Spectrum and Energy Efficiency Optimization for Heterogeneous Networks based on IEEE 802.22

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Abstract: ***The 4G methodologies like LTE, LTE-A cellular network has been developed. Such technologies are considered to improving the network capacity and end user throughput. To improve the profitability, WANs should use the energy and spectral efficient design. The goal of this project is to present the design of novel hybrid approach to improving the spectrum and energy efficiency. we presented the optimal policies by designing the methods of cell size zooming, migration of user and sleep mode for various types of base stations. The spectrum and energy efficiency problem is formulated as the quasiconvex optimization and then it is converted into similar form of problem of MILP. The quasiconvex optimization problem is solved by bisection method and MILP solved by software tools. Finally, we contributed with third algorithm of improving the spectrum and energy efficiency in this project. The practical work and simulation of proposed approach conducted using NS2.***

Keywords: Energy, Spectrum, LTE, Heterogeneous networks, Base station, Cellular, NS2

1. Introduction

Fourth generation technologies such as LTE cellular systems have been developed and are expected to be important technologies to improve end-user throughput and network capacity. With such technological capability to improve information services, mobile operators have been experiencing annual increases in data traffic volumes and so in revenues. Meanwhile, points out that the operational expenditure accounts for more than 18% of the energy bill, and that 60% of the power consumption in the network equipment is from base stations (BSs). The increasing data amount raises the profit at the expense of energy consumption increased. From the mobile operator perspective, it is of interest to operate wireless networks in an economically efficient fashion [1] [2].

It was analyzed deploying different types of BSs is able to help on expenditure reduction and increase revenues. Thus, a hybrid of cellular deployments provides great leeway to the network operators to attain financial improvements. Nevertheless, one of the concerns with HetNets is the growing number of small cell sites. This raises important questions about the energy efficiency implications of HetNet deployment [3]. Hence, energy efficient operation in a heterogeneous setting becomes a pressing issue in order to reduce the energy expenditure. On the other hand, when evaluating the energy saving mechanisms, the impact on spectrum efficiency should also be taken into account [4].

The derived analytical expression shows that the increase in energy efficiency will inevitably bring down the spectrum efficiency. Schemes aimed at joint optimization of energy efficiency and spectral efficiency should be well studied. However, these two network efficiency improvement problems are focused and studied disjointedly in the literature. Therefore, in this paper, a spectrum-energy efficiency optimization model is developed for the heterogeneous network environments. We define maximizing network spectrum-energy efficiency as optimizing the spectrum allocation while minimizing the total energy consumption [8] [9].

There is a long-term economic objective of spectrum energy efficiency optimization. The spectrum-energy efficiency can be considered as a metric to quantify the revenue-per-cost capacity, serving as an indicator of operators profitability. It is a generalized objective function that maximizes the ratio of spectrum efficiency over energy consumed for the service operation [10]. The goal is to attain a network design which is cost-effective, improving the data rate per resources managed. As an efficient network is capable of growing in data volume conveyed successfully, within given cost in terms of energy consumption, the revenue then increases, coming from expanded data services offered. With the optimal service rate per resource, the most profitable network design can be realized.

Along with the fairness in IEEE 802.22 wireless networks; there is another performance metrics which is related to energy efficient dynamic spectrum access (DSA) in a cognitive Third Generation Partnership Project (3GPP) long-term evolution (LTE) network based on IEEE802.22 architecture [11]. According to the IEEE802.22 standard, wireless access is offered by a wireless regional area network (WRAN) consisting of a number of service providers (SPs), which share the total available spectrum using a spectrum manager (SM). The SM uses some flexible dynamic spectrum access (DSA) policy to maximize the capacity and quality of service (QoS) for their users. Motivated by this concept of CR network (CRN), many papers have developed various forms of spectrum access strategies to assign the available network resources (bandwidth, transmission rate and transmission power). Most papers assume non-strategic non-greedy users following some general resource allocation policy [12]. The recent methods do not have efficient tradeoff between transmission power, bandwidth and transmission rate for LTE networks. This becomes the current research problem in advance communication systems. We proposed new method to solve these problems for heterogeneous wireless networks. In section II, related work is presented. In section III, design and algorithm of proposed method is discussed. Section IV, the results and analysis is presented. Finally conclusion and future work is discussed in section V.

2. Related Works

In this section we are discussing different methods proposed for dynamic spectrum allocation and resource utilization.

In [1], author presenting approach in which the Cognitive Radio nodes collaborating in making the decision about spectrum availability. Simulation result indicates that both polynomial and linear classifiers provide high detection rate of primary users with a constant false alarm rate at very small signal to noise ratio conditions. For instance, the proposed method s can achieve above 90% detection probability at Eb⁄No = -7dB with observation window of 50 bits and 10% false alarm rate. It is additionally indicated that the performance improves as we increase the sensing time for both methods.

In [2], author introduced the prediction model of channel usage time is proposed, which is based on the mobility of Cognitive Radio users and spectrum transmission spectrum. The channel predicted usage time is main metrics for the spectrum sharing. In sequence to decrease channel handoffs resulting from short channel usage time, a usage threshold time is set for the channel allocation. When channel handoff cannot be implemented in a single hop, the multi-hop routing will be established to keep the communication.

In [3], author of this paper taking cue from our earlier implementation work on simple Snapshot ED and CUSUM based algorithms for single node spectrum sensing, explained the implementation of Sequential change detection algorithm in co-operative method, the Dual-CUSUM. Single node sensing is not reliable, particularly, when the nodes are subjected to shadow fading due to obstacles (hidden node problem). Simulation results reveal that the amount of channel handoffs can be considerably reduced after using the predicted channel usage time and channel utilization is enhanced and the handoff blocking probability is also dramatically decreased simultaneously. In addition, the further simulation results show that apart from the PU activity, CR node's mobility is also vital to the channel handoffs and link available time.

In [4], author of this paper proposed the slotted call admission control method integrated with dynamic channel allocation to address the issue. In the proposed method, admitting user only occurs at the beginning of a new slot; thus, new SUs arriving between two slots ought to first enter a waiting queue until the next slot arrives. By imposing a compulsory so far limited waiting time on new SUs, the proposed method offers an opportunity to allow admitted SUs to fully utilize the available primary spectrum. An analytical framework using a 3D discrete time Markov chain is developed to analyse the impact of the proposed method on both the call-level and packet level performances of SUs. Simulation result verifies that the accuracy of the analysis and show the effectiveness of the proposed method in terms of reducing blocking and dropping probabilities, lowering packet queuing delay, and improving spectrum utilization efficiency.

In [5], author proposes and analyses the performance of virtual reservation in collaborative cognitive networks. Virtual reservation is a narrative link maintenance strategy that aims to maximize the throughput of the cognitive network through full spectrum utilization. Performance evaluation shows significant improvements not only in the SUs blocking and forced termination probabilities but also in the throughput of cognitive users.

In [6], the authors examine resource allocation in an orthogonal frequency-division multiple-access-based cognitive radio (CR) network which dynamically senses primary users (PUs) spectrum and opportunistically uses available channels. The aim is resource allocation such that the CR network throughput is maximised under the PUs maximum interference constraint and cognitive users (CUs) transmission power budget. Then, author formulate the uplink resource allocation problem to maximise the CR network sum bit rate (throughput) under the CUs transmission power budget and PUs maximum interference constraints. In this paper, author explained how to reformulate the subcarrier assignment problem into an equivalent problem defined on a conceptual system in such a way that a least square based adaptive algorithm can find the solution.

In [7], author investigated the energy consumption issue of Cognitive Radio (CR) systems. The aim of this work is to maximize the energy efficiency of the considered CR system with practical constraints, such as the power budget of the CR system, the interference thresholds of the primary users, the minimal throughput requirements and the proportional fairness of the CR users.

In [8] author proposes centralized and distributed algorithms to verify the reduction of power consumption of a cellular network with cell zooming, and to avoid coverage hole when BSs are turned off. Some work only count transmits power, and the load-independent components of the energy consumption the power to active sleep mode is not considered.

3. Methodology

To overcome the limitations of recent methods novel hybrid approach is proposed with goal of improving the spectrum and energy efficiency LTE Advance Cellular Networks. This paper is contributed in main three parts: (i) analytical method for optimal BS (base station) operation, modulation method selection and user association. (ii) Heuristic algorithms that process the near optimal solutions generation. (iii) Link efficiency algorithm to further improve the capacity and energy efficiency. The design is conducted as:

- Analytical method for optimal BS (base station) operation, modulation method selection.
- EHeuristic algorithms for near optimal solutions.
- Link efficiency algorithm to further improve the capacity and energy efficiency.

The EHeuristic algorithms are designed to suggest the computationally efficient solutions to the current optimization problem. Link efficiency algorithm is designed to improve the throughput and energy performances. Based on this below is design showing in figure 1 for proposed spectrum allocation method in LTE-A networks.

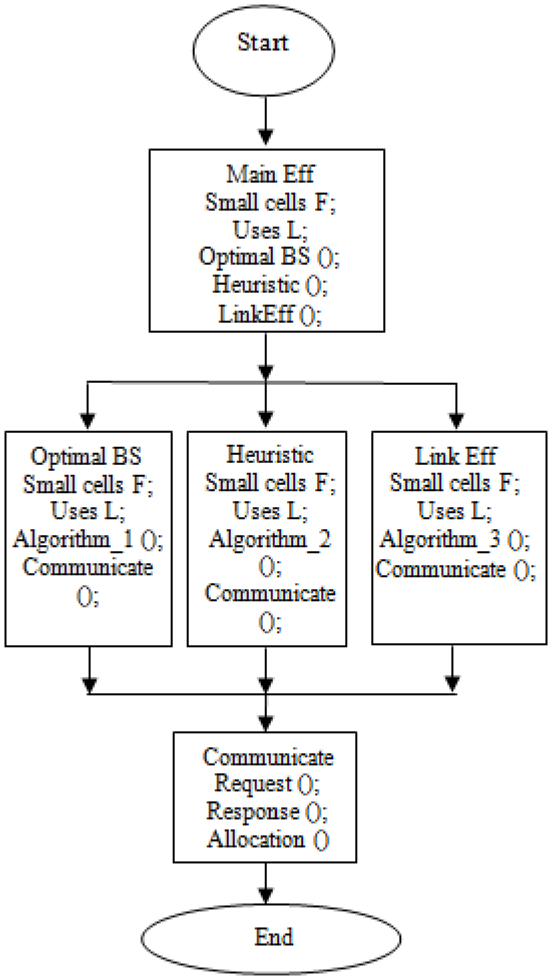

Figure 1: System design diagram of EHeuristic approach

Algorithm 1: ***max$_x$f(x)***

Given $l \leq f^* \leq h$ *and the tolerance* $\varepsilon > 0$;

While $(h - l) > \varepsilon$ *do*

$\propto = \frac{h+l}{2}$;

$f(x) \geq \gamma$,

$f_k(x) \leq 0, k = 1, \ldots\ldots, m,$

$Ax = b.$

if *feasible* ***then*** $l = \propto$;

else $h = \propto$;

End

Algorithm 2: Spectrum-Energy Efficiency Maximization

Input:

Input:

S, $L, K, M, F, N, E, R_b, \mathbb{B}_s, \mathbb{U}_L, Q_k, \mathbb{B}_A, \mathbb{B}_o, U_X, U_W, C, I, D, P, H_m, R, P_{active}, P_{sleep}, P_{max}$.

Output: y ***and*** Z.

1. Compute $g_{lk}^s \in \Omega, \forall s, l, k;$
2. ***for*** $l = N + 1$ *to* L ***do***
3. Find s and k combination that gives best g_{lk}^s;
4. $y_{lk}^s \leftarrow 1$ *and* $z_s \leftarrow 1$;
5. ***for*** $s = 1$ *to* M ***do***
6. **Macro-Femto ();**
7. **Sleeping ();**
8. **While** there exists an s that can cover more users **do**
9. **Zooming ();**
10. ***for*** l *having no service and s active* ***do***
11. **If** exists s, l, k combination to improve c **then**
12. $y_{lk}^s \leftarrow 1$ *and* $Zs \leftarrow 1$;
13. ***While*** $\sum_{s \in B_s, l \in U_L, k \in Q_X} y_{lk}^s \geq \delta$, ***do***
14. find s, $\forall z_s = 0$ *covering the most non-served users;*
15. ***for*** $c_l^s = 1$ ***do***
16. ***if*** $y_{lk}^s \leftarrow 1$ *satisfies constraints* in equations below:
17. $\sum_{h_g^m \in H_m, l \in U_l, k \in Q_K} \left[\left(y_{lk}^m + y_{lk}^{h_g^m}\right) . r_{lk}\right] \leq R^m, \forall m,$
18. $\sum_{l \in U_L, k \in Q_x} (y_{lk}^m \cdot p_{lk}^m) \leq p_{max}^m, \quad \forall m \in B_A,$
19. $\sum_{l \in U_L, k \in Q_K} \left(y_{lk}^m \cdot p_{lk}^f\right) \leq p_{max}^f, \forall f \in B_O$ ***then***
20. $y_{lk}^s \leftarrow 1$ ***and*** $z_s \leftarrow 1$;
21. ***for*** l *having association* ***do***
22. ***if*** *there exists a k that can improve C* ***then***
23. $y_{lk}^s \leftarrow 1$ *and* $z_s \leftarrow 1$;

Return y and z.

4. Results

The current results of method EHeuristic with their performance graphs and NAM animator are presented in this section. Next figure 2 is showing the NAM animation results for 100 users in LTE-A network. Beyond this we cannot read much information. Blue nodes are indicating the small cell nodes and green nodes indicating the LTE-A users. Red nodes are indicating the current communicating nodes in network. Graph in figure 3 is showing the performance analysis of average energy consumption for the network scenario.

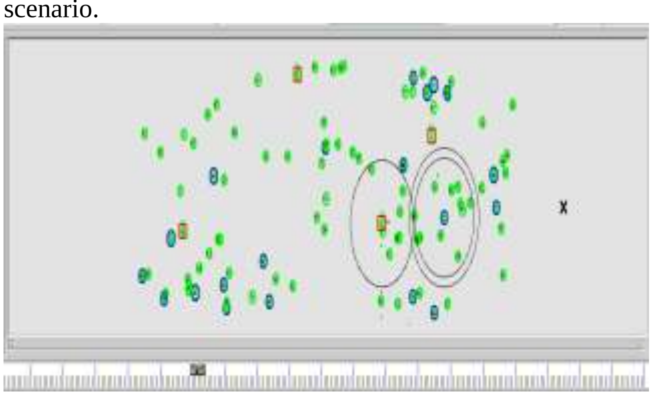

Figure 2: 100 Users LTE-A Network

Table 1: Configuration Parameters

Number of Cognitive user	100-600
Traffic patterns	CBR (constant bit rate)
Network size (X, Y)	(1500,100)
Simulation time	30s
Transmission packet rate	10 m/s
Push time	1.0s
MAC protocol	802.22
Channel data rate	11 Mbps
Mobility speed	5 m/s
Spectrum Allocation method	EHeuristic
Initial Energy	25 J
Transmitting energy	1 J
Received energy	1 J

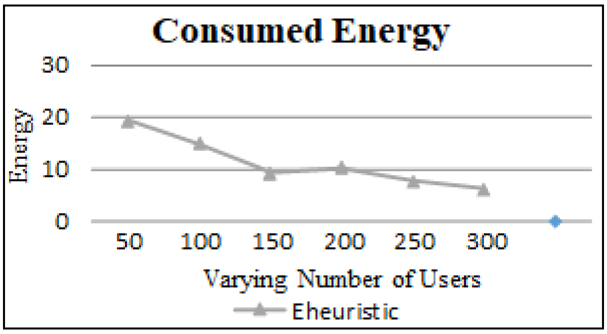

Figure 3: Energy Consumption

The graph in figure 4 is showing the spectrum efficiency results for different LTE networks. As the number of users increasing the performance of spectrum efficiency is decreasing, this is due to congestion in network.

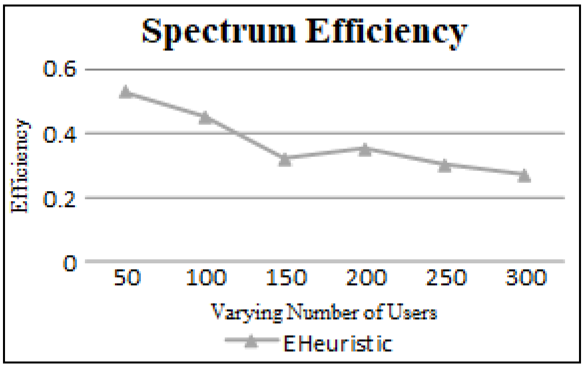

Figure 4: Spectrum Efficiency

5. Conclusion and Future Work

In this paper, the roadmap for novel and hybrid spectrum efficiency method is proposed with its algorithm and the current simulation results. The goal is to optimize the performance of spectrum efficiency, energy efficiency and over LTE networks throughput. In this report, the introduction, literature review is discussed. Then system design, flowchart and work plan is presented. The current results of work done are added at the last. The results are conducted using heuristic spectrum efficiency method. This results shows the there is huge impact of increasing number of mobile users in network over the performance of spectrum and energy efficiency. Future work will be on designing the algorithms of proposed techniques discussed in this paper.

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