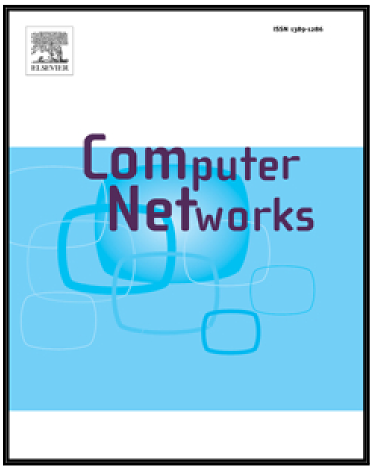

Improving the Queue Size and Delay Performance with the I-CSMA Link Scheduling Algorithm

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Improving the Queue Size and Delay Performance with the I-CSMA Link Scheduling Algorithm

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***Abstract*—In a prior work, we proposed a new CSMA-like randomized link scheduling algorithm for wireless networks, called I-CSMA, based on a modified version of the Ising model in physics. I-CSMA is a generalization of earlier Glauber-dynamics-based algorithms, and it was shown to be throughput-optimal. In this paper, we evaluate the queue size/delay performance of I-CSMA. The simulation results show that, while maintaining throughput-optimality, I-CSMA gives better queue-size/delay performance than the popular Q-CSMA algorithm. The improvement is significant and consistent, particularly in the regime of low to moderately high traffic intensity. We analyze the control overhead of I-CSMA, discuss parameter tuning for the algorithm, and show the effects of parameter tuning with simulation results. We also propose a simpler, heuristic I-CSMA algorithm and show that it has similar performance as I-CSMA. To make I-CSMA immediately useful, we provide a device-based implementation of the I-CSMA algorithm as a reference implementation.**

***Index Terms*—Link Scheduling, Wireless Networks, CSMA, Markov Chain, Glauber Dynamics, Queue Sizes and Delay**

I. INTRODUCTION

Efficient utilization of the network resources is vitally important in wireless networks, as the capacity of such networks is often severely limited. Link transmission scheduling is one of the key mechanisms for improvement in both network resource utilization and user perceived performance. An ideal link scheduling algorithm should achieve high throughput, low delay, and it should do so at low complexity. A family of scheduling algorithms has attracted much attention recently: randomized algorithms in which the link activation probabilities are dependent on the queue sizes [1] [2] [3] [4] [5] [6]. A representative one is the Q-CSMA algorithm [4]. These algorithms can be implemented similarly to the Carrier Sense Multiple Access (CSMA) scheme used in practical systems such as WIFI 802.11x. The implementation is decentralized and requires only local information and control. Interestingly, despite having simple operations, some of these algorithms are proven to be throughput-optimal. These algorithms share a common feature: Behind the scene, they each have a Glauber dynamics, which is a special type of Markov chain.

Previously, we introduced a new CSMA-like randomized link scheduling algorithm, called I-CSMA, based on a physics model called the Ising model [7]. I-CSMA is a generalization of earlier Glauber-dynamics-based, throughput-optimal algorithms, and it has removed a major restriction in earlier related algorithms. I-CSMA in fact has many different versions. We have shown that all versions of I-CSMA are throughput-optimal, in the sense that they each can stabilize the network queues for all arrival rate vectors in the interior of the capacity region. Thus, I-CSMA offers more flexibility and expands the choices of throughput-optimal algorithms. A network can exploit that new freedom to achieve secondary objectives after achieving throughput-optimality. Important secondary objectives considered by the community include the delay experienced by packets and practicality of the algorithm [5], [8]–[11].

Having known that I-CSMA is throughput-optimal, this paper focuses on the queue-size/delay performance. The main contribution of the paper is to show that a version of I-CSMA results in a significantly smaller expected total queue size (thus, by Little's Law, less expected delay) than the closest related algorithm, Q-CSMA. Such improvement has been reliably demonstrated by our extensive simulation experiments on different networks under different traffic models. The improvement is generally over the entire range of traffic intensity; it is especially consistent in the regime of low to moderately high traffic intensity. I-CSMA works especially well, with respect to the queue-size/delay performance, under weight functions that increase very slowly with the queue size, e.g., $\log\log$ function of the queue size.

Our second contribution is to make I-CSMA more practical and more useful. This consists of two parts. First, to make I-CSMA simpler to operate and easier to implement, we provide a heuristic version of I-CSMA. Our simulation experiments have shown that the heuristic algorithm performs nearly as well as I-CSMA[1]. Second, for ease of presentation, the main I-CSMA algorithm is presented as a link-based algorithm, where the subject that executes the algorithm is a link. However, in reality, a control algorithm is implemented at the wireless devices. To make I-CSMA immediately useful, we provide a device-based description of the algorithm as a reference implementation.

Our third contribution is that we analyze the control overhead of I-CSMA, discuss parameter tuning for the algorithm, and illustrate the effects of parameter tuning with simulation

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[1] We should point out that even the non-heuristic I-CSMA algorithm has fairly simple operations and is easily implementable, although it is slightly more complex than Q-CSMA. It requires only local communications for coordination and collection of information from a device's neighborhood. On that point, other CSMA-like algorithms also need to listen to the transmissions from neighboring links and gather information.