THEORETICAL ANALYSIS FOR PERFORMANCES OF BROADBAND CELLULAR SYSTEMS

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ABSTRACT

This thesis presents theoretical analysis on digital signal transmissions over cellular communication system. Our work can be divided into 3 parts. The first part is on the signal analysis of modern cellular environment in which femto-cell technology is employed. Based on the spectrum deployment technique, multiple femto cells share the identical frequency in the same coverage area. With the guaranteed signal quality, we introduce a new mathematical model to evaluate the maximum number of femto cells that can be accommodated in the same coverage area. On arbitrary system parameters and channel conditions, the proposed model gives the maximum number of femto cells. The second and the third part are on the in-depth analysis of probability of bit error and spectral efficiency on Rayleigh and Nakagami fading environments. Due to the difficulty of random variable computation, most of the previous work use computer simulation to evaluate those parameters which is time consumption. Instead of applying simulation, we propose new mathematic models for probability of bit error and spectral efficiency. This benefits us finding exact values of both parameters under various system parameters and channel conditions.

KEY WORDS: FEMTOCELL/ PROBABILITY OF BIT ERROR RATE/
CHANNEL CAPACITY

64 pages

การวิเคราะห์เชิงทฤษฎีสำหรับสมรรถนะของระบบสื่อสารบรอดแบนด์เซลลูลาร์

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บทคัดย่อ

งานวิจัยนี้นำเสนอการวิเคราะห์เชิงทฤษฎีการส่งสัญญาณดิจิตอลบนระบบสื่อสารเซลลูลาร์ งานของเราสามารถแบ่งได้เป็น 3 ส่วน ส่วนแรกเป็นการวิเคราะห์สัญญาณของสิ่งแวดล้อมเซลลูลาร์รุ่นใหม่ที่มีการใช้เฟมโตเซลล์ บนพื้นฐานของเทคนิคการใช้สเปกตรัมเดียวกัน เฟมโตเซลล์หลายเซลล์จะใช้ความถี่ร่วมกันบนพื้นที่เดียวกัน ด้วยการประกันคุณภาพของสัญญาณ เรานำเสนอโมเดลคณิศาสตร์ในการหาจำนวนเฟมโตเซลล์สูงสุดที่สามารถรองรับได้ในพื้นที่เดียวกัน โดยสามารถเซตค่าพารามิเตอร์ระบบและสภาวะช่องสัญญาณได้ตามต้องการ สำหรับในส่วนที่ 2 และ 3 จะเป็นการวิเคาะห์เชิงลึกของค่าความน่าจะเป็นและค่าประสิทธิภาพสเปกตรัมบนสิ่งแวดล้อมเรย์เลห์และนากากามิ แต่เนื่องจากความยากในการคำนวณตัวแปรสุ่ม งานในอดีตส่วนใหญ่จะใช้คอมพิวเตอร์ซิมมูเลชันในการหาค่า ซึ่งเสียเวลามาก แต่ในงานของเราจะนำเสนอโมเดลในการคำนวณหาค่าความน่าจะเป็นและค่าประสิทธิภาพ ซึ่งเป็นประโยชน์ในการหาค่าที่แน่นอนบนค่าพารามิเตอร์ระบบและสภาวะช่องสัญญาณต่าง ๆ

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LIST OF ABBREVIATIONS

Symbols	Definition
β	Blockage level parameter. If β is high, blockage level will be high as well
B	bandwidth of interference signal from environment
C	Channel capacity
h_0	channel gain of signal from macro cell
h_1	channel gain of signal from femto cell i
d_0	distance between interrupting femto cell and macro user
d_i	distance between interrupting femto cell to femto cell
S_0	of signal from macro cell
S_i	transmitted power of signal from femto cell i
N_0	power density of interference signal from environment
η	interference signal
m	Nakagami fading index
γ	allowance SINR
Q_C	probability which SINR is less than allowance SINR
P_e	Probability of bit error rate

LIST OF ABBREVIATIONS (cont.)

Symbols	**Definition**
N_{max}	maximum number of femto cells
$Poutage$	outage probability
$\lvert h(t) \rvert^2$	channel gain random variable
$\phi(t)$	assigned as phase channel
$\mathrm{E}[e^{-\gamma h_i \Gamma_i}]$	average value
Γ_{avg}	average path loss power
$erfc$	error rate and efficiency

CHAPTER I
INTRODUCTION

Wireless communication has been developed from radio in 1947, cellular network is registered a patent and has been employed for 40 year, and then it has been improved rapidly and continuously. Obviously there are several researches at the moment; developing receivers, transmitters, and user equipment which subscribers have various options for employing. Wireless communication consists of major factors as:

- Data: data or information can be transmitted by changing radio and television signals to be voices and pictures; moreover, information from computer will be sent with radio wave that is one part of spectrum or radio frequency. All information can be conveyed by using radio frequency.
- Modulation: information is mired up with radio frequency by modulation procedure sand then it is sent. When receives obtain those signals, they use demodulation procedure to divide and take wanted information.
- Base Station: in each cell, there is a base station which transmit and receive signal user equipment.
- Cells: cellular mobile has an idea from cells which divide a whole area to small portions so information is transmitted and received in only a target cell.
- Transmitter and Receivers: radio frequency combined with information is conveyed and received by transmitters and receivers in order.

In this thesis, we employ mathematics to analyses signals in modern cellular network. (see more details in next section)

1.1 Background Problem statements

Subscribers need more demands continuously in wireless communication era, therefore, capacity and coverage are significant factor in wireless system. Macro cells service a large area, and then we use femto cells service a large area, and then we use femto cells in the area to improve capacity for subscribers. Femto cell uses the same channel with macro cell, this causes interferences which is a main problem to maintain quality of service. This idea comes from reduction of cell size to reuse frequencies. Femto cell is sub-station to transmit and located in buildings or target areas.

Advantage of femto cells is collaboration with WCDMA, 3G, 4G, OFDM, WiMax and LTE, and femto cells is the idea of decreasing call size to reuse more frequencies. Accordingly, femto cells are employees to enhance capacity in same areas. Femto cells are sub-station that transmit signal range. And use low power, α-channel deployment is the only trouble for femto cells.

In this thesis, we analyze and propose method that precisely calculates performances of transmission in cellular network; furthermore, we also analyze and propose a closed from of probability bit error rate and spectral efficiency (C) in Rayleigh and Nakagami environments on cellular system.

1.2 Research Objective

- To study and analyze physical cellular communication in term of mathematics.
- To design mathematics model for calculating the number of femto cells while concerning the quality of signals.
- To analyze and propose mathematics models for computation performances of signals in cellular network via parameters in physical layer.

1.3 Scope of work

- Proposed the equation to maximize the number of femto cells in macro cell while concerning the quality of signals via outage probability indicating SINR (signal to Interference plus noise radio)
- The closed from of spectral efficiency is analyzed and proposed on Rayleigh and Nakagami environment in cellular network
- The expression from of probability bit error is analyzed and proposed on Rayleigh and Nakagami channel model I cellular network.

The scenario of this thesis can be explained as follows; we focus the signal analysis on both downlink and uplink cellular communications via system performance indices. In chapter 3, the downlink is considered and the probability outage is chosen as the key parameter. In chapter 4 and 5, the uplink is concerned while the probability of error rate and channel capacity are regarded.

1.4 Action Plan

No.	Activities	2014						2015						2016				
		Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec	Jan	Feb	Mar	Apr	May
1.	Study cellular networks	✓	✓															
2.	Study modern cellular system: femto cells			✓	✓													
3.	Proposing a new strategy to maximize the number of femto cells with QoS gurantee					✓	✓											
4.	Simulate and conclude the results							✓	✓									
5.	Study spectral efficiency and probability of bit error in cellular systems									✓	✓							

No.	Activities	2014						2015						2016				
		Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec	Jan	Feb	Mar	Apr	May
6.	Analyze and propose close forms for spectral efficiency and probability of bit error in cellular systems in various channel conditions										✓	✓	✓					
7.	Simulate and conclude the results													✓	✓	✓		
8.	Write the manuscript																✓	✓

1.5 Major contributions

- A new optimal model for evaluation of maximum number of femto cells deployed on the same coverage area.
- An original accurate mathematical expression for probability of bit error on signal transmissions in Rayleigh and Nakagami fading
- A precise mathematical expression for spectral efficiency in Rayleigh and Nakagami fading.

1.6 Thesis outline

- There are 6 chapters in this thesis and each chapter has defaults as following:
- In chapter 2, we describe and theory which are used for analysis performances of wireless communication: including involved literatures.
- We study and analyze femto cells system in chapter 3 and employ optimization method to maximize the number of femto cells while it is still under quality constraint via outage probability.
- We calculate probability of bit error rate (P_e) in Rayleigh and Nakagami environment on femto cell in chapter 4. Probability of bit error rate is computed by SINR in both of environment and we plot graphs to compare probability of bit error rate with other parameters.
- In chapter 5, we proposed method to calculate channel capacity from SINR in Rayleigh and Nakagami fading cell system and demonstrate the relation between channel capacity and other parameters by graphs.
- In chapter 6, we summize a whole these is and mention future work in broadband wireless communication

CHAPTER II
LITERATURE REVIEW

2.1 Femto cell

In digital era, communication is extremely useful and significant I as a result transmit and receivers want to convey tremendous information and send as fast as they can. Therefore equipment, and others technologies have been developed to support demands of subscribers continuously and be the state of the-art. Capacity is an important factor in wireless communication to be enough and coverage has to cover all service areas. Femto cell technology is used since it is efficient, cheap, supporting more subscribes and covering all areas. The idea of femto cell comes from reduction cell size and spectrum can be numerously reused and is sufficient to service all users. Femto cell is sub-station for transmission which is located in buildings or some areas where need do enhance signal; moreover, transmitting of femto cell employ low power due to short distance. As a result, battery is longer life.

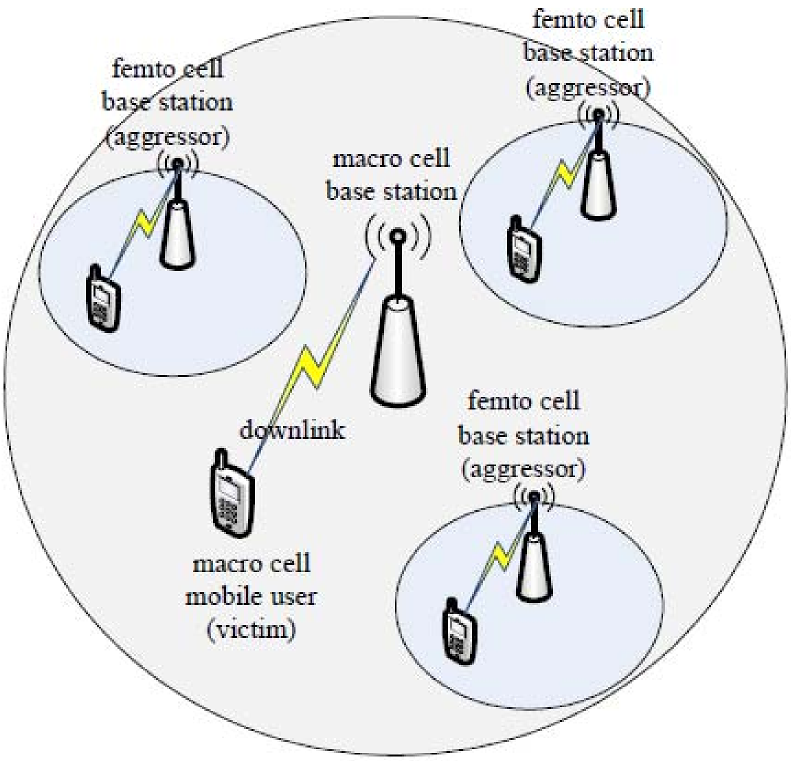

Figure 2.1 Co-channel deployment on femto Cells

Femto cell, being small and using low power, is designed for employment in hoses, small offices or in building, and then femto cell is connected to service network via broadband or cable wire. So femto cell can improve capacity and cover all areas for all subscribers

Femto cell makes mobile phone employment to across from wire telephone network to fixed line network and acts as access point, Normally, Fixed line network is more efficient and faster than wireless network ; and then, femto cell can improve coverage in indoor areas. Moreover its figure likes router wireless, and it use frequencies of 2G 3G or 4G network. So we can use our mobile phone to communicate through femto cell and broadband network when, we stay at home, and we still connect to base station and public mobile network as usual if we stay, outside.

Femto cell technology can cover the smallest areas, this idea comes from wanting to cover areas being small cell. Normally, to use station cover area from half past to many kilometers but femto cell cover a few square meter in building or small firms. Femto is appropriate to be home office while it has an equipment being like access point of WiFi to connect to telephone or modem cable. Finally, femto cell transmit signal like normal base station but it use low power.

Some applications, namely sending messages and surfing the internet via mobile phone or high wireless broadband (HSPA), are communicated by the same way with WiFi. However mobile phone does not need to support wifi but has normal function.

Femto cell is not only the way that mobile phan can access the internet but also access fixed line network such as backup downloaded songs on mobile phone or computer, steam VDO from VDO player to smartphone and present some pictures from mobile phone to television.

However there are various point to consider; for example, inferences from adding femto cell may influence on efficiency of network; specially, 3G uses CDMA technology. Macro cell and femto cell use the same frequency so signal from mobile phone which we want to send to macro cell can became to interfere with femto cell:

2.2 Co channel Deployment

From Figure2.1, big circle is macro cell area which has base-station to convey downlink signal to mobile phone; and there are femto cells in small circles that is sub-station for downlink transmission. Signal of femto cell is co-channel deployment. We call interfered used as victim and call interfering femto cell as “aggressor”

Co- channel deployment is using the same channel, frequency, path, tome and code. From femto cell case, case, femto is in macro cell and co-channel deployment of femto can happen due to using same frequency for transmission. So there are 2 type of interferences for transmission: interference from all femto cells and background which cause less quality of service or loss of communication. To sum up, we have to define allowance signal to onte-plus (SINR) for using femto cell technology on macro cell network efficiently. If quality is more that limitation the system can operate successfully (see more details in section 2.4)

In the next section, we consider channel because transmission in wireless communication has several patterns and operation. Accordingly, we propose various channel to compare and analyze.

2.3 Analysis channel in wireless communication

There are 2 channel models in wireless communication, namely transmitters and receivers are not the same channel and they are in the same channel.

2.3.1 Rayleigh Fading

Rayleigh fading is non line of sight: transmitter and receiver are not necessary to be the same channel. For example, transmission mobile, base station (transmitter) is not need to be the same path with users and receive the signals in area which bases station services.

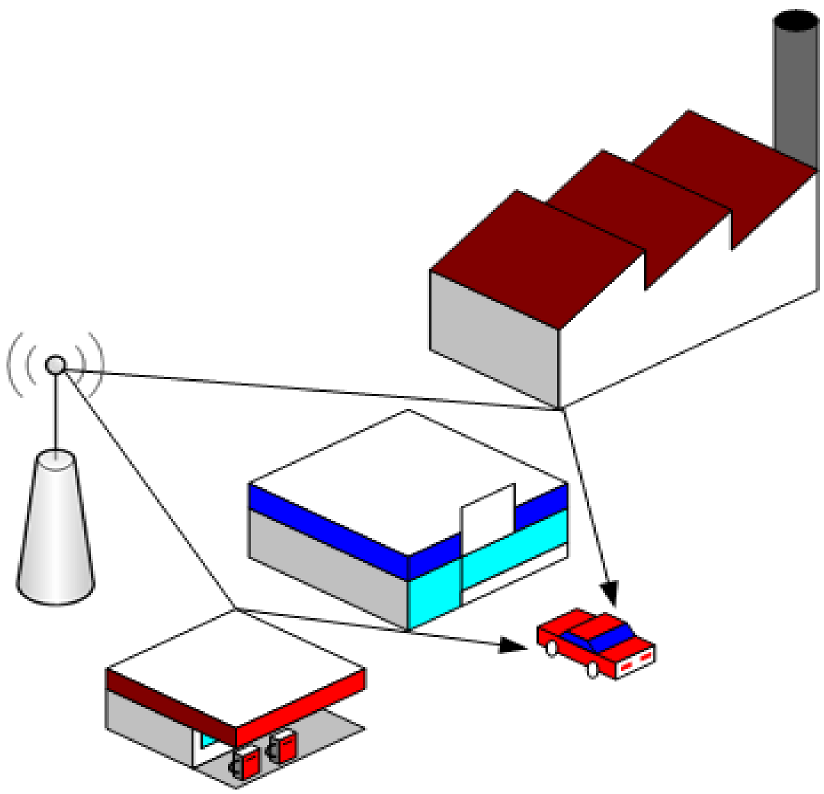

Figure 2.2 Transmission in Rayleigh

From basis of electrical engineering, power of signal equal to the square of voltage of signal; thus we use this concept with Rayleigh fading

In Rayleigh channel, signals are distributed as

$$P_y = \frac{1}{2\sigma^2} e^{-y/2\sigma^2}, y \geq 0 \tag{2.1}$$

From the equation 2.1, power of signal is independent so we use it so calculate SINR which is distribution of voltage sampling signal in Rayleigh distribution. Normally power of signal is the square of voltage; therefore, Rayleigh distribution can be written as following;

$$P_R(r) = \frac{r}{\sigma^2} e^{-r^2/2\sigma^2}, r \geq 0 \tag{2.2}$$

Due to consider, $F(X,\lambda) = \lambda e^{-\lambda x}; x \geq 0$ is negative exponential function.

2.3.2 Rician Fadding

Rician fading is line of sight between transmitter and receiver that means transmitter and receiver are the same way without any obstacles; namely remote and television, or air condition. When we want to transmit signal we have to being remote to be in the same cannel with television or air condition so we can communicate. From fig 2.3, there are various ways for transmission; directs, indirect and reflection way, therefore, calculation will be very complicated method.

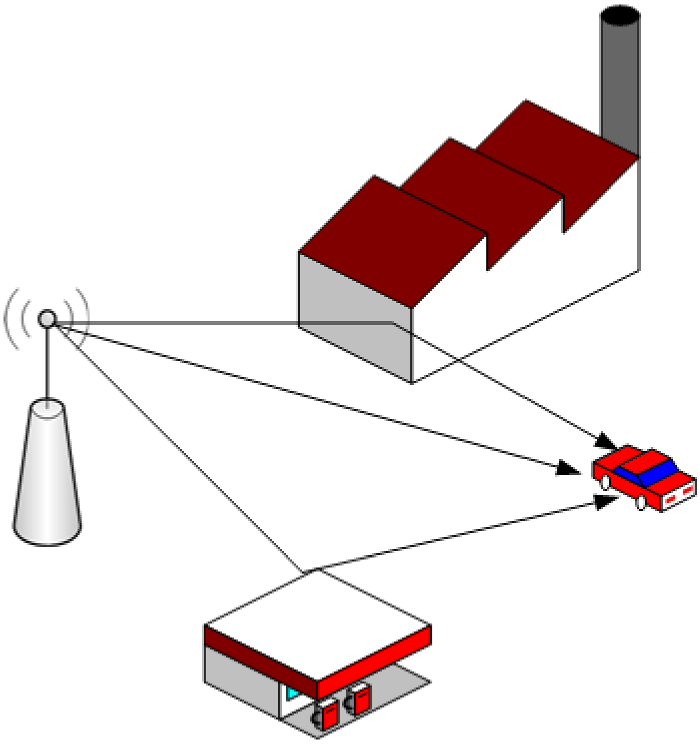

Figure 2.3 Transmission in Rician

Rician channel model; has equation as $F(X,m)=\frac{x^{m-1}}{(m-1)!}.m^m.e^{-mx};x\geq 0$ which distributed equation is in term of gramma.

Signal in Rician fading can be written as

$$P_Y(y)=\frac{1}{2\sigma^2}e^{-(s^2+y)/2\sigma^2}I_0(\sqrt{y}\frac{s}{\sigma^2}),y\geq 0 \quad (2.3)$$

We consider power of signal and use it to compute SINR under Rician environment. Normally, power of signal can be presented as power being the square of voltage. Therefore, power of Rician can be defined as

$$P_R(r)=\frac{r}{\sigma^2}e^{-(r^2+s)/2\sigma^2}I_0(\frac{rs}{\sigma^2}),r\geq 0 \quad (2.4)$$

2.3.3 Nakagami Model

Nakagami model represents an equation which combines both Rayleigh and Rician equation:

$$P_R(r)=\frac{2}{\Gamma(m)}\left(\frac{m}{\Omega}\right)^m r^{2m-1}e^{-mr^2/\Omega} \quad (2.5)$$

Where *m* is blockage level. If *m* is low, blockage level will be high; on the other hand, blockage level is small when m is high. Furthermore, if m equation will be reduce from to be Rayleigh distributed equation, and the equation is Rician term we can prove that *m* = 1 is put into equation (2.5);

$$P_R(r) = \frac{2}{(1-1)!}\left(\frac{1}{\Omega}\right)^1 r^{2-1} e^{-r^2/\Omega}$$

$$P_R(r) = \frac{2r}{\Omega} e^{-r^2/\Omega}$$

$$\Omega = E(R^2) = E(Y) = 2X^2 = 2\sigma^2$$

$$P_R(r) = \frac{r}{\sigma^2} e^{-r^2/\sigma^2}$$ This is from of Rayleigh fading.

2.4 Parameter for evaluation the quality of signals

2.4.1 SINR

From figure 4, transmission from macro cell to user equation with inferences from femto cell is shown therefore, we can find equation of signal at UE from signal-to- (SINR) SINR is the ratio between wanted power and total interferences and it is employed to measure the quality of signal. It SINR is high, power is also high and the system is good state.

$$SINR = \frac{h_0 S_0 d_0^{-\beta}}{\sum_{i=1}^{N} h_i S_i d_i^{-\beta} + \eta} \tag{2.6}$$

h_0 ; channel gain of signal from macro cell

h_1 ; channel gain of signal from femto cell i

d_i ; distance between interrupting femto cell and macro user

S_0 : of signal from macro cell

S_i ; transmitted power of signal from femto cell i

β ; blockage level parameter. If β is high, blockage level is high as well

N_0 ; power density of interference signal from environment

B ; bandwidlh of interference signal from environment

Power of interference signal (η) $\eta = \frac{N_0 B}{2}$

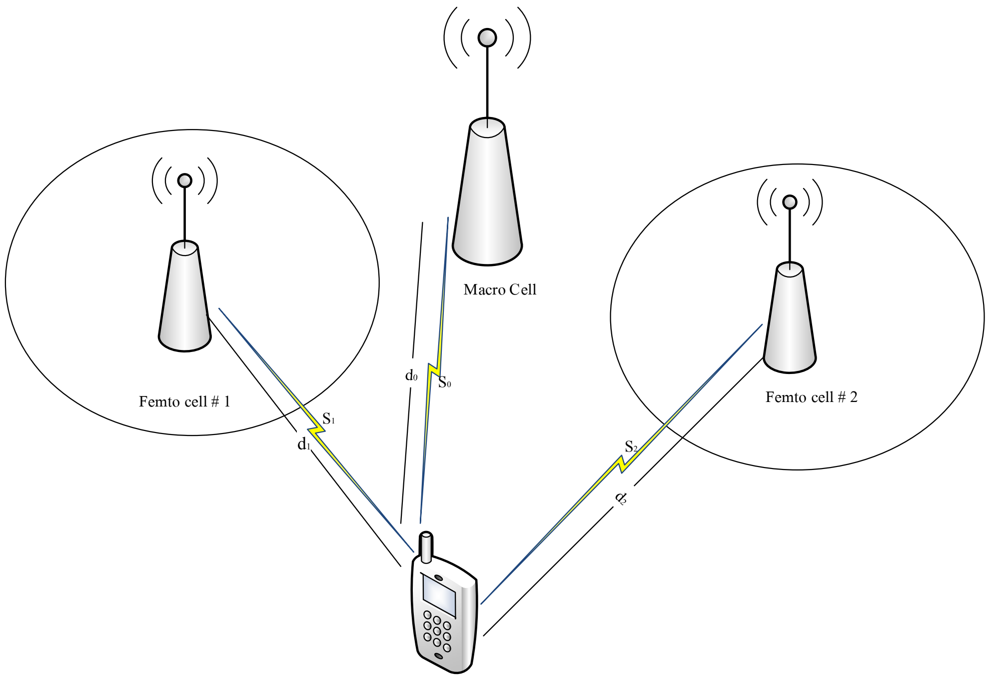

Figure 2.4 Transmission from cell to user equipment with interferences from femto cell.

2.4.2 P_{outoge}

P_{outage} presents performance of signals. If P_{outage} is high, quality of signal will be low; on the other hand, quality of signals will be great if P_{outage} is low. Poutage is defined as:

$$P_{outage} = P_r(SINR > \gamma) \leq Q_C \quad (2.7)$$

γ is allowance SINR

Q_C is probability which SINR is less than allowance SINR

From the equation, if we defind criteria γ of SINR being high, the number of femto cells will be less. Q_c is maximum acceptable Poutage, If P_{outage} is high, quality of signal will not be good, therefore, Qc might be minimum acceptable quality of signal.

2.4.3 Probability of bit error rate (P_e)

For calculation probability of bit error rate; we can gain a simple from to calculate (see initiate equation of P_e in chapter 4) and find under different environments; Rayleigh and Nakagami fading

$P_e = \frac{1}{2} E\left[erfc\left(\sqrt{SINR}\right)\right]$ We can explain this equation that

Probability of total error is average probability of error in each case.

We assign; P_{e0} is probability of error transmitting bit 0 but receiving bit 1.

P_{e1} is probability of error transmitting bit 1 but receiving bit 0.

P_0 is probability of transmitting bit 0.

P_1 is probability of transmitting bit 1.

Accordingly, probability of total error equals to $P_e = P_0 P_{e0} + P_1 P_{el}$. In general, $P_0 = P_1 = 1/2$. $P_e = ½ P_{e0} + ½ P_{e1}$.

Normally, P_0 P_{e0} P_{e1} From analysis the area under error distribution graph, so we have

$$P_{e0} = \frac{1}{2} erfc\left(\frac{V}{\sqrt{2\sigma}}\right) \quad ; \quad \frac{V}{\sqrt{2\sigma}} \equiv SINR$$

$$P_{e1} = \frac{1}{2} erfc\left(\frac{A - V}{\sqrt{2\sigma}}\right) \quad ; \quad \frac{A-V}{\sqrt{2\sigma}} \equiv SINR$$

Where $erfc$ is average of errors

Then, we gain $P_e = \frac{1}{2} E\left[erfc\left(\sqrt{SINR}\right)\right]$

2.4.4 Ability of channel to transmit information: C

$C = E\left[\log_2\left(I + SINR\right)\right]$, we can explain the equation by Shannom Fomula in environment with Gaussian signal

From Shannon and Heartly theory, channel has bandwidth being B and positive. Additive white Gaussian Noise (AWGN) signal; moreover has spectrum density power being, $N_o/2$. In bandwidth channel B, maximum capacity can be written as:

$$C = B\left[log_2\left(1 + \frac{P}{\sigma^2}\right)\right] \text{ bit per second}$$

P is Average of Power transmit, σ^2 is Interference

So we get

$$C = B\left[\log_2\left(1 + \frac{P}{N_0 B}\right)\right] \text{ bit per second}$$

$\frac{P}{N_0 B}$ is SNR or SINR in case have interference

$$C = B[\log_2(1 + SNR)] \text{ in case have interference}$$

$$C = B[\log_2(1 + SINR)] \text{ in case not have interference}$$

And, in case concerning capacity per 1 Hz, we obtain $C = [\log_2(1 + SINR)]$ with bit per second per Hz unit.

2.5 Literature Review

In our literature review, we have related work as explained below; The work in [1] is on the power control management in femto cell. This paper prose Greedy α-ASE convergent for reducing outage and power.

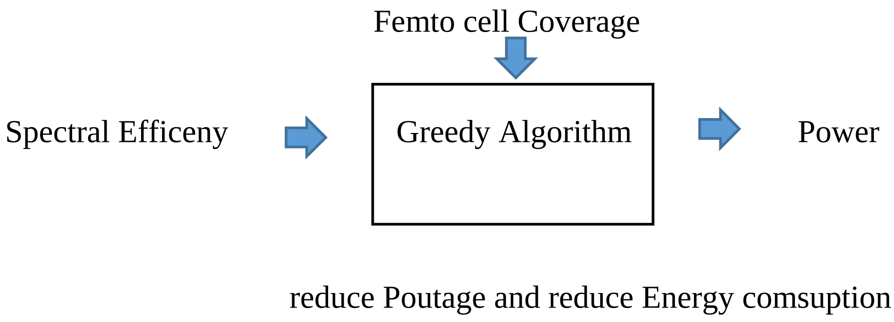

Figure 2.5 Greedy Algorithm

They propose 2 input as:

1.Spectral Efficiency are calculated in them of SINR then they use.

2.Femtocell Coverage

By input via Greedy algorithm procedure and yield and yield is optimal which can be used in that area

In simulation method they test in different 10,000 places, and repeat each place 100 times. As a result 30 femto cell decrease power from 6 days to 8 hours, we can summarize that Greed α- ASEcover use femto cell reducing 30% of Poutage and 14% of energy consumption.

This work shows reducing Poutage and energy consumption but does not display the number of femto cells

Similarly, the work in [2] can be summarized as follows. This paper control power of downlink signal and minimize transmitted power for mitigation interferences on femto cells. Each femto cell still guarantee acceptable SINR which indicate the quality of signals by using:

$$SINR_{MUE} = \frac{PT_m g_{mj}}{\sum PT_f g_{fj} + N_{th}}$$

PT_m, PT_f are the transmit power of eNB and H_eNB wheras F is the set H_eNBs in the block.

Power control's equation

$$P_{tx} = \min\left(\max\left\{ P_{t\max} \times \left[10^{\frac{1}{N}\left(PL(d) - PL_{\max(d)}\right)} \right]^{EXP} + I_{comp}, P_{t\min} \right\}, P_{t\max} \right)$$

This equation minimize transmitted power and they choose maximum value.

CaseI If $P_{t\max} \times \left[10^{\frac{1}{N}\left(PL(d) - PL_{\max(d)}\right)} \right]^{EXP} + I_{comp} > P_{t\min}$

Use $P_{t\max} \times \left[10^{\frac{1}{N}\left(PL(d) - PL_{\max(d)}\right)} \right]^{EXP}$

CaseII If $P_{t\max} \times \left[10^{\frac{1}{N}\left(PL(d) - PL_{\max(d)}\right)} \right]^{EXP} + I_{comp} < P_{t\min}$

Use $P_{t\min}$

In case I, P_{tmax} is maximum value that is calculated; however in care II, P_{tmin} is minimum of limit. If power is more than $P_{tmax,}$ they will use P_{tmax} which is compute from SINR.

From experiment, P_{outage} decrease 41 percentage comparing without power P_{outage} and interference of macro cell also lessen.

Their work can drop P_{outage} and interference but the number of femto cells are constant while our work can adjust the number of femto cells.

The work in [3] is about rate Optimization for Femtocell Networks. This work is about Co-tier interference that happens between femto cell and femt ocell and still maintains quality of signals on femto cell. They want to maximize data rate of femto cell under acceptable SINR level concern downlink.

Femto cell on WCDMA, Moreover, they focus on femto cell users which have co-tier interference to other cells. In this work, data rate is maximized under allowance quality of signal by using SINR parameter while the number of femto cell is I

$$\max \sum_{i=1}^{N} w_i R_i$$

$$\text{Subject to} \qquad \gamma_i \geq \Gamma_{\min}$$

$$\begin{bmatrix} \gamma_1 & 0 & 0.... & 0 \\ 0 & \gamma_2 & 0... & 0 \\ 0 & 0 & \gamma_3... & 0 \\ 0 & 0 & 0... & \gamma_N \end{bmatrix} \geq \begin{bmatrix} \Gamma_1 \\ \Gamma_2 \\ . \\ \Gamma_N \end{bmatrix}$$

This work maximizes data rate of femto cell and still maintain quality of signal. Maximization of this, paper use linear programing which is not complicated as other researches, but bandwidth and the number of femto cell are fixed.

The work in [4] is on the opportunistic power management. In this work, they propose algorithm of opportunistic power control to mitigate interference from femto cell. In uplink term, there are 2 algorithm; centralized and distributed sensing algorithm, so they can measure Poutage and throughput from these algorithm.

From simulation, SINR is set as 10 and 20 dB, and then they compare Poutage from centralized and distributed. Poutage from distributed algorithm is lower than centralized one because distributed transmitted power in macro cell is low. However throughput in distributed drops by 2.1% since distributed of each femto cell has lower transmitted power than centralized.

On the other hand, the work in [5] is on spectrum management. In this paper, they propose a spectrum arrangement to alleviate interference from co-channel deployment; normally, signal from femto cell are the same frequency with macro cell which cause co-channel deployment's interference.

The work in [6] gives a concept of interefence management of femto cell. Overview of using efficient femto cell is described in this work and interfence is a main problem for using femto cell. There are 2 type of interferences; Co-tier and cross tier interference; moreover, they mention various of interference management methods. For example, femto aware spectrum agreement; femto cell has to know frequency which is used in its area and neighboring femto cell. Clustering femto cell is grouping femto cell to use different frequency. Beam subset selection strategies is the method of antenna which can aim beam to specific area to mitigate interference from other areas. Collaborative frequency schedule is schedule management in employing frequency from femto cells. Power control approach is the method of allocating proper transmitted power to reduce interference between femto cell and femto cell or femto cell and macrocell under acceptable quality. In this work, they propose power control approach by using mathematics equation to calculate transmitted power follow P_{outage} and SINR

The work in [7] proposed a technique to evaluate probability outage. In this paper, an equation proposed to analyze and Probability outage of downlink for femto cell and Macro cell using the same frequency. Femto cell can control Probability outage by adjusting transmitted power and density for the number of femto cell in macro cell. They validate the results from calculation and simulation. Disadvantage of this paper is assignment power control and the number of femto cell to find probability outage. However, in our work, we defind probability to find the number of femto cell; normally probability outage is in proper value which we know from checking quality of signal. Therefore calculating the number of femto cell by defind probability outage is more appropriate.

The work in [8] presented the cross-layer analysis on packet Error Probability and Delay Constrained over Fading Channels This work analyzes or which consists of 3 patterns:

1) Packet drop due to full butter

2) Packet drop due to delay bound violation

3) Packet decoding error due to channel noise

Couse of the first and the second pattern is packet waiting for long time, so they calculate delay of packet. If packet waits longer than limit, packet will be dropped while delay or time of packet transmission is the function. Of C under Rayleigh fading. They use simulation instead of calculate to find out.

Calculating of delay bound and packet drop is difficult because they compute in datalink layer bring the advantage of this work. Disadvantage of the work is calculating C by employing simulation. Method, although calculation method is more accurate and compute more quieter

Similarly, the work in [9] proposed the calculation of Bit Error Probability of Optimal Muliuser Detector in Cooperative Cellur Natwork. They propose the equation of P_e from Uplink signals in cellular system while the system transmit signal to multi-users. P_e is figured out from SNR; moreover, low SNR is used for calculating at lower bound and high SNR is employed for figuring at upper bound. Both are accuracy. There are calculated from range of lower and upper bound are not precise.

The work in [10] presented a new technique computing bit error rate. Novel MGF – based is proposed to figure out P_e of digital signal by using MGF (moment generating function) technique; furthermore they find from SNR which analyze generalized fading channel. The equation can compute under all environments: Rayleigh, Ricean, and Nakagami; advantage of this work. On the other hand, the equation is complicated because there are a lot of parameters.

The work in [11] presented the channel Capacity of MINO Systems under Correlated Rayleigh Fading. In this work, they maximize channel capacity of MINO system under Rayleigh fading by using matrix, and consider parameters which have, an effect on channel capacity. In addition, of MIMO system relate to transmitted and receivers are adjusted to gain the maximum channel capacity and capacity of MIMO system relate to transmitted and received. In Rayleigh flat fading, uniform circle array anterma can provide capacity more than uniform linear array (ULA). There are some disadvantages of this work; namely using simulation method to find out capacity – because the initial equation is matrix them, they find a closed from difficulty. Moreover, they concern only a user it is not practical.

Likewise, the work in [12] presented capacity of Nakagami Multipath fading Channels. A closed from of capacity for Nakagami multipath fading (NMF) is proposed by power 3 terms and rate adaptation method; after that they compare NMF capacity and AWGN capacity. NMF has to be less than AWGN capacity. To sum up, optimal power with rate adaptation can provide capacity more than optimal rate with constant power way. Slightly, and fixed transmission rate method is the worst.

With the same authors, the work in [13] presented an exact Performance Evaluation for Modern Wireless Communications in Nakagami Fading. They propose equation to compute Pe and C for analysts' performances of wireless communication under Nakagami fading, and use basic probability function by employing SINR. So bit error rate and C are computed precisely, and this equation can be tested by Monte Carto Simulation. Moreover, it is accurate and not complicated.

The equation can find probability of bit error ratr and C in CDMA an OFDMA system. WE can add parameter Eb/no in CDMA and Summation of transmitted sub currier in OFDM

The work in [14-15] proposed analysis on Downlink Spectral Efficiency of DS/CDMA cellular for both full and semi orthogonal CDMA. Capacity of downlink signal in cellular DS/CDMA system on Rayleigh is analyzed in 2 papers, and they propose closed from to calculate C by probability function of SINR, Capacity and bit error rate average are found out under Rayleigh environment; furthermore, orthogonally, propagation and channel nice be checked precisely by considering hexagonal cell array. A cell is interfered by neighboring cell: 18 cells, Path loss is a parameter that indicates propagation path, so if path loss is less than 3, transmission will be good. However, transmission is low when path loss is high value; from the reuse both of calculation, and simulation method orthogonally has an impact on capacity more than other. Factors SNR representing background noise and path loss exponent being blockage level od channel.

Analogous, the work in [16] presented the spectral efficiency calculation for VSG CDMA in Nakagami and Rician Fading. In this work, a closed from of C in VSG CDMA is proposed on Nakagami and Rician environment by using parameter of fading index and background noise and property transmitting power. In addition, C is figured out by mathematics analysis of dual class and 5 – class system. The closed from can be employed accurately. The number of fading inder and background noise level inference a choosing appropriate transmitted power. From analysis the number of dual class and 5 – clears, capacity will be optimal when Eb/N_o of user is equal if SNR is high. If SNR is low, capacity will be opimal when we apportion power to user which transmit by high data rate.

Lastly, the work in [17] presented spectral efficincy evaluation for Non – Orthogonal communications. In this work, capacity of downlink in non – orthogonal multiple access (NOMA) is considered under Rayleigh environments and a closed expression for NOMA is proposed. Capacity in this work is estimated, and the equation can used in others system by changing othoynality factor. So the equation can be employed in other encoding techniqe; namely OFDMA.

There are several researches about future radio access (FRA) to enhance spectral efficiency and utilization; arrange high traffic properly. Non – orthogonal multiple access (NOMA) is promising technique which user will has all capacity and is multiplexed with other users in power domain by successive inferences cancellation (SCI) method. NOMA is a technology which will be se in the future or 5G and their throughput is more than OMA or OFDMA by 30% from experiment.

This work 5G technology, state – of – the – art; therefore, researcher has to acknowledge about probability, random variables and NOMA for analysis. However, this technology's researches is addressed only signals part and not coverage of analysis in data link layer yet.

CHAPTER III
MAXIMIZATION NUMBER OF FEMTO CELLS

Currently, the demands of wireless communications have been increased. The number of subscribers or capacities, which are significant factor of wireless systems, have to be enough to service the users; moreover, the systems have to cover service areas as well. Femto cell technology being one of cutting-edge technology is used because it is low cost, efficient capacity and good coverage. Cell – size reduction is a concept of this technology to reuse spectrum. Femto cell is a small base station located indoor area to transmit signals and its transmission uses low power due to short distance – In addition, femto cell can be cooperated with other wireless technologies such as WCDMA 3G 4G OFED WIMAX and LTE .

There are several advantages of femto cell usage in wireless communications; for examples femto cell increase capacity to be adequate to service and solve dead zone’s problem Moreover, it is low power and its battery life is longer. From these boons, we consider the quality of service to transmit efficiently. Consequently, in this chapter, we proposed theory and method to maximize the number of femto cells which their quality is still acceptable.

In this chapter, we use the system model as in Figure 2.1, Chapter 2. In the figure, we consider the downlink signals from the macro cell to a mobile user while the signals are interfered by the femto cells therein the area. The channel is modelled by Rayleigh distribution with the system parameters defined as in the following sections.

3.1 Calculating Average SINR

SINR (signal–interference-pulse-noise-ratio) is the factor that we use for identification the quality of signals. From previous researches, there are two methods to figure out average SINR:

1.) Simulation Method this method gathers different means that imitates real situation to create simulation; and then the simulation is used to find out. From the equation (2.6), each of $h_0, h_1, h_{2,...,} h_n$ has values, and we may gain a million of h_0. So we average those amounts to get the most possible outcome. For instance sum of outage probability in term of SINR is shown below. (see more details in section 3.3)

```
Set SINR=0, P=0, and P_sum =0 //set initial values
For i=1 to 1,000,000 //simulate for 1,000,000 iterations
{
Generate h_0 ,h_1 ,h_2,...,h_n
Calculate SINR and P_outage
P_sum=P_sum+ P_outage
}
P_outage = P_sum/1,000,000 //find the average of P_outage
```

2.) Average Each of Channel Gain $h_0, h_1, h_{2,...,} h_n$

In SINR'S equation, each of $h_0, h_1, h_{2,...,} h_n$ is averaged to get a value.

$$\mathrm{E[SINR]} = \frac{\mathrm{E}[h_0]S_0 d_0^{-\beta}}{\sum_{i=1}^{N} \mathrm{E}[h_i]S_i d_i^{-\beta} + \eta} \tag{3.1}$$

The value is compared with the simulation whether the outcome , which we obtain still be guessing value, is close to the result from the simulation or not. In this chapter, we propose the method to find average which is more accurate the other researches by using characteristic of channel gain random variables and identity of mathematics to maximize the number of femto cells N_{max} .

In equation 3.1, the summation term represents the inferences whereas η stands for the background noise. In the following chapters, we will show the impacts of both parameters on the system key performance indices, i.e. Poutage (chapter 3), probability of bit error (chapter 4) and channel capacity (chapter 5).

In channels of wireless system, signals are transmitted with noise and interferences, so that signals will be random at receiver. For example transmitted signal is assigned to be s_0^2 , and the signal at receiver equals to the equation (3.2):

$$r(t) = s_0^2 |h(t)|^2 e^{-j\phi(t)} \tag{3.2}$$

Where $|h(t)|^2$ is channel gain random variable, and $\phi(t)$ is assigned as phase channel which is $[0,2\pi]$ $|h(t)|^2$ has an effect on error detection at receiver because detection considers amplitude or power that is set by $|h(t)|^2$.

As a result, we model $|h(t)|^2$ as random variables which transmitter and receiver are non line of sight (NLOS) case. Signals bring scattering are detected at receiver; additionally, there no dominant signal in NLOS case. From this reason, the total average of signal equals to zero from central theory, we gain $h(t)$ model by Gauss procedure in equation below; (3.3.)

$$h(t) = h_i(t) + jh_j(t) \tag{3.3}$$

Where $h_i(t)$ and $h_j(t)$ are real and imaginary part, respectively, and they are Gauss random variable that its density probability function is defined as

$$f_H(h) = \frac{h}{\Omega[h]} e^{-h^2/2\Omega[h]} \tag{3.4}$$

Where $\Omega[h] = \mathrm{E}[h^2] = \mathrm{VAR}[h] = \sigma_h^2$ since $\mathrm{E}[h] = 0$ is ZERO From the equation (3.2), when $h(t)$ is a Rayleigh random variable, $|h(t)|^2$ is negative exponential random variable.

The next section, we describe and employ property of exponential random variable to calculate outage probability ($\mathrm{P}_{\mathrm{outage}}$)

3.2 Exponential Random Variable

From our concerning, $h_0, h_1, h_{2,...,} h_n$ are independent and negative exponential distribution. X is distributed, Function of exponential variable and graph shows probability of $P_r(X > a)$, $X > a$ in shaded area (see fig 3.1). Normally, probability of exponential variable is written as $P(X) = f(x,\lambda) = \lambda e^{-\lambda X}$; $x \geq 0$

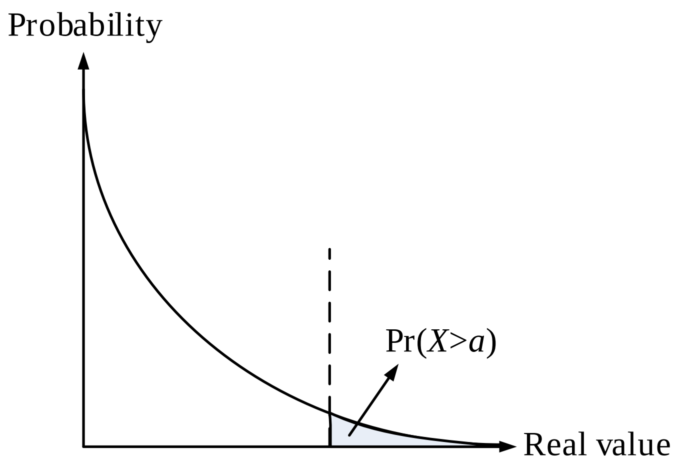

Figure 3.1 Distributed function of exponential a is real number

3.3 Using Property of Exponential Variable

From the equation (2.7), we have P_{outage} as

$$P_{outage} = P_r(SINR < \gamma) \leq Q_c \tag{3.5}$$

So outage probability can be written as following

$$P_r(SINR < \gamma) = 1 - P_r(SINR > \gamma) \tag{3.6}$$

Finding $P_r(SINR < \gamma)$ is significant factor which SINR is in term of exponential random variable

$h_0, h_1, h_{2,...,} h_n$ is probability of X random variable. When a is any constant, we obtain

$$P_r(X > a) = e^{-a} \tag{3.7}$$

Consequently, outage probability in equation (3.1) can be shown as below;

$$P_r(\text{SINR} < \gamma) = 1 - e^{-\frac{\gamma}{S_0 d_0^{-\beta}}\left[\sum_{i=1}^{N} h_i S_i d_i^{-\beta} + N_0 B/2\right]} \tag{3.8}$$

Writing in simple from by

$$\phi = exp\left(-\frac{\gamma N_0 B/2}{S_0 d_0^{-\beta}}\right) \tag{3.9}$$

$$\Gamma = \frac{S_i / S_0}{(d_i / d_0)^{-\beta}} \tag{3.10}$$

Accordingly, we reform equation (3.8) to be

$$P_r(\text{SINR} < \gamma) = 1 - \phi \exp\left(-\sum_{i=1}^{N} \gamma h_i \Gamma_i\right) \tag{3.11}$$

Then we write it in term of multiply as below:

$$\text{P}_{\text{outage}} = P_r(\text{SINR} < \gamma) = 1 - \phi \prod_{i=1}^{N} e^{-\gamma h_i \Gamma_i}$$

(3.12)

Next step, we average the equation (3.12), so we get

$$P_{outage} = 1 - \phi \prod_{i=1}^{N} \text{E}\left[e^{-\gamma h_i \Gamma_i}\right]$$

(3.13)

3.4 Maximization the Number of Femto Cells

$\text{E}[e^{-\gamma h_i \Gamma_i}], i = 1,2,3,..., N$ Found from exponential function, $\text{E}[e^{-\gamma h_i \Gamma_i}]$ is average value, and h_i is negative random variable.

$$E\left[e^{-\gamma h_i \Gamma_i}\right] = \int_0^{\infty} e^{-\gamma h_i \Gamma_i} e^{-h_i} dh_i$$

$$= \int_0^{\infty} e^{-(1+\gamma \Gamma_i) h_i dh_i}$$

$$= \frac{1}{1 + \gamma\Gamma_i} \tag{3.14}$$

We replace (3.14) to (3.13), so we get

$$P_{outage} = 1 - \phi \prod_{i=1}^{N} E\left[e^{-\gamma h_i \Gamma_i}\right]$$

$$= 1 - \phi \prod_{i=1}^{N} \frac{1}{1+\gamma\Gamma_i}$$

$$= 1 - \phi \left(\frac{1}{1 + \gamma\Gamma_{avg}} \right)^N \tag{3.15}$$

Which Γ_{avg} is the average of $\Gamma_i, i = 1,2,3,...,N$

then we put equation (3.15) into (2.7) $P_{outage_{\max}} = Q_c$

$$1 - \phi \left(\frac{1}{1+\gamma\Gamma_{avg}} \right)^{N_{MAX}} = Q_C \tag{3.16}$$

$$\phi \left(\frac{1}{1+\gamma\Gamma_{avg}} \right)^{N_{MAX}} = 1 - Q_C \tag{3.17}$$

After that we take log at both sides to solve the equation as;

$$\log\phi - N_{max} \log(1+\gamma\Gamma_{avg}) = \log(1-Q_C) \tag{3.18}$$

Finally, maximization for the number or femto cells can be formed as;

$$N_{\max} = \frac{\log\phi - \log(1-Q_C)}{\log(1+\gamma\Gamma_{avg})} \tag{3.19}$$

We can calculate maximization for the number or femto cells from the equation (3.19) and we obtain the results which are inspected by simulation method from figure 3.1 In this figure, dashes line shows simulation's result and symbols live represents $N_{\max}$ from equation (3.13) ; moreover , β is a parameter to identity states of channel. If β is high, channel has many obstructions

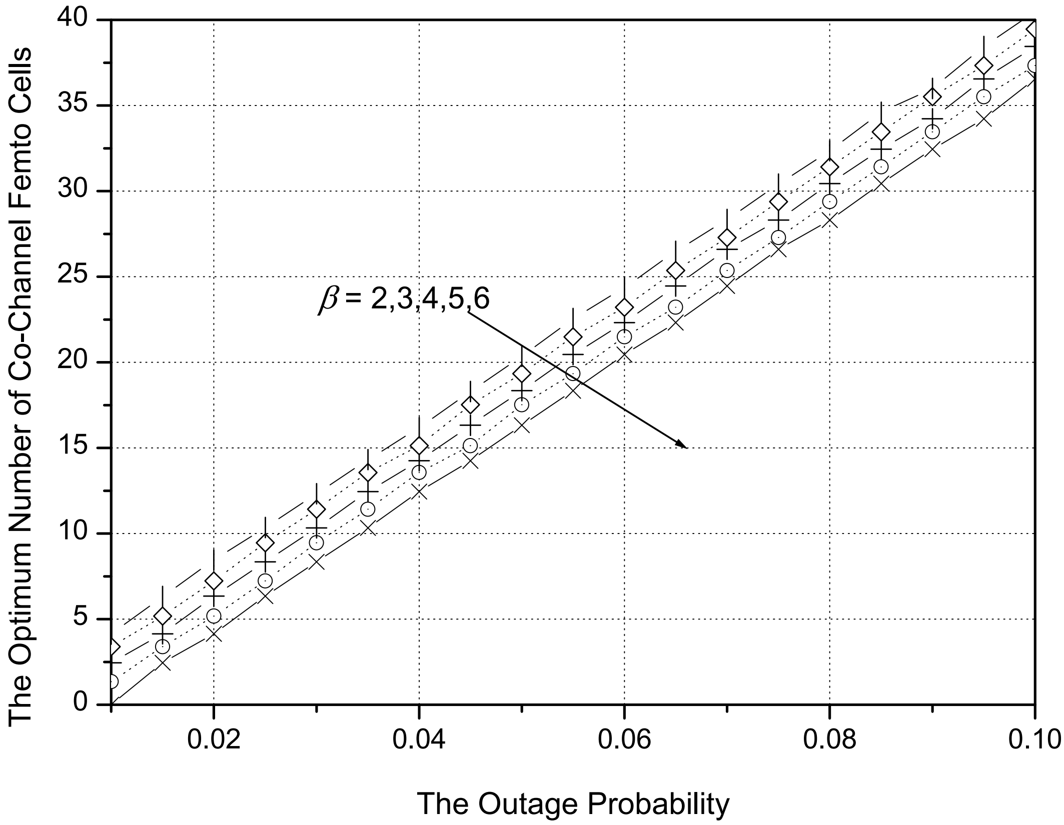

Figure 3.2 the optimum number of co-channel femto cells and outage probability

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Graphs from figure 3.2 show relation between number of co-channel femto cells under acceptable SINR with outage probability, We set parameters as follow; acceptable SINR equal to 3 dB, Average Path Loss Power (Γ_{avg}) = 0.5 is 0.5 and Interference Signal Power is defined as 0.3 dB. The results show that outage probability is less while the maximum number of femto cells as we; on the other hand, the maximum number of femto cells is higher when the number or femto cells is also higher. The solutions from simulation harmonize with the ones from equation (3.19) As a result, if we decrease the quality of signal, the quantity of interferences will be increased from higher femto cells. In the same way. Of the number of femto cells is small, the interferences will be loss, so that the quality of signal is higher.

The results that we gain can represent real situation thus we can employ the equation (3.18) to maximize number of femto calls under quality conditions

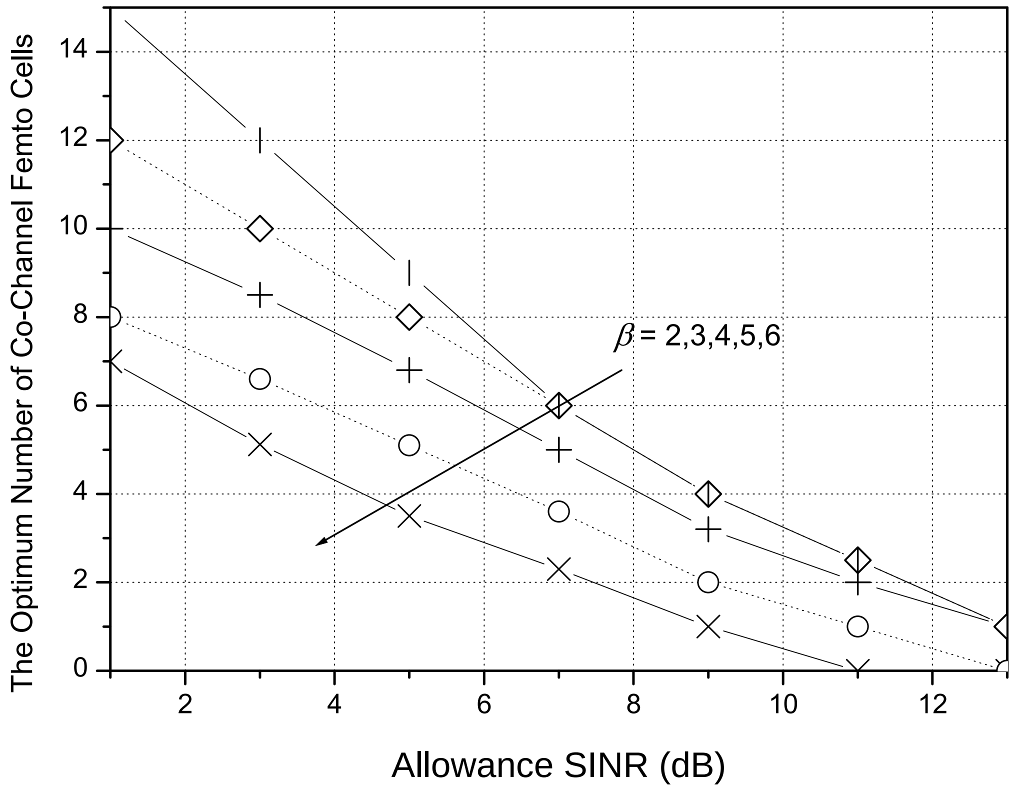

Figure 3.3 The optimum number of co-channel femto cells and allowance SINR

Figure 3.3 illustrates the optimum number of co-channel femto cells and allowance STNR. There are assigned parameters; P_{outage} is 0.03, Γ_{avg} is 0.5 and N_0 is defined as 0.3 dB. From the graphs, the number of femto cells is gradually less when we increase SINR that means we have to lessen the number of femto cells or interferences to gain a better quality.

3.5 Conclusion

In this chapter, we propose the close form expression to maximize number of femto cells while the quality of signals is still guarantee. P_{outage} is a parameter to represent the quality in Rayleigh case. There is an advantage from our proposed equation that we need not to simulate a lot of values for reliable yield but we just and relative transmitted powers and distances. From the results, the maximum number of femto cells can be solved under minimum required P_{outage} and allowance SINR which environment is different. Moreover, the out outcomes of our proposed relate with the simulation ones that means our equation is certified.

CHAPTER IV
PROBABILITY BIT ERROR RATE

4.1 Parameters of Wireless System on femto cell

Unlike the previous chapter, we focus on the uplink communications. The uplink signals are then analyzed with our proposed mathematical models. There are 2 major parameters for the uplink performance, i.e. probability of bit error and the spectral efficiency. In this chapter, the probability of bit error is considered and the channel is modeled by Rayleigh and Nakagami fading as below.

Probability bit error rate (P_e) is a parameter which we analyze signals whether are on acceptable constraint or hot this parameter is computed starting from SINR's equation;

$$\text{SINR} = \frac{S_0}{\sum_{k=1}^{k} S_k + \eta} \tag{4.1}$$

Where SINR's equation (4.1) is defined as additive white Gaussian noise (AWGN) , which equals to $\frac{N_0}{2}$, and k total neighboring femto cells, and $S_0, S_1, ...S_N$ are assigned as signal powers in Rayleigh environment that are negative exponential random viable. Hint that the power $S_0, S_1, ...S_N$ are considered as random variables. This implies that the channel gains and the transmitted power levels are included in the same symbols. SINR in the equation – desired signal power total interference ratio- is mainly concerned total interference ratio – is mainly concerned to analyze quality of signal ; especially , in high data transmission, interferences and middling from neighboring femto cells are significant to consider

In wireless communication, effective transmission depends on environment conditions, so that there are two parameters to illustrate fault detection; probability bit error rate (P_e) and channel capacity (C). We will describe P_e in this chapter and C in chapter 5.

Bit error rate shows the number of bits transmitted error comparing bits all bits transmitted; therefore, P_e represents probability of bit transmitted error in wireless system. If P_e is low value, system can quite completely receive signals, but if P_e is high, Fault of channel is large or transmission may be fail as well. P_e can be written as;

$$\text{Pe} = \frac{1}{2} E\left[erfc\left(\sqrt{SINR}\right)\right] \tag{4.2}$$

Which $erfc$ is error rate and efficiency

From

$$erfc(x) = 1 - erfc(x) \tag{4.3}$$

And

$$erfc(x) = 1 - \frac{2}{\pi}\int_0^{\infty} e^{-t}\,dt \tag{4.4}$$

4.2 Calculating P_e by SINR on Rayleigh Fading

We have SINR's equation to measure quality and then find probability bit error rate. As a consequence, we propose SINR starting from equation (4.1) and (4.2):

Given $g(z)$ as negative exponential random variable that values from 0 to ∞, from

$$E(g(z)) = \int_{-\infty}^{\infty} g(z) f_Z(z) dz$$ That "z" is SINR.

So we replace $E(g(z))$ in the equation (4.2)

Then we have

$$P_e = \frac{1}{2}\left[\int_{-\infty}^{\infty} erfc\sqrt{z}\, f(z) dz\right] \tag{4.5}$$

$$f_Z(z)dz = P(SINR > z)dz$$

Step forward, we know that

$$f_Z(z)dz = P(SINR > z)dz \tag{4.6}$$

Then the equation (4.5) is replaced by the equation (4.6) and we gain.

$$Pe = \frac{1}{2}\left[\int_{-\infty}^{\infty} erfc\sqrt{z}P(SINR > Z))dz\right] \tag{4.7}$$

From equation (4.7), $P(SINR > z)$ is SINR that is constant in that of exponential random variable:

$P(SINR > z)$ known that $SINR = \dfrac{S_0}{\sum_{k=1}^{k} S_k + N_0/2}$

We obtain $P(Y > a) = e^{-a}$ when is negative exponential variable and a is any constants from property of exponential.

$$P\left(\frac{S_0}{\sum_{k=1}^{k} S_k + N_0/2} > z\right) = e^{-z}$$

$$P_r(SINR > z) = e^{\frac{-zN_0}{2}} \prod_{K=1}^{K-1} V(z) \tag{4.8}$$

If $V(z)$ is exponential random variable and k is any constants,

We have

$V(z) = E[e^{-zS_k}]$

Form theory $\qquad E(g(z)) = \int_{-\infty}^{\infty} g(z) f_Z(z)dz$

$$V(z) = E\left[e^{-zS_k}\right] = \int_0^{\infty} e^{-zS_k} \cdot e^{-S_k} ds_k$$

$$= \int_0^{\infty} e^{-S_k(z+1)} ds_k$$

$$= \left.\frac{e^{-S_k(z+1)}}{z+1}\right|_0^{\infty}$$

$$= \frac{1}{1+z}$$

$$V(z) = \frac{1}{z+1} \tag{4.9}$$

Due to property of exponential, we get

$$P_r(SINR > z) = e^{\frac{-ZN_0}{2}} \prod_{K=1}^{K-1} \left(\frac{1}{1+z} \right) \tag{4.10}$$

Then we put equation (4.10) into (4.5), so equation can be written as:

$$P_e = \frac{1}{2}\left[\int_0^{\infty} erfc\sqrt{z} \left(e^{\frac{-N_0}{2}.Z} \right) \left(\frac{1}{1+z} \right)^{k-1} dz \right] \tag{4.11}$$

We replace $erfc(x)$ from the equation (4.4) in (4.11)

$$P_e = \frac{1}{2}\left[1 - \int_0^{\infty} \frac{e^{-Z}}{\sqrt{\pi Z}} \left(e^{\frac{-N_0}{2}.Z} \right) \left(\frac{1}{1+z} \right)^{k-1} dZ \right] \tag{4.12}$$

Finally, we obtain the closed expression for finding probability bit error rate (P_e), and then we compare results in different conditions in sub-section 4.4.1

4.3 Calculating Probabiity of bit error rate in Nakagami Fading

In wireless communication, there are various environments for transmission; normally, Rayleigh and Ricean fading are studied. Nakagami fading has an equation which represents both Rayleigh and Ricean fading (see in equation (2.5)). Consequently, we compute P_e in Nakagami fading that its signal is gramma distribution in this section while its equation is defined as

$$P_e = \frac{1}{2}\int_0^{\infty} erfc\sqrt{z}\, \frac{z^{m-1}}{\Gamma(m)} (mI)^m e^{-zmI} dz \tag{4.13}$$

And then, we integrate by part m times in equation (4.13) and get (4.14)

$$E\left[erfc\left(\sqrt{SINR} \,|I \right) \right] = -\sum \phi_i(z)(mI)^{m-i-1} e^{-zmI} \Big|_{z=0}^{\infty} + \int_0^{\infty} \phi_m(z) e^{-zmI} dz \tag{4.14}$$

By $\phi_i(z) = \frac{1}{\Gamma(m)} \frac{d^i}{dz^i} z^{m-1} erfc\left(\sqrt{z}\right)$

$\phi_i(z)$ exists

$\phi_i(0) < \infty \forall i < m$

$$\phi_i(0)=\{^{0,i<m-1}_{1,i=m-1} \quad (4.15)$$

From the equation (4.14) and (4.15), we rewrite as follow:

$$E\left[erfc\left(\sqrt{SINR}\,|I\right)\right]=1+\int_0^{\infty}\Psi_m(z)\phi_m(mz)dz$$

(4.16)

And give

$$\Psi_m(z)=-\frac{2}{\pi}\frac{\Gamma\left(m+\frac{1}{2}\right)}{\Gamma(m)}\frac{e^{-z}}{\sqrt{z}}{}_1F_1\left(1-m;\frac{3}{2};z\right) \quad (4.17)$$

From theory [16] Reference,

$$erfc\left(\sqrt{z}\right)=1-\frac{2z}{\sqrt{\pi}}{}_1F_1\left(\frac{1}{2};\frac{3}{2};-z^2\right) \quad (4.18)$$

Which ${}_1F_1\left(\frac{1}{2};\frac{3}{2};-z^2\right)$ is Hyper Geometric Function

We define as a simple from as following:

$$P_e=\frac{1}{2}\left[1+\int_0^{\infty}\Psi_m(z)\phi(mz)dz\right] \quad (4.19)$$

Where $\Psi_m(z)$ equals to equation (4.17) and

$$\phi(mz)=e^{-\frac{zmN_0}{2}}\prod_{k=1}^{K-1}V(z) \quad (4.20)$$

We put equation (4.17) and (4.20) in (4.19) and gain

$$P_e=\frac{1}{2}\left[1+\int_0^{\infty}\left(-\frac{2}{\pi}\frac{\Gamma\left(m+\frac{1}{2}\right)}{\Gamma(m)}\frac{e^{-z}}{\sqrt{z}}{}_1F_1\left(1-m;\frac{3}{2};z\right)e^{-\frac{zmN_0}{2}}\prod_{k=1}^{K-1}V(z)\right)dz\right] \quad (4.21)$$

4.4 Result and Discussion

From previous section , we obtain the closed from of probability bit error rate in Rayleigh and Nakagami fading, so we use the equation (4.12) and (4.21) to compute P_e in Rayleigh and Nakagami, respectively.

4.4.1 Result and Discussion on Rayleigh Fading

We can solve P_e from the equation (4.12) while parameter are variously assigned. Fig 4.1 shows relation between probability bit error (P_e) and SNR in Rayleigh case. We calculate P_e from defining N_0 in $SNR = 10\log\frac{S}{N_0}$

So that s is appointed as 1 and we vary No to get SNR from 1 to 20 dB. From the graphs, when SNR rises, P_e slightly drops; on the other hand, if we decrease SNR, P_e is higher. These mean when SNR is high, it shows the system being good quality of signals and having less interferences. But the quality in the system is terrible and has more interferences when SNR is small due to SNR representing background noise level. Furthermore, the number of neighboring femto cells (k) is large while probability bit error rate is increasing. However, the number of neighboring cells n have more effect on P_e than SNR.

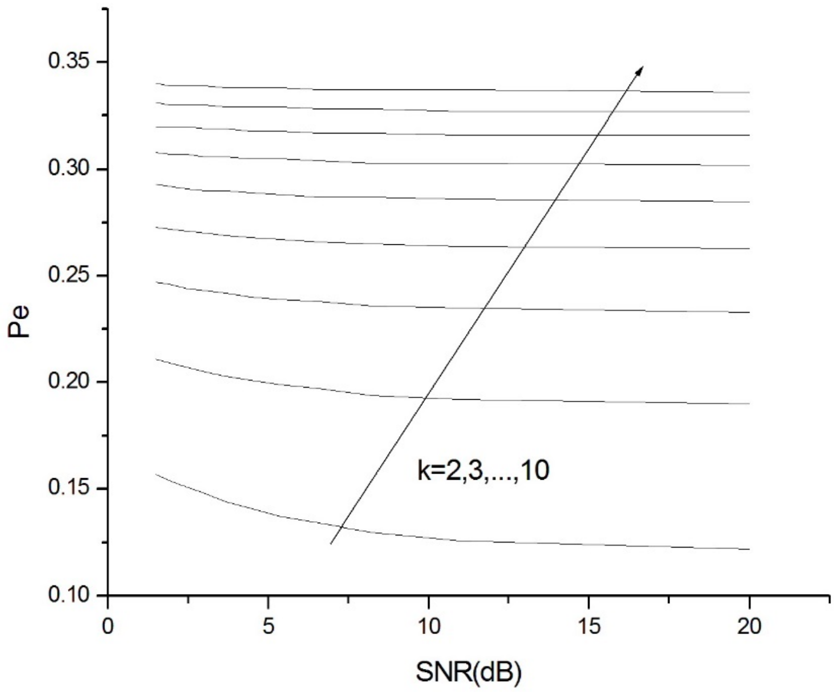

Figure 4.1 P_e and SNR

Comparison probability bill error rate (P_e) with the number of femto cells from the equation (4.13) is shown in figure 4.2 From the graphs, if we add more femto cells in the system, P_e sharply increase; on the contrary, P_e is small when k is dropped. We can explain that increasing the number of femto cells likes occurring more interferences as a result to high probability bit error. We assign four different SNR: 20, 6.576, 3.665 and 1.938 , from the graphs when SNR is low, P_e will be high as real situation. Conclusion, the number of femto cells act as interferences which have more impact than SNR being noise in the system.

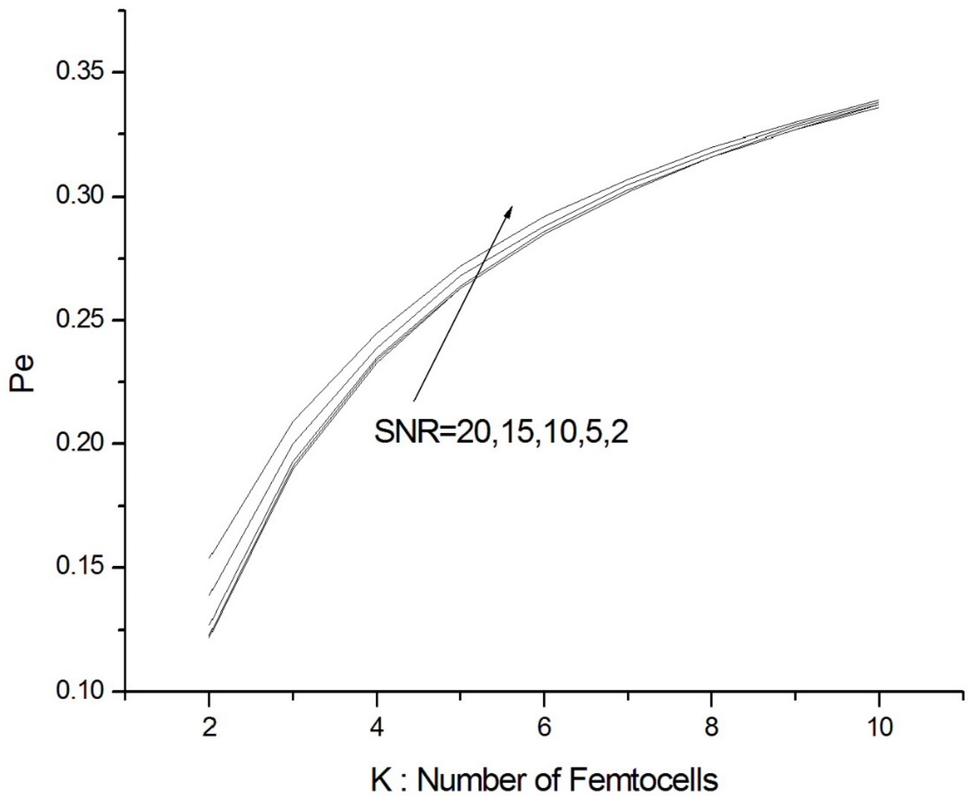

Figure 4.2 showing P_e with Number of femtocell

4.4.2 Result and Disussion on Nakagami Fading

We find P_e Nakagami fading from the equation (4.21) while SNR is defined as 1 to 20 dB; Nakagami index (m) is 2 to 6: the number of femto cells (k) are appoint from 2 to 6.

Figure 4.3 shows relation between P_e and SNR on Nakagami case while we assign m to be 3. The results are similar to Figure 4.1 but probability of bit error rate in this figure is lower than figure4.1 due to having better channel (m=3)

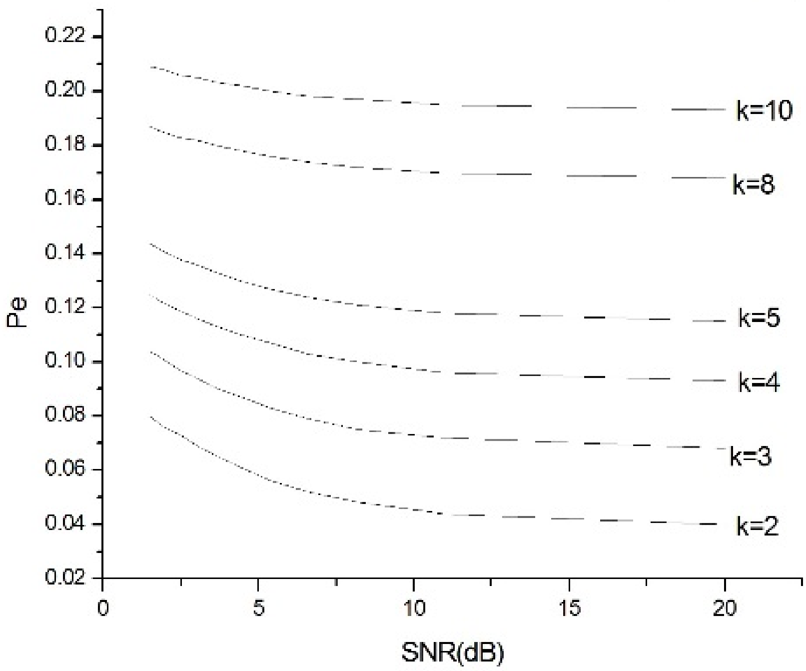

Figure 4.3 Pe and SNR

Figure 4.5 illustrates P_e and m while SNR assigned to is dB. If obstruction in the system is less at m = 5, 6, P_e is very small; on the other hand, P_e is larger when m equals to 2and 3. In term of various k, P_e rises while number of femto cells are added

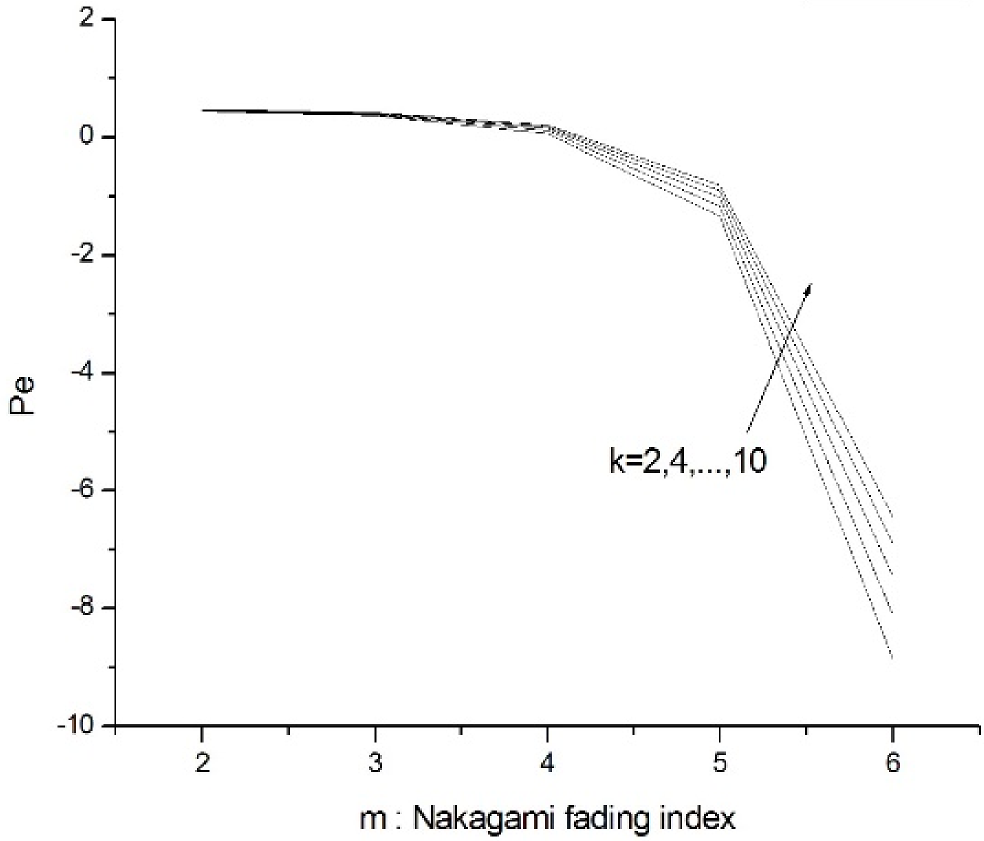

Figure 4.4 P_e and m

Comparison probability bit rate with the number of femto cells is represented in figure 4.5 by assigning SNR = 15 dB. Probability of bit error rate rises when we add more Number of femto cell (k); after that we also concern m which presents status of obstacles. If m is 6 (good channel), P_e value is the to west

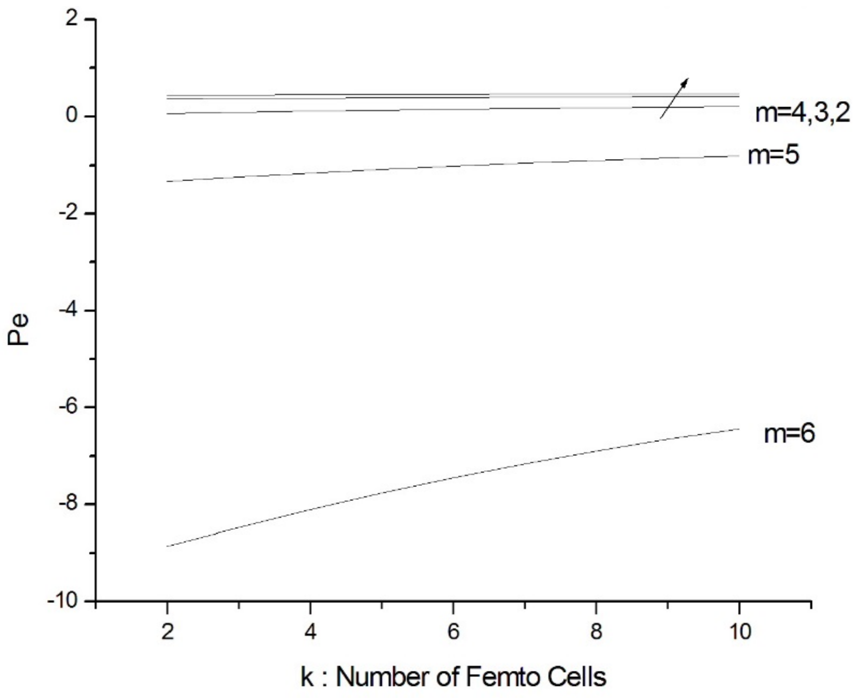

Figure 4.5 Probability of bit error rate and Number of femto cell

Figure 4.6 is similar to figure 4.3; however, we vary on Nakagami fading index (m) instead number of femto cells (k). To sum up, SNR slightly effects on probability of bit error rate when m is small but if m is large, P_e clearly drops.

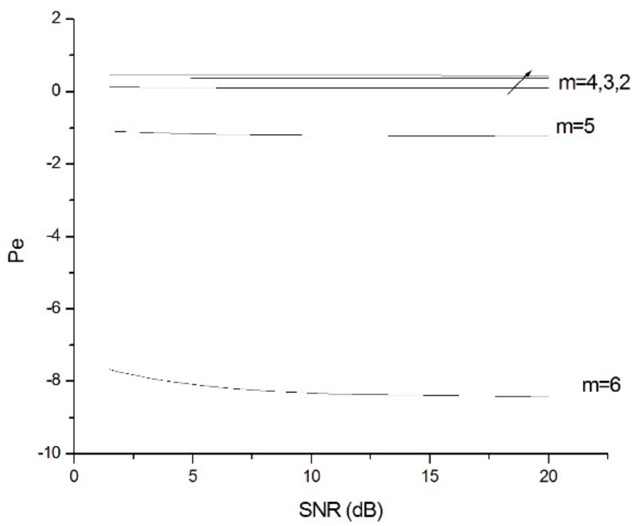

Figure 4.6 P_e and SNR

Figure 4.7 shows graphs between probability of bit error rate and m, and then we define l to be 4 P_e is small value when we increase m so that P_e reverse variation to m Moreover, SNR does not affect to P_e whereas m is small value, see the graphs. To sum, up, obstruction is less, Nakagami fading index (m) being large, error of transmission is low as well.

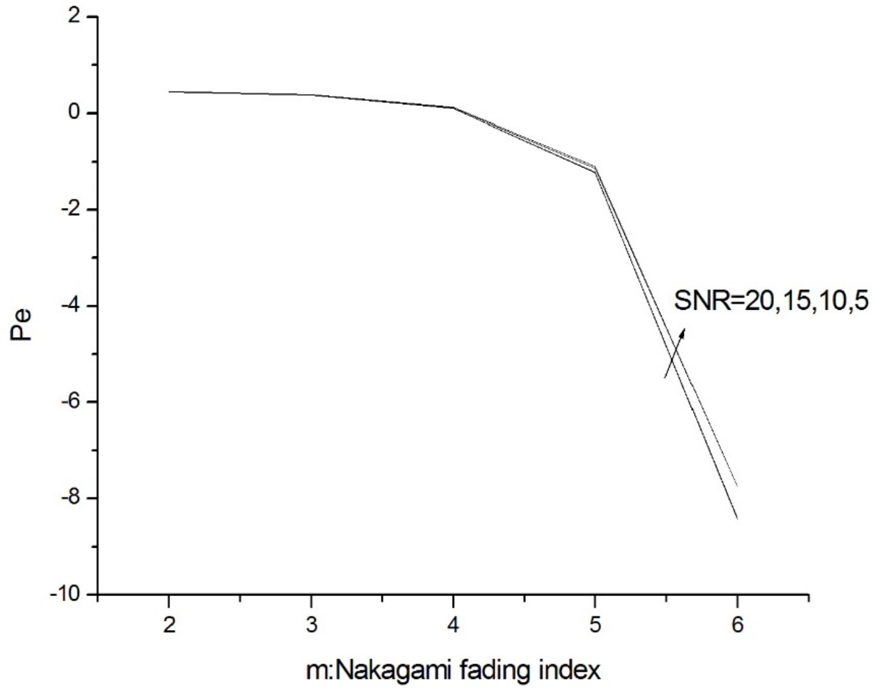

Figure 4.7 P_e and Nakagami Fading index (m)

We compare P_e with the number of femto cells (k) in figure 4.8 while m is defined as 3. From the graphs, P_e sharply rises when the number of femto cells are added more in the system. This means that increasing k likes occurrence more interferences in the system. Furthermore, SNR represents the quality of signals, P_e is small if SNR is large value which the signal in system are good. The results harmonize with actual status.

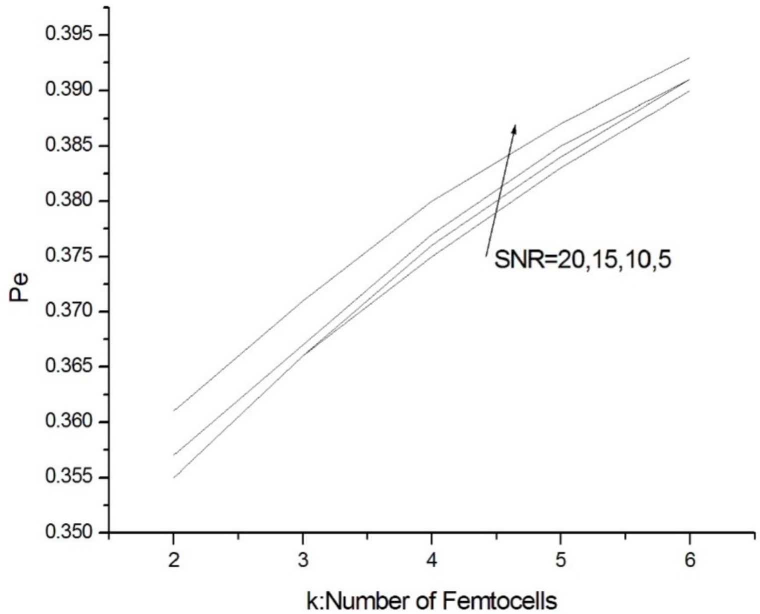

Figure 4.8 P_e and Number of Femto cells

4.5 Conclusions

There are two crucial factors for transmission in wireless communication: the quality of signals and enough capacities to service. We consider the quality in this chapter and the other in the chapter 5.

SINR's parameter is used to measure the quality of signals in wireless communication, as a result we employ it to analyze probability of bit error rate under Rayleigh and Nakagami environment on femto cells. From previous section, we obtain the closed from to calculate P_e in them of SINR and set interferences and the number of femto cells to figure out. The results are shown in Fig 4.1 – 4.2 under Rayleigh condition and in Fig. 4.3 – 4.8 on Nakagami Fading, moreover, we concern relation between probability of bit error rate and some parameters.

From the equation 4.11, under Rayleigh fading environment, there are two parameters: interference signal (N_0), and the number of femto cell (k) considered to find probability of bit error rate, see Figure 4.1 - 4.2. Figure 4.1 illustrates relation between P_e and SNR while SNR is computed by No, and then we compare SNR 10 and Nakagami fading index (m) in range of 2 to 6, sequentially.

- Comparison P_e with m is shown in Fig 4.4 and 4.7; besides, we also compare with the number of femto cells, 2-10 cell, and SNR, 1 – 20 dB, respectively.
- In Fig 4.5 and 4.8, we compare P_e with k while vary on. M in the range of 2 to 6 and SNR in the range of 1 to 20 dB.

From all of the graphs in Nakagami, we sum up that when there is high obstruction, SNR and the number of with the number of femto cells in the range of 2 to 10. Comparison P_e and k is displayed in Fig. 4.2; furthermore, we also vary on SNR in the range of 1 to 20 dB. We summarize that probability of error increase when there is more interfersuces or the number of femto cells is higher Fig 4.1 – 4.2.

In Nakagami environment, see Figure 4.3 – 4.8, we calculate P_e from the equation 4.18 and gain 6 figures as following;

- Figure 4.3 and 4.6 show relation between P_e and SNR and vary on the number of femto cells in range of 2 to 10 and Nakagami fading index (m) in range of 2 to 6 sequentially
- Comparison P_e with m is show in figure 4.4 and figure4.7; beside, we also compare with the number of femto cells, 2-10 cells and SNR 1-20 dB, respectively.
- In figure 4.5 and 4.8, we compare P_e with k while vary on m in the rage of 2 to 6 and SNR in the range of 1 to 20 dB.

From all of the graphs in Nakagami, we sum up that when there is high obstruction, SNR and the number of femto cells have less effect on the system. On the other hand, SNR and the number of cells extremely effect on the quality when there is less obstacle.

CHAPTER V
CHANNEL CAPACITY

5.1 Parameters of Wireless Communication on Femto Cells

It is important noting that we use the same assumptions as in Chapter 4, i.e. uplink scenario as well as the other system parameters. Analogous, we focus on the performance parameter namely channel capacity (or spectral efficiency) instead. The further explanation can be shown as below.

Channel capacity is an important parameter which represent capability of transmission; normally, we can compute channel capacity (C) from the equation 4.1

There are various demands for transmission, therefore we have to concern about the most efficient means to service our subscribers. However, the amount of information and occurrence of errors. In the system, the higher data rate we use to transmit, the more errors are happened, so we must to consider how much data rate that we should use under acceptable errors. From C.E. Shannon theory, if data is lower than channel capacity (C), there is a little mistake and we can reduce it by encoding technique. On the other hand, if C is less than data rate while channel has interferences, we cannot mitigate flows by any ways.

Unit of C is bit per second while B is defined as bandwidth of channel is Hz unit, and S/N is the radio between signals and interference. Capacity depends on bandwidth and S/N from concerning, hence increasing channel capacity means that the system can transmit more information. In addition, the quality of channel is better or there is less interferences from rising S/N, furthermore, Channel will have no any interferences and capacity is no limitation without bandwidth concerning when S/N reaches to infinity (∞). If we increase bandwidth unit being infinity, we will gain channel capacity reaching to infinity: however, channel which has interferences is not boundless rising of channel capacity. Then, while noise interference occurs in channel while spectrum is constants and No is fix in W/Hz unit, as s result power of interference will count on the bandwidth of channel and equal to N_0B. Increasing channel capacity by adding bandwidth may be in vain if channel is limited by S/N, thus channel has to be looked into maximum of capacity which it can serve and employ data rate being less than its channel capacity. Finally, if channel has enough capacity, the system can transmit information and increase ability of channel.

5.2 Calculating C from SINR in Rayleigh Fading

From the equation 4.1

So we can compute C from SINR equation and obtain as following:

$$C = E\left[\log_2\left(1 + SINR\right)\right] \tag{5.1}$$

Then, we know that $E(z) = \int_{-\infty}^{\infty} f_Z(z)dz$ Where Z is SINR and $E(z)$ is replaced in the equation (5.1)

Accordingly, we get

$$C = \int_{-\infty}^{\infty} \left[\log\left(1 + SINR\right)\right] dz \tag{5.2}$$

And then we reform the function as

$$C = \int_{-\infty}^{\infty} \left[\log\left(1 + z\right) fSINR\left(z\right)\right] dz \tag{5.2}$$

We know that $f_Z(z)dz = P(SINR > z)dz$ and obtain

$$C = \int_{-\infty}^{\infty} \left[\log\left(1 + z\right) P\left(SINR > z\right)\right] dz \tag{5.3}$$

From the equation (5.3), we have

$$P_r\left(SINR > z\right) = e^{\frac{-zN_0}{2}} \prod_{k=1}^{k-1} V\left(z\right) \tag{5.4}$$

And, from the chapter 4, we understand that

$$V\left(z\right) = E\left[e^{-z_{Sk}}\right] = \frac{1}{1 + z} \tag{5.5}$$

Due to the property of exponential,

$$erf(x) = 1 - erfc(x) = 1 - \frac{2}{\pi} \int_{0}^{\infty} e^{-t} dt \tag{5.6}$$

After that we put the equation (5.6) into (5.3), so we get

$$C = \log_2 \int_{-\infty}^{\infty} \left[\frac{e^{\frac{-zN_0}{2}} \left(\frac{1}{1+z} \right)^{k-1}}{1+z} \right] dz \tag{5.7}$$

5.3 Calculating Channel capacity in Nakagami Fading

In this section, we calculate Channel capacity under Nakagami environment as follow:

$$C = \int_0^{\infty} log_2 (1+z) f_{SINR}(z) dz \tag{5.9}$$

We comprehend that $f_Z(z)dz = P(SINR > z)dz$ and gain

$$C = \int_0^{\infty} log_2 (1+z) d\ Pr(\ SINR > z\ ) \tag{5.10}$$

From logarithm theory, we change the base log shown as

$$C = \int_0^{\infty} \frac{\log_e 1+z}{\log_e 2} \Pr(SINR > z) dz \tag{5.11}$$

$\log_e 2$ is a constant value and use the constants of integration

$$C = \log_2 e \int_0^{\infty} \log_e (1+z) \Pr(SINR > z) dz \tag{5.12}$$

Moreover, $log_e(1+z)$ is written as natural logarithm:

$$C = log_2 e \int_0^{\infty} ln(1+z) Pr(\ SINR > z\ ) dz \tag{5.13}$$

And we gain from integration $ln(1+z)$ as

$$C = log_2 e \int_0^{\infty} Pr(\ SINR > z\ ) \frac{dz}{1+z} \tag{5.14}$$

Then, we replace $Pr(SINR > z)$ with the equation (5.6) and get

$$C = log_2 e \int_0^{\infty} \left(\frac{1}{z} \left(1 - \frac{1}{(1+z)^m} \right) \cdot e^{\frac{-z \cdot m \cdot 0.5}{2}} \left(\frac{1}{1+z} \right)^{k-1} \right) dz \tag{5.15}$$

5.4 Result and Discussion

In this section, we compute channel capacity in Rayleigh fading from the equation (5.9) and in Nakagami environment from the equation (5.12) by vary on some parameter: afterward, we have 8 figure: 2 figure of capacity under Rayleigh and another in Nakagami condition

5.4.1 Result and Discussion on Rayleigh Fading

In Rayleigh environment, we can find the channel capacity while vary on some parameters, then are 2 figure which show their connection

Firstly, relation between channel capacity and SNR that is calculated from the equation (5.9) is displayed in Figure 5.9 and we find Channel Capacity by definding N_0. Besides, SNR is computed from $SNR = 10\log\frac{S}{N_0}$ while S is set to 1, and then we assign N_0 value until SNR being between 1 to 20 dB. Then we bring Channel Capacity to plot the graphs. From the graphs, Channel Capacity is high when SNR is high as well, this means that they are direct variation. Moreover, the Channel Capacity will be high when the system has a small number of femto cell, and then we also consider a large number of neighboring femto cells which SNR has less effect on capacity. However, SNR will influence on channel capacity if the number of femto cells are small (k=2)

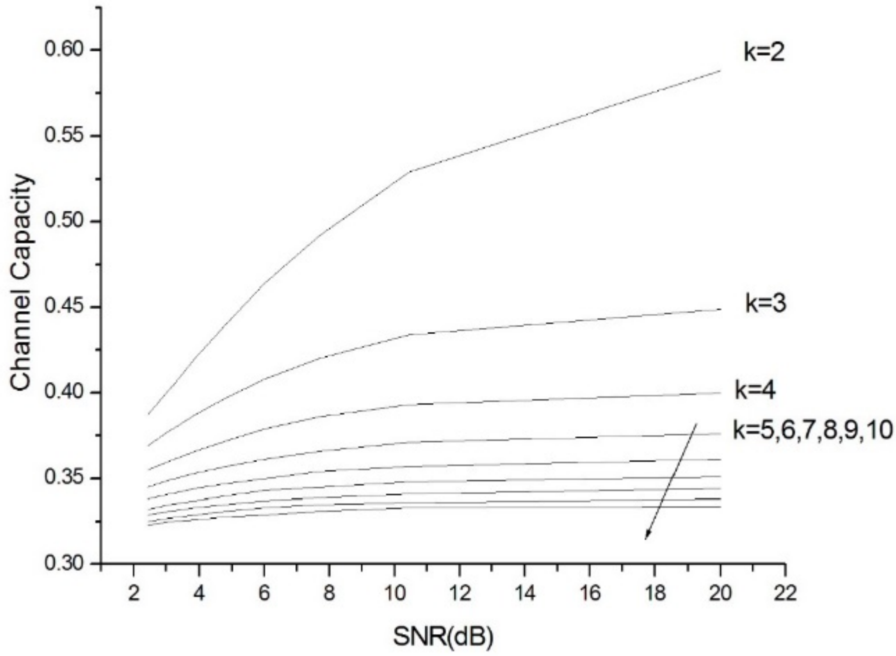

Figure 5.1 channel capacity and SNR

Secondly, Figure 5.2 presents the results of capacity with the number of femto cell; from the the graphs, capacity lessens when we add more neighboring femto cells into the system. In addition; channel capacity decreases whereas *SNR* also diminishs, and *SNR* an impinge on capacity evidently in small number of femto cell case (k=2). Nevertheless, influence between capacity and *SNR* is less when k is large value, this means that the effect from interferenes (the number of femto cells) is more severe to channel capacity than from *SNR*

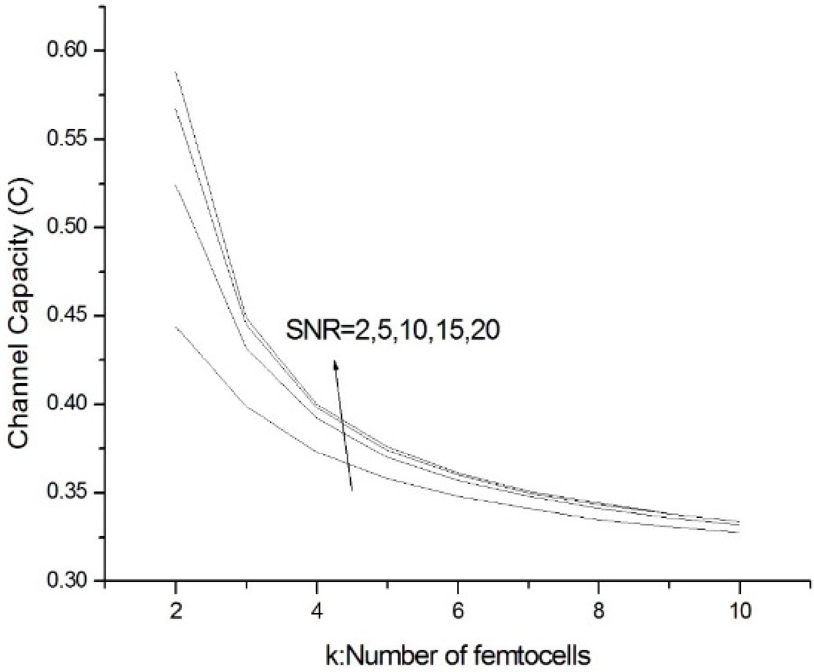

Figure 5.2 channel capacity and number of femtocell

5.4.2 Result and Discussion on Nakagami Fading

Figure 5.3 – Figure 5.8 display relation between channel capacity and some parameters in Nakagami case which we can find from the equation (5.15)

We defind SNR to be 1 – 20 dB, assign the number of femto cells being 2 – 10 cell, and m is Nakagami fading index.

From Figure 5.3, we set m that equals to 3 and the results of capacity and SNR are displayed. SNR has an effect on channel capacity when femto cells are 2 – 3 cell; however, if there are 4 – 10 femto cells in the system, SNR slightly influence on channel capacity. Accordingly, we can summarize that the number of femto cells has more effect on capacity than SNR value

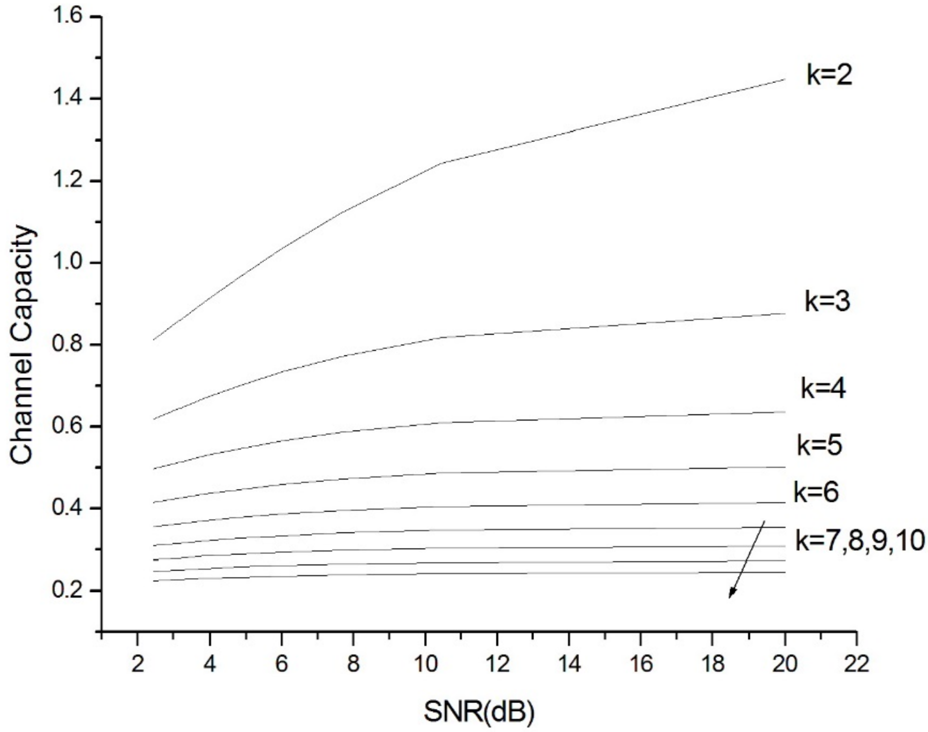

Figure 5.3 Channel capacity and SNR

Correlation between channel capacity and Nakagami fading index (obstacle level) is exhibited in Figure 5.4, and then we set SNR to be 10 dB. Capacity gradually increases while m also rises and the number of femto cell drop from the graphs. To sum up, the number of femto cells and m parameter have a dramatic impact on channel capacity; however, the number of femto cell is more serious than Nakagami fading index (m)

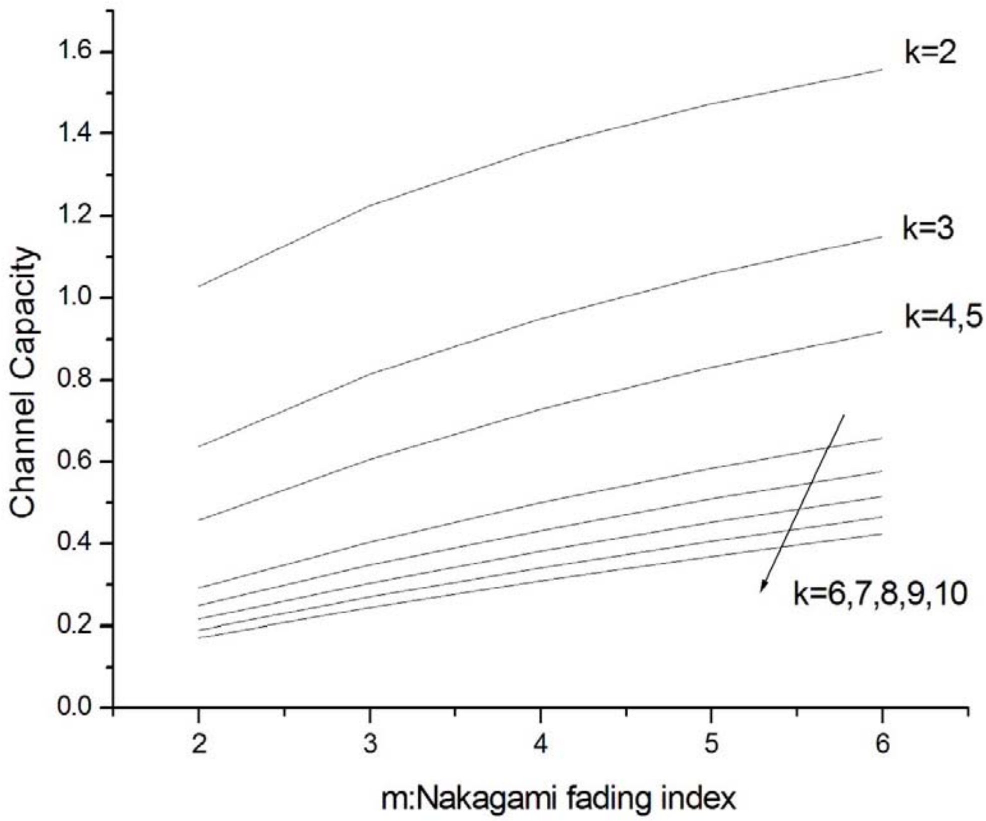

Figure 5.4 Channel capacity and Nakagami fading index

In figure 5.5 we determine *SNR* that equals to 10 dB, and the results of capacity that are varied on k and m are presented. We can concern that k and m affect the channel capacity. When the number of femto cells and Nakagami index are high, the capacity is less and more respectively. The outcome from Fig 5.5 and 5.4 are similar

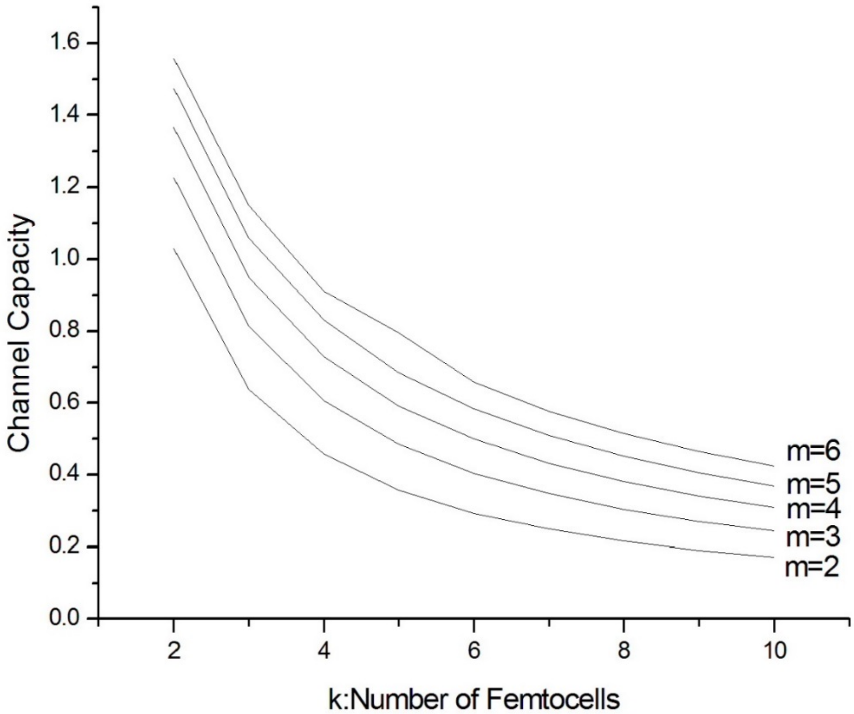

Figure 5.5 Channel capacity and Number of Femto cell

Channel capacity is direct variation with *SNR* and Nakagami in Figure 5.6; furthermore, changing of m being 6 is clearer than m=2. So, Nakagami has an impact on capacity more serious than SNR value.

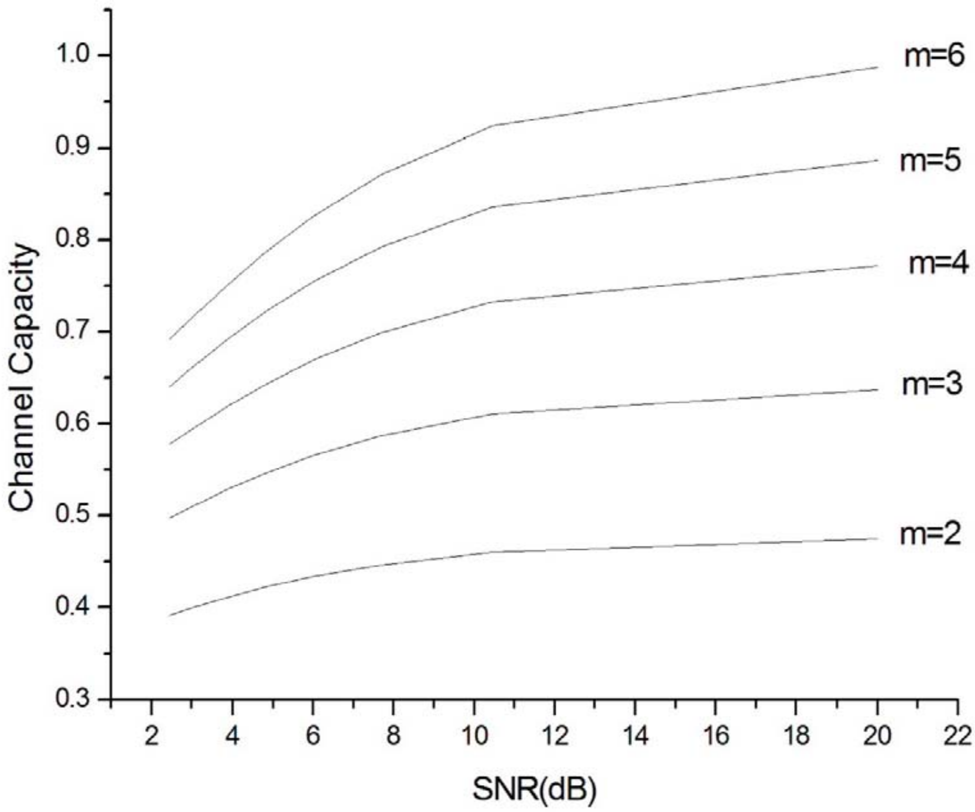

Figure 5.6 Channel capacity and SNR vary Nakagami fading index

Figure 5.7 demonstrates relation between channel capacity and m whereas we assign the number of femto cell to be 4. Channel capacity sharply rises when the value of m and *SNR* is large, from the previous statement, we can conclude that *SNR* has an effect on capacity less than Nakagami index.

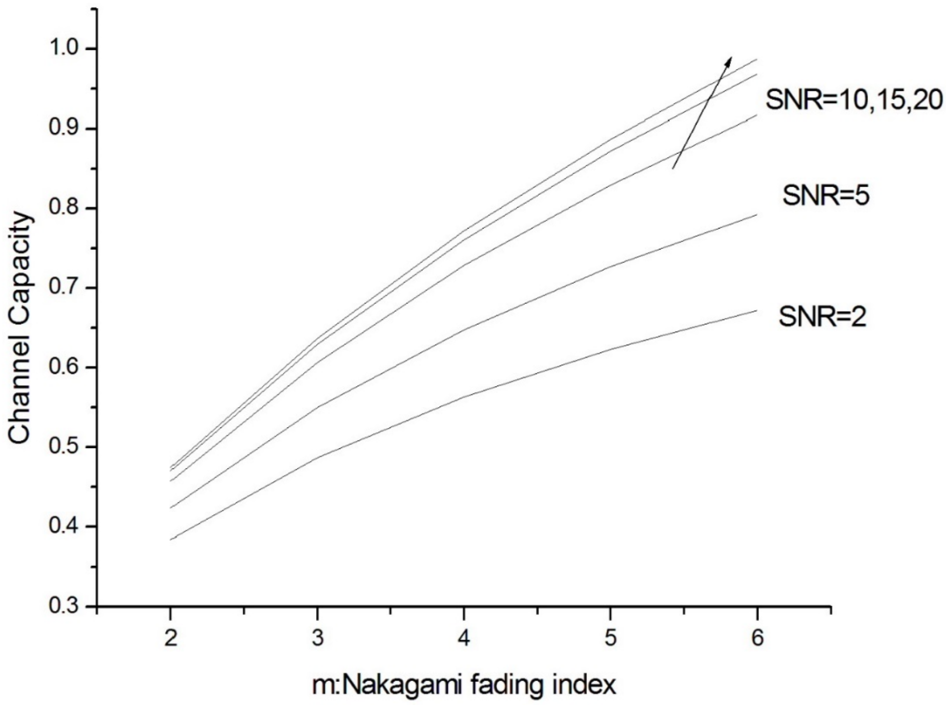

Figure 5.7 C and Nakagami Fading index (m)

In Figure 5.8, we set m to be 3, and the results are similar to figure 5.5. When the number of femto cells are 8 – 10 cell, *SNR* has less influence on channel capacity, accordingly, femto cell is more important to channel capacity that *SNR* value.

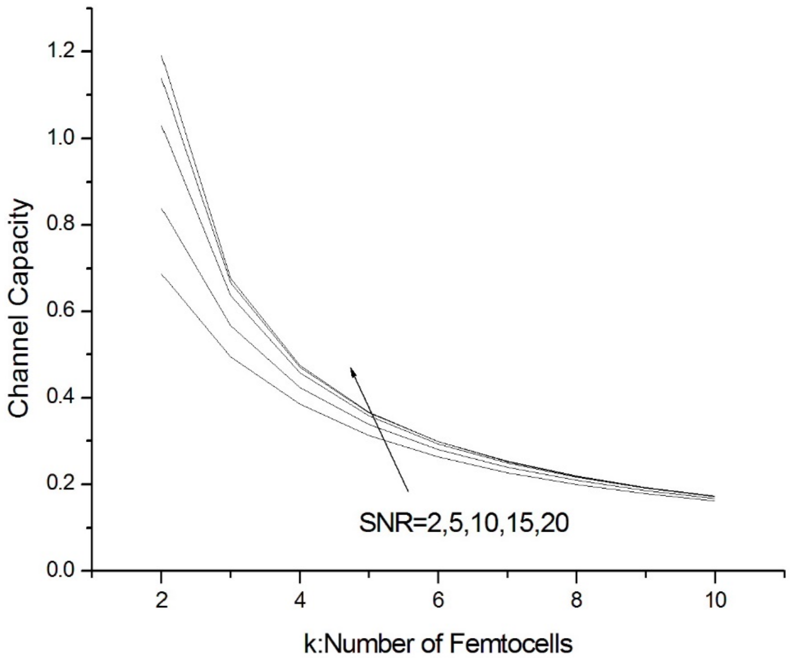

Figure 5.8 Channel capacity and Number of femto cell

5.5 Conclusion

Ability of channel to transmit information or channel capacity is a significant factor in wireless communication to support subscriber's requirement, ad a result we propose the closed form of channel capacity in both of environment: Rayleigh in 5.4.1 and Nakagami fading in 5.4.2 to calculate Channel capacity while we determine interference and the number of femto cells. There are 2 figure in Rayleigh case; see Fig 5.1 and 5.2

Relation between channel capacity and other parameters in Nakagami fading is presented from fig 5.3 to Fig 5.8 and then we can conclude that the number of femto cells have an effect on capacity the most. Finally Nakagami fading is harsher to channel then SNR

CHAPTER VI
SUMMARY

In this thesis, we analyze quality of signals a cellular mobile network while SINR is used for analysis and function of other parameters, namely P_e (Probability of bit error rate), P_{outage} and C (Channel Capacity). We analyze P_{outage} in chapter 3 , Probability of bit error rate in chapter 4 and Channel Capacity in chapter 5 ; furthermore we employ knowledge of mathematics, probability theory and identity of mathematics to transform an equation of Probability of bit error rate, P_{outage} and Channel Capacity being the closed from which gain outcomes predict without using simulation method. Each chapter can be summarize as following subsection including future work. Our work is modern so there are several inventions and studying new technologies.

6.1 Maximization the number of femto cell

Femto cell technology is used for improving capacity or increasing frequency reuse to enough service subscribers. Femto cells bring sub-station in transmission are always located indoor or dead spot areas to improve the signals. Transmission of femto cells use low power; moreover, femto cells can collaborate with several technologies in wireless communication, namely WCDMA, 3G,4G,OFDM,WIMax, LTE and 5G. IN this thesis, we analyze the signals of femto cells by using SINR to indicate quality of signals, and then we propose the quation to maximize the number of femto cells under acceptable SINR. Normally, other research use average SINR solution being multi random variable which consist of 2 way. Firstly, simulation method will choose various of SINR value and average them to get the value. Secondly, average channel gain method will average each of channel gain ($h_0, h_1, h_{2,...,} h_n$) and substitute it into SINR's equation. On the other hand, we calculate average SINR in them of mathematics by employing characteristic of $h_0, h_1, h_{2,...,} h_n$

variables which are assumed to be exponential variables to maximize the number of femto cells, and we apply Poutage, being the function of SINR, which is constraints.

We maximize the number of femto cells by varying on various on various parameters, namely minimum required Poutage, allowance SINR, and relative transmitted powers and distances, and the results relate to environments and parameters in the systems; minimum required Poutage, allowance SINR, and obstruction of channel.

6.2 Analysis P_e in Rayleigh and Nakagami on Femto cell

Probability of bit error rate (P_e) shows the number of errors which occur in transmission. System can receive signals almost completely if probability of bit error rate is super low; on the other hand, when probability of bit error rate is high value; errors are extremely taken place in channel and failure of transmission might be happed. Equation of probability of bit error rate can be written as where $erfc$ is error rate and efficiency. From the equation (4.2), we can calculate probability of bit error rate by integrating $SINR$ which is multi random variable, so we have to integrate several times or use simulation method instead. As a result, we proposed a closed from of probability of bit error rate by using property of channel gain variable from probability theory, and then our proposed can calculate probability of bit error rate accurately both Rayleigh and Nakagami channel model. Fundamental equation of Nakagami channel represents the combination or Rayleigh and Ricans fading, so there is gramma distribution in Nakagami environment. We employ mathematics by using integration by part method and hyper geometric function theory to derive the equation, and obtain it to find probability of bit error rate.

From the results, probability of bit error rate increase when interferences or the number of femto cells, are high, in addition, environment has a lot of obstacles, an influence of SINR and the number of neighboring femto cells is less.

6.3 Calculations C in Rayleigh and Nakgami on Fem to cells

Channel capacity (C) is ability's transmission in wireless commutation and has bit per second unit. B is bandwidth of channel in the unit and S/N is defined as the ratio between signals and interferences. Accordingly, capacity depends on bandwidth and S/N

In this topic, we compute C from SINR on Rayleigh and Nakagami by using the same mathematics to reckon P_e, and then plot graphs to demonstrate relation between channel capacity and other parameters. To sum up, the number of femto cells is the most impact on capacity, and obstruction level and SNR are follow respectively.

6.4 Future Work

In chapter, we analyze C in femto cell and employ knowledge to compute channel capacity (C) of channel arrangement technique for non orthogonal multiple access (NOMA) or 5G in fig 6.1.

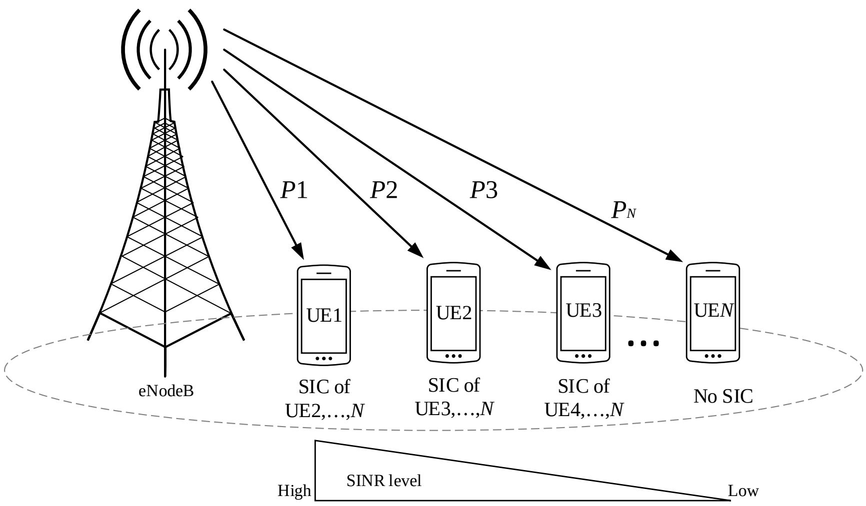

Figure 6.1 Demonstrates Noma Technology

Figure 6.1 demonstrates NAMA technology which base station (eNodeB) provides service to users. Each user will be multiplexed by power domain based on NOMA technology; additionally, each user (receiver) employs successive interference cancellation (SIC) to decode the wanted signal. SIC receiver will sub start stronger signal; therefore, this technique is adverse to normal receivers. Finally we can gain signals of each user and find an equation of channel capacity as

$$C_1 = \log_2\left(1+\frac{P_1|h_1|^2}{\eta_{0,1}}\right),$$
$$C_2 = \log_2\left(1+\frac{P_2|h_2|^2}{P_1|h_2|^2+\eta_{0,1}}\right),...,$$
$$C_N = \log_2\left(1+\frac{P_N|h_N|^2}{\sum_{i=1}^{N-1}P_i|h_N|^2+\eta_{0,N}}\right).$$

Then, channel capacity of UE_n can be written as following

$$C_n = \log_2\left(1+\frac{P_n|h_n|^2}{\sum_{i=1}^{n-1}P_i|h_n|^2+\eta_{0,n}}\right)$$

After that we average it by probability theory:

$$\begin{aligned} C_n &= \mathrm{E}\left[\log_2(1+SINR)\right] \\ &= \int_0^\infty \log_2(1+z)\, f_{SINR}(z)dz \end{aligned}$$

From pdf $f_{SINR}(z)$, we can use analysis in chapter 5 both Rayleigh and Nakagami to derive a closed from of channel capacity (C) for NOMA technology.

REFERENCES

1 Michael Lin and Thomas La Porta, "Energy-Aware Enterprise Femtocell Deploymemt" in *IEEE WCNC'14 Track 3(Mobile and Wireless Networks)* pp.2312-2317

2 Sawsan Ali Saad, Mahamod Ismail, and Rosdiadee Nordin, "Autonomous Power Control Scheme for LTE-Advanced Marcro-Femto Networks" in *2013 IEEE Student Conference on Research and Development(SCOreD)*,16-17 December 2013, pp. 524-528

3 Jidapa Hansawangkit, Tatcha Chulajata, and Pongsatorn Sedtheetorn, "A New Optimization Technique for Femtocell Networks" in *Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), 2015 12th International Conference* on Date 24-27 June 2015, pp. 1-4

4 Mi Seong Jin, Seung Ah Chae, and Dong In Kim, "Per Cluster Based Opportunistic Power Control for Heterogeneous Networks" in *Vehicular Technology Conference (VTC Spring), 2011 IEEE 73rd*, 15-18 May 2011, pp1-5.

5 Yi Wu, Dongmei Zhang, Hai Jiang, Ye Wu, "A Novel Spectrum Arrangement Scheme for Femto Cell Deployment in LTE Macro Cells" in *2009 IEEE 20th International Symposium on Personal, Indoor and Mobile Radio Communications* on Date 13-16 Sept. 2009, pp. 6-11

6 Nazmus Saquib,Ekram Hossain, Long Bao Le and Dong In Kim, "Interference management in OFDMA femtocell networks: issues and approaches" in *Published in: IEEE Wireless Communications (Volume:19, Issue: 3),* on June 2012, pp. 86 – 95

7 Xiaoli Chu, Joyce Yuhua Wu and Haibo Wang, "Outage Probability Analysis for Collocated Spectrum-Sharing Macrocell and Femtocells" *IEEE* Proceeding of *VTC Spring*, vol. 1, June 2013, pp. 1-5

8 Xihua Dong, Xiaochen Li and Dapeng Wu "Analysis of Packet Error Probability in Delay Constrained Communication Over Fading Channels" in *2009 6th IEEE Consumer Communications and Networking Conference* on 10-13 Jan. 2009, pp 1-5

9 Rajitha Senanayake,Phee Lep Yeoh and Jamie S. Evans "On the Bit Error Probability of Optimal Multiuser Detectors in Cooperative Cellular Networks" in *IEEE Transactions on Vehicular Technology (Volume:63 , Issue: 5)* on date 27 Nov 2014 pp. 2472 – 2478

10 Ferkan Yilmaz and Mohamed-Slim Alouini, "Novel MGF-based expressions for the average bit error probability of binary signalling over generalized fading channels" in *2014 IEEE Wireless Communications and Networking Conference (WCNC)* on date 6-9 April 2014, pp.1121 - 1125

11 Author(s) Jun Wang, Quan Zhou, Jinfang Dou and Lede Qiu, "On the Channel Capacity of MIMO Systems under Correlated Rayleigh Fading" in *2007 International Conference on Wireless Communications, Networking and Mobile Computing* on date21-25 Sept. 2007, pp.134 - 136

12 Mohamed-Slim Alouini and Andrea Goldsmith, "Capacity of Nakagami multipath fading channels" in *Vehicular Technology Conference, 1997, IEEE 47th (Volume:1)*On date 4-7 May 1997, pp. 358 - 362

13 Pongsatorn Sedtheetorn, "The exact performance evaluation for modern wireless communications in Nakagami fading" in *Communications and Information Technologies (ISCIT), 2013 13th International Symposium* on date 4-6 Sept. 2013 pp.10 – 13

14 Pongsatorn Sedtheetorn, "Theoretical analysis on spectral Efficieny of semi-orthogonal downlink communications in mobile cellular systems" in *Intelligent Signal Processing and Communications Systems (ISPACS), 2013 International Symposium* on date 12-15 Nov. 2013, pp. 636 - 639

15 Pongsatorn Sedtheetorn "Theoretical analysis on spectral efficieny of semi-orthogonal downlink communications in mobile cellular systems" in Intelligent Signal Processing and Communications Systems (ISPACS), 2013 International Symposium on 12-15 Nov. 2013, pp. 636 – 639

16 Khairi Ashour Hamdi and Pongsatorn Sedtheetorn "On the Spectral Efficiency of VSG CDMA in Nakagami and Rician Fading" in *IEEE Transactions on Wireless Communications* (Volume 6, Issue: 4) on April 2007, pp. 1153 - 1158

17 Pongsatorn Sedtheetorn and Tatcha Chulajata "Spectral efficiency evaluation for non-orthogonal multiple access in Rayleigh fading" in *2016 18th International Conference on Advanced Communication Technology (ICACT)* on Jan. 31 2016 - Feb. 3 2016, pp 747-750

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