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Maximising system throughput in wireless powered sub-6 GHz and millimetre-wave 5G heterogeneous networks

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ABSTRACT

Millimetre wave (mm-Wave) bands and sub-6 GHz are key technologies in solving the spectrum critical situation in the fifth generation (5G) wireless networks in achieving high throughput with low transmission power. This paper studies the performance of dense small cells that involve a millimetre wave (mm-Wave) band and sub-6 GHz that operate in high frequency to support massive multiple-input-multiple-output systems (MIMO). In this paper, we analyse the propagation path loss and wireless powered transfer for a 5G wireless cellular system from both macro cells and femtocells in the sub-6 GHz (μWave) and mm-Wave tiers. This paper also analyses the tier heterogeneous in downlink for both mm-Wave and sub-6 GHz. It further proposes a novel distributed power to mitigate the inter-beam interference directors and achieve high throughput under game theory-based power constraints across the sub-6 GHz and mm-Wave interfaces. From the simulation results, the proposed distributed powers in femtocell suppresses inter-beam interference by minimising path loss to active users (UEs) and provides substantial power saving by controlling the distributed power algorithm to achieve high throughput.

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1. INTRODUCTION

The massive MIMO system will be a critical ingredient for millimeter wave technology, which is part of the 5G wireless cellular networks. The high beamforming gain from the massive MIMO system will combat the path loss of millimeter wave transmission. As a result, the power consumption significantly increases with limited channel state information (CSI) of the transmitting signals from the base station (BS) to the active user equipment (UE). The fifth generation (5G) is likely to be operated in the dense mm-Wave BS cellular networks bands 20-100 GHz. 5G cellular networks will be adopted in the massive MIMO, mm-Wave and sub-6 GHz. 5G is designed to operate with high bandwidth to achieve high throughput (gigabits per second) with high reliability and low latency [1-4]. The massive multi-input-multi-output (MIMO) system requires managing these frequencies to enhance beamforming gain and array gain. Furthermore, massive MIMO systems can control propagation loss due to channel similarities for the UEs and mitigate the interference between the UEs [5-9]. Massive MIMO systems require focusing the desired signal direction resulting from the high path loss and directional channels for both sub-6 GHz BS and mm-Wave.

Huge antenna arrays are used in the sub-6 GHz BS and mm-Wave BS to maximise throughput under the criterion power transfer beamforming to active users (UEs). Wireless 5G for sub-6 GHz BS and mm-Wave BSs is prepared with their corresponding antenna arrays [10]. The obtainable mm-Wave uses directional beamforming for antenna arrays to provide the smallest propagation distance and a large bandwidth frequency. The path loss implies the need in employing the omnidirectional antennas throughout the radio frequency coverage area. The propagation loss in mm-Wave is higher than the sub-6 GHz based on the type of factors contributing to atmospheric absorption. The greater the number of BS antennas, the more the base station density reduces because of the reduced densification gains. Due to the large power consumption of the analogue-to-digital converter, the large bandwidth for mm-Wave is decreased [11]. A large number of antenna arrays delivers several of the received signals or interferes with the power gained corresponding to the angles of departure/arrival.

The achievable throughput is nearly equalled to the bandwidth, while power consumption increases linearly due to converting the analogue-to-digital converter in the power circuit with bandwidth. The high capacities in 5G depend on low power transmissions and low signal-to-interference-noise ratio (SINR), which are obtained using the mm-Wave bands [12]. The large bandwidth channel in the mm-Wave uses the lower distance with highly directional antennas to sever propagation path loss and generate the GB/s communication rates. In addition, the mm-Wave band restricts the higher path loss in macro cells and femtocell and also increases the spatial reuse of radio resource in the cellular system. The mm-Wave for femtocell and macro cells could be used resourcefully when an association is achievable.

The lower power transmission of femtocells and the signal separation due to dispersion loss by walls may also radically limit the interference from neighbouring femtocells and macro cells [13]. Moreover, the antenna in the mm-Wave has a small effected area causing a loss in energy distribution as the antenna has a limited effective area and cannot transmit more energy. Moreover, a large number of sub-6 GHz BSs needs more wireless power transmissions. In addition, the sub-6 GHz in massive MIMO can suppress the interference by using a large number of antennas to serve a large number of UEs. The sub-6 GHz for BS can provide for all coverage areas when the mm-Wave connection fails or does not exist.

From the existing works, the authors in [13] developed a framework of performance area spectral efficiency while understudying an SINR in the uplink; based on the distance from a line-of-sight (LOS) and a non-line-of-sight (non-LOS) user in a fractional power control to decreases path loss. The authors in [14] investigated the performance network in the downlink for 5G hybrid networks that consists both sub-6 GHz and mm-Wave bands to analyse the energy efficiency and spectral efficiency. The authors in [15] concentrated on the transferring of power in cellular networks in the uplink by focusing on the impacts of many antennas and bandwidths at lower and higher frequencies. This was in addition to how many mm-Wave in small cells can be used to obtain the accepted level of harvested energy more than the sub-6 GHz small cells. Furthermore, to mitigate the energy scarcity in sub-6 GHz and mm-Wave, the authors in [16] proposed the optimal rate and energy efficiency for a physical layer using the power constraints to maximise the sum rate in both the transmitter and receiver. In addition, to optimise the energy efficiency, the authors in [16] used fractional programming and Dinkelbach's algorithm. The authors in [17] believed that the high capacity in 5G could be achieved using hybrid cellular networks in sub-6 GHz and mm-Wave for small cells. To achieve high capacity, the authors in [17] used the analytical model and derived the SINR and coverage probability in both downlink and uplink. [18-20] proposed an outer layer non-cooperative game-theoretic method to maximise energy efficiency in the uplink of a hybrid cellular system with a femtocell access point that improves the sum rate by choosing a sub-6 GHz or mm-Wave.

In this paper, we maximise the achieved high throughput with low transmission powers under the propagation path loss and game theory-based power constraints by proposing a novel distributed power algorithm to mitigate the interference in downlink massive MIMO for both sub-6 GHz and mm-Wave interfaces. In addition to, this paper analyses the tier heterogeneous in downlink for both the mm-Wave and sub-6 GHz to mitigate the inter-beam interference and achievable high throughput under a game theory-based power constraint across the sub-6 GHz and mm-Wave interfaces. Figure 1 shows the system model of mm-Wave enabled 2-tier HetNet.

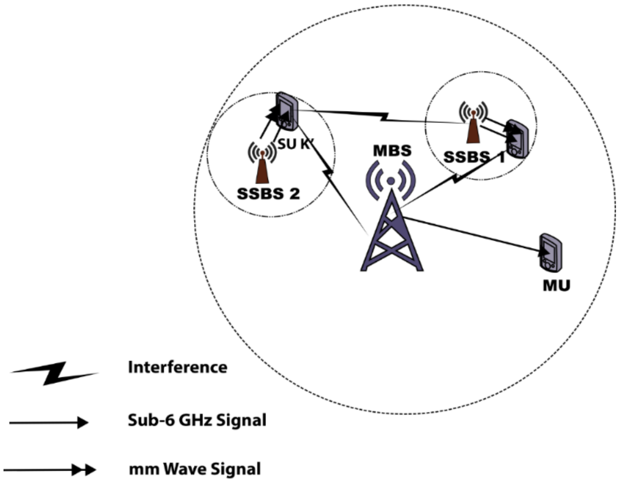

Figure 1. System model of mm-Wave enabled 2-tier HetNet

2. SYSTEM MODEL

In this paper, we consider a wireless cellular network in the downlink transmission, which consists of a typical two-tier small cell operating at sub-6 GHz and the mm-Wave frequency band. We assume that every active user (UE) has a single receiver antenna and is served by the closest BS where each sub-6 GHz small BS is equipped with several antennas and every mm-wave small BS has directional mm-Wave antennas. The BS with a tier k heterogeneous network associated with UEs is given as:

$$s = arg \max_{k \epsilon 6Ghz,mm} Q_k \alpha_k \frac{1}{\gamma_k} \quad (1)$$

where the Q_k is the power transmission from BS to UEs, k^{th}, α_k is the bias factor and $\frac{1}{\gamma_k}$ represents the path loss of UEs at transmitting signals from BS to UEs at distance d. The UE depends on the maximum transmitted power when $\alpha_k = 1$, while when $\alpha_k = 0$, the UE depends on the maximum biased received power.

2.1. Path loss

Path loss (high gain directional beam) provides better radio frequency coverage for distance and estimating the cell coverage based on the number of BS and UEs. The small wavelength in mm-Wave makes transmitting beamforming more viable in the small cells coverage area by using a large antenna array. Moreover, with the variation of the absorption and transmission effect, the propagation loss at the mm-Wave is more significant than the sub-6 GHz. Furthermore, every mm-Wave BS distributes mm-Wave radio frequency transmits power to mm-Wave UEs that has the smallest path loss to reduce the beam, while every sub-6 GHz BSs transmits power for distributing energy to the adjacent sub-6 GHz UE [12-18]. We will have two independent path loss for the mm-Wave and sub-6 GHz between every BS and UEs. The path loss scaled in dB over all distances can be modelled in mm-Wave $\rho_{mm(d)}$ as:

$$\rho_{mm(d)} = \begin{cases} \mathcal{O} + 10\Psi_{\mathcal{L}}\, log(d) + y_L \\ \mathcal{O} + 10\Psi_{\mathcal{N}}\ log(d) + y_N \end{cases} \quad (2)$$

while the path loss for sub-6 GHz $\rho_{6Ghz\,(d)}$ can be expressed as:

$$\rho_{6Ghz\,(d)} = 20\, log\left(\frac{4\pi d_0}{\lambda}\right) + 10\Psi\, log(d) + y_{6Ghz} \quad (3)$$

from (2), d represents the distance in metres, y_L represents the zero mean normal random log adaptable for a line of sight, y_N represents the zero mean normal random log adaptable for non-line of sight, Ψ represents the path loss exponent for both lines of sight and the fixed path loss is expressed as $\mathcal{O} = 32.4 + 20\log(f_c)$. From the sub-6 GHz in (3), d_0 represents the close reference distance and λ represents the wavelength equivalent to the carrier frequency f_c. The transmission power from BS in mm-Wave and sub-6 GHz to UEs in downlink based on a subcarrier (z), can be expressed as:

$$\mathcal{G}(z) = \begin{cases} \frac{\mathcal{Q}_t \mathcal{F}(\varphi)\Omega(\varkappa)}{\rho_{mm(d)}} & mmWave \\ \frac{\mathcal{Q}_t\, \Omega(\varkappa)}{\rho_{6Ghz\,(d)}} & sub-6Ghz \end{cases} \quad (4)$$

where $\mathcal{Q}_t$ is the transmit power, $\mathcal{F}(\varphi)$ is the antenna gain for the azimuthal angle φ of the BS beam alignment and $\Omega_{ij}(\varkappa)$ represents the channel between the i th UE at the j th BS for subcarrier $\varkappa$ and all channels that undergo independent identically distribution (i.i.d.). When the number of antennas goes to infinity, the Rayleigh channel distribution for sub-6Ghz is suitable. The pattern transmitter beam becomes perfectly aligned in the case of $\varphi = [\varphi_0 - \Delta \mho/2, \varphi_0 - \Delta \mho/2]$, the $\Delta \mho$ represents the half power beam width and the active user in sub-6 GHz is assumed to be omni-direction.

Based on mitigating the cross interference of UEs in the subcarrier z and the good quality of service, we assume the connection $\mathscr{g}_i^j(z) \in [0,1]$ from the i th UE at the j th BS is competent to obtain the optimal transmit power $\mathcal{Q}_i^j$ of i th UE. From the heterogeneous network and the femtocell access points effective in mm-Wave, we express the interference threshold $\zeta_{mm}(k)$ of the kth UEs subcarrier as $\sum_{j\in m}\sum_{i\in n}\mathscr{g}_i^j(k_m)E_{ij}(k_m)\mathcal{Q}_i^j(k_m) \le \zeta_{mm}(k_m)$, where the m and n are femtocell access points operating in the mm-Wave and the macro cell user equipment in sub-6 GHz. The power loading factor, $\hbar_k \in \mathbb{C}^{\mathcal{N}_r \times \mathcal{N}_t}$ is the channel matrix assumed to be independent and identically distributed (i.i.d.).

2.2. Network throughput of femtocells

In the mm-Wave, there is no need to significantly grow the interference due to its use of high gain directional antennas. Similarly, the heterogeneous network of the interference threshold transmits the signal to the k th UEs in sub-6 Ghz for the macrocells access points $\sum_{j\in m}\sum_{i\in n}\mathscr{g}_i^j(k)E_{ij}(k)\mathcal{Q}_i^j(k) \le \zeta_{6Ghz}(k)$ and the sub-6 Ghz channel power gain is controlled through random path loss for a large number of antennas. Moreover, it cancels the interference from the inter and intra cells between the macro and femtocells to optimise the system performance of HetNet, where E_{ij} represents the magnitude of channel gain from UE j to the receiver of UE $i \neq j$ and the inverse path loss from user j to the receiver of user $i \neq j$.

In the downlink transmission, the mm-Wave BS uses lower transmission of power in the case of a line of sight. The noise in a large bandwidth mm-Wave is limited according to a UE in the mm-Wave that used a lower transmission of power to limit interference [21-24]. Based on the multi-user equipment in cellular networks and the orthogonality of frequency bands for the distribution of a downlink signal-to-inter ference-noise ratio (SINR), the mm-Wave should use lower transmission in a line of sight to Ξ th on suthe bcarrier k_m of the n th multi-users equipment. The transmission of power in SINR concerning the cell coverage of mm-Wave BS to UEs can be written as:

$$\Gamma_{\Xi}^{m}(k_m) = \frac{\mathcal{G}_{\Xi}^{m}(k_m)}{\tau^2(k_m)+\zeta_{\Xi}^{m}(k_m)} \quad i \in r \quad (5)$$

where τ represents the parameter of centre frequency for both the mm-Wave and sub-6 GHz. The sensitivity of the mm-Wave is based on the connected UE with a line of sight mm-Wave BS or non-line of sight mm-Wave BS. When the femtocell reuses the frequency resources in a macro cell, the macro cell must ensure reliable transmission. The available reduced spectrum requires mitigating the SINR of sub-6 GHz for all distributed path loss of UEs served by the multi-user equipment in a cellular network [22-25]. The bandwidth of sub-6Ghz is smaller than the bandwidth for the mm-Wave as the e th for the multi-user equipment operates in the sub-6 GHz for subcarrier k in the multi-user equipment. The transmitted power to SINR of sub-6 GHz BS to UEs can be written as:

$$\Gamma_{e}^{m}(k) = \frac{\mathcal{G}_{\Xi}^{m}(k)}{\tau^2(k)+\zeta_{\Xi}^{m}(k)} = \frac{E_{ij}\,\mathcal{Q}_i}{I_i} \quad i \in r \quad (6)$$

where $I_i = \tau^2(k) + \zeta_{\Xi}^{m}(k)$ represents the interference for the femtocell access points. We assumed that every BS has at least one UE who can be served. Hence, the SINR coverage of sub-6 GHz in the DL multi-user equipment e th [15, 18] can be defined as:

$$\zeta_e^m(k) = \sum_{j=1}^{m}\sum_{i=1}^{\Xi}\left(1-\prod_{y=i}^{m}1_{\mathscr{g}_e^y(k)=0}\right)\mathcal{G}_{\Xi}^{m}(k) + \sum_{i=1,i\neq n}^{m}\left(1-\prod_{j=i}^{m}1_{\mathscr{g}_i^j(k)=0}\right)\mathcal{G}_e^m(k) \quad sub-6Gz \quad (7)$$

The interference from the inter cell for the femtocells is cancelled to optimize signal. The SINR coverage for the mm-Wave in the DL multi-user equipment m th subcarrier can be defined as:

$$\zeta_e^m(k_m) = \sum_{j=1}^{m}\sum_{i=1}^{\Xi}\left(1-\prod_{y=i}^{m}1\mathcal{g}_e^y(k_m)\right)\mathcal{G}_\Xi^m(k_m) + \sum_{i=1,i\neq M}^{m}\left(1-\prod_{j=i}^{m}1\mathcal{g}_e^j(k_m)\right)\mathcal{G}_e^m(k_m) \text{ mmWave} \quad (8)$$

Due to the densification gain and utilising large sub-6 GHz small cells, the achievable high throughput can be increased. By adding more femtocells as follows, the sub-6 GHz provides a better coverage rate $\Re = \varsigma \log\left(1+\Gamma_e^m(k)\right)$ for the high transmission throughput with k th UEs:

$$\text{Th} = \sum_{i=1}^{m} \Re \times \Gamma_e^m(Q) \in r_m \quad (9)$$

where ς represents the strategy vector of m th femtocell access point in sub-6 GHz.

Transmitting the optimal power allocation from any j th BS to i th users for any subcarrier, $\curlywedge$ can be represented as $Q_i^j(\curlywedge)$, as the path loss between the i th users and j th BS is based on the constraint power:

$$Q_i \leq Q_i^{max} \quad (10)$$

where Q_i^{max} represents the maximum power for the UEs and the maximum threshold Q_i^{max} is controlled when transmitting power from BS to every UEs. When the BS transmits maximum power control on sub-6 GHz, its coverage is limited.

When a BS needs direct power transmission from a reserve UE, the BS will be associated with the sub-6 GHz active user that gives the greatest sub-6 GHz signal power. The BS will be associated with the mm-Wave BS to give the greatest conventional mm-Wave signal power. To achieve high throughput for the multi-user equipment, the power transmitted should ensure the number of multi-user equipment for SINR is smaller than the target value of SINR $\mathbb{\Gamma}_i$, because the sub-6 GHz networks interference is limited at the lower budget in order to obtain better channel conditions.

$$\Gamma_e^m(k) \geq \mathbb{\Gamma}_i \ \forall\, i \in r_m \quad (11)$$

where r_m is the set of multi-user equipment (MUE). We assume the system operates at lower SINR to make the estimate more tractable. The optimal transmission power in sub-6 GHz can be obtained when considering a huge number of antennas as the power grows proportionally to the number of antennas. The large transmission of sub-6 GHz BSs improves the reception of high throughput located at the edge cell.

The interference in between BS and users are homogeneous Poisson Point Processes (PPP) allocated and the elimination region nearby the UE is the same. In sub-6 GHz macro cells, based on using game theory for power constraints, the directed transmitted power that controls the path loss based on using the pricing function $r(Q_i)$ for distributed UEs from [24, 25] and the cost function $\mathfrak{f}_i$ of the Nash Equilibrium is:

$$\mathfrak{f}_i\left(Q_i, \Gamma_e^m(Q)\right) = r_i(Q_i) - \sigma_i\left(\Gamma_e^m(Q)\right) \quad (12)$$

The first term in (12) which is $r_i(Q_i)$ represents the cost incurred by UE $i \in r$ and the second term, $\sigma_i\left(\Gamma_e^m(Q)\right)$ is the degree of satisfaction of achieving high throughput. To deviate transmit power Q_i^*, the Nash Equilibrium is able to enhance its cost function by using the transmit power as:

$$\mathfrak{f}_i\left(Q_i^*, \Gamma_e^m(Q_i^*)\right) \leq \mathfrak{f}_i\left(Q_i^*, \Gamma_e^m(Q_1^*, Q_2^* \ldots\ldots\ldots, Q_{i-1}^*, Q_{n+m}^*)\right) \ \forall\, i \in r \quad (13)$$

The derivative of the Nash Equilibrium power that provides game theory for substantial power savings $\mathfrak{f}_i\left(Q_i, \Gamma_e^m(Q)\right)$ concerning Q_i and associating to zero is:

$$\frac{\partial \mathfrak{f}_i}{\partial Q_i} = \frac{\partial r_i}{\partial Q_i} - \frac{\partial \sigma_i}{\partial \Gamma_e^m}\frac{\partial \Gamma_e^m}{\partial Q_i} = 0 \quad (14)$$

where $\frac{\partial \Gamma_e^m}{\partial Q_i} = \frac{E_{ij}}{I_i}$, the derivative of the utility function can be expressed as:

$$\frac{\partial \sigma_i}{\partial \Gamma_e^m} = \frac{I_i}{E_{ij}}\frac{\partial r_i}{\partial Q_i} = \frac{Q_i}{\Gamma_e^m}\frac{\partial r_i}{\partial Q_i} \quad (15)$$

The [22-26] guarantees the achievable throughput requirements to obtain efficient transmitted power by reducing the power consumed and mitigating interference from both the multi-user equipment and the femtocell access points. The interference power can be a limited underused non-coherent combination and the SINR to the path gain of the UE from the user-specific β_i can be written as:

$$\beta_i = \frac{I_i}{E_{ij}} = \frac{Q_i}{\Gamma_e^m} \tag{16}$$

In sub-6 GHz, the greater coverage area can be obtained at lower SINR thresholds. Moreover, the sub-6 GHz provides better SINR due to low interference from the mm-Wave at the edge cell when the UEs are placed close to the BSs.

2.3. Distributed transmitted power allocation algorithm based on SINR

In designing the communication network, the transmission power is the key to obtaining high throughput in large antenna arrays for dense small cells. We propose using the distributed transmitted power algorithm in order to adjust the transmitted power in the femtocell based on the microcell/femtocell co-channel employment overcome. Minimizing the transmitted power at the BS to multi-user communication is important to achieve certain SINR. From (11), the optimal Γ_e^m for every sub-6 Ghz BSs should be equal to the target of $\mathbb{\Gamma}_i$. To identify the cost variation between the prefects Γ_e^m and target $\mathbb{\Gamma}_i$ at non-zero levels of SINR in sub-6 GHz, BSs for UE could be positive and convex for both $\sigma_i\left(\Gamma_e^m(Q)\right)$ and $r_i(Q_i)$ of the sub-6Ghz for user equipment $i \in r_m$ [26-29], can be expressed as:

$$\sigma_i(\Gamma_e^m) = -(\mathbb{\Gamma}_i - \Gamma_e^m)^2 \tag{17}$$

$$r_i(Q_i) = 0 \tag{18}$$

The maximum signal power for sub-6 GHz can be obtained through directly transferred power from sub-6 GHz BS to sub-6 GHz UE. From (12), the transmitted optimal power allocation for i th sub-6 GHz for user equipment power and SINR can be written as:

$$\digamma_i^m(Q_i, \Gamma_e^m) = x_i Q_i + \left(\mathbb{\Gamma}_i - e^{v_i, \beta_i}\Gamma_e^m\right)^2 \ \forall\, i \in r_f \tag{19}$$

where x_i and v_i represent the non-negative weight factors, and e^{v_i, β_i} is the local gain for the proposed game theory in regards to the transmitted power allocation algorithm. From (19), the first term represents the pricing power, which is always positive. The mitigated SINR of sub-6 GHz should distribute all the path loss of UEs served by the user equipment in the cellular network. The SINR $\left(\mathbb{\Gamma}_i - e^{v_i, \beta_i}\Gamma_e^m\right)^2$ is also positive due to a square of SINR error. From (19), the non-negative factor should mitigate SINR when $x_i / e^{v_i, \beta_i} < 1$, while when the selected $x_i / e^{v_i, \beta_i} > 1$, the transmit power for users is more important.

Guaranteeing the achievable high throughput requires obtaining the target Γ_e^f in sub-6 GHz for user equipment points to every user $i \in r_f$. Using the Nash Equilibrium yields small SINR from the target of SINR. Based on the target $\mathbb{\Gamma}_i$ in sub-6 GHz for the user equipment, the game theory for transmitted power is reduced and cross-tier interference is mitigated using the Nash Equilibrium for i th users; the first derivative of user equipment in sub-6 GHz:

$$\frac{\partial \digamma_i^f}{\partial Q_i} = 0 = x_i - 2e^{v_i, \beta_i}\left(\mathbb{\Gamma}_i - e^{v_i, \beta_i}\Gamma_e^f\right)\frac{\partial \Gamma_{e\,i}^f}{\partial Q_i} \tag{20}$$

$$\frac{\partial \digamma_i^f}{\partial Q_i} = x_i - 2e^{v_i, \beta_i}\left(\mathbb{\Gamma}_i - e^{v_i, \beta_i}\Gamma_e^f\right)\frac{E_{ij}}{I_i} \tag{21}$$

from (21), the costs function of user equipment for sub-6 GHz when the $\frac{\partial \digamma_i^f}{\partial Q_i} = 0$; the optimal SINR can be written as:

$$\hat{\Gamma}_e^f = \frac{\mathbb{\Gamma}_i}{e^{v_i, \beta_i}} - \frac{x_i I_i}{2\left(e^{v_i, \beta_i}\right)^2 E_{ij}} \tag{22}$$

the optimal power can be derived from (6) based on the optimal SINR $\hat{\Gamma}_e^f$ of sub-6 GHz to distribute the path loss of UEs using the Nash Equilibrium, where:

$$Q_i^* = max\left[\frac{I_i \mathbb{\Gamma}_i}{e^{v_i,\beta_i}\mathrm{E}_{ij}} - \frac{x_i\ I_i^2}{2\,\mathrm{E}_{ij}^2\left(e^{v_i,\beta_i}\right)^2}, 0\right] \tag{23}$$

from (23), when the $x_i \rightarrow 0$, the spending power increases and the optimal power becomes $Q_i^* = \frac{I_i \mathbb{\Gamma}_i}{e^{v_i,\beta_i}\mathrm{E}_{ij}}$.

While when the $v_i \rightarrow 0$ and $x_i \rightarrow 0$, the optimal SINR can be obtained as $\hat{\Gamma}_e^f = \mathbb{\Gamma}_i$. The game theory for transmitted power can be updated for proposed power of user equipment in sub- 6 GHz to achieve the actual SINR using the minimum transmitted power of user i at repetition k and $k + 1$. The optimal transmitted power is needed in a dense small cell between the active users and is connected to BS. Noting when the $Q_i^{k+1} = \mu_i^k Q_i^k$ can be expressed as:

$$Q_i^{k+1} = \frac{I_i^k \mathbb{\Gamma}_i}{e^{v_i,\beta_i^k}\ \mathrm{E}_{ij}^k} - \frac{x_i\left(I_i^k\right)^2}{2\left(\mathrm{E}_{ij}^k\right)^2\left(e^{v_i,\beta_i^k}\right)^2},\ Q_i^k > 0 \tag{24}$$

From (16), (24) should fulfil $Q_i^{(k)} \neq 0$ when the $k = 0$, according to the new specific e^{v_i,β_i^k} in the first term in the denominator. (24) provides different power balancing. Moreover, in the second term, both the square of interference $\left(I_i^k\right)^2/\left(\mathrm{E}_{ij}^k\right)^2$ and square local gain in the proposed transmit power of interference $\left(e^{v_i,\beta_i^k}\right)^2$ are negative in (24). This requires $\left(I_i^k\right)^2/\left(\mathrm{E}_{ij}^k\right)^2$ and $\left(e^{v_i,\beta_i^k}\right)^2$ to use a single measurement at every repetition for k and $k + 1$ and implement the distributed transmitted power control in the femtocell access points.

2.4. mm-Wave

The large losses are caused by the circuit power consumption due to the conversion from analogue-to-digital and the high losses in the channel [30]. In this case, the transmit power is a scarce resource and the directed transmitted power is controlled by the mm-Wave path loss. From (17), (18) and (12), the cost function of distributed transmit power in mm-Wave can be written as:

$$\digamma_i^m(Q_i, \Gamma_e) = (\mathbb{\Gamma}_i - \Gamma_i^m)^2\ \ \forall\, i \in r_m \tag{25}$$

the optimal Γ_i^m could be equal to the target $\mathbb{\Gamma}_i$ for every active user $\in r_m$, by the respect the first derivative of the mm-Wave in term Γ_e:

$$\frac{\partial \digamma_i^f}{\partial \Gamma_i^m} = 0 = 2\Gamma_i^m - 2\mathbb{\Gamma}_i \qquad 26)$$

from transmitted power of SINR, and based on (26):

$$\hat{\Gamma}_i^m = \mathbb{\Gamma}_i \tag{27}$$

based on the use of the game theory, the optimal iterative distributed power Q_i^{k+1} can be obtained based on (27) and from transmitting SINR in (6) when $\mathrm{E}_{ij}\frac{Q_i}{I_i} = \mathbb{\Gamma}_i$ as:

$$Q_i^{k+1} = \frac{I_i}{\mathrm{E}_{ij}}\mathbb{\Gamma}_i = \frac{I_i^k}{(\Gamma_i^m)^k}\mathbb{\Gamma}_i \tag{28}$$

Algorithm I Iterative distributed power
Input $v_i, x_i, k, Q_i, \mathrm{E}_{ij}$ and β_i
Identify the cost variation for prefect Γ_e^m and target $\mathbb{\Gamma}_i$
Collect from every user i at repetition k and location $(\beta_i, I_i, \mathrm{E}_{ij}, Q_i, \Gamma_e^m)$.
Compute actual $\hat{\Gamma}_e^f$ using the minimum transmit power Q_i and mitigated cross-tier interference using the Nash Equilibrium for ith users.
If $v_i \rightarrow 0$ and $x_i \rightarrow 0$
Compute the actual SINR $\hat{\Gamma}_e^f = \mathbb{\Gamma}_i$.
Mitigate SINR when $x_i/e^{v_i,\beta_i} < 1$

Use the game theory for power transmission by repetition k and $k+1$.
When $x_i \rightarrow 0$ the cost of a power increases
Estimate $Q_i^{(k)} \neq 0$ according (24).
Use a single measurement to mitigated interference $(I_i^k)^2/(\mathrm{E}_{ij}^k)^2$ and $(e^{v_i,\beta_i^k})^2$ for every repetition k and $k+1$.

End if
Computing the optimal iterative distributed power Q_i^{k+1} (28).

3. RESULTS AND DISCUSSION

In this section, the proposed method is tested using MATLAB-based Monte Carlo simulations against the performance of our proposed scheme. The factors are mm-Wave the carrier frequency at 20GHz, available bandwidth at 1 GHz, the sub-6GHz the carrier frequency at 1GHz and the bandwidth at 1MHz. In Figure 2, we investigate the throughput versus the number of femtocell access points in mm-Wave. The high throughput was obtained at the minimum SINR threshold Γ_i by suppressing the inter-beam interference and at a minimum path loss when the number of UEs increases. The short distance in small cells reduces the attenuation and absorption by limiting the effects of cross interference of UEs in the subcarrier to provide the high throughput. The mm-Wave provides better coverage for users at cell edges with a greater SINR. When a user in the mm-Wave is located nearest to the neighbouring BSs, they experience low interference. From Figure 2, by deploying the densification gain, the high throughput for Monta Carlo simulation provides more throughput than lower bound when deploying a large number of antenna arrays in the mm-Wave BS, with distributed UEs K = 100 and K = 50. From Figure 1, when the number of femtocell access point is 50 and the high throughput is 2.3Gbps based on the number of distributed UEs K=100 while the high throughput is 1.25 Gbps when the number of distributed UEs K = 50. The number of femtocell access points causes large interference in the overall network due to the number of distributed users in every femtocell.

In Figure 3, we investigate the throughput versus the number of femtocell access points in sub-6 GHz. The SINR will decrease and reduce the inter-beam interference based on low distributed power transmission for movement UEs at the femtocell access point. The sub-6 GHz provides a high throughput to UEs in the dense small cells when the number of femtocells increases due to low interference from the neighbouring cells. From Figure 3, the Monta Carlo simulation improves throughput more than the analytical lower bound. When the number of femtocells = 40, the performance throughput = 44 Mbps at a number of UEs = 100, while at same values for the number of femtocells, the performance throughput in all networks decrease to 23Mbps when the number of movements is UEs = 50. Moreover, when the UEs are located near the BS, the sub-6 GHz provides better coverage based on the lower SINR threshold and the lower interference from adjacent UEs. Finally, Figure 3 shows the increment of high throughput when the number of femtocell access points increases.

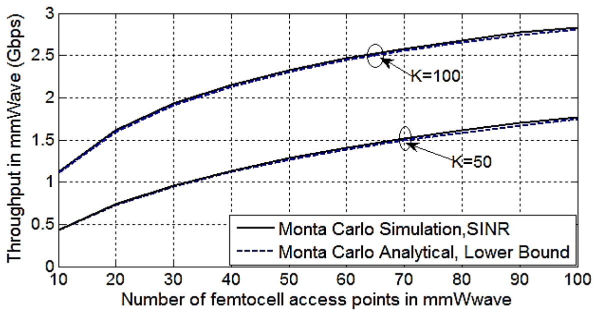

Figure 2. Throughput versus femtocell access points in mm-Wave

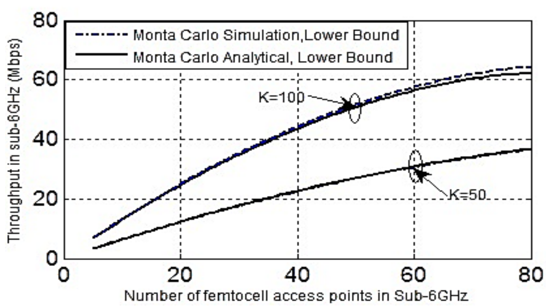

Figure 3. Throughput versus the number of femtocell access points in sub-6GHz

Figure 4 presents throughput versus the number of femtocell access points depending on the controlled power. The power transmits in mm-Wave BS to UEs is lower based on the control energy harvested created from the digital-to-analogue converter (DAC) and the large number of antennas for RF chains and energy propagation loss in the downlink. The low transmission power in the mm-Wave is more viable and provides high throughput for all femtocells with controlled power, while the throughput is small without controlling the distributed power as shown in Figure 4. However, when the number of femtocells = 20, the high throughput = 5Gbps with controlled distributed transmit power, while the high throughput = 1 Gps without control distributed power. Moreover, the distributed power in the femtocell of UEs depends on SINR in order to mitigate cross-tier interference at the microcell and provides a better indoor voice and lower consumption of power resulting in prolonger battery life. This is due to controlling distributed power in mm-Wave BS that uses a local gain e^{v_i,β_i^k} to mitigate SINR.

From Figure 5, the high throughput can be obtained for the mm-Wave with low transmitted power. The high throughput can be obtained due to the mm-Wave directivity and densification gained for the mm-Wave transmitted power ranging from (-10, 10) dBm. The throughput for the mm-Wave in lower bound give the small value of transmitting power from (-10, 8) dBm, compared with the mm-Wave Monta Carlo simulation of SINR and analytical SINR. The transmitted power is dominated by the mm-Wave path loss and the mm-Wave BS is adapted to distribute power active UEs and begin saturation when Q = 9 dBm. The directional beamforming and the high gain in the transmitter limit the effects of the path loss and multi-path for the mm-Wave and are adopted at each mm-Wave small BS. From Figure 5, the throughput values provide a constant value and reaches saturation when the Q = 9 dBm.

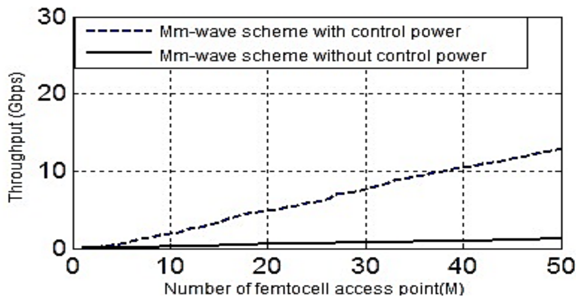

Figure 4. Throughput versus the number of femtocell access points

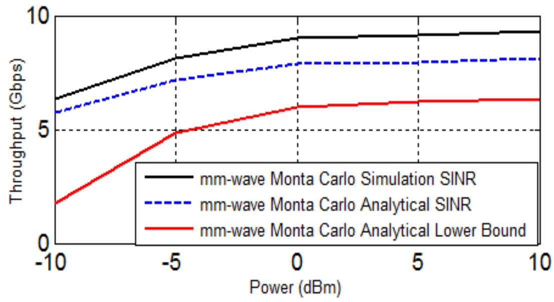

Figure 5. Throughput versus transmitted power

4. CONCLUSION

In this paper, we analysed the propagation path loss for macro cells and femtocells in the sub-6 GHz and mm-Wave tiers based on a proposed novel distributed game theory for the transmission of power to mitigate the inter-beam interference. The mm-Wave provides high coverage performance and outperforms its sub-6 GHz counterpart because the mm-Wave limits noise to increase transmission power and the directional transmission of the signal is more resistant to eavesdropping. The low power should ensure that the number of multi-users for co-channel interference equipment for SINR becomes small for the target value of SINR to guarantee maximum network throughput and mitigate interference for both multi-user equipment and femtocell access points.

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