# Randomized FIFO Mechanisms

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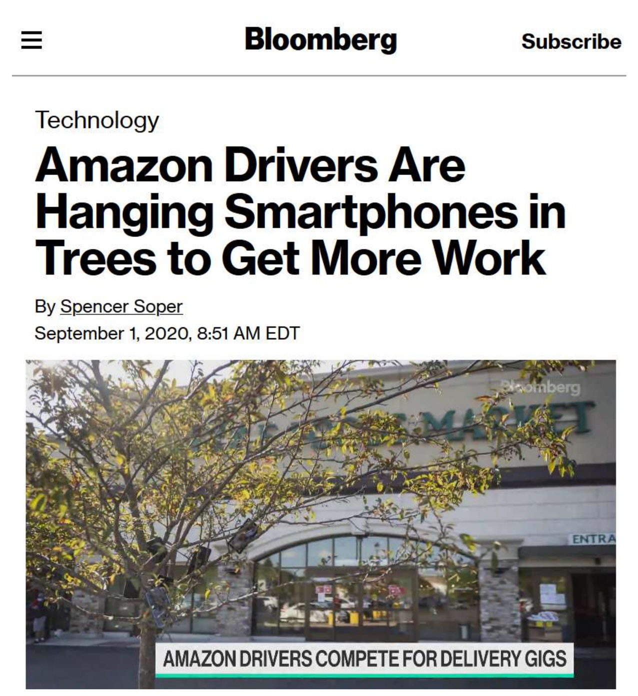
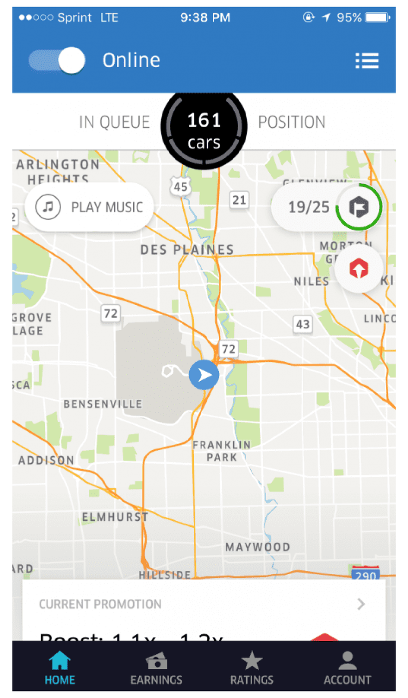
## MATCHING IN TWO-SIDED PLATFORMS

(a) Two-sided platforms



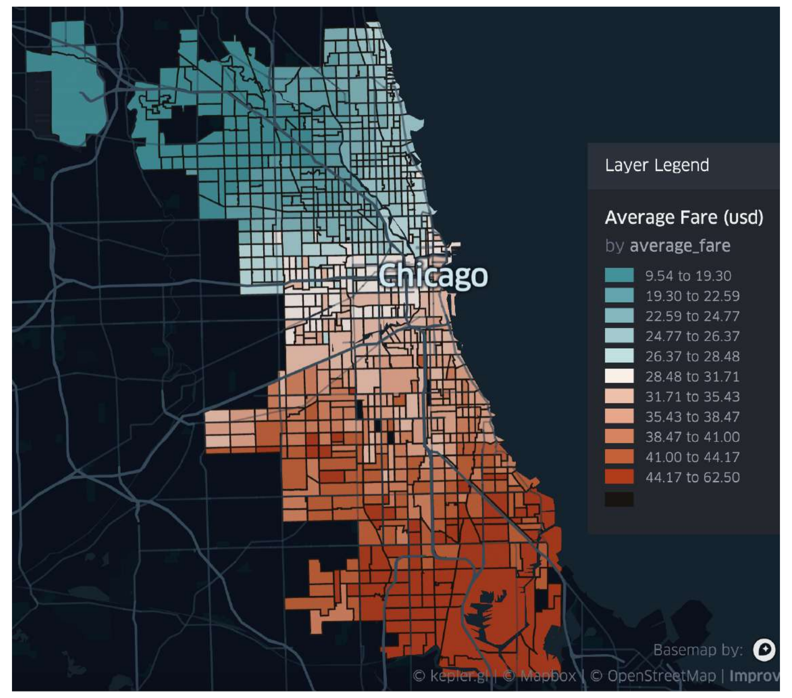

(b) Amazon - assignment to closest drivers



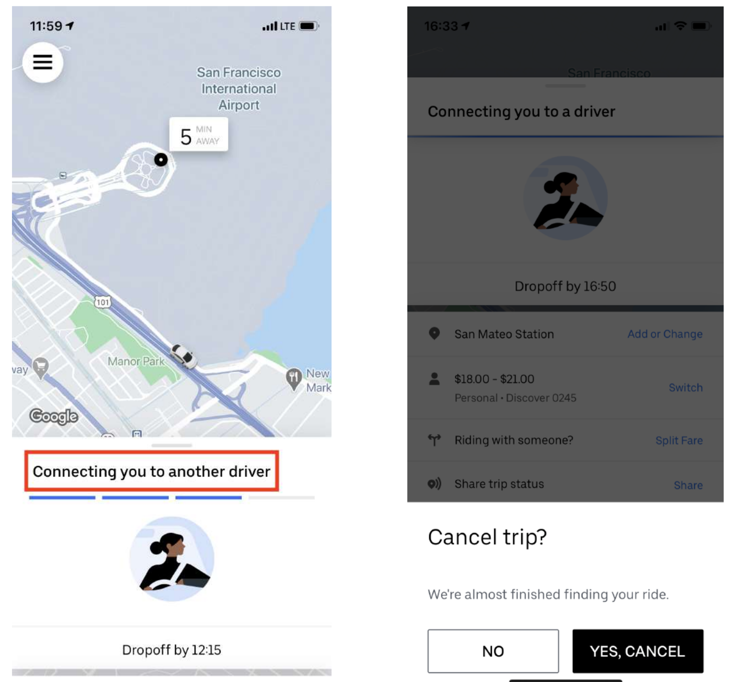

(c) Ridesharing - virtual queues at airports

- Assigning jobs to closest drivers leads to congestion— all drivers try to get closer
- Today's ridesharing platforms (e.g. Uber and Lyft) maintain virtual FIFO (first in first out) queues at airports, for drivers who are waiting in designated areas

## HETEROGENEOUS EARNINGS & IMPATIENT RIDERS




(a) Average fare by destination for trips originating from Chicago O'Hare




(b) Riders cancel trip requests if getting matched takes too long

**Loss of reliability, revenue and trip throughput under FIFO dispatching**

- Heterogeneity in earnings by destination: long trips pay substantially more
- Drivers close to the head of the queue are incentivized to cherry-pick based on destinations, leading to repeated declines for lower-earning trips
- Riders have limited patience: repeated declines by drivers → long waiting time for getting matched to a driver → riders canceling trip requests

**Some trips are necessarily more lucrative than the others**

- Difficult to reduce earnings from long trips due to minimum time/distance rates
- Suboptimal to increase fares of short trips to match the earnings from long trips

**This work:** align incentives and reduce earning inequity using *waiting times*, when we do not have the power to tell drivers what to do, or the full flexibility to set prices

## DYNAMIC DISPATCHING MECHANISMS

**A simple model**

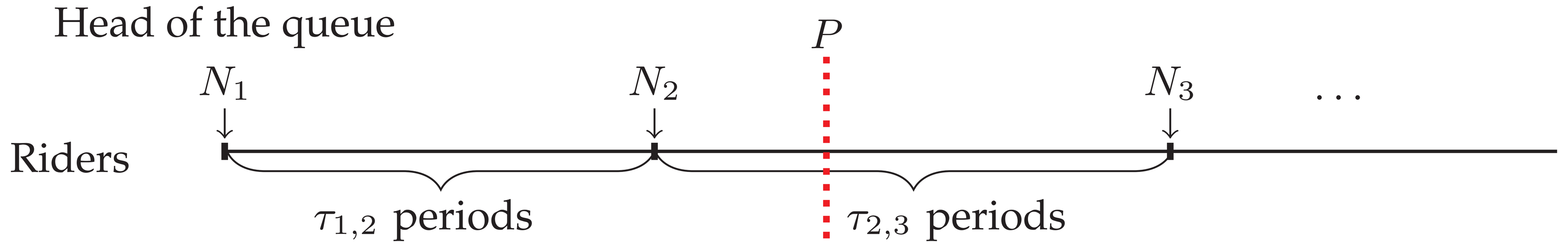
- Continuous time, stationary and non-atomic supply and demand
- Destinations: $\mathcal{L} = \{1, 2, \ldots, L\}$; Arrival rate of riders to destination $i \in \mathcal{L}$: $\mu_i$
- Riders' patience level: $P$— a rider will cancel trip request after $P$ driver declines
- Arrival rate of drivers: $\lambda$; Opportunity cost of driver's time: $c$
- Net earnings from a trip to location $i \in \mathcal{L}$: $w_i$. Assume $w_1 > w_2 \cdots > w_L > 0$

**Transparency and flexibility**

- Drivers know the supply, demand, queue length, their positions in the queue.
- Drivers may freely decline trip dispatches based on trip destination and earnings, or at any time leave the queue, or re-join the queue at the tail.

**Goal:** optimize platform's net revenue (total driver earnings minus waiting costs) and trip throughput in equilibrium.

## EQUILIBRIUM OUTCOME UNDER STRICT FIFO




- Driver at the head of the queue: accept only trips to location 1 (i.e. highest earning trips). First position in the queue willing to accept location 1 trips: $N_1 = 0$.
- In comparison to location 2, a driver is willing to wait for an additional $\tau_{1,2}$ periods for a trip to location 1. We know $w_1 - \tau_{1,2}c = w_2 \Rightarrow \tau_{1,2} = (w_1 - w_2)/c$.
- Little's Law ⇒ first position willing to accept location 2 trips $N_2 = \tau_{1,2}\mu_1$. Can similarly find the first position $N_i$ where driver is willing to go to location $i \geq 3$.
- With rider patience level $P$, a location 3 trip (offered to drivers starting from the head of the queue under strict FIFO) is canceled by the rider after $P$ declines.
- All trips to location $i$ with $N_i > P$ are *unfulfilled*— poor revenue and throughput.

## THE DIRECT FIFO MECHANISM

**Direct FIFO.** Dispatch location $i$ trips starting from the $N_i^{\text{th}}$ position in the queue.

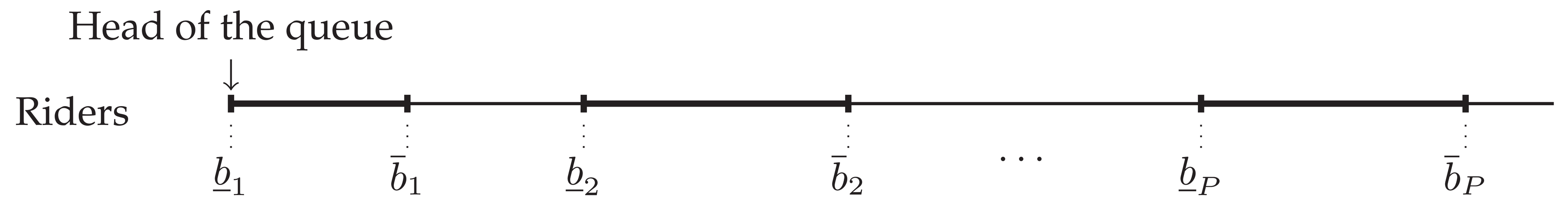
**Theorem.**

- It is a subgame-perfect equilibrium (SPE) for drivers to accept all dispatches from direct FIFO. The equilibrium outcome is ex-post envy-free.
- The mechanism achieves in SPE the *second best*, i.e. the highest achievable revenue and trip throughput when drivers are strategic.

**Discussion.**

- The option to skip the rest of the line incentivizes drivers further from the head of the queue to accept lower earning trips.
- Direct FIFO is ill fitted for practice, since drivers close to the head of the queue are not eligible for dispatch for most trips, and this may be considered unfair.

## THE RANDOMIZED FIFO MECHANISM




**A randomized FIFO mechanism** is specified by $P$ "bins". A trip is first dispatched to a driver in the first bin $[\underline{b}_1, \bar{b}_1]$ uniformly at random. If declined for $k^{\text{th}} - 1$ times, then for the $k^{\text{th}}$ time a trip request is dispatched, select a random driver from $[\underline{b}_k, \bar{b}_k]$.

**Theorem.** Randomized FIFO achieves the second best in Nash equilibrium.

**Discussion.**

- When drivers are straightforward, drivers closer to the head of the queue are prioritized for trips to any destination— fair, and robust to idiosyncratic preferences
- Randomization increases the waiting times for the next dispatch (vs the driver at the head of the queue under strict FIFO), raising the costs of cherry-picking
- Drivers who have waited longer in the queue (i.e. in earlier bins) will accept higher earning trips → small variance/uncertainty in drivers' net payoffs

## SIMULATION RESULTS

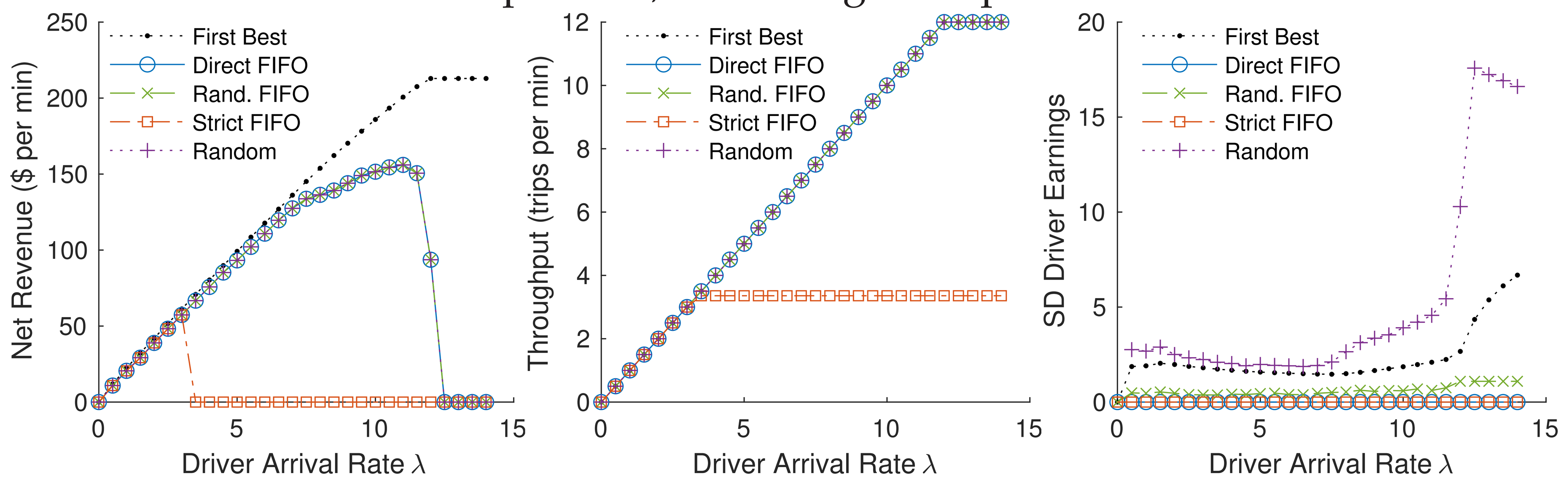
**Data from the City of Chicago**

- Ridesharing trips originating from Chicago O'Hare, Nov. 2018 - Mar. 2020
- A total of around 800 destinations (census tracts in Chicago)

**The *first best*.** Drivers are dispatched upon arrival to locations in dec. order of $w_i$.

**Varying arrival rate of drivers $\lambda$**

Total rider arrival rate: 12 per min; Assuming rider patience $P$ = 12




**Varying rider patience level $P$**

Fixing rider arrival rate at 12 per min, and driver arrival rate at 10 per min