Improving Age of Information in Wireless Networks With Perfect Channel State Information

Rajat Talak, Sertac Karaman, and Eytan Modiano, *Fellow, IEEE*

***Abstract*— Age of information (AoI), defined as the time that elapsed since the last received update was generated, is a newly proposed metric to measure the timeliness of information updates in a network. We consider AoI minimization problem for a network with general interference constraints, and time varying channels. We propose two policies, namely, virtual-queue based policy and age-based policy when the channel state is available to the network scheduler at each time step. We prove that the virtual-queue based policy is nearly optimal, up to a constant additive factor, and the age-based policy is at-most a factor of 4 away from optimality. Comparison with previous work, which derived age optimal policies when channel state information is not available to the scheduler, demonstrates significant improvement in age due to the availability of channel state information. Our analysis relies on the *age conservation law* and *age-square conservation law* developed in this paper, which hold more generally and may be of independent interest.**

***Index Terms*— Age of information (AoI), wireless networks, scheduling, information freshness, channel state information.**

I. Introduction

TIMELY delivery of information updates is gaining increasing relevance with the emergence of cyber-physical systems, internet of things, and unmanned aerial vehicular networks. In unmanned aerial vehicular networks, timely delivery of status updates, such as vehicle position and velocity, may be critical to network safety [1], [2]. In internet of things or cyber-physical systems, timely delivery of sensor information can significantly improve the overall system performance [3].

Age of information (AoI) is a recently proposed time evolving measure of information freshness that is defined as the time that elapsed since the last received update was generated by the source [4], [5]. Figure 1 shows the typical evolution of AoI at a destination node, as a function of time. Upon reception of a new update packet AoI drops to the time that elapsed since the generation of the packet, and grows linearly until the next delivery. Therefore, AoI is a destination centric measure, unlike packet delay, and is better suited for applications involving dissemination of time sensitive information. Peak and average age are two metrics of AoI. Peak age is defined as the average of all the peaks in the AoI curve, shown in Figure 1, whereas the average age is time average of the AoI.

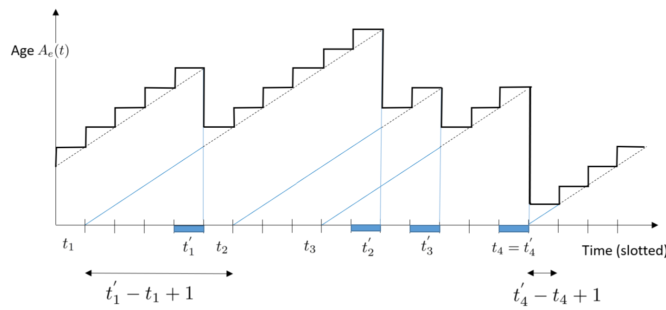

Fig. 1. Time evolution of age, $A_e(t)$, of a link e. Times t_i and t_i' are instances of ith packet generation and reception, respectively. Upon reception of packet i, the age is reset to $t_i' - t_i + 1$.

In [4], a simulation study considered AoI in a network of vehicles exchanging status updates. Motivated by [4], AoI was analyzed for several queueing models [5]–[22]. The advantage of having parallel servers and setting packet deadlines was studied in [6]–[9] and [11]–[13], respectively. The problem of determining an optimal, or near-optimal, queue scheduling discipline for minimizing AoI was considered in [15].

However, prior to this work, AoI minimization for communication links operating in a wireless network with interference had received very little attention. A problem of scheduling finitely many update packets under physical interference constraints was shown to be NP-hard in [23]. Age for a broadcast network, where only a single link can be activated at any time, was studied in [24], [25]. Distributed ALOHA like random access to minimize AoI was considered in [26], [27]. Age in multi-hop wireless network has been studied in [28].

In [29], we considered the problem of age minimization for a wireless network under general interference constraints, and time varying channel. We considered two types of sources: *active sources*, which generate fresh information in every slot, and *buffered sources*, which cannot generate fresh information in every slot. We showed that for a network with active sources, a stationary scheduling policy, which schedules links according to a stationary probability distribution, is peak age optimal and factor-2 average age optimal. We also showed that the same scheduling policy, with a certain packet generation

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The authors are with the Laboratory for Information and Decision Systems (LIDS), Massachusetts Institute of Technology (MIT), Cambridge, MA 02139 USA (e-mail: talak@mit.edu; sertac@mit.edu; modiano@mit.edu).

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