Resource Allocation: Current Issues and Future Directions

Popovska Avramova, Andrijana; Ruepp, Sarah Renée; Yan, Ying; Dittmann, Lars

Publication date:
2013

Citation (APA):
Popovska Avramova, A., Ruepp, S. R., Yan, Y., & Dittmann, L. (2013). Resource Allocation: Current Issues and Future Directions. Paper presented at 4th Nordic Workshop On System And Network Optimization For Wireless (SNOW 2013), Äkäslompolo, Finland.

Resource Allocation: Current Issues and Future Directions

Andrijana Popovska Avramova, Sarah Ruepp, Ying Yan and Lars Dittmann
Department of Photonics Engineering
Technical University of Denmark
Ørsteds Plads 343, 2800 Kgs. Lyngby, Denmark
Email: {apop, srru, yiya, ladit}@fotonik.dtu.dk

I. Introduction

With the switch over from 2G to 3G, the users have been experiencing higher bit rates. In LTE, in order to achieve higher spectrum utilization, the air interface has been enhanced with advanced technologies such as OFDMA (Orthogonal Frequency Division Multiple Access) and MIMO (Multiple Input Multiple Output). The air interface capacity in LTE has reached near the theoretical limit [1] and higher bit rates per hertz have been achieved. On the other hand, the demand for data traffic has increased due to the rapid development of rich multimedia content services and mobile devices that support these services. This has resulted into a need for heterogeneous networks (multi-RAT, multi-tier, multi-architecture) that will provide high data rates per hertz per area.

The vision of heterogeneous networks is to ensure that the users are always best connected and served. Complementing the macro cell with low power nodes as well as other standards, has shown that there is a need for coordination and cooperation among tiers and different Radio Access Technologies (RATs) [2]. The introduction of new LTE-A features such as Beamforming, Coordinated Multipoint transmission and Reception (CoMP), and Carrier Aggregation (CA) have further increased the complexity of Radio Resource Management (RRM). Self Organizing Networks (SON) and the SON's successor - Cognitive Radio Networks (CRN) have been seen as a way of providing automated operation and management process for future mobile networks [3]. RRM encompasses a range of functionalities such as network planning, fault management, mobility, load balancing etc. This paper focuses on the subcarrier allocation at the Base Stations (BS) as part of the RRM of the future networks. Its main goal is to identify the challenges and to show the need for coordinated resource allocation that will ensure maximum capacity meeting users expectations and traffic demand.

II. Cross Layer Scheduler Design

The design of the resource scheduler in LTE plays a major role in optimizing radio resource utilization while achieving high system performances. The scheduler needs to assign the subcarriers (Resource Blocks, RB) to the radio bearers (UEs), adapt the modulation and coding (AMC) to the channel conditions as well as adjust the power transmission. The decision needs to be made on every 1ms transmission time interval which further increases the complexity of the scheduler.

So far, there has been a lot of a research effort in modelling the scheduler in order to achieve high Quality of Service (QoS), reduce latency, and avoid starvation to edge users [4]. The results have shown that the scheduler needs to be designed in a cross layer fashion: be aware of the channel conditions (physical layer) as well as of higher layer specific information (e.g. size of the buffers, type of services). Fig. 1 illustrates such cross layer design. In order to simplify the radio resource management, the scheduler process is divided into three components: time domain, frequency domain - subcarrier allocation and frequency domain - bit selection. For each of the components, the limitations and possible input parameters are listed.

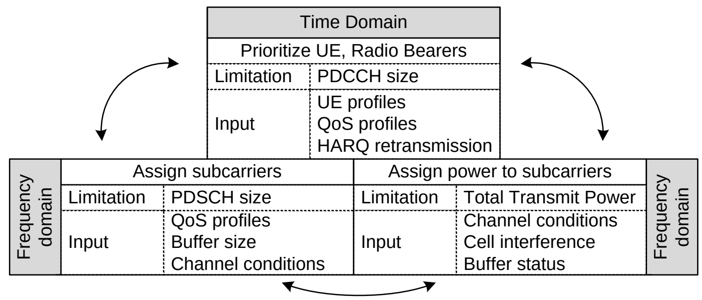

Fig. 1: Cross layer scheduler design

III. Challenges in Multy-tier Architecure

Multi-tier architecture relieves the Macro BS (MBS) by offloading the traffic to smaller cells served by low power nodes: Femto Access Points (FAP), Pico Base Stations (PBS) or Relay Stations (RS). While MBS provide wider coverage and reduce the number of handovers for high mobility users, smaller cells increase the cellular capacity on hotspots like airports, cafes, stadiums etc. and/or extend the coverage where coverage holes exist. One of the crucial elements of the success of multi-tier architecture is to provide carrier reuse across tiers. The main challenge in spectrum reuse is the co-interference which can degrade the performance or even worse create coverage holes. Therefore, in order to mitigate the interference and improve the channel utilization, an intelligent radio resource management scheme is required. There are several interference mitigation techniques known in the literature of which we focus on the first one:

– Synchronization of scheduling schemes,
– Interference mitigation through carrier agregation,
– enhanced Inter-Cell Interference Coordination (eICIC)[5],

– Low Duty Cycles: neighboring FAPs take turns in which they transmit the control signals [6],

The synchronization of scheduling schemes between nodes includes coordinated scheduling, beam-forming and CoMP. The scheduling done at the BS can also include mitigation of inter-cell interference in the optimization process by controlling the power assigned to the subcarriers. By applying particular antenna pattern (beam), interference towards users that are not served by the node can be significantly reduced. Users that are located at the cell edge and/or experience deep fading can experience reduced signal strength. By simultaneously transmitting the signal from multiple points, the received signal quality can be improved. Therefore CoMP is seen as a promising way of increasing data rates and a way to combat the interference. The techniques in eICIC can be grouped as: time-domain, frequency-domain and power control techniques. In the time-domain, Almost Blank Subframes (ABS) are utilized. ABS is a subframe where data transmission does not occur (only mandatory control channels). Therefore the cell that transmits ABS decreases the cell-interference during that subframe. In the frequency-domain the orthogonal property is utilized as a way of a simple frequency planning. With the power control techniques, the transmission power of the small cells is controlled. Different schemes can be applied depending on the design requirements; e.g. wheather QoS is crucial for the macro or the femto (pico) cell. In the section below we focus on beam-formning and CoMP and their challenges.

A. Beamforming and CoMP

When the scheduler needs to consider AMC, power adjustment, RB assignment and beam-forming, the complexity optimization process of the scheduler is increased. Suboptimal solutions have been proposed, where one or two conditions are considered at the same time. The beam-forming vectors need to be constructed such that the signal quality is increased, while interference to other terminals is decreased [7]. In case of beam-forming, deciding which terminal will be served by which transmitting antenna is one of the main challenges. Therefore there is a need for cooperation among the scheduling units. CoMP is similar to MIMO, with a main difference that with CoMP the transmitting antennas are not physically collocated. The data to be transmitted needs to be available at all transmitting points. CoMP requires that scheduling decision is done in cooperation among the transmitting points. The joint scheduling and joint transmission increases the amount of signalling and data among transmitting points which leads to high load and complexity in case of large networks. Additionally CoMP may lead to decreased frequency reuse and cell-splitting gain which in turn can decrease the overall system throughput and utilization [8].

IV. Coordinated Resource Allocation

As discussed in the previous section, interference mitigation and avoidance techniques require coordination and cooperation among transmitting points at multiple cells. In order to provide the communication part, X2 connections among small cells as well as HeNB gateways can be seen as one possible direction. The new concepts of BS architecture, Distributed Antenna System (DAS) and Cloud Radio Access Network (C-RAN) introduce numerous improvements and they are more promising for achieving communication among scheduling units. In DAS, the BS where processing is performed, is connected to Remote Radio Heads antennas, while in C-RAN the baseband processing is centralized in a common pool of processing units. As mentioned in the introductory section, SON and CRN provide simplified, automated management with reduced cost. Self organization can be done in centralized or distributed fashion. As scheduling needs to be done in very short time scale, a distributed approach is more appropriate. Fig. 2 illustrates the logical communication among the scheduling units based on the cognitive cycle. The scheduling units need to sense the environment (channel quality information, interference level) as well as coordinate the decision with the other scheduling units.

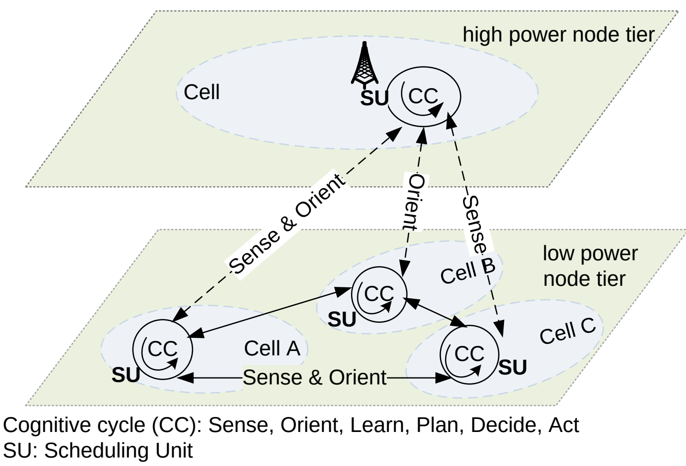

Fig. 2: Coordinated joint scheduling through CRN concept

V. Conclusion

This paper gives an overview of research issues in radio resource management at the BS. It focuses on the resource allocation in case of heterogeneous network deployment and indicates the need for coordination and cooperation among the scheduling units. We show that the joint scheduling can be improved by applying the cognitive concept in order to aid and optimize the decision making process.

References

[1] A. Khandekar, N. Bhushan, Ji Tingfang; V. Vanghi; "LTE-Advanced: Heterogeneous networks," Wireless Conference, 12-15 April 2010

[2] S. Landström, et al.; "Heterogeneous Networks (HetNets) an approach to increasing cellular capacity and coverage", Ericsson Review, Jan. 2011

[3] S. Hamalainen, H. Sanneck and C. Sartori (Eds.); "LTE Self-Organizing Networks (SON)", John & Wiley Sons, Ltd., 2012.

[4] B. Sadiq, R. Madan, A. Sampath; "Downlink Scheduling forMulticlass Traffic in LTE", EURASIP Journal onWireless Communications and Networking, Volume 2009

[5] 3GPP, TS 36.300, "E-UTRA and E-UTRAN; Overall Description, Stage 2", Dec. 2012.

[6] Shu-Ping Yeh, et al.; "Capacity and coverage enhancement in heterogeneous networks," Wireless Communications, IEEE , vol.18, June 2011

[7] Samano-Robles, Ramiro; "Joint user scheduling, link adaptation and beam-forming for distributed antenna systems," 20th Telecommunications Forum (TELFOR), pp.588-591, 20-22 Nov. 2012

[8] R. Chen, R. Bendlin, E. Onggosanusi, A. Ekpenyong; "Single and Multi-Cell Scheduling in Coordinated Multi-Point Distributed Antenna Systems," Globecom - Wireless Communications Symposium, Dec. 2012