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Editorial

Fairness in Radio Resource Management for Wireless Networks

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Radio resource management (RRM) techniques such as admission control, scheduling, subcarrier allocation, channel assignment, power allocation, and rate control are essential for maximizing the resource utilization and providing quality of service (QoS) in wireless networks. In many cases, the performance metrics (e.g., overall throughput) can be optimized if opportunistic algorithms are employed. However, opportunistic RRM techniques always favor advantaged users who have good channel conditions and/or low interference levels. The problem becomes even worse when the wireless terminals have low mobility since the channel conditions become slowly varying (or even static), which might lead to long-term unfairness. The problem of fair resource allocation is more challenging in multihop wireless networks (e.g., wireless mesh networks and multihop cellular networks). This special issue addresses some fairness issues and solutions in using RRM techniques in modern wireless communication systems.

We received an overwhelming response to our call for paper of this special issue. From the large number of high quality submissions we received, we have selected sixteen papers grouped in six subtopics, namely, (1) *fairness of RRM in WiMAX networks*, (2) *fairness of RRM in OFDM/OFDMA systems*, (3) *fairness of RRM in CDMA/UMTS system*s, (4) *fairness of RRM in MIMO systems*, (5) *fairness of RRM in multihop and mesh networks*, and finally (6) *fairness of multiuser resource allocation*.

In the first group, three papers address the fair resource management in WiMAX networks.

The first paper titled "Fair adaptive bandwidth and subchannel allocation in the WiMAX uplink" by A. Morell, G. S. Granados, and J. L. Vicario proposes an uplink scheduling mechanism for mobile WiMAX networks. The scheduling mechanism implements a dynamic bandwidth allocation solution in a network utility maximization framework. The problem is decomposed into two subproblems, namely, a flow allocation subproblem and a subchannel allocation subproblem. To solve the optimization problem, the authors apply the mean value cross-decomposition method, which results in an implementation-friendly solution. The second paper titled "Fairness and QoS guarantees of WiMAX OFDMA scheduling with fuzzy controls" by C. L. Chen et al. proposes a fuzzy control-based scheduling mechanism for WiMAX. The objective of the proposed scheduling mechanism is to provide delay and jitter control for real-time connections, and throughput control for non-real-time connections. The scheduling method provides intra- and interclass fairness with QoS guarantees, and it has low implementation complexity. With intraclass fairness, the connections within the same class achieve equal degree of QoS. With interclass fairness, the connections with QoS requirements achieve their demands and those without QoS requirements equally share the remaining resources.

The third paper titled "CDIT-based constrained resource allocation for mobile WiMAX systems" by F. Brah, J. Louveaux, and L. Vandendorpe addresses the problem of

subchannel assignment and power allocation for mobile WiMAX systems. The authors consider a fast fading environment, where the transmitter has only the channel distribution information (CDI) instead of the full instantaneous channel state information. The objective is to maximize the ergodic weighted sum rate under long-term fairness, minimum data rate requirement, and power budget constraints. The authors formulate the problem as a nonlinear stochastic constrained optimization problem and provide an efficient analytical solution based on Lagrange dual decomposition framework. For the proposed CDIT-based resource allocation framework, the trade-off between reduction in computational complexity and performance degradation is analyzed.

The papers in the second group consider the fair resource allocation in OFDM/OFDMA systems.

The first paper titled "Cross-layer resource scheduling for video traffic in the downlink of 4G wireless multicarrier networks" by F. Bokhari et al. presents a cross-layer scheduling scheme which is designed for packet scheduling and resource (subcarrier) allocation in the downlink of 4G wireless multicarrier networks. The authors propose an adaptive method for parameter selection which integrates packet scheduling with resource mapping. The performance of the proposed scheme is compared to that of the Round Robin and the Score-Based schedulers, considering varying interference and network loading conditions in a multicell environment. The authors further analyze the proposed scheme with different fairness indices available in the literature in order to quantify the achieved fairness as compared to the reference schemes.

The second paper titled "Busy bursts for trading-off throughput and fairness in cellular OFDMA-TDD" by B. Ghimire, G. Auer, and H. Haas proposes a decentralized interference management algorithm for OFDMA operating in TDD cellular systems. Interference aware allocation of time-frequency slots is accomplished by letting receivers transmit a busy burst (BB) in a time-multiplexed minislot, upon successful reception of data. A link adaptation method using BB signaling is proposed, where the transmission format is dynamically adjusted based on the channel conditions.

The third paper titled "A fair opportunistic access scheme for multiuser OFDM wireless networks" by C. Gueguen and S. Baey proposes a new access scheme for efficient support of multimedia services in OFDM wireless networks. Access to the medium is granted based on a system of weights that dynamically accounts for both the experienced QoS and the transmission conditions. This new approach enables the full support of multimedia services with the adequate traffic and QoS differentiation while maximizing the system capacity and keeping a special attention on fairness.

In the third group, three papers investigate the fair resource management in CDMA/UMTS networks.

The first paper titled "Decentralized utility maximization in heterogeneous multi-cell scenarios with interference limited and orthogonal air-interfaces" by Ingmar Blau et al. treats the problem of resource allocation in terms of optimum air-interface and cell selection in cellular multi-air-interface scenarios. The adopted model applies to arbitrary heterogeneous scenarios, where the air-interfaces belong to the class of interference limited systems like UMTS or to a class with orthogonal resource assignment such as TDMA-based GSM or WLAN. The performance of the dynamic algorithm is then evaluated for a heterogeneous UMTS/GSM scenario.

The second paper titled "Joint throughput maximization and fair uplink transmission scheduling in CDMA systems" by C. Li and S. Papavassiliou studies the optimal scheduling for uplinks of a code division multiple access wireless system while satisfying the quality of service requirement and maintaining fairness among users. The throughput maximization problem is formulated as a multiconstraint optimization problem and then expressed as a weighted throughput maximization problem under power and QoS weight constraints that nicely relate the fairness. The authors use the concept of power index capacities to convert the problem under investigation to a binary knapsack problem, and then the optimal solution is obtained through a global search mechanism using a two-step approach.

The third paper titled "Spatial and temporal fairness in heterogeneous HSDPA-enabled UMTS networks" by A. Mader and D. Staehle investigates spatial and temporal fairness aspects in HSDPA-enabled UMTS networks for different link level scheduling schemes. Spatial fairness refers to the spatial distribution of perceived data rates among users while temporal fairness refers to the long-term time-average user throughput. A flow-level simulation that is used for this study considers traffic dynamics for both QoS flows and best-effort (or elastic) flows. The impact of network-wide interference and multipath propagation effects is also considered.

In the fourth group, three papers address the fair resource management in multihop and mesh networks.

The first paper titled "Outage probability versus fairness trade-off in opportunistic relay selection with outdated CSI" by J. L. Vicario et al. analyzes the performance of opportunistic relay selection in a decode and forward cooperative relaying wireless network. In order to achieve global balance in terms of performance and tradeoff, a relay selection strategy has been proposed based on max-normalized SNR criterion. The tradeoff in terms of system performance (outage probability) versus fairness (relay node power consumption) among relays is studied for different relay selection strategies using portfolio theory. The impact of availability of accurate channel state information on the performance is also investigated.

The second paper titled "Cross-layer optimal rate allocation for heterogeneous wireless multicast" by A. Mohamed and H. Alnuweiri addresses the problem of rate allocation for heterogeneous multicast sessions over multihop wireless networks. The problem is formulated as a nonlinear optimization problem with an objective to optimizing resource allocation while providing system-wide fairness for end-to-end multirate multicast flows.

Based on primal-dual and pricing methods, the problem is decomposed into subproblems, which are easier to solve in a modular structure. The authors propose an iterative algorithm to solve the problem in a distributed ad hoc network environment with asynchronous computations.

The third paper titled "A novel approach to fair routing in wireless mesh networks" by J. Matti, H. Määttä, and T. Braysy proposes a novel centralized routing algorithm for wireless mesh networks. The proposed scheme can assure fairness, leads to a feasible scheduling, and does not collapse the aggregate network throughput with a strict fairness criterion.

The papers in the fifth group address the problem of fairness in RRM for MIMO systems.

The first paper in this group titled "On throughput-fairness trade-off in virtual MIMO systems with limited feedback" by A. A. Dowhuszko et al. investigates the performance of channel-aware scheduling algorithms designed for the downlink of a wireless communication system. The study focuses on a two-transmit antenna cellular system, where the base station can only rely on quantized versions of channel state information to carry out scheduling decisions. Virtual MIMO system selects at each time instant a pair of users that report orthogonal (quantized) channels. Closed-form expressions for the achievable sum-rate of three different channel-aware scheduling rules are presented using an analytical framework.

The second paper titled "Throughput versus fairness: channel-aware scheduling in multiple antenna downlink" by E. A. Jorswieck, A. Sezgin, and X. Zhang studies the trade-off of using four channel-aware scheduling algorithms using majorization theory for a space-time coded multiple antenna downlink system, where TDMA-based scheduling is employed and spatial diversity is exploited. The scaling laws of average sum rate and of average worst case delay are derived. The impact of user distributions on the system performance and the average worst case delay are analyzed.

The papers in the last group deal with the problem of multiuser fair resource allocation.

The first paper titled "Optimal and fair resource allocation for multiuser wireless multimedia transmissions" by Z. Guan, D. Yuan, and H. Zhang proposes an optimal and fair strategy for multiuser multimedia radio resource allocation based on copetition, a mixture of cooperation and competition. The copetition strategy is formulated as sum utility maximization under constraints from both APP and PHY and is shown to be effective to allocate power among multiple video users.

The second paper titled "Performance analysis of SNR-based scheduling policies in asymmetric broadcast ergodic fading channels" by J. Perez et al. analyzes the performance of SNR-based scheduling algorithms in broadcasting ergodic fading channels by exploiting multiuser selection diversity. At each fading state, the base station transmits to the user of the highest SNR. By arranging weights to users according to a specific scheduling policy, QoS or fairness can be achieved.

We hope the readership will find the papers in this special issue useful for their research. Finally, we would like to thank the authors of all submissions, the reviewers for their enormous help with the review process, and the editorial staff of EURASIP JWCN for their support during all phases of this special issue.

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