Green Deployment Strategy for HetNets under Matern Hard Core Point Process

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Abstract: ***As one of the main pillars and the future trends of mobile communication technology, heterogeneous networks have received a lot of attention in the wireless industry. Explosive growth in mobile data traffic, leads to rapid increases in energy consumption of cellular networks. Improving energy efficiency by sleep operations of Base Stations (BS) may bring coverage holes. Hence the trade-off between energy efficiency and coverage performance is an important factor to be considered. This paper investigates on the impact of point processes on energy conservation of Het Nets (Heterogeneous cellular network) with guaranteed coverage. Fist, the relation between the average coverage probability and deployment parameters i.e; the BS density and transmission power is analysed by assuming Poisson Point Process (PPP) and Matern Hard Core Point Process (MHCPP). The analysis can lead to a optimal green deployment framework. The existing optimal green deployment strategy is based on a poisson distribution. The comparison of the stationary processe's performance over the green deployment strategy shows that compared with a poisson distributed, heterogeneous network deployment, MHCPP distributed hetnet has slight improvement in system energy consumption reduction with sufficient coverage performance, and it incorporate dependence between deployment points as encountered in practice.***

Keywords*:* heterogeneous cellular network, MHCPP, SINR, energy efficiency, coverage probability

1. Introduction

In the strive for lessening of the environmental impact of the information and communication industry, energy consumption of communication networks has recently received increased attention. It is estimated that 3% of the world‟s electrical energy consumption and 2% of CO2 emissions are caused by the information and communication technology (ICT) industry. And about a tenth of this can be attributed to cellular systems [1], [2]. The deployment of small, low power base stations, alongside conventional sites is referred to as Het Net. Deployment of such low power Mi BS (Micro Base Stations), offload the traffic of Ma BS (Macro Base Station) and there by provide solutions for challenges faced by exponential surge in cellular network traffic. Meeting such a traffic demands through Het Nets will cause a significant increase in operator energy consumption.

Decreasing the BS (Base Stations) density of Het Nets to cut down the system energy consumption through sleep operations may bring coverage holes which are not covered by less BSs. It has a bad effect on UE (User Equipment)‟s experience when UEs move to coverage holes or when sessions are established in coverage holes. An energy-efficient deployment strategy under coverage performance constraints for Het Net can serve needs of energy reduction along with guaranteed coverage performance. The existing work considering an energy related deployment factor and jointly optimizing BS transmission power and BS density is based on Poisson Point Process (PPP) [2]. While PPP allows a deployment which is far from reality since the BSs locations in real cellular networks are not totally independent. The dependent thinning of a PPP, MHCPP (Matern Hard Core Point Process) can maintains a minimum distance separation between the BSs. It will not allow the BSs to get close to each other, which might occur for a PPP. The BS intensity also can be further optimized, which provides an energy efficient deployment. Even though it is not easily tractable, a real deployment strategy with higher system energy conservation and sufficient system coverage performance can be obtained using MHCPP based deployment. Finally analyzing the impact of deployment factor on coverage probability also comparing the system power consumption under both schemes. From the results forming a more energy efficient optimal deployment framework with MHCPP.

2. System Model

Consider a heterogeneous cellular network consisting of 2tiers of BSs as shown in Figure 1(b). Where tier m and M represent MiBSs and MaBSs and λ_m and λ_M represents their intensities, respectively. Assume that BSs in tier i use the same link transmission power $\{P_i\}_{i=m,M}$.

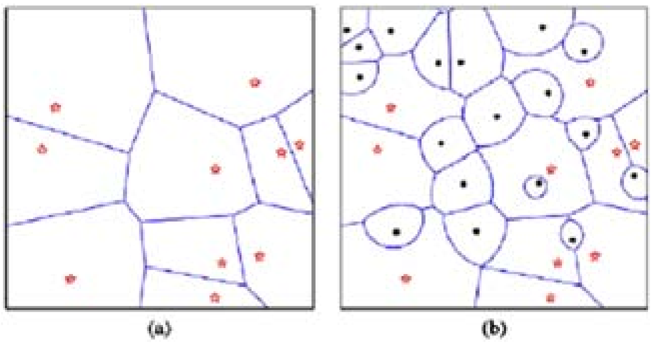

Figure 1: Close up view of coverage regions in homogeneous cellular networks and two-tier heterogeneous cellular network. Red stars and black points represent MaBSs and MiBSs respectively.

2.1 Channel Model

The analysis is conducted on a typical user located at the origin. The fading loss between a BS located at x_i (belonging to ith tier) and the typical user is denoted as h_{x_i}, The fading is assumed to be i.i.d exponential (Rayleigh fading), i.e., $h_{x_i} \sim \exp(1)$. The standard path loss function can be given by $l(x_i) = \|x_i\|^{-\alpha}$.Where α is the path loss exponent which is having a value as $\alpha \rangle 2$. The received power at a typical user from a BS located at point x_i is $p_i h_{x_i} \|x_i\|^{-\alpha}$. The resulting signal to interference plus noise ratio (SINR) expression assuming the user connects to the BS is :

$$SINR = \frac{p_i h_{x_i} \|x_i\|^{-\alpha}}{I_{x_i} + \sigma^2} \quad (1)$$

Where $I_{x_i} = \sum_{j=m,M} \sum_{x_j \in \phi_j / x_i} P_j h_{x_j} \|x_j\|^{-\alpha}$ is the interference, and σ^2 is the constant additive noise power [2].

2.2 Spatial Point Process

A spatial point process (PP) is a random collection of points in space. A PP is simple if no two points are at the same location, i.e $x \neq y$ for any $x, y \in \phi$. A random set of points in ϕ can be represented as a countable set $\{x_i\}$ random variables that take values in R^2. The intensity measure of ϕ is, $\wedge(B) = E[\phi(B)]$ where $E[\phi(B)]$ is the expected number of points in $B \subset R^2$. A stationary Poisson point process of intensity λ_{ppp} is characterized by the following two properties:

- The number of points in any set $B \subset R^2$ is a Poisson random variable with mean $\lambda|B|$, i.e.

$$P(\phi(B) = k) = e^{-\lambda|B|} \frac{(\lambda|B|)^k}{k!} \quad (2)$$

- The number of points in disjoint sets are independent random variables.

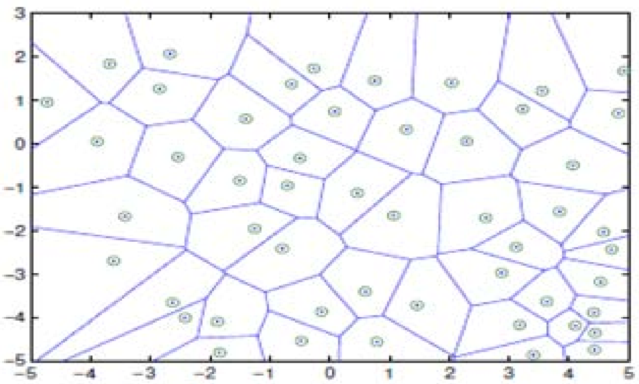

Figure 2: Actual MaBS deployment from a rural area

2.3 Matern Hard Core Point Process

A matern hard-core point process ϕ_{mhc} is generated by a dependent thinning of a stationary Poisson point process. Let, X_i where i = 1,2,3,…N, be a sequence of random variables independently and uniformly distributed in finite observation. Where N is a positive integer. Consider a $B(o,d)$, a ball of radius d centered at O. $\phi_{mhc(i)}$ is the set of points selected after i steps. At the ith step, the point X_i is distributed and selected in $\phi_{mhc(i)}$ if and only if none of the $i-1$ previous points, even the inactive ones, lies in the finite plane B_{x_i}, the ball centered at X_i with radius d. After all of the N points are processed the procedure finally ends [5].

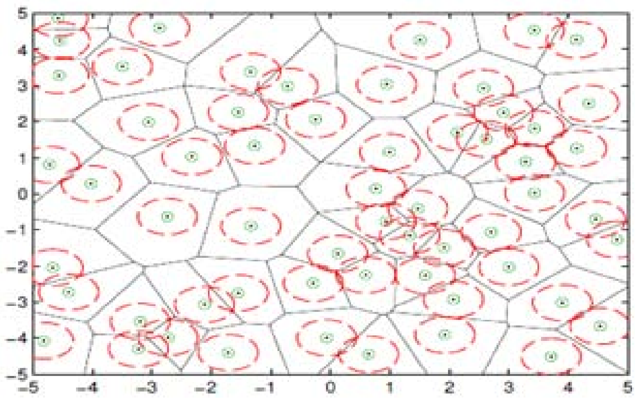

Figure 3: A sample realization of MHCPP

The probability of an arbitrary point x is retained in ϕ_{mhc} is given by:

$$p = \frac{1 - \exp(-\lambda_{ppp} \pi d^2)}{\lambda_{ppp} \pi d^2} \quad (3)$$

The density of the MHCPP ϕ_{mhc} is $\lambda_{mhc} = p\lambda_{ppp}$, i.e.

$$\lambda_{mhc} = \frac{1 - \exp(-\lambda_{ppp} \pi d^2)}{\pi d^2} \quad (4)$$

3. Coverage Performance

In this section the analysis of the relations between the average coverage probability and SINR threshold values as well as the dependence of coverage probability on deployment strategy (i.e., BS density and BS transmission power) under PPP and MHCPP is carrying out. The separate terms BS density and BS transmission power are combined in to a single term called energy efficient deployment facto A. The coverage probability [6] of a user is defined as:

$$P_C = P[SINR \geq \gamma] \quad (5)$$

where γ is the outage threshold. (5) can be calculated as follows:

$$P_C = E_{x_i}(P[SINR(x_i) \geq \gamma]) \quad (6)$$

Where $E_{x_i}(.)$ represents the expectation with respect to x_i and the $P[SINR(x_i) \geq \gamma]$ is the coverage probability given that the user is associated with the BS located at point x_i, which can expressed as:

$$P[SINR(x_i) \geq \gamma] = P\left[\frac{p_i h_{x_i} l(x_i)}{I_{x_i} + \sigma^2} \geq \gamma\right]$$
$$= P\left[h_{x_i} \geq \frac{\gamma(I_{x_i} + \sigma^2)}{p_i l(x_i)}\right]$$
$$\underset{=}{a} \exp\left(\frac{-\gamma\sigma^2}{p_i l(x_i)}\right) E_{I_{x_i}}\left(\exp\left(\frac{\gamma I_{x_i}}{p_i l(x_i)}\right)\right) \quad (7)$$

3.1 Probability of Coverage

Consider a PPP, where a fixed number of BSs is uniformly randomly placed in a certain area. The interference in a PPP with intensity λ_{PPP} is $I(\lambda_{ppp})$. Due to the superposition property of the PPP, the interference is proportional to λ_{PPP}. The mean interference can be expressed as :

$$E(I) = \sum_{x \in \phi_{PPP}} h_x l(\|x\|) = \lambda_{PPP} E(h) \int_{R^n} l(\|x\|) dx \quad (8)$$

Where ϕ_{PPP} is a point process of interferers on R^n. $l(\|x\|)$ is the path loss function and h_x model the interference [7].

Now consider a stationary process MHCPP with intensity λ_{MHC}, which is obtained by dependent thinning of the PPP. Since the local density of interferers is higher for the homogeneous PPP, the interference is much higher. While the hard core process enforces a minimum distance between the BSs. There will not be any BS as interferer for a serving BS within the fixed distance „d ‟.

3.2 Impact of Deployment Factor

The average coverage probability is dependent on the term $A = \lambda_m P_m^{2/\alpha} + \lambda_M P_M^{2/\alpha}$, which is the energy related deployment factor. Where λ_M, λ_m, P_M and P_m are deployment parameters to be optimized to form a more green HetNet. Obviously, the network energy consumption is also an increasing function of both the P_M (P_m) and λ_M (λ_m) because the larger P_M (P_m) means larger transmission power and the larger λ_M (λ_m) represents more BSs [2]. First consider MaBS modeled as independent homogeneous PPP ϕ_{MPPP} with intensity λ_{MPPP} and MiBS modeled as independent homogeneous PPP ϕ_{mPPP} with intensity λ_{mPPP}. Then obtain MHCPPs from this PPPs as ϕ_{MMHC} for MaBS with intensity λ_{MMHC} and ϕ_{mMHC} for MiBS with intensity λ_{mMHC}. The transmission power is assumed to be same for both stationary processes. For a typical randomly located user in the heterogeneous networks consisting of MaBSs and MiBSs, when $\alpha > 2$ and $\sigma^2 > 0$ the coverage probability is a monotonically increasing function of energy related deployment factor A. It is the fact that the coverage probability is always not larger than 1, and hence the coverage probability of both schemes ultimately converges to a fixed value with the increase of corresponding A values.

4. System Energy Consumption

The Energy consumption of each deployment scheme increases as the values A_{PPP} and A_{MHC} values increases. APC (Area Power Consumption) is used as the energy efficiency metric. Since the APC depends on intensity of BSs as shown in equation (9), further system energy consumption reduction is possible for MHCPP while compared to the existing deployment strategy. For a MHCPP, the APC can be expressed in terms of deployment parameters and other power parameters of BSs as follows:

$$APC = \lambda_{MMHC}(a_{MMHC} NP_{MMHC} + b_{MMHC})$$
$$+ \lambda_{mMHC}(a_{mMHC} NP_{mMHC} + b_{mMHC}) \quad (9)$$

Based on the analysis over coverage performance and energy efficiency can formulate a more optimal deployment frame work which could further determines the optimal deployment parameters i.e.; Optimal BS density and transmission power. The optimization framework is as follows:

$$\underset{\lambda_{MMHC}, P_{MMHC}, \lambda_{mMHC}, P_{mMHC}}{Minimize} \quad APC$$

Subject to
$$P_C(\lambda_{MMHC}, P_{MMHC}, \lambda_{mMHC}, P_{mMHC}) \geq P_{\exp}$$
$$P_{MMHC,\max} \geq P_M \geq 0$$
$$p_{mMHC,\max} \geq P_m \geq 0$$
$$\lambda_{MMHC,\max} \geq \lambda_M \geq 0$$
$$\lambda_{mMHC,\max} \geq \lambda_m \geq 0 \quad (10)$$

5. Numerical Results

In order to obtain the P_C of PPP and MHCPP under Rayleigh fading , take the total BS bandwidth as 20 MHz (N1=10). The coverage probability is obtained for an outage threshold value ranging from $\gamma = -10dB$ to $\gamma = 10dB$ as shown in Figure 4 and Figure 5. The higher γ is, smaller the P_C value. It is harder to satisfy the coverage requirement with larger outage threshold. The path loss exponent values consider from a range of $\alpha = [3,4]$. The P_C decreases as the path loss exponent increases. The reason is that smaller α means better channel environment. With better environment the QOS requirement is more easy to be satisfied.

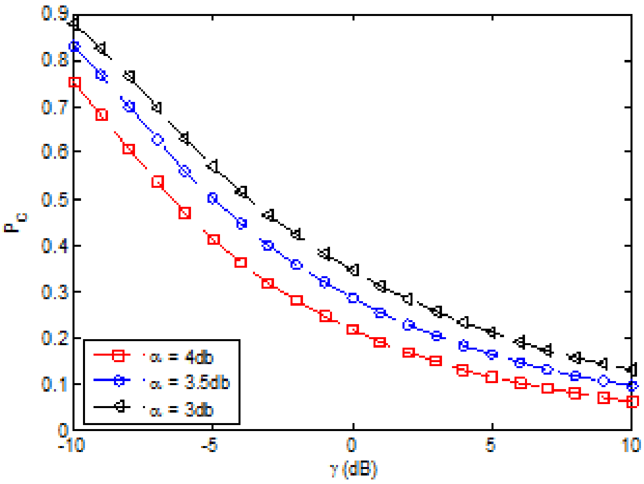

Figure 4: Coverage probability under a poisson point process distribution

The P_C is seems to be improved for a MHCPP. The number of interferes for a MHCPP is lesser than the PPP for a particular threshold value.

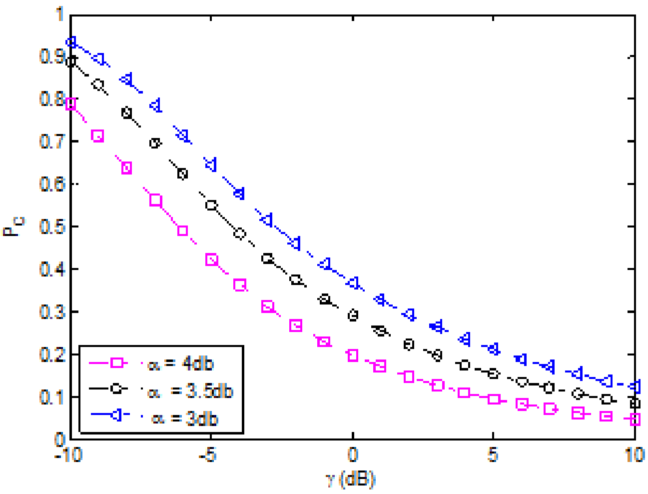

Figure 5: Coverage probability under a Matern Hard Core Point Process distribution

4.1 Impact of Deployment Factor on Coverage Probability

Figure 6 shows the dependence of average coverage probability on the deployment parameters. Set the simulation parameters as additive noise power $\sigma^2 = -100dBm$, path loss exponent $\alpha = [3.5, 4.5]$. The Max. available MaBS density $\lambda_{MPPP,\max} = 10^{-6} m^{-2}$ and Max. available MiBS density $\lambda_{mPPP,\max} = 2\times10^{-6} m^{-2}$ for PPP. The d value for MaBS as $d_1 = 10^{-4}$, d for the MiBS as $d_2 = 2\times10^{-4}$. Max. MaBS transmission power. $N.P_M = 40W$. Max. MiBS transmission power $N.P_m = 2W$. MaBS power parameters $a_M = 22.6, b_M = 412.4W$ and MiBS power parameter $a_m = 5.5, b_m = 32W$.

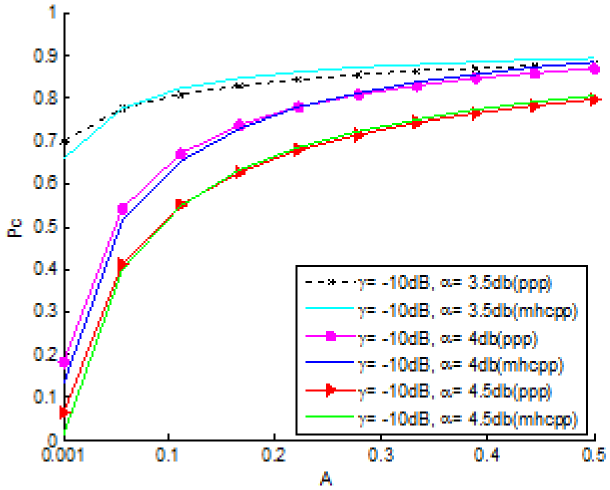

Figure 6: Coverage probability as a function of energy related deployment factor A

The coverage probability increases with the increment in A. After a particular point it will converges to a fixed value. Which shows that further increment in A will not provide any improvement for P_C value. It is a probability value and will not have a value larger than 1. The MHCPP based scheme converges after a small increment in P_C when compared to PPP based scheme. The convergence of P_C value in both schemes is because of the interference affected from other BSs as the BS density and transmission power increment uniformly.

4.2 Energy Consumption

The energy consumption under MHCPP and PPP based schemes can be compared using the following result.

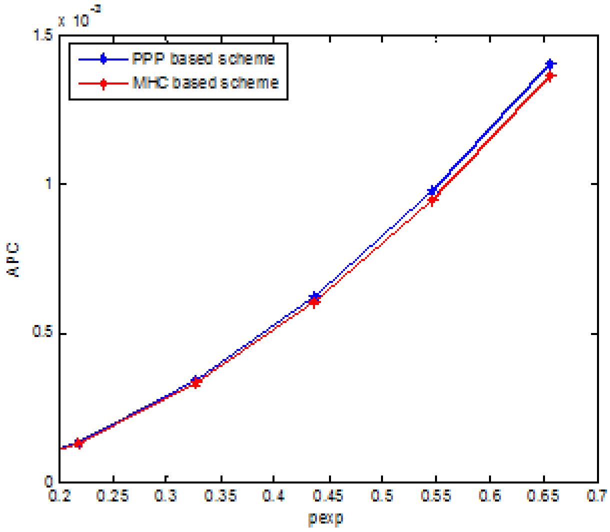

Figure 7: Area power consumption comparison of MHCPP and PPP

APC can be reduced in MHCPP based deployment scheme. To satisfy an expected coverage probability of 0.55, MHCPP require only around 0.87 W/km^2. While for the same expected coverage PPP require 1 W/km^2

6. Conclusion

The impact of stationary processes on network energy consumption minimization work which optimize the deployment parameters with coverage probability constraints is carried out in this paper. The existing method is based on the stationary poisson point process deployment. The analysis of variation of coverage probability P_C provided by a Het Net with respect to outage threshold and an energy related deployment factor is carried out under both MHCPP based and PPP based deployment schemes. From the results, find that the system coverage performance first increases then converges to a fixed value with the increase of energy-related deployment factor $A = \lambda_m P_m^{2/\alpha} + \lambda_M P_M^{2/\alpha}$ under both deployment schemes. For a MHCPP based scheme, the convergence is occurred after a small increment in coverage probability as the deployment parameters increased to obtain maximum coverage. Also while comparing both scheme‟s energy consumption, MHCPP have slight improvement in system energy conservation. Hence the deployment parameters can be optimized more efficiently under MHCPP, which enables a more optimized green deployment strategy.

Compared to PPP based analysis, MHCPP based deployment provides a real deployment strategy. The points derived from PPP are independent to each other. Hence PPPs are practically useless as a model for a spatial point pattern as most spatial point patterns exhibit some degree of interaction among the points. Generalization of the independent PPP analytical framework in to a MHCPP point process maintains a minimum separation between BSs in an attempt to provide a real HetNet.

References

[1] Hauke Andreas Holtkamp, „Enhancing the Energy Efficiency of Radio Base Stations‟, doctoral diss., The University of Edinburgh, UK, November 2013.

[2] Jinlin Peng, Peilin Hong, and Kaiping Xue, “Energy-Aware Cellular Deployment Strategy Under Coverage Performance Constraints", IEEE Transactions on Wireless Communication, vol.14, no. 1, January 2015.

[3] Yong Sheng Soh, Tony Q. S. Quek, MariosKountouris, and Hyundong Shin, “Energy Efficient Heterogeneous Cellular Networks”,IEEE Journal on Selected Areas In Communications, Vol. 31, no. 5, May 2013.

[4] Abdelrahman M. Ibrahim, Tamer ElBatt, Amr ElKeyi, "Coverage Probability Analysis for Wireless Networks Using Repulsive Point Processes",13 Sep,2013.

[5] Juan Wen, Min Sheng,, Xijun Wang, Jiandong Li, and Hongguang Sun,“On the Capacity of Downlink Multi-Hop Heterogeneous Cellular Networks”, IEEE Transactions on Wireless Communications, Vol. 13, no. 8, August 2014.

[6] Martin Haenggi, Radha Krishna Ganti**,** ’Interference in Large Wireless Networks‟; University of Notre Dame, USA, 2008

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