Generation of Optimal Almost Blank Frames using Genetic Algorithm

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***Abstract*— The interference suffered by users at the CRE area of pico cells is one of the main factors that affects performance of a HetNet. In order to assist pico downlink transmissions, the Macro-eNB can mute all downlink transmissions to its users in certain subframes termed ABS. In this paper, we propose a genetic algorithm to find optimal ABS pattern that maximizes the network capacity and provides better fairness in resource allocation between all users. Results indicate that the ABS pattern provided by GA achieve a Fainess Jain Index 59,63% better compared with use of random pattern.**

***Keywords*— HetNet, eICIC, ABS, GA**

I. INTRODUCTION

Mobile broadband traffic has been growing very fast through the past few years due to the new generation of wireless gadgets (e.g smartphones, tablets,etc.), it has surpassed voice traffic and is expected to grow even more due to current shift in the traffic pattern from data-centric to video-centric applications. The concept of HetNet (Heterogenous Network) has attracted a lot of interest recently to optimize the network performance. A HetNet consists of regular macro cells transmitting typically at high power level, overlaid with low-power small cells such as pico cells, femto cells, Remote Radio Head (RRH), Relay Node (RN), etc. [1], as shown in the Fig. 1.

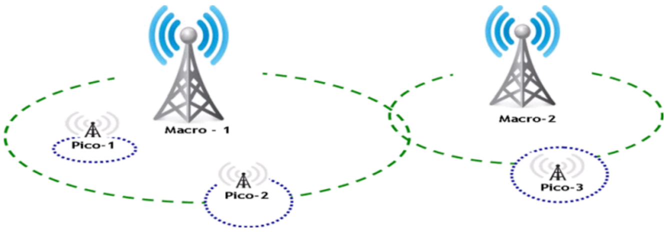

Fig. 1. A typical LTE HetNet architecture with macro and pico cells. Pico cell 1 is used for throughput enhacement in a possible traffic hotspot location, Pico cells 2 and 3 are used for improving edge throughput [4].

The main approach to enhance performance is to improve the network topology that is done in the Hetnet scenario by overlaying the planned network of high Macro base stations with smaller low power Pico base stations that are distributed in an unplanned manner or simply in hotspots where a lot of traffic is generated. These deployments can improve the overall capacity and the cell edge user performance.

The heterogeneous architecture also introduces several concerns regarding the cell access and mobility procedures. Despite the significant network performance expected from the deployment of picocells, challenging technical problems, such as interference management need to be overcome. Note, that in this architecture, the user located in the edge of picocell suffers of high level interferences. The Fig. 2 shows that.

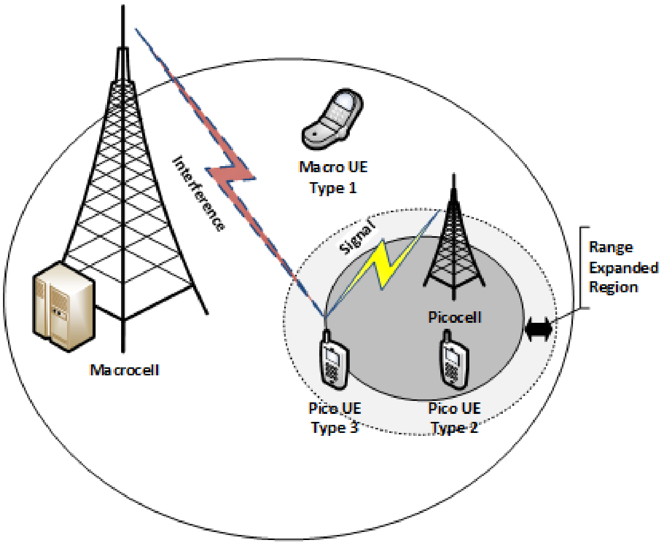

Fig. 2. The dominant DL cross-tier interference scenario in HetNet.

The eICIC new technique overcomes this problem by reserving for the edge of picocell area a part of macrocell resources through Almost Blank Subframes (ABS) approach.

This paper is organized as follows. Section II provides a background on eICIC highlighting ABS approach to mitigate interference suffered by user located in edge of picocells and describes some important related work. Section III presents the system modeling. In Section IV, we present the proposed schema. In Section V we present the numerical results. Finally, we conclude this work in Section VI.

II. BACKGROUND: EICIC AND RELATED WORK

In a HetNet, the Macro-eNB transmission, due to high tranmission power of the Macro-eNBs, is associated with a high interference to the Pico-eNB users which denies them to use the same physical resources. Due to the difference in transmission powers of the Macro-eNBs and Pico-eNBs, in the edge of the pico-cell.

The Enhanced Inter-Cell Interference Coordination (eICIC) proposal in LTE standards serves two important purposes: allow for time-sharing of spectrum resources (for downlink transmissions) between macros and picos so as to mitigate interference to pico in the downlink, and, allow flexibility in user equipament (UE) association so that picos are neither underutilized nor overloaded [2][3][4][7].

A. *Cell Range Extension (CRE)*

Cell selection in LTE is based on terminal measurements of the received power of the downlink signal or more specifically the cell specific reference (CRS) downlink signaling. This approach for cell selection would be unfair to the low power nodes (Pico-eNBs) due different type of base stations that have different tranmission powers including different powers of CRS. Thus, the terminal most probably will choose the high power base stations (Macro-eNBs) even if the path loss to the Pico-eNB is smaller. This can lead to problems such as:

- Uplink coverage: terminal will select the Macro-eNB even if has a lower path loss to the pico-eNB.
- Downlink capacity: Pico-eNBs will be under-utilized as fewer users are connected to them while the Macro-eNBs could be overloaded even if Macro-eNBs and Pico-eNBs are using the same resources in terms of spectrum, so the cell-splitting gain is not large and resources are not well utilized.
- Interference: Macro-eNB transmission is associated with a high interference to the Pico-eNB users due to the high transmission power of the Macro-eNBs.

The eICIC technique overcomes these two first problems by extending the picocell radius by adding the so called Extesion (CRE). As a consequence, the coverage area of the Pico-eNB is extended increasing the number of users served by the small cell. On the other hand, the user in the extended cell area, where the power received from the Macro-eNB is much higher than the power received from Pico-eNB, are subject to severe interference from the Macro-eNB. In order to mitigate the interference effects associated with CRE is used Almost Blank Subframes approach.

B. *Interference Management using ABS*

In order to assist pico downlink transmissions, each macro remains silent for certain periods, termed Almost Blank Subframes (ABS periods), during which a Pico-eNB can transmit at reduced interference. These subframes are called ”almost blank” because a macro-eNB can still transmit some broadcast control signals over these subframes. Since these control signals only occupy a small fraction of the OFDMA subcarries, the overall interference caused by macro-eNB, in the picocell, is much less during these ABS periods. Thus, the pico-eNB can transmit to its UEs at a much higher data rate during ABS periods. It is important to note, a pico-eNB can transmit to its UEs during non-ABS periods, which can provide good enough performance to UEs very close to the it.

The relevant previous work focused on studying the influence CRE parameters on the performance and find optimal values for ABS ratio [2].

The goal of this paper is to developer a genetic algorithm that find optimal ABS sequence for a given network scenario.

III. SYSTEM MODEL

Since the eICIC proposal by LTE standard aims to protect downlink pico transmissions and our goal is to develop a genetic algorithm for optimal ABS pattern setting, we only consider downlink transmission in this work.

Network Topology: We consider the network topology that contains 1 Macro-eNB and 1 Pico-eNB, as shown in Figure 2.

In this scenario, we will consider three types of UEs:

- *Type 1 UE*: UE located inside of the macrocell coverage area.
- *Type 2 UE*: UE located inside of the picocell coverage area.
- *Type 3 UE*: UE located inside of the edge of the picocell coverage area.

The macrocell only need to stop transmission during ABS subframes to protect UEs connected to the picocells that located on its edge. Pico-eNBs sends data to the type 3 UE during ABS subframes and to the Type 2 UE using non-ABS subframes, as illustrated in Fig. 3.

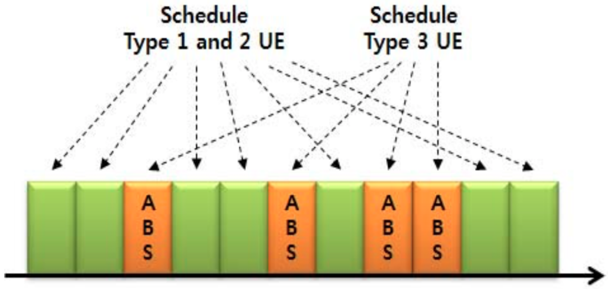

Fig. 3. Interference management using ABS [7].

Interference Modeling: For the purpose of eICIC algorithms, it is important to distinguish macro-pico interference from the rest.

- *Macro-pico interference*: The UEs of pico-cell can be interfered by macro-cell only during non-ABS subframes.
- *Macro-Macro and pico-pico interference*: Picos can interfere with each other and similarly for a macros. A pico UE can be interfered by another pico both during ABS and non-ABS subframes.

To better understand these two kind of interferences, consider a given user u associated to the Pico-cell. Suppose the total interference power it receives from all other interfering pico-cells and all interfering macro-cells be $P_{Int}^{pico}(u)$ and $P_{Int}^{macro}(u)$, respectively. Denoting by $P_r^{pico}(u)$ the received downlink power of UE-u, the downlink SINR of UE u that belongs to a given pico-cell can be modeled as

$$SINR(u) = \\ \begin{cases} \dfrac{P_r^{pico}(u)}{P_{Int}^{pico}(u) + N_o}, \text{ for ABS subframes} \\ \dfrac{P_r^{pico}(u)}{P_{Int}^{pico}(u) + P_{Int}^{macro}(u) + N_o}, \text{ for non-ABS subframes} \end{cases} \tag{1}$$

In the equation 1, we can interpret that during ABS subframes all interfering macros remain silent and so the only interference is from the interfering picos-cells. However, during non-ABS subframes there is interference from all interfering pico-cells and macro-cells both. However, for a given UE-*u* that belongs to a given macro-cell, during non-ABS subframes, will suffer with interference from all interfering picos-cells and macros-cells both. Thus the SINR expression can be modeled as

$$SINR(u) = \frac{P_r^{macro}(u)}{P_{Int}^{pico}(u) + P_{Int}^{macro}(u) + N_o} \tag{2}$$

where $P_{Int}^{pico}(u)$ and $P_{Int}^{macro}(u)$ denote the interference from interfering pico-cells and macro-cells, respectively.

Pathloss Model: The received power (P_{Rx}) is calculated assuming a path loss model L^{pico} for users attached to Pico-eNB that transmits with a power P_t^{pico} is given by

$$P_r^{pico} = P_t^{pico} S - H - L^{pico} \tag{3}$$

where P_t^{pico} is the transmit power of pico-eNB, S is shadow loss and H is the Slow fading loss. The path loss is calculated according to

$$L^{pico} = 38 + 30log_{10}(R) \tag{4}$$

with R in meters. In the same way, the receive power for users attached to Macro-eNB that transmits with a power P_t^{macro} is given by

$$P_r^{macro} = P_t^{macro} S - H - L^{macro} \tag{5}$$

where L^{macro} is defined by

$$L^{macro} = 128.1 + 37.6log_{10}(R) \tag{6}$$

with R in kilometers.

The basic system parameters are presented in Table I.

TABLE I

BASIC PARAMETERS OF PROPAGATION ENVIRONMENT FOR THE CHANNEL MODEL

Parameter	Value	Ref.
Macro cell radius	500 m	[2]
Pico cell radius	50 m	[2]
Macro-eNB transmit power	43 dBm	[6]
Pico-eNB transmit power	38 dBm	[6]
Macro cell pathloss model	128.1 + 37.6 log10(d)	[6]
Pico cell pathloss model	38 + 30 log10(d)	[6]
Shadowing std. dev. (Macro)	8 dB	[6]
Shadowing std. dev. (Pico)	10dB	[6]
Thermal noise power	-112dBm	[6]
Monte Carlo	800000	

d is the distance between communicating devices in meters

IV. PROPOSED SCHEME

Genetic algorithms (GA) is inspired by the mechanism of natural selection, a biological process in which stronger individuals are likely be winners in a competing environment. It presumes that the potential solution of a given problem is an individual and can be represented by a set of parameters. These parameters are regarded as the genes of a chromosome and can be structured and represented by a set of parameters [3].

GA search parallel from a population of points. Therefore, it has the ability to avoid being trapped in local optimal solution like traditional methods, which search from a single point. Thus, we implemented an genetic algorithm to find the best ABS pattern that maximizes the performance of the network.

The ABS pattern is periodical with 40 subframes for FDD mode, while the value in TDD mode depends on the uplink/downlink configuration [6]. In the simulations, we will adopt an ABS pattern composed of a sequence 40 subframes that comprises 4 frames. Thus, an individual for GA is a sequence composed of 40 chromosomes that represents an ABS sequence, as shown in Fig. 4.

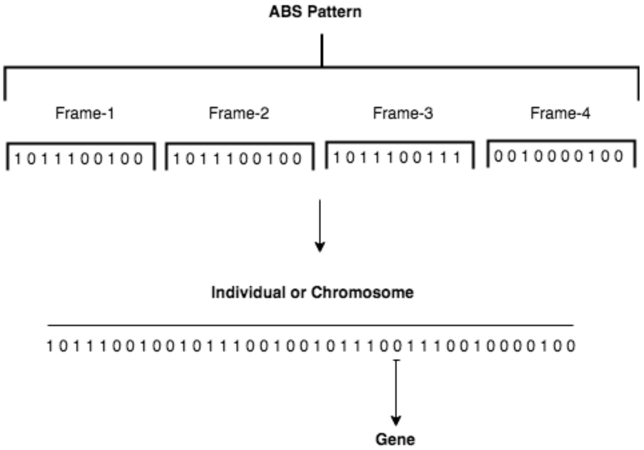

Fig. 4. Chromosome that represent an ABS sequence for GA.

To evaluate individuals performance of a given population, we need to define a fitness function. The fitness function is responsible for performing this evaluation and returning a fitness value, that reflects how optimal the solution is: the higher number, the better solution. In ABS pattern optimization problem, we trying to improve the throughput of UEs located in edge of the picocells, as well as of all other users. The goal of this algorithm is to find the best ABS sequence that maximizes the sum of throughput of all users, as described in equation

$$Fitness(i) = \frac{\sum_{j=1}^{N} C_j}{n \cdot ||C||} \tag{7}$$

where C_j denote the throughput of user j.

In order to provide fair throughput for all users, we will use the Fairness Jain Index (J). For a given vector $x \in \Re_+^N$, $J : \Re_+^N \longrightarrow \Re_+$ is given by the following expression

$$J(x_1, x_2, ..., x_N) = \frac{(\sum_{j=1}^{N} x_j)^2}{N \cdot \sum_{j=1}^{N} x_j^2} \tag{8}$$

where x is a vector.

Thus, our fitness function can be rewritten as

$$Fitness(i) = \alpha \cdot \frac{\sum_{j=1}^{n} C_j}{n \cdot ||C||} + (1 - a) \cdot \frac{(\sum_{j=1}^{n} C_j)^2}{n \cdot \sum_{j=1}^{n} C_j^2} \tag{9}$$

where α is a weighting parameter.

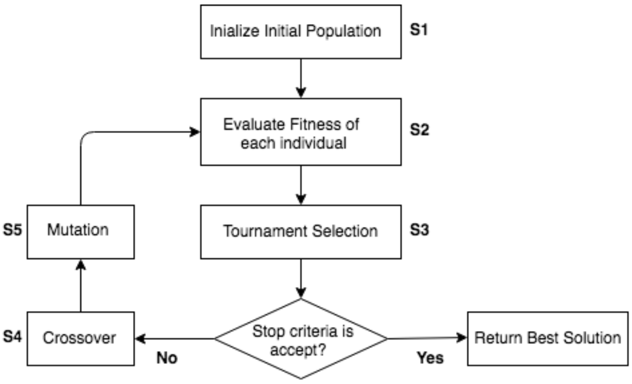

Fig. 5. Genetic algorithm diagram.

Throughout a genetic evolution, a fitter chromosome tends to yield good-quality offspring, which means a better solution for the problem. In ABS pattern optimization problem, the GA starts creating a initial population. The initial population is created according to P_{abs} parameter that controls the ABS ratio for each individual. For example, given that a frame consists of ten subframes, a $P_{abs} = 0.6$ means that six of these subframes are ABS. In each cycle of genetic operation, a subsequent population is created from the chromosomes in the current population through the tournament selection process. In this process, the genes of parents are to be mixed and recombined for the production of offspring in the next generation. It expected that from this process of evolution, the fitter chromosome will create a larger number of offspring, and thus has a higher probability of surviving in the subsequent generation. This evolutionary cycle is repeated until a desired stop criteria is reached and the best ABS pattern is returned, as shown in Fig 5. We will use as criteria the number of evolution cycles. After several experiments were carried out, it was observed that the GA tends to converge before a hundred generations. Therefore, we use one hundred generations as stop criteria. There are two fundamental operators required in evolution cycle, crossover and mutation. The crossover probability (P_c) and mutation probability(P_m) control parameters are defined with values 0.65 and 0.001, respectively [8].

V. Performance Analysis

The objective of our research is to create an genetic algorithm that find the optimal ABS sequence pattern for a given network setup. The experiments are conducted in a basic cluster that consists of: one Macro-eNB and one Pico-eNB that share the same bandwidth.

We first develop an algorithm to find optimal values for α and P_{abs} described in Section IV.The values of α and P_{abs} are defined as 0.4 and 0.6, respectively. These values are obtained in a Monte Carlo experiment that test the GA behavior for the $0 < \alpha < 1$ and $0 < P_{abs} < 1$. In order to measure the gain, we analize behavior of fitness function throughout eight hundred thousand subframes when set ABS pattern by the sequence provided for GA and compare with the results obtained when use random sequences.

For a user the throughput, in terms of bits/Hz, is given by Shannon equation, as described in Eq. 10:

$$C = B \cdot \log_2(1 + SINR) \tag{10}$$

We delop a MATLAB software to study HetNet performance, in terms of users throughtput based on Eq.9.

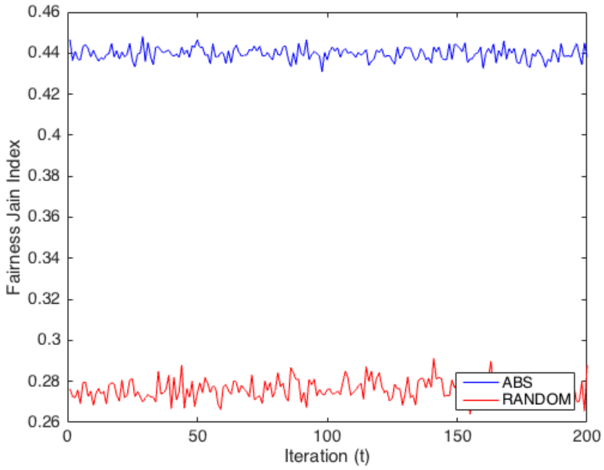

Fig. 6. Fairness Jain Index over 800000 subframes.

In terms of fairness, we note in Fig. 6 that using the sequence provided by GA we obtain better values for Jain Index. The ABS sequence provided by GA achieve an average Jain Index 59,63% better compared with results obtained when we use random sequences. It can be observed in the Fig. 7 that, although lower than the values obtained by the random pattern, the average throughput keeps in an acceptable range for the system.

VI. Conclusion

CRE technique aims to balance the Macro and Pico cell loads by enlarging the Pico cells area and increasing the number of user attached in Pico cell. To mitigate the large interference in the Range Extesion Area ABS, schem is introduced in eICIC. In this work, we have developed a genetic algorithm for optimal ABS pattern configuration based on actual network topology, propagation data, traffic load etc. Our

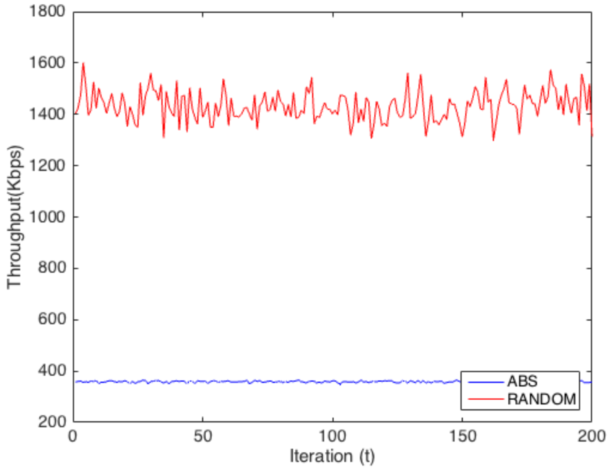

Fig. 7. Throughput curve over 800000 subframes.

results demonstrates the gains that can be reached using an ABS pattern sequence generated by GA when compared with random ABS pattern. Although, the random pattern achieve better average throughput, the farness is sacrificed. GA reaches better results in terms of fairness keeping throughput within an acceptable range.

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