Beyond Nash Equilibrium: Mechanism Design with Thresholding Agents

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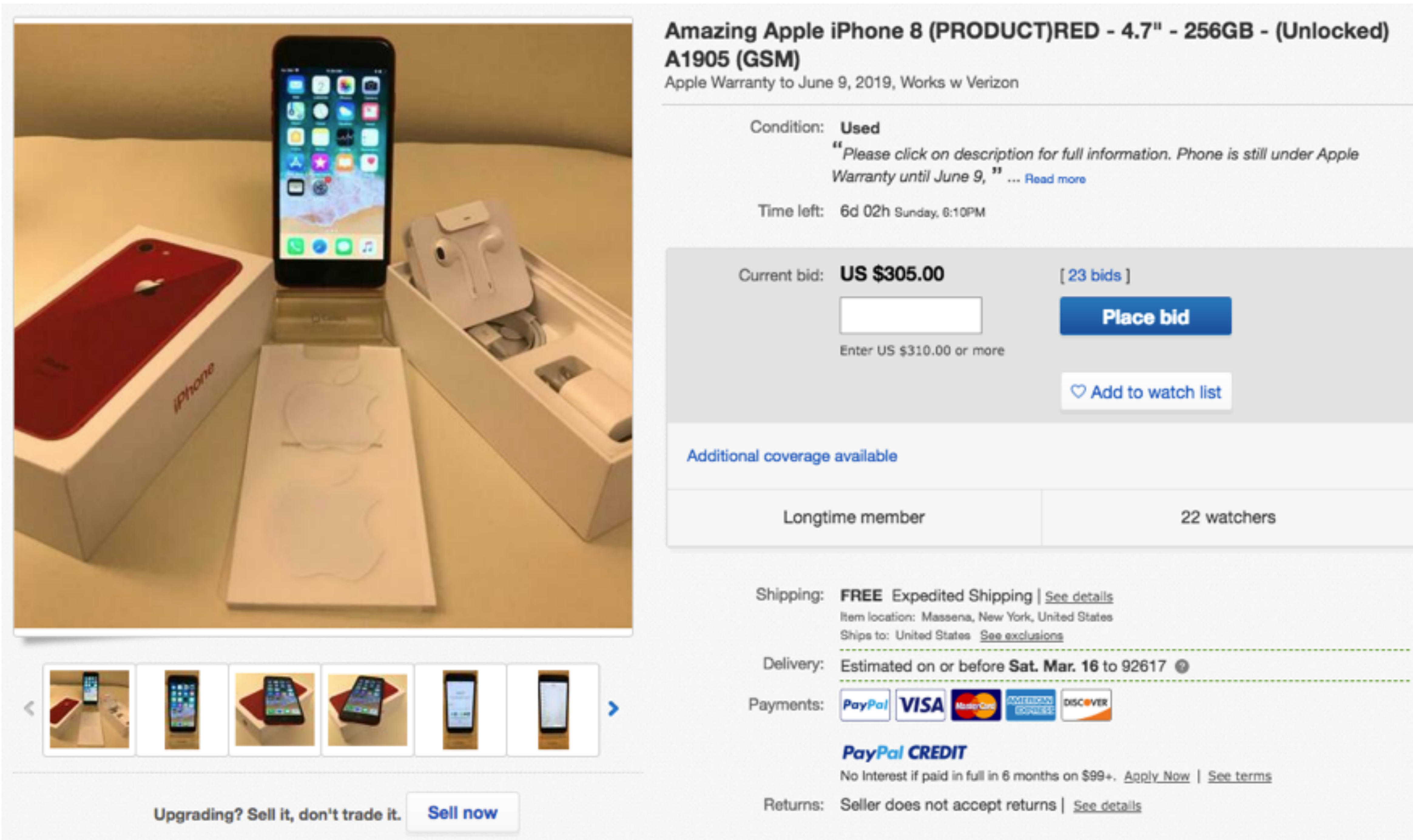
Conflicts I: Selling Products



Seller VS Buyers

Credit: eBay

Conflicts II: Transportation Systems

Credit: Artsy

Transportation Authority VS Individual Commuters

Conflicts III: Open Source Software Development

Credit: linkedin

Contributors VS Non-Contributors

Conflicts and Agent-Based Modeling

- **Agents**
  - **Autonomy**
    — individuals are not centrally governed
  - **Heterogeneity**
    —individuals have different interests
  - **Local views**
    —no individual has a full global view (e.g., due to system complexity)

    (Wooldridge 02)
- **Stakeholder**
  - **Goal**
    — influencing agents' behavior to achieve desirable outcomes (e.g., smooth traffic)
  - **Methods**
    —incentives, information, regulations (e.g., laws) (Shen et al. HAI'17)

OCTA

Metro

Los Angeles County Metropolitan Transportation Authority (Metro)

Credit: LATimes

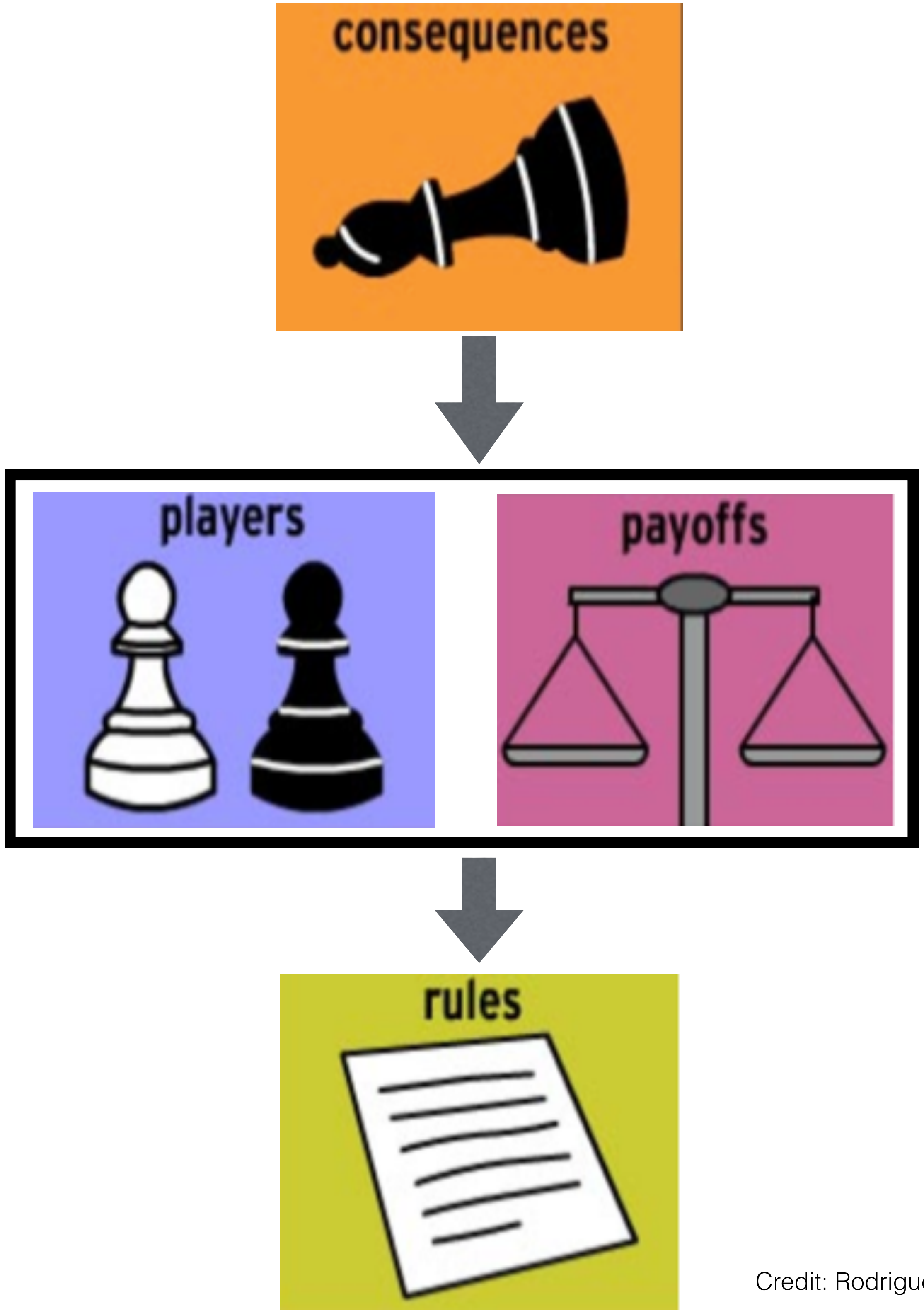
Outline

- **Background**
- Mechanism Design with Thresholding Agents
- Case Study I: Information Design for Crowdfunding
- Case Study II: Post-Price Mechanism for Ridesharing
- Case Study III: Contest Mechanism for Countering Manipulations
- Conclusions, Future Directions and Timeline

Mechanism Design

- **Mechanism design**
    - Reverse game theory
- **Goal**
    - Compute the rules that influence agents' behavior so that desirable outcomes can be achieved

(Nisan Algo. Game Theory '07)



Credit: Rodriguez

How It Works

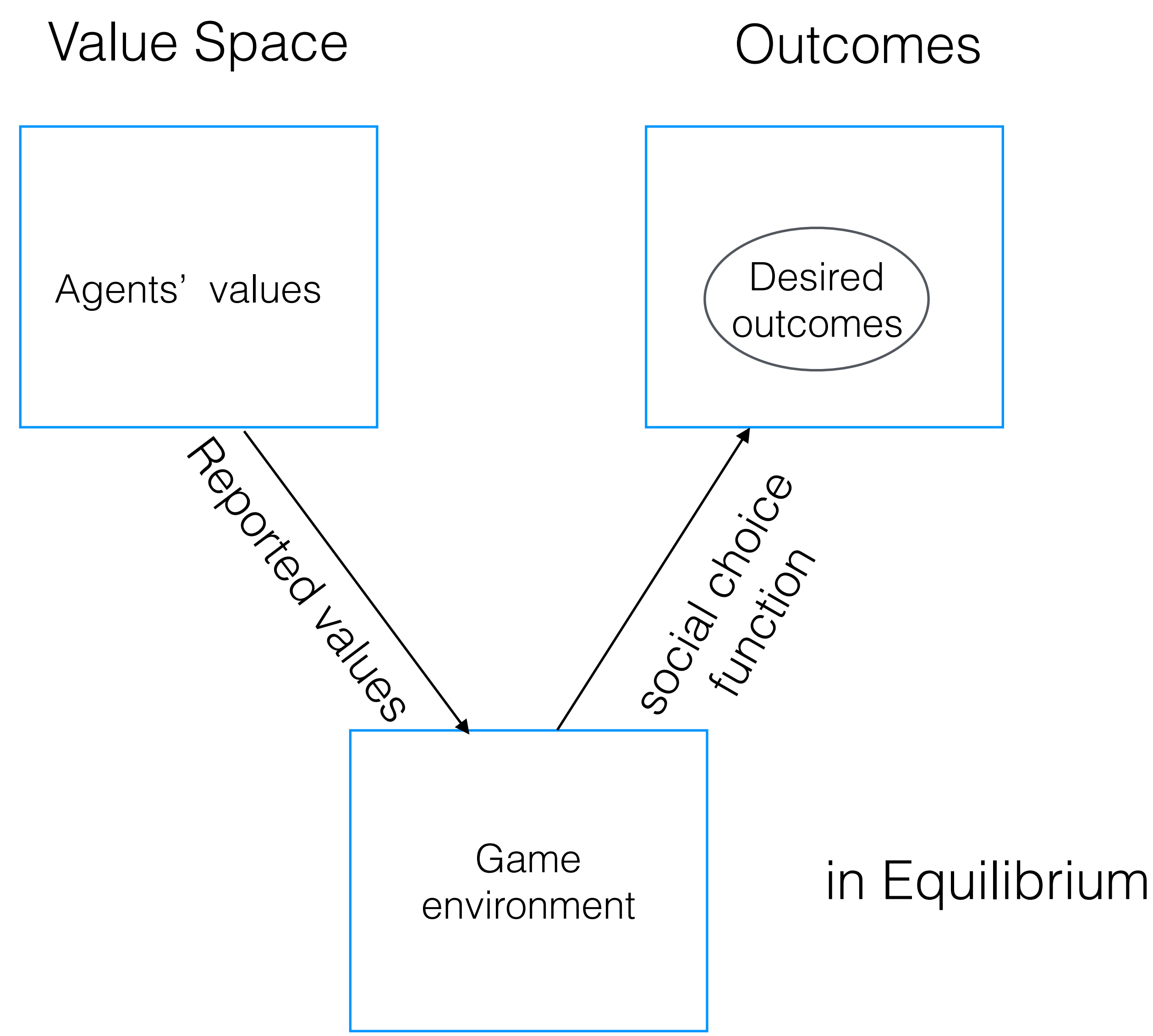
Nash Equilibrium

— No one can gain by a unilateral change of strategy if others' strategies remain unchanged (Nash 50)

Mechanism Design

— Social choice function (allocation and payment function) in equilibrium (Hurwicz and Reiter 06)

— Two types: Public good and revenue optimization (Clarke 71; Myers and Satterthwaite 83)

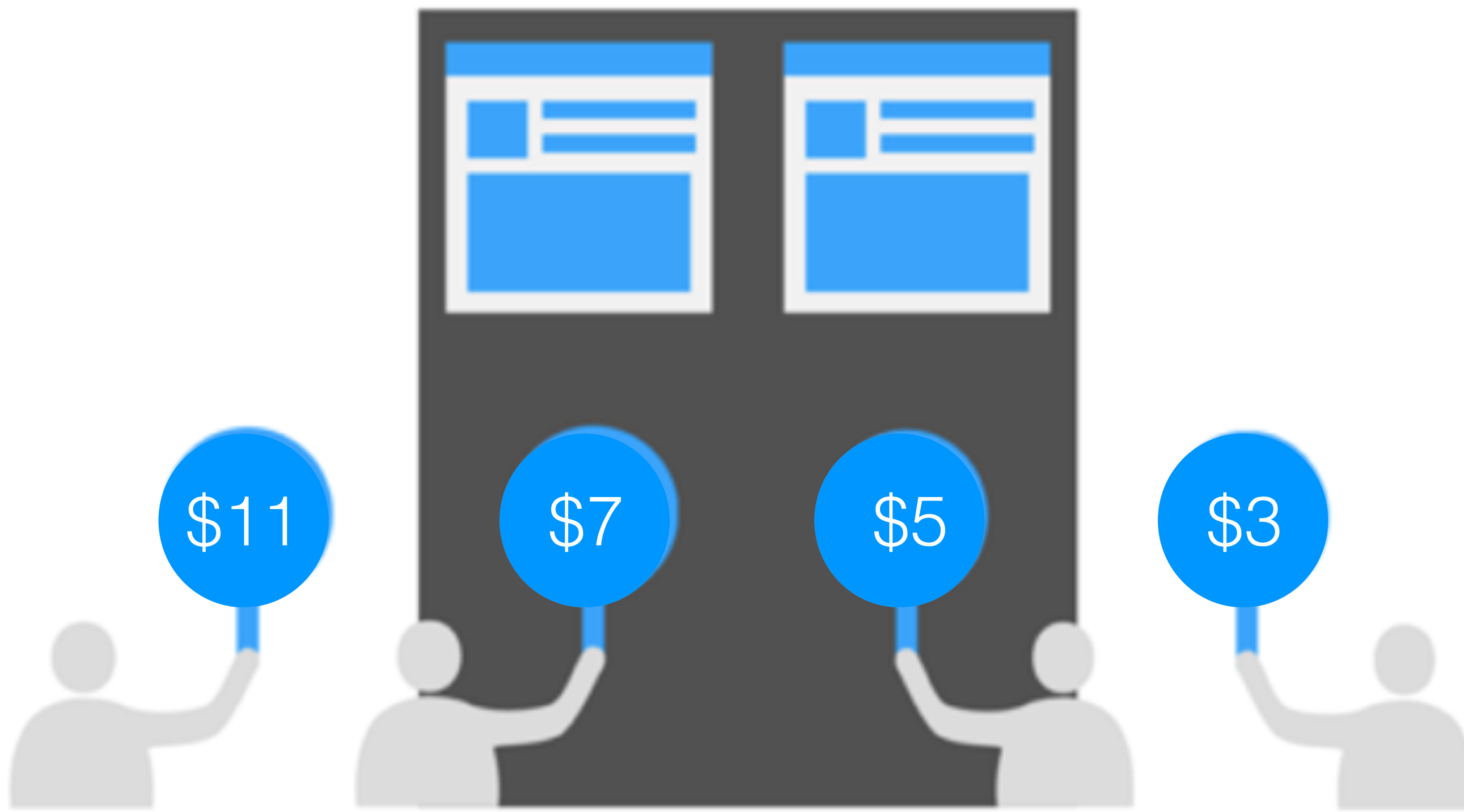


Mechanism Design for Public Good

Credit:times, medium

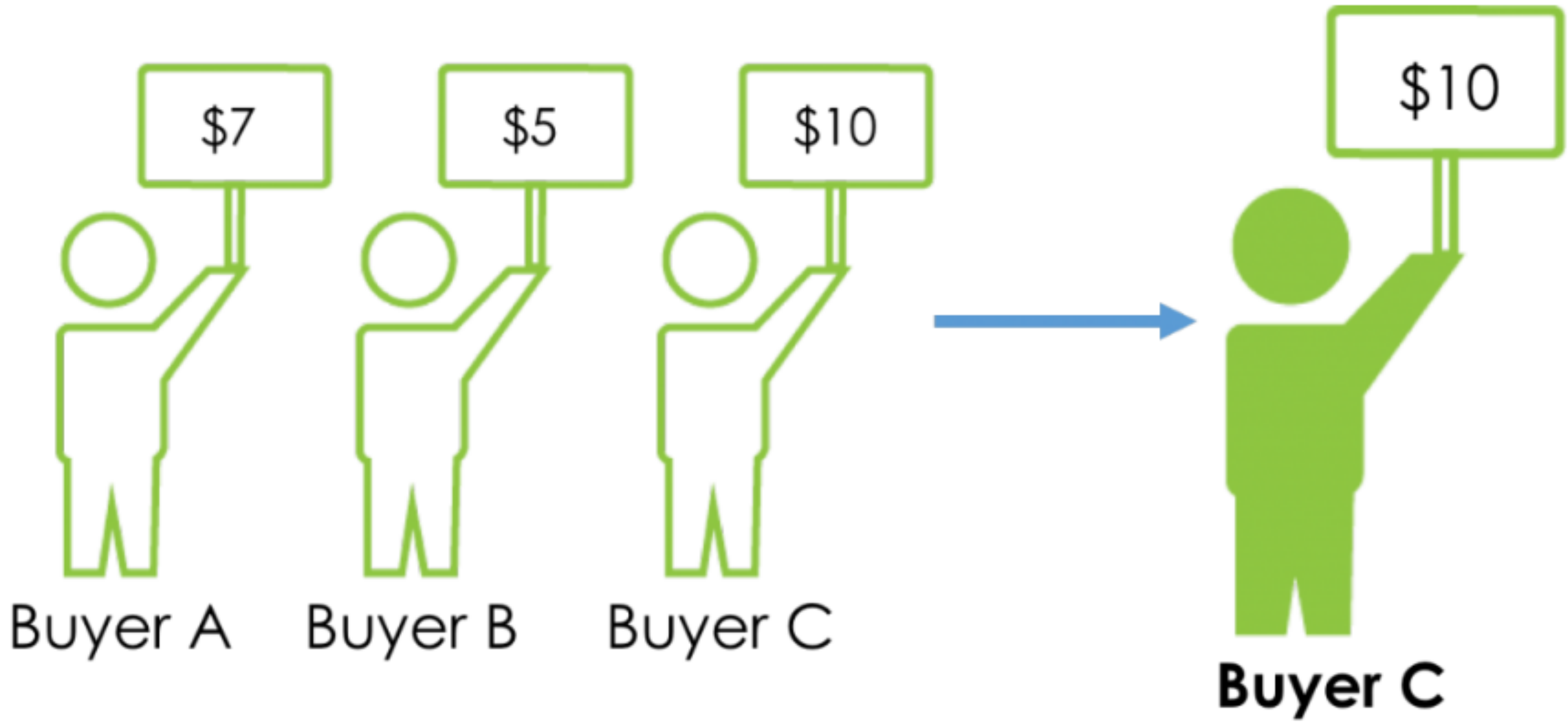
Social Welfare Maximization

Mechanism Design for Revenue Optimization



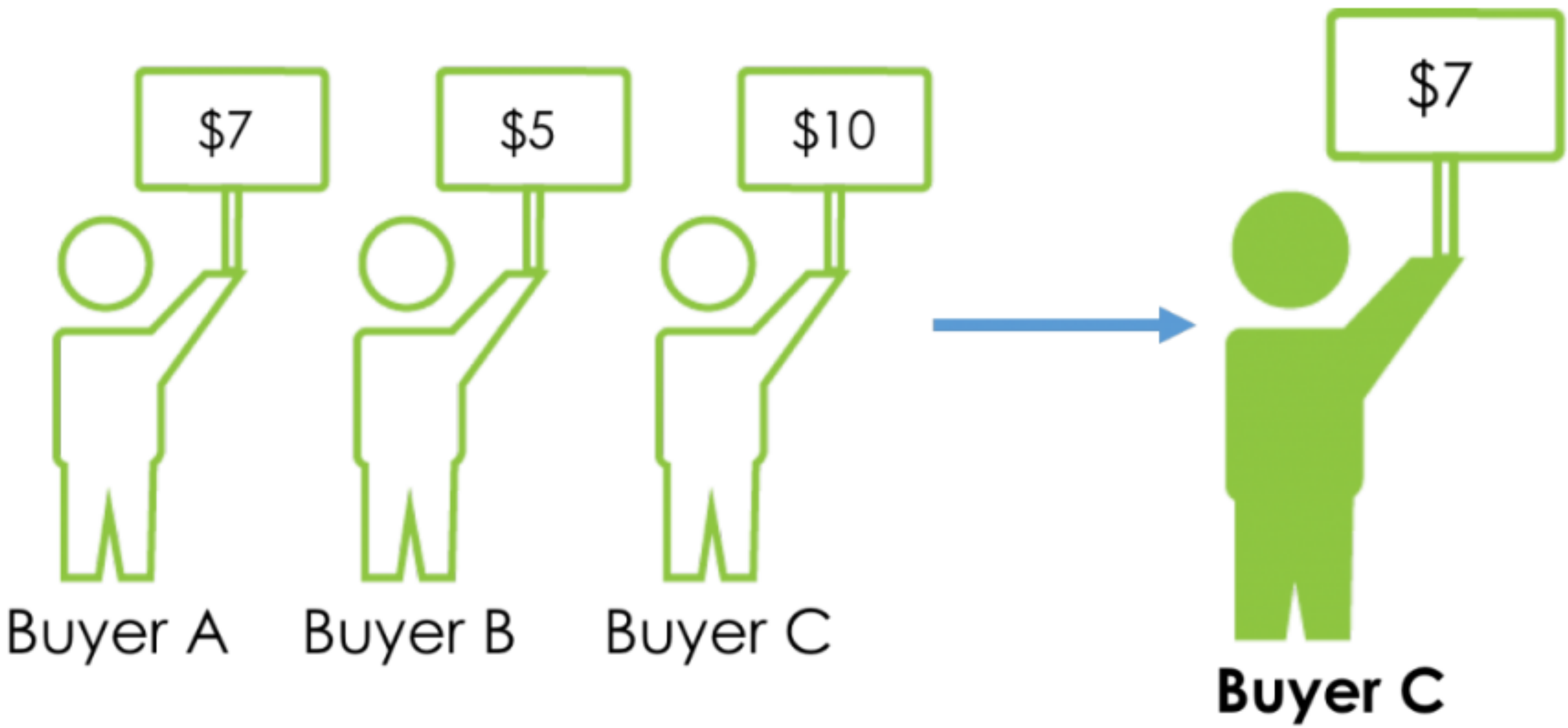
Revenue Maximization

Example I: First Price Auction



First Price Auction: not incentive compatible (i.e., buyer C has an incentive to underreport her/his value)

Example II: Second Price Auction



Second Price Auction: incentive compatible

Theory vs Reality

- Full Rationality Assumption
    - Agents may make mistakes (Selten 90, Tiwana et al. 07, Fror 08, Su 08, Lim et al. 14,)
- Direct Preference Revelation
    - Agents may be unwilling/unable to state their preferences. (Naor et al. 99, Huang et al. 15, Wu et al. 15)
- No Group Manipulation
    - False-name attacks, collusion can happen (Wagman and Conitzer 08, Todo et al. 11, Drucker et al. 12, Mar 97, Che and Kim 09)

Challenges

- How to relax the full rationality assumption
- How to coordinate agents when they are unwilling/unable to reveal their preferences directly
- How to counter the manipulations caused by more than one agent (e.g., false-name attacks, collusion)

Related Work

- **Modeling Agents**
  - Aspiration adaptation theory (Selten JMP'98, Rosenfeld and Kraus JAAMAS'12)
  - Quantal response equilibrium (Mckelvey and Thomas GEB'15)
  - Simple agents (Ghosh and Kleinberg EC'14)
- **Indirect Mechanisms**
  - Post-price mechanism (Badanidiyuru, Kleinberg and Singer EC'12)
- **Manipulation-Resistant Mechanisms**
  - False-name-proof mechanism (Drucker and Fletcher EC'12)
  - Group-strategy-proof mechanism (Goldberg and Hardline SODA'05)

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Mechanism Design with Thresholding Agents

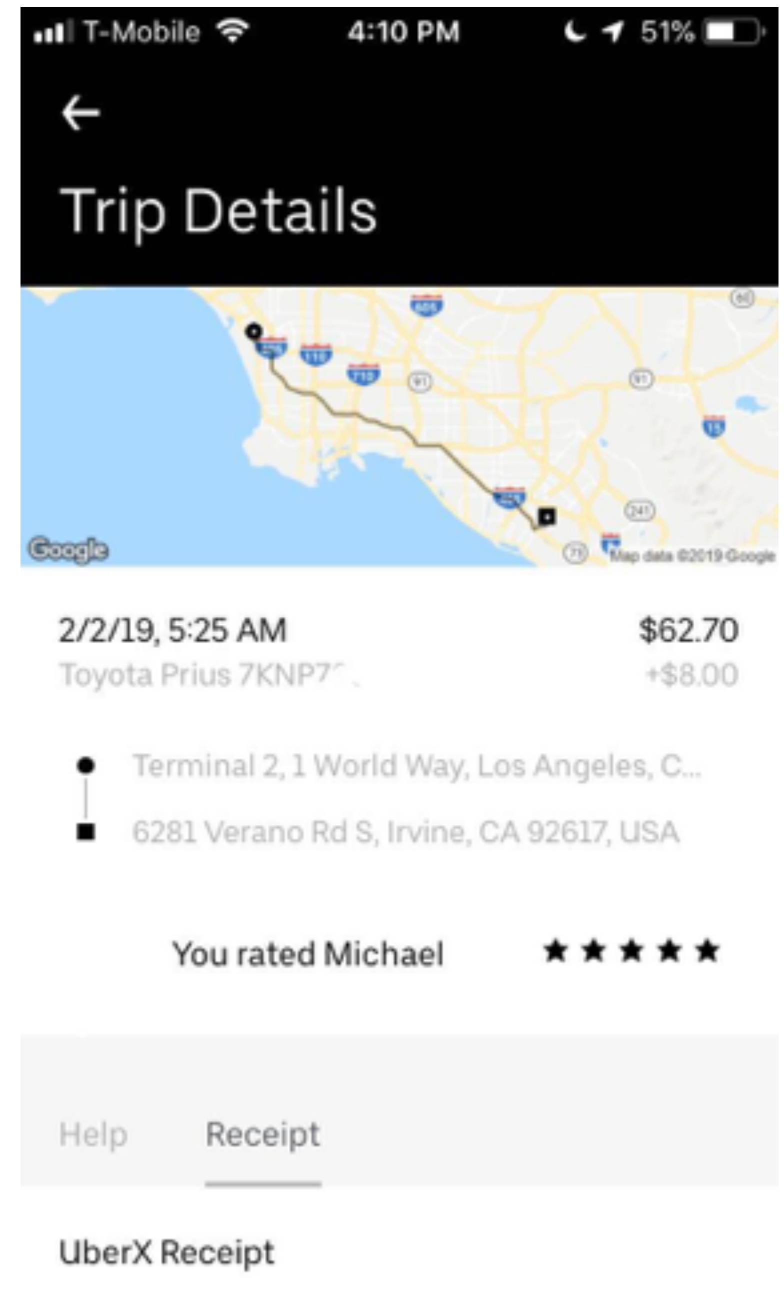
- **Thresholding agents**
    - Threshold policy: agents have private thresholds to trigger the decisions
    - Relative order of agents' preferences

Credit: psychology today

Maximizer vs Satisficer

Mechanism Design with Thresholding Agents

- **Privacy-preserving mechanisms**
  - Post-price mechanism



Mechanism Design with Thresholding Agents

- **Manipulation-resistant mechanisms**
    - Intuition: Using contests to increase competitions among individual players so that performing group manipulations is not profitable.

Credit: shutterstock

Thesis Statement

- Mechanism design with thresholding agents is more realistic and performs better than traditional approaches. Furthermore, it is robust with respect to group manipulations.

Methodology

- Three applications comparing thresholding agents with other existing approaches
  - **Crowdfunding** (revenue optimization): my approach generates more revenue than the baseline
  - **Ridesharing** (public good): my approach outperforms existing approaches in terms of social welfare
  - **Information Diffusion** (revenue optimization): my approach is resistant to false-name attacks (robust) — no baseline comparison, because possible baselines don’t scale

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Crowdfunding

VS

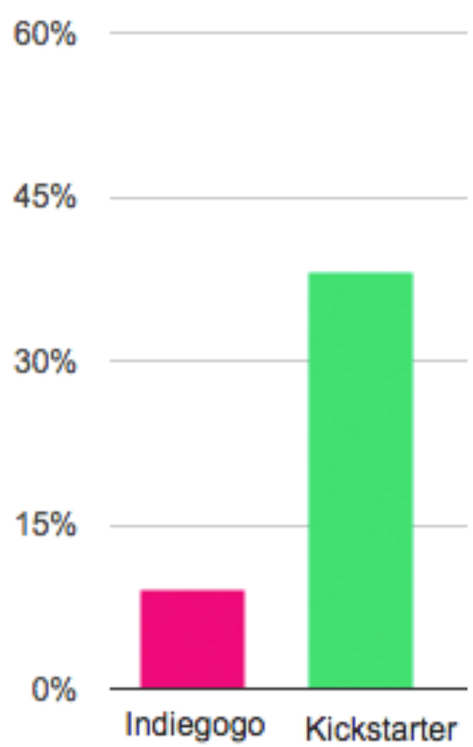
Credit: e27.co

Traditional fundraising
- large amount from few sources
- can be sophisticated

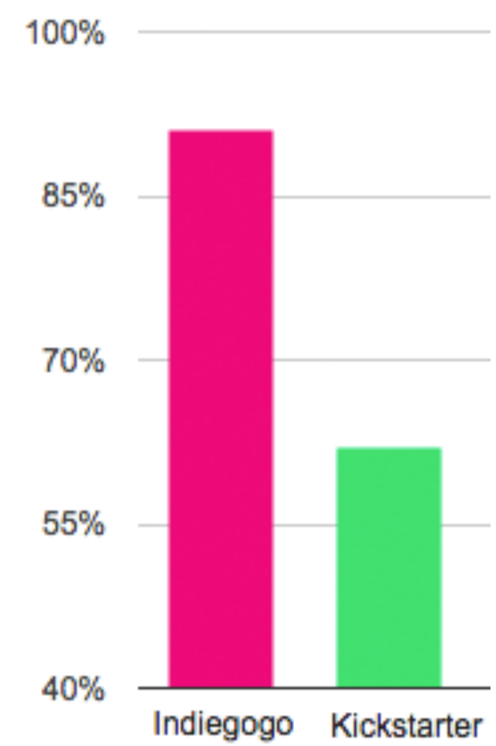
Crowdfunding
- small contributions from many individuals
- easy and simple

Crowdfunding

Overall success rate



Overall failure rate



Observation: Less than **40%** campaigns succeeded.

(Short et al. 17)

Crowdfunding

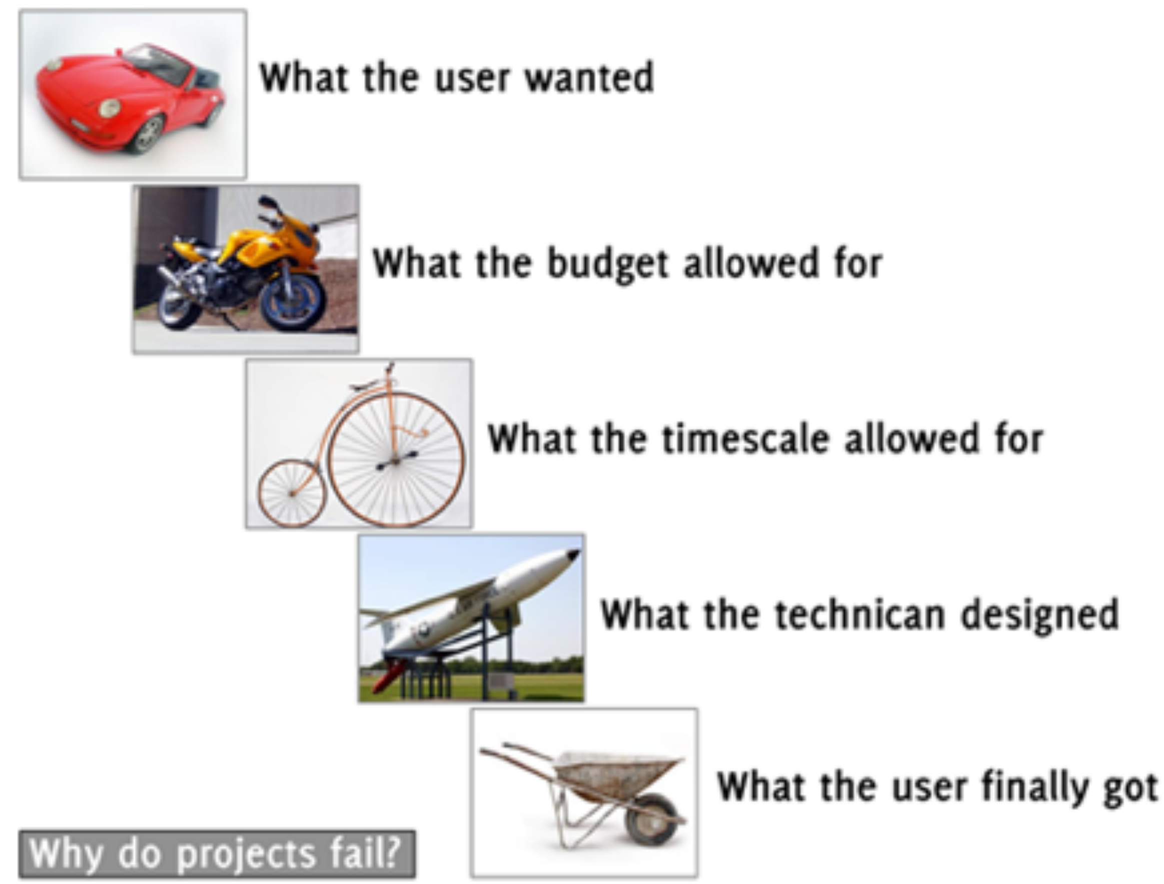
Reasons:

- **Early contributions** are crucial to the success of a campaign: signaling; and information diffusion.

(Colombo 15, Skirnevskiy 17)

- Backers are often reluctant to contribute in the early days of a campaign due to **high uncertainty** (e.g., the probability of success that the campaign will get funded or the award will be delivered).

(Alaei et al. 16, Kuppuswamy and Bayus 15, Mollick 14)

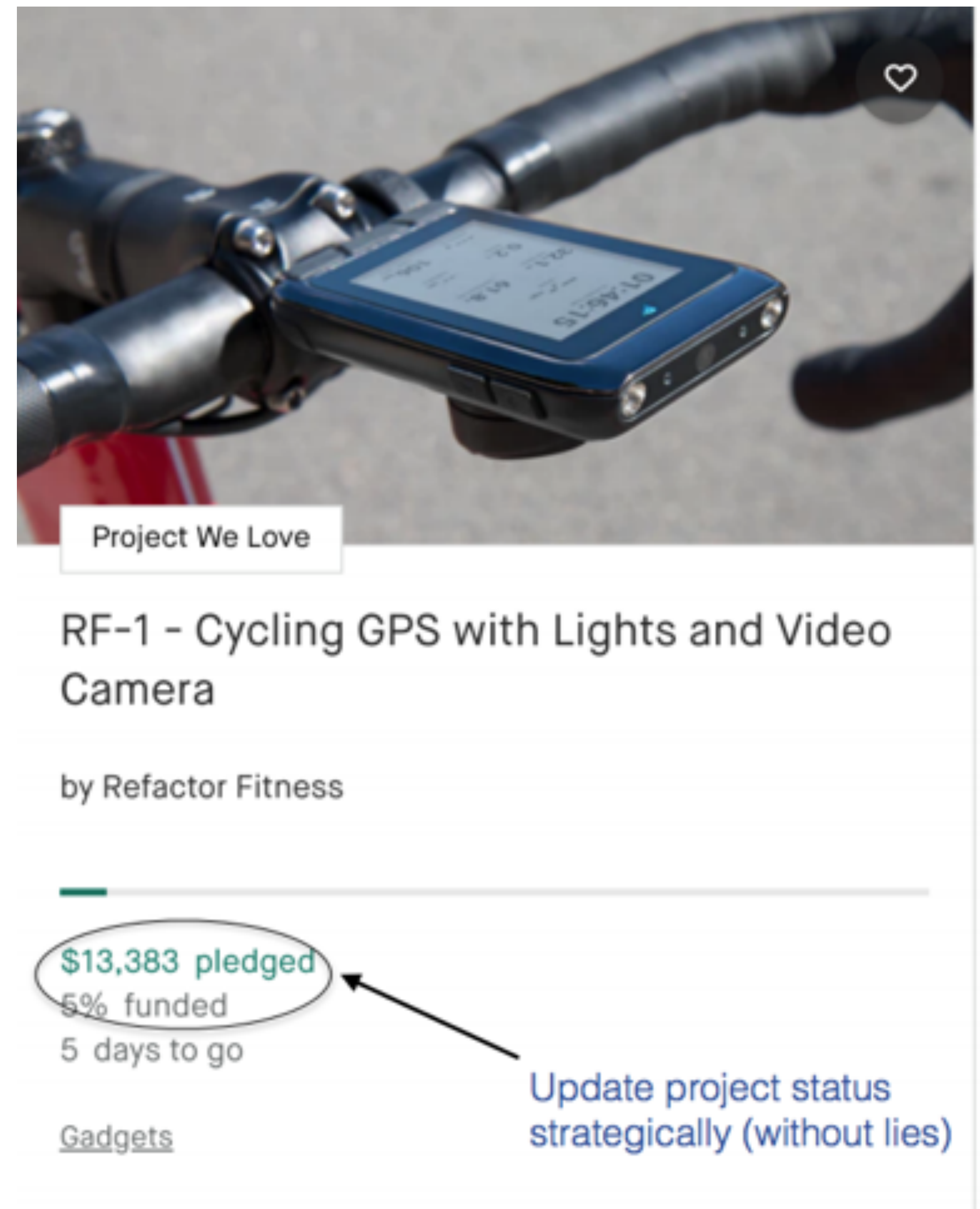


Credit: crowdfunding.com

Information Design for Crowdfunding

- Definition: the approach of designing **information structures** that determine which pieces of information are disclosed to whom for desirable outcomes.

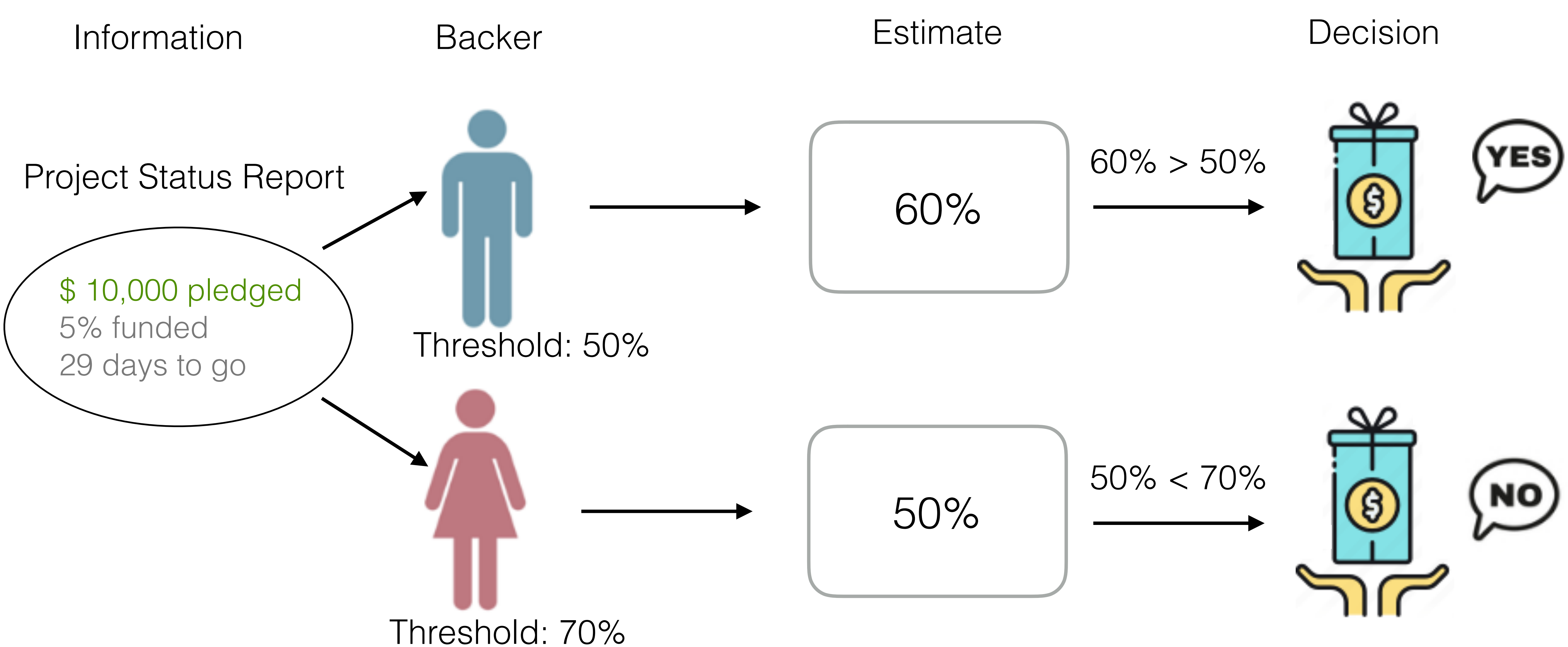
- In the context of crowdfunding: the entrepreneur can voluntarily disclose the **project status** (i.e., how many contributions have been collected up to a given timestamp).



Credit: Kickstarter

Decision Models

- **The backers**
  - Use thresholding policies to determine whether to contribute or not to increase their utility



Order of Project Status Reports

- An earlier report of project status is always preferred if the project status of the two reports are the same.

$ 10,000 pledged
5% funded
29 days to go

$\geq$

$ 10,000 pledged
5% funded
15 days to go

Day 1

Day 15

Order of Project Status Reports

- A later report of project status is always preferred if it has a higher growth rate than the earlier report.

5% / 1 = 5%

$ 10,000 pledged
5% funded
29 days to go

Day 1

≤

20% / 2 = 10%

$ 40,000 pledged
20% funded
28 days to go

Day 2

Excessive Information Shrinks Revenue

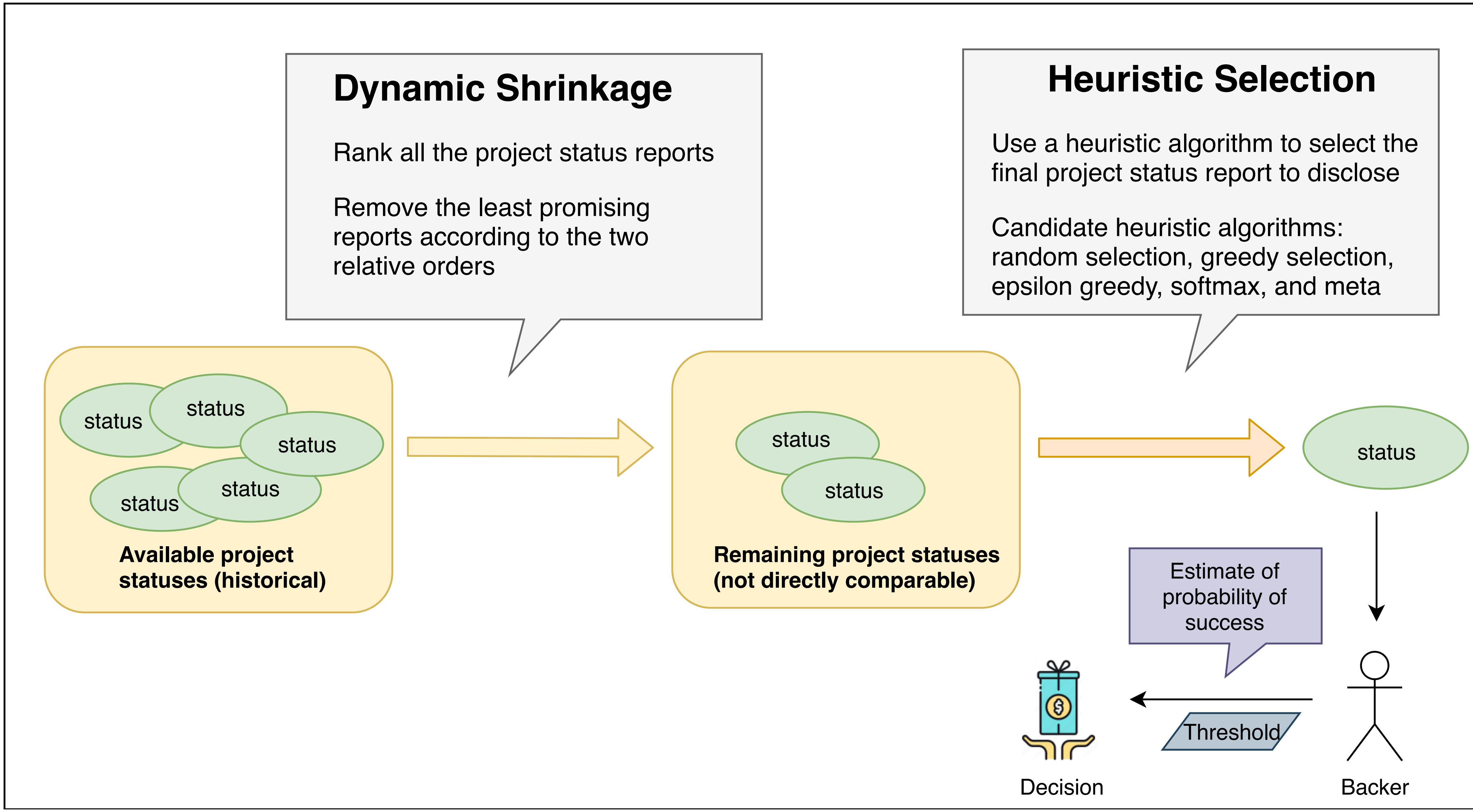
- If the order of two project status reports can be identified, the low-order report does not increase the chance of backers' contribution

- If the order of two project status reports cannot be identified, excessive information disclosure decreases agents' projection of campaign's probability of success

Indication: The entrepreneur should only reveal the information that is necessary

Dynamic Information Design

Dynamic Shrinkage with Heuristic Selection



(Shen, Crandall, Yan, Lopes AAMAS'18)

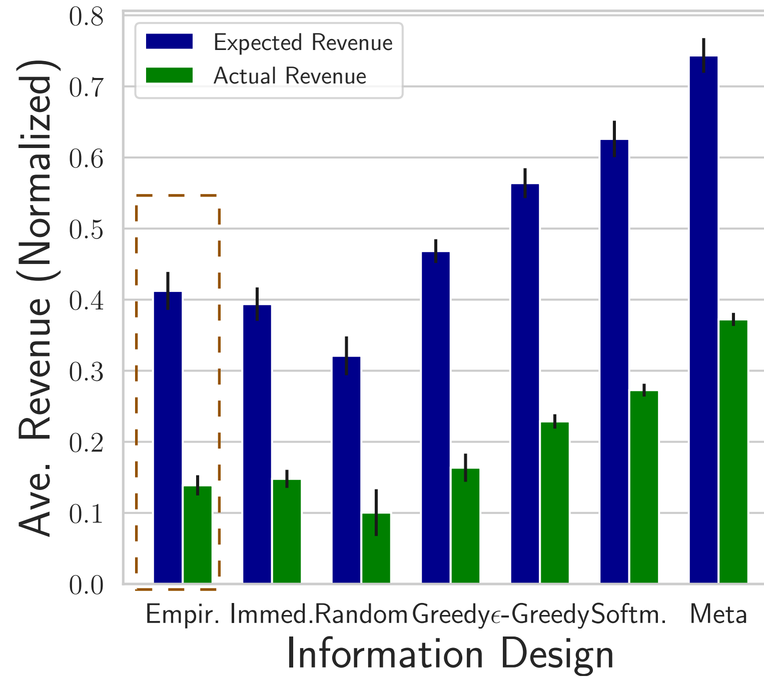
Experimental Settings

- **Data**
  - 1,569 projects (reward-based, all-or-nothing) from Kickstarter
  - Only the early bird pledges and the regular pledges were selected
  - Backers' arrivals: Poisson distribution (i.i.d. with a mean of 0.1) (Marwell '15)
  - Backers' estimate of probability of success: anticipating random walk (Alaei, Malekian and Mostagir EC '15)
  - Backers' valuation of a reward: Gaussian distribution with a mean that equals to the value of the reward

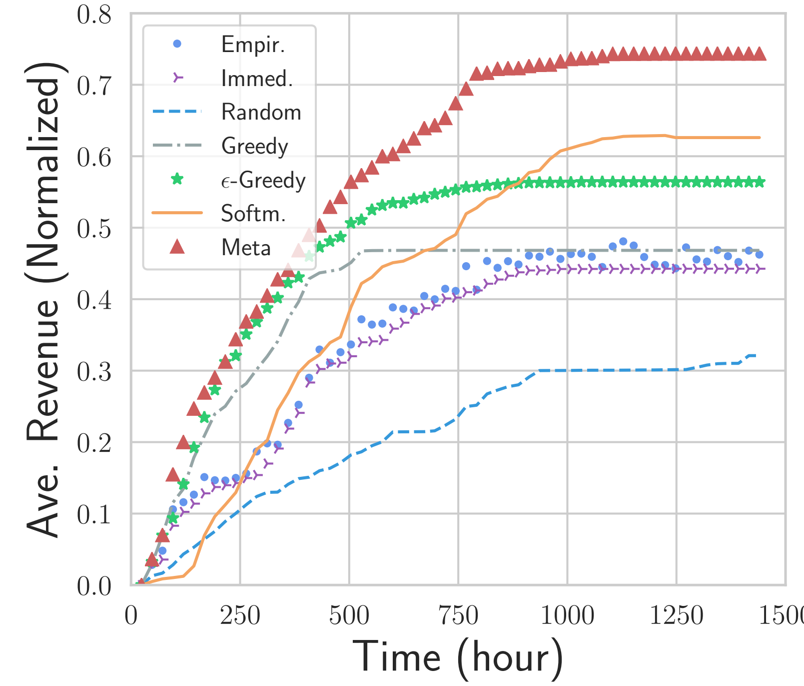
- **Procedure**
  - Six groups: immediate disclosure, and DSHS with five heuristics (random selection, greedy selection, epsilon-greedy exploration, softmax exploration and meta)
  - Each group was run 30 times on the same 2.9 GHZ quad-core machine; only the average numbers were reported.

Simulation Results

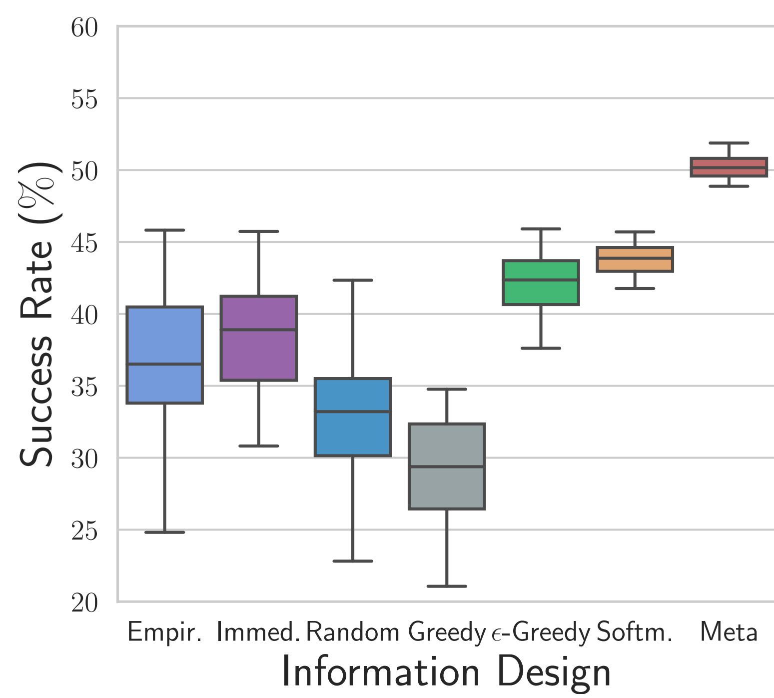
- **Observations**
  - Meta group performed consistently the best among all the groups in terms of both actual and expected revenue.
  - Meta group had the highest project success rate.
  - Meta group required the most computational time.
- **Indications**
  - Immediate disclosure is not always optimal in crowdfunding.
  - Dynamic information design is helpful



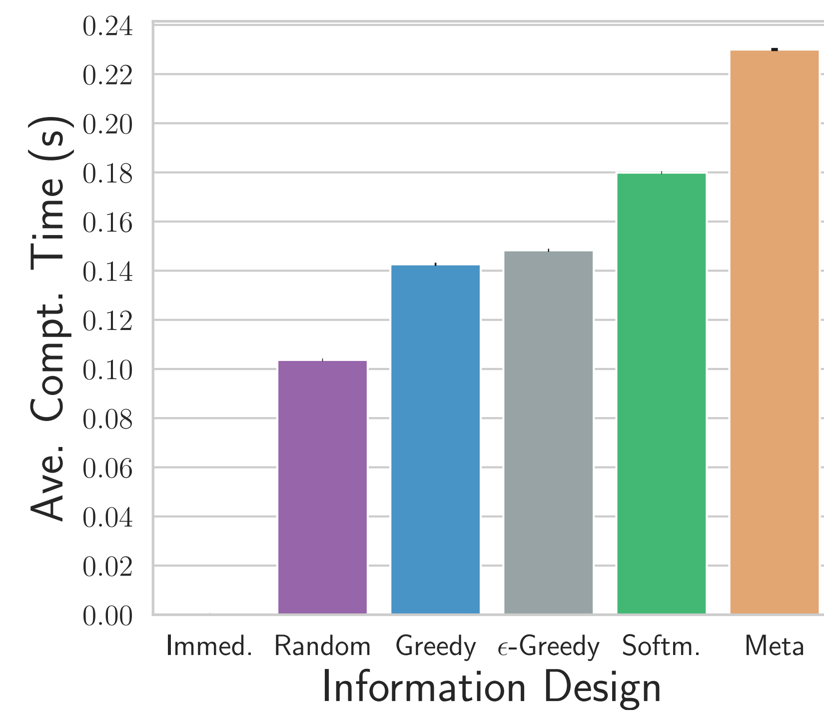
(a) Overall revenue ($t = 1440$)



(b) Expected revenue over time



(c) Project success rate (%)



(d) Computation time

Discussion

- **Our contributions**
  - We present the first study on information design where a sender interacts with multiple receivers that follow thresholding policies.
  - We also demonstrate how the entrepreneur can benefit from dynamic information disclosure with appropriate heuristics.
- **Messages to take away**
  - Excessive information disclosure shrinks the revenue in crowdfunding when backers use cutoff policies.
  - The widely-adopted immediate-disclosure policy is not optimal.
- **Future directions**
  - Applications to other domains (e.g., online shopping marketplace, transportation systems, open source software development).
  - Information design when agents use other decision models (e.g., no-regret learning).

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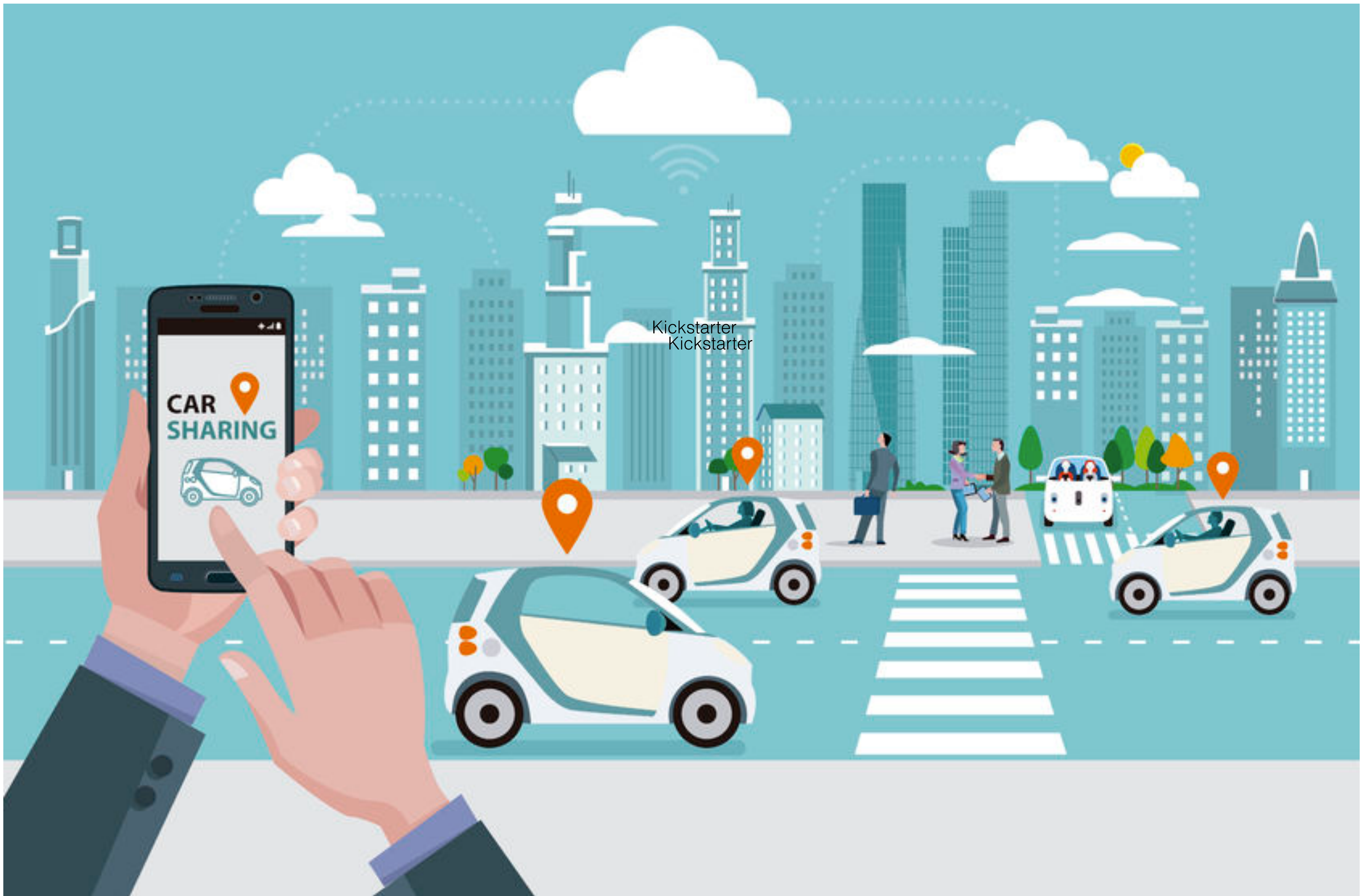
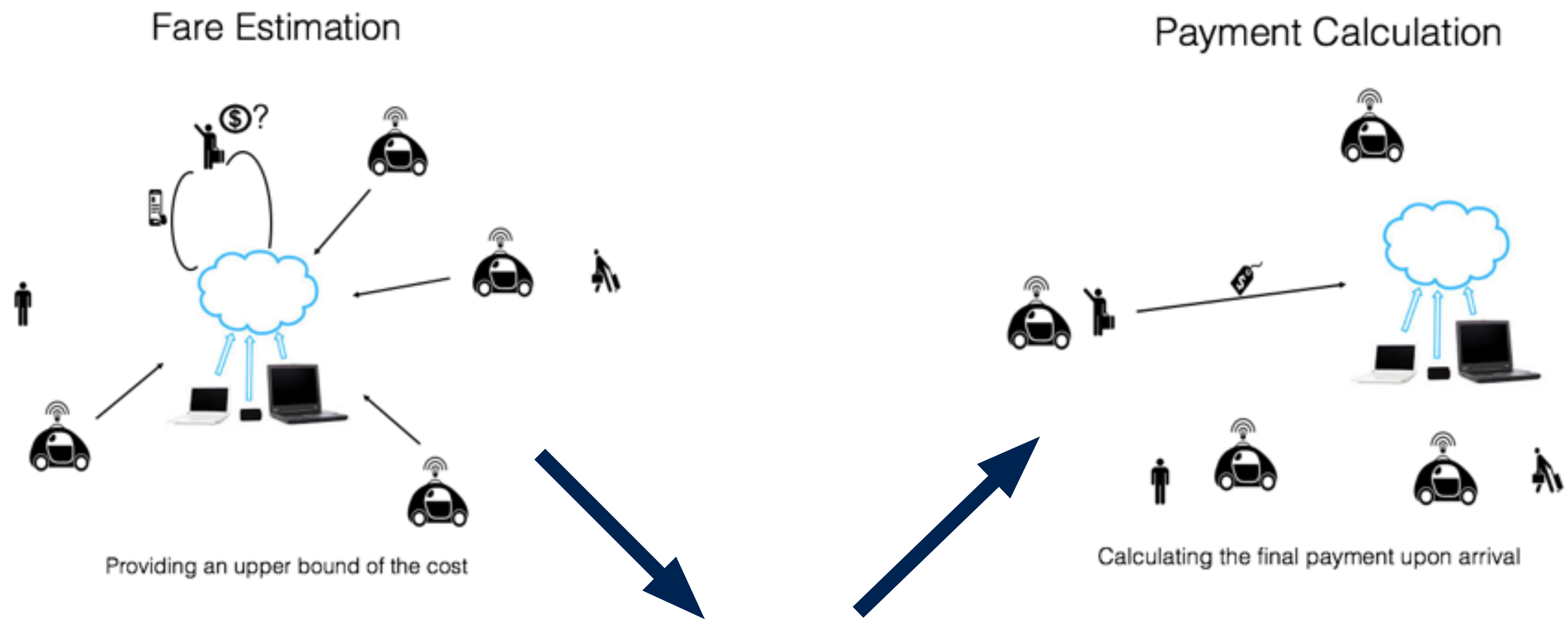
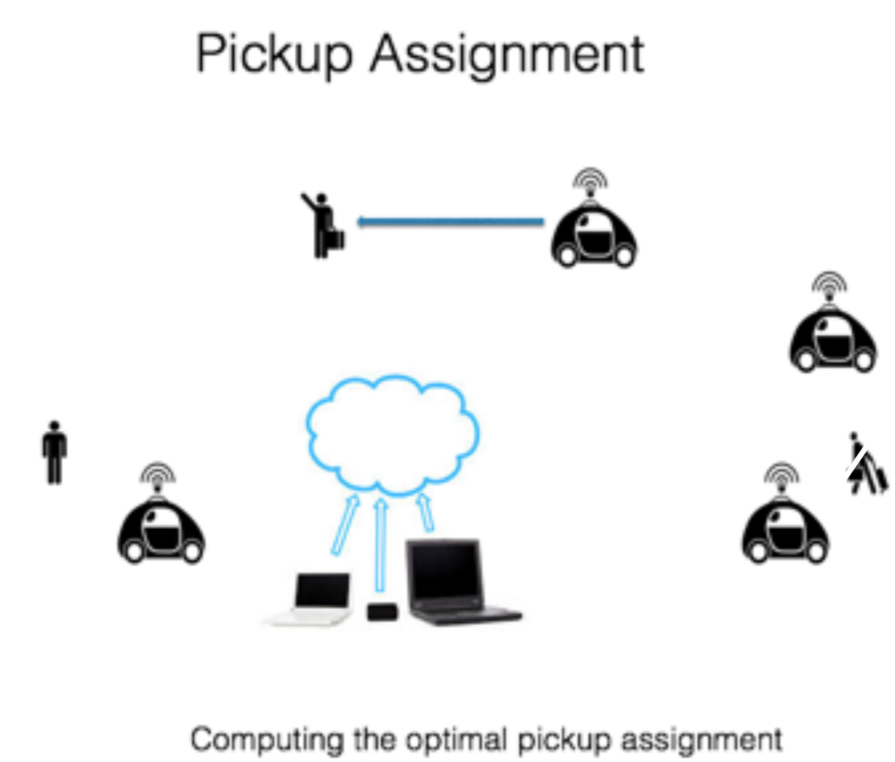
Autonomous Mobility-on-Demand Systems



Credit: marketers media

A Post-Price Online Mechanism for RideSharing





Objective:
To minimize the operational cost per unit demand.

Properties:
-Ex-post incentive compatibility
-Individual rationality
-Budget constraint

(Shen, Lopes, Crandall IJCAI'16)

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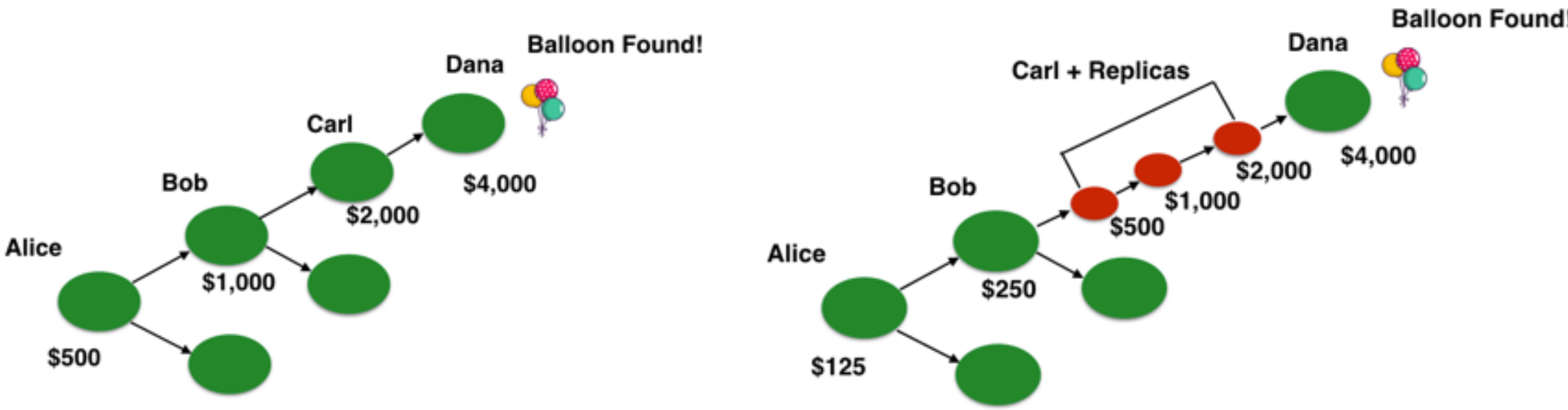
Countering False-Name Attacks



(a) Honest diffusion (b) Diffusion with manipulations

- **Multi-Winner Contests Mechanism**:
  - Uses the post-price mechanism to determining the task rewards
  - For diffusion rewards, the mechanism initially assigns virtual credits to the players that have made task efforts and a successful referral. It then conducts a contest among the players in the same subgraph and assign the rewards proportionally.

(Shen, Feng, and Lopes AAAI'19)

Countering Collusion

Generalized Contest Mechanism:

-Uses a superadditive function to determine the virtual credits

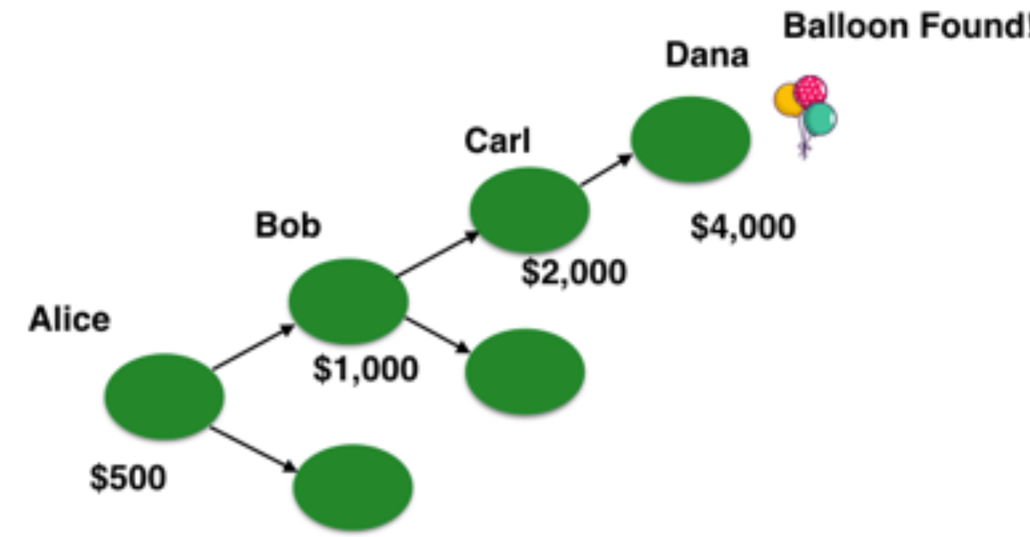
$$f(x+y) \geq f(x) + f(y)$$

-Uses an increasing and bounded function to cap the total diffusion rewards of a referral

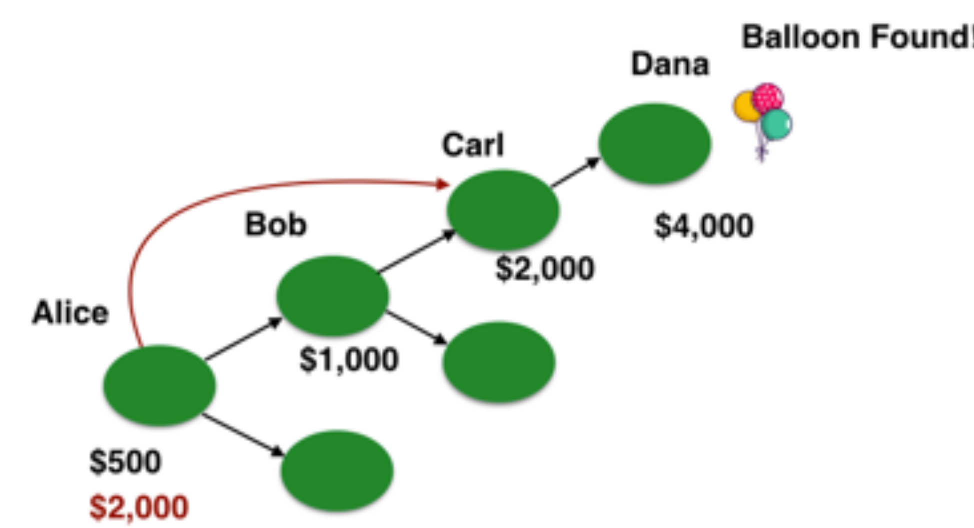
$$x \leq y \rightarrow f(x) \leq f(y)$$

$$L = \lim_{x \rightarrow +\infty} f(x)$$

(Shen, Yan and Lopes Working Paper 19)



(a) No collusion



(b) Collusion

Countering Free Riding

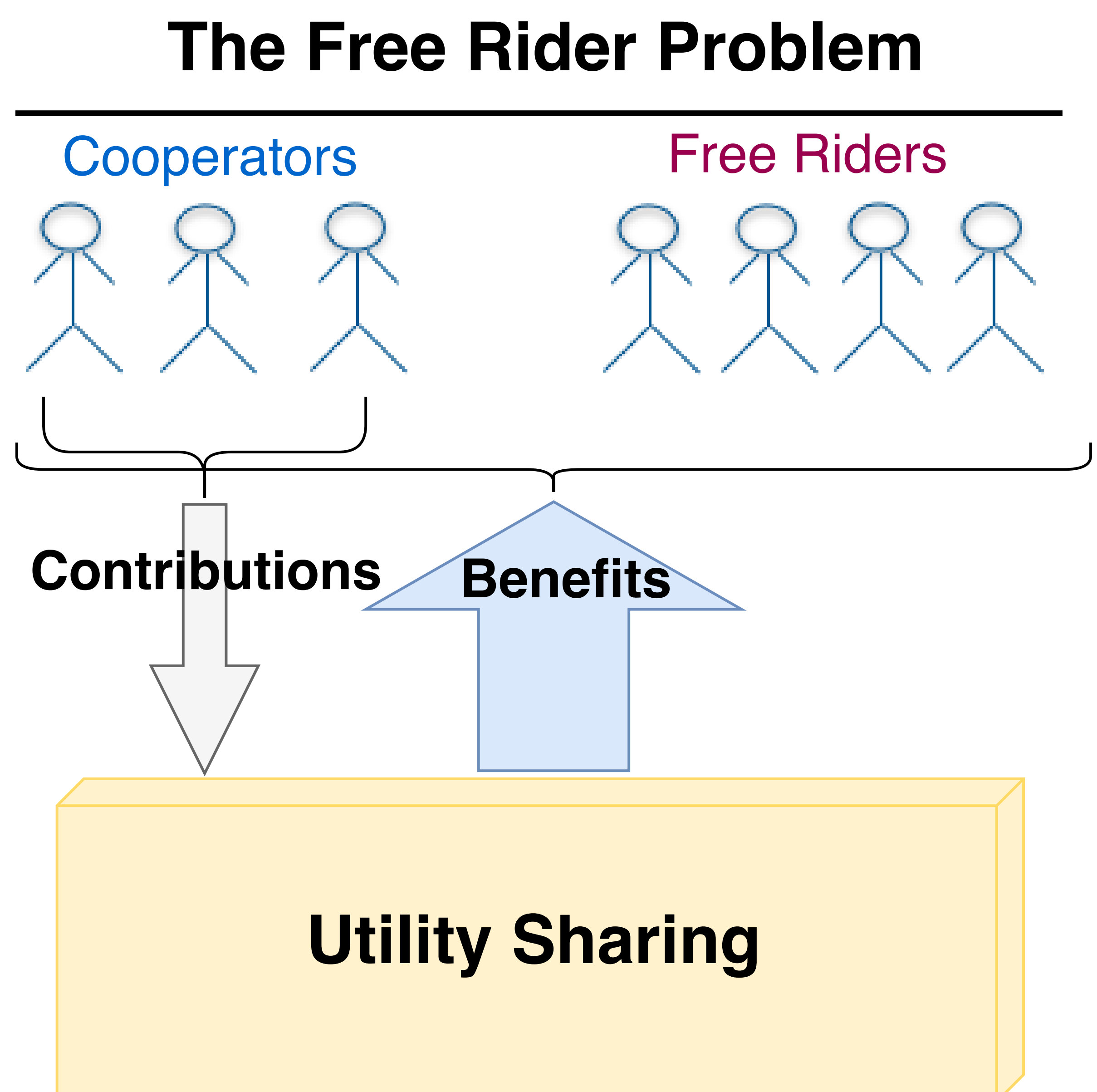
Sequential Contest Mechanism:

-Selects a private threshold to terminate the utility production

-Conducts a sequential contest to attract players to contribute

-Provide rewards to the players that have made contributions before the termination of the utility production

(Shen and Lopes Working Paper 19)



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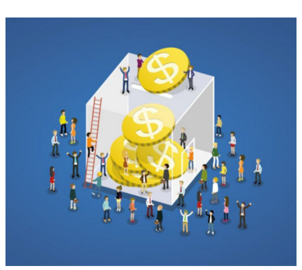
Mechanism Design with Thresholding Agents

Motivation: how to attract early donations
Approach: dynamic information design
Results: outperforms immediate disclosure

Motivation: how to promote ridesharing
Approach: post-price online mechanism
Results: outperforms the auction-based mechanism, comparable to the optimal approach

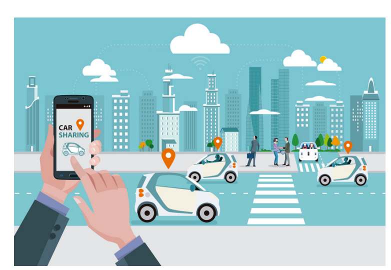
Motivation: how to counter manipulations
Approach: using contests to increase competitions
Results: robust to false-name attacks, collusion, free riding

Crowdfunding



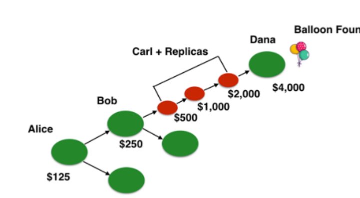
Shen, Crandall, Yan, Lopes AAMAS'18

Ridesharing



Shen, Lopes, Crandall IJCAI'16

Countering Manipulation



Shen, Feng, Lopes AAAI'19
Shen, Yan, Lopes Working Paper
Shen, Lopes Working Paper

Publications

Published Papers

W. Shen, Y. Feng, C.V. Lopes: Multi-Winner Contests for Strategic Diffusion in Social Networks.
In Proc. of the 33rd AAAI Conference on Artificial Intelligence (*AAAI 2019*).
K. Yan, **W. Shen**, H. Lu, and Q. Jin: Emerging Privacy Issues and Solutions in Cyber-Enabled Sharing Services.
IEEE Access, 7 (2019), pp. 26031-26059.
W. Shen, R. Achar, C. V. Lopes: Toward Understanding the Impact of User Participation in Autonomous Ridesharing Systems.
In Proc. of the 2018 Winter Simulation Conference (*WinterSim 2018*).
W. Shen, J.W. Crandall, K. Yan, C. V. Lopes: Information Design in Crowdfunding under Thresholding Policies.
In Proc. of the 17th International Conference on Autonomous Agents and Multiagent Systems (*AAMAS 2018*).
K. Yan, Z, Ji, **W. Shen**: Online Fault Detection Methods for Chillers Combining Extended Kalman Filter and Recursive
One-class SVM. *Neurocomputing*, 229 (2017), pp 205-212.
W. Shen, A. A. Khemeiri, A. Almehrezi, W. Al-Enezi, I. Rahwan, J.W. Crandall: Regulating Highly Automated Robot Ecologies.
In Proc. of the International Conference on Human-Agent Interaction (*HAI 2017*). Best Student Paper Award.
W. Shen, C. V. Lopes, J. W. Crandall: An Online Mechanism for Ridesharing in Autonomous Mobility-on-Demand Systems.
In Proc. of the 25th International Joint Conference on Artificial Intelligence (*IJCAI 2016*).
W. Shen, C. V. Lopes: Managing Autonomous Mobility on Demand Systems for Better Passenger Experience.
In Proc. of the 18th International Conference on Principles and Practice of Multi-Agent Systems (*PRIMA 2015*).

Working Manuscripts

W. Shen, K. Yan, C. V. Lopes: Manipulation-Resistant Mechanism Design for Strategic Network Diffusion.
W. Shen, C. V. Lopes: Countering Free Riding in Utility Sharing with Sequential Contests.
W. Shen, R. Achar, C. V. Lopes: A Simulation Analysis of Large Contests with Thresholding Agents.

Future Directions

- **Short term (Summer 2019)**
  - Incentives in open source software development (OSSD)
    - How to provide better incentives (e.g., information structures) to contributors in order to promote high-quality software development?
    - Do competitions help increase the quality of open source software development?
    - How to encourage newcomers (usually with limited skills) to contribute and reduce players' free riding behavior in OSSD?
- **Long term (Postdoc & Beyond)**
  - Learning to design mechanisms
    - Preference learning: learn agents' behavioral models from data
    - Adaptive mechanism design: optimize the mechanism based on the learned behavior models
    - Theoretical analysis
  - New applications
    - Software Engineering: promote collaboration in global software development, crowdsourcing software development
    - Cybersecurity: eliminate/reduce the incentives of attacks
    - Cyber-Physical Systems: coordinate societies of autonomous machines

Timeline

Administrative

- Final defense by June 3rd, 2019
- Final paper work by June 7th, 2019

Research

- June 2019: data collection and analysis, mechanism design
- July 2019: experiments and writing; manuscript ready by July 30th, 2019.
- August 2019: start the postdoc
- Fall 2019: paper submission

Thank You!

Q & A