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Interference Mitigation Approach towards 5G network

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Abstract

In the recent years, the demand for higher data rates has been continuously growing to satisfy consumers' desire for a faster, safer, and smarter wireless network. Since current wireless systems are facing a bottleneck in spectrum resources which make it difficult to enhance performance in the limited available bandwidth. To overcome this problem new Generation of mobile communication known as fifth generation (5G) comes into the picture. The goals of 5G network design are to achieve not only large network capacity, but also ultra-low latency and heterogeneous device support. 5G adopt multi-tier architecture where several low-power Base Stations (BSs) inside small cell are deployed within the coverage area of the macrocell. However, interference by the simultaneous usage of the same spectrum in these cells creates severe problems which reduce system throughput and network capacity. Hence, the resource management is an integral part of 5G HetNets so that interference between different devices can be minimized. The main aim of this work is comprehensive study about the different Interference mitigation approaches in 5G network.

Keywords— 5G cellular wireless, Interference management, HetNets, multi-tier networks, Heterogeneous Networks, co-tier interference, cross-tier interference

1. INTRODUCTION

Over a last few decades, there is a drastic change in the users demand for higher data rate in the wireless mobile communication. Mobile data traffic has been forecasted to grow more than 24 fold between 2010 and 2015 and more than 500 fold between 2010 and 2020 [1]. To meet these demands, drastic improvements need to be made in the cellular network architecture. 4G networks have reached the theoretical limits on the data rates[2] and therefore are not sufficient to accommodate the above challenges since current wireless systems are facing a bottleneck in spectrum resources which makes it difficult to enhance performance in the limited available bandwidth. All above issues are putting more pressure on mobile network operators. This ultimately leads to the driving forces towards the Next Generation mobile communication system known as 5G (Fifth Generation Mobile Technology) [3]. 5G denote the next major phase of mobile telecommunication standards beyond the 4G standards [4]. The 5G networks will use large number of nodes and cells with heterogeneous characteristics and capacities (e.g., macrocells, femtocells, picocells, radio relay heads (RRH) and D2D user equipment [UEs] etc.), which will result in a multi-tier architecture as shown in Figure1. Thus, by deploying large number of small cells in heterogeneous networks the capacity will significantly increase. However deployment of HetNets faces a number of challenges, among which interference management is a biggest concern. In 5G, the existing traditional schemes for mitigating interference will not be sufficient as it is applicable only for single-tier systems, thus it requires advance interference management techniques for example eICIC, advanced receiver, CoMP etc. Although cell densification provides significant benefits to both the user and mobile operator, it is essential to realize that there is possibility for cross-tier and co-tier downlink interference that affects throughput and QoS of victimized users of macrocell and small cell.

The primary focus in this paper is to analyze the multiple advanced interference mitigation techniques which can be incorporated in 5G network.

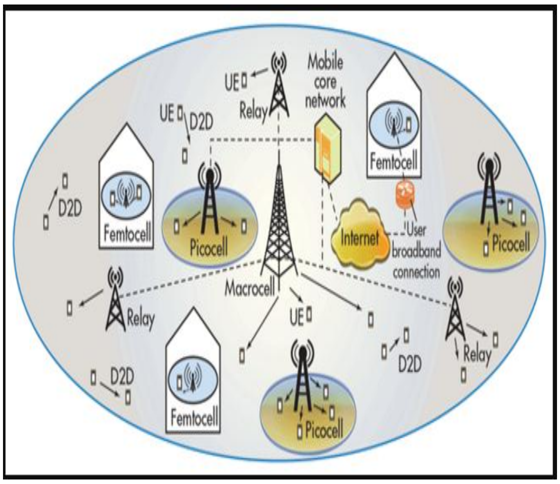

Figure 1. A potential 5G multi-tier network composed of macrocells, picocells, femtocells, relays, and D2D links. Arrows indicate wireless links, while the dashed lines denote the backhaul connections. (Source from Reference [9])

2. Goals for 5G

With continuing growth of Internet and its numerous applications, there was challenge in handling several classes of traffic to meet the different QoS requirements of diverse applications like video streaming, data, VoIP calls, etc Existing wireless network will struggle to deliver: wireless health service, virtual and augmented reality, vehicle to vehicle and vehicle to Infrastructure transportation system, Internet of Things (IOT), etc. 5G cellular network is envisioned to support all of these devices and applications unlike previous cellular networks. As per International Telecommunication Union (ITU), 5G would be supporting primarily massive machine type communications, mobile broadband services, and ultra-reliable and low latency communications, respectively [5]. Multiple devices and application scenarios require more sophisticated networks that not only support high IOPs, but also provide efficient energy consumption scheme, large scalability to accommodate a higher number of devices, low latency in data delivery, and ubiquitous connectivity for users. In this section, we explain these requirements and describe how they can be met by required solutions.

2.1. High Data rates

With the advancement of cellular internet and services such as High definition (HD) video streaming, video sharing, virtual reality, better data rates are now acting as an inevitable driving force. Pertaining to these demands for different applications, 5G network is expected to have highest data rates of around 10Gbps which is much better than existing 4G networks. Area capacity is another important factor which characterizes data rate; it specifies the total data rate the network can serve per unit area. Area Capacity is supposed to go up by 100 times in 5G in comparison to 4G network. All these demands of higher data rates can be met using millimetre wave, software defined networking and massive MIMO systems etc.

2.2. Low Latency

Current latency in 4G networks is 15 milliseconds. For applications like virtual reality and HD gaming that 5G networks are expected to support, latency should be faster than the current network at the value of 1 millisecond. There are many emerging applications for which wireless network will be utilized for real-time control. Latency required for such applications are determined by interaction between real and virtual objects without creating any network-sickness. These applications would be feasible at around latency of 1 millisecond. Typical use case will be intelligent traffic system where in vehicles require timely exchange of data for traffic efficiency and safety to avoid any accidents scenarios. Software defined networking in wireless is key factor contributing to this change.

2.3. Low Energy consumption

The 5G networks are expected to support the IoT devices which are basically some sensors that gather information about an environment and transmit it to a central server. These devices are mostly low-power, low-cost devices with life-spans as long as several years. Since these devices are not always connected to the base station and are only switched on occasionally, their battery life cannot afford the process of synchronization with the base station every time, as the synchronization step costs more energy than that of actual data transmission. With the increasing number of connected smart devices, the number of base stations required to support these devices will also escalate. This foreseeable trend demands the base stations to be energy efficient since even a small improvement in energy efficiency will translate to huge energy savings in large scale.

2.4. High Scalability

It is expected that the number of devices

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connected to the cellular network will grow to 50 billion by 2020[2]. Thus to support increasing amount of mobile devices that connect to the wireless network and communicate with each other, network scalability becomes an important factor in design of the next generation wireless communications network.

2.5. Improved connectivity and reliability

With the increase in density of the base stations and the number of devices connected, as well as the introduction of femtocells and picocells, the number of handovers that the base station should handle will increase by at least two orders of magnitude. To support this demand, novel handover algorithms and techniques that provide improved coverage in cell edge areas are required.

2.6. Improved Security

The security aspect of wireless network recently attracts high attention, especially after 2015, when the applications of mobile payments and digital wallet became popular. Thus to transfer data securely over a wireless network is one of the goals for 5G technology.

3. Types of interference

The creation of HetNets gives rise to two layers or tiers in the wireless network: the macrocell layer and the small cell layer. Thus interference can be divided into two types, Cross-tier (between small cells and macrocells) and Co-tier (between small cells). The types of interference in two tier small cell networks are depicted in Figure 2.

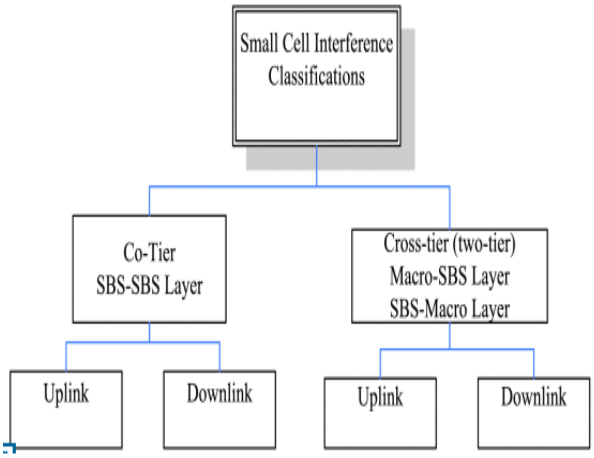

Figure 2. Interference Classification in two tier small cell network

3.1. Co-tier Interference

The co-tiered interference is the interference among small base stations (SBSs) that belong to the same tier in the Heterogeneous networks and it is a challenging problem due to possible close proximity of a large numbers of small cells as shown in Figure3. Users in the coverage of different cells overlapped may interfere with each other due to the fact that more and more SBs are randomly distributed in a surrounding area. Co-tiered interference occurs in a small-cell network between neighbouring small-cells. For example, uplink co-tiered interference to the neighbouring SBSs caused by a small-cell user (SU). On the other hand, a SBs acts as a source of downlink co-tiered interference to the neighbouring SUs in overlapping regions. When the number of SBSs is large for example in urban areas, severe co-tiered interference is difficult to mitigate.

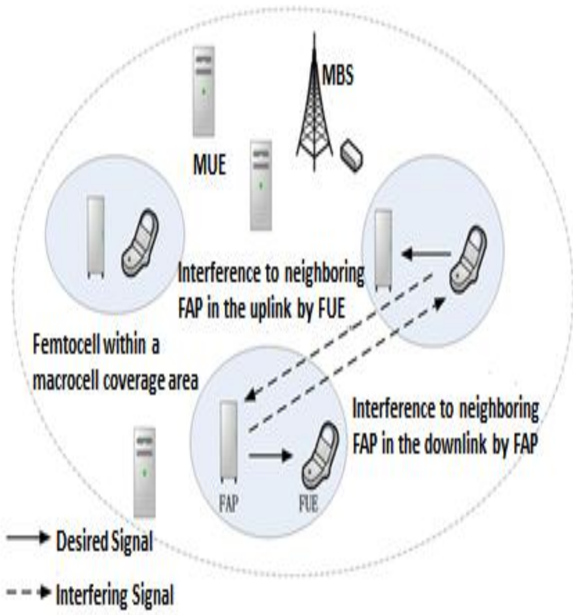

Figure 3. A scenario showing co-tier interference between neighbouring femtocells. (Source from Reference [7])

3.2. Cross-tier Interference

Cross tier interference between the small cell and macrocell network occurs particularly when the small cell networks share the same frequency band as the surrounding macrocell network as shown in Figure4. This means that small cells may cause and suffer co-channel interference with the overlaying macrocell network.

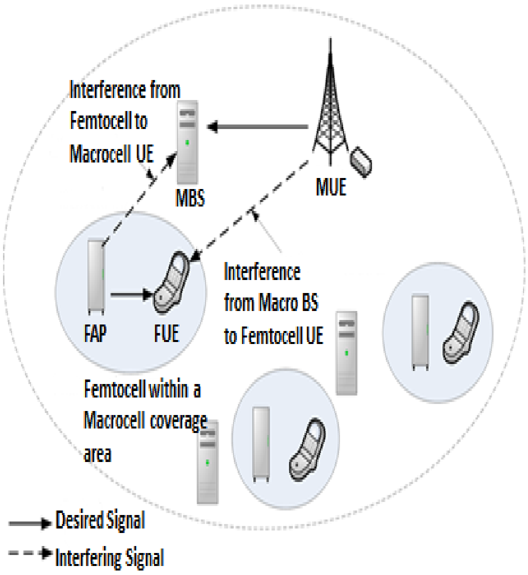

Figure 4. A scenario showing cross-tier interference between femtocell and macrocell

Below Figure5 shows combined view of co-tier and cross-tier interference in a multi tier network.

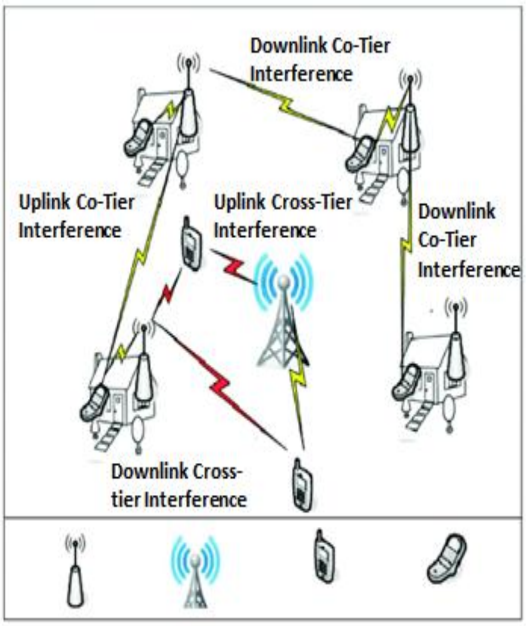

Figure 5. Co-tier and cross-tier interference

3.3. Already Existing interference mitigation techniques and their drawbacks

In below figure 6, typical interference technique is shown. The conventional approach to mitigate interference is:

3.3.1. Interference from the cells which use the same frequency can be decrease by increasing the reuse distance between cells. But in this case as the frequency is reused less, so there would be less impact on system throughput and it would not be more than before.

3.3.2. The interference between subscribers can be mitigated by utilizing the orthogonalization of the shared time/frequency resource.

3.3.3. The interference can be minimized by treating other transmitters' signals as noise.

We need more effective interference mitigation approach in 5G due to its Heterogeneous layered architecture in order to get higher capacity and data rate, less end to end latency, massive number of connections, as well as sustainable cost and consistent quality of experience (QoE).

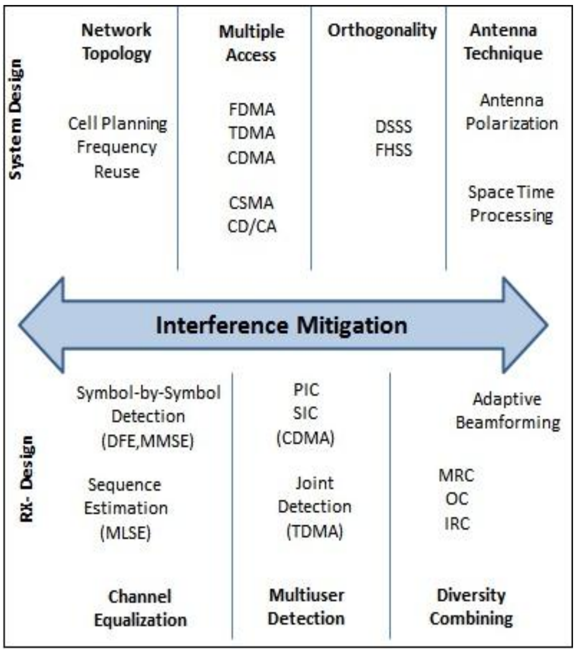

Figure 6. Typical interference mitigation techniques

4. Advanced Interference Mitigation approach towards 5G network

As 5G network are made of multiple network tiers of different sizes, transmission power and large number of smart and heterogeneous devices are connected so interference problem arises which include both cross-tier interference that affects macro users from other tiers and co-tier interference which is among users belong to same tier. So interference mitigation becomes a critical challenge in resource allocation in the 5G context. In the following subsections, different advanced interference mitigation approached is presented.

4.1. UE-side interference management

In 4G cellular network biggest obstacle is co-channel interference which badly impact on cell throughput. Although in 4G cellular network some Network-side interference management technique has been introduced however putting interference management responsibility completely on network yields lots of practical issues and limitations such as backhaul and feedback overheads. The advanced interference management techniques (AMI) will play a potential role in 5G initiation which will consist both UE-sides as well as network-side interference management [8]. Thus by incorporating UE-side interference management technique issues and the limitations of network-side interference management can be overcome.

The two important usage of AMI can be considered as:

- UE-side interference management by advanced receivers with joint detection/decoding.
- Network-side interference management by joint scheduling

4.2. Advanced Receiver

In conventional cellular systems, the interference was treated as noise. In spite of this there is a difference between noise and interference signal. Interference signal has similar structure to desired signal and poses severe performance failure. Advanced interference management at the receiver, or an advanced receiver is the technique which helps in Interference mitigation. The receiver will make use of structure of interference signals in detection and decoding of the interference signal symbols within the modulation constellation, coding scheme, channel, and resource allocation. Then based on detector/decoder output, the interference signal can be reconstructed and removed from the desired signal.

Advanced receivers not only help in mitigating inter cell interference at the cell boundaries, but also includes intra cell interference management as in the case of massive MIMO. Henceforth more mature inclusion of advanced receiver technologies would be required into the specification for next generation.

4.3. Distributed Cell association and power control (CAPC) methods for multi tier network

The existing CAPC schemes where each user can associate to single BS, should be improved to support simultaneous association of user to multiple BSs in 5G multi tier network. Thus interference management in 5G networks need efficient distributed CAPC scheme. Prioritized power control scheme [9] where users in different tiers have different priorities for channel access is required. In the same way resource- aware Cell association schemes where user can associate with most suitable cell so that their performance maximized can be used in a next generation wireless communication.

4.4. Joint scheduling

The role of joint scheduling is to jointly determine serving UEs and transmission schemes for a set of multiple Transmission Points (TPs), to which we refer as a cluster, so that the overall utility function of the cluster is optimized. The joint scheduling, depending on the specific scheme, can be implemented in either a centralized or distributed manner.

In the centralized case, all the required information is first sent from the TPs within the cluster to the central controller which determines all the calculation and sends a corresponding scheduling data to each TP. Although centralized schemes often outperform distributed schemes, they suffer from a heavy processing load and proper backhaul. On the other hand, in the distributed case, each TP does its own calculation and exchanges a small amount of summary information with the others for overall coordination. The distributed schemes are beneficial when the cluster size is very large since generally the amount of this summary information is very small. In many cases, the distributed schemes are iterative and suffer from large delay. Thus AMI schemes by joint scheduling need to be specified in more detail in the next generation systems.

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4.5. Enhanced inter-cell interference coordination (eICIC)

ICIC is a frequency domain technique where frequency is divided into sub-bands to reduce inter-cell interference. But it is not suitable for heterogeneous network. To manage the interference in a HetNeT, the eICIC techniques are used effectively which is based on time domain for co frequency inter-cell interference coordination. Time is considered in eICIC, and some UEs of different cells are orthogonal to each other in time domain It not just help in reducing interference of traffic channels but also reduces interference of control channels in different cells as well.

There are two main techniques in eICIC. One is called Almost Blank Subframe (ABS), and the other is named Cell Range Expansion (CRE)[10].

4.5.1. Almost Blank Sub frame (ABS): eICIC can be implemented in the pico-cells in order to suppress the interference to the control channels of the macro UEs which is caused by overlap of control and data channels of the macro-cell BS and the pico BS if their sub frames used for throughput enhancement are aligned. By minimizing its transmission, the pico-cell BSs reduce the interference to its surrounding neighbours, including the macro BS. Thus the pico-cell BS stop its transmission in some sub frames. These muted sub frames are called almost blank sub frames (ABSFs) approach.

Below Figure7 represents subframes without eICIC and Figure8 shows with ABSFs.

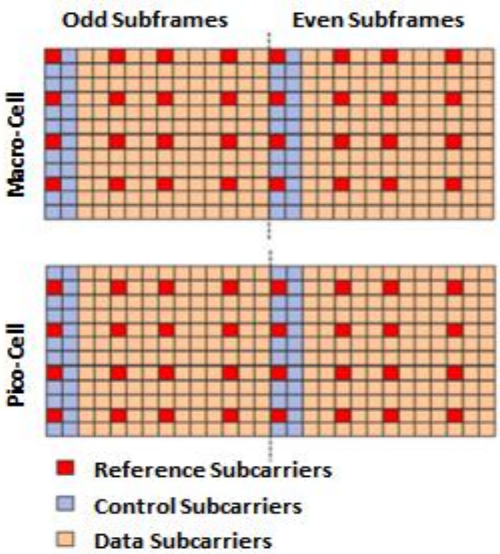

Figure 7. Illustration of macrocell and picocell subframes without any eICIC.

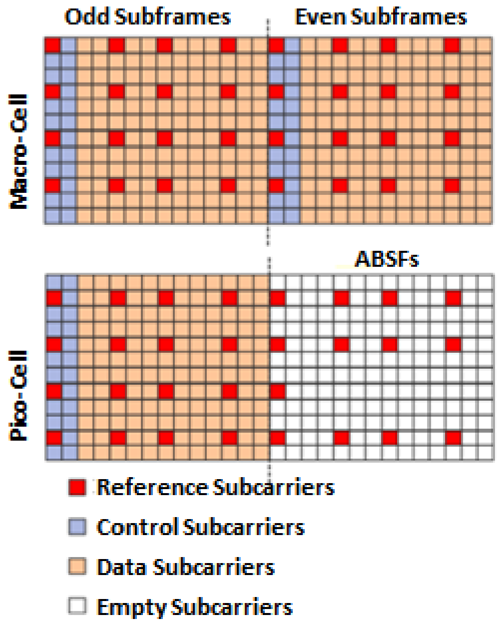

Figure 8. Illustration of macrocell and picocell, used for throughput enhancement, subframes with ABSFs.

4.5.2. Cell Range Expansion(CRE):
CRE effectively helps in reducing the problem of load imbalance in the downlink. It increases the downlink coverage footprint of low power BSs by adding a positive bias to their signal strengths. Such BSs are referred to as biased BSs. This biasing allows more users to associate with low power or biased BSs and thereby achieve a better cell load balancing. Nevertheless, such off loaded users may experience unfavourable channel from the biased BSs and strong interference from the unbiased high-power BSs

4.6. Coordinated multipoint (CoMP) for interference management

CoMP introduces the possibility of transmitting in a coordinated way from diff erent network points toward users that are on the cell edge and more vulnerable to interferences. Specifically, in CoMP a number of TX points provide coordinated transmission in the downlink, and a number of RX points provide coordinated reception in the uplink. Diff erent operation modes have been supposed, from the easiest selection of the best transmission point, to the joint transmission from diff erent network points or coordinated scheduling and beam forming schemes.

Conclusion

With appropriate application of interference cancellation, suppression and avoidance techniques, interference can be mitigated sufficiently as to boost system capacity towards attaining 5G goals. So for 5G networks, the interference mitigation techniques should be more flexible and open to the variations as changes in the traffic and deployment are expected to occur more rapidly than existing networks. For the upcoming new 5G technology, the advanced schemes and architectures of interference mitigation should be developed so that the spectrum efficiency is enhanced as well as the capacity of the network.

References

[1] T. Nakamura, S. Nagata, A. Benjebbour, Y. Kishiyama, H. Tang, X. Shen, N. Yang, and N. Li, “Trends in Small Cell Enhancements in LTE Advanced”, IEEE Communications Magazine, vol. 51, no. 2, pp. 98-105, Feb 2013.

[2] Cisco, Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2013- 2018, White Paper, 2014.

[3] A. Osseiran, et al., "Scenarios for 5G Mobile and Wireless Communications: The Vision of the METIS Project", IEEE Communications Magazine, Vol. 52, No. 5, 2014, pp. 26-35.

[4] W. Cheng-Xiang, F. Haider, X. Gao, X. You, Y. Yang, d.Yuan, H. M. Aggoune, H. Haas, S. Fletcher, E. Hepsaydir, “Cellular Architecture and Key Technologies for 5G Wireless Communication Networks”, IEEE Communications Magazine pp 122-130, Feb. 2014

[5] S. Talwar, D. Choudhury, K. Dimou, E. Aryafar, B. Bangerter, K. Stewart, “Enabling Technologies and Architectures for 5G Wireless”, IEEE Communications Magazine June 2014.

[6] Jiandong Li; Chungang Yang, Interference Mitigation and Energy Management in 5G Heterogeneous Cellular Networks,IGI Global, 2016

[7] Zahir, T., Arshad, K., Nakata, A., Moessner, K, "Interference management in femtocells", IEEE Communications Surveys & Tutorials Volume: 15, Issue: 1, First Quarter 2013

[8] Wooseaok Nam, Dongwoon Bai, Jungwon Lee, Lnyup Kang, “Advanced Interference Management for 5G cellular Networks”, IEEE Communications Magazine May 2014..

[9] Ekram Hossain, Mehdi Rasti, Hina Tabassum, Amr Abdelnasser, “Evolution Towards 5G Multi-tier Cellular Wireless Networks: An Interference Management Perspective”, IEEE Wireless Communications Volume: 21, Issue: 3, June 2014.

[10] Afolalu O.F, Petinrin J.O, Ayoade M.A, “A Survey of Interference Challenges and Mitigation Techniques in 5G Heterogeneous Cellular Networks”, International Conference of Sciences, Engineering and Environmental Technology, vol. 1 no. 2, 18-22 August 2016.

[11] Cadambe, V., Jafar, S, “Interference alignment and degrees of freedom of the K-user interference channel”, IEEE Transactions on Information Theory May 2008.

[12] Chandrasekhar, V., & Andrews, J. G., “Uplink capacity and interference avoidance for two-tier femtocell networks”, IEEE Transactions on Wireless Communications Volume: 8, Issue: 7, July 2009.