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Editorial
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Resource Optimization in Wireless Networks

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Index Terms

Broadband radio access networks; green wireless communication; resource allocation; optimization techniques; convex optimization; power-rate optimization; energy efficiency; spectral efficiency; energy and spectral efficiencies trade-off; game theory; (non-)cooperative games.

Wireless communications have experienced fast technological innovations in the last few decades. Broadband radio access networks (BRANs), such as 3G/4G cellular, wireless local area networks (Wi-Fi), and wireless mesh networks (WMNs), as well as wireless sensor networks[#] (WSNs) are under rapid deployment.

Planning and optimization techniques play a vital role in the deployment and operation of almost types of networks. Specifically, the adoption of optimization and planning procedures are still in progress during the lifetime of a broadband radio access network. The proper adoption of planning and optimization procedures enables the successfully deployment and expansion of the BRANs. In the initial phase, planning deals with issues of network dimensioning and configuration, including the number and locations of base stations (BSs) and their configuration parameters. (Re-) optimization tasks take place during network operation; frequently, a network is subject to re-optimization in order to adapt to changing demands and additional service requirements. It is worth noting the direct application of the optimization and/or planning solutions obtained in the context of broadband cellular system-based networks is not optimal for the ad-hoc networks.

Resource optimization (RO) techniques, primarily power/energy consumption minimization, are becoming increasingly important in wireless systems and networks design, since battery technology evolution has not followed the explosive demand of mobile devices. Specifically, typical optimization problem in WSNs consists in efficiently reduce the required energy consumption while maximizing the lifetime of the network sensors. For that, source and path redundancy techniques is commonly used. As a result, the number of active sensor nodes can be optimized in order to sense and communicate with base station (BS), while a time slots duration strategy to each sensor nodes is assumed.

Due to the large amount of investments spent on radio access, appropriate planning and optimization procedures are crucial to any business model. As a benefit, a well-planned network, especially BRAN, requires less infrastructure, mainly fewer BS sites, which has been proven to be a severe constraint in provisioning 3G/4G networks. Besides, well-planned BRAN makes more efficient use of radio resource, offering extra capacities under the same infrastructure.

However, wireless network planning and optimization is quite challenging, mainly because in radio access networks there are many network elements, each with a large set of parameters to be dynamically (re-)configured. As a consequence, manual tuning approach for the set of parameters is not able to deliver satisfactory results. On the other hand, automated network planning and optimization procedures, approaches and tools, are outperforming manual one in cost, time, and performance.

Hereafter, the focus will be on wireless networks optimization issues. Traditionally, RO in wireless networks aim to maximize the sum of utilities of link rates for best-effort traffic; this approach was systematically applied in [1]. The usual approach consists in considering the problem jointly, i.e., optimizing the joint power control and link scheduling, which has been extensively investigated in the literature and is known to be notoriously difficult to solve, even in a centralized manner. Hence, the methodology in [1], consists in identifying a class of utility functions for which the power control problem can be converted into an equivalent convex optimization problem. The convexity property is a key ingredient in the development of powerful and efficient power control algorithms.

One of the most interesting ways of dealing with the power allocation problem is the energy-efficiency (EE) approach [2-4], which aims to maximize the transmitted data per energy unit (measured in bits per Joule), and closely related to green communication techniques [5]. Recent works in the field include the EE problem formulation in the context of multiple-access networks, such as OFDMA [4,6] and CDMA [3,7], with particular interest in MC-CDMA system-based networks. The energy-efficient approach on CDMA system-based networks can include the joint strategies of spreading-code and receiver optimization [8]. On the receiver side, multiuser detection (MuD) techniques [9] could be included in order to reduce the multiple access interference (MAI) effects.

As pointed out by [10], one of the most important trades-offs on green wireless communications is energy efficiency *versus* spectral efficiency (EE-SE) trade-off; the goal consists in balancing these two important conflicting metrics. Inside this, one of the most important issues is the characterization of the EE-SE trade-off in multi-user (MU) environments, such as CDMA, MC-CDMA, OFDMA system-based networks. The problem posed in this context that deserves attention can be formulated as: Does the optimum EE-SE trade-off (with overall wireless networks benefits) exist? Is this EE-SE operation point unique? Does the optimum solution always exist?

In [11], the authors have demonstrated that the EE-SE trade-off gap in OFDMA system-based networks is reduced when interference increases, assuming some restrictions in user's power and position. The same EE-SE trade-off optimization issue was posed in [12], considering now a multiple access DS-CDMA system-based network and the

[#]Typically narrowband radio access networks. A sensor network is composed of a numerous, small and independent sensor nodes with sensing, processing and communicating capabilities. Minimal amount of on-board computing power and limited battery lifetime are key features of sensor nodes.

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signal-to-interference-plus-noise ratio (SINR) evaluation after MuD filters. Besides, the impact of MuD utilization is assessed; motivated by the fact that the gap between optimal-EE and maximal-SE is reduced when the MAI is increased. Since those detectors are capable to reduce (or even eliminate) the MAI from other users, their deployment could result in more energy-efficient systems, meaning the same SINR can be achieved with less power consumption.

Hence, from a wider approach, the power control problem could be formulated aiming to optimize the deployment of two main resources scarcely available, primarily at mobile terminals (or even in base station), i.e., spectrum and energy, considering multiple access system-based networks. Besides, the EE-SE trade-off behavior would be extensively characterized under different interference levels scenarios. Recently, game theory, which has its roots in the economy field, has been broadly applied in wireless communications for random access and power control optimization problems. More importantly, from the analysis of two conflicting metrics, namely throughput maximization and power consumption minimization, the distributed energy efficiency cost function can be formulated as a non-cooperative game [10,12], as well as cooperative game [13]. Indeed, the overall EE of the network depends on the behavior of each user; so, the power control problem could be more properly modeled as non-cooperative game. Efficiency cost function can be formulated as a non-cooperative game [10,12], as well as cooperative game [13]. Indeed, the overall EE of the network depends on the behavior of each user, so the power control problem could be more properly modeled as a non-cooperative game.

Since SE is a monotonic increasing function of the transmitting power level, in multiple access system based networks, which are limited by interference level, it is also constrained by the maximum transmitted power available at each distributed network node. As a consequence, although the sum-rate capacity increases with the number of active users, the generated level of interference induced by the new users sharing the same bandwidth increases too. Hence, by one side the total network power consumption enlarges in order to achieve the optimum SINR, while, on the other hand, the EE is reduced in terms of transmitted bits per Joule units. As a solution in that context, the best EE-SE trade-off can be achievable when each node allocates exactly the power necessary to attain the best SINR value, which guarantees the maximal EE while SE is determined by the attainable rate in each node given by Shannon capacity equation. Besides, the energy efficiency is normally reduced by the efficiency function, coding factor and by the circuit power consumption as well. Interestingly, for MuD linear filters results, in [12] have been indicated that the received SINR in the max-EE equilibrium is almost the same for a large range of multiple access interference levels, and even more noteworthy when the interference levels are medium or high.

The promising research directions and open issues in the broadband network optimization resources usage include: a) address and solve resource optimization problems in each specific scenario/system based, primarily those problems including scarce resources such as spectrum and energy; b) energy and spectral efficiencies analysis in multiple access system-based networks, from the perspective of conflicting metrics (multi-objective optimization), such as throughput maximization and power level consumption minimization; c) assessment of the impact of the filter receiver optimization over the EE-SE trade-off and overall multiple access network performance; d) application of the EE-SE trade-off optimization to collaborative relaying multiple access BRANs, including relay best placement problem. The optimal relay placement depends mainly on the transmission and scheduling strategies, as well as the transmitted power level of the relays.

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