The problem

- Traffic congestion responsible for **20% of fuel consumption** and **90% of CO** in large urban areas.
- Cost of traffic congestion will reach **$2.8T** in the US by 2030 (≈ annual tax revenue).
- On a per-driver basis, cost of traffic congestion is **$1740** annually in US/Europe.
- Boston recently made news being declared **#1** in hours lost in rush-hour traffic per driver in 2018.
Congestion Maps for the Boston Area: 2012→2015


(Salo Wollenstein)

3/10 Yannis Paschalidis, Boston University Beyond Congestion: Maps
Transportation Network Models

- **Transportation** network modeled as a graph.

- **Dynamics**: Drivers have a congestion function function of flow for each arc and pick the cheapest arcs to traverse. Collective decisions lead to a Nash (Wardrop) equilibrium.

- To control/design we need to build accurate predictive models.

- Data: Traffic flows.

- Can we learn (the congestion function) from data?
Price of Anarchy\textsuperscript{1}

- Having the congestion function allows us to answer many “what-if-questions”.
- We can also formulate a problem to obtain a socially optimal equilibrium.
- Price-of-Anarchy:

$$\text{PoA} = \frac{\text{Congestion under Selfish Behavior}}{\text{Congestion under Socially Optimal Behavior}}$$

- Useful to assess how good/bad things are, but also to design interventions.

\textsuperscript{1}Zhang, Pourazarm, Cassandras, Paschalidis, CDC 2016, IFAC 2017, Proceedings IEEE 2018.
Boston Area Data\(^2\)

Eastern Massachusetts (EMA) Network

- **Spatial average speeds** for 13,000 road segments for each minute of 2012 (50 GB) and 2015 (130 GB).
- **Capacity data** in different times-of-day: lanes, peak vehicles counts, etc.

Price-of-Anarchy (2012)
Road Congestion: Socially Optimal vs. User Optimal

“Spreading the traffic” results in:

![Graph showing congestion metrics for user-centric and system-centric models. The x-axis represents link indices, and the y-axis represents congestion metric (PM period of 4/18/2012). The graph compares the performance of user-centric and system-centric models, highlighting differences in congestion levels across various links.]
Control and Interventions

1. **Sensitivities:** Where to intervene?
2. **Socially optimal route recommendations:** Can be shown that we can achieve the *Socially Optimal* solution through *User Optimal* actions if users use a properly modified congestion function!
   - Easier to incorporate in apps, even enforce with autonomous vehicles.
   - Take the driver “out of the picture.”
3. **Change demand!** Congestion pricing and incentives!
Final remarks

- We have developed a new general framework for modeling driver behavior using data.

- Policy space: How to address traffic allocation issues and prevent NIMBY reactions?