

## Editorial introduction

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This is the second volume of the special issue “Recent Trends in the Mathematics of Wireless Communication Networks: Algorithms, Models, and Methods,” bringing together a collection of papers describing various recent advances in the mathematical treatment and stochastic analysis of wireless communication systems.

The paper by Banerjee, Gopalan, Reddy, Shakkottai, and Ying studies the problem of distributed scheduling in wireless networks, where each node makes individual scheduling decisions based on heterogeneously delayed network state information (NSI). This leads to inconsistency in the views of the network across nodes, which coupled with interference, renders it hard to schedule for high throughputs. The paper characterizes the network throughput region for this setup, and devises optimal scheduling policies to achieve the same. The proposed scheduling policies have a threshold-based structure and, moreover, require the nodes to use only the “smallest critical subset” of the available delayed NSI to make decisions. In addition, Markov chain mixing techniques are used to assess the impact of delayed NSI on the throughput region. This not only highlights the value of extra NSI for scheduling, but also quantifies the loss in throughput incurred by lower complexity scheduling policies which use homogeneously delayed NSI.

The paper by Banerjee, Gupta, and Shakkottai addresses the design of network algorithms for function computation in sensor networks. The paper specifically seeks dynamic joint aggregation, routing, and scheduling algorithms that have analytically provable performance benefits due to in-network computation as compared to data forwarding. The authors define a class of “fully-multiplexible” functions, which includes several functions such as parity, MAX, and  $k$ th order statistics, and for which the maximum achievable refresh rate of the network can be exactly characterized in terms of an underlying graph primitive, the min-min-cut. In wireline networks, they show that the maximum refresh rate is achievable by a simple algorithm that is dynamic, distributed, and only dependent on local information. In the case of wireless

networks, a MaxWeight-like algorithm with dynamic flow splitting is provided and proved to be throughput-optimal.

The paper by Celik and Modiano considers the use of controlled mobility in wireless networks where messages arrive randomly in time and space. Mobile receivers (collectors) are responsible for gathering these messages via wireless transmission by dynamically adjusting their position in the network. The central objective is to use a combination of *wireless transmission* and *controlled mobility* in order to improve the throughput and delay performance. The authors first analyze a system with a single collector, and establish a necessary and sufficient stability condition. They also present lower bounds for the expected message waiting time and develop policies achieving an asymptotically optimal delay scaling. It is demonstrated that the combination of mobility and wireless transmission results in a much better delay scaling than in the corresponding system without wireless transmission. A system with multiple collectors is considered as well. For the case where simultaneous transmissions to different collectors do not interfere, it is shown that both the stability condition and the delay scaling extend from the single-collector case. For the case where simultaneous transmissions do interfere, the stability region is characterized, and a frame-based version of the MaxWeight policy is proved to stabilize the system.

The paper by Chaintreau, Ioannidis, and Massoulié addresses the problem of sharing content over a mobile network through opportunistic contacts. In previously proposed scenarios, users store content that they download in a local cache and share it with other users they meet, e.g., via Bluetooth or WiFi. The storage capacity of mobile devices is typically limited, however, and determining which content a user should store in her cache is therefore a fundamental problem in the operation of any such system. The authors propose Psephos, a novel mechanism for obtaining the caching policy of each mobile user. Psephos is fully distributed: users compute their own policies individually, in the absence of a central authority. Moreover, it is designed for a heterogeneous environment, in which demand for content, access to resources, and mobility characteristics may vary across users. Most importantly, the caching policies computed by the proposed mechanism are optimal: Psephos is shown to maximize the system's social welfare.

The paper by Eryilmaz and Srikant considers the use of Lyapunov functions in deriving bounds for steady-state queue lengths. The Foster–Lyapunov theorem and its variants serve as the primary tools for studying the stability of queueing systems, with wireless networks as specific examples. It is well known that “setting the drift of the Lyapunov function equal to zero” in steady state provides bounds for the expected queue lengths, but such bounds are often loose due to the fact that they fail to capture resource pooling effects. In order to show that the approach of “setting the drift of a Lyapunov function equal to zero” can be used to obtain bounds which are tight in a heavy-traffic regime, the paper establishes an appropriate notion of state-space collapse in terms of steady-state moments of weighted queue length differences. As an application of the methodology, the authors prove the steady-state equivalent of Stolyar's heavy-traffic optimality result for wireless networks operating under the MaxWeight policy.

The paper by Georgiadis, Paschos, and Tassiulas studies the problem of scheduling packets from several flows traversing a given node which can mix packets be-

longing to different flows. Practical wireless network coding schemes rely on knowledge of overhearing events which is obtained either by acknowledgments or statistically. In the latter case, the knowledge about each packet improves progressively with feedback from the transmissions. The authors propose a virtual network mechanism in order to characterize the throughput region of such a system for the case where only pairwise XORing is allowed. They also provide the policy which achieves the throughput region and compare it to simple heuristics. The latter policy is a modification of the standard backpressure policy, designed to take into account that in the proposed virtual network the destination of a transmitted packet is known only probabilistically. Simulation results demonstrate that scheduling with statistical information can provide significant throughput benefits, even for relatively small overhearing probabilities.

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