INTERFERENCE MITIGATION AMONG INDOOR PHONE SUBSCRIBERS IN LTE BASED HETEROGENEOUS NETWORKS USING FAST RESPONSE FREQUENCY REUSE TECHNIQUE

Osagie Ibhadode¹, A. Adekunle¹, C. O. Nwafor¹, I. I. Umanah¹

¹Nigerian Building and Road Research Institute (NBRRI), Km 10 Idiroko Road, Ota, Ogun state, Nigeria.
(Federal Ministry of Science and technology, Abuja, Nigeria)

Corresponding Author: Osagie.ibhadode@gmail.com

Abstract
Mobile phone users both for voice and data have increased tremendously in the last decade thereby making it necessary for service providers in the telecommunication industry maintain quality of service as much as possible. The huge complaint from indoor mobile users concerning signal coverage and capacity has made it a necessity to conduct this research. The aim of this research is to minimize interference among indoor phone subscribers in long term evolution (LTE) based heterogeneous networks using fast frequency reuse technique. Femtocells are deployed in varying number within the macrocell coverage area. For communication between femto and macro users within the network, a fast frequency response technique was proposed and parameters such as path loss, SINR and channel capacities were determined to ascertain the level of performance of the system when compared with a situation with random and unplanned deployment. Results show that a high SINR results when the bit error rate is low, this consequently improves communication and throughput in the network. The high values of throughputs for edge macro-femto users compared to inner edge-macro users are due to distance of macro and femto users from the macrocell. As femtocells increase for edge macro-femto users within the coverage area, throughputs reduced gradually

Keywords: Femtocell, Interference, Indoor, Throughput

1. INTRODUCTION
The world of telecommunication has become one of the fastest growing construction industries recorded by researchers. Cell phone networks are now on the increase on daily basis so there is a high demand for extra capacity among users. The high rise of cell phone subscribers in both rural and urban cities, [with the noise emissions from cell towers and the accompanying hazardous effects] have made it a herculean task for macrocells providers to deal with capacity and coverage problems. It has been discovered that the deployment of femtocells within the network of macrocells without proper coverage strategy made it difficult to maintain quality of service [1-5]. Despite the gradual increase in the cost of mobile phones, there is an alarming increase in the number of cell phone users. Users globally are not merely using more voice services but also using more data services accordingly. Coverage problems in several parts of urban areas are due to wall attenuation in indoor and underground locations. Service providers have to ensure solutions are provided using the limited spectrum available. Smaller cell sizes such as microcells and nanocells have been used to gain more capacity in urban centers and to improve coverage too [6-8]. These are quite effective but also exorbitant as they require huge capitals in securing sites, equipment, connections and logistics.
The dire need to employ femtocells has become necessary as it offers a better approach and solution to interference challenges as compared to other devices. They operate with low power and can cover short range for users. They can communicate with about five users at the same time [2]. As femtocells are installed indoors, they will definitely assist in achieving better indoor coverage [3] because of the distance between such femtocell and its user. It will be of great advantage to people in rural areas because it will make them enjoy better coverage. This femtocell is a smaller system when compared with macrocell in terms of coverage radius, size and capacity for users depicted in Figure 1. Femtocell employs the electromagnetic license spectrum in conjunction with macrocell base station through broadband modem or internet within the operator’s network as shown in Figure 2. Spontaneous deployment of large numbers of femtocell devices within a particular coverage is bound to result in interference problems which will lead to inadequate performance of the system. This study is meant to uncover a model that can reduce interference within femtocell network especially when there is vast deployment and to reduce interference situations among indoor phone subscribers in LTE based heterogeneous networks using fast frequency response technique while the specific objectives are to describe how fast frequency response technique works, to compare with non-frequency reuse using MATLAB simulation, to evaluate performance of the system and discuss results obtained

1.1 The shortcomings of Macrocell Base Station
- Coverage in areas closer to the boundary of the covered region may prove to be inadequate and unreliable because of inter-cell interference and propagation loss [9-10].
- Reduced throughput and spectral inefficiency are somewhat expected which ultimately diminish the performance of the system.
- Data rate for each user reduces during data transmission when there is latency thereby leading to capacity constraints for a base station at a given time.
- The exponential growth in demand for data and consequent increase in power consumption in macrocell increases the monetary cost for operators and power utilized by users.
Figure 1: A Typical Macrocell Tower

Figure 2: Femtocell deployed within macrocell network

Table 1: Power and coverage comparison for base stations [11]

| Cell Type  | Coverage Radius | Power range  | Installed by     | Connection type | Price    | Capacity          | Primarily Used |
|------------|-----------------|--------------|------------------|-----------------|----------|--------------------|----------------|
| Macrocell  | Above 1km       | 20w to 160w  | Network Operator | Wireless        | Expensive| 1000 users and beyond | Outdoor        |
| Microcell  | 250m to 1km     | 2w to 20w    | Network Operator | Wireless        | Cheap    | Above 500 users    | Indoor         |
1.2 Benefits of Femtocells to Operators and Users

From the operator’s point of view [12-13]:

- Femtocell helps to control the exponential growth of traffic.
- It helps to increase the reliability of macrocell network.
- It saves backhaul cost for mobile operators.
- Physical coverage distance from each tower is extended because of offloading.
- It provides an improved infrastructure and capital cost.
- It uses the licensed electromagnetic spectrum allocated to service providers.
- It uses the same protocols as macro cellular network.
- It improves capacity by reducing the number of phones trying to use the network.
- It improves coverage indoors and minimize loss of signal through buildings.

From the user’s point of view:

- It provides better indoor signal strength and high data rates.
- It provides improved quality of service in indoor environment.
- It provides extension of battery life for user because of reduced transmitter and receiver distance.
- It expends less power for communication and very affordable to purchase.
- It can control and interact among home devices from a distance.

1.3 Different Categories of Interferences Among Mobile Users

Figure 2 depicts a heterogeneous network where macrocell base station is superimposed with different femtocell base station. Every user is found to communicate on a particular subcarrier frequency that is equivalent to the base station that gives the strongest signal strength. It is important to note that interference is bound to occur if a different base station communicate or uses such sub-channel that has an already established communication session.

1.3.1 Co-Tier Interference

This kind of interference takes place between adjacent or nearby femtocells [14]. When femtocell user equipment uses the same sub-channel as the neighboring femto base station, uplink co-tier interference occurs as shown in Figure 3. In the same way, a femtocell base station that communicates on the same sub-channel as the neighboring femto user results into downlink co-tier interference. In the first case, the femto user is the invader while the sufferer is the femto base station. The second case shows that femto base station is the invader and the sufferer is the femto user.

1.3.2 Cross-Tier Interference
This is an interference involving combination of femtocells and macrocells. Once a femto user and macro user interferes with neighboring MBS and FBS respectively then uplink cross-tier interference occurs [15]. Also, if the MBS and FBS interfere respectively with neighboring macro user and femto user, then downlink cross-tier interference occurs.

![Figure 3: Mobile wireless network showing expected and interfered signals](image)

| Communication devices/Interfering signals | Descriptions                  |
|------------------------------------------|-------------------------------|
| Femtocell base station                   |                               |
| Femto user                               |                               |
2. METHODOLOGY

2.1 SYSTEM MODEL
Frequency reuse is such that macrocell coverage is divided into center zone and edge zone with 8 sectors in each zone to ensure that interference between users and base stations are below harmful level. Each zone is assigned different frequency subbands. The center zone macro users (MUs) are allocated sub band $A$. The rest of the sub channels are divided into 8 sub bands ($B, C, D, E, F, G, H$ and $I$) at the edge zone sectors as shown in figure 3. Frequency reuse factor of 1 is applied to the center zone while 8 applied to the edge zone MUs. Any MU located in the edge zone of macrocell with sub band $B$ will experience inter cell interference from any other MU in the edge zone using the same sub channel or frequency as MU in $B$. This means that cell edge macro users may not interfere with neighboring cell edge zone macro users if frequency reuse is adopted. Also, Intra cell interference is minimized because center zone MUs do not share same spectrum with edge zone MUs which means that cell edge zone macro users do not interfere with center zone macro users. When HeNB is deployed, it senses the neighboring macrocell signals and chooses sub bands not used in the macrocell sub area because of the small Power of HeNB. When HeNB is located in the center zone, it avoids the subband used in the center zone, Subband used by macrocell in the edge zone of the current sector and two subbands that are used by macrocell in edge zones adjacent to current sector. For example, When HeNB is in the edge zone 01, it would use sub band $A, C, D, E, F, G, H, I$ and exclude $B$ since $B$ is already used by the macrocell in 01 as depicted in figure 3. When HeNB is in the center zone 11, it avoids $A, B, C$ and $I$ since the received signal power of $C$ and $I$ would be relatively strong for that HeNB. Therefore, HeNB in 11 would use $D, E, F, G$ and $H$. With reduced macrocell sub area a HeNB has more frequencies to select thereby reducing interference significantly. Interfering femtocells are those within a circular
coverage radius of 50m centered at a femto user or macro user under consideration [4]-[17]. Each of femto users communicates with the femtocell with the strongest signal as shown in figure 2.2.

Figure 4: The proposed fast frequency reuse scheme

Figure 5: A network of seven Macrocells
2.2 Operational Algorithm

**Algorithm 1**: Algorithm for fast frequency reuse

**INPUT**: MBS, FBS, macro users, femto users, J (available sub-bands)
**OUTPUT**: An optimal sub-band allocation such that sub-band of $FBS_i \neq \text{subband of } FBS_j$ for all $i$ and $j$

1: The macrocell coverage area is modeled into inner and outer zone of 8 sectors each
2: Macro users are deployed at the inner and edge zones. They are assigned frequency bands each.
3: Femtocell is deployed and switched on
4: Femtocell scans through neighboring macrocell signals, estimates RSSI for each frequency band ($/g_{1844}/g_{3036}$) and determines max $/g_{1844}/g_{3036}$
5: If max $/g_{1844}/g_{3036}$ = A, then femtocell is at inner zone, otherwise at edge zone
6: Determine $S_{hRSSI}$ (Group of sub-bands with high RSSI values or interfering neighbors)
7: Obtain usable sub-band ($/g_{1836}/g_{3022}$) by excluding $S_{hRSSI}$ from J
8: The algorithm terminates when all femtocells have been assigned J

2.3 PERFORMANCE METRICS

The performance of the frequency reuse and NO frequency reuse schemes are investigated, evaluated and compared by performing simulations on MATLAB to determine downlink signal to interference plus noise ratio (SINR), system capacity and system throughput and user satisfaction. The entire network is made up of 7 macrocells with each placed at the center of each cell. Femtocells with at least 1 user are uniformly deployed over macrocells. A macro user is interfered from 6 neighboring macrocells and all adjacent femtocells. The following parameters are used to determine the downlink SINR of a macro user, m on subcarrier t, SINR (m, t):
E (M, t) - Power transmission of a serving macrocell on a subcarrier t in watts
E (M’, t) - Power transmission of neighboring macrocell on a subcarrier t in watts
E (F, t) - Power transmission of neighboring femtocell on a subcarrier t with respect to a macro user in watts
G (m, M, t) - System channel gain between macro user m and serving macrocell M on a subcarrier t (no unit)
G (m, M’, t) - System channel gain between macro user m and neighboring macrocell M’ on a subcarrier t (no unit)
G (m, F, t) - System channel gain between macro user m and neighboring femtocell F on a subcarrier t (no unit)
N0=Noise power spectral density (dBm/Hz)
Δf=subcarrier spacing (kHz)

2.3.1 Channel gain and path loss
The channel gains can be obtained through the following expressions below:

\[
\text{Channel gain (G)} = \frac{\text{Absorbed Power(PR)}}{\text{Transferred Power(PT)}} \tag{1}
\]

\[
\text{Log G (dB)} = \log_{10}\left(\frac{\Delta f}{\gamma}\right) \tag{2}
\]

G (m, M, t) is obtained from the outdoor path loss (L_{outdoor}) due to serving macrocell and its user since macro user is considered to be outside the apartment

\[
L_{outdoor}=28+35\times \log_{10}d_1 \text{ (dB)}, \text{ since Low}=0 \text{ (no wall between macrocell and the user)}
\]

\[
G (m, M, t) = 10^{\left(-\frac{L_{outdoor}}{10}\right)} = 10^{\left(-\frac{(28+35\times \log_{10}d_1)}{10}\right)} \tag{3}
\]

G (m, M’, t) is obtained from the outdoor path loss (L_{outdoor}) due to neighboring macrocell and its user

\[
G (m, M’, t) = 10^{\left(-\frac{L_{outdoor}}{10}\right)} = 10^{\left(-\frac{(28+35\times \log_{10}d_1)}{10}\right)} \tag{3}
\]

G (m, F, t) is obtained from both indoor and outdoor path losses due to indoor femtocells and outdoor macro user:

\[
L_{indoor}=38.5+20\log_{10}d_2+L_{iw} \text{ (dB)} \tag{4}
\]

Where d_2 is the distance between femtocells and its user (meters) while Liw is the indoor wall penetration loss.

Total path loss=28+35*\log_{10}d_1+38.5+20*\log_{10}d_2+L_{iw}+ \text{Low (dB)}
2.3.2 Signal to interference plus noise ratio (SINR) of macro user incoming

$$\text{SINR} = \frac{P_{\text{arriving signal}}}{P_{\text{noise}} + P_{\text{interference}}}$$ \quad \text{(5)}

$$\text{SINR} (m, t) = \frac{\left( \frac{E (M, t) + 10^{-10 \text{Loudoor}}}{10} \right)}{P_0 \cdot \Delta f + \sum E (M', t) \cdot 10^{-10 \text{Loudoor}} + \sum E (F, t) \cdot 10^{10 \text{Loudoor}}} = \frac{P_0 \cdot \Delta f + \sum E (M', t) \cdot G (m, M, t) + \sum E (F, t) \cdot G (m, F, t)}{P_0 \cdot \Delta f + \sum E (M', t) \cdot 10^{10 \text{Loudoor}}}$$ \quad \text{(6)}

2.3.3 Signal to interference plus noise ratio (SINR) of femto user

Just like that of a macro user, the femto user $f$ is interfered from all the 7 macrocells and neighboring femtocells, the downlink SINR of a femto user, $f$ from a serving femtocell on subcarrier $t$, is obtained as follows;

- $E (F, t)$ – Transmission power of a serving femtocell on a subcarrier $t$ in watts
- $E (M, t)$ – Transmission power of a neighboring macrocell on a subcarrier $t$ in watts
- $E (F', t)$ – Transmission power of neighboring femtocell on a subcarrier $t$ in watts
- $G (f, F, t)$ – Channel gain between femto user $f$ and serving femtocells $F$ on a subcarrier $t$ (no unit)
- $G (f, F', t)$ – Channel gain between femto user $f$ and neighboring femtocells $F'$ on a subcarrier $t$ (no unit)
- $G (f, M, t)$ – Channel gain between femto user $f$ and neighboring macrocells on a subcarrier $t$ (no unit)

$$\text{SINR} (f, t) = \frac{\left( \frac{E (F, t) \cdot 10^{-10 \text{Loudoor}}}{10} \right)}{P_0 \cdot \Delta f + \sum E (F', t) \cdot 10^{-10 \text{Loudoor}} + \sum E (M, t) \cdot 10^{10 \text{Loudoor}}} \quad \text{(7)}$$

$$\text{SINR} (f, t) = \frac{P_0 \cdot \Delta f + \sum E (F', t) \cdot G (f, F', t) + \sum E (M, t) \cdot G (f, M, t)}{P_0 \cdot \Delta f + \sum E (F', t) \cdot 10^{10 \text{Loudoor}}} = \frac{P_0 \cdot \Delta f + \sum E (M, t) \cdot 10^{10 \text{Loudoor}}}{P_0 \cdot \Delta f + \sum E (F', t) \cdot 10^{10 \text{Loudoor}}} \quad \text{(8)}$$

2.3.4 Distance $d$ between transmitting base station and user

In order to ascertain the distance of users from their individual base stations, distance between two points in a line as obtained in coordinate geometry is employed. The coordinates of FBS as well as FU are $(X_{FBS}, Y_{FBS})$ and $(X_{FU}, Y_{FU})$ respectively.
Figure 8: Graph showing, distance \( d \) and the location of femtocell and its user.

\[
d = \sqrt{(X_{FBS} - X_{fu})^2 + (Y_{FBS} - Y_{fu})^2}\] \[16\]  \....................................................... (9)

2.3.5 Channel capacity of femto user

The channel capacity \( C(f, t) \) of a femto user \( m \) on subcarrier \( t \) is obtained by using Shannon theorem:

\[
C = \text{bandwidth} \times \log_2 \left( 1 + \left( \frac{\text{Signal}}{\text{Noise}} \right) \right) [17] \................................................................. (10)
\]

\[
C(f, t) = \text{BW} \times \log_2 \left( 1 + \left( \frac{-1.5}{\ln(\text{SBER})} \times \text{SINR}(f, t) \right) \right)
\]

\[
= \text{BW} \times \log_2 \left( 1 + \left( \frac{-1.5}{\ln(\text{SBER})} \times \frac{\text{E}(F,t) \times 10^{-\left(38.5+20\log d+1+Lw\right)}}{\text{P}_0+\text{Af}+\sum \text{E}(F',t) \times 10^{-\left(38.5+20\log d+2+Lw\right)}} \right) \right) \ldots \ldots (11)
\]

2.3.6 Throughput

The total throughput of serving femtocell \( f \) is expressed as follows:

\[
T(F, t) = \sum \sum X(f, t) \times C(f, t) [8] \................................................................. (12)
\]

\[
= \sum \sum X(f, t) \times \text{BW} \times \log_2 \left( 1 + \frac{-1.5}{\ln(\text{SBER})} \times \text{SINR}(f, t) \right)
\]

\[
= \sum \sum X(f, t) \times \text{BW} \times \log_2 \left( 1 + \frac{-1.5}{\ln(\text{SBER})} \times \frac{\text{E}(F,t) \times 10^{-\left(38.5+20\log d+1+Lw\right)}}{\text{P}_0+\text{Af}+\sum \text{E}(F',t) \times 10^{-\left(38.5+20\log d+2+Lw\right)}} \right) \ldots \ldots (13)
\]

2.3.7 Bit Error Rate

The constant target of bit error rate as obtained by Shannon theorem is expressed as shown in Equation (11)

\[
\Phi = \frac{-1.5}{\ln(\text{SBER})} [17] \................................................................. (14)
\]
3.0 RESULTS AND DISCUSSION

Table 3 – Input parameters used in the simulations [5]

| PARAMETER                      | VALUE                                           |
|--------------------------------|-------------------------------------------------|
| Number of Femtocells          | 20-120/macrocell                                |
| Number of Macrocells          | 7                                               |
| Macrocell Coverage            | 250m                                            |
| Femtocell Coverage Radius (R) | 25m                                             |
| Size of Inner Zone            | 0.55m of macrocell coverage                     |
| Femtocell Transmit Power      | 20mW                                            |
| Macocell Transmit Power       | FR:19W and 24W for center and edge users       |
|                               | respectively                                    |
|                               | NFR:14W                                         |
| Maximum number of femto users | 120                                             |
| Maximum number of macro users | 100                                             |
| Subcarrier Spacing            | 15KHz                                           |
| System Bandwidth              | 10MHz                                           |
| Carrier Frequency             | 2GHz                                            |
| White noise power density     | -174dBm/Hz                                      |
| Indoor Path Loss              | \[PL = 38.5 + 20 \log_{10} d + Liw\] [3]        |
|                               | \(Liw = 7\) dB, where 0<d<10                    |
|                               | \(Liw = 10\) dB, where 10<d<20                  |
|                               | \(Liw = 15\) dB, where 20<d<30                  |
| Outdoor Path Loss             | \[PL = 28 + 35 \log_{10} d \] (dB), [3]         |

Table 4 – Bandwidths for each sub-band

| Frequency bands | Bandwidths (MHz) |
|-----------------|------------------|
| A               | 0.022            |
| B               | 0.044            |
| C               | 0.066            |
| D               | 0.088            |
| E               | 0.111            |
| F               | 0.133            |
| G               | 0.156            |
| H               | 0.178            |
| I               | 0.2              |
Figure 9: Matlab interface for simulation

Figure 9 shows Matlab simulation interface for gradual deployment of femtocells within macrocell environment. Simulation parameters were used to determine performance metrics like capacities, throughputs, SINR and BER as shown in figures 10 and 11.
Figure 10: Matlab interface for simulation of twenty femtocells
Figure 11: Matlab interface for simulation of forty fentocells
Figure 12: Matlab simulation for deployment of 30 FBS
Figures 12 shows the simulation of 30 femtocell within a particular coverage area depicting SINRs and percentage of users. Majority of the users have low SINRs because of high interfering neighbors they are faced with. 10% of the users have SINR 0.28. The least user have an SINR of 0.07 compared to the maximum user with 0.34.

Figure 13: Matlab simulation for deployment of 35 FBS
Figure 13 shows the simulation of 35 femtocell within a particular coverage area depicting SINRs and percentage of users. Majority of the users have low SINRs because of high interfering
neighbors they are faced with. 10% of the users have SINR 0.25. The least user have an SINR of 0.06 compared to the maximum user with 0.33. As more femtocells are deployed within the same coverage as 30 femtocell, interference situations increased.

Figure 14: Matlab simulation for deployment of 40 FBS

Figure 14 shows the simulation of 35 femtocell within a particular coverage area depicting SINRs and percentage of users. Majority of the users have low SINRs because of high interfering neighbors they are faced with. 10% of the users have SINR 0.2. The least user have an SINR of 0.053 compared to the maximum user with 0.32. As more femtocells are deployed within the same coverage as 35 femtocells, interference situations increased.
Figure 15 shows the throughput for inner edge-macro users in Mbps. As femtocells increase within the coverage area, throughputs reduced gradually. The gradual reduction for the proposed method was from 11.8 to 9.1 Mbps while without FR reduced from 88.0 to 4.0 Mbps. The higher values accrued to the proposed method is as because it has the ability to minimize interference more than the other method even though the femtocells were faced many interfering neighbors.
Figure 16: Throughput for edge macro-femto users

Figure 16 shows the throughput for edge macro-femto users in Mbps. As femtocells increase within the coverage area, throughputs increased gradually. The gradual increase for the proposed method was from 40 to 105 Mbps while without FR increased from 20.0 to 80.0 Mbps. The higher values accrued to the proposed method is because it was able to minimize interference more than the other method even though the femtocells were faced many interfering neighbors. The high values of throughputs for edge macro-femto users compared to inner edge-macro users is due to distance of macro and femto users from the macrocell.
The results as obtained in figure 17 reveal the signal against bit error rate when path loss models are considered. This bit error rate in any communication system is a key factor when data is transmitted within the network. Interference and path loss usually contribute to the degradation of the signal. Figure 17 shows that a high SINR results when the bit error rate is low, this consequently improves communication and throughput in the network. The first path loss model from the graph shows lower SINR compared with the second model which means the latter provides a better signal strength.

4. CONCLUSION
In this section, we have discussed frequency reuse scheme that helps to minimize interference and enhance throughput when there is vast deployment of femtocells within the macrocell coverage area. The types of interference that the scheme is able to minimize are inter-cell interference, intra-cell interference, co-tier interference and cross tier interference. Overall network is considered to be made up of a known number of adjacent cells while each cell contains a number of users either MUs or FUs. FBS are uniformly deployed in the topology. We also consider that MUs are outdoor users while FUs are located indoor. Results show that a high SINR results when the bit error rate is low, this consequently improves communication and throughput in the network. The high values of throughputs for edge macro-femto users compared to inner edge-macro users are due to distance
of macro and femto users from the macrocell. As femtocells increase for edge macro-femto users within the coverage area, throughputs reduced gradually.

REFERENCES

1. O. Ibhadode, I.T, Tenebe, P.C. Emenike, O.S. Adesina, A.F. Okougha, and F.O. Aitanke, (2018) “Assessment of Noise-levels of Generator-sets in Seven Cities of South-Southern Nigeria.” African Journal of Science, Technology, Innovation and Development, vol. 10, pp.125-135. DOI: 10.1080/20421338.2017.1400711

[2] V. Chandrasekhar, J. Andrews, (2008 )"Spectrum Allocation in Two-tier Networks" IEEE Asilomar Conference on Signals, Systems and Computer.

[3] Y. Ji-Hoon and G. S. Kang, (2010) “Distributed self-organized femtocell management architecture for co-channel deployment”. The University of Michigan, Ann Arbor, Chicago, Illinois, USA, 20-24.

[4] P. Lee, T. Lee, J. Jeong, and J. Shin, (2010) “Interference Management in LTE Femtocell Systems Using Fractional Frequency Reuse,” in Advanced Communication Technology (ICACT), 2010 The 12th International Conference on, vol. 2, Feb. 2010, pp. 1047 –1051.

[5] 3GPP TR 36.922 v9.1.0 (2010) “Evolved universal Terrestrial Radio Access (E-UTRA); TDD Home eNodeB (HeNB) Radio Frequency (RF) requirement analysis (Release 9)”. 3rd Generation Partnership Project Tech. Rep.

[6] Wang Boyan,Lu Xiao,Chen Jie, Zhang Yanping. (2013) Design of frequent point optimization of GSM based on EGA. Computer Technology and Development, 23(2), pp.23-27, 2013.
[7] Cao Gen, Yang Dacheng, An Ruihong, Ye Xuan, Zheng Ruiming and Zhang Xin (2011). An adaptive sub-band allocation scheme for dense femtocell environment. *Wireless Communications and Networking Conference (WCNC)*, pp.102-107.

[8] Tan Li, Feng Zhiyong, Li Wei, Jing Zhong and Gulliver T.A. (2011) Graph coloring based spectrum allocation for femtocell downlink interference mitigation. *Wireless Communications and Networking Conference (WCNC)*, pp.1248-1252.

[9] Sghiri, J. and Ayadi, M. (2014) An innovative approach for automatic frequency planning. *International Symposium on Networks, Computers and Communications*, pp.1-5.

[10] H. Claussen, “Performance of Macro- and Co-Channel Femtocells in a Hierarchical Cell Structure, (2015)” in Proc. of the 18th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), Athens, Greece, Sep. 3–7, pp. 1–5.

[11] Z. Bharucha, H. Haas, A. Saul, and G. Auer, (2013) “Throughput Enhancement through Femto-Cell Deployment,” *European Transactions on Telecommunications*, vol. 21, no. 4, pp. 469–477, Mar. 31 (invited).

[12] V. Chandrasekhar, J. Andrews, and A. Gatherer, (2008) “Femtocell Networks: A Survey,” *IEEE Communications Magazine*, vol. 46, no. 9, pp. 59–67.

[13] Y.-Y. Li, M. Macuha, E. Sousa, T. Sato, and M. Nanri, (2009) “Cognitive Interference Management in 3G Femtocells,” in *Proc. of the IEEE Personal, Indoor and Mobile Radio Communications (PIMRC)*, Sep.13–16, pp. 1118–1122.

[14] Jian Zhou, Lusheng Wang, Weidong Wang and Qingfengzhou, (2017) “Efficient resource allocation scheme using maximal independent set for randomly deployed small star networks, *IEEE Communications Magazine*, Vol. 17, pp.8 -12, Nov.

[15] E. Tsalolikhin1, I. Bilik2, N. Blaunstein3, Y. Babich3 (2012) “Channel Capacity in Mobile Broadband Heterogeneous Networks Based Femto Cells” pp.5 -9.

[16] Adekunle A.; Ibe K.E.; Kpanaki M.E.; Umanah I.I.; Nwafor C.O.; Essang N. (2015) “Evaluating the effects of radiation from cell towers and high tension power lines on inhabitants of buildings in Ota, Ogun state” (*JSDS*, ISSN 2201-7372, Vol.3, Number 1, 1-21 https://www.infinitypress.info/index.php/cas/article/download/872/494)

[17] Adekunle A., Abimiku Y. K., Umobik N.M and Ameh E.E (2018) “Radio wave detection using cost 231-Hata model for wireless network planning; a case study of senate building environs of Unilag, Nigeria”. (*IJASRE*, E-ISSN: 2454-8006, Vol.4 Issue 12, December 2018, DOI: http://doi.org/10.31695/IJASRE.2018.32992)