Incentives in Ridesharing with Deficit Control

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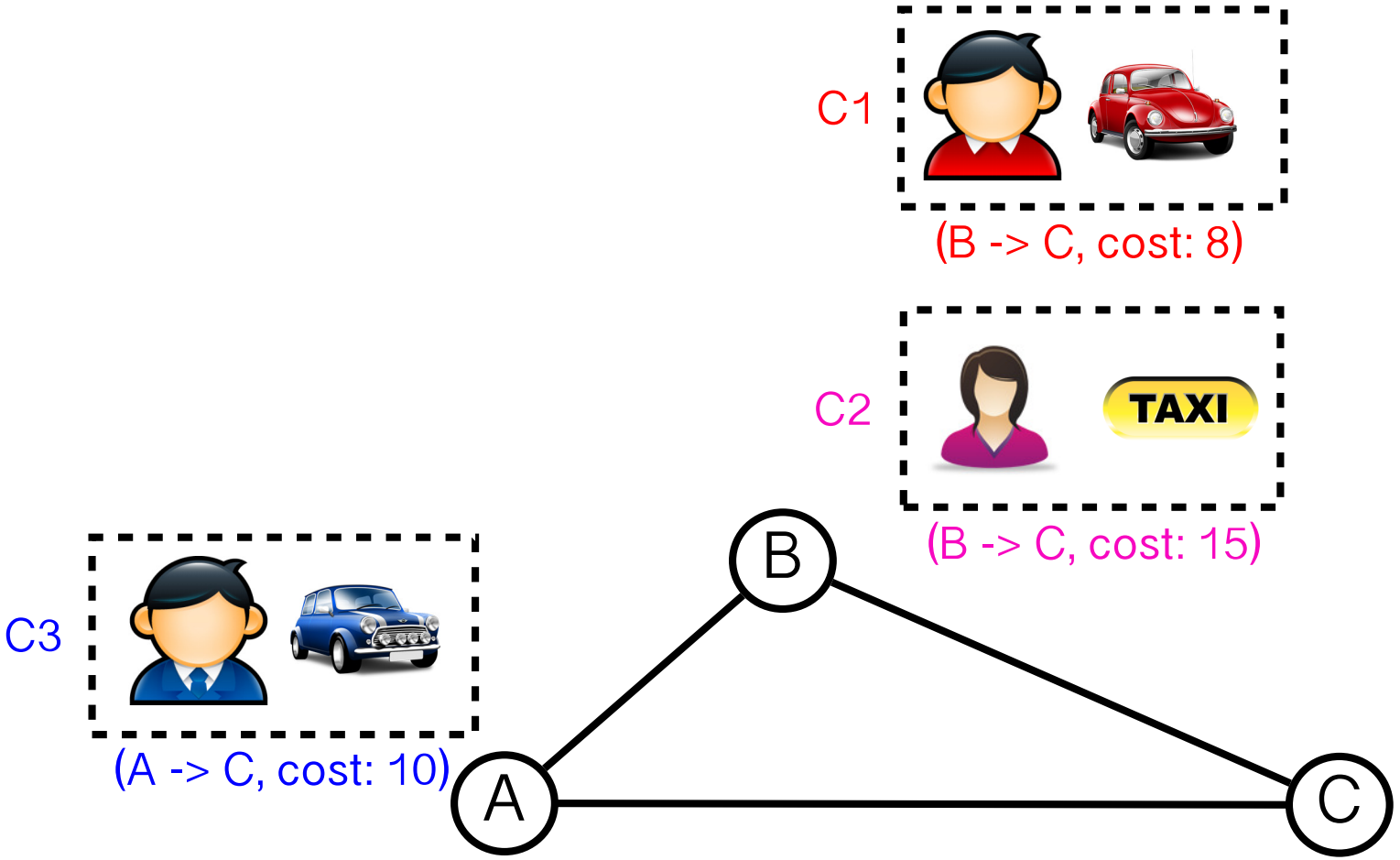
Ridesharing Example



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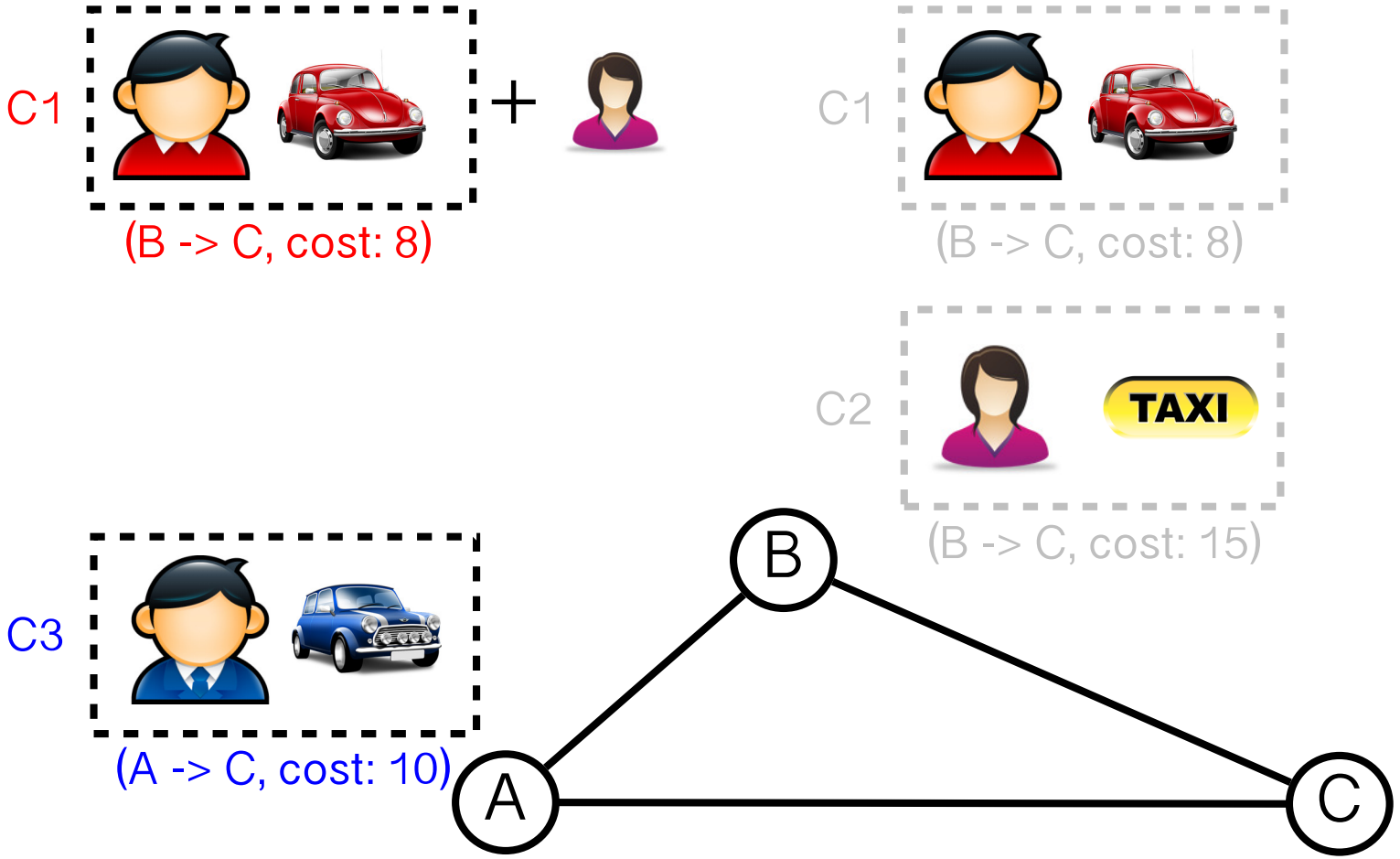

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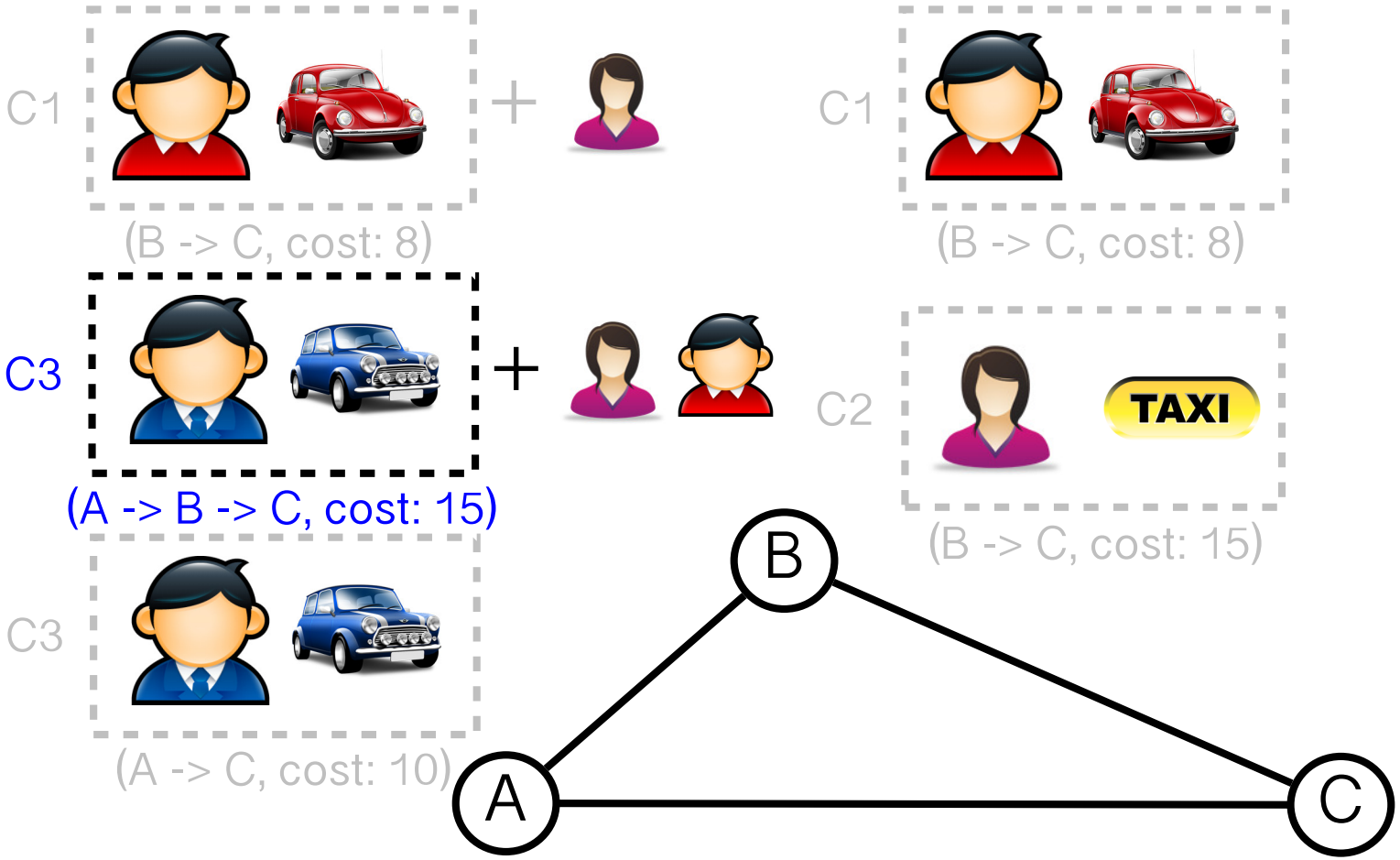

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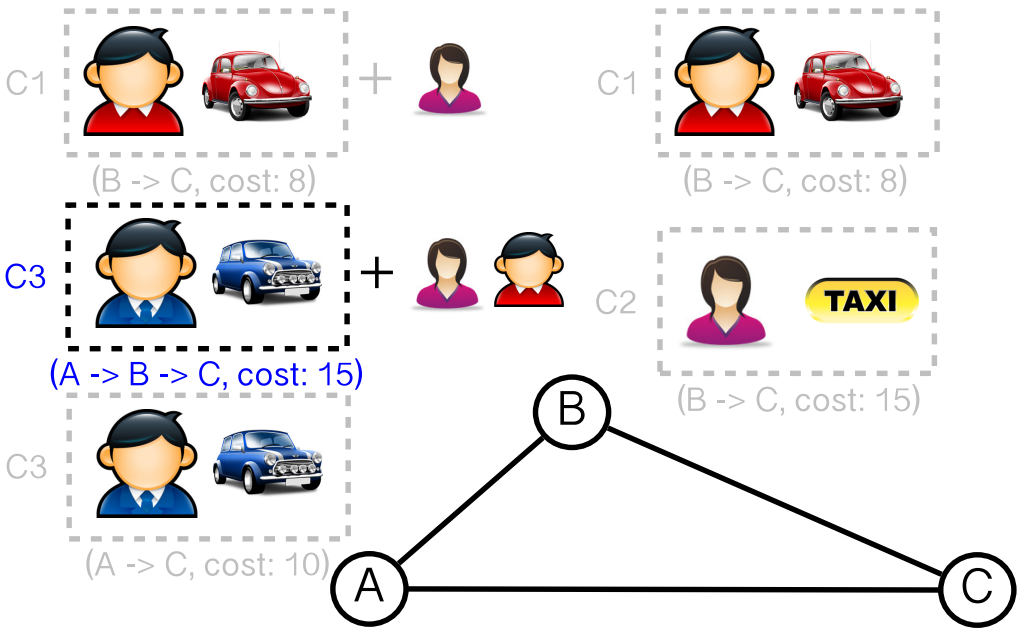


Questions:

- How to arrange the sharing?
- How much should they pay/receive?

History

- Began in the 1940s in North America
- Been promoted because of
  - fuel shortages, air pollution and traffic congestion
- Peaked in the US in 1970 with a commute mode share of 20.4%

Public and Private Promotions

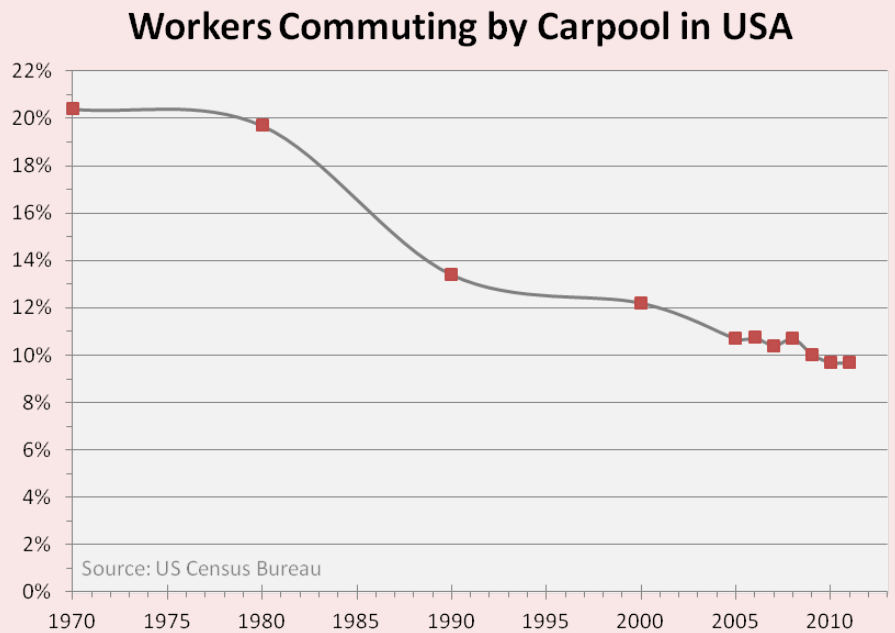
zimride
share the ride

BlaBlaCar

carpooling.com
CLICK. RIDE. SAVE.

People are still NOT well motivated!

not going well...



- Australia (Queensland) will end ridesharing lanes
- The average car carries just 1.6 people

What are the obstacles?

- Safety and Privacy
- Flexibility and Reliability
- ...

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- Flexibility and Reliability
- ...
- Complicated join procedures
- No free market competition!

What we can do?

Use Mechanism Design to build ridesharing:

- Automated ride matching
- Automated (profitable) price setting

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to answer...

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Outline

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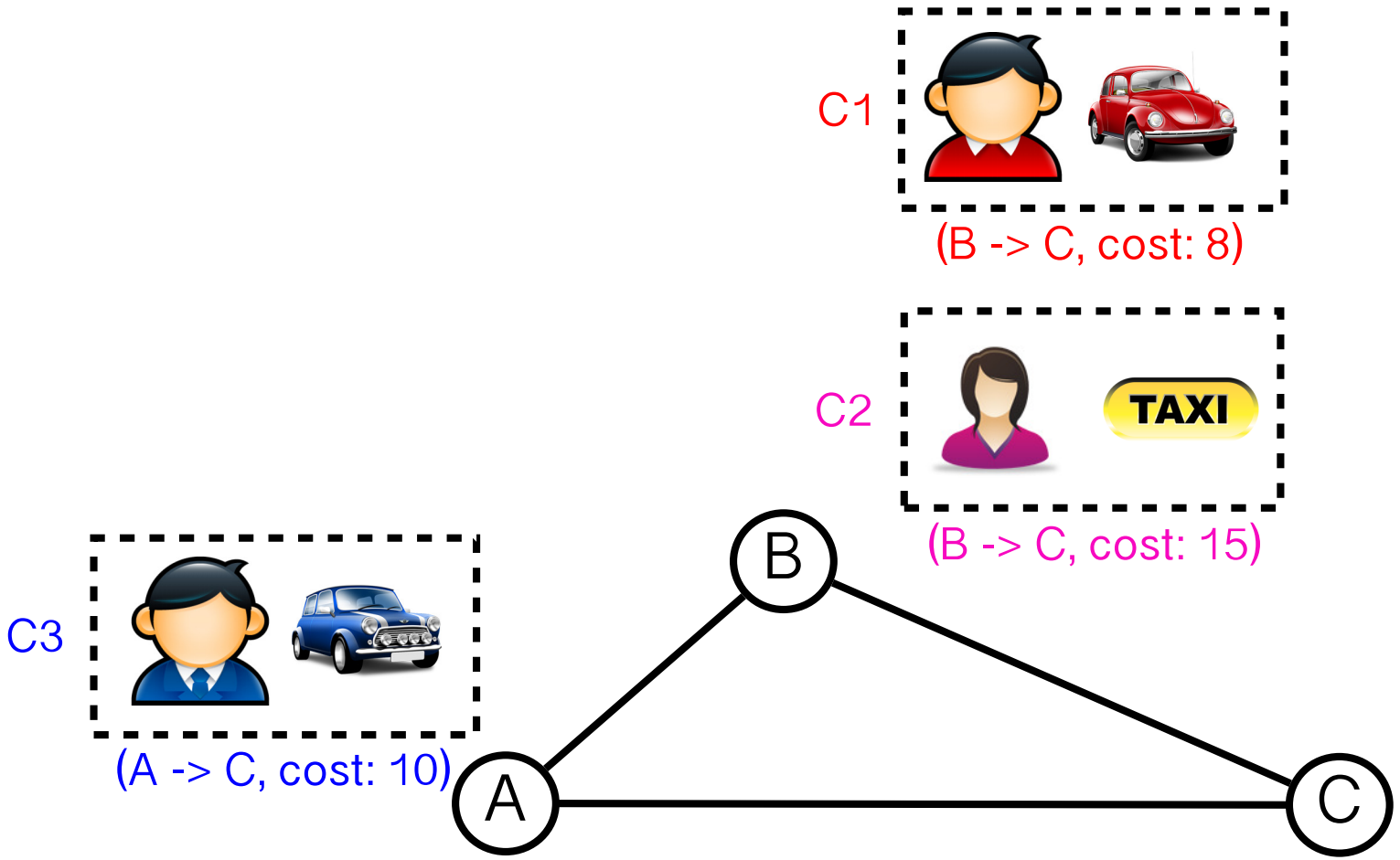
System Overview



System Overview

- Route map: a graph $G = (L, E)$,
  - L: stopping points/locations,
  - E: routes between stopping points,
  - $w(e)$: time required to travel via route $e \in E$.
- i's trip type: $\theta_i = (l_i^d, l_i^a, t_i^d, t_i^a, c_i, q_i)$
  - $l_i^d, l_i^a \in L$: departure and arrival locations,
  - t_i^d, t_i^a: earliest departure and latest arrival time,
  - $c_i \in \mathbb{R}^+$: travel cost to finish the trip,
  - $q_i \in \mathbb{N}$: extra seats available on the trip.

System Overview

- Allocation/Scheduling:
  - driver: drives and takes riders
  - rider: shares with drivers
  - unmatched: goes with his original preference
- Payments:
  - driver: receives money
  - rider: pays money
  - unmatched: no payment

The Goal of the System

- Minimize the total travel costs (efficiency)
- Incentivize participation and against manipulations
  - Agents never receive negative utility (individual rationality)
  - Truthfully report their trip information is a dominant strategy (truthfulness)
- Control deficit (budget balance)
  - The system owner should not lose too much money

Solution: Applying VCG Mechanism

- Efficient (cost minimizing)
- Individually rational
- Truthful
- High deficit (m times of the cost saved!)

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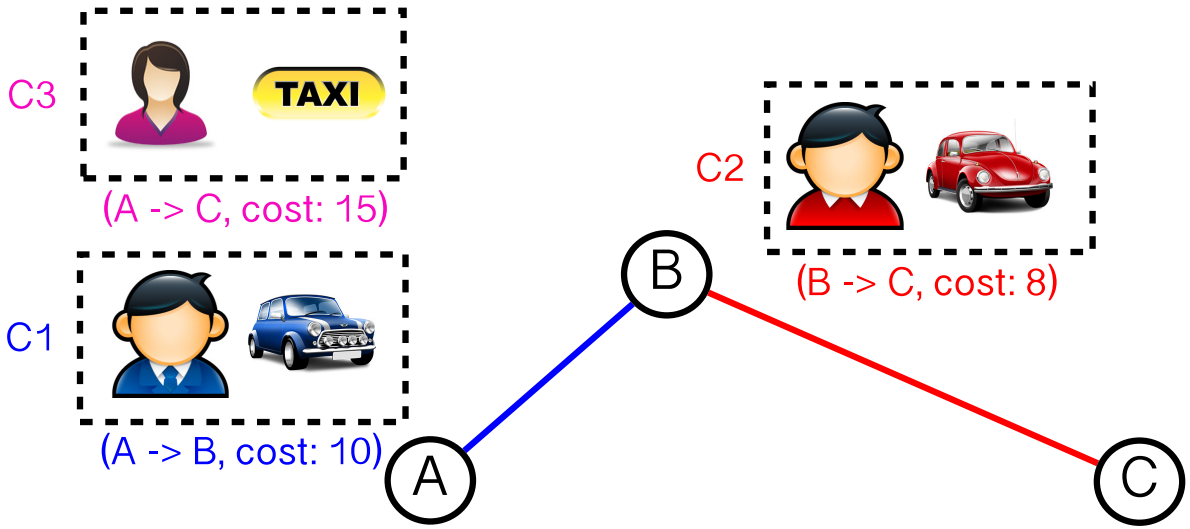

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- Individually rational
- Truthful
- High deficit (m times of the cost saved!)

Question

How to control deficit?

Our Solutions (Overview)

We propose...

Fixed-price Mechanisms :

- Flexible deficit control (outperforms VCG)
- Truthful and individually rational
- Very inefficient

VCG with Reserve Prices :

- Flexible deficit control (outperforms VCG)
- (Partially) truthful and individually rational
- Flexible efficiency control

Outline

Fixed Payments $x^{fixed}(p^0, p^1)$

Given predefined values $p^0 \geq 0$ (for riders) and $p^1 \leq 0$ (for drivers), fixed payments are defined

- Allocation independent
- Allocation dependent
  - location dependent (shortest path)
  - detour dependent
  - sharing dependent
  - ...

Dictatorship Mechanism

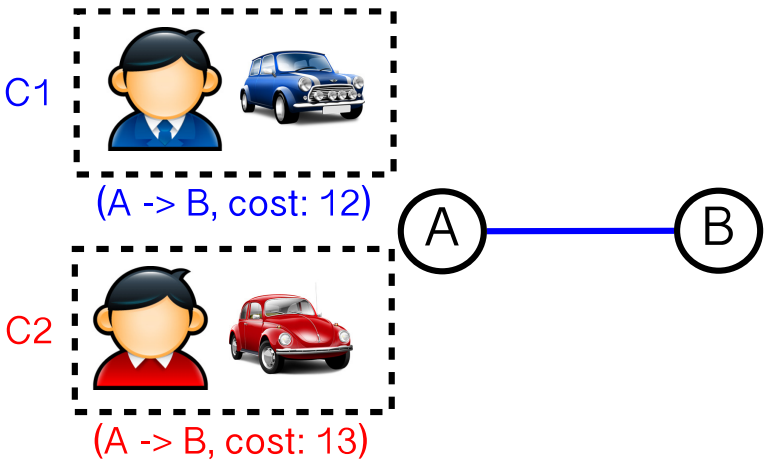
Serial Dictatorship Mechanism with fixed payments

1. Predefine the set of (potential) drivers and riders
2. Order potential drivers and riders
3. Maximize drivers' utility according to the order
4. Each driver/rider gets the fixed payment

Properties

- truthful and individually rational
- better deficit control than VCG
- very inefficient

Problems of Non-dictatorship Mechanisms



Case I:

- fixedPay = 10
- both prefer drive
- potential problem for deterministic mechanisms

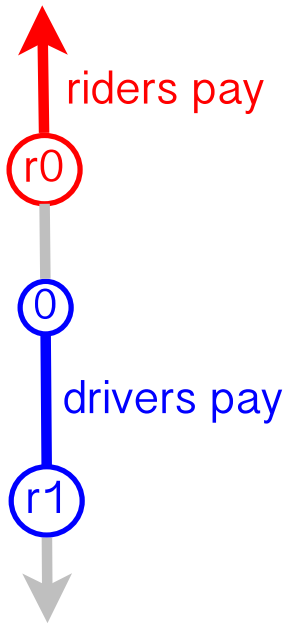
Case II:

- fixedPay = 1
- both prefer ride
- potential problem for all mechanisms

Outline

VCG with Two-Sided Reserve Prices $\mathcal{M}^{VCG}(r^0, r^1)$

Predefined reserve prices $r^0 \geq 0$ (for riders) and $r^1 \leq 0$ (for drivers),

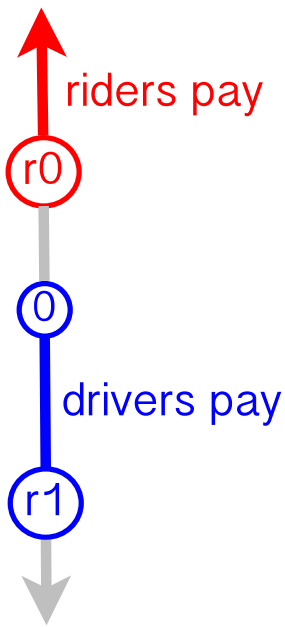


Note: r_0 and r_1 can be allocation dependent.

Properties of $\mathcal{M}^{VCG}(r^0, r^1)$

$\mathcal{M}^{VCG}(r^0, r^1)$ is

- truthful iff $r^0 \geq -r^1$. Otherwise, the manipulation gain is bounded ($\max(-r^1 - r^0, \delta_i^{max}(-r^1 - r^0))$).
- weakly budget balanced without detour. Otherwise, deficit is bounded ($-n_d \delta^{max} r^1 - n_r r^0$).
- more efficient as $r^0 + r^1$ decreases.



Outline

What is NEW?

- The first comprehensive ridesharing model studied from a pure game-theoretic point of view.
- Auction-based ridesharing system incentivizing participation.
- Flexible deficit control rather than completely remove deficit.

Future Work

- Tradeoff between deficit and efficiency (theoretically or simulations).
- The problem of finding optimal schedules is computationally hard (optimal in range).
- Allow agents to submit trips dynamically over time (online mechanism design).