Selecting Compliant Users for Opt-in Microtolling

Josiah Hanna[1], Guni Sharon[2], Stephen Boyles[1], and Peter Stone[1]

1. University of Texas at Austin
2. Texas A&M University

Micro-tolling

In the U.S., traffic congestion costs were estimated at $305 billion during 2018 [Citylab 2018].

Q: Can selfish drivers be incentivized to act socially?
A: Yes! By imposing tolls [1].

Q: Does the system optimum require that all drivers respond to tolls?
A: No! Influencing a specific subset of the drivers (~50%) is usually sufficient [2].

Our Question:

What if the subset of influenced drivers is limited in size?

Motivation

Tolling is unpopular! [3]

Our solution: Optional participation in a tolling scheme.

Opt-in Microtolling

Some drivers are charged tolls and others are not.

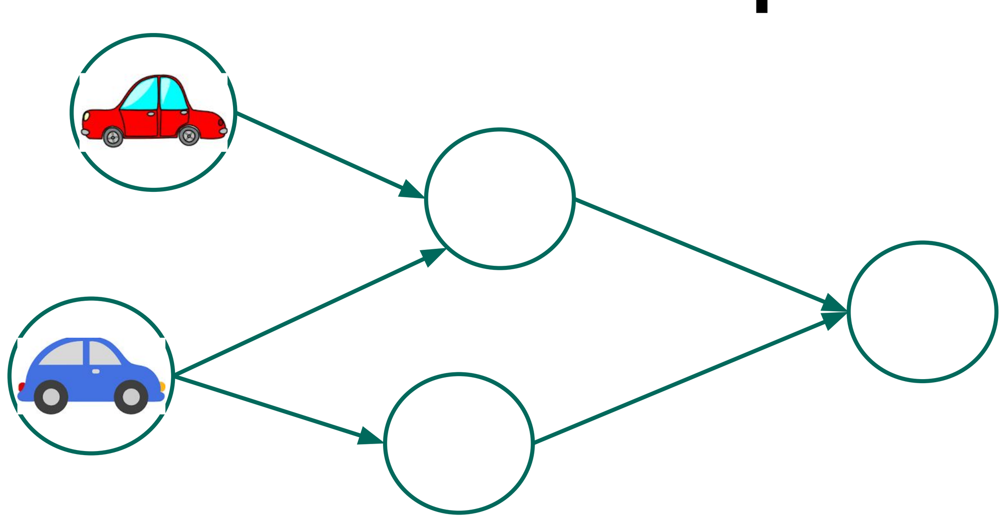
- Charged tolls = compliant agents
- Not charged tolls = non-compliant agents

All drivers can take any link in the road network.

Rational agents would need to be incentivized up front to join system:

- Not the focus of this paper.

It matters who is compliant!



- Red car has a single path to destination.
- Blue car has two paths to choose from.
- If the red car is compliant it has no effect.

What limited subset of agents should we incentivize to comply to achieve the largest improvement in social welfare?

Determining the Compliant Subset

1. Estimate the benefit of making a particular agent compliant instead of non-compliant.
2. Greedily select the agent's with the highest predicted benefit if compliant.

Determining "benefit of compliance"

The benefit of agent a being compliant:

$$h^*(a) = m_l - m_g + (l_l - l_g)\, v_a$$

Where:

- m_l is the marginal impact of a if non-compliant.
- m_g is the marginal impact of a if compliant.
- l_l is the latency suffered by a if non-compliant.
- l_g is the latency suffered by a if compliant.
- v_a is agent a's value of time.

Marginal impact is unknown in practice.

We approximate h* with the **difference in marginal cost path** heuristic:

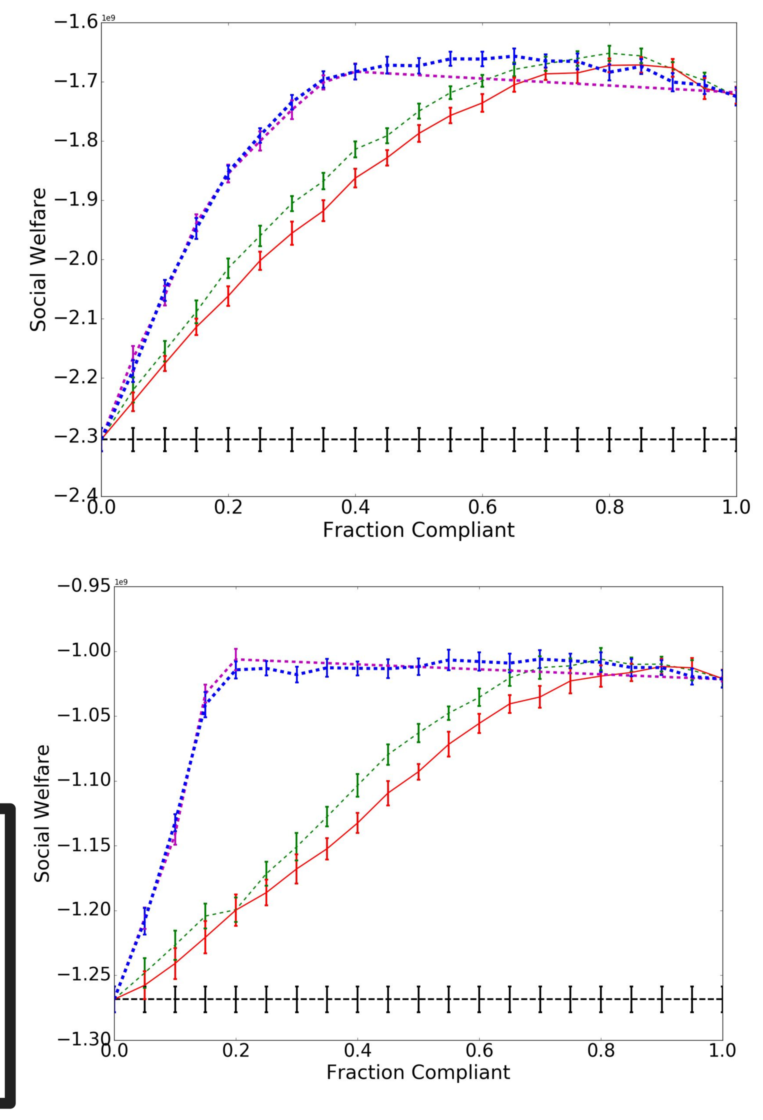
$$\text{DMCP}(a) = \tau_l - \tau_g + (l_l - l_g)\, v_a$$

Where:

- τ_l is the approximated marginal cost toll paid by a if non-compliant.
- τ_g is the approximated marginal cost toll paid by a if compliant.

Experimental Results:

1. Use Δ-Tolling to approximate marginal-cost toll [4] for DMCP.
2. Evaluate on three traffic scenarios (two shown).
3. Compare to other agent selection mechanisms.
   a. TE: Use negative of agent's value of time to approximate h*.
   b. RANDOM: Random assignment.



DMCP and DMCP+TE achieve near optimal performance with less than 50% of agents compliant!

[1] **The Economics of Welfare.** A. Pigou. Macmillan and Co. 1920.
[2] **Traffic Optimization For a Mixture of Self-interested and Compliant Agents.** Sharon et al. 2018.
[3] **New York City's congestion pricing experience and implications for road pricing acceptance in the United States.** B. Schaller. 2010.
[4] **Network-wide Adaptive Tolling for Connected and Automated vehicles.** Sharon et al. 2017.