Network and Complex Systems
ISSN 2224-610X (Paper) ISSN 2225-0603 (Online)
Vol.5, No.6, 2015

www.iiste.org

Femtocell Congestion Mitigation Technique using Poisson Point Process

Ajaegbu C Omotosho O.J Awodele O Ogbonna A.C
School of Computing and Engineering Sciences, Department of Computer Science, Babock University,
Ilisan, Remo, Ogun state, Nigeria.

Abstract

The idea of femtocell technology came in order to boost the signal strength of indoor Universal Mobile Telecommunication System (UMTS) users. The number of subscribers a femtocell device can accommodate is closed from the manufactures' end in order to check the capacity limit. The challenge with this form of technology is that only registered subscribers are permitted to gain access. This study seeks to enable flexibility in the control of its capacity limit by employing Poisson Point Process as a congestion control tool. The outcome of the study showed that the spatial Poisson Point Process can effectively be used to control the capacity limit of femtocell device, using co-channel interference technique. This will enable the device to operate as an open system while controlling the capacity limit.

Keywords: Femtocell, Poisson Point Process, Cellular Network, Home NodeB

1. Introduction

Studies have shown that most phone calls are made indoor and that the signal of UMTS gets weak for indoor users. The idea of a Home NodeB (femtocell) device came as a result to boost UMTS signals for indoor users.

Femtocell standardization saw its light by May 2008 when one of the existing 3G interface between Node B and the Core network was fully adapted and employed as the interface between femtocell and the core network. Despites the good deeds of Femtocell as Home Node B, gaps such as radio interference mitigation and management, Regulatory aspects and location detection (knisely, yoshizawa and favichia, 2009) have been observed by scholars. Among all these, the need for a femtocell to be able to intelligently handle congestion without any form of complexity is the aim of this study. This will help to eliminate the challenge of closing femtocell devices from the design level. Hence, another aspect of poisson point process mechanism is exploited in this article.

A point process can be described as a random variable whose actualizations are group of points probably enclosed within a location. Adrain (n.d) asserted that a spatial point process is a random process in d-dimensions. The d-dimensions could be in various forms where "d" could be either two or three in applications. One good example of a point process is the spatial passion point process distribution.

The poisson point process as an aspect of stochastic geometry, plays a vital role in real life application as a tool or building blocks for more complicated random set models (e.g Boolean model), and as simple examples for random sets (Adrian, n.d).

However, some works have been carried out in the past using this technique to model out randomized points in real life scenario. This study will look at some of the related works in the field of networking and cellular communication and will also incorporate related literature in the area of small cell backhaul connection.

2. Related works

Studies have shown that the effectiveness of wireless transmission lies on the distance between a transmitter and a receiver. In order to manage this effect, researchers came up with a link-budget analysis anchored by fading margins.

Andrews, Ganti, Haenggi, Jindal and Weber (2010) opined that such analysis is best for a point-to-point wireless links and tends to offer a bad analysis when networks are involved; and that is due to the high occurrence of interference.

The researchers also argued that most simplified models for interference that have been developed in lieu of paying attention to traceability did not contribute positively trying to manage interference by capturing the true nature of wireless propagation.

Managing interference in wireless transmission is a challenging task in space whereas; it can be less tedious to manage in time and frequency.

In any wireless transmission design, spatial configuration follows a sort of imagined possibilities. This is because for an efficient spatial configuration in any wireless system/device, the statistical spatial model of device/node location should be a necessity.

Andrew et al (2010) also noted that the importance of evolving techniques in the wireless world such as wireless network coding and interference alignment follows or adhere to the transmitters and receivers location respectively thus making an accurate evaluation possible with accurate probabilistic modelling of the positions.

Studies in the area of wireless networking have shown that mathematical tool such as stochastic geometry, has offered strong tool in wireless network research. This mathematical tool has also been extended in other forms of wireless paradigm like the random distribution of transmitter and receivers in space.

This new informed paradigm in the study of spatial random distribution of nodes for instant mobile devices has to address some of the challenges that were foreseen as not achievable. Some of them are: the distribution of millions of small cell technology like femtocell in such that it will not disrupt the well planned structure of cellular network; the use of cognitive radios in free space so that it does not conflict with the performance of an existing user distributed in space with unknown location.

Andrew et al (2010) demonstrated the power of spatial models and the use of analytical techniques in the design of wireless networks and also to give an insight on the use of this technique in wireless planning. Thus their specific objectives were: to support the fact that such tool can be used to understand fundamental network qualities such as connectivity, coverage and capacity, to give a guide on how these tools can be applied for modelling and analysis and to identify future research areas where these tools may also serve.

The researchers adopted an analytic technique where spatial point process modelling of nodes, was used to investigate or measure the three (3) major wireless network metrics of connectivity, capacity/throughput and reliability.

Andrew et al, (2010) also opined that the connectivity of a random network is measured by the probability that arbitrary pair of nodes is able to exchange information at a specified rate. Their study showed that spatial models offered good statistical representation of wireless networks like ad hoc networks, cognitive radio and white space and femtocell deployments since each transmitter paired with a receiver (in these 3 cases) occurs in a random direction at a known distance.

Bettstetter and Hartmann (2005) described a multihop network as one without a base station. Each of the mobile devices acts like a node and mobile terminal while communication with each other is a peer-to-peer process.

The researchers argued that most models that have been employed in the study of connectivity related properties appears simple in the sense that the channel effect is been considered only when two nodes are not further apart from a certain threshold distance. Thus, there is need for a purely geometric model that will yield result in as much as deterministic distance-dependent channel models are considered. The main objective of their study was to looked at the network connectivity with respect to shadow fading. Thus, the specific objectives were: to model out nodes in a randomized manner and to examine connectivity from the local viewpoint of node. Their study employed the use of homogenous Poisson Point Process to model out spatial node distribution. Their method defined two major properties:The number of nodes N in each finite subarea and the number of nodes N_i in disjoint (non-overlapping) areas labelled A_i.

Their study showed that both the area size and fading variance have significant impact on connectivity. Where the qualitative influence of A is straight forward, the impact of fading variance requires deeper investigation.

Andrew, Baccelli, Francois and Ganti (2011), opined that the cultural way of modeling cellular base station in a grid form, offers the same accuracy when modelling with stochastic geometry. The researchers went further to argue that Other-Cell- Interference (OCI) is one of the challenges being faced by cellular network. in spite of research interest and effort in this area, no tracetable model have been able to offer solution to this problem. Thus, an accurate and tractable model is needed in order to combat this challenge. The main objective of their study was to develop a downlink capacity and coverage tractable model putting into consideration full network interference. Thus, their specific objectives were: to review some of the common approaches and their limitations and to model out base stations using poisson point process. The researchers employed the homogenous poisson point process technique, where the positions of base stations were randomized instead of the normal placement of base stations in a grid pattern. Their study presented a framework for the downlink cellular and network analysis that is more tractable than the traditional grid-based models.

Empirical underpinnings have suggested that six to eight neighbours can increase the probability rate of connection in a small network. However, (Xue and Kumar , 2004) opined that as the number of nodes increases in a wireless network, the network becomes disconnected with probability one (1) whether one connects to six or eight neighbours. Their main objective was to address the issue of the number of nodes that should be connected simultaneously and still ensured a certain level of efficiency in wireless network. Their study in cooperated the Poisson Point Process technique alongside with other mathematical formulations in order to measure the degree of connectivity among the nodes. Their study showed that asymptotic connectivity results when every node is connected to its $5.1774\log_n$ neighbours while asymptotic disconnection occurs when node is connected to less than $0.074\log_n$ nearest neighbours.

Wan and Yi (2006) argued that the assumption of poisson point processes on a square using toroidal metric possess some challenges in wireless sensor network application. Thus suggesting the use of Euclidean metric to be more relevant in application and this is because, Euclidean metric takes care of boundary effect. Their main objective was to study the probability that a covered area by randomly deployed sensors changes with the sensing radius or the number of sensors. Their study employed an analytical method by assuming the deployment of wireless sensor using poisson point process or a uniform point process. The study showed that, for k >= 1, gthe boundary effects completely dominates the probability of (k + 1)- coverage, while for k =0 the boundary effect still; affects the probability of (k + 1) coverage. Where k = wireless sensor network.

From the review, it showed that Poisson Point Process has shown positive result in practical demonstration of randomized points. However, the application of Poisson Point Process in networking and cellular communication has not been used to show the saturated point of small cell devices (i.e the number of mobile devices allowable to establish connection through the small cell).

The aim of this study is to model a real life scenario of random mobile devices and also to illustrate how the capacity limit of the proposed femtocell device can be determined using uniform spatial poisson point process.

3. Model

Let X be the random variable distributed in a particular Region R, it means that X ϵ R. also let (x_1^T, x_2^T x_3^T…… x_i^T) ϵ X, then $x_i^T \subseteq X$.
Let x_i^T = number of random mobile devices that get access through Femtocell in a peak hour within an Area A. This implies that x_i^T ϵ A and A ϵ R.

3.1 Assumptions

- Every peak hour is like any other peak hour meaning the number of mobile device that get access through a femtocell device in a particular peak hour is same for another peak hour.
- The number of calls sent or received through the femtocell device in an hour does not affect the next number of calls sent or received through the femtocell device in another hour.

In essence, to estimate the average calls through the femtocell device in a peak hour in other words the Expexted value (E).

$E(x_i^T) = \lambda$, where λ = number of calls placed or received through a femtocell per peak hour while $\lambda = n.p$

Where, n indicates whether a call is sent or received through the femtocell in a given second (assuming 1sec to be the smallest time interval between one call and another).
p indicates the success probability of calls measured as $p = \lambda/n$.
the probability that the random variable x^T equals some given value μ (where μ = success value from the random variable x^T) is given as:

$$P(x^T = \mu) = \binom{3600}{\mu} \left(\frac{\lambda}{3600}\right)^{\mu} \left(1 - \frac{\lambda}{3600}\right)^{3600-\mu}$$

From mathematical prove, taking the limit of n that is n = ∞ results to Poisson Point Process (PPP) distribution. This could be illustrated using the parameters in the study as

$$\frac{\lambda\,\hat{}\,\mu}{\mu!} e^{-\lambda}$$

Assuming, the proposing Femtocell congestion technique has been designed to accept 10 users within its range of operation, it then implies that λ which is the $E(x^T) = 10$.
In order to prove the saturated point of the device by estimating the probabilities that, using the following values 2,3,4,5,6,7,8,9,10 and 11 mobile devices is being served concurrently by the femtocell.
Table 1 shows the corresponding probability of success for the above values.

The table values are generated by making the following substitutions (using μ = 2 as an illustration) gives:
When μ = 1

$$P(x^T = 2) = \frac{10\hat{}2}{2!} e^{-10} = 0.00227$$

Other table values are generated using the same method and is shown as:

µ	P
1	0.000454
2	0.00227
3	0.0076
4	0.0189
5	0.0378
6	0.0631
7	0.0901
8	0.1126
9	0.1251
10	0.1251
11	0.1137

Table 1: Success values with its corresponding success probability of coverage by femtocell

4. Result

The above experimental data shows that, the mobile devices were maintaining a uniform random distribution process till when µ was 10. This showed that mobile device 9 and 10 are been affected by edge effect (see figure 1) and this showed that any other mobile device coming in within this area of coverage, is going to affect the quality of service of one of the mobile devices already served by the femtocell (see fig 2).

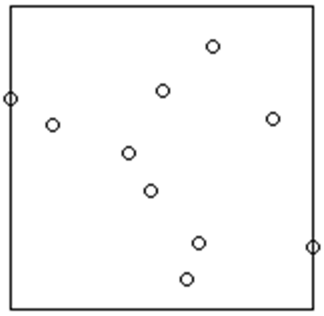

Figure 1: simulation of the point process for the maximum in-take of the femtocell

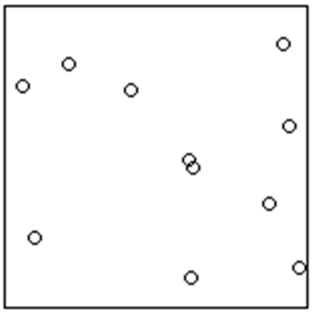

Figure 2: Effect when there is an eleventh active mobile device within the coverage area of the femtocell

In other words, devices 1 to 8 will receive good signal strength from the femtocell device, as will be experienced when close to the macrocell.

5. Conclusion

In conclusion, the result of the study proved that the existing femtocell device can be made flexible in the control of capacity by using the Possion Point Process (PPP). Besides, the use of PPP technique in the femtocell system, it can also serve as a good congestion control tool in wireless communication. The idea of using PPP as a congestion control mechanism for femtocell devices, takes the form of co-channel interference. This will help in order to open up the femtocell capacity other than closing it up from the design level.

ACKNOWLEDGEMENT

My sincere gratitude goes to the Association of African Universities (AAU) for awarding me the research grant that aided the further acquisition of knowledge and the completion of this project. Your assistance was immeasurable.

References

Adrian B and Rolf T (n.d). Getting started with spatstat. Retrieved from http://cran.r-project.org/web/packages/spatstat/vignettes/getstart.pdf

Andrews, J. G., Ganti, R. K., Haenggi, M., Jindal, N., & Weber, S. (2010). A primer on spatial modeling and analysis in wireless networks. *Communications Magazine, IEEE*, *48*(11), 156-163.

Andrews, J. G., Baccelli, F., & Ganti, R. K. (2011). A tractable approach to coverage and rate in cellular networks. *Communications, IEEE Transactions*, *59*(11), 3122-3134.

Bettstetter, C., & Hartmann, C. (2005). Connectivity of wireless multihop networks in a shadow fading environment. *Wireless Networks*, *11*(5), 571-579.

Knisely, D.N, Yoshizawa, T, Favichia F, (2009). Standardization of Femtocells in 3GPP. IEEE Communication Magazines. 47(9), 68-75.

Wan, P. J., & Yi, C. W. (2006). Coverage by randomly deployed wireless sensor networks. *IEEE/ACM Transactions on Networking (TON)*, *14*(SI), 2658-2669.

Xue, F., & Kumar, P. R. (2004). The number of neighbors needed for connectivity of wireless networks. *Wireless networks*, *10*(2), 169-181.