Poster: Optimal Load-Balancing for High-Density Wireless Networks with Flow-Level Dynamics

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Motivation

To maintain high quality wireless communication in high-density areas such as airport lounge (see Fig. 1), multiple access points (APs) must be deployed to meet network performance requirement.

Questions: (1) Which AP should each incoming user associate with? (load-balancing); (2) Within each AP, which users should be served? (scheduling), with the goal of maximizing system throughput (or equivalently supporting network users as many as possible) and minimizing average user's delay.

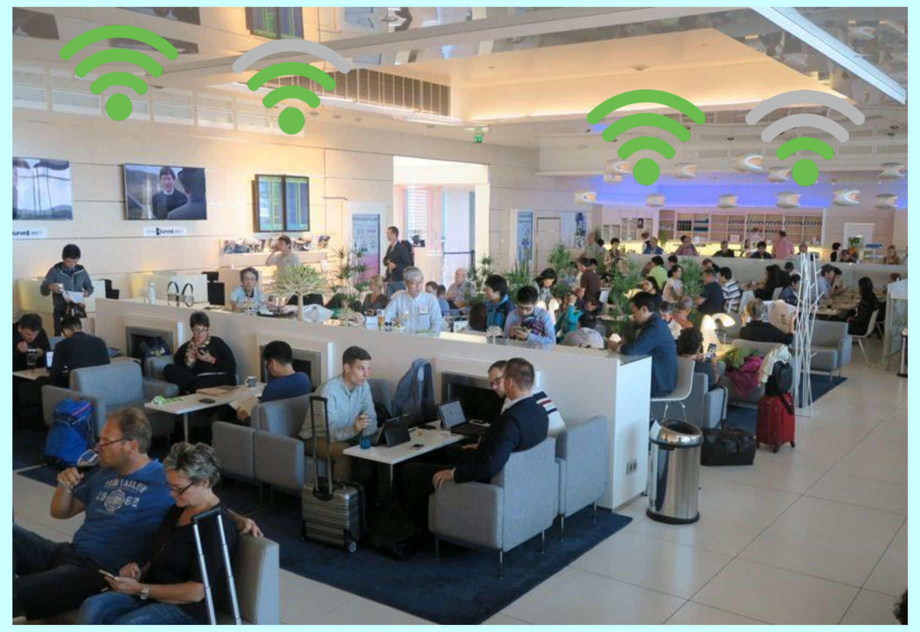

Fig. 1 An airport lounge

Flow-Level Dynamic Model

We consider a wireless network with M APs operating in M different orthogonal channels. Each incoming user requests a certain amount of service and leaves the system once its service is completed (referred as flow-level dynamic model).

Fig. 2 Two snapshots of a system at different time instances

Next, we consider the following scheduling policy: in each time slot, each AP always serves a user with the maximum channel rate among all its existing users. Thus, we mainly focus on load-balancing algorithm design in this work.

Best Channel First (BCF) Algorithm

Algorithm: Forward each incoming user to the AP with the largest channel rate, break ties uniformly.

- The BCF Algorithm is not *throughput optimal.*

To see it, we consider a system with two APs where users in both APs suffer from independent ON-OFF channel fading, as shown in Fig. 3. The probability that an incoming user joins AP 1 is $(1+p_1-p_2)/2$ and hence the mean arrival rate to AP 1 should be less than $2/(1+p_1-p_2)$ in order to maintain the system stability. However, the maximum allowable arrival rate in this setup is 2. Thus, the BCF algorithm suffers from the throughput loss, as shown in Fig. 4.

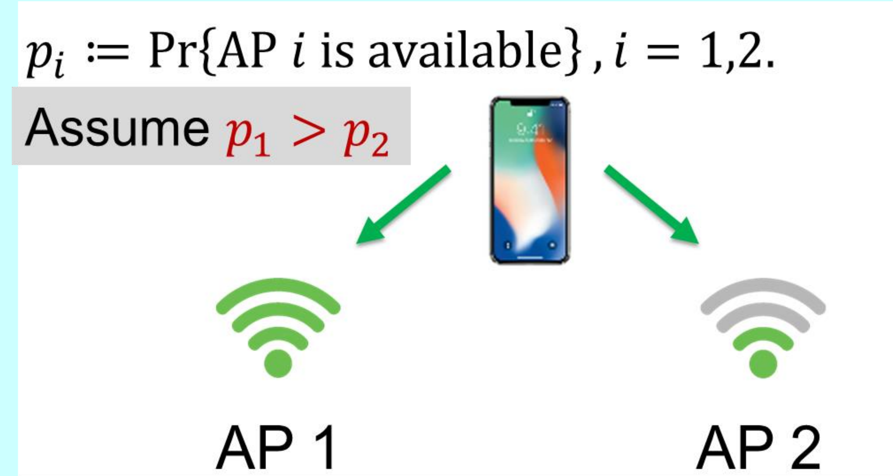

Fig. 3 A two-AP system

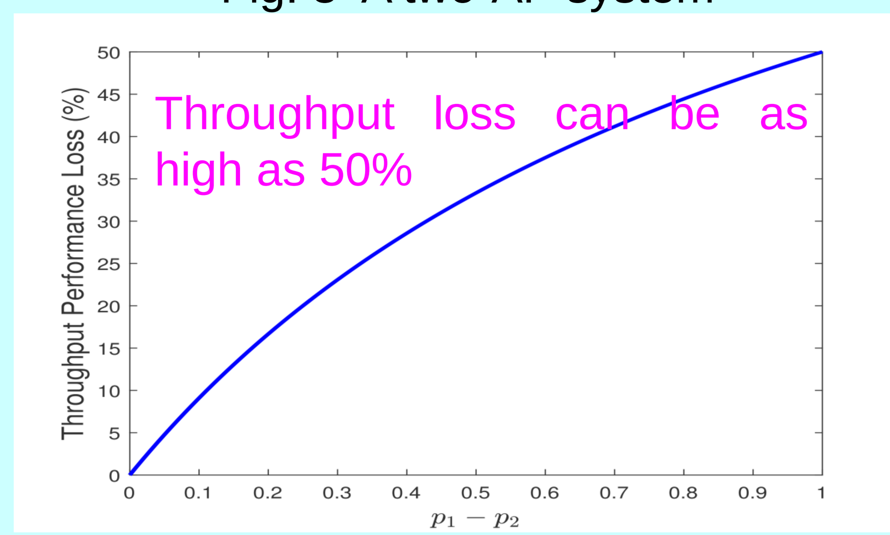

Fig. 4 Throughput performance loss

Randomized Load-Balancing (RLB) Algorithm

Algorithm: Forward each user to each AP uniformly at random.

- The RLB Algorithm is *throughput optimal.*
- However, its system workload (measured by the number of time slots to finish the existing traffic) *scales with the number of APs*, which is strongly undesirable in high-density wireless networks.

Indeed, we calculate the mean workload under the RLB Algorithm in the heavy-traffic regime as follows:

$$\lim_{\epsilon \downarrow 0}(\epsilon \times \text{Mean Total Workload}) = \frac{1}{2}\left(Var(\text{arrivals}) + M(M-1)\right)$$

where ϵ is the heavy-traffic parameter capturing the closeness of the traffic intensity and the capacity region, and M is the number of APs.

However, the theoretical lower bound can be shown as follows:

$$\lim_{\epsilon \downarrow 0}(\epsilon \times \text{Mean Total Workload}) = \frac{1}{2}Var(\text{arrivals})$$

Joint Load-Balancing and Scheduling (JLBS) Algorithm

Algorithm: In each time slot, given the current workload, forward all the arriving users to the AP with the smallest workload.

- The JLBS Algorithm is *throughput optimal.*
- The JLBS Algorithm is *heavy-traffic optimal*, i.e., it achieves the derived lower bound in the heavy-traffic limit.
- Its workload performance *does not degrade as the number of APs increases*, which is desirable in high-density wireless networks.

Main differences from the heavy-traffic analytical framework in [Eryilmaz, Srikant'2012]: (i) The dynamics of the users is short-term; (ii) Each individual user suffers from an independent channel fading.

Simulation Results