Shadowing Effect on the Area Spectral Efficiency of a Macro-Femto Heterogeneous Network for Cell-Edge Users

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Abstract **–** For rural and urban environment, the combined effect of the multiple impairments like multipath fading and shadowing result in faster reduction in the average signal strength as the distance from the single macrocell transmitter increases. These impairments affect the signal power causing users situated in the cell edge to experience poor reception. The deployment of femtocells around the cell edge region has proven to be an effective way of minimizing the shadowing and multipath effects thereby increasing the overall efficiency of any given cellular network. This paper only considered the impairment effect caused by shadowing. A Monte-Carlo simulation process has shown a much improved spectral efficiency for the Macro-Femto network than the macro-only setup. The results show that the area spectral efficiency for the macro-femto network increased to 75 bps/Hz/Km^2 for a distance of 300 m when compared to the single macro-only network which was 5.5 bps/Hz/Km^2 for the same distance.

Index Terms **-** Cell edge, Femtocells, Heterogeneous networks, Macrocells.

I. INTRODUCTION

The propagation of communication signal over a long distance faces several challenging situations like multipath fading, shadowing and total loss of signal. To meet these challenging necessities, heterogeneous network transmission techniques [1–2] are regarded to be one of the most promising solutions. One of the current heterogeneous network approaches is the deployment of low-power and low-cost femtocells within and around the main macro cellular infrastructure to service accommodate more users. This is referred to as two-tier heterogeneous network [3–4]. This promises to enhance an integration of space-based sensor networks with terrestrial mobile communications [5].

This paper considers the effect of shadowing on the area spectral efficiency (ASE) of this two-tier heterogeneous network called the macro-femto heterogeneous network (MFHN).

II. SYSTEM MODEL AND ANALYSIS

From Fig. 1, the first tier heterogeneous network comprises of the macro-only network in which the carrier frequency is re-used at a minimum distance D[m]. This first tier heterogeneous network comprises of a circular macrocell of radius R_m[m]. The user is considered to be randomly located within the macro-cell bounded by R_o and R_m, where R_o is the minimum distance a user can be with reference to the macrocell base station.

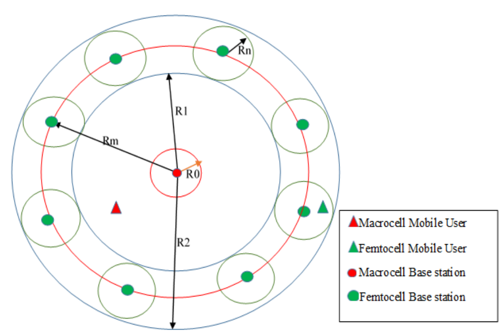

Fig. 1. Femtocells distribution at the cell edge in the Macro-Femto network.

The second tier is made up of N circular femtocells each of radius R_n[m] with low-powered low-cost user deployed femto base station at the center. The femtocells are deployed using the Femto-On-Edge (FOE) configuration in [6]. For the simulation, the number of femtocells per macrocell, N, is given as:

$$N = \mu \frac{A_m}{A_n}, \tag{1}$$

where A_m is the area of the macrocell, A_n is the area of each of the femtocells and μ is referred to as the femto population factor (FPF) which controls the number of femtocells per macrocell. Simplifying this further, gives:

$$N = \mu \frac{4 \times R_m}{R_n}. \tag{2}$$

III. SIMULATION PARAMETERS

Table 1: Simulation parameters values

Simulation parameters	Femtocell	Macrocell
System bandwidth	20 MHz	
Cell radius	30 m	100-600 m
Path-Loss Exponent	2	2
BS antenna height	5 m	25 m
Mobile User antenna height	1.5 m	1.5 m
Femto Population Factor, μ	1	
R_o	100m	

IV. RESULT AND DISCUSSION

Shadowing occurs due to objects obstructing the relative propagation path between the transmitter and receiver. For a long-distance propagation, the received signal is modelled as a log-normal distribution with values in dB. A case of light shadowing ($\sigma_d = \sigma_I$=4 dB) and heavy shadowing ($\sigma_d = \sigma_I$= 6 dB) are considered. Figure 2 shows the effect on the MFHN for a shadowing parameter of 4 dB. From Fig. 2, a Log-normal shadowing parameter of 4 dB reduces the ASE for the macro only network.

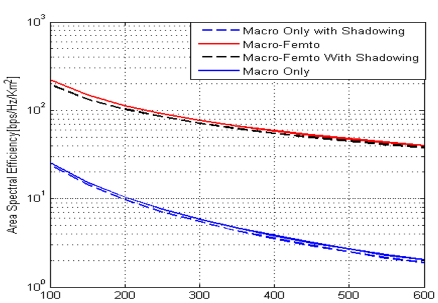

Fig. 2. Effect of shadowing on the area spectral efficiency for $\sigma_d = \sigma_I$ =4 dB.

For the macro-femto network, shadowing effect is negligible. In Fig. 3, the increase in the shadowing parameter to 6 dB further reduces the area spectral efficiency of the macro-only network. The area spectral efficiency of the macro-femto network is minimally affected. Comparing Figs. 2 and 3, the lower effect of shadowing on the macro-femto network can be attributed to the deployment of the low powered femtocells at the cell edge, which provides the platform of signal reception for the cell-edge user rather than receiving communication signal directly from the traditional macro base station which is subject to more shadowing effect.

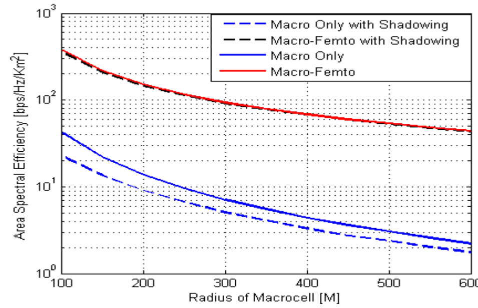

Fig. 3. Effect of shadowing on the area spectral efficiency for $\sigma_d = \sigma_I$ =6 dB.

V. CONCLUSION

A Monte-Carlo simulation process has been carried out to investigate the effect of shadowing on the area spectral efficiency of a macro-femto network. This effect is compared with a macro-only network. The simulation result shows that the shadowing effect in the macro-femto network is minimal when compared with the macro-only network. Next-generation networks will depend on heterogeneous network hybrids for a reliable seamless global communication.

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