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Development of Dynamic Cell Coordination Framework for Interference Management in 4G Heterogeneous Networks

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Abstract:

This paper presents the development of dynamic cell coordination framework for interference management in 4G heterogeneous network. The study performed an empirical study of a heterogeneous network to read interference using parameters such as signal to noise ratio, signal to interference to noise ratio, throughput and latency. The problem was solved, developing a dynamic cell coordination framework to control cell behaviors and improve quality of service. The model was implemented with simulink and performance evaluated. The result showed that the carriers were coordinated in between the cells and quality of service achieved with 72% throughput.

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Keywords — **Interference, 4G network, heterogeneous network, quality of service, throughput**

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I. INTRODUCTION

The last decade has witnessed a rapid growth in the application of internet of everything due to the evolution Fourth Generation (4G) network. This network makes the possibility of limitless social applications, cloud storage, among numerous functions taking place via the cloud today a reality. However, the need to sustain the efficiency of the broadband ecosystem triggered the deployment of more radio resources deployed to support the main bigger radio cell in a heterogeneous structure.

According to [1], Heterogeneous Network (HetNet) is a combination of multiple cell types such as Macro cell, Pico, Femto and Micro to operate using the same bands and in the principle of frequency reuse. This HetNet have successfully improved quality of service by addressing problems of cell overload, improve signal strength, network coverage among other merits, however [2; 3; 4] revealed that the varying properties of this cells, makes the bigger cells interferes with users at the cell edge of smaller cells, thus resulting to Intercell Interference (ICI) which has remained a major problem till date.

[5] Researched on adaptive cell range extension technique for the mitigation of ICI in 4G network an achieved good performance in cell range coverage issues. [6] Presented a dynamic fractional frequency reuse solution to the coordination of ICI in 4G network and achieved better performance when compared with static frequency reuse algorithm. [7] Used almost blank sub frame technique to coordinate ICI in HetNet and a achieved better performance when tested in two tier HetNet. [8] Used optimal dynamic enhanced ICI cancellation model to coordinate interference in 4G network and also achieved improvements, among other numerous ICI solutions proposed in [9; 10; 11and 12]. All these solutions achieved great success in mitigating interference to some extent, but despite their success have not provided optimal reliability for quality of service.

Quality of service is a major factor in which has to achieve in wireless broadband networks to guarantee optimal user experience and satisfaction. This will be achieved in this research developing a dynamic cell coordination framework using frequency and time control functions to manage carriers within the cells and prevent interference on user signals.

II. METHODOLOGY OF MODELLING

The methodology employed for the system modeling considered a two tier heterogeneous network made up of macro cell and Femto cell. The model of the HetNet is presented in the figure 1 showing the problem formulation as the macro cell signal interference with users of the femto cell at the edges, thus resulting to interference.

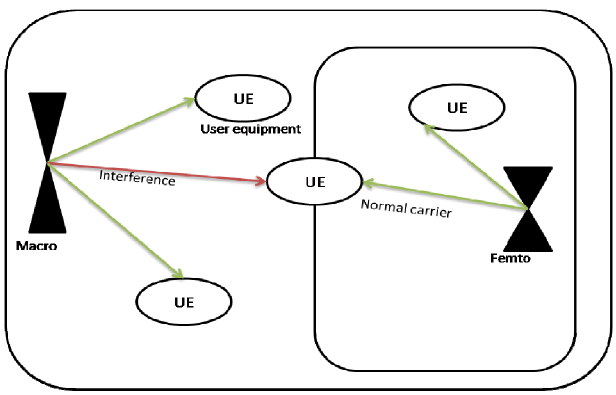

Figure 1: Modeling diagram of the two tier heterogeneous network

The model of the two tier HetNet presented the impact of ICI on user equipment during downlink communication. The signal to noise ratio model of the cell was developed using the relationship between the carrier signal strength of users, signal of the cells and interference from other cell as presented in [13] for two tier heterogeneous network and then the signal to interference and noise ratio respectively.

$$\mathrm{SINR} = \frac{S_c^u . Pt}{N_b + \sum_{j \neq Bn} I_j^u} \quad (1)$$

Where N_b is the noise from the background, S_c^u is the allocated signal from the user cell station defined as B, n is the number of cells, based on normal sub carrier u or reduced power sub carrier resource block c; I_j^u is the interfering signal from other scheduled cell station j detected by the user equipment u; Pt is the power of transmission in the cells, with interference was affected based on Rayleigh fading and user channel are assumed independently.

Resource Allocation

Generally speaking, cells simplify the resource allocation by mapping Resource Elements (REs), which are considered the smallest unit of the frame and contain a single complex value of data from a physical channel, into a larger group known as Resource Blocks (RBs). This RB is the smallest unit allocated to a user by an scheduler of the eNodeB [14]. It represents a time-frequency grid of REs where the reserved band which in this case is 180kHz and have 12 subcarrier channels with each having 15kHz width in frequency domain and 7 OFDM symbols in time domain as presented as shown in figure 3;

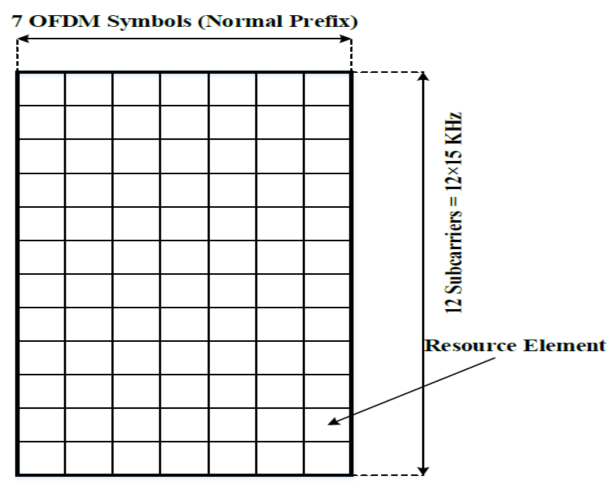

Figure 3: The mapping blocks

The scheduling process based on the mapping block above was done using time and frequency control function which are the demodulated reference signal (DM-RS) and Phase Tracking Reference Signal (PT-RS) techniques respectively. The DM-RS was used to estimate the radio channel in time domain based on OFDM. The PT-RS is the phase tracking reference signal that has a low density in the frequency domain and a high density in the time domain. PT-RS always occurs in combination with DM-RS and only when the network has configured PT-RS. The time control parameters of the PT-RS is the DM-RS which uses symbol location and time density which depends on the modulation schedule and CDM scheme.

Methods for the development of the inter cell interference mitigation algorithms

The algorithm used frequency and time control function based on phase tracking reference signal and frequency domain resource control function to allow downlink operation of carrier. During this process the resource allocation ensures that the carrier channels are free for downlink or uplink using the Physical Downlink Sub Carrier Channel (PDSCH) via Orthogonal Frequency Division Multiplexing (OFDMA) to sense the availability channel and detect idle spectrum for downlink using Demodulated reference signal (DM-RS). When the channel is not free, the time control set delay of 1ms and then checks again until the channel is free, then throughput is allowed for the cell. The pseudocodia of the cell coordination framework is presented as;

THE PSEUDO CODE OF THE CELL COORDINATION ALGORITHM

1. **Start**
2. Setup phase tracking reference signal % time function
3. Set time as 2ms
4. Setup frequency domain resource control function % frequency function
5. Initialize Demodulated reference signal (DM-RS) % for detection of free blocks
6. Identify the subcarriers channels in PDSCH based on OFDMA
7. Map and Check for free resource blocks using Phase Tracking Reference Signal (PT-RS)
8. **If**
9. Free resource block is true
10. Then
11. Allow carrier throughput
12. **Else**
13. Wait for 2ms
14. Return to step (7)
15. Do until free resource block is true
16. Initiate step (11)
17. End if
18. End

III. IMPLEMENTATION OF THE DEVELOPED SYSTEMS

The system was implemented using long term evolution toolbox and communication toolbox in Simulink. These tool were used to implement the algorithms on the two tier heterogeneous network using femto and macro cell which transmitted based on frequency reuse and OFDMA with broadband range of 800-850MHZ as shown in figure 2;

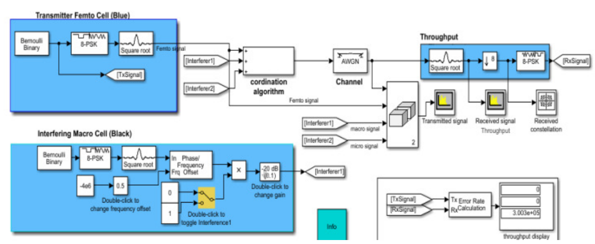

Figure 2: Simulink model of the Heterogeneous network

The figure 2 presented the Simulink model of the heterogeneous network improved with the cell coordination algorithm developed to mitigate interference. The model was simulated using the parameters in the table 1 and the results are discussed in the next section.

Table 1: Simulation parameters for the 4G Network [13]

Parameters	Values
Carrier frequency	2.14GHz
System bandwidth	12MHz
Standard deviation shadow fading	8dB
SINR threshold	-4.5dB
UE gain UE noise speed	560km/h
Inter site distance	500m
Noise spectral density	-174dBm/Hz
Special sub frame ratio	2/8 (1 ABS + 1 RPS)
Traffic model	Fill buffer, VOIP
Total voice packet used for the simulation	0.6mb
Channel model	Typical Urban
Modulation	16QAM, 64QAM, QPSK
Sub-frame duration	1s
Subcarrier number	12
Time window size	9
Frequency window size	13
Specification for VOIP	2 x 88bit
The Macro Cell Station	
Parameters	**Values**
Transmission power	46dBm (40W)
Reduced transmission power	23dBm(200mW)
Antenna gain	15dBi
Antenna height	20m
Distance in radius	289m
Femto Cell Station	
Parameters	**Values**
Transmission power	26dBm (1W)
Reduced transmission power	35dBm(15mW)
Antenna gain	7dBi
Antenna height	10m
Distance in radius	69m

IV. RESULTS AND DISCUSSIONS

This section presented the performance of the heterogeneous network and the impact of the cell coordination algorithm developed to help mitigate interference. The result of the network is presented in figure 3;

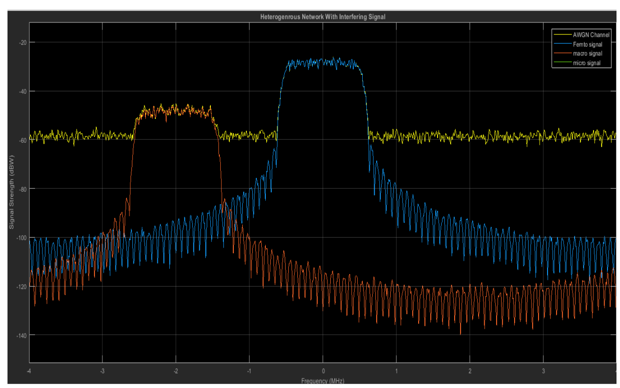

Figure 3: Result of the HetNet without algorithm

The figure 3 showed the problem formulation model where the two cells interferes i.e the macro cell signal (red) interfering with the femto cell signal (blue) along the carrier channel (yellow). The reason for this was due to the macro cell having signal extension to the femto user area and hence when users are at the femto cell edge where the femto signal strength is low, the macro cell signal interferes and cause poor service quality. This problem was addressed in this research using the algorithm developed as shown in the figure 4;

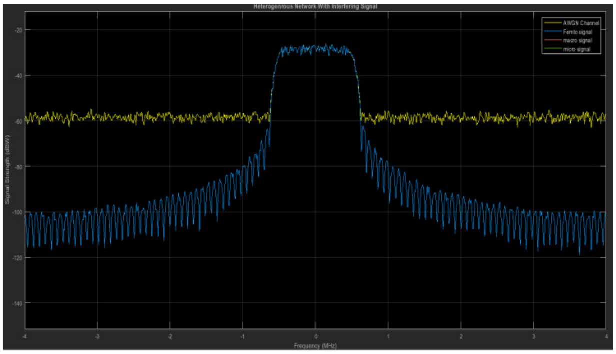

Figure 4: The coordinated signal

The figure 4 presents the performance of the algorithm deployed on the cell to coordinate the interfering signal from the macro cell. The result showed that the algorithm was able to deny the macro cell signal access to the channel while the femto signal was engaged with the resource block. This ensured that only the femto signal was allowed throughput put and hence the user experienced quality of service. The throughput performance of the network measured with the throughput model in [13] was presented in the figure 5;

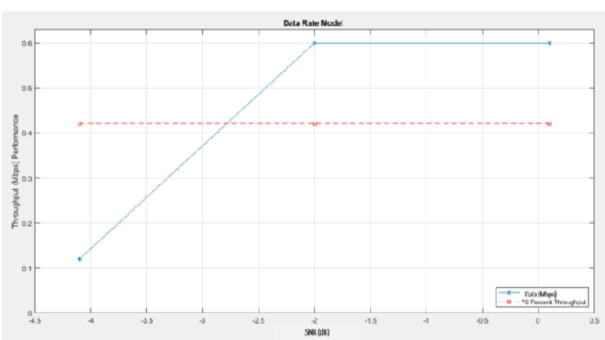

Figure 5: The throughput performance of the data rate model

The figure 5 presented the throughput performance of the network with the algorithm. The aim was to measure the quality of throughput percentage on the network and ensured that the throughput performance was not affected by the algorithm. From the result data rate model in [4] was used to measure the amount of data transmitted and the throughput delivery rate and the result showed that 70% average throughput was recorded which according to the Nigerian communication commission is good for quality of service.

The impact of the algorithm was compared with empirical data collection when sample size of 229 average users within a two tier HetNet was studied, with focus o the femto cell and the data of the network reported in the table 2 alongside the performance of the algorithm when deployed on the testbed as shown;

Comparative Throughput performance in percentage

Transmission frequency (MHz)	Users	Data rate (Mb/s)	Throughput with ICI algorithm	Throughput without ICI algorithm
800-829	150	10000	78	70
812-843	167	12000	78	70
840-850	169	13000	78	68
833-850	175	14000	76	67
822-850	179	15000	76	67
830-843	185	16000	74	66
817-844	189	17000	74	65
804-832	192	18000	74	65
805-824	203	19000	73	63
844-850	220	20000	72	60
820-829	222	21000	72	60
832-843	225	22000	72	56
800-850	256	23000	70	54
833-850	275	24000	70	53
812-850	279	25000	68	51
820-843	285	26000	67	49
812-844	289	27000	67	46
824-832	292	28000	67	46
815-824	303	29000	67	45
844-850	320	30000	67	44
Average	229	20400	58.25	72

The table 2 presented the comparative performance of the femto cell with interference and when deployed with the developed coordination algorithm. The percentage throughput analyzed was presented as show below;

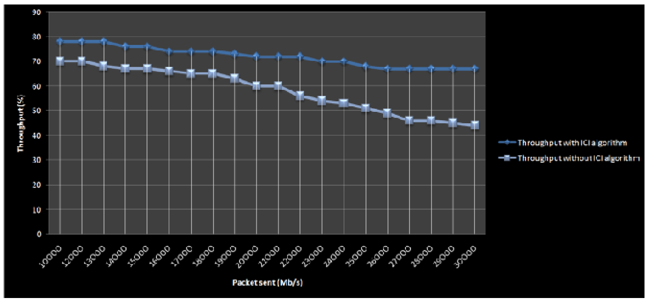

Figure 6: Comparative throughput percentage

The result in figure 6 presented the comparative throughput performance in percentage for the femto cell. From the result first it was noticed that the throughput percentage without interference is a lot better than the cell when characterized with interference. Secondly the average percentage throughput for the cell with interference is 58.25 while that of the cell with the interference coordination algorithm is 72%. The percentage difference and throughput improvement in the new developed 4G cell is 19.1% throughput performance increment.

V. CONCLUSION

Over the years the impact of inter cell interference has hindered the full realization of HetNet potentials. This problem ICI is inevitable and can only be managed to ensure quality of service. This problem was solved in this research using a cell coordination framework which ensures that the multi cells do not transmit with the same resource block at the same time. This was implemented with simulink and tested. The result showed that the algorithm was able to mitigate interference and achieve average throughput of 72% which is an indicator or quality of service.

VI. CONTRIBUTION TO KNOWLEDGE

A dynamic cell coordination framework was developed for the mitigation of interference in 4G network.

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