Resource Allocation Under Strict AoI Constraints

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***Abstract*—In response to strict data freshness demands within Internet of Things (IoT) networks, coupled with scarce wireless resources, this paper proposes a low complexity algorithm that minimizes bandwidth usage while ensuring heterogeneous Age of information (AoI) constraints of multiple IoT nodes. Numerical results show that the proposed algorithm reduces the time cycle required for resource allocation that satisfies AoI constraints compared to the existing algorithm.**

***Index Terms*—Age of information (AoI), Internet of Things (IoT), resource allocation, scheduling.**

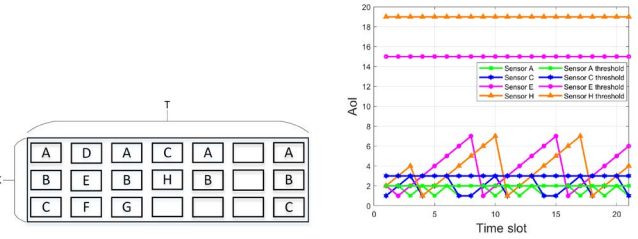
I. Introduction

In recent years, the tremendous growth of the Internet of Things (IoT) has led to applications that demand up-to-date information at their destinations [1]. To quantify the freshness of information, the concept of Age of Information (AoI) has emerged as a crucial metric [2], [3]. Due to limited bandwidth, an efficient scheduler is necessary to meet AoI requirements of hetorogenoeus IoT devices. A polynomial-time algorithm is proposed in [4] to construct a scheduler that guarantees any given AoI constraint vector. In this paper, we propose a low-complexity algorithm that constructs a scheduler minimizing bandwidth usage while still satisfying AoI constraints.

II. Problem Formulation

We consider an IoT network with N IoT devices. Each IoT device n generates an information packet which must be sent to a central access point (AP) using orthogonal wireless resource blocks (RBs). All packets generated by devices have the same size and require one slot for transmission. Let $\Delta_n(t)$ denote the AoI of device n at the AP at time slot t. If a packet from device n is received by the AP at time $t+1$, $\Delta_n(t+1)$ is reset to 1 otherwise it is incremented by 1 for $n \in \{1, 2, ..., N\}$ and $t \in \mathbb{Z}^+$. Each device n is subject to have a strict AoI constraint, represented by $d_n \in \mathbb{Z}^+$. Let $D = \{d_1, d_2, ..., d_N\}$ be the vector containing the AoI constraints of N devices, where $d_1 \leq d_2 \leq \cdots \leq d_N$. At any time slot t, let $\eta(t) \in [1 : N]$ be the number of devices scheduled for transmission. We assume that at each time slot, R orthogonal resource blocks (RBs) are available for transmission such that $R \gg N$. Then the optimization problem for minimizing the RB usage while satisfying the AoI constraints is represented by

$$\lim_{T\to\infty} \frac{1}{T} \sum_{t=1}^{T} \left(\min_{\eta(t)} \max \sum_{n\in[1:N]} \mathbf{1}_{(\Delta_n(t)\leq d_n)} \right), \qquad (1)$$



(a) User schedule. (b) AoI of the users.

Fig. 1: RB allocation and AoI results.

where the minimum operate takes over all possible RB allocations to provide a minimum bandwidth usage.

III. Exemplary Numerical Evaluation

We propose a low complexity scheduler that reduces the time cycle required for resource allocation that satisfies AoI constraints. To demonstrate the performance of the proposed scheme, we consider a scenario where $N = 8$ with AoI constraint vector $D = \{2, 2, 3, 9, 15, 16, 19, 19\}$. Fig. 1 (a) plots the user schedule obtained from the proposed algorithm and Fig. 1 (b) plots the resulting AoIs of IoT devices.

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