JOINT RELAY ASSOCIATION AND RESOURCE ALLOCATION OPTIMIZATION IN LTE CELLULAR NETWORKS

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Abstract

As the demand for higher data rates is growing exponentially, homogeneous cellular networks have been facing limitations when handling data traffic. These limitations are related to the available spectrum and the capacity of the network. Heterogeneous Networks (HetNets), composed of Macro Cells (MCs) and Small Cells (SCs), are seen as the key solution to improve spectral efficiency per unit area and to eliminate coverage holes. Due to the large imbalance in transmit power between MCs and SCs in HetNets, intelligent User Association (UA) is required to perform load balancing and to favor some SCs attraction against MCs. As Long Term Evolution (LTE) cellular networks use the same frequency sub-bands, User Equipments (UEs) may experience strong Inter-Cell Interference (ICI), especially at cell edge. Therefore, there is a need to coordinate the Resource Allocation (RA) among the cells and to minimize the ICI. In this paper, we propose a generic algorithm to optimize user association and resource allocation in LTE networks. Our solution, based on game theory, permits to compute Cell Individual Offset (CIO) and a pattern of power transmission over frequency and time domain for each cell. Simulation results show significant benefits in the average throughput and also cell edge user throughput of 40% and 55% gains respectively. Furthermore, we also obtain a meaningful improvement in energy efficiency.

1.INTRODUCTION

There exist various possible solutions to meet the increasing traffic demands and to fulfill the customer expectations for mobile broadband services (Landstrom et al., 2011). One of the solutions is improving the macro layer capacity with the techniques like more spectrum allocation, massive multiple input multiple output (MIMO) and advanced signal processing. These solutions will improve the link spectral efficiency. The other simple solution to address the above issue is increasing the network capacity. In second generation (2G) and third generation (3G) networks, network capacity is increased by including additional carriers or cell splitting (Khandekar et al., 2010; Damnjanovic et al., 2011). This arrangement is additionally perplexing and iterative. This will increase the system cost, power consumption and interference. Present wireless standards like long term evolution (LTE) and LTE-A are well known for lower latency and higher spectral efficiency (Damnjanovic et al., 2011; Wang and Chuang, 2015). Third generation partnership project (3GPP) has been taking a shot at different aspects like carrier aggregation, massive MIMO and HetNets to further enhance the performance of LTE and LTE-A standards. The practically achievable link spectral efficiency has reached the theoretical limits as specified in fourth generation (4G) standards. Any effort to improve the link spectral efficiency is meaningless. The main objective of the future wireless standards is to improve the spectral efficiency per unit area. In other words, the future standards are expected to offer uniform high quality experience to all the users anywhere inside the cell range.

The only possibility to improve the spectral efficiency per unit area is to increase the node deployment density.

2.LITERATURE SURVEY

Till the past few years, homogeneous LTE cellular networks, composed of identical Base Stations (BS) called macro BSs, managed to optimize the coverage and to handle the data traffic generated by the users. Generally, the deployment of these macro BSs is planned in a way that minimizes the overlap between the cells and at the same time guarantees a continuous coverage for all users in the network. However, because of the exponential increase in the number of connected devices, the rapid growth of data traffic and the demand for higher data rates, LTE networks have been facing great difficulty to handle the data amount, especially in the most crowded environments and at cell edges. These limitations are related to the available spectrum and network capacity bound. The first element to increase channel capacity is bandwidth. As spectrum is scarce, the acquisition of licensed bands is often very expensive, at least for the time being. Network operators prefer to use the available licensed spectrum more efficiently. Another approach consists of enhancing the macro network layer efficiency through some technology upgrades.

For instance, the performance of these networks can be improved thanks to advancement in the air interface, using multi-antenna techniques and implementing more efficient modulation and coding schemes. Cell size is another factor that affects the number of users that we can support by the base stations. One of the most wellknown capacity-enhancing strategies is the use of smaller cells. This permits to increase the frequency reuse, also known as cell-splitting gain. The macrocell network can also be densified by adding more sectors per macro site or by deploying more BSs. However, it becomes more difficult and expensive to find new macro sites. Based on cell densification, HetNets has been proposed by the 3rd Generation Partnership Project (3GPP) [1] to cope with the limited amount of spectrum. What is HetNets and how does it improve the network capacity? The idea behind HetNets is to overlay existing homogeneous LTE networks, commonly called the macro layer, with additional smaller power low-complexity base stations using the same spectrum to increase the bit rate per unit area. Small cells (e.g., femto, pico, micro, metro cells, etc.) have coverage range that varies from a few meters to several hundreds of meters, in contrast to the tens of kilometers covered by macro cells.

3.PROPOSED METHOD

We consider an LTE cellular network composed of K cells: M macro cells and N small cells, where N ≥ 0, to model both homogeneous and heterogeneous networks. Each base station k has S sub-frames in the time domain and R resource blocks in the frequency domain, respectively. The duration of all sub-frames is the same and the bandwidth of all RBs is also a constant; for example according to 3GPP LTE standard [1], they are 1 ms and 180 kHz, respectively.

3.1 System Model

In our LTE frequency sub-band coordinated scheduling system, all the RBs are first grouped into F frequency subbands, where each sub-band consists in a number Rf of RBs, f = 1, 2, . . . , F. The bandwidth of each sub-band is thus given by RfB, where B = 180 kHz. In the same manner, we regroup the S sub-frames into T time slots, where each slot consists in a number St of sub-frames, t = 1, 2, . . . , T. The duration of each slot t is equal to St ms. Here, we only consider downlink (DL). The LTE transmissions in each cell are synchronized such that there is no intracell interference. However, there exists inter-cell interference, i.e., a transmission from a cell will cause interference to other cells which reuse the same RBs at the same time. We will use Pk,f,t to denote the power allocated by cell k to frequency sub-band f at time slot t. Note that Pk,f,t is in discrete value. We also define vector Pk := (Pk,1,1, Pk,2,1, . . . , Pk,F,1, Pk,1,2, Pk,2,2, . . . , Pk,F,2, . . . , Pk,F,T). The total power of a cell k at time slot t is limited by a maximum value P max k such that X f∈F Pk,f,t ≤ P max k , ∀t ∈ T, ∀k ∈ K. (1)

In the following, we will describe the algorithm and its operation in performing user association and frequency/time resource allocation via power patterns optimization for LTE cellular networks. This solution based on game theory is an extension to our work on coordinated scheduling via frequency and power allocation optimization presented in [19]. Fig. 1 shows the design where a coordinator optimizes CIO values, virtually attaches the users to corresponding cells, performs a dynamic resource distribution, virtually schedules the users in the network, and computes a utility function. Then, it sends the optimal parameters (power allocation patterns and CIO values) to each cell. The CIO values are added to RSRP measurements and this impacts the user association and handover decision. Then, each local eNB scheduler allocates its provided RBs according to its scheduling policy and uses the power settings determined from the optimizer.

1) Step 1 – Data Collection: Each user (UE) reports to its serving eNB long term statistics, such as Channel Quality Indication (CQI) and Reference Signal Received Power (RSRP). These measurements are processed by the eNB to group the users in pools having similar channel quality, then they are sent via S1 protocol to the coordinator. Various examples of UE grouping are presented in Fig. 2, for illustration. The grouping allows to limit the data exchange between the eNBs and the central entity that is in charge of the optimization. In this way, the eNB keeps a precise and real time knowledge of its attached users. Meanwhile, the coordinator keeps a global view over the cells in the network with access only to longterm statistics that are averaged both in spatial dimension (by the UE grouping) and in time dimension (between two update messages).

2) Step 2 – Optimization: At the end of collection step, the coordinator has a database containing the needed information concerning the state of the network. Working on this database, it performs an optimization to deliver the optimal parameters: CIO value and transmission power pattern for each cell. Fig. 1 shows the performed iterations. a) Steps 2.1 & 2.2 – Choose a cell and store initial state and utility: The coordinator picks up a cell randomly. It stores the initial network state, which refers to the CIO and power setting of each cell in the system. The coordinator Fig. 1.

Framework overview. computes the initial global utility which indicates the network performance.

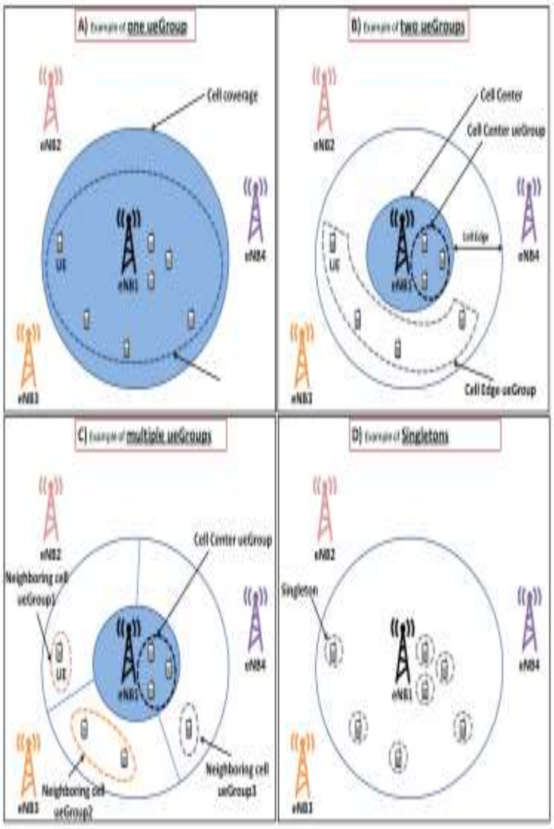


Fig. 2. Example of various UE grouping policies.

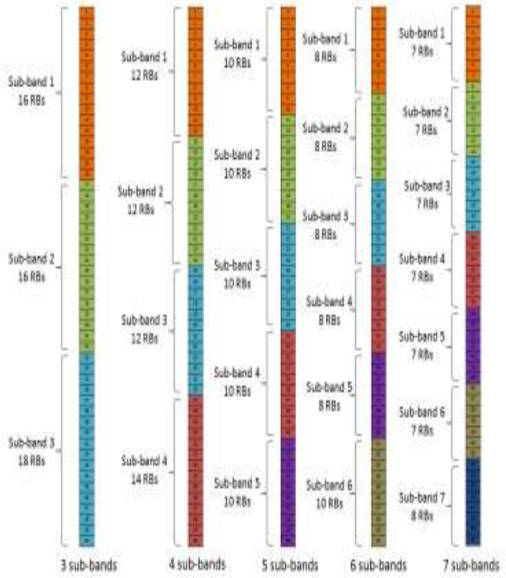


Fig. 3. Frequency bandwidth are divided into sub-bands.

b) Step 2.3 – Sampling: This step consists in sampling the tuple (Pk, Ok) for the selected cell. For each neighboring cell, we attribute a CIO value, which can be positive or negative.

Fig. 3 shows the details in the case of 10 MHz. In the same manner, we regroup the S subframes into T equally sized slots. One resource element is defined by the frequency sub-band and time slot. Sampling Pk consists of allocating a transmission power over each frequency sub-bands and time slot. Note that the sampling of states is performed among the admissible combinations of power settings and CIO values. In practice, the sampling of states can be done in parallel. Given Nk neighboring cells and I possible offset values, we have I Nk possible samples for Ok. Given F frequency sub-bands, T time slots and Y power levels per RB, we have Y F ×T samples for the power patterns. This implies that one will have I Nk Y F ×T cases to be sampled for the cell selected in Step 2.1. However, some combinations can be easily discarded with respect to some constraints such as maximum power. As mentioned, performing disjoint optimization is also possible in our framework. The complexity of the sampling can be then reduced. For instance, in ABS optimization, only macro cells are concerned with the muting.

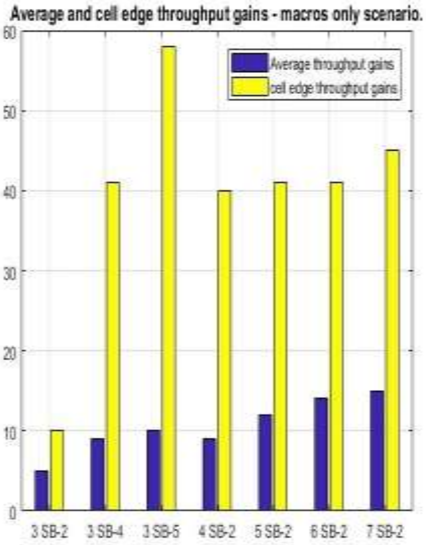
c) Step 2.4 – Virtual handover: For each sampled case where the CIO has been changed, we perform a virtual handover by calling a simulated UE grouping function. This function tests if the user group would make a handover to a neighboring cell due to the change in the CIO. It compares the RSRP measurements to the serving and neighboring cells after adding the new sampled CIO value, and virtually changes the user association accordingly.

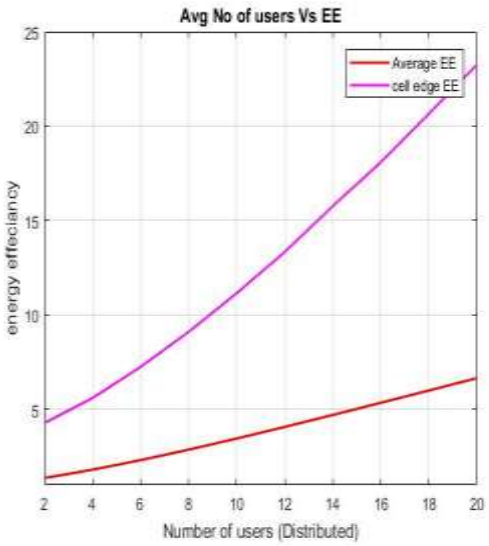
d) Step 2.5 & 2.6 – Virtual scheduling & utility computation: For each sampled configuration, the optimizer calls this function to render the scheduling performed by each eNB (the one being selected in Step 2.1 and its neighboring eNBs) in order to estimate the expected performance (resulting bit rates). Several options are available such as proportional fairness, absolute fairness (max-min), sum rate maximization, etc. For each eNB and its UEs, we adopt the well-known Proportional Fair Scheduling (PFS) algorithm used in today's LTE [2]: the PFS will serve a UE um when its instantaneous channel quality is the highest according to um = arg max u∈Uk Ru(m, t) R¯ u(t) (15) where R¯ u(t) denotes the experienced average throughput of user u at time t and Ru(m, t) is the achievable rate by user u if it may get served by the RB m. To compute the throughput utility for each cell, we propose a virtual scheduling approaching to the PFS. These inputs are needed:

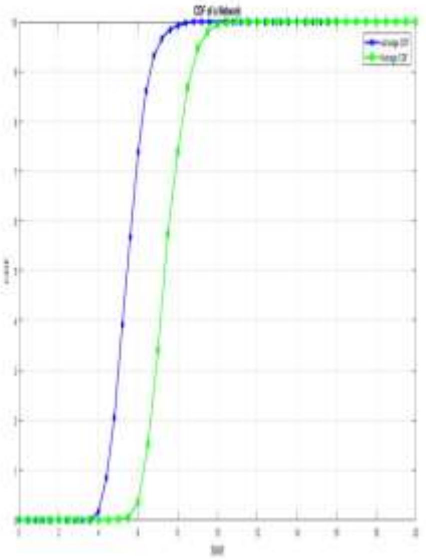
- S sub-frames grouped in T time slots. For simulation purposes, S is equal to 80.
- F sub-bands and Rf number of RBs in each frequency sub-band.
- The averaged spectral efficiency seu,f,t for each user u over each sub-band f during time slot t is derived from SINRu,k,f,t.

After calling the virtual scheduling function for the selected cell and its neighboring cells, the coordinator computes the utility function based on the resulting achievable rates ru's. Note that indeed the proposed framework can support various optimization tools and utility definitions, depending on operator's strategy. It is not limited to proportional fairness utility. e) Step 2.6 – Choosing optimal sample: After sampling all the possible states of the chosen cell and computing their corresponding utility values, the coordinator chooses the best configuration for maximum value, i.e., best response. As previously discussed, the best response update is guaranteed to converge to a Nash equilibrium through a finite number of iterations. 3) Step 3 – Distribution & Execution: After the optimization, the coordinator sends the optimized setting to each eNB. The optimized CIO values are added to RSRP measurements to trigger possible handovers. The local schedulers allocate their provided RBs with respect to their power level patterns over time and frequency dimension, as advised by the coordinator.

4.SIMULATION RESULTS







5. CONCLUSION

Based on potential game setup, we offer a practical solution to optimize user association and coordinate inter-cell interference among multiple cells in LTE. The algorithm can provide optimal cell individual offsets and power settings over frequency and time resources for each cell to maximize a network utility. We observe that the proposed algorithm outperforms the frequency reuse-1 scheme and achieves more than 50% gain in cell edge throughput and also substantial enhancement in the average throughput and energy efficiency. From simulations, we see that the algorithm converges to a Nash equilibrium point and only requires a small number of iterations. This would allow us to optimize a dynamic system due to its fast convergence. Since each iteration follows the best response greedy strategy, the network is always improving by the proposed scheme towards the optimal solution.

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