

Improvement of Carrier to Interference plus Noise Ratio in WiMAX Networks Using Femtocell Base Station Concept

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Abstract: A Femtocell is a small cellular base station; the concept of deploying femtocells over macrocell has recently attracted growing interests in academia, industry, and standardization forums. Various technical challenges towards mass deployment of femtocells have been addressed in recent literature. Interference mitigation between neighboring femtocells and between the femtocell and macrocell is considered to be one of the major challenges in femtocell networks because femtocells share the same licensed frequency spectrum with macrocell. In this paper, we focus on how received signal quality can be improved by deploying femtocell base stations in a WiMAX system. We propose a Femtocell model to analyze the potential improvement on the CINR (carrier to interference plus noise ratio) when using different channel assignment schemes and different deployment densities of femtocell base stations within a macro cell. CINR can be enhanced when large number of femtocell base station is deployed within macro cells. Least-Interfered-First (LIF) femtocell channel assignment scheme is used to measure the lowest interfering signal level. This scheme can reduce co-channel interference induced by neighboring femtocell base stations in turn showing the improvement in CINR.

Keywords: CINR, Femtocell, macrocell, WiMAX, LIF.

1. Introduction

The demand for higher data rates in wireless networks is unrelenting, and has triggered the design and development of new data-minded cellular standards such as WiMAX. The frequency spectrum has been an important design issue in wireless networks because of more demand for higher data rates frequency bandwidth can be reduced. this increases the system capacity but it also introduces co-channel interference. A suburban model is to build understand the deployment of femtocell which will affect the received signal quality. a recent development are femtocells, also called home base stations are of short range, low cost and low power base stations installed by the consumer for better indoor voice and data reception. The user-installed device communicates with the cellular network over a broadband connection such as DSL, cable modem, or a separate RF backhaul channel. While conventional approaches require dual-mode handsets to deliver both in-home and mobile services, an in-home femtocell deployment promises fixed mobile convergence with existing handsets. Compared to other techniques for increasing system capacity, such as distributed antenna systems and microcells, the key advantage of femtocells is that there is very little upfront cost to the service provider. Studies on wireless usage show that more than 50% of all voice calls and more than 70% of data traffic originates indoors. Voice networks are engineered to tolerate low signal quality, since the required data rate for voice signals is very low, on the order of 10 kbps or less. Data networks, on the other hand, require much higher signal quality in order to provide the multi-mbps data rates users have come to expect. For indoor devices, particularly at the higher carrier frequencies likely to be deployed in many wireless broadband systems, attenuation losses will make high signal quality and hence high data rates very

difficult to achieve. To solve this problem the end user is facilitated to install a short range low power link in particular locations that is being considered. The concept of femtocell provides the mobile users with higher data rates and reliability and also reducing the amount on traffic on expensive macro cell network.

2. Proposed System

Femtocell is a small cellular base station typically designed for used in a home or small business. It includes Femtocell, Broadband router, DSL or Cable, WiMAX and Microcell base station in suburban area. Figure 1 shows the schematic of femtocell. In the proposed system a 19-macrocell structure in a suburban area, is considered as shown in Figure 2 where the coverage of each macrocell is approximated by a hexagon. The reason that a 19-macro cell structure is chosen is because the co-channel interference from macrocells beyond two tiers is negligible. Since we focus on the user SINR in a typical macro cell. In the suburban area, streets form a grid structure and run in the north-south or east-west direction. Femtocell architecture. The square blocks separated by streets. There are 100 houses within each block. Some houses have femtocell base stations installed, some have not

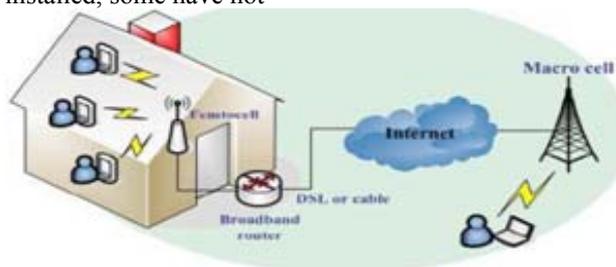


Figure 1: Schematic representation of Femtocell

Whether a house has femtocell base station or not follows a uniform probability distribution. The mean of the uniform distribution is also called the femtocell density. Users are randomly placed in the area. A user may be inside the house (indoors) or on the street (outdoors). A user may communicate with the macrocell base station or the femtocell base station, depending on the received signal strength. The CINR is calculated by considering interference from the other 18 macrocells and nearby femtocell base stations

3. Design Considerations

In the suburban area, streets form a grid structure and run in the north-south or east-west direction. Houses are situated in Figure 2 Cell Hexagon Architecture. The square blocks separated by streets. There are 100 houses within each block. Some houses have femtocell base stations installed, some have not. Whether a house has femtocell base station or not follows a uniform probability distribution. The mean of the uniform distribution is also called the femtocell density. Users are randomly placed in the area. A user may be inside the house (indoors) or on the street (outdoors). A user may communicate with the macrocell base station or the femtocell base station, depending on the received signal strength. The CINR is calculated by considering interference from the other 18 macrocells and nearby femtocell base stations

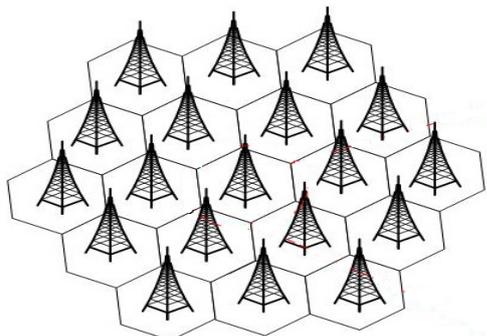


Figure 2: Cell Hexagon Architecture

4. System Parameters

The WiMAX system parameters and OFDMA parameters are chosen based on the IEEE802.16m Evaluation Methodology Document (EMD) and IEEE802.16-2004. These parameters are shown in Table 4.1 and Table 4.2. Femtocell base stations will be deployed in a great quantity. However, it is not necessary to calculate the interferences from all femtocells to a user because femtocell base station is a low power home device. Therefore, when calculating the interference from femtocells, I ignore the interference from femtocells that are at least 200 meters away

Table 4.1 System Parameters

Parameter	Value
Macrocell Transmit Power [dBm]	46.532(45W)
Femtocell Transmit Power [dBm]	10.02(.01W)
Macrocell Coverage Range [m]	1000
Femtocell Coverage Range [m]	30
Macrocell Antenna Height [m]	12.5
Mobile Station Antenna Height [m]	1.5
Noise Figure [dB]	5
Noise Power [dBm]	-169.93+10log10 (BW)

Table 4.2: OFDMA parameters

Parameter	Value
Carrier frequency [GHz]	2.5
Channel Bandwidth [MHz]	10
FFT size	2048
Frame duration [ms]	5
OFDMA symbol duration [gs]	102.86
Permutation type	PUSC
Number of sub channels	60
Number of subcarriers	28
Number of sub channels per MS	2

A house occupies a 14x14 meter square area, centering within a 20x20 meter square land. Therefore the distance between two neighboring houses in the same block is 6 meters. The width of the street is assumed to be 30 meters. In Figure 3 shows the relationship among houses, blocks and streets. Each side of a square block is 200 meter long and 100 houses are located within each block.

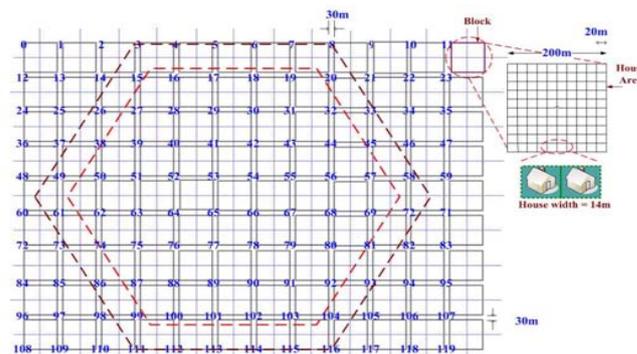


Figure 3: Streets, blocks, and houses in a macrocell

4.1 Frequency Reuse

Since the Femtocell is deployed within the coverage of a macrocell and it is also within the interference range of several neighboring macrocells and femtocells, it should try to avoid using the same frequency channels as those used by neighbor cells. On the other hand, there are limited frequency channels for the wireless communication system. Frequency reuse with minimized co-channel interference is common practice to increase the system capacity. For frequency reuse at the macrocell level, the following (c, s, n) notation is used. The number c represents how many cells share the frequency spectrum. It is also called the frequency reuse factor or the cluster size. For example, if c is equal to 1, it represents that all neighboring cells use the same set of frequency channels. The number s represents the number of sectors in each cell. If s is 3, it means that each cell is divided into 3 sectors and the angle of each cell is 120 degrees. An example of the resulting channel reuse pattern is shown in Figure 4.

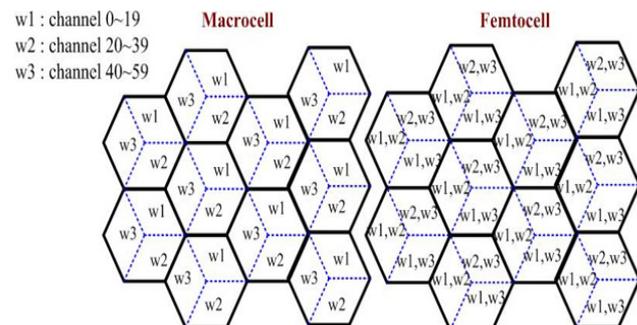


Figure 4: frequency reuse for macrocells and the resulting femtocell frequency reuse pattern

For the Femtocell, I choose to allow it to use the frequency channel that does not overlap with the channels that its sector is allocated. The implementation of frequency reuse at femtocell density 0.5 is as shown in Figure 5

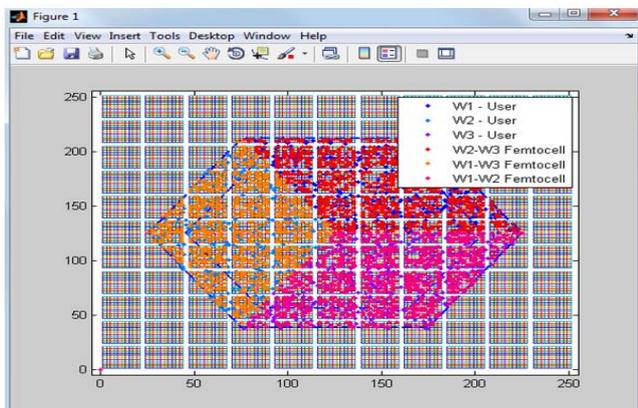


Figure 5: Frequency reuse concept illustrated when Femtocell density is 0.5

5. Results and Analysis

The only channel assignment requirement is to make sure that any two users in the same macrocells do not use the same channels. In the following, I compare the random channel assignment and LIF channel assignment for femtocell users in terms of the average CINR and probability that an arbitrary user will connect to the femtocell. Primarily used channel assignment strategy is Random Channel assignment. In this I propose a new channel assignment strategy i.e. Least Interference First Channel assignment strategy. First I will discuss about the Random channel Assignment Strategy.

5.1 Random channel Assignment Strategy

When a user connects to the femtocell, the femtocell randomly assigns a channel from the allowed groups of channels to the user. Table 5.1 shows the average CINR and the probability that an arbitrary user will choose to connect to the femtocell. It can be seen that when the density of the femtocell base station becomes higher, the probability of connecting to a femtocell becomes higher, and the system average CINR improves more. In the environment without the femtocell base station, the average CINR is 15.32dB. When the femtocell density is 0.1, 0.5, and 0.9, the average CINR improves by approximately 1.3dB, 7dB, and 12 dB, respectively.

Table 5.1 The Average CINR and Probability of Connecting to Femtocells with the Random Channel Assignment

Femtocell density	Average CINR prob.	Prob. connecting to Femtocell
0	15.32	0
0.1	16.78	0.046
0.5	22.21	0.224
0.9	27.82	0.412

It is obvious that CINR varies as the user (MS) moves in and out of houses. The total moving distance is 190m and the distance from the macrocell BS is roughly 780m. Will calculate the received CINRs with respect to the serving macrocell and femtocell (with the strongest RSS) as the MS moves and plot the stronger of the two CINR in Figure 6. The stronger CINRs (in the 50-60dB range) occur mostly when the MS is indoors. The MS connects to the femtocell BS in this case. As the MS moves out of the house, the femtocell BS signal attenuates severely through the wall so that the MS will pick up the stronger signal (roughly 10dB in CINR) from the Macrocell BS and thus choose to connect to macrocell BS. Figure 6 plots the cumulative distribution function (CDF) of the CINR. It can be seen that as more femtocells are deployed, the probability of getting high CINR (larger than 50 dB) becomes higher. On the other hand, if observe the low 5 percentile, it is found that only roughly 1dB and 2dB improvement for femtocell density at 0.5 and 0.9, respectively.

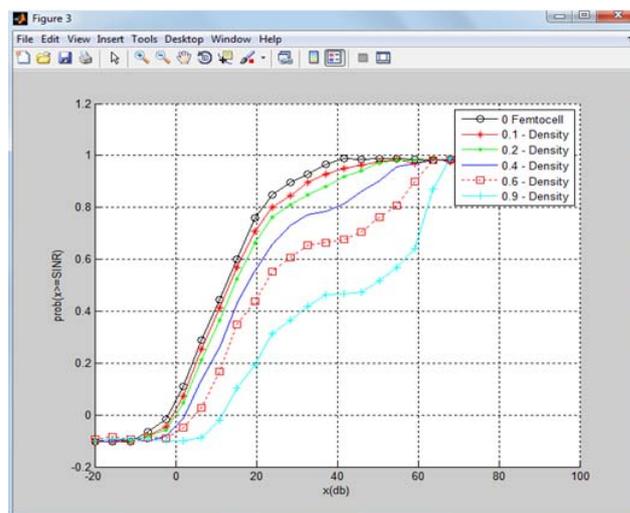


Figure 6: The CDF of CINR with random channel assignment

Figure 7 shows the CINR probability density function (pdf) for femtocell density=0.1. Without the femtocell base stations, the CINR pdf has a peak near CINR= 5dB. As the femtocell density increases, the peak at 5dB drops and peaks near -5 dB. Notice that the gain peaks in -ve dB, it's obvious as the femtocell density increases.

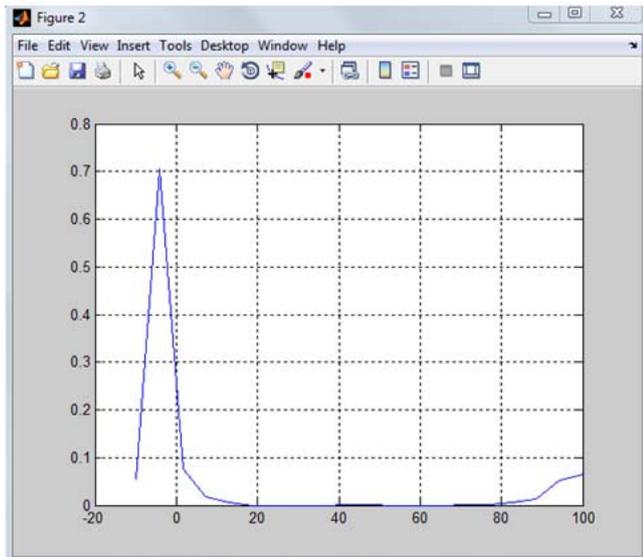


Figure 7: The PDF of CINR with the random channel assignment scheme for Femtocell density 0.1.

5.2 LIF Channel Assignment

Table 5.2 shows the average CINR and the probability that an arbitrary user will choose to connect to the femtocell when the LIF mechanism is used. Similar to the random channel assignment scheme, when the density of the femtocell base station becomes higher, the probability of connecting to a femtocell becomes higher, and the system average CINR improves more. When the femtocell density is 0.1, 0.5, and 0.9, the average CINR improves by 1.5dB, 7.5dB, and 14.5dB, respectively

Table 5.2. The average CINR with the LIF scheme.

Femtocell density	Average CINR prob.	Prob. connecting to Femtocell
0	15.32	0
0.1	16.78	0.046
0.5	22.80	0.224
0.9	29.80	0.412

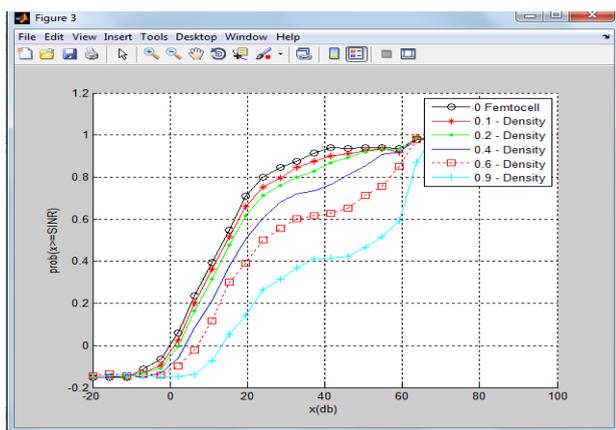


Figure 8: The CDF of CINR with LIF channel assignment scheme.

In comparison with the random channel assignment (Table 6.1), the LIF scheme improves the average CINR by up to 2dB (at femtocell density=0.9). This is not a great deal of improvement by considering the amount of extra effort needed for the LIF to work. Figure 8 is the CDF of CINR when the femtocell uses the LIF channel assignment scheme. It is very similar to the CDF in Figure 6. The low 5

percentile is improved by about 3dB when the femtocell density is 0.9, a little better than when the random channel assignment scheme is used.

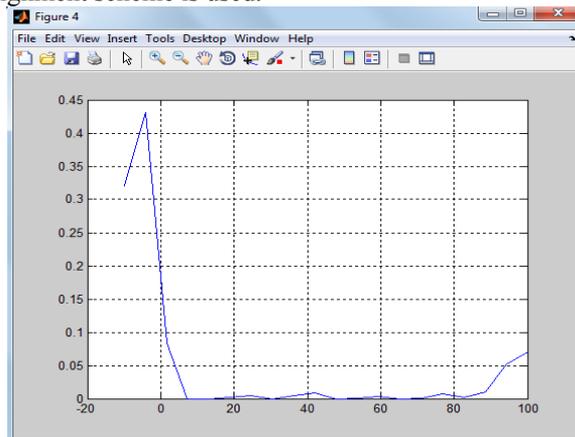


Figure 9. The probability distribution functions of CINR with the LIF channel assignment scheme with Femtocell density 0.1.

6. Conclusion

Femtocell is going to be upcoming technology in telecommunication industry; in this paper I have proposed a suburban femtocell model that is suitable for evaluating the CINR improvement when femtocell base stations are deployed in a WiMAX network. The model considers how femtocell base stations are placed, how frequency reuse is configured, along with appropriate path loss models for different user-BS communicating scenarios. The major benefit of deploying femtocells is in its improvement of the indoor users CINR to the 50-60dB range. As more femtocells are deployed, more indoor users connect to the femtocell instead of the macro cell, greatly increasing the average CINR.

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