INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

Joint optimization on resource allocation with coordinated scheduling-based transmission for interference handling in Femtocell networks

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Abstract

Background: The most challenging problem in femtocell networks is alleviating the Inter-Cell Interference (ICI) between the macro and femtocells while broadcasting the video streams in the Heterogeneous Networks (HetNets). It degrades the spectral efficacy and throughput significantly. To alleviate this problem, a Joint dynamic Layer, Channel and Power assignment with Further enhanced ICI Coordination (JLCP-FeICIC) method was recommended to assign the resources within every User Equipments (UEs) and enhance the throughput in a two-tier HetNets. Nonetheless, it schedules only the Cell Range Expansion (CRE) UEs of femtocells while the center UEs are not assigned and so the fairness of Resource Block (RB) allocation is reduced. **Objective:** Therefore in this study, JLCP-FeICIC is further enhanced with the Coordinated Multipoint Transmission (CMT) method (JLCP-FeICIC-CMT) for maximizing the efficiency of the HetNetcenter UEs. **Methods:** In this method, RBs are assigned by a primary scheduler. Also, the UE is detected in every eNodeBs (eNBs) according to the determination of the interference from the adjacent cells. Then, the Modulation and Coding Scheme (MCS) level is selected in all eNBs for UEs with and without the support of CMT according to the interference-free RB allocation. So, a higher level of spectral efficiency is achieved for corresponding RBs. **Findings:** Finally, the experimental results exhibit the JLCP-FeICIC-CMT achieves an increased efficacy than the JLCP-FeICIC.The efficiency is analyzed based on the average of Peak Singal-to-Noise Ratio (PSNR) per Femtocell UE (FUE), utility, monetary cost and Playback Interruption Rate (PIR).

Keywords: Femtocell network; HetNet; JLCPFeICIC; coordinated multipoint transmission; modulation and coding scheme

OPEN ACCESS

Received: 24.08.2020

Accepted: 28.10.2020

Published: 24.11.2020

Citation: Madhu P, Sujatha V (2020) Joint optimization on resource allocation with coordinated scheduling-based transmission for interference handling in Femtocell networks. Indian Journal of Science and Technology 13(41): 4287-4296. https://doi.org/10.17485/IJST/v13i41.1618

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Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

1 Introduction

Normally, the conventional wireless networks have the limited accessibility of video traffic that degrades the spectral efficiency. In contrast, the video streaming at higher downlink rates is constantly increasing in these days due to the advanced networks. As a result, the model of Long-Term Evolution-Advanced (LTE-A)-based HetNets is invented for enhancing the spectral efficacy and throughput by facilitating the low-cost flexible network deployments. These networks employ a combination of macro, pico, femto and relay Base Stations (BSs) for providing the standardized broadband experience to all users in the network. In typical, Femto BSs (FBSs) are single-modecost-effective that can improve the Macro BSs (MBSs) capacity because FBSs exploit a specific spectrum as MBSs(1). If these FBSs are not controlled properly, then they will overwhelm the spectrum of their MBSs and cause ICI between macrocells and femtocells. In HetNets, the crucial challenge is mitigating the ICI since it can reduce the achievable gain of femtocells. So, its pattern is completely varied. The amount of users at cell boundaries has smaller throughputs because of the high interference with a large number of femtocells.

Basically, FBSs are applied in an ad-hoc network without being planned by the users that increase the challenges in the ICI mitigation. Hence, one of the major research fields is solving the challenges in ICI prevention. Mainly, there are two kinds of interferences such as co-tier and cross-tier(2). Co-tier interference may occur between the neighboring FBSs whereas cross-tier interference may present between FBSs and MBSs. To mitigate the ICI and enhance the spectral efficiency, many schemes have been suggested. On the other hand, such schemes have high computational complexity due to the overlay of femto-macro systems. For this reason, resource allocation(3) is needed for each femto-network in order to autonomously exploit the resources which are not occupied by the macro-network. So, the ICI is effectively prevented when guaranteeing the Quality-of-Service (QoS) requirements.

To achieve this, Yang et al.(4) aimed at a JLCPmethod that formulates the issue of scalable video streaming from femtocells as a constrained stochastic optimization problem under a pricing method. Similarly, the actual long-term average utility issue was decomposed as a pair of near-instantaneous optimization sub-issues by considering the Lyapunov's stochastic optimization method to derive the low-complexity resource allocation and video layer activation scheme. Also, the logical bounds were determined for both time-averaged queue lengths and achievable utility. Conversely, this method handles only sparsely positioned FBSs and needs better ICI prevention methods. As a result, JLCP-FeICIC method(5) was proposed based on the four phases. At first, each user is associated with the MBS, Full-Duplex (FD)-FBS on the basis of CRE biases. After that, the users in FD-FBSs are paired based on the Hungarian algorithm for executing the FD transmission. Then, the resource blocks are assigned to each user to maximize the system throughput when ensuring the QoS requirements according to the Nash Bargaining Solution (NBS)-based optimization challenge. After, the closed-form energy control factor was used to determine the optimum transmit power of all users in the FD mode. However, only the CRE UEs of femtocells were scheduled whereas the center UEs were not allocated. In this case, the fairness of RB allocation is reduced.

Hence in this research article, a JLCP-FeICIC-CMT method is proposed for increasing the efficiency of the HetNetcenter UEs. In this method, RBs are assigned by the primary scheduler. The UE is detected in each eNBs by measuring the interference from the adjacent cells. Based on the RB assignment in the scheduler, the MCS level is elected in all eNBs for the UEs with and without the aid of CMT via coordinated link adaptation. Therefore, a higher level of spectral efficiency can be achieved for corresponding RBs.

2 Literature Survey

Kafafy & Elsayed(6) proposed an efficient autonomous power allocation scheme on the basis of two ICIC methods. The primary method was based on the closed-form solution that has an overall interference limit on each cell whereas the second method was based on the iterative solution which has different interference limits on different resource blocks in each cell. Also, semi-autonomous heuristic and optimum adaptive strategies were introduced for tuning the interference limits. Besides, the interference occurred by overloaded cells was avoided for achieving fairness among different cells in HetNets. Moreover, a technique based on the Kalman filter was applied for predicting the overall interference in the time between overall interference exchanges. But, the system parameters were not optimized and the computational complexity was high.

Yang et al.(7) investigated the multi-cell LTE uplink resource allocation issue by mitigating the ICI on the basis of the interference graph. An Enhanced Interference Graph (EIG) and Simplified Interference Graph (SIG) were derived according to the network channel data. For EIG, the edge between two UEs was associated with the weight values related to the interference state between them. For SIG, the edge between two UEs was presented only when they interfere with each other. Based on these EIG and SIG, heuristic algorithms were proposed for mitigating the ICI. Conversely, it has a high complexity on computation.

Merwaday&Guvenc(8) suggested an optimized FeICIC using the stochastic geometryfor enhancing the power and spectrum efficacy in two-tier LTE HetNets. Also, range expansion and FeICIC were considered to prevent the interference issues between the macrocells and the picocells. However, the interference power from neighbor LTE eNBs was high.Kumar et al.(9) proposed a novel eICIC based on the consideration of the Centralized Processing Controller with Almost Blank Subframe (eICIC-CPC-ABS) for HetNets. The resource allocation of each FBS was decided by using the CPC at MBS. The ICI was prevented by the ABS pattern and the system throughput was increased by the subcarrier allocation. Also, the subcarrier allocation and the transmit power were adaptively optimized by a different number of FBSs and UEs by tuning their transmit power in each cell according to the system traffic loads. Conversely, the UE performance was not effective for all the systems and the impact of signaling overhead was not analyzed.

Wang & Chien(10) proposed an Energy-efficient Pricing and resource Scheduling (EPS) method for solving energy consumption and dynamic pricing issues in resource scheduling. In this method, HetNet was considered where picocells were densely deployed in each macrocell and the users were split into three classes. The picocells were clustered into groups and a coordinator was chosen for arranging the service in each group for distributing loads of picocells and reducing the energy consumption of base stations. After that, a two-layer scheduling method was adopted for allocating the resources to each flow on the basis of its user class, channel quality and packet delay. Also, the amount of cost to each user was adaptively adjusted for balancing operator profit and network usage. But, energy efficiency and the total throughput were not effective.

Wang & Huang(11) proposed a Joint Interference and Power Management (JIPM) method for improving the LTE-advanced performance by integrating the ABS and Discontinuous Reception (DRX). In this method, the number of resources assigned to each UE was computed as well as the parameters of ABS and DRX were adjusted on the basis of the channel conditions and traffic requirements of UEs. However, only DRX long cycles were addressed for reducing the energy consumption whereas the parameters of short cycles were needed to achieve the fine-tuning of the DRX method.

3 Proposed Methodology

In this section, the JLCP-FeICIC-CMT method is explained in brief. List of symbols used in the papers are listed in Table 1. In JLCP-FeICIC-CMT, the PRBs are allocated by the primary scheduler. Then, the coordinated multipoint UE is identified in all eNBs according to the UE feedback data By using the assigned RBs, the MCS is chosen in every eNB for the UEs with and without the aid of coordinated multipoint. Consider the MBS only a function in the Half-Duplex (HD) mode while some FBSs have the capacity of FD communication. Figure 1 portrays a block diagram of the JLCP-FeICIC-CMT method.

Table 1. List of Symbols

Symbols	Description
m,g and h	LTE cells
u	user element
k	channel
I	interference
G	channel gain
p	power
r	rate that can be achieved
η	thermal noise
R	total throughput system

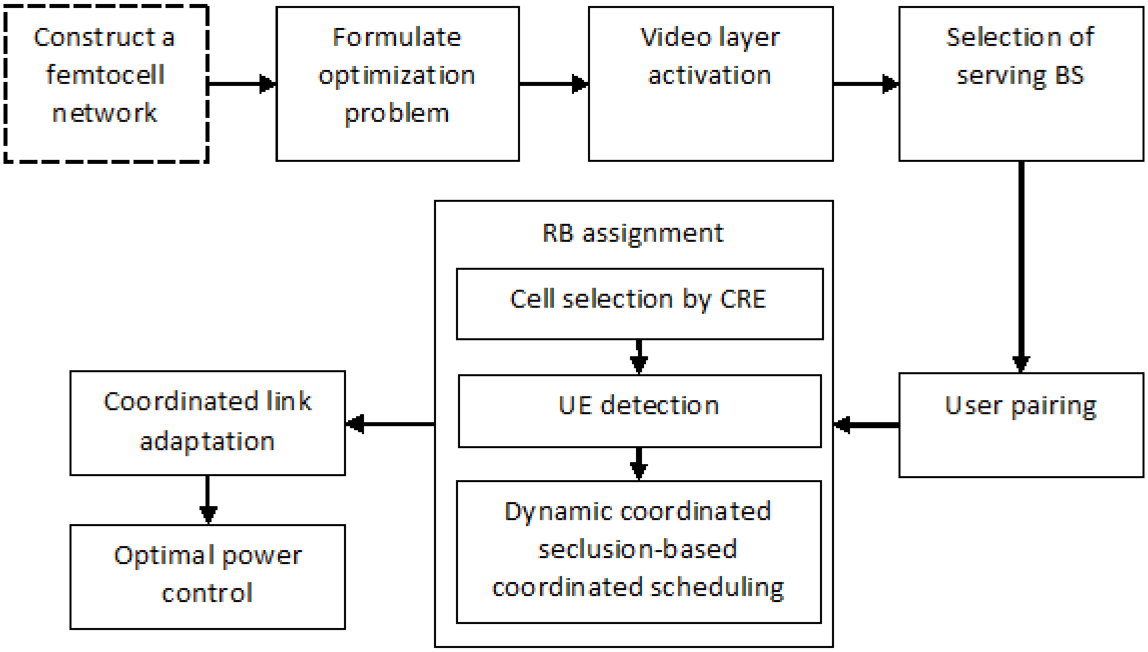

Fig 1. Block diagram of JLCP-FeICIC-CMT method

A set of LTE cells *M* and UEs *U* for each cell are assigned in a random way. If eNBs are subject to the highly congested requirements, femtocell availability is enhanced to encourage many UEs to be offloaded and the eNBs support the remaining UEs with higher throughput. The offloaded UEs can be explicitly co-channel interfered with the eNBs. Indeed, ABS is applied to avoid conflict with the offloaded UEs. This proposed system has three processes such as electing the cell with CRE, detecting the UE and scheduling. Here, the center UEs served by the eNBs are also scheduled while JLCP-FeICIC is taken for avoiding ineffective use of resources during ABS and achieving responsive fairness scheduling for both UEs.

The SINR computed by the UE u on RB k during a regular subframe is given as:

$$SINR^{k}_{m,u} = \frac{G^{k}_{m,u} p^{k}_{m,u}}{\sum_{g\in M} I^{x}_{g,u} + \sum_{h\in M, h\neq g} I^{x}_{h,u} + \eta}, \quad u \in U_M \tag{1}$$

In Equation (1) ,$p^{k}_{m,u}$ denotes the transmit power of eNBs on k, $G^{k}_{m,u}$is the channel gain from cell m to u on k, $I^{k}_{g,u}$ and $I^{k}_{h,u}$ is the interference to u from nearby cell g and h on k, accordingly and $\eta$is the thermal noise per RB along with the UE noise figure. The interference obtained by u from nearby eNBs g is as:

$$I^{k}_{g,u} = G^{k}_{g,u} p^{k}_{g,u}, \quad g \in M \tag{2}$$

The SINR of the UEs supported by the eNBs at ABS is determined as:

$$SINR^{k}_{m,u} = \frac{G^{k}_{m,u} p^{k}_{m,u}}{\sum_{g\in M} \left(\frac{I^{k}_{g,u}}{10^{\triangle}} \right) + \sum_{h\in M, h\neq g} I^{k}_{h,u} + \eta}, \quad u \in U_M \tag{3}$$

In Equation (3), $\triangle$ refers to the power reduction range in dB related to the maximum transmit power at normal subframes. The entire system throughput for JLCP-FeICIC is defined as:

$$\begin{gathered} R_{JLCP-FeICIC} = \sum_{m\in M} \sum_{x\in RB^{m}_{np}, u\in U_M} r^{k}_{u} + \sum_{m\in M} \sum_{x\in RB^{m}_{p}, u\in U_M} r^{k}_{u} + \\ \sum_{m\in M} \sum_{x\in RB^{m}_{fp}, u\in U_M} r^{k}_{u} + \sum_{m\in M} \sum_{x\in RB^{m}_{rp}, u\in U_M} r^{k}_{u} \end{gathered} \tag{4}$$

In Equation (4),$RB^{m}_{np}$and RB^{m}_{p}indicatethe set of RBs reserved by $m$at ABSs which are trustworthy resources and at normal subframes which are untrustworthy resources, accordingly, $RB^{m}_{fp}$and RB^{m}_{rp} denotethe set of RBs reserved by $m$at normal subframes using full transmit power and reduced transmit power, accordingly and r^{k}_{u}stands for the rate acquired by k while scheduled to u.

3.1 Dynamic coordinated seclusion-based coordinated scheduling task

At first, it is implied that certain eNBs are in a coordinated multipoint set and there is the primary scheduler that will analyze the data generated from every eNB fairly. The interference from the nearby cell will be assessed using Equation (5) to identify which UEs allow coordinated multipoint assistance and which adjacent cells will get the assistance:

$$SIR^{i}_{u} > SIR\_TH \tag{5}$$

In Equation (5), $SIR^{i}_{u}$is the Signal-to-Interference Ratio (SIR) for u and interfering cell i. As UE seems to have a major priority than that of the residual UEs prepared by the eNBs, the UE will be arranged primarily and the nearby eNB will segregate the corresponding RBs when the UE needs coordinated multipoint assistance. Besides the remaining UEs, there are pricing strategies available. The core coordinated multipoint controller can randomly pick one eNB to have the scheduling choice regarding the efficient scheduling strategy for fairness as:

$$u = argmax\left(\frac{r_u^k}{mean\_TH_u}\right) \tag{6}$$

In Equation (6) , $mean\_TH_u$ denotes the mean UE throughput. After that, the interference measures are verified for finding the requirement of coordinated multipoint support for UE. If the interference measures are verified, the RB cannot be scheduled in the nearby eNB, but remaining eNBs can utilize the RB. Or else, the remaining eNBs can exploit the RB.

Let$M$ be the total cells and K be the RBs and U be the UEs for each cell. For each k, the picked cell $M_v$requests to offer the scheduling choice for electing u. Because the UE choice is according to the fairness factor in Equation (6), the utmost $M-1$ cycles of analysis are essential. If the RB is scheduled to the UE which doesn't want coordinated multipoint assistance, then the scheduling choice is executed for the nearby cells ofM_v i.e., M_{v+1} andM_{v-1}. IfM_v schedule the RB to the UE which wants coordinated multipoint assistance, M_{v-1} and M_{v+1} must segregate their $k$and M_{v-2}, as well as M_{v-3} can allocate k.

Consider that there are no nearby of them using k, they will schedule it to either UE which wants the coordinated multipoint assistance or not. This task is repeated until each cell executed its scheduling choice of k. For all RBs, utmost M cells will offer their scheduling choice and every choice obtains utmost $M-1$ cycles analysis. Once the RB is scheduled, the bits for the corresponding UE is determined through table searching and subtracted from the overall bits required by UE.

3.2 Coordinated link adaptation based on multiple CSI tasks

It must be observed that if the adjacent cell isolates specific resources for assisting the UE that requests coordinated multipoint support, the MCS level must be chosen on the basis of the assumption of no conflict from the nearby cell.

So, better spectral efficacy for corresponding RBs is obtained. Because only the coordinated multipoint set composes the eNBs, eNBs are situated for every UE supported by eNBs; utmost one nearby cell will lead to excessive interference to the UE. Consequently, only every cell edge UE request to segregate the corresponding RBs. For detecting that if UE requests coordinated multipoint support from an adjacent cell and performs adaptive link adaptation while the adjacent cell isolates specific RBs, then every UE desires Channel State Information (CSI) under 2 assumptions:

- CSI when UE discovers conflict from the nearby cell;
- CSI when UE discovers no conflict from the nearby cell.

So, every UE is designed with 2 CSI tasks. CSI task-0 is arranged for acquiring common Channel Quality (CQ) indexes wherein each cellcontains the same RBs. CSI task-1 signifies the gain obtained by the UE if it segregates the robust conflicting cell. CSI task-1 is executed via encouraging the nearby eNBsto utilize the orthogonal RBs for reference signal transfer. The MCS level for the UEs supported by the coordinated multipoint assistance is decided according to CQ assessed by the CSI task-1. Besides, these CSI tasks are applied to aid the computation of interference by the UE using Equation (5). CMT system where the transmission and/or reception at multiple, geographically separated antenna sites is dynamically coordinated in order to improve system performance

4 Simulation Results

In this part, the JLCP-FeICIC-CMT is implemented in MATLAB 2017b and its efficiency is analyzed with the JLCP-FeICIC. The comparative scrutiny is made in terms of performance metrics such as average PSNR per FUE, average utility, average monetary cost and average PIR.The simulation parameters such as carrier frequency, network bandwidth, number of FUE, sub-channels, RBs, etc., are given in Table 2.

Table 2. Simulation Parameter

Parameters	Value
Carrier frequency	2.2GHz
Network bandwidth	20MHz
No. of sub-channels	20
No. of FUE	13
Power limit of FBS	23dbm
Allocation of channel gain between FBS and FUE	Rayleigh with variation 0.376
Allocation of channel gain between FBS and macro UE	Rayleigh with variation 0.05
Allocation of interference cost	Gaussian (Mean=50 & Standard deviation=10)
No. of RBs	120

4.1 Average PSNR per FUE

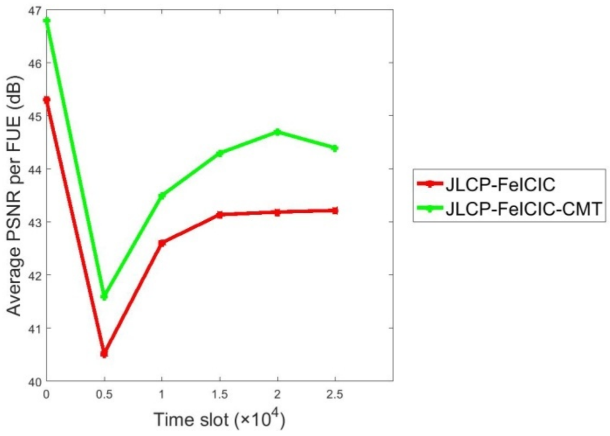

Fig 2. Average PSNR per FUE vs. Time Slot

Figure 2 shows the average PSNR per FUE (in dB) for the JLCP-FeICIC-CMT method and the JLCP-FeICIC method. From this analysis, it is observed that the JLCP-FeICIC achieves higher PSNR than the JLCP-FeICIC by mitigating the interference from adjacent cells. For example, if the time slot is 2×10^4, then the average PSNR per FUE for JLCP-FeICIC-CMT is 3.24% increased than the JLCP-FeICIC method.

4.2 Average Utility

Figure 3 shows the average utility for the JLCP-FeICIC-CMT method and the JLCP-FeICIC method. From this analysis, it is observed that the JLCP-FeICIC-CMT achieves higher utility than the JLCP-FeICIC by assigning RBs and the MCS level in eNBs. For example, if the time slot is 2×10^4, then the average utility for JLCP-FeICIC-CMT is 2.61% increased than the JLCP-FeICIC method.

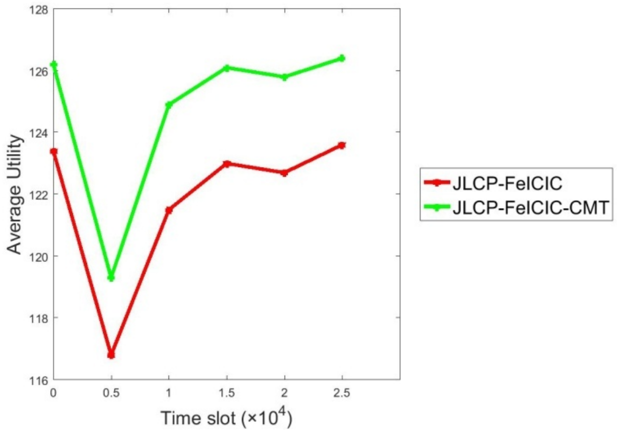

Fig 3. Average utility vs. Time slot

4.3 Average monetary cost

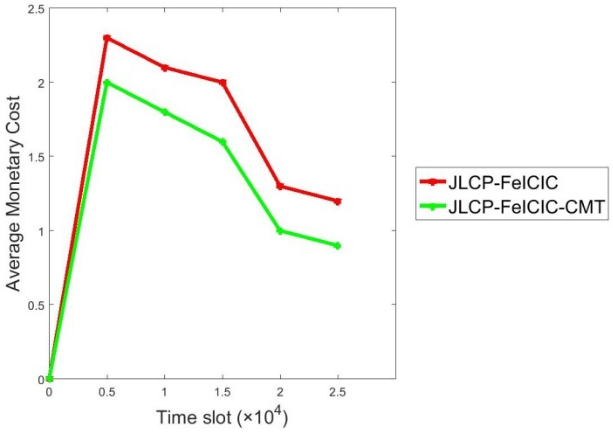

Fig 4. Average monetary cost vs. Time slot

Figure 4 shows the average monetary cost for proposed JLCP-FeICIC-CMT and existing JLCP-FeICIC methods. From this analysis, it is observed that the JLCP-FeICIC-CMT achieves less monetary cost as compared to the JLCP-FeICIC due to effectively detecting UEs and assigning RBs. For example, if the time slot is 2×10^4, then the average monetary cost for JLCP-FeICIC-CMT is 30% increased than the JLCP-FeICIC method.

4.4 Average Playback Interruption Rate

Figure 5 shows the average PIR (in per min) for the JLCP-FeICIC-CMT and the JLCP-FeICIC methods. From this analysis, it is observed that the JLCP-FeICIC-CMT achieves less PIR than the JLCP-FeICIC. For example, if the time slot is 2×10^4, then the average PIR for JLCP-FeICIC-CMT is 17.39% increased than the JLCP-FeICIC method. Thus, JLCP-FeICIC-CMT attains higher spectral efficiency with reducing interference from adjacent cells by assigning RBs and MCS level in each eNBs for UEs.

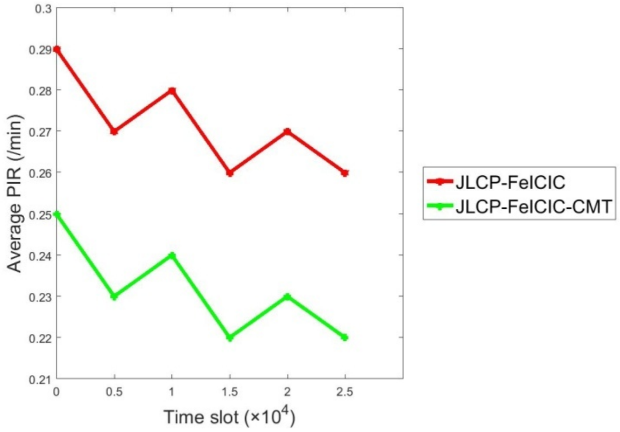

Fig 5. Average PIR vs. Time slot

5 Conclusion

In this article, a JLCP-FeICIC-CMT method is proposed to increase the efficiency of HetNetscenter UEs. In this method, the primary scheduler is used to assign the RBs and the UE in eNBs is detected via determining the interference from the adjacent cells. Based on this assignment of RB in the primary scheduler, the MCS level is chosen in every eNB for UEs with and without CMT support by using the hypothesis of no interference from the adjacent cell. As a result, a higher level of spectral efficiency is achieved for respective RBs. Finally, the experimental results proved that the efficacy of the JLCP-FeICIC-CMT than the JLCP-FeICIC method.

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