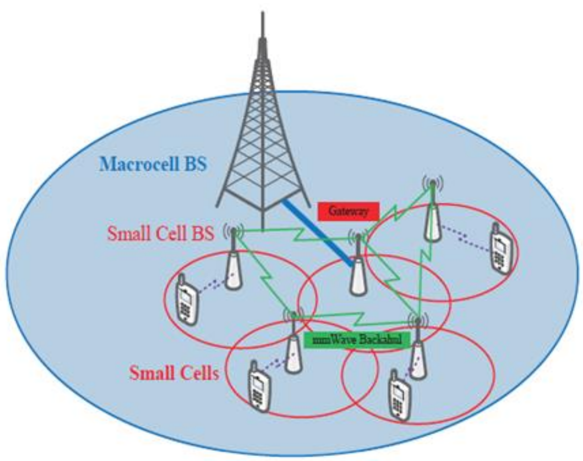

FIGURE 1 mm Wave topology of 5G network

The limitation and problem in this study The connectivity between dense small cells deployed in the serving area, how to optimize the throughput of the uplink, downlink, and the overall system of all the small cells and The energy consumption of the system and how to optimize the energy dissipated in the system.

And the aims of this research To investigate dense small cells deployment in 5G networks concepts, features, and design requirement with the use of mm Wave.To simulate the use of mm Waves backhauling for two system topology like star and mesh considering LOS channels between small cells And To analyze and discuss about how the small cell configuration affects the BER of the two configurations.

star configuration in 5g network

To keep up with the explosive growth of mobile traffic demand, massive densification of small cells has been proposed to achieve the 10,000 fold increase in network capacity by 2030 (Niu et al. 2015).

FIGURE 2 Star topology architecture

Figure 2.3 shows the system model of the star topology . It consists of a macrocell BS (MBS) and SBSs are assumed to be uniformly distributed in the macrocell. All SBSs are configured with the same transmission power and coverage (Nasr&Fahmy 2016).

In this figure the wireless configuration is a star topology which means that all the traffic of the small cells are transmitted to the main base station called MBS in the macro cell using mmWaves. All the traffic then from the MBS to the mobile network center is forwarded by using fiber to the cell (FTTC) links which considered the backhauling of the system (Rajagopal et al. 2014).

Mesh configuration in 5G networks

Figure 3 shows the second configuration of the small cells in 5G. It shows the Mesh topology .The main difference between this topology and that obtained from figure2 is that there is no MBS in the system in order to gather the small cells information and relayed it to the network center.

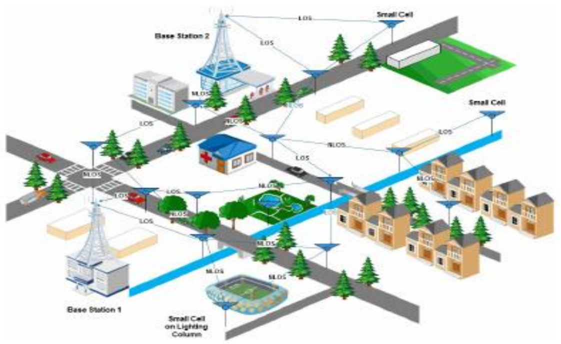

FIGURE.3: Mesh topology architecture

The process of work starts from gathering information from users in the small cells then each SBS transfers the backhaul traffic to the adjacent SBS in a cooperative way. To forward all backhaul traffic, a specific SBS is introduce to perform this operation and connected to the network center by an FTTC links (Shokri-Ghadikolaei et al. 2015).

RELATED WORKS

(Niu et al. 2017) simulates the heterogeneous cellular networks to minimize the energy consumption using scheduling and power control for mm Wave backhauling of small cells.

While (Huang&Psounis 2017) invents a wireless backhaul architecture where cells are grouped into clusters where one small cell per cluster plays the role of a cluster head connecting the rest of the small cells to the macro cell via a mauve MIMO link by jointly selecting the cluster heads and the number of BS antennas dedicated to each mm Wave MIMO link between the BS and each cluster head as a mixed integer nonlinear program (MINLP) and prove its NP-hardness. (Vardakas et al. 2017) simulates optical-wireless backhauling network for the provision of high speed connectivity to end users. The features based on the utilization of Ultra-Dense Wavelength Division Multiplexing Passive Optical Networks as the backhaul network, providing access to hyper dense mm Wave networks.

(Prasad et al. 2017) enhance the BER performance of the small cells configuration using coordinated radio access network with backhauling operation using self-backhauling nodes, which are essentially base stations with features enabling wireless backhaul connectivity, to minimize network power consumption in 5G ultra dense networks.

Also (Chaudhari&Murthy 2017) simulates the small cells configuration by simulating femto-to-femto network topology to determine which backhaul links can be scheduled concurrently by finding the upper bound for the interfering distance based on the alignment of different lobes of the directional antennas.(Nasr&Fahmy 2016) simulates two different topologies; a star topology and a mesh topology in LOS and NLOS 5G networks in order to enhance the throughput of the system with the enhancing BER.

(Medbo et al. 2016) presents a novel map-based propagation model that satisfies the 5G requirements, and also introduces new extensions to existing stochastic models of the advanced wireless system depends on satisfying the propagation model of the channel. And (Shariat et al. 2015) presents the Radio Resource Management (RRM) in wireless Backhaul (BH) of mm Wave networks focusing on Routing and Link scheduling algorithms in such BH architecture.

A smart combination of small cells is simulated in (Jungnickel et al. 2014) by joint transmission coordinated multipoint (JT CoMP), and massive MIMO to enhance the spectral efficiency with affordable complexity. (Coldrey et al. 2013) presents high-frequency microwave technology as a very interesting alternative for wireless backhauling of small cells for NLOS wireless backhauling. This study can be useful because of the use of NLOS transmission to enhance the performance of the network. This project use the concept of cell configuration to overcome the challenge of backhauling between ultra dence networks. The proposed two configurations of cells are the mesh configuration and the star one with the presence of LOS and NLOS transmission at the mmwave frequency band.One of the main performance metrics that can governs the performance of a cellular system is the system bandwidth that can be increased by using additional spectrum,(Nasr&Fahmy 2016)

METHODOLOGY

In this project, the simulation process perform simulation of the performance evaluation of the two scenarios of network configuration (Star and Mesh) The simulation performed under changing the most effective parameters on mm wave backhauling like the effect of changing the frequency bands, the effect of changing the path loss coefficient, and the coverage probability of the mesh topology.

The simulation process for all simulation stages starts from determining all variable parameters required for the simulation which are the node positions, the energy used for each node, and the path loss coefficient .The system simulation calculates the energy efficiency of the system for all cells in the network for both scenarios in order to study the performance of the system for LOS simulation.

THE SIMULATION SCENARIOS AND SIMYLATION PARAMETER

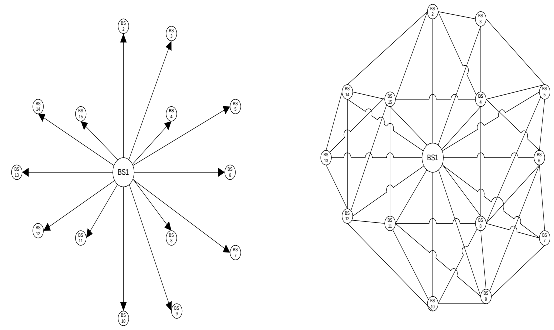

FIGURE 5 Simulation scenarios for star and mesh topology

The network proposed for star configuration consists of main base station used to rout communication between all nodes in the area. which depends on that all signals should passe the main BS than rout to the distination one. There are 15 node with varying raduis for each node starts from 30 m to 100m.

The mesh configuration consists of the same 15 node but differ in the topology of routing. The mesh system is called distributed where there is no main BS . The carrier frequency used is the 28 GHz to satisfy the 5G requirement and mmwave concept.

The simulation starts to simulate the energy efficiency of both configurations under changing the mmwave frequency band . The effect of changing the path loss coefficient on 28 GHz band is also simulated. The performance evaluation of the two proposed system considers LOS communication between nodes.

TABLE 2 Simulation parameters and values

Parameters	Values
Nodes height	3 – 4 m
Carrier frequency	28 GHz
Modulation schems	16QAM
Bandwidth	20 MHz
Simulation area	1500×1500 m^2
Configuration types	Mesh and Star
Number of nodes	15 with main BS
Communication types	LOS

The flow chart of the simulation is as shown in figure 6 The simulation process starts from initializing MATLAB for the simulation parameters required like number of nodes, nodes configuration and simulation area boundaries. The process starts to simulate the effect of changing the frequency bands with different number of nodes for both configurations at LOS communication between nodes.

The simulation repeated until number of nodes reached 15 nodes then the energy efficiency calculated for each frequency bands.

The simulation asks for fixed frequency band which is 28 GHz and calculating the effect of changing path loss coefficient with varying cell radius from 30 m to 100 m. also the energy efficiency calculated here.

At the end of the simulation, the coverage probability of mesh configuration has been obtained at different SNR

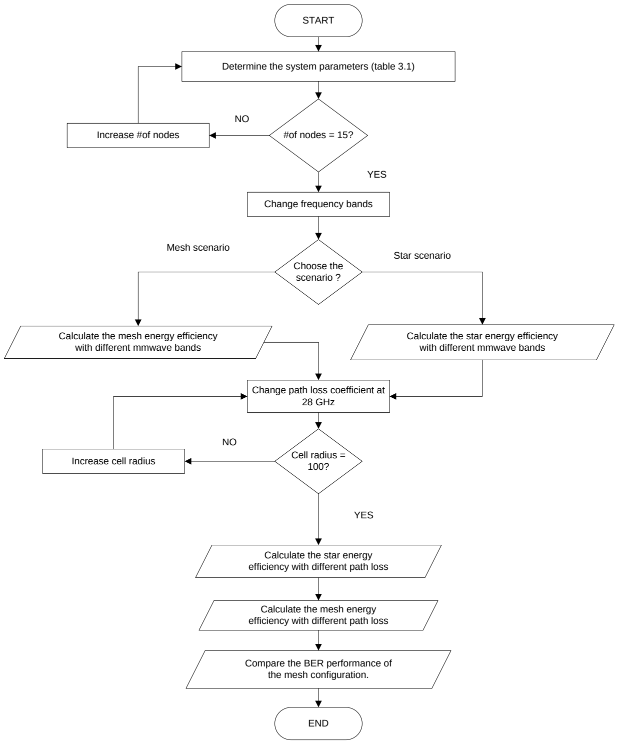

FIGURE 6 The flowchart of the simulation

SIMULATION RESULTS

28 GHz with comparison with other mmwave bands

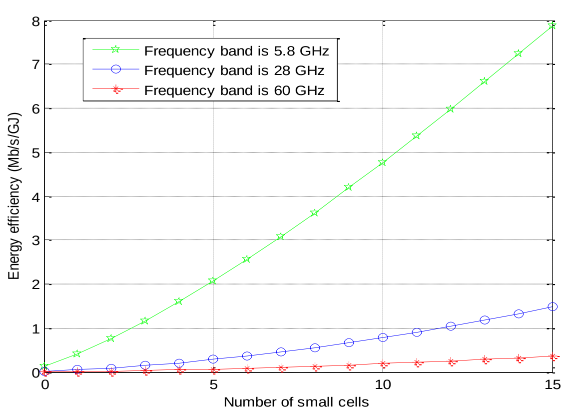

FIGURE 7 Energy efficiency of the star configuration for different mmwave bands for 15 nodes only

The simulation performance peformed under 15 nodes at each configuration as in figure 7 for star configuration. in figure 7, the energy efficiency of wireless backhaul networks linearly increases with the increase in the number of small cells in the star solution.

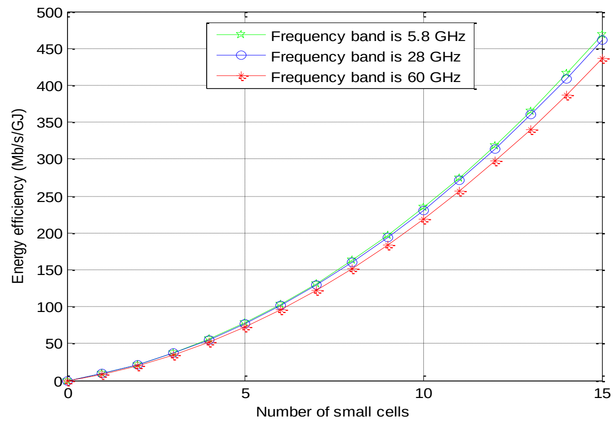

FIGURE 8 Energy efficiency of the mesh configuration for different frequency bands

In figure 8, the energy efficiency of wireless backhaul networks exponentially increases with the increase of the number of small cells in the mesh solution. The results in the two figures 7 and 8 show that the three mmwave frequency bands in mesh configuration have nearly the same energy efficiency reached to 450 Mb/s at 15 nodes.

Path loss effect at 28 GHz

The path loss coefficient plays an important role to determine the transmitted power of the small cells which this power related to the energy consumption andenergyefficiency

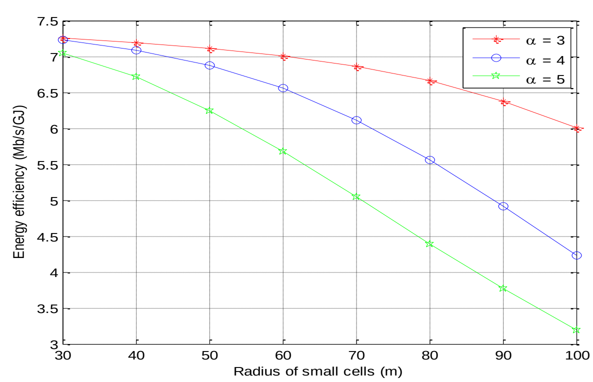

FIGURE 9 Energy efficiency of the star configuration for different values of path loss

When the radius of small cells is less than or equal to 50 m, the energy efficiency of wireless backhaul networks increases with the increase of the path loss coefficient.

When the radius of small cells is larger than 50 m, the energy efficiency of wireless backhaul networks decreases with the increase of the path loss.

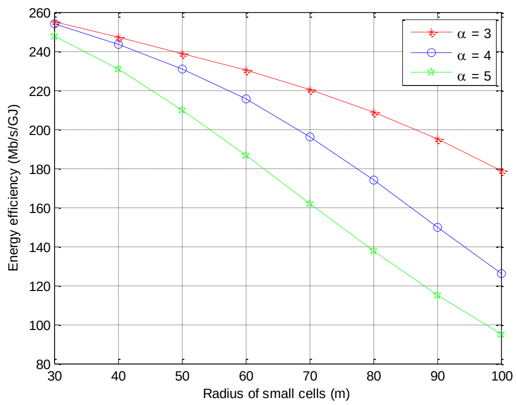

FIGURE 10 Energy efficiency of the mesh

configuration for different values of path loss coefficient.The reason for these results is that based on the Shannon capacity theory, the increase of path loss coefficients have a slight attenuation effect on the wireless capacity when the radius of small cells is less than or equal to 50 m.

Compared with star and mesh configuration in figure 9 and figure 10, the energy efficiency of the star configuration is obviously less than the energy efficiency of the mesh solution under the same radius of small cells and the path loss coefficient.

SINR Coverage Probability For 28 Ghz Mesh Configurations

Figure 4.6 shows the SINR coverage probability of the mesh configuration as a type of D2D network as a function of the SINR thresholdIt shows that by increasing the density of blockages, the SINR coverage probability of mesh base station receivers in the 28 GHz mmWave band decreases.

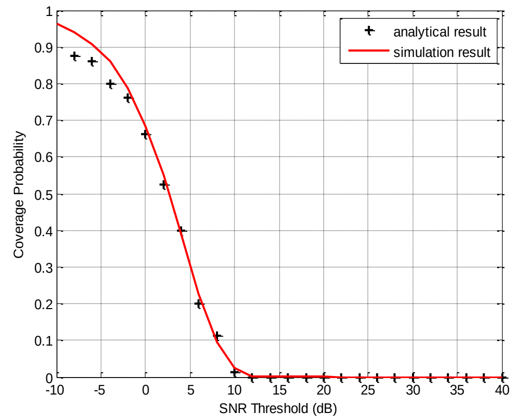

Figure11 SINR coverage probability

It is in agreement with the observation that increasing the number of blockages in the environment, lowers the chance of LOS links, decreases the SINR coverage probability.

CONCLUSION

The deployment of small cells in 5G networks to complement macrocellular networks and increase the coverage of the system is considered in this project by simulating the energy efficency of two mmwave small cell configurations.

The first one is the star configuration and the second one is the mesh. The two configurations are widely used in building 5G systems to increase the capacity and energy efficiency of the overal system.

The energy efficiency of wireless backhaul networks is compared for different network architectures and mmwave frequency bands with addition to different values of path loss cooefficient. The simulation results show that the mmwave frequency band plays an important role to choose the network configuration star configuration in order to decrease the routing load when transfering data from one cell to another.

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