Dynamic Spectrum Allocation Scheme for Heterogeneous Network: BER Analysis

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***Abstract*—The latest advancement in wireless communication technology enables mobile users to communicate with each other more easily and at a very high speed. With the developed technology that encourages fast delivery of data and signal, mobile users can experience the best kind of service provided by the network operators. However, with the increasing number of users in an area that consists of femtocell and macrocell users, the data and signal transmission can sometimes be corrupted with the presence of cross-tier interference. This interference occurs when the femtocell and macrocell operate in the same carrier frequency. Therefore, such interference mitigation method must be implemented in order to maximize the throughput and increase the spectral efficiency of a wireless network. In this paper, a Dynamic Spectrum Allocation (DSA) scheme is proposed in order to correlate with the bit error rate, which will in turn contribute to throughput maximization factor in a heterogeneous network.**

***Index Terms*—Dynamic Spectrum Allocation (DSA); Bit Error Rate (BER); Heterogeneous Network (HetNet)**

I. INTRODUCTION

There are many interference mitigation techniques for wireless networks that have been studied by researchers all over the world. These techniques were tested and implemented in their researches and most of them produce positive results. One of the interference mitigation techniques is the Multi-Layer Rate Splitting Scheme [1]. The authors proposed a novel distributed power allocation algorithm that shows that the performance of cell-edge user equipment in a tri-sectored network can be enhanced by using this method with the proposed power allocation algorithm [2]. Moreover, the authors in [3] designed power control strategies to mitigate inter-AN interference in the downlink part of a network where they developed a set of algorithms to solve this constrained power control problem based on an iterative function evaluation method. Besides that, the authors in [4] studied on the evaluation of three state-of-the-art FFR deployment schemes for OFDMA-based two-tier heterogeneous networks. They proved that the average gains in spectral efficiency (of the network are higher for the proposed scheme.

In [5], the authors introduced cooperative communication schemes with interference management for cooperative wireless networks that are based on best relay and user selection method. They maximize the received SNR while minimizing the interference by an optimal time slot allocation for the users. The technique successfully enhanced the system performance and interference management. Besides that, the authors in [6] proposed a method for interference mitigation in two ways. Firstly, from the signaling point of view, power constraint is employed and secondly from the transmission point of view, a joint cross-tier and intra-tier interference mitigation sub-scheme are utilized. They explain that the proposed method achieves significant enhancement in SE compared to conventional schemes. Moreover, in [7], a basic co-channel HetNet deployment scenario with two cell layers is measured which results in enhancing energy efficiency and system performance in terms of both cell edge users' SINR and system capacity.

Apart from that, the DSA technique has been widely studied in previous researches for various types of implementations. In [8], in order to assure the fairness of the spectrum allocation, the proposed DSA scheme is said to consider not only the spectrum utilization but also the wireless systems' economic factor. Furthermore, it also restrains the presence of inter-system interference accordingly. However, it did not study that much regarding throughput maximization, which is an impending factor for interference mitigation. Authors [9] have proposed a novel cross-layer DSA for cluster-based cognitive radio ad hoc network where it divides the network into clusters based on three values, namely spectrum availability, the power level of node and current speed of the node. It is said to outperform the conventional protocols in terms of throughput, power consumption and packet transmission delay. However, it did not mention thoroughly on the interference mitigation matter.

In [10], the proposed DSA scheme maximizes the achievable throughput for secondary S-D by formulating the spectrum allocation problem as a linear integer optimization problem under spectrum availability constraint, spectrum span constraint and interference-free constraint. It is a good approach as it is tested on a heterogeneous network where the interference is very likely to occur.

The study in [11] proposed channel allocation problem to maximize the spectrum usage of a cognitive radio network that employs opportunistic spectrum access. It also achieves channel allocation robustness and regulates network interference. Authors [12] have proposed a DSA algorithm to integrate both interweave and underlay spectrum access schemes. The algorithm considers several factors such as the locations of the nodes, the interference in the networks and the communications of the users. The authors in [12] also proposed Energy Harvesting (EH) method for cognitive radio networks to prolong their lifetime. Since Secondary Users (SUs) can either access the spectrum or harvest energy, EH is integrated by the implementation of DSA, in order to increase both the energy and spectrum efficiencies [13].

According to the study in [14], the authors propose a new DSA method for the hybrid access cognitive femtocell where a segment of subchannels is allocated by the macro base station to the femto access point. This is to urge the access points to provide the users in the macrocell. Then, the femto access points allocate the subchannels and power so that the femtocell network utility is maximized.Besides that, throughput maximization is one of the impending factors that contribute to the interference minimization. There are many researches that studied the throughput maximization of a wireless network. Among them are the studies made in [15] and [16] where they use different approaches for maximizing the throughput in the wireless network.

II. DSA SYSTEM MODEL

Figure 1 shows the DSA scheme proposed for this research. Firstly, in the spectrum management box, there are two processes to be performed. The left-hand side is Spectrum Allocation (SA) and the right-hand side is Interference Analysis (IA). For the interference analysis, the three factors namely SINR, Throughput and Spectral Efficiency will be taken into account. Then, the processes will include the transmission of signals to the base stations and users via the Allocation agents (AA). These processes will be used and analyzed during the later stage of the research.

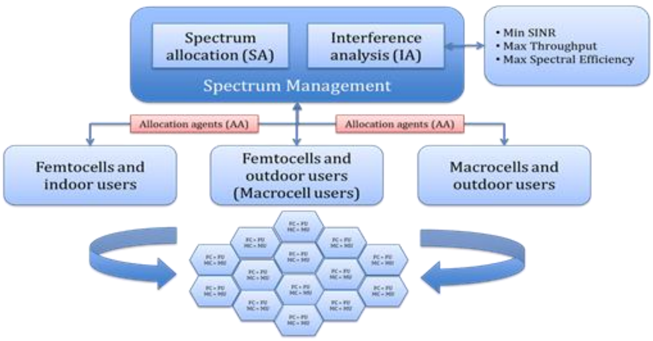

Figure 1: DSA Scheme

III. SYSTEM CONFIGURATION USING GNU RADIO SOFTWARE

A. LTE Configuration without DSA implementation

The flow graph for the LTE configuration for the transmitter, without DSA implementation, is shown in Figure 2. The upper part shows the mapping of data in packets for transmission and the lower part is the implementation of OFDM and transmission. This configuration is considered as LTE configuration because it uses OFDM as the multiplexing method. As seen in the flow graph, the random data are generated from the Random Source block and is passed through the stream blocks where the data are converted to stream data. The data are then separated into header and payload bits. After that, the header and payload bits are passed through the Chunks of Symbols blocks to be transformed to symbols. For the lower part, Pre-OFDM symbols will go through the OFDM Carrier Allocator block where the packets are grouped into different device IDs and allocate them on specific subcarriers. They are then sent to Cyclic Prefixer block to eliminate the Inter-Symbol Interference (ISI). As for the receiver, shown in Figure 3, the upper part of the flow graph shows the Schmidl and Cox OFDM Sync block uses SC algorithm to gain the timing metric and frequency offset. After calculation the timing metric, it sends the trigger to inform the next block where the start symbol of a packet is. The Header / Payload demux block is responsible for the received data processing. Channel Estimator block calculates the initial channel taps and sends them to the rest of the blocks by tags. The other blocks such as OFDM Frame Equalizer, OFDM Serializer, and Packet Header Parser are also essential in the reception and equalization process of the reception process. For the lower part, it shows the end step of the demodulation process where the Payload stream is converted to Payload IQ by going through the FFT, OFDM Frame Equalizer and OFDM Serializer blocks.

B. LTE Configuration with DSA implementation

LTE configuration with the implementation of DSA, shown in Figure 4 and Figure 5, the blocks of the flow graph used are mostly the same as the configurations in Figure 2 and 3, except for the first block, which is the base station core and the OFDM Carrier, Allocator. In this block, the data are dynamically assigned to the users instead of generating a random set of data. This is where the idea of DSA is implemented. The performance of this study is mainly focused on the BER parameter. The BER can be calculated manually by using the formula below:

$$BER = Number\ of\ errors\ /\ Total\ number\ of\ bits\ (transmitted)$$

From BER, we can then calculate the transmit power by using the following steps. Firstly, after determining the ratio of Energy per Bit (Eb) to the Spectral Noise Density (No), Eb/No from the desired BER, it will be converted to Carrier to Noise Ratio (C/N) using the equation below:

$$\frac{C}{N} = \frac{E_b}{N_o} \cdot \frac{f_b}{Bw}$$

where f_b is the bit rate and Bw is the receiver noise bandwidth. Noise power, N can then be computed using Boltzmann's equation, as shown below:

$$N = kTB$$

where k is Boltzmann's constant (k = 1.380650x10-23 J/K), T is the effective temperature in Kelvin (K) and B is the receiver bandwidth. The path loss in dB, denoted as PL can then be calculated by using the formula below [6]:

$$PL = 22dB + 20\log\left(\frac{d}{\lambda}\right)$$

where d is the distance between transmitter and receiver and λ is the wavelength of the RF carrier. By adding the desired fading margin, we can then calculate the transmit power. This paper analyses the BER considering the Heterogeneous network. Once we get the Bit Error Rate, the SINR, throughput and Spectral Efficiency can easily be calculated and analyzed in the later stage of this research.

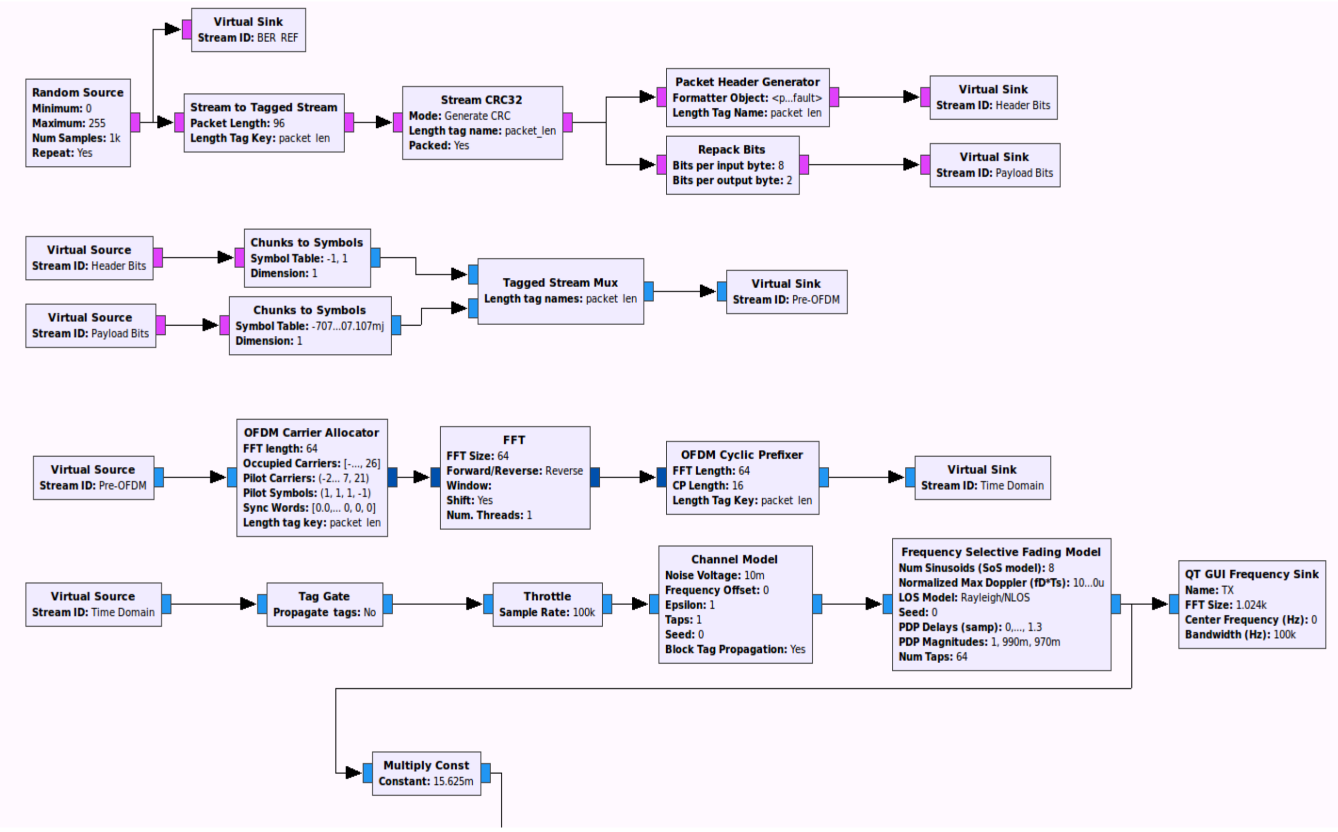

Figure 2: Flow graph of Transmission (Without DSA Implementation)

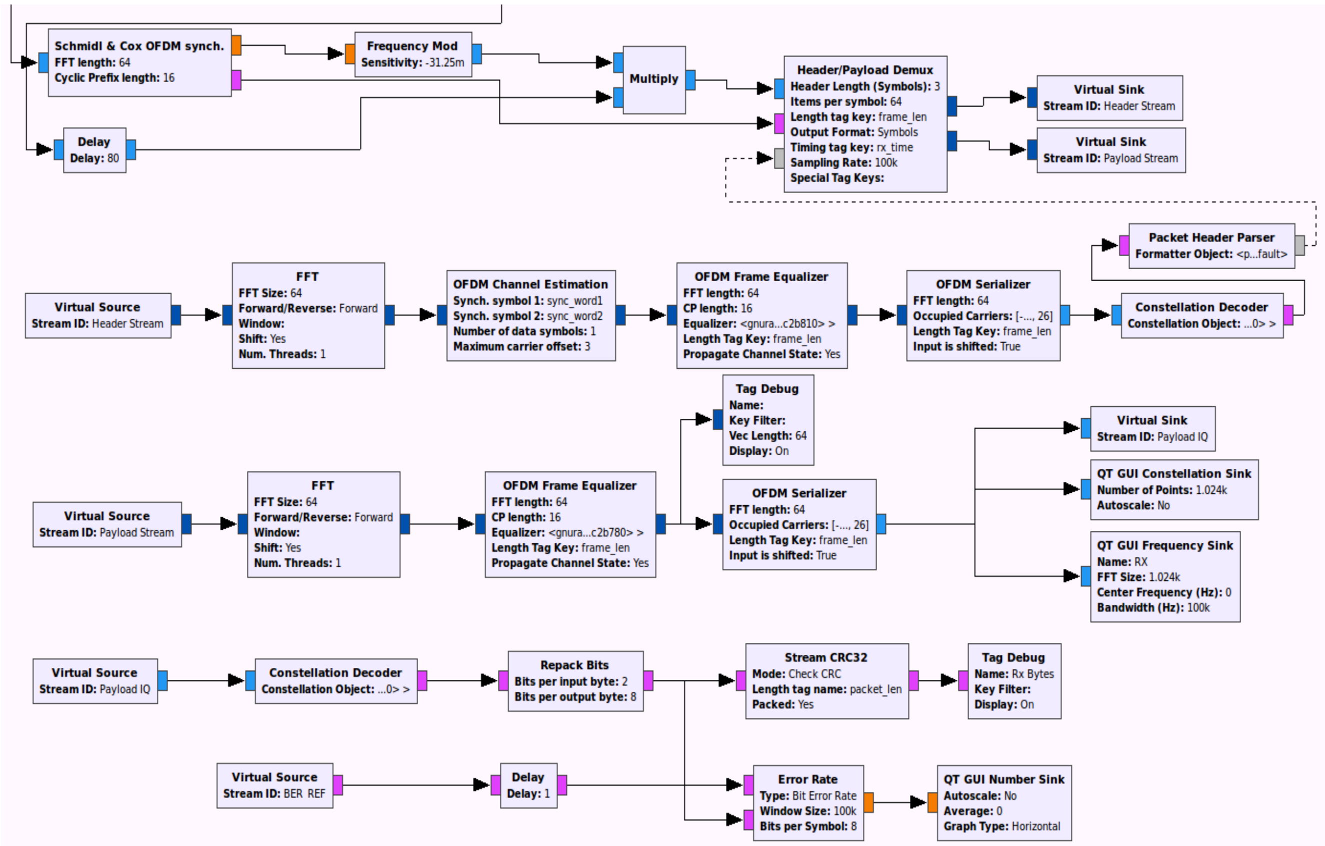

Figure 3: Flow graph of Reception (Without DSA Implementation)

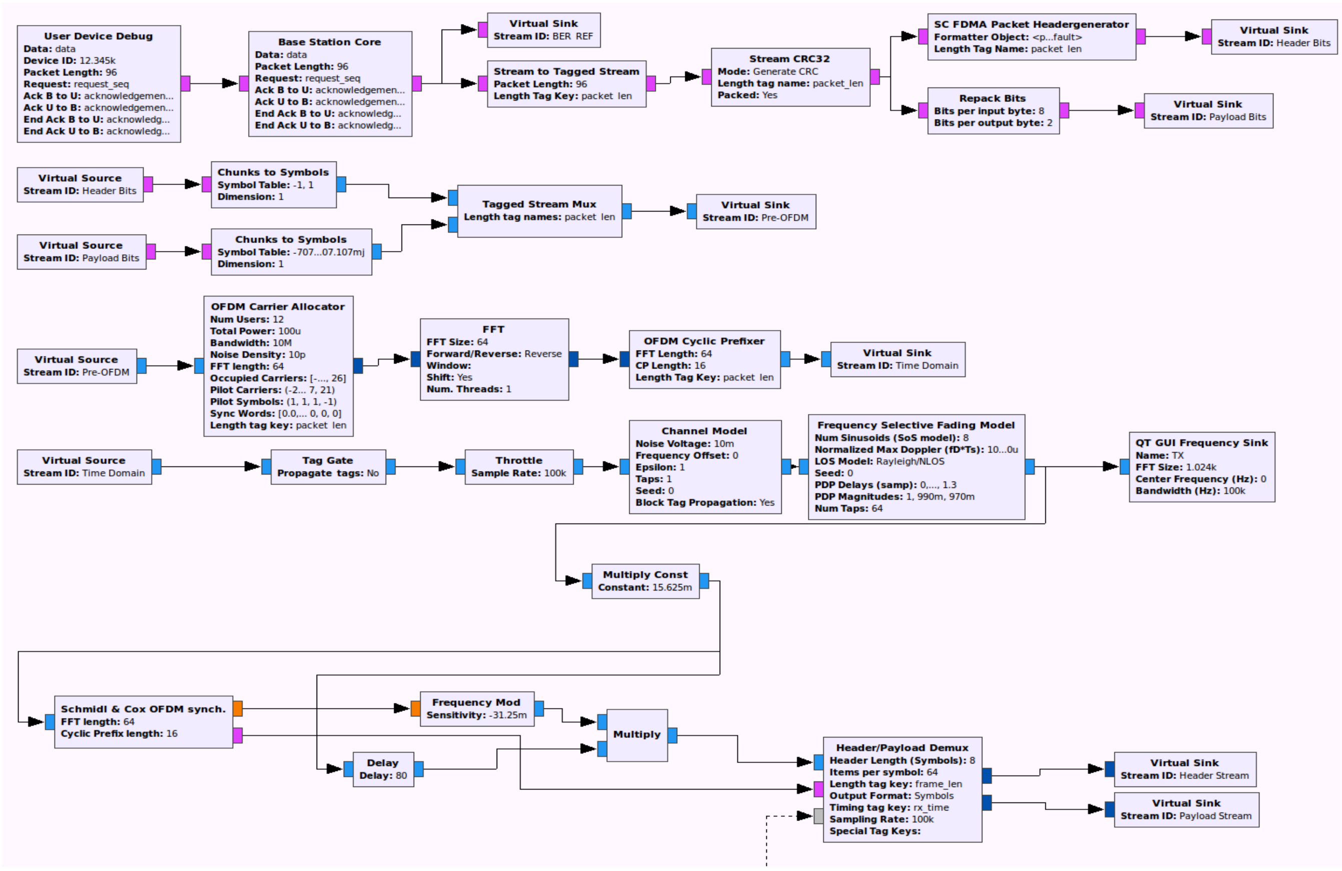

Figure 4: Flow graph of Transmission (With DSA Implementation)

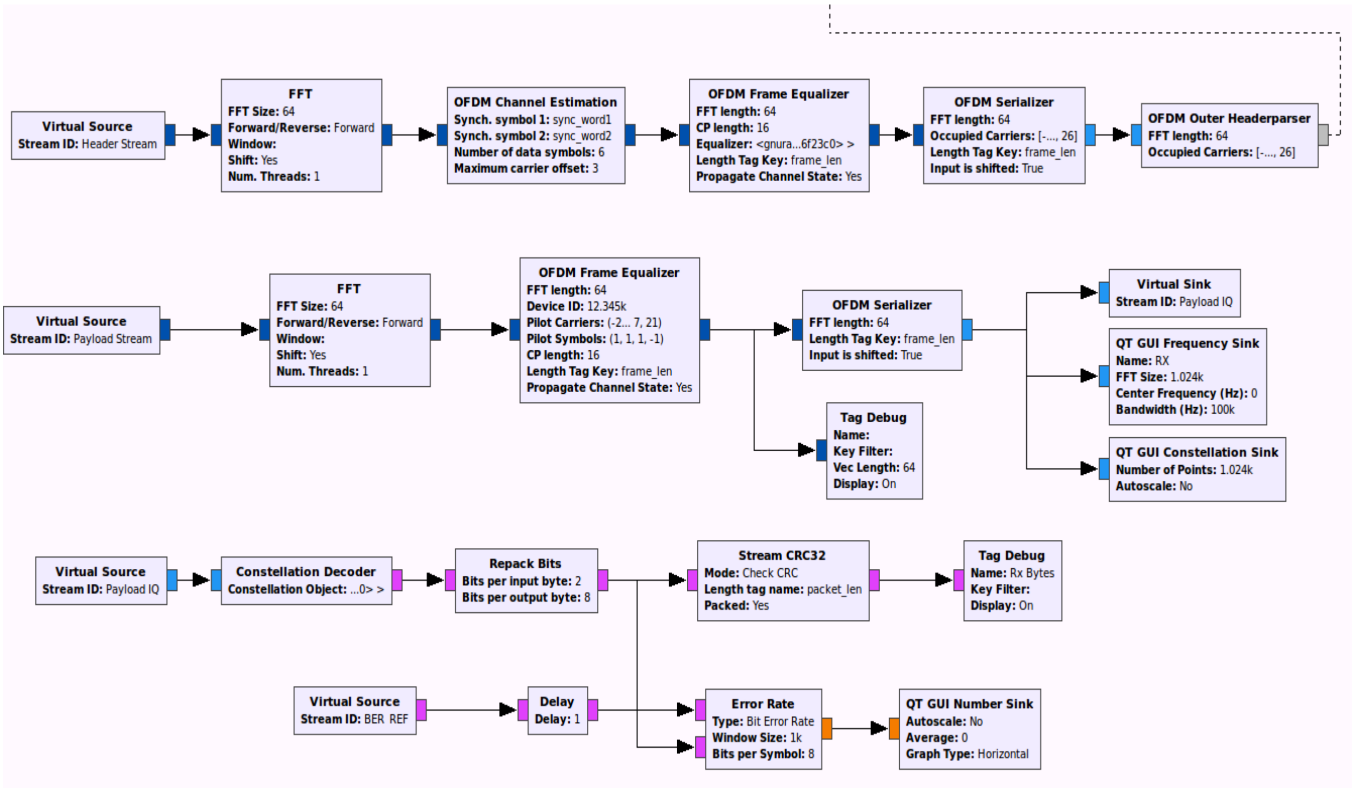

Figure 5: Flow graph of Reception (With DSA Implementation)

IV. Result and Discussion

In this section, we present the results obtained by running the simulation of the flow graphs in Section III using GNU Radio software. The parameters used in the experiment are shown in Table 1 below.

Table 1
Parameters used for flow graph configurations in Section III

	Without DSA Implementation	With DSA Implementation
Source of data	Random source	Fixed number of data
FFT length	64	64
CP length	16	16
Bandwidth (Hz)	10M	10M

Referring to Table 1, both the configurations have the same parameters except for the source of data. The configuration without DSA implementation generates random data whereas the other one has already fixed the amount of data. These two configurations are considered as LTE configuration because their bandwidths are 10MHz, which is within the LTE bandwidth range. Besides that, they also use OFDM as their multiplexing method. The DSA algorithm used in this experiment is based on the Nash Bargaining Solution [17]. A minimum rate is set for each user where the algorithm will continue searching for the second largest channel if the current user rate is lesser than the minimum rate. After users achieve the minimum rate, the allocation logic iterates until all of the subcarriers are engaged. After running the simulations using GNU Radio software, the output signals of the two configurations were compared. Besides that, the BER of both configurations were recorded and also compared. Figure 6 and 7 shows the output signals for both of the configurations.

The comparison of the results between the configuration with and without the DSA implementation is shown in Table 1 below:

Table 2
Table of Comparison of BER of the two configurations

	Without DSA Implementation	With DSA Implementation
Bit Error Rate	0.625	0.174
Difference (%)	72.16%	

BER is the rate at which errors occur in the transmission of digital data [18]. As you can see in Table 2, the output signal for the configuration without DSA implementation shows that the signal has more peaks as compared to the one with DSA implementation. This shows that the interference for the one without DSA implementation is higher than the one with DSA implementation. Besides that, the BER for the one without DSA implementation is also higher by 72.16% than the second one. This explains why there are more errors present in the configuration without DSA implementation, thus, causing more interference. From this, we can see that with the implementation of DSA, we can achieve minimal interference and errors in the network.

V. Conclusion

After observing the previous studies, there is no doubt that Dynamic Spectrum Allocation is one of the best techniques for interference mitigation in cellular networks. For future works, we will identify improvement in DSA in LTE configuration where the solution is able to significantly mitigate cross-tier interference impact. This technique will be validated by the use of software simulation as well as hardware platform basis. Besides that, we will also establish algorithm and implement the result from GNU Radio using USRP Evaluate performance based on SINR, throughput and Spectral Efficiency factors.

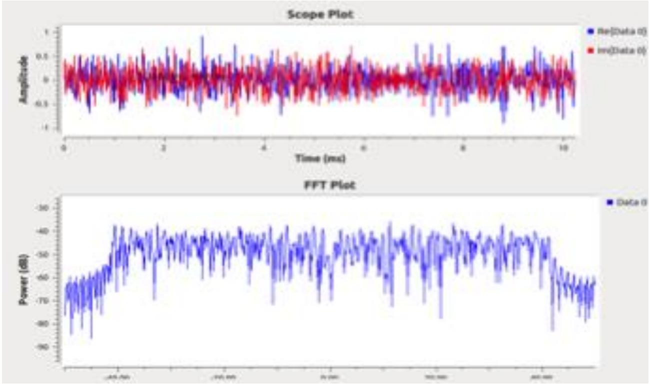

Figure 6: Output signal for configuration without DSA implementation

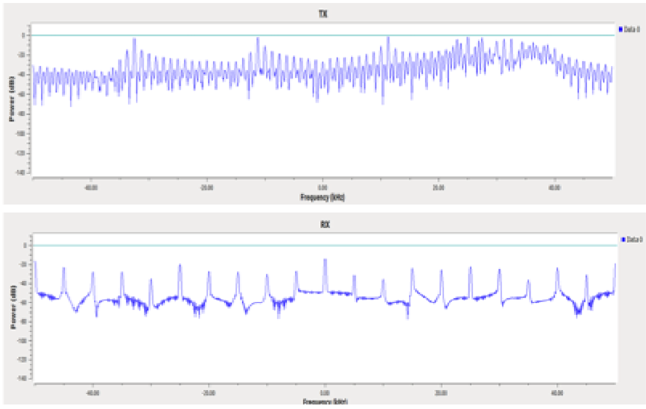

Figure 7: Output signal for configuration with DSA implementation

References

[1] G. Zhou, G. Bauch, J. Berkmann, and W. Xu, “Multi-layer rate splitting scheme for interference mitigation in tri-sectored wireless networks,” In *Communications (ICC), 2012 IEEE International Conference on*, pp. 4202-4206, Jun. 2012. IEEE.

[2] M. K. Hasan, A. F. Ismail, A. H. Abdalla, K. Abdullah, H. Ramli, S. Islam, and R. A. Saeed, “Inter-cell interference coordination in LTE-A HetNets: A survey on self-organizing approaches,” In *Computing, Electrical and Electronics Engineering (ICCEEE), 2013 International Conference on*, pp. 196-201, Aug. 2013. IEEE.

[3] H. Dahrouj, W. Yu, J. Chow, and R. Selea, “Interference mitigation via power control under the one-power-zone constraint,” In *Global Communications Conference (GLOBECOM), 2012 IEEE*, pp. 5050-5055, Dec. 2012. IEEE.

[4] N. Saquib, E. Hossain, and D. I. Kim, “Fractional frequency reuse for interference management in LTE-advanced hetnets,” *IEEE Wireless Communications*, vol. 20, no. 2, pp. 113-122, 2013.

[5] A. F. Ismail, M. K. Hasan, N. I. Othman, and W. Hashim, “Assessment of Dynamic Spectrum Allocation Technique in Heterogeneous Network,” *International Journal Of Future Generation Communication And Networking*, vol. 10, no. 3, pp. 41-47, 2017.

[6] M. K. Hasan, A. F. Ismail, S. Islam, W. Hashim, and B. Pandey. “Dynamic Spectrum Allocation Scheme for Heterogeneous Network,” *Wireless Personal Communications*, pp. 1-17, 2016.

[7] X. Chen, H. Xia, Z. Zeng, S. Wu, and W. Zuo, “User partitioning based resource allocation and interference coordination in heterogeneous networks,” In *Personal, Indoor, and Mobile Radio Communication*

(PIMRC), 2014 IEEE 25th Annual International Symposium on, pp. 1104-1108, Sep. 2014. IEEE.

[8] V. Le, Z. Feng, P. Zhang, Y. Huang, and X. Wang, "A dynamic spectrum allocation scheme with interference mitigation in cooperative networks," In *Wireless Communications and Networking Conference, 2008. WCNC 2008. IEEE*, pp. 3175-3180, Mar. 2008. IEEE.

[9] M. Zareei, A. M. Islam, N. Mansoor, and S. Baharun, "Dynamic spectrum allocation for cognitive radio ad hoc network," In *Advances in Electrical Engineering (ICAEE), 2015 International Conference on*, pp. 178-181, Dec. 2015. IEEE

[10] W. Zhang, L. Deng, and Y. C. Kiat, "Dynamic spectrum allocation for heterogeneous cognitive radio network," In *Wireless Communications and Networking Conference (WCNC), 2016 IEEE*, pp. 1-6, Apr. 2016. IEEE.

[11] M. K. Hasan, A. F. Ismail, W. Hashim, and S. Islam, "Investigation of Enhanced Particle Swarm Optimization Algorithm for the OFDMA Interference Management in Heterogeneous Network," *International Journal of Future Generation Communication and Networking*, vol. 9, no. 9, pp. 15-24, 2016.

[12] M. K. Hasan, A. F. Ismail, A. H. Abdalla, H. A. Ramli, W. Hashim, and S. Islam, "Throughput Maximization for the Cross-Tier Interference in Heterogeneous Network," *Advanced Science Letters*, vol. 22, no. 10, pp. 2785-2789, 2016.

[13] A. Sabbah and M. Ibnkahla, "Integrating energy harvesting and dynamic spectrum allocation in Cognitive Radio Networks," In *Wireless Communications and Networking Conference (WCNC), 2016 IEEE*, pp. 1-6, Apr. 2016. IEEE.

[14] Lei Zhang et. al., "Dynamic Spectrum Allocation for the Downlink of OFDMA-Based Hybrid-Access Cognitive Femtocell Networks," *IEEE Transactions on Vehicular Technology*, vol. 65, no. 3, Mar. 2016.

[15] Y. Luo and T. Ratnarajah, "Throughput of Two-Tier Heterogeneous Wireless Networks with Interference Coordination," 2014 *IEEE 25th International Symposium on Personal, Indoor and Mobile Radio Communications*, 2016.

[16] D. Siswanto, L. Zhang, K. Navaie, and G. C. Deepak, "Weighted sum throughput maximization in heterogeneous OFDMA networks," In *Vehicular Technology Conference (VTC Spring), 2016 IEEE 83rd*, pp. 1-5, May 2016. IEEE.

[17] H. Cheng, "Implementation of Dynamic Resource Allocation for LTE System Using GNU Radio," *Doctoral dissertation*, Faculty of George Mason University in Partial Fulfillment of The Requirements for the Degree of Master of Science Electrical and Computer Engineering, 2015.

[18] T. Pollet, M. Van Bladel, and M. Moeneclaey, "BER sensitivity of OFDM systems to carrier frequency offset and Wiener phase noise," *IEEE Transactions on communications*, vol. 43, no. 234, pp. 191-193, 1995.