Outage Probability Reduction Using Power Control in Heterogeneous Cellular Networks

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Received: April 12, 2013 Revised: July 3, 2013 Accepted: July 13, 2013

ABSTRACT:
In this paper, we have proposed a distributed power control algorithm to reduce interference and then outage probability in a heterogeneous cellular network based on Poisson point process (PPP) model. For adjusting of power, we have considered *m* tier outage probability in which introduces outage probability for macro user located on origin that femto BSs creates interference for him. Our study has done on network with K-tiers being modeled as independent Poisson point processes. Simulation results confirm mitigation of outage probability using proposed power control algorithm in this model.

KEYWORDS: Poisson point process, heterogeneous networks, outage probability, power control.

1. INTRODUCTION

Increasing wireless users in traditional cellular networks to prepare coverage over large area and service for all users was a fundamental problem for network operators. Hence, 3rd Generation Partnership Project Long Term Evolution-Advanced (3GPP LTE-Advanced) has proposed using of heterogeneous cellular networks as a solution to overcome this problem [1].

Heterogeneous cellular networks is traditional cellular networks concatenated with macrocells that covered by low power nodes (LPNs) such as micro, pico, femtocells, relays, and distributed antennas, which work at same frequency band with macrocells. The elements are different in terms such as transmit power and coverage areas. Low power nodes prepared more coverage in poor coverage areas and fulfill coverage holes in deployment. In addition to these advantages, heterogeneous cellular networks faced by some challenges such as interference, self-organization, backhauling and handover [2].

Interference is unavoidable in heterogeneous networks and mitigates network performance. Growth of interference reduces Signal-to-Interference-Noise Ratio (SINR) in heterogeneous networks. So, ways of reducing interference has studied in literature [2]. For example, [3] has discussed on frequency reuse procedures such as hard frequency reuse, fractional frequency reuse, and soft frequency reuse which reduce interference in the downlink and the uplink. As another way, using power control algorithms have proposed and has discussed about this approach, extensively. In [4], uplink power control scheme has been proposed in case of 2-tiers network consisting of macro and femto co-channel deployment. In the same paper power control algorithm applied such that guarantees mitigation of interference effects. Also, using cell rang expansion (CRE) is another scheme confronting with interference [5]. Femtocells become in network by end-users installation, small coverage areas, low transmit power, and usually have a closed subscriber group (CSG). It has proposed a probabilistic power control scheme based on Poisson point process [6]. The authors computed transmit power for femto BSs and broadcasts its result from macro BS to the femto BSs.

More recently, it expanded a statistical geometry to model heterogeneous cellular networks [7-8]. In this model BSs and users situate in the network according to a Poisson point process (PPP) Φ of intensity λ in two-dimensional space. In [9], outage probability has calculated for this geometry. The authors simulated K-tier heterogeneous cellular network in two cases, when each tier has modeled with independent PPP or an actual LTE network (for tier 1) and $K-1$ independent Poisson point process for another tiers. In [10], it is intended a guard region to study interference effect with using Poisson point process in heterogeneous cellular networks.

In this paper, we consider link outage in a heterogeneous cellular network using Poisson point process. Hence, we use a power control algorithm and calculate outage probability for the obtained power. Simulation results confirm mitigation of outage probability in heterogeneous cellular networks using Poisson point process.

The reminder of this paper is organized as follows. In Section 2 system model and derivation of outage probability are explained. In Section 3, we use power control algorithm in our system and study improvement of outage probability using power which has obtained from power control algorithm. The detailed simulation results and discussion are given in Section 4 and we make our concluding remarks in section 5.

2. SYSTEM MODEL

We consider K-tier heterogeneous cellular network model consist of a tier mobile users and BSs distributed identically independent Poisson point process. It is assumed mobile users in each tier distributed as a Poisson point process Φ_j of density λ_j as well as BSs in *i*-th tier distributed as a Poisson point process Φ_i of density λ_i, and have transmit power P_i and signal-to-interference ratio (SIR) target of τ. We assume user of macro located at the origin. The distance between each BS and its corresponding mobile user is x_i and fading power is i.i.d exponential. In [9], denoted the effect of noise is negligible and outage probability calculated in an interference limited network. We use these results for our simulations.

The SIR expression by ignoring of thermal noise is [9]:

$$SIR_m(x) = \frac{P_m h_m \|x\|^{-\alpha}}{\sum_{i=1}^{N_f} P_i h_{x_i} \|x_i\|^{-\alpha}}, \quad (1)$$

where $SIR_m(x)$ is an interference limited system without considering noise effect. In addition it is assumed path loss exponents are equal for all K tiers. Here, it has considered SIR for macro user and interference has created by femto BSs.

Link outage reported when SIR is lower than target SIR of τ. So, outage probability is cumulative distribution function (CDF) of the effective received SIR, and mathematically m tier outage probability is [11]:

$$O_m = E_x\left[P\left(SIR_m(x) \le \tau\right)\right]$$

$$= E_x\left[P\left(\frac{P_m h_m \|x\|^{-\alpha}}{\sum_{i=1}^{N_f} P_i h_{x_i} \|x_i\|^{-\alpha}} \le \tau\right)\right] \quad (2)$$

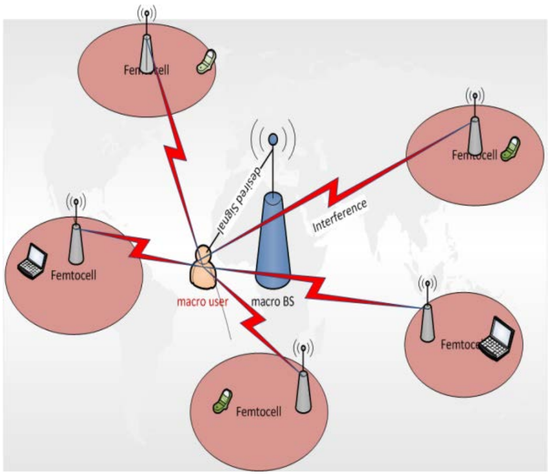

Fig. 1. The deployment of network including one macro user and five femto users. Femto BSs create interference for macro user in downlink.

From theorem 1 in [11], *m* tier outage probability obtained by following above expression.

$$O_m = 1 - 2\pi\lambda_m \int_0^\infty x \exp\left(-\frac{\tau}{SNR} - \pi\sum_{i=1}^{K} C_i x^2\right) dx \quad (3)$$

Here, we assume that thermal noise is ignorable. So, *m* tier outage probability is:

$$O_m = 1 - 2\pi\lambda_m \int_0^\infty x \exp\left(-\pi\sum_{i=1}^{K} C_i x^2\right) dx \quad (4)$$

and,

$$O_m = P_{outage} = 1 - \frac{\lambda_m}{\sum_{i=1}^{K} C_i}, \quad (5)$$

where, $C_i = \lambda_i \hat{P}_i^{2/\alpha}\left[1 + Z(\tau,\alpha,1)\right]$. We denote ${}_2F_1[.]$ as Gauss hypergeometric function and derive an expression for Z (τ, α, 1):

$$Z(\tau,\alpha,1) = \frac{2\tau}{\alpha-2}\,{}_2F_1\left[1,1-\frac{2}{\alpha};2-\frac{2}{\alpha};-\tau\right] \quad (6)$$

So, the tier *m* outage probability is defined by density of BSs, transmit power, and target SIR in each tier.

So we consider a two-tier network including of macro and femto BSs in each cell as macro BSs have higher power than femto BSs. Typical values in [11] are on the order 53 dBm, and 23 dBm, respectively. Thus femto BSs coverage smaller area than macro BSs. With the knowledge of the matter, adding femto BSs to network is created better coverage for deadzones and enhanced performance in network.

For user of macro located in the origin, femto BSs create interference and enhance outage probability. Power control algorithms used in the network helps us reduce outage probability by adjusting the power.

3. PROBLEM STATEMENT

Now, we introduce proposed scheme for improving of outage probability in a two-tier network including of macro and femtocells. First, we follow the proposed algorithm for allocated power, afterward simulate outage probability based on allocated power and compare results in two cases. We expect that outage probability reduces using power control algorithm.

In this Section, we use power control scheme similar to proposed scheme in [12]. Proposed scheme based on mitigation of the *m* tier outage probability. So, we follow conditions that:

Minimization O_m

Subject to P_i, $i = 1,\ldots,K$

Now, we propose following algorithm to allocate optimal power to femto BSs where mitigates interference in (1).

Proposed Algorithm:

$$P_i(t+1) = \min\{O_m P_i(t), P_{\max}\}$$

Fig. 1 illustrates the deployment of network including one macro user and five femto users. Femto BSs creates interference for macro user, which we expect by using of proposed power control algorithm transmit power reduces and so, interference mitigates in network.

In such deployment femto BSs interferer to macro user and macro user receives desired signal from macro BS. So, we expect by using of proposed algorithm interference is mitigate. Here, this algorithm implement in a 2-tier network. Too, this approach is useful in 3-tier network. Simulation results show that using proposed algorithm improve m tier outage probability in 3-tier network better than 2-tier network. In fact, m tier outage probability in 3-tier network without power control is higher than 2-tier network. But using of proposed power control algorithm m tier outage probability in 2-tier network is higher than 3-tier network and improvement of m tier outage probability is more impressive.

We expect using this approach improves conditions and power of femto and macro BSs is lower than initial power. In this case interference is reduced by femto BSs in a 2-tier network. In the end, outage probability lowered compared with the power control isn't performed. So we obtain desired conditions in network.

4. NUMERICAL RESULTS

In this section the results obtain through the simulations are brought. The system parameters considered in the simulations given in the Table 1. Here, channel is modeled by identically independent

Table 1. Considered Value in Simulation.

Parameters	
Shadowing	not modeled
User distribution in cell	Poisson point process
BS distribution in cell	Poisson point process
Channel distribution	Rayleigh fading
path loss exponent (is equal in each tier)	3.8
Power for macro BS	53 dBm
Power for pico BS	33 dBm
Power for femto BS	23 dBm
radius of macro cell	500 m
number of macro BS in site	1
number of pico BS in site	2
number of femto BS in site	20

distributed exponential, i.e. Rayleigh fading where $h_x \sim \exp(1)$. We don't consider details such as shadowing, frequency reuse, and beamforming. We assume typical user as macro user located in origin connects to macro BS. In fact, macro BS prepares strongest signal for him and reminder of BSs in K-1 tier creates interference for macro user. Also, we use an equal path loss exponent for each tier $\alpha = 3.8$ and $P_{macro} = 53$ dBm as initial power macro BS and $P_{pico} = 33$ dBm, $P_{femto} = 23$ dBm as initial power for pico and femto BSs, respectively. The BSs and users in 2-tier and 3-tier deployed according to Poisson point process and we have allowed usage of the equations that obtained from this geometry.

Fig. 2, compares *m* tier outage probability in two cases. It can be seen from this figure that there is an improvement in outage probability when we apply power control algorithm for macro users. Starting from an initial power set for macro and femto BSs and applying proposed power control algorithmmitigates initial power set to a lower power set. So, we obtain conditions that m tier outage probability mitigates in a two tier network including of macro and femtocells. In higher SIRs reduction of power can't mitigate m tier outage probability and seems that target SIR overcomes reduction of power.

Fig. 3, shows that *m* tier outage probability improves using of power control in 3-tier network and in higher SIRs reduction of power can't mitigate m tier outage probability and seems that target SIR overcomes reduction of power. More accurate study illustrate improvement of outage probability in 3-tier is better than 2-tier. As shown in Fig. 2 and Fig. 3, m tier outage

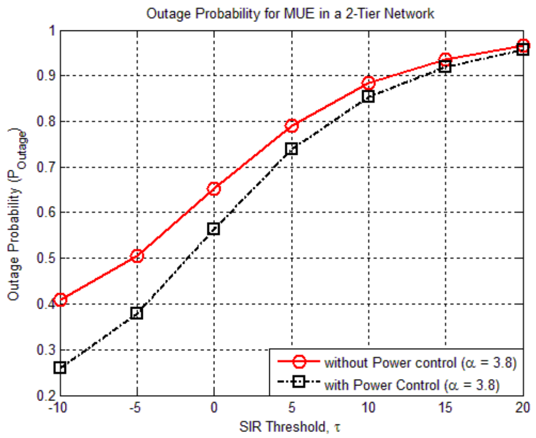

Fig. 2. The *m* tier outage probability in 2-tier network without using of power control algorithm and with power control.

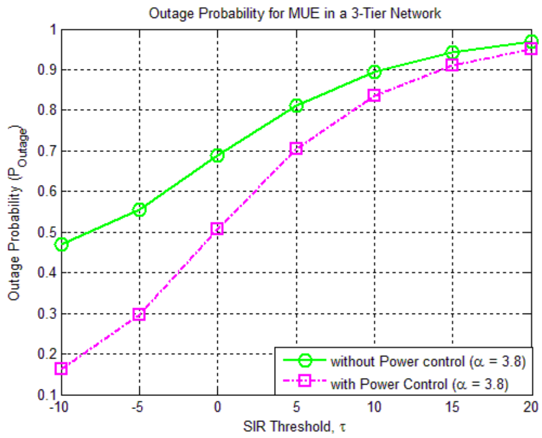

Fig. 3. The *m* tier outage probability in 3-tier network without using of power control algorithm and with power control.

probability in 2-tier network without power control is higher than m tier outage probability in 2-tier network without power control. But using of proposed algorithm in 2 networks improves m tier outage probability. So, using of proposed algorithm in 3-tier network compared with 2-tier is more effective on improvement of m tier outage probability.

5. CONCLUSION

In this paper, we present an algorithm for adjusting of desired power to BSs in downlink. The simulation results show that proposed algorithm prepares power set which mitigates m tier outage probability in a K-tier network. Our studies have been done in a network that BSs and users have distributed based on Poisson point process. The geometry is approximate of actual network model which has been expanded, recently. We expect using of new power control algorithms prepare better results in downlink and uplink. Considering of outage probability for users of reminder of tiers is an important challenge too.

REFERENCES

[1] T. T. Tran, Y. Shin and O. Shin, **"Overview of enabling technologies for 3GPP LTE-advanced,"** *EURASIP J. Wireless Netw. DOI:10.1186/1687-1499-2012-5, Feb. 2012: Springer.*

[2] D. Lopez-Perez, I. Guvenc, G. de la Roche, M. Kountouris, T. Q.S. Quek and J. Zhang, **"Enhanced Inter-cell Interference Coordination Challenges in Heterogeneous Networks, "** *IEEE J. Wireless Commun.,vol. 18, no. 3, Jun. 2011.*

[3] V. Pauli, J. D. Naranjio, and E. Seidel, **"Heterogeneous LTE Networks and Inter-cell Interference Coordination,"** *Nomor Research GmBH 2010.*

[4] J. Gora, K. I. Pedersen, A. Szufarska and S. Strzyz, **"Cell-Specific Uplink Power Control for Heterogeneous Networks in LTE, "** *IEEE VTC-Fall, Ottawa, Sept. 2010.*

[5] J. Liu, D. Wang, J. Wang, J. Li, J. Pang, G. Shen, Q. Jiang, H. Sun and Y. Meng, **"Uplink Power Control and Interference Coordination for Heterogeneous Network, "** *IEEE PIRMC, Sydney, Sept. 2012.*

[6] R. Bendlin, Y. F. Huang and J. A. Nossek, **"Probabilistic Power Control for Heterogeneous Cellular Networks with Closed-Access Femtocells,"** *IEEE 2011 Conference Record of the Forthy Fifth Asilomar Conference on (ASILOMAR), Pacific Grov., Nov. 2011.*

[7] J. G. Andrews, F. Baccelli and R. K. Ganti, **"A Tractable Approach to Coverage and Rate in Cellular Networks, "** IEEE. Trans. Commun., vol. 59, no. 11, Nov. 2011.

[8] J. G. Andrews, P. Xia, H. S. Jo, H. S. Dhillon and T. D. Novlan, **"Heterogeneous Cellular Networks: From Theory to Practice,"** *IEEE Commun. Mag., vol. 50, no. 6, 2012.*

[9] H. S. Dhillon, R. K. Ganti, F. Baccelli and J. G. Andrews, **"Modeling and Analysis of *K*-Tier Downlink Heterogeneous Cellular Networks, "** *IEEE J. Sel. Areas Commun., vol. 30, no. 3, Apr. 2012.*

[10] R. W. Heath Jr. and M. Kountouris, **"Modeling Heterogeneous Network Interference with Using Poisson Point Processes, "** *IEEE Trans., vol. PP,no. 99, 2013.*

[11] H. S. Jo, Y. J. Sang, P. Xia and J. G. Andrews, **"Outage Probability for Heterogeneous Cellular Networks with Biased Cell Association, "** *Global Telecommunications Conference (GLOBECOM 2011), 2011 IEEE , pp.1,5, 5-9 Dec. 2011.*

[12] Ch. W. Tan, **"Optimal Power Control in Rayleigh-fading Heterogeneous Networks,"** *in Proc. IEEE Int. Conf. Comput. Commun., Shanghai, China, 2011, pp. 2552–2560.*