Interference Mitigation by Power Optimisation & Frequency Reuse on Femtocell LTE Network

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***Abstract*— This paper present the analysis of interference mitigation method on femtocell in LTE network. Femtocell deployment required to provide better coverage for user in building. The simulation by power measurement & frequency reuse using EXata Qualnet 5.3. The simulation results conclude the mitigation technique can reduce the interference and give better user experiences.**

***Index Terms*—Long Term Evolution (LTE), Femtocell, Qualnet, Interference Mitigation,**

I. Introduction

Long Term Evolution (LTE) technology is widely used nowadays to provide better high speed data and better voice quality. This will increase the user experience which providing better throughput with lower latency as compared to previous HSPA technology. The technology also provides lower cost due to the equipment reduction deployment whereby the architecture become simpler as Radio Network Controller (RNC) on 3G is replaced by the eNodeB itself.

A femtocell is a tiny and low-power base station [1] maximum power of transmission below 25dBm [2], as per guideline from Malaysian Communications and Multimedia Commission (MCMC), implemented in building like commercial office or house which can be deployed via DSL connectivity [3]. This femtocell network offer more adaptability and versatility for the deployment into existing structure. This will solve the problem of coverage at the cell edge of the macrocell coverage and also with simplified concept as per shown at Figure 1.

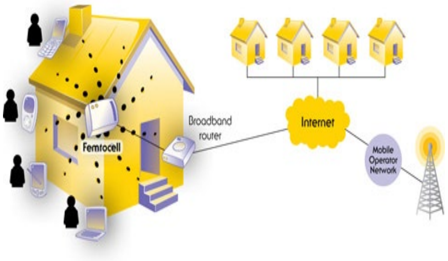


Figure 1: HeNB System Concept

The enhanced coverage will be advantages for most of the user since they have a base-station inside their building. In any case, to support highly capacity of user and provide high data service, substantial number of femtocell are required to deploy which will increase the interference of overlapping most of the femtocell in the same frequency. This interference will impact the Quality of Services (QoS) for the user and operators will encounter huge drop call feedback from users.

A. Frequency Reuse

Research which actualized the technique of Fractional Frequency Reuse [5] and Soft Frequency Reuse [6] to solve the interference issues in femtocell demonstrate that proposed scheme enhance total/edge throughput and reduces the outage probability in overall network, especially for the cell edge users. The interference reduction between the macrocell and the femtocell using the FFR strategy by allocating frequency sub-bands into macrocell and femtocell. The femtocell chooses sub-bands which are not used in the macrocell sub-area. The study put into the consideration are the formulation of Signal to Interference and Noise Ratio (SINR) and Received Signal Strength Indication (RSSI) quality between macrocell and femtocell sub-band. Clearly the scheme does not increase the total blocking rate dramatically but reduce blocking rate of edge user efficiently.

B. Power Transmission Optimisation

By controlling the downlink (DL) power and uplink (UL) reception power [7] from strongest macrocell and neighbouring cell also would mitigates interference to macrocell while keeping up good femtocell indoor coverage. As the penetration loss act as the indicator of this study, the femtocell coverage improved as the penetration loss is high which will reduce the interference signal from macrocell coverage. Therefore, the proposed scheme at edge of macrocell improved to 73% greater than fixed power setting scheme.

A study on load balancing scheme [8] to mitigate interference comprises of two mechanisms. Firstly, Femtocell User Equipment (FUE) measure path-loss relationship between co-existing Femtocell Access Point (FAP) and FUE report called UE Measurement Report (UMR). After that, Femtocell Cooperation Message (FCM) gives the path-loss and traffic load information between FAP and FUE from FAP. By giving the information, the load balancing will improve the current UE and capacity that FAP can provide at one time and maintaining low interference between FAP. The outcome, it produce fairness performance per UE 68% capacity as per simulated, suitable for dense and skewed FUE distributions.

In this paper we will identify the effectiveness of various frequency reuse method in reducing interference in LTE femtocell network and to further enhance the interference reduction mechanism by optimising the power control of femtocell. This paper is organized as follows, in Section II, the proposed scheme is discussed. Section III describes the. Section IV show the simulation model and scenario parameters. Section V discusses the simulation result and Section VI concludes the paper.

II. PROPOSED CALCULATION

A urban environment for Femto-Macro LTE networks is considered. There are 2 HeNB for Femto area and 1 eNB for Macro coverage with all considering >4 UE attached by each eNB. The real will be difference since HeNB will cater up to 4 users for home usage or up to 11 users for enterprise premises. This to take consider on sub urban environment with possibility of UE at macro cell on the mobility mode. The simulation will be recorded for FUE sides as the victim of the interference occurs. Femtocell on 1st storey building, height at table top (~1meter)

A. Pathloss Model

Firstly we need to figure the path loss between femto eNB and UE equal between macro eNB and UE. The path loss for mobile macro user outdoor in an urban area can be expressed as below [9], [10]:

$$PL(dB) = 15.3 + 37.6\log_{10} R$$

Whereas, for an indoor macro user the path loss as following equation:

$$PL(dB) = 15.3 + 37.6\log_{10} R + L_{ow}$$

where R, distance(m) between the receiver, R_x and the transmitter, T_x and the L_{ow} , penetration loss of an outdoor wall.

The path loss between a femto eNB and a UE is computed as following equation [9], [10]:

$$PL(dB) = 38.46 + 20\log_{10} R + 0.7d2D_{indoor}$$

Applying $0.7d2D_{indoor}$ term need to takes account of penetration loss as walls inside the building and expressed in m.

Lastly, we consider the case of an outdoor femto user associated to an indoor femto eNB. For this situation, we consider the outdoor wall loss [9], [10]:

$$PL(dB) = \max\left(15.3 + 37.6\log_{10} R\, , 38.46 + 20\, log_{10} R\right) + 0.7d2D_{indoor}$$

B. Signal to Interference and Noise Ratio (SINR)

The main target of this approach is to mitigate interference and improve the system capacity. We use an OFDM system with a number of Resource Block (RB). We consider a building per macrocell network for simplicity. Interference between Femto and Macro is increased when same frequency band is used for them.

As the macro user interfere from neighbouring macrocell and nearby femtocell, with the calculated SINR of macro user and subcarrier. Equation as follows:

$$SINR_{m,k} = \frac{P_{M,k} G_{m,M,k}}{N_0 \Delta f + \sum_{M'} P_{M',k} G_{m,M',k} + \sum_{F} P_{F,k} G_{m,F,k}}$$

where $P_{M,m,k}$ and $P_{M',k}$ is power transmit from serving macrocell M and neighbouring macrocell M' on subcarrier k. The channel gain between macro user, m and serving macrocell, M on subcarrier, k expressed *as* $G_{mM,k}$. While $G_{m,M',k}$ is the channel gain from neighbouring. $P_{F,k}$ is transmit power of neighbouring femtocell F on subcarrier k. White noise power spectral density, N_0 and subcarrier spacing, Δf. Femto user f on subcarrier k interfered by all macrocells and nearby femtocells, the received SINR can be expressed as [9], [10]:

$$SINR_{f,k} = \frac{P_{F,k} G_{f,F,k}}{N_0 \Delta f + \sum_{M} P_{M,k} G_{f,M,k} + \sum_{F'} P_{F',k} G_{f,F',k}}$$

The path loss value will affect the channel gain; depend on outdoor and indoor scenarios. So, it can be expressed as:

$$G = 10^{-PL/10}$$

C. Throughput Calculation

After getting the SINR value thru calculation, now we can calculate the data throughput. The capacity of macro user,m on subcarrier k can be computed as the follows [9], [10]:

$$C_{m,k} = \Delta f . \log_2(1 + \alpha SINR_{m,k})$$

where, α equal constant target Bit Error Rate (BER), also expressed by $\alpha = -1.5/\ln(5BER)$. For this scenario, BER is set to 10^{-6}

Overall throughput of serving macrocell M can be consider as follows:

$$T_M = \sum_{m}\sum_{k} \beta_{m,k}\, C_{m,k}$$

where, $\beta_{m,k}$ is the subcarrier assignment for macro users. If β=1 the subcarrier k is as-signed to macro user m. Else, β=0.

At every time slot in a macrocell, each subcarrier is associate to only one macro user, same as characteristics of the Orthogonal Frequency-Division Multiple Access (OFDMA) system.

The equation as follows:-

$$\sum_{m=1}^{Nm} \beta m, k = 1$$

where the number of macro users in a macrocell, *Nm*.

Readjust FBS transmission Power periodically in order to achieve the desired SINR value at a user specified range when that is feasible. If $SINR_t$ (target SINR) and $SINR_c$ (current SINR, the converging power control algorithm is given by [11]

$$P(k+1)= (SINR_t/SINR_c)\ P(k)$$

where *P(k)* denotes the power level of FBS at the k^{th} iteration converges adequately or reaches the maximum allowed value.

III. Simulation & Result

In this section, there are several scenarios to be considered for interference cancellation. Each simulation result were recorded, tabulated and have been analyzed in detail.

A. Simulation Scenario

In this paper, it will focus on scenario of a sub urban environment for Femto-Macro LTE networks is considered. There are 2 HeNB for Femto area with 2 FUE attached by each HeNB, while 1 eNB for Macro coverage cater for 6 UE. The reality will be difference since HeNB will cater up to 4 users for home usage or up to 11 users for enterprise premises. For eNB will depend on the RRC averaging 50-75 UE per cell. Assume the simulation take place on sub urban environment with possibility of UE at macro cell on the mobility mode.

Step 1

Starting value parameter from maximum femtocell dBm until 0dBm and choosing the best power transmission required. No changes on eNB since the macrocell should considering the other edge of cell coverage

Step 2

After using optimized power transmission design, use frequency channel allocation to reduce interference and to get better throughput & lower packet loss.

Step 3

By changing the propagation model with same node allocation on the map; Okumura, Two Ray, Hata-231 for optimum result.

The simulation of parameter & design which will be simulated will be as per below Table 1 and Figure 2. The simulation shows at Figure 3.

Table 1: Simulation Parameter

Property		Value
Simulation-Time		60S
Simulation-Area		1.5Km X 1.5Km
Propagation-Channel-Frequency		2.4GHz
Propagation-Model		Two Ray Okumura Hata-231
Channel-Bandwidth		10MHz
Propagation-Speed		3x108 mps
Antenna-Model		Omni directional
Antenna-Gain		0.0dB
eNB Parameter	PHY-LTE-Tx-Power	46dBm
	Antenna-Height	20m
HeNB parameters	MAC-LTE-Scheduler-Type	Simple-Scheduler
	PHY-LTE-Tx-Power	23dBm
	Antenna-Height (Table Top)	1.0m
UE parameters	MAC-LTE-Scheduler-Type	Simple-Scheduler
	PHY-LTE-Tx-Power	23dBm
	Antenna-Height	1.5m

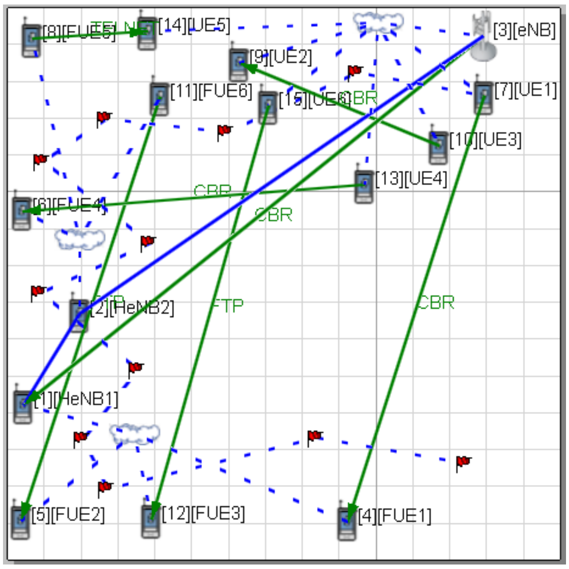


Figure 2: Simulation Design

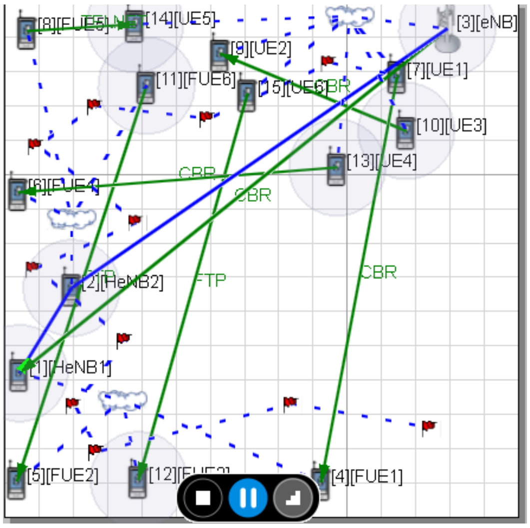


Figure 3: Simulation on Progress

B. Simulation Result

As per following step of the simulation, the result were compared and being tabulated in below following graph.

Table 2: Result for Power Adjustment

HeNB Power Tx (dBm)	Femto Data Throughput (Mbps)	Macro UE Data Throughput (Mbps)
0	24.67	49.978
4	23.56	47.08
8	22.15	45.21
12	21.75	43.123
16	20.95	42.037
23	19.87	39.89

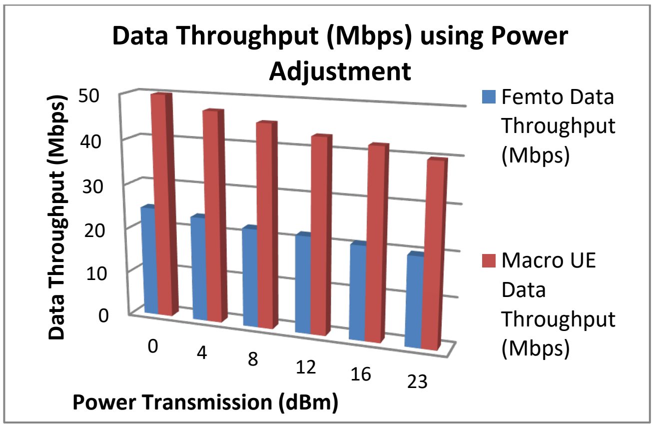


Figure 4: Throughput (dBm) Analysis of Power Transmission on Femto & Macro

As per shown at Figure 4, result shows the lower of Femto power transmission, the better throughput and lower packet loss from FUE at Figure 5 due to less interfered with the signal from macrocell with no power alteration. However the lower power transmission, the coverage will shrink.

Table 3: Result for Power Adjustment on Packet Loss

HeNB Power Tx (dBm)	Femto Packet Loss	Macro Packet Loss
0	5%	10%
4	25%	23%
8	46%	45%
12	64%	59%
16	75%	68%
23	80%	76%

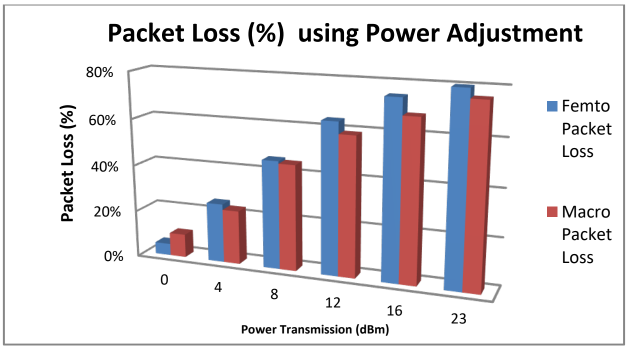


Figure 5: Packet Loss (%) Analysis of Power Transmission on Femto & Macro

For this test, assume FUE nearby the HeNB and no effect on coverage shrinking. The result will be much better as there is no interference with eNB at all.

Table 4: Result for Frequency Reuse Factor

Frequency Reuse Factor	Femto Data Throughput (Mbps)	Macro Data Throughput (Mbps)
FR-1	17.79	30.564
FR-2	19.12	38.78
FR-3	24.7	49.3

By referring to Table 4 and Figure 6, result shows that frequency reuse factor-3 & factor-2 are much improved throughput than not using any frequency reuse method (FR-1).

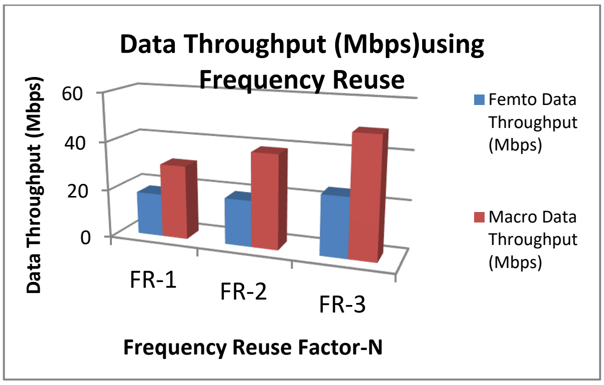
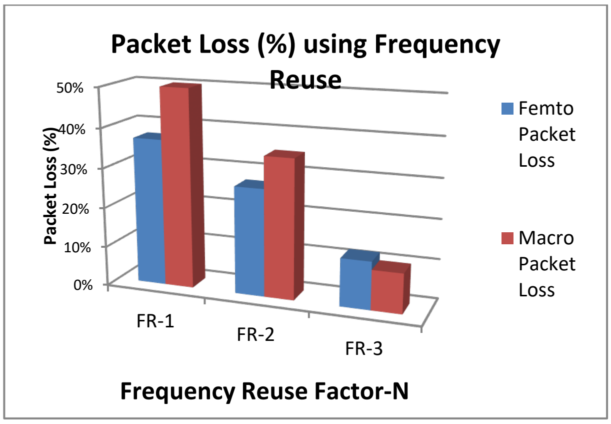


Figure 6: Analysis of Frequency Reuse

For Figure 7 below, the result for using frequency reuse method shows smaller packet loss when using frequency reuse factor-3 instead without using any frequency reuse technique.



IV. CONCLUSIONS AND FURTHER WORKS

The result conclude that interference mitigation can be reduced with various technique proper planning to be consider to avoid overlapping coverage and to provide better user experience. Femtocell is best option for operator with lowest cost of deployment compared to base station deployment due to acquisition as well on the equipment investment. Future recommendation study can considering

As for future work, it will be concentrated on simulation with building/ infrastructure to explore better view of interference avoidance method.

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