AN INVESTIGATION OF THE INFLUENCE OF FEMTOCELLS NETWORK ON A SMALL SIZE INDOOR ENVIRONMENT USING ITU-R AND WINNER II PATH LOSS MODELS

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Abstract

The rapid integrations of wireless controls in mechatronics, the broadening applications of wireless radio communications in aviation, and the exponential increase in the growth of mobile phone users in the last decade have made it necessary to expand the capacity of GSM users and ultimately increase the system performance. It has also become imperative for service providers to ensure adequate coverage is provided for all mobile users in areas with poor or no service. Even though many solutions such as distributed antenna system, relays, macrocells, and picocells were developed but they could not proffer the needed solution to indoor users. In this perspective, researchers were of the opinion that femtocells have a gifted technology to enhance indoor coverage because of properties such as short power, short coverage area, reduced distance between device and user and being a plug and play device. It was however discovered that research findings on large deployment of femtocells does not corroborate when a handful is deployed. This study therefore examines the influence of femtocells network on a small size indoor environment using ITU-R and WINNER II path loss models. To accomplish this, femtocells were modeled in six apartments of a building and parameters such as path loss, received power and signal to interference plus noise ratio were determined to ascertain the performance of a particular femtocell under the influence of co-tier interference. Results show that the ITU-R model was found to experience lower path losses which produced higher received powers than WINNER II (-57.0445dBm on the average).

Keywords: ITU-R, WINNER II, Path loss, Femtocell

1. INTRODUCTION

Telecommunication engineering industry is found to be one of the fastest growing industries in the world today, which finds practical applications in many high-tech fields including mechatronics, medicine, security and aviation—despite the accompanying aviation noise pollution etc. [1]. The need for more capacity for mobile operations cannot be overemphasized. As the costs of mobile phones and rate of calls are gradually falling, the number of users is increasing. Globally, subscribers now use more of voice and data services with their respective phones in indoor areas. Research has proven that 60% of the entire voice calls and 65% of the entire data traffic is from indoor environments. Indoor users are faced with poor coverage resulting from penetration loss from walls and underground regions thereby leading to overall signal loss because of attenuation. This is penetration loss from walls is due to density and type of walls. The conventional macrocells which stimulates wireless devices can no longer provide adequate coverage for indoor users since the distance between such macrocells and such indoor users are very large.
Femtocells were predicted and introduced as solution to bad signal coverage within indoor areas. Femtocells are otherwise known as home evolved node base stations (HeNBs) which works with the conventional macrocells using the same electromagnetic spectrum. The HeNBs gateway serves as the mediator between HeNBs and the core of the mobile network. It is able to connect with the core operator’s network through broadband internet services. The coverage distance (10-30m) and power (10-100mW) of femtocell is kept low so that it can have minimal interference with macrocells. It can communicate with four or more indoor users at the same time depending on the hardware technology. Due to the two layer design of femtocells, co-tier interference becomes a serious threat if the network is not planned to accommodate such interference. Also when an area is covered with large number of femtocell coexisting with macrocell, then cross-tier interference may likely occur. Femtocells can be deployed in both urban and rural regions where there is dearth of such base stations within a macrocell base station to ensure overall efficiency of the system. Managing femtocells from a centralized controller is practically unrealistic because of the unplanned nature of deployment [2].

To tackle interference problems without central controller, some procedure is essential to avoid interference as much as possible. Such techniques have been adopted by computing true life situations, generating models and analyzing parameters such as path loss, received power, signal to interference plus noise ratio. These parameters are then used to execute interference minimization scheme and performance of the system. The path loss models employed in this study are ITU-R and WINNER models to determine the parameters stated in the long term evolution (LTE) between femtocell base stations and their users. Path loss or attenuation takes place naturally with distance. The quantity of path loss is determined by frequency of signal and hindering material type and thickness. In general, when the frequency of communication is reduced then a better signal will travel through air and objects. In [3], power control method was adopted. This is a scheme where femtocells are employed to counter the interference in the system. As long as the transmission power of femto base station is controlled and optimized, the macro user is also secured. He highlighted open loop power settling and close loop power settling. These two methods reduce the interference of the macro users originated by femtocell. Femto aware spectrum technique was developed by [4] to put off uplink cross tier interference. The available spectrum is shared into two portions namely: devoted channel for macrocell only and the remaining is shared mutually between macrocells and femtocells. [5] Worked on resourceful channel allotment using open access mode, close access mode and hybrid access mode. For open access, all the users within femtocell coverage are automatically permitted access to femtocell. For close access, only the users subscribed to femtocell coverage area are permitted access. For hybrid users, precedence is given to users that subscribe to femtocell. The aim of this research is to conduct an investigation into the influence of femtocells network on a small size indoor environment using ITU-R and WINNER II path loss models while the specific objectives are to deploy femtocell in apartments on a small scale, to determine path losses for each user using the models considered, to determine the received powers and to determine signal to interference plus noise ratio (SINR) [6] [7] [8] [9].
2. METHODOLOGY

2.1 Introduction

Femtocells are deployed within apartments of a building with minimum of one user in each apartment. As shown in Figure 2. Based on the number of walls between femtocells, users and path loss models used, path losses are determined for each user with respect to the base stations adopted. Other parameters such as received powers and SINR are subsequently obtained.

Fig 2: Small scale deployment of femtocells in a building

2.2 ITU-R P1238-7 Model

This is known as international telecommunication union radio communication path loss model developed to be engaged in situations within indoor environments [10]. This model is to be operated
on frequencies between 900MHz-6GHz. The path losses are for both line of sight and non-line of sight as shown equations (1) and (2)

\[ L_{LOS} = 18 \cdot \log(f_c) + y \cdot \log(x) - 28 \]  

\[ L_{NLOS} = 18 \cdot \log(f_c) + y \cdot \log(x) + 4n_w - 28 \]  

Where;
- \( f_c \) = carrier frequency in MHz
- \( y \) = Coefficient of Power loss = 28
- \( x \) = distance between femtocell and user
- \( n_w \) = number of walls

### 2.3 WINNER II D112 V1.2 Model

This path loss model is known as the Wireless World Initiative New Radio (WINNER) developed to improve performance of mobile communication. It was adopted for different situations ranging from indoor to outdoor environments and the frequency range is 2 to 6 GHz [10-11].

\[ L_{LOS} = 46.8 + 20 \cdot \log \left( \frac{f_c}{5} \right) + 18.7 \cdot \log(x) \]  

\[ L_{NLOS} = 46.4 + 20 \cdot \log \left( \frac{f_c}{5} \right) + 20 \cdot \log(x) + 5(n_w - 1) \]  

Channel gain \((G)\) = \( \frac{\text{Power Received(PR)}}{\text{Power Transmitted(PT)}} \) \( \frac{P_r}{P_t} \)  

Therefore, path loss \((L)\) in terms of channel gain = \( \frac{1}{G} \)  

\[ \frac{1}{L} = \frac{P_t}{P_r} \]  

\[ P_r = \frac{P_t}{L} \]  

\[ P_r = P_t - L \text{ (dBm)} \]  

SINR = \( \frac{P_r}{I + T_N} \)  

Where;
- \( P_r \) = Power received
- \( I_t \) = Total interference power based on femto user (Power receive from other femtocell base station)
- \( T_N \) = Thermal noise at 150 KHz

### 3. RESULT AND DISCUSSION

Table 1: Input parameters and their values

| Parameter                  | Value    |
|----------------------------|----------|
| Number of femtocells       | 6        |
| Apartment size (m)         | 4m by 4m |
| Number of femto users      | 12       |
| Carrier frequency          | 2GHz     |
| Carrier bandwidth          | 150KHz   |
| Transmission Power         | 18dBm    |
Table 2: Distance between femtocells and FUEs in meters (m)

| FEMTOCELLS/ USERS | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 | F10 | F11 | F12 |
|-------------------|----|----|----|----|----|----|----|----|----|-----|-----|-----|
| FBS1              | 4.1| 5.2| 5.0| 5.0| 3.0| 5.1| 8.1| 9.8| 8.0| 10.0| 11.4| 12  |
| FBS2              | 5.1| 6.8| 1.4| 2.0| 5.1| 4.1| 3.2| 5.2| 6.4| 7.8  | 7.3  | 9.4 |
| FBS3              | 10.0| 8.1| 6.1| 5.4| 7.8| 5.7| 2.2| 7.0| 5.1| 5.1  | 2.8  | 5.8 |
| FBS4              | 8.1| 14.1| 7.0| 6.1| 3.0| 4.5| 8.1| 9.3| 5.8| 7.6  | 10.0 | 9.5 |
| FBS5              | 13.0| 9.0| 9.9| 8.5| 7.6| 6.4| 7.6| 1.0| 3.6| 3.0  | 6.1  | 3.6 |
| FBS6              | 15.1| 13.9| 11.2| 10.0| 11.2| 9.1| 7.3| 7.1| 6.3| 4.5  | 3.2  | 2.8 |

Table 3: Distance between FBSs in meters (m)

| FBS1 | FBS2 | FBS3 | FBS4 | FBS5 | FBS6 |
|------|------|------|------|------|------|
| FBS1 | 6.4  | 9.8  | 4.2  | 10.4 | 14.1 |
| FBS2 | 5.2  | 8.1  | 10.0 | 10.4 |      |
| FBS3 | 10.0 | 8.1  | 5.8  |      |      |
| FBS4 | 7.0  | 12.1 |      |      |      |
| FBS5 |      |      | 6.4  |      |      |
| FBS6 |      |      |      |      |      |

Table 4: Number of walls between FUEs and FBSs

| FEMTO USERS | Number of walls |
|-------------|-----------------|
| F1          | w.r.t.FBS1: 1, 1, 2, 1, 2, 3 |
| F2          | w.r.t.FBS2: 1, 1, 2, 1, 2, 3 |

Cell Layout

|                | Circular cell |
|----------------|---------------|
| Thermal noise  | -121.42dBm/Hz |
| FEMTO USERS | ITU-R (dB) | w.r.t.FBS1 | w.r.t.FBS2 | w.r.t.FBS3 | w.r.t.FBS4 | w.r.t.FBS5 | w.r.t.FBS6 |
|-------------|-----------|------------|------------|------------|------------|------------|------------|
| F1          | 48.57649  | 55.2305    | 67.4154    | 60.8512    | 70.60895   | 76.42989   |
| F2          | 51.46663  | 58.72879   | 64.8512    | 67.59668   | 66.13733   | 75.42295   |
| F3          | 54.9897   | 35.51012   | 37.40778   | 39.08132   | 67.29633   | 72.79664   |
| F4          | 54.9897   | 39.84738   | 55.92557   | 57.40778   | 65.44227   | 71.41854   |
| F5          | 48.77794  | 55.2305    | 64.39719   | 44.77794   | 60.8132    | 68.79664   |
| F6          | 55.2305   | 52.57649   | 50.8304    | 49.70849   | 57.99158   | 66.2717    |
| F7          | 64.8512   | 49.56274   | 41.00637   | 64.8512    | 60.8132    | 59.59158   |
| F8          | 67.17287  | 55.46663   | 55.08132   | 66.53606   | 35.41854   | 59.25377   |
| F9          | 64.70506  | 61.99158   | 55.2305    | 56.79452   | 46.99501   | 57.80008   |
| F10         | 67.41854  | 64.39719   | 55.2305    | 60.8132    | 44.77794   | 53.70849   |
| F11         | 73.01188  | 63.59158   | 47.93896   | 67.41854   | 57.40778   | 53.87627   |
| F12         | 73.63561  | 66.66612   | 56.79452   | 66.7948    | 50.99501   | 43.93896   |

Table 5: Path loss using NLOS ITU-R P1238-7 Model

| FEMTO USERS | WINNER (dB) | w.r.t.FBS1 | w.r.t.FBS2 | w.r.t.FBS3 | w.r.t.FBS4 | w.r.t.FBS5 | w.r.t.FBS6 |
|-------------|-------------|------------|------------|------------|------------|------------|------------|
| F1          | 105.6969    | 112.5926   | 123.4412   | 116.6109   | 125.7201   | 132.0207   |
| F2          | 107.7613    | 115.0914   | 121.6109   | 121.4256   | 122.5261   | 131.3008   |
| F3          | 112.4206    | 96.3676    | 114.1478   | 115.3432   | 123.3539   | 129.4256   |
| F4          | 112.4206    | 99.4618    | 113.0891   | 114.1478   | 122.0296   | 128.4412   |
| F5          | 107.9836    | 112.5926   | 121.2831   | 102.9836   | 116.0575   | 124.4256   |
| F6          | 112.5926    | 110.6969   | 118.5587   | 106.5055   | 114.5648   | 122.622    |
| F7          | 121.6109    | 108.5442   | 100.2597   | 121.6109   | 116.0575   | 115.7077   |
| F8          | 123.2657    | 112.7613   | 110.3432   | 122.8109   | 98.4412    | 115.4664   |
| F9          | 121.503     | 119.5648   | 112.5926   | 113.7098   | 104.5672   | 114.428    |
| F10         | 123.4412    | 121.2831   | 112.5926   | 116.0575   | 102.9836   | 111.5055   |
| F11         | 129.5793    | 120.7077   | 107.3844   | 123.4412   | 114.1478   | 103.5442   |
| F12         | 130.0248    | 122.9038   | 113.7098   | 122.9957   | 109.5672   | 102.3844   |
Figure 3: Path loss with respect to FBS1

Figure 4: Path loss with respect to FBS2
Figure 5: Path loss with respect to FBS3

Figure 6: Path loss with respect to FBS4
Figures 1 to 8 show that every femtocell experiences diverse path loss due to different distances as obtained in table 1. It also shows that as femto users are farther away from femto base stations, the path losses increase but decreases when users are at close proximity to the femtocells. Comparing the two path losses considered, ITU-R model shows much lower path losses (57.04449 on the average) owing to the disparities in penetration loss of walls and power loss coefficient.

Table 7: Received Power using NLOS ITU-R P1238-7 Model

| FEMTO USERS | ITU-R (dBm) |
|-------------|-------------|
|             | w.r.t.FBS1  | w.r.t.FBS2  | w.r.t.FBS3  | w.r.t.FBS4  | w.r.t.FBS5  | w.r.t.FBS6  |
| F1          | -30.5765    | -37.2305    | -49.4185    | -42.8561    | -52.609     | -58.4299    |
| F2          | -33.4666    | -40.7288    | -46.8561    | -49.5967    | -48.1373    | -57.423     |
| F3          | -36.9897    | -17.5101    | -39.4078    | -41.0813    | -49.2963    | -54.7966    |
| F4          | -36.9897    | -21.8474    | -37.9256    | -39.4078    | -47.4423    | -53.4185    |
Table 8: Received Power using NLOS WINNER II D112 V1.2 Model

| FEMTO USERS | WINNER (dBm) |
|-------------|--------------|
|             | w.r.t.FBS1   | w.r.t.FBS2   | w.r.t.FBS3   | w.r.t.FBS4   | w.r.t.FBS5   | w.r.t.FBS6   |
| F1          | -87.6969     | -94.5926     | -105.441     | -98.6109     | -107.72      | -114.021     |
| F2          | -89.7613     | -97.0914     | -103.611     | -103.426     | -104.526     | -113.301     |
| F3          | -94.4206     | -78.3638     | -96.1478     | -97.3432     | -105.354     | -111.426     |
| F4          | -94.4206     | -81.4618     | -95.0891     | -96.1478     | -104.03      | -110.441     |
| F5          | -89.9836     | -94.5926     | -103.283     | -84.9836     | -98.0575     | -106.426     |
| F6          | -94.5926     | -92.6969     | -100.559     | -88.5055     | -96.5648     | -104.622     |
| F7          | -103.611     | -90.5442     | -82.2897     | -103.611     | -98.0575     | -97.7077     |
| F8          | -105.266     | -94.7613     | -92.3432     | -104.811     | -80.4412     | -97.4664     |
| F9          | -103.503     | -101.565     | -94.5926     | -95.7098     | -86.5672     | -96.428      |
| F10         | -105.441     | -103.283     | -94.5926     | -98.0575     | -84.9836     | -93.5055     |
| F11         | -111.579     | -102.708     | -89.3844     | -105.441     | -96.1478     | -85.5442     |
| F12         | -112.025     | -104.904     | -95.7098     | -104.996     | -91.5672     | -84.3844     |

Table 7 and Table 8 show Received Power using NLOS ITU-R P1238-7 and Received Power using NLOS WINNER II D112 V1.2 Models. They were obtained through distances of femtocells from one apartment to another as shown in Tables 1 to 3. These received Powers were employed to determine the various throughputs obtained afterwards.
Figure 9: Received power with respect to FBS1

Figure 10: Received power with respect to FBS2
Figure 11: Received power with respect to FBS3

Figure 12: Received power with respect to FBS4
Figures 9 to 14 show the power received for individual femtocells and users for WINNER II and ITU-R models. The ITU-R model was found to experience lower path losses which produced higher received powers than WINNER II (-57.0445dBm on the average).
Figure 15 shows SINR plot for twelve users where ITU-R model has higher SINRs compared to WINNER II model. It means interference is more paramount in WINNER II model. This interference problem in WINNER II model is a result of high concrete penetration wall.

4. CONCLUSION
This study considered deployment of indoor femtocells on small scale. Indoor penetration loss is a key parameter in this study. SINR plot for twelve users was obtained where ITU-R model has higher SINRs compared to WINNER II model. It also shows that as femto users are farther away from femto base stations, the path losses increase but decreases when users are at close proximity to the femtocells. It was also observed that the power received for individual femtocells and users for WINNER II and ITU-R models were obtained. The ITU-R model was found to experience lower path losses which produced higher received powers than WINNER II (-57.0445dBm on the average).
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