CS243: Introduction to Algorithmic Game Theory

Week 9.3 Double Auctions/Exchanges (Dengji ZHAO)

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Simple Bilateral Trade

Bilateral trade:

- One buyer and one seller trade one item.
- The seller's valuation is v_s and the buyer's valuation is v_b.
- The possible allocations are {Trade, NoTrade}.

Applying VCG:

- If $v_b \leq v_s$, NoTrade
- if $v_b > v_s$, Trade, and the payment for the buyer is v_s and the payment for the seller is $-v_b$ (there is a deficit for the market owner).

Myerson and Satterthwaite's Impossibility Theorem

Theorem (Myerson and Satterthwaite, 1983)

In bilateral tradings/double auctions, there does not exist a mechanism that is truthful, efficient, individually rational without outside subsidies (budget balanced).

Deficit Control

- reduce efficiency (trade reduction).
- ...

A Classical Double Auction Setting

- A set of buyers B and a set of sellers S, $B \cap S = \emptyset$.
- Each seller sells one unit of one commodity and each buyers wants to buy one unit of the commodity.
- Each seller/buyer i's valuation for the item is v_i, i.e. v_i is the minimum price to sell or the maximum price to buy.

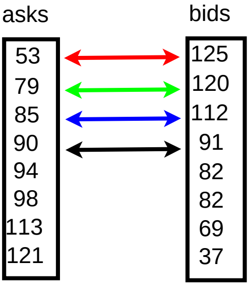
Question

How to find an efficient allocation in the above setting?

Efficient Allocation

- Each buyer/seller reports her valuation (bid/ask) to the market.
- The market finds the efficient allocation as the following:

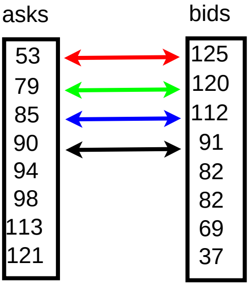
The Application of VCG



Under VCG:

- What is the payment for each buyer?
- What is the payment for each seller?

The Application of VCG



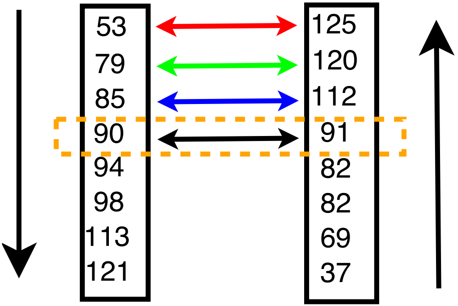
Under VCG:

- What is the payment for each buyer? 90
- What is the payment for each seller? -91

There is a deficit of 4 for the market owner!

McAfee's Trade Reduction (1992)

- Remove one buyer-seller pair with the least social welfare increase from the efficient allocation.
- Use the removed buyer/seller's valuation to set the payments for the remaining matched buyers/sellers.



VCG payments:

- sellers: -91
- buyers: 90

Deficit: 4

McAfee's payments:

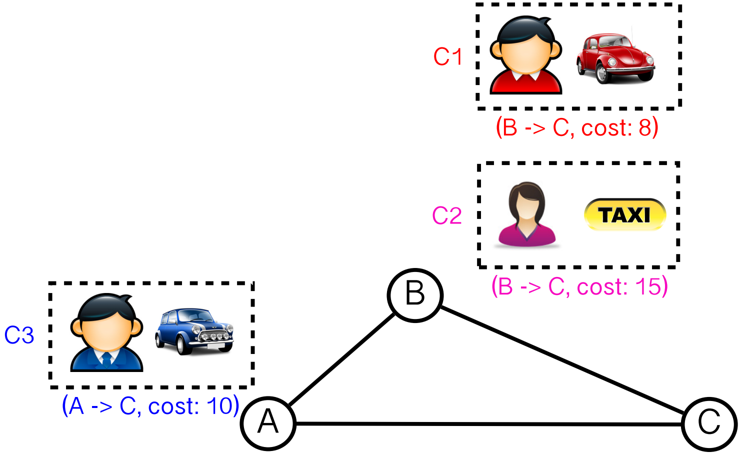
- sellers: -90
- buyers: 91

No deficit!

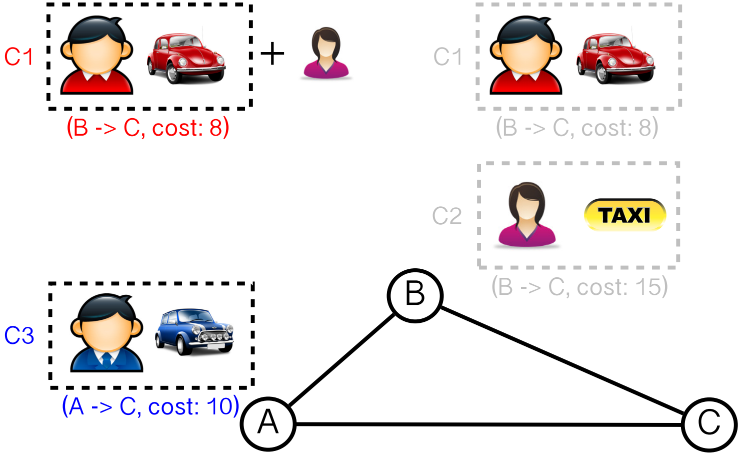
Model a Carsharing as a Double Auction

- How to model a carsharing as a double auction?

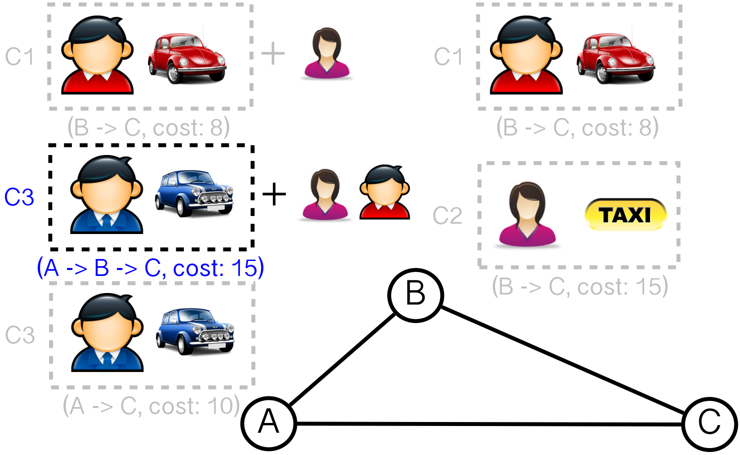
Carsharing Example



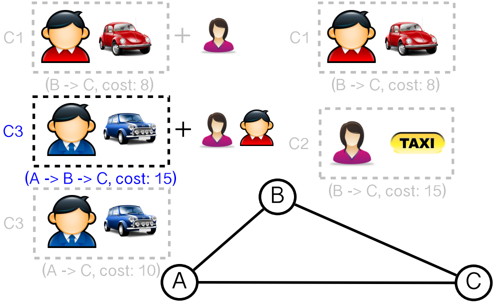
Carsharing Example



Carsharing Example



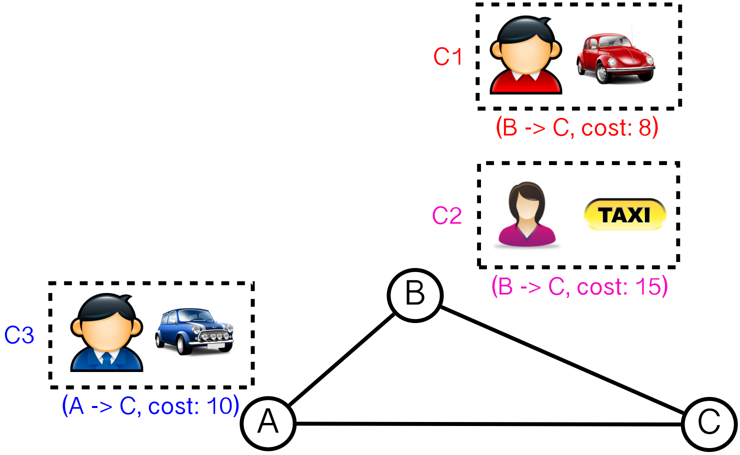
Carsharing Example



Questions:

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

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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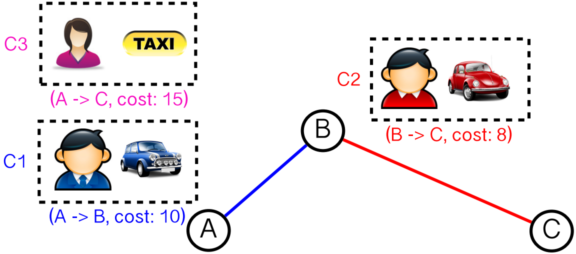


Solution: Applying VCG Mechanism

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

Question

How to control deficit?

Our Solutions (Zhao et al. AAMAS 2014)

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

A Simplified Version of Carsharing: Dual-Role Exchanges

Dual-role examples:

- people with cars can both drive and ride,
- electric vehicles can be charged and discharged,

▶ <u>but not at the same time.</u>

The model:

- a set of traders exchanging one kind of commodity.
- each trader has two valuations (v_i^b, v_i^s) for buying and selling respectively.

The mechanism:

- who is going to buy/sell
- how much they pay/receive
- *goals*: efficient, IC, IR, **non-deficit**

Balanced Trade Reduction (Zhao et al. AAAI 2015)

VCG:

- efficient, IC and IR, but runs a huge deficit
- $v_i^b - x_i^{vcg} \geq v_i^s - \hat{x}_i^{vcg}$ (if i is allocated to buy)

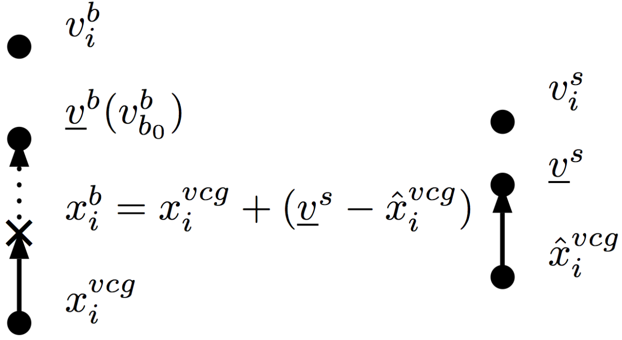
McAfee's Trade Reduction [McAfee, 1992]:

- remove one pair from VCG, increase payments
- $v_i^b - (x_i^{vcg} + \delta_1) \ngeq v_i^s - (\hat{x}_i^{vcg} + \delta_2)$, where $\delta_1 \neq \delta_2$
- not efficient, not IC

Our solution: Balanced Trade Reduction

- remove $k \geq 1$ pairs, balance the payment increases
- $v_i^b - (x_i^{vcg} + \delta) \geq v_i^s - (\hat{x}_i^{vcg} + \delta)$, where $\delta = \min(\delta_1, \delta_2)$
- not efficient, IC, deficit control, requires k "backups"

Balanced Trade Reduction (Zhao et al. AAAI 2015)



$$\text{VCG}: v_i^b - x_i^{vcg} \geq v_i^s - \hat{x}_i^{vcg}$$

$$\mathcal{M}^{btr}: v_i^b - (x_i^{vcg} + \delta) \geq v_i^s - (\hat{x}_i^{vcg} + \delta)$$

Advanced Reading

- Myerson, R. B., and Satterthwaite, M. A. 1983. *Efficient mechanisms for bilateral trading*. Journal of Economic Theory 29(2):265–281.
- Dengji Zhao, Dongmo Zhang, Enrico Gerding, Yuko Sakurai, Makoto Yokoo: *Incentives in Ridesharing with Deficit Control*. AAMAS 2014.
- Dengji Zhao, Sarvapali Ramchurn, Enrico Gerding, Nick Jennings: *Balanced Trade Reduction for Dual-Role Exchange Markets*. AAAI 2015.