

Beyond Nash Equilibrium: Mechanism Design with Thresholding Agents

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Conflicts I: Selling Products



Upgrading? Sell it, don't trade it. [Sell now](#)

**Amazing Apple iPhone 8 (PRODUCT)RED - 4.7" - 256GB - (Unlocked)
A1905 (GSM)**

Apple Warranty to June 9, 2019, Works w Verizon

Condition: **Used**
"Please click on description for full information. Phone is still under Apple Warranty until June 9, " ... [Read more](#)

Time left: 6d 02h Sunday, 8:10PM

Current bid: **US \$305.00** [23 bids]

[Place bid](#)

Enter US \$310.00 or more

[Add to watch list](#)

Additional coverage available

Longtime member 22 watchers

Shipping: **FREE Expedited Shipping** | [See details](#)
Item location: Massena, New York, United States
Ships to: United States [See exclusions](#)

Delivery: Estimated on or before Sat. Mar. 16 to 92617 ⓘ

Payments:     

PayPal CREDIT
No Interest if paid in full in 6 months on \$99+. [Apply Now](#) | [See terms](#)

Returns: Seller does not accept returns | [See details](#)

Seller VS Buyers

Credit: eBay

Conflicts II: Transportation Systems



Credit: Artsy

Transportation Authority VS Individual Commuters

Conflicts III: Crowdsourcing



Credit: fabrikbrands

Task Owner VS Task Workers

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)



Los Angeles County Metropolitan
Transportation Authority (Metro)

- **Methods**
 - incentives, information, regulations (e.g., laws)

(Shen et al. HAI'17)

Credit: LATimes

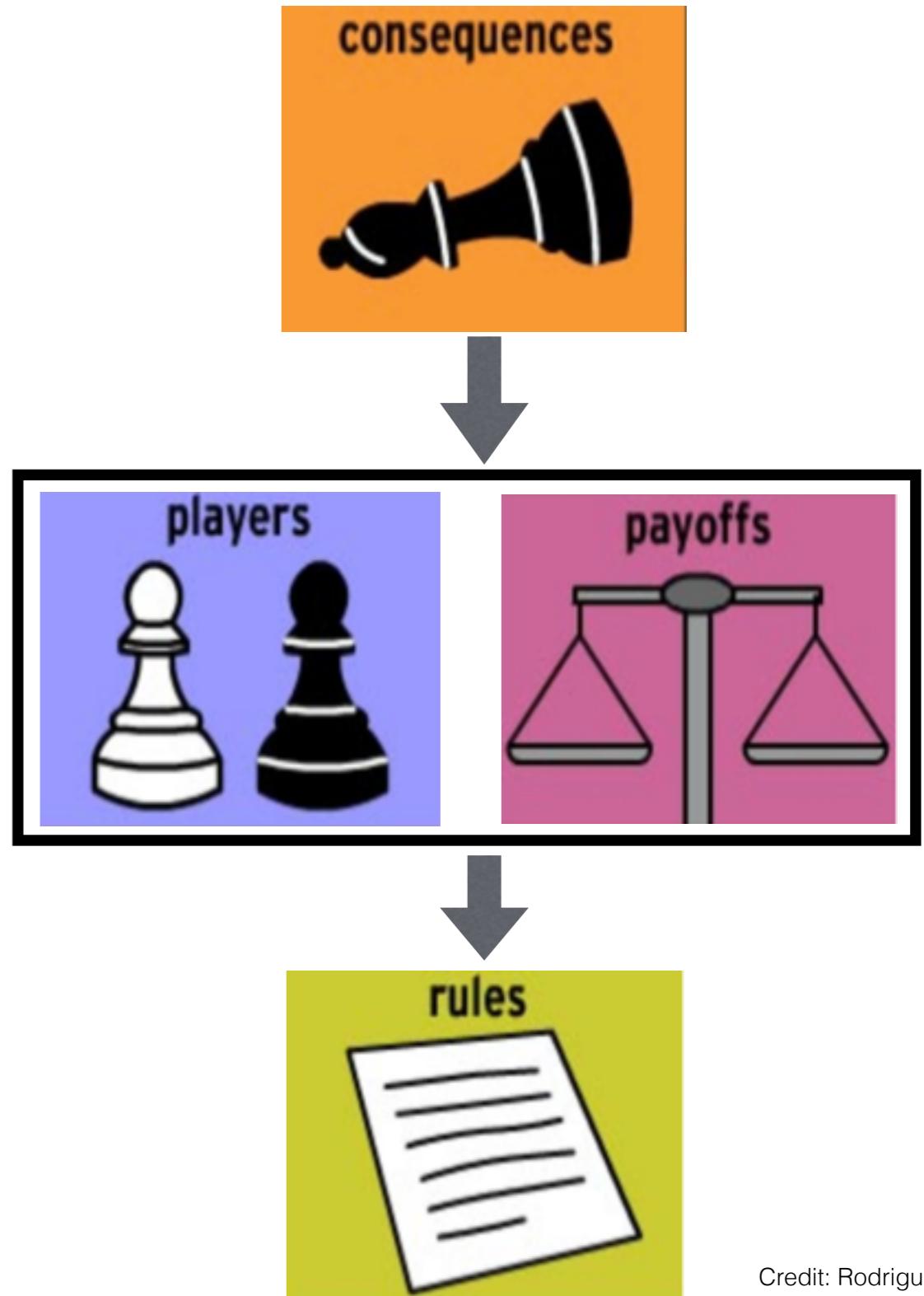
Outline

- **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 and Future Directions

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

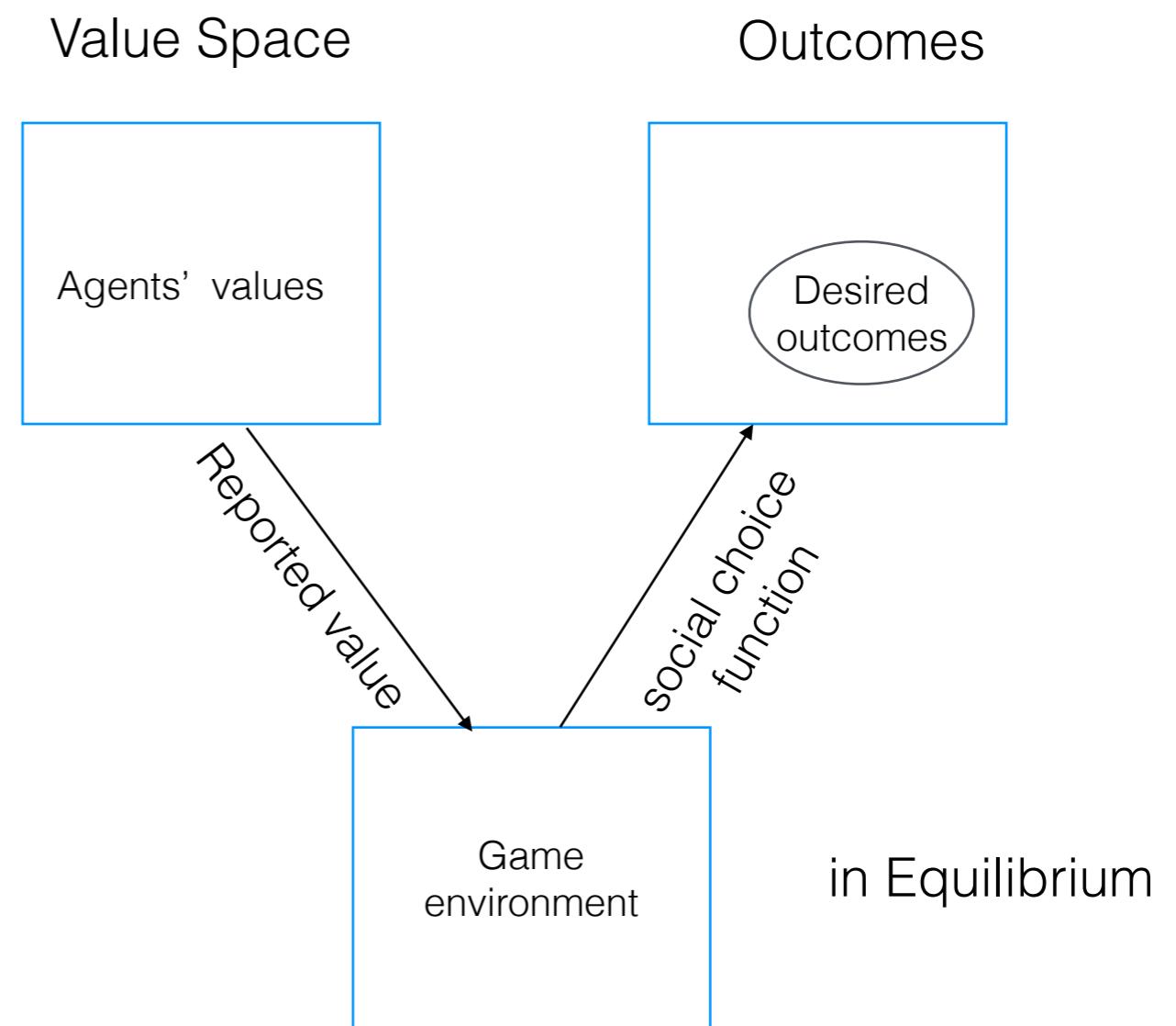
How It Works

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)



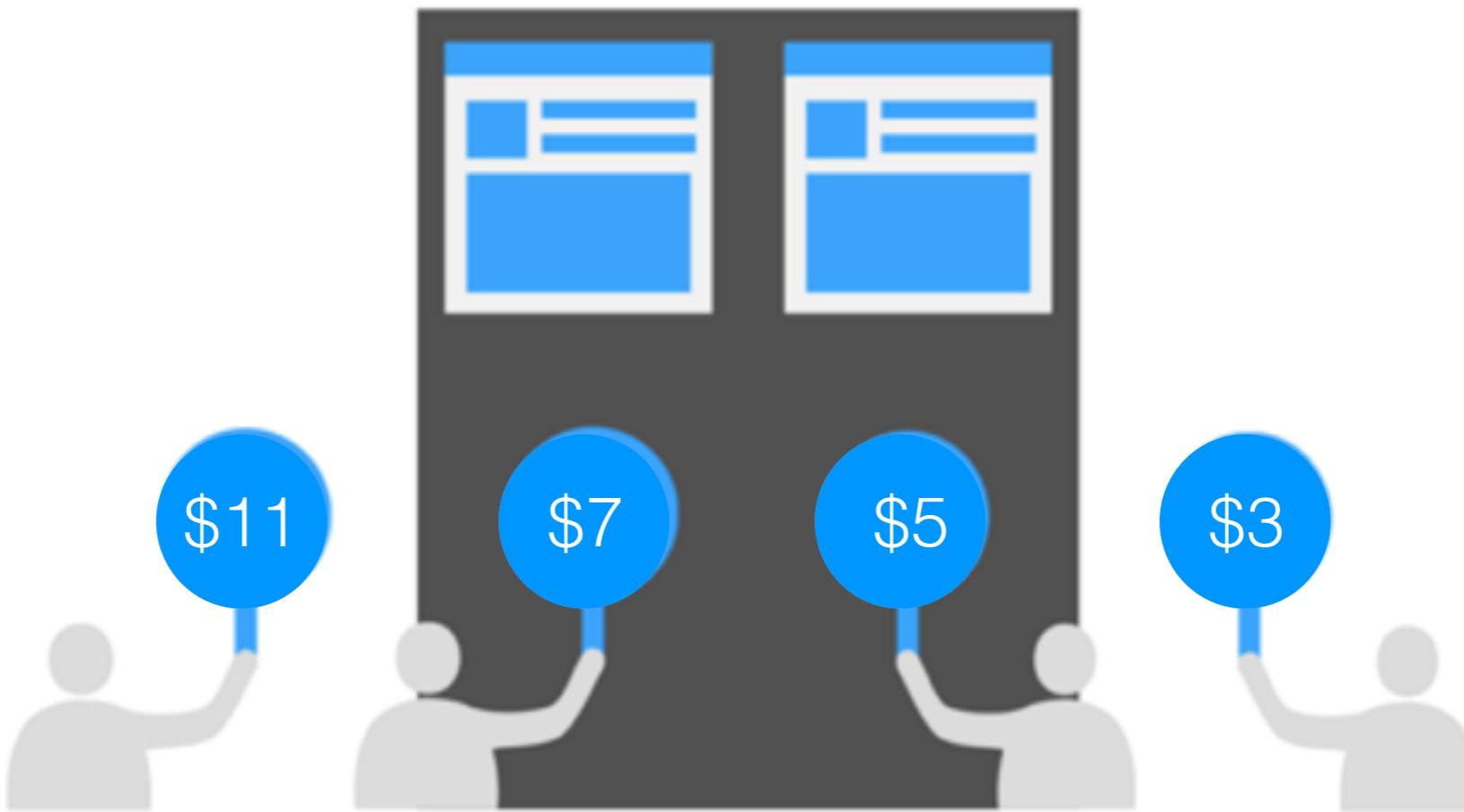
Mechanism Design for Public Good



Credit: latimes, times

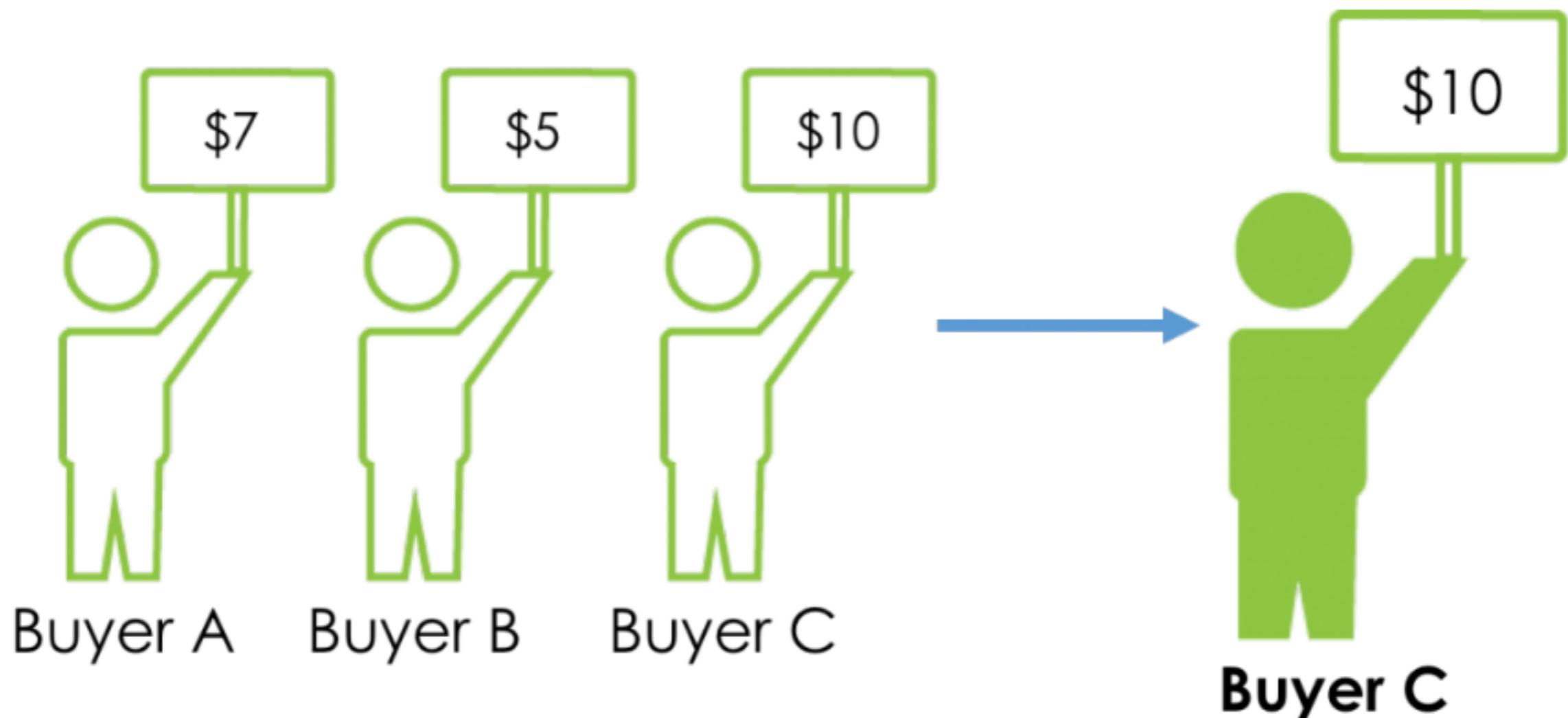
Social Welfare Maximization

Mechanism Design for Revenue Optimization



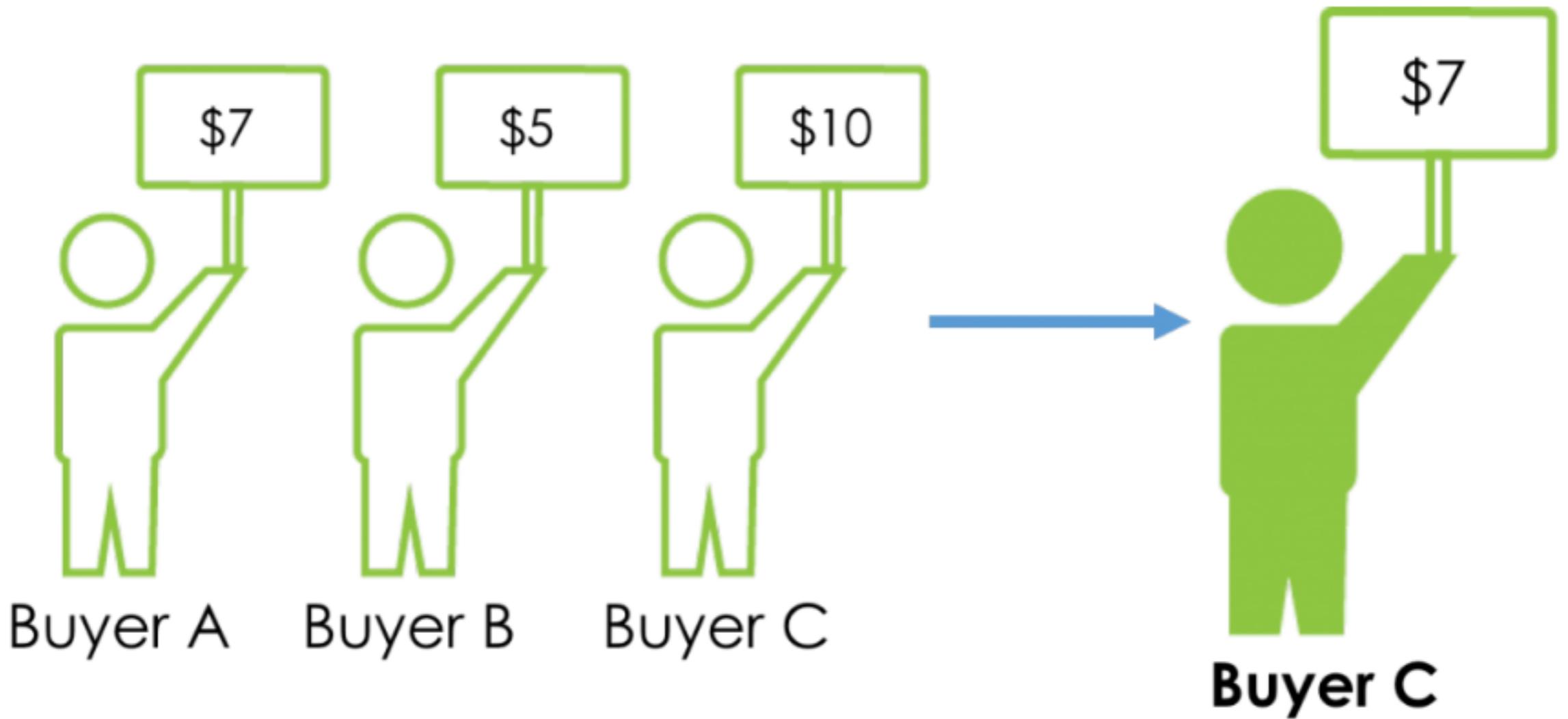
Revenue Maximization

First Price Auction



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

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



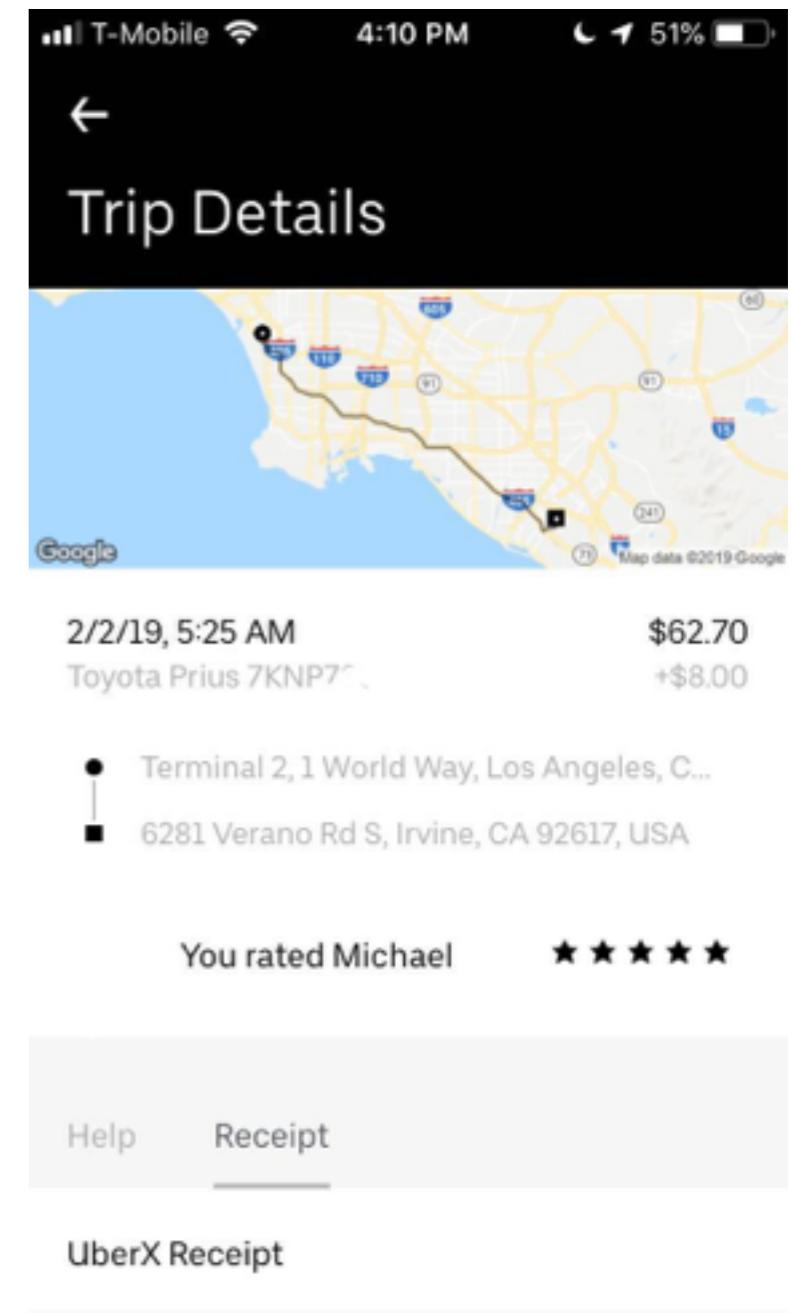
Credit: psychology today

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

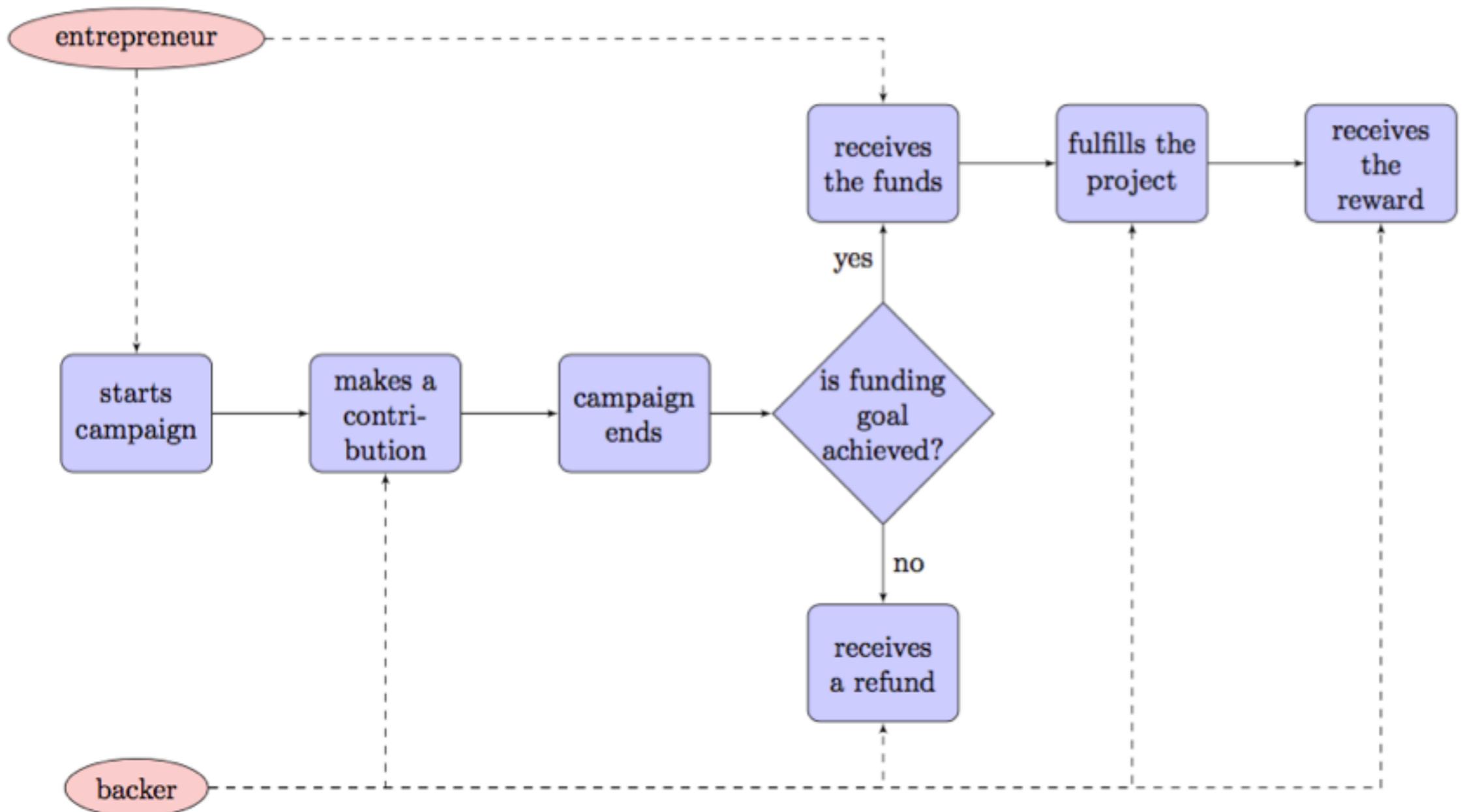
Traditional fundraising

- large amount from few sources
- can be sophisticated

Crowdfunding

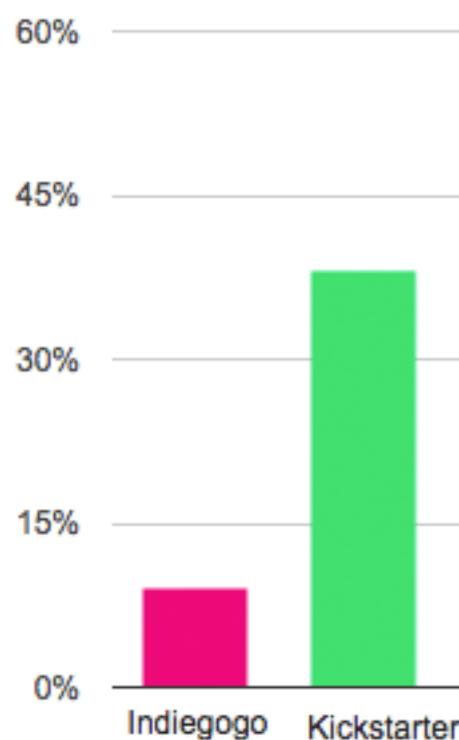
- small contributions from many individuals
- easy and simple

A Typical Campaign

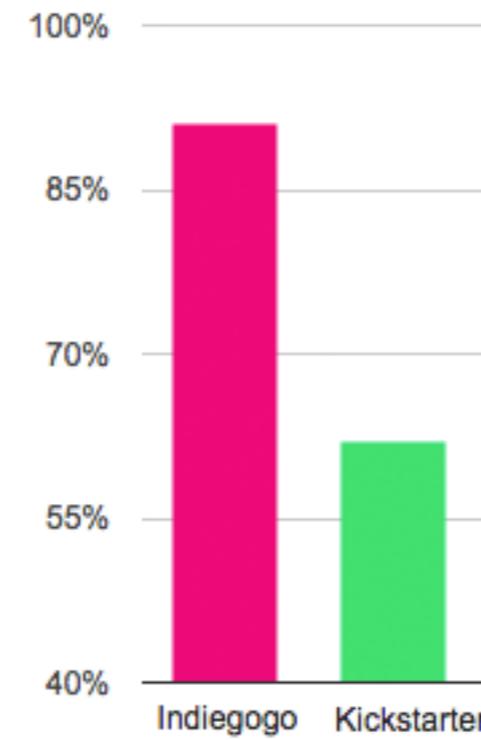


Crowdfunding

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)



What the user wanted



What the budget allowed for



What the timescale allowed for



What the technician designed



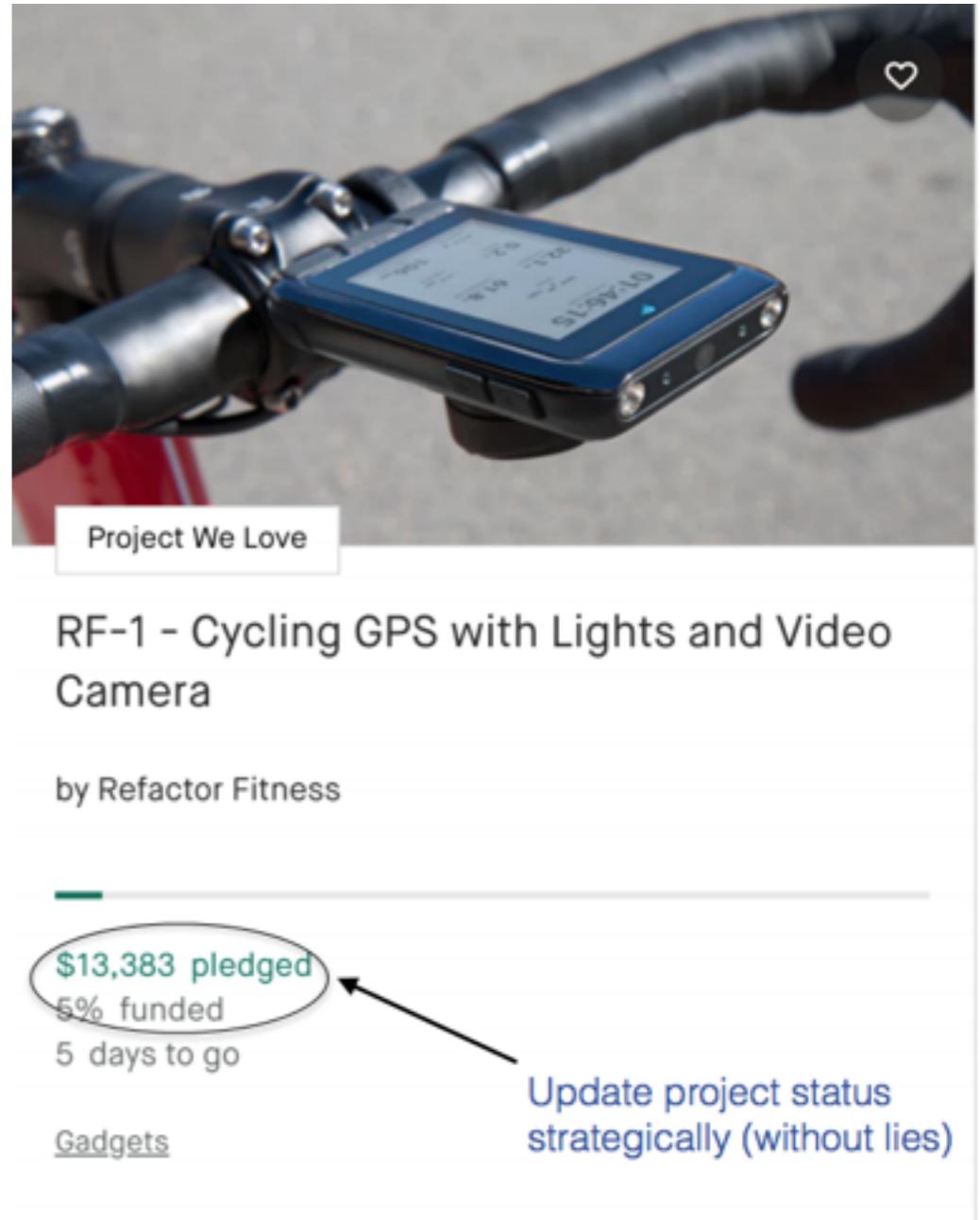
What the user finally got

Why do projects fail?

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).

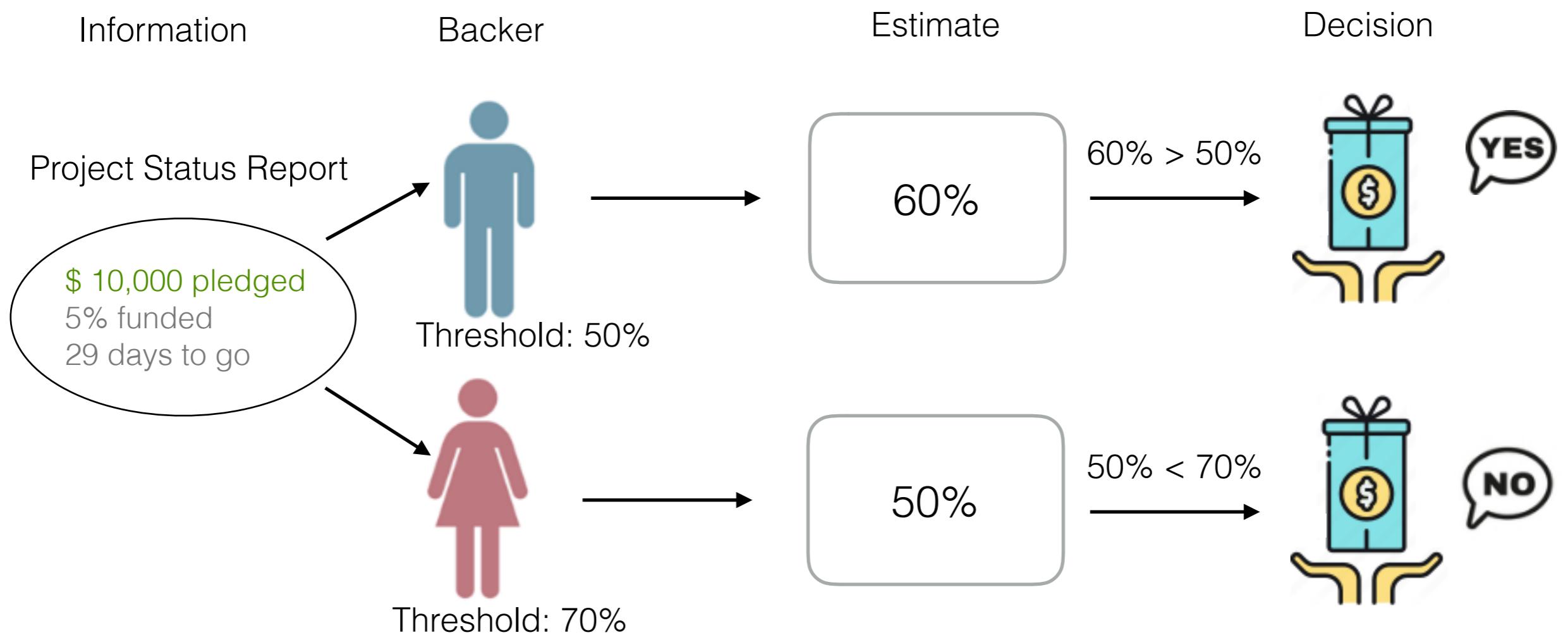


Credit: Kickstarter

Decision Models

- **The backers**

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



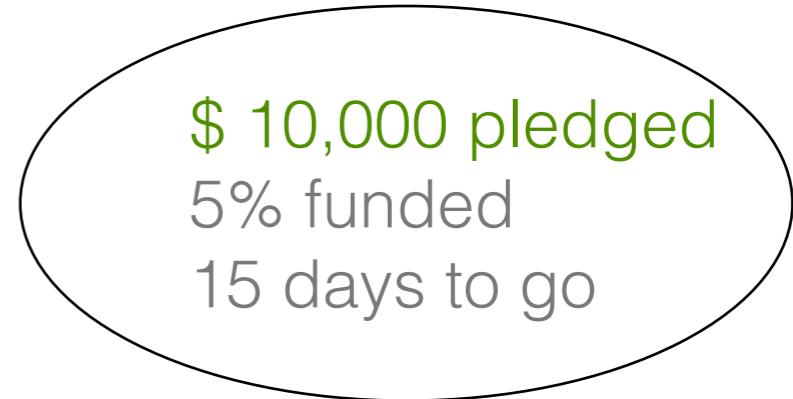
Order of Project Status Reports

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



Day 1

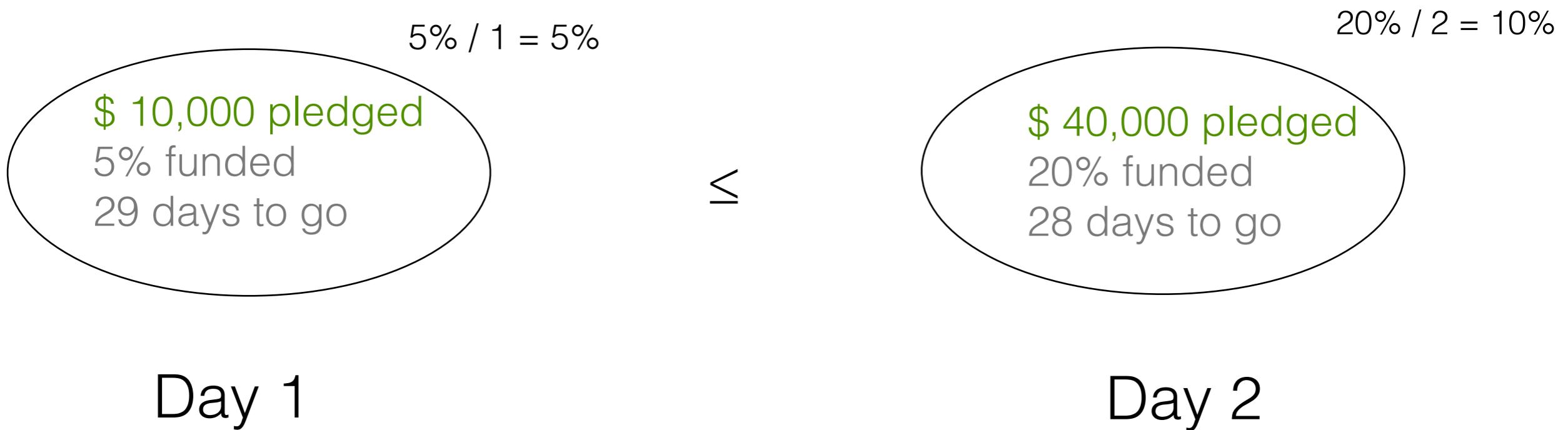
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Day 15

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.



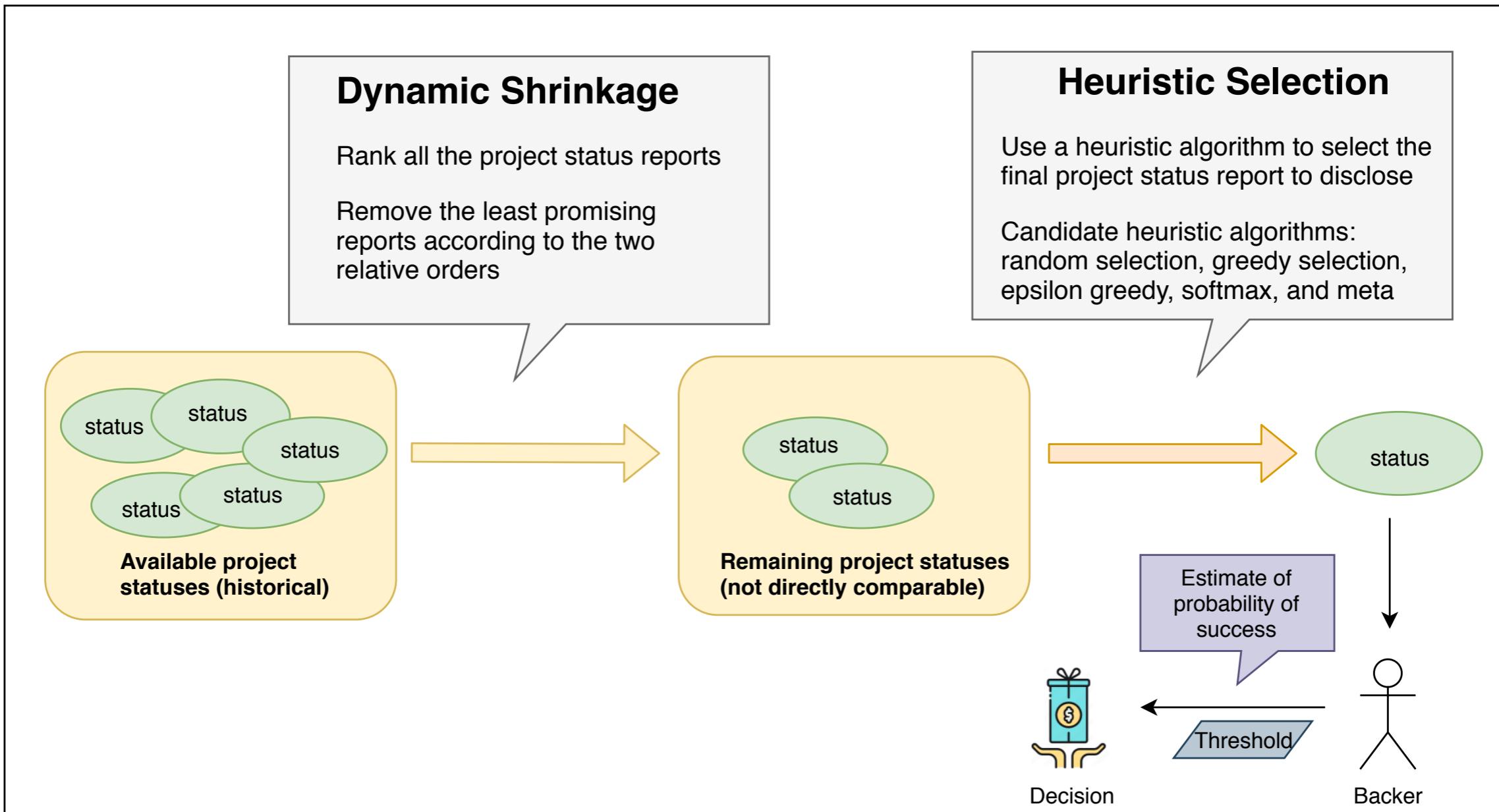
Excessive Information Shrinks Revenue

- 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



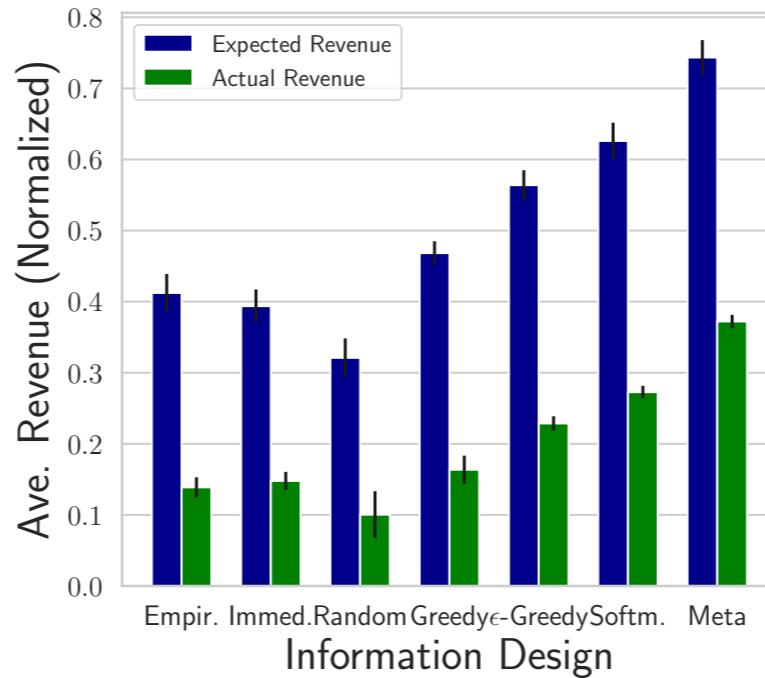
Experimental Settings

- **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.

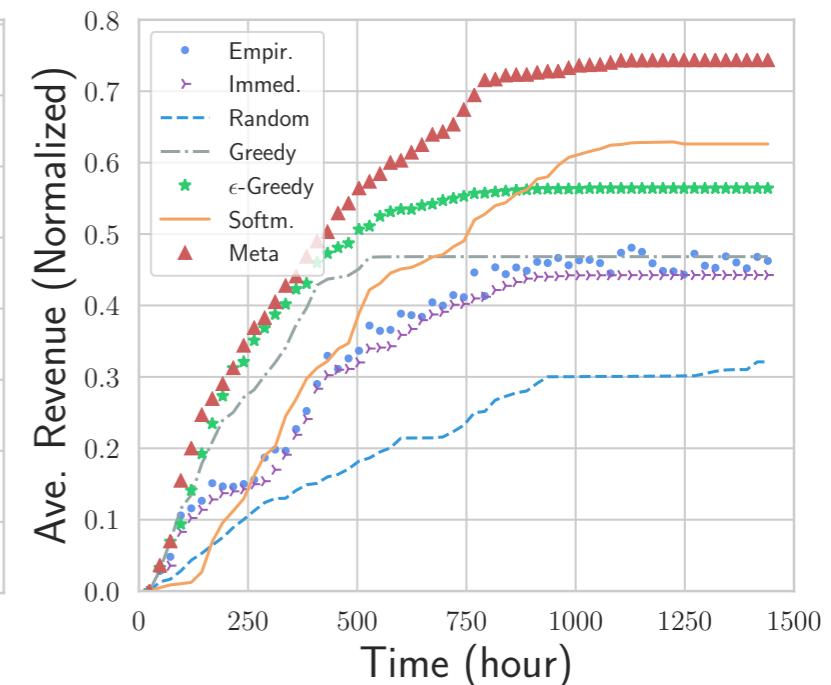
Simulation Results

• Observations

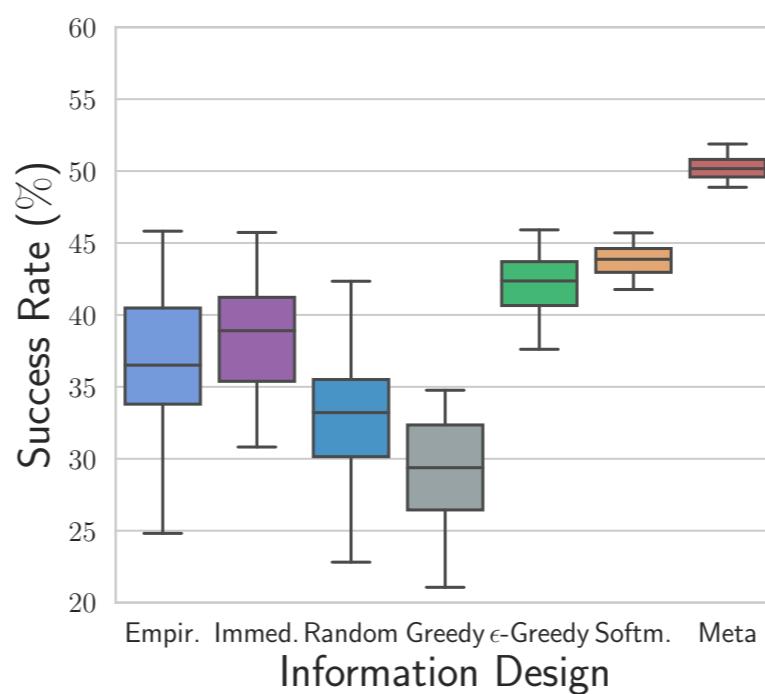
- Meta group performed consistently the best among all the groups in terms of both actual and expected revenue.
- Meta group had the highest project success rate.
- Meta group required the most computational time.



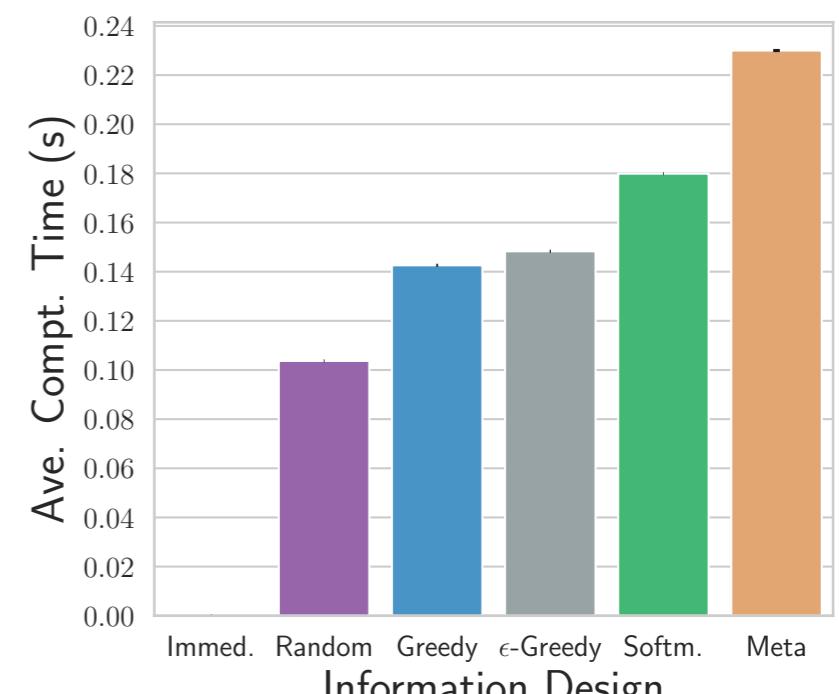
(a) Overall revenue ($t = 1440$)



(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, smart grids).
- Information design when agents use other decision models (e.g., no-regret learning).

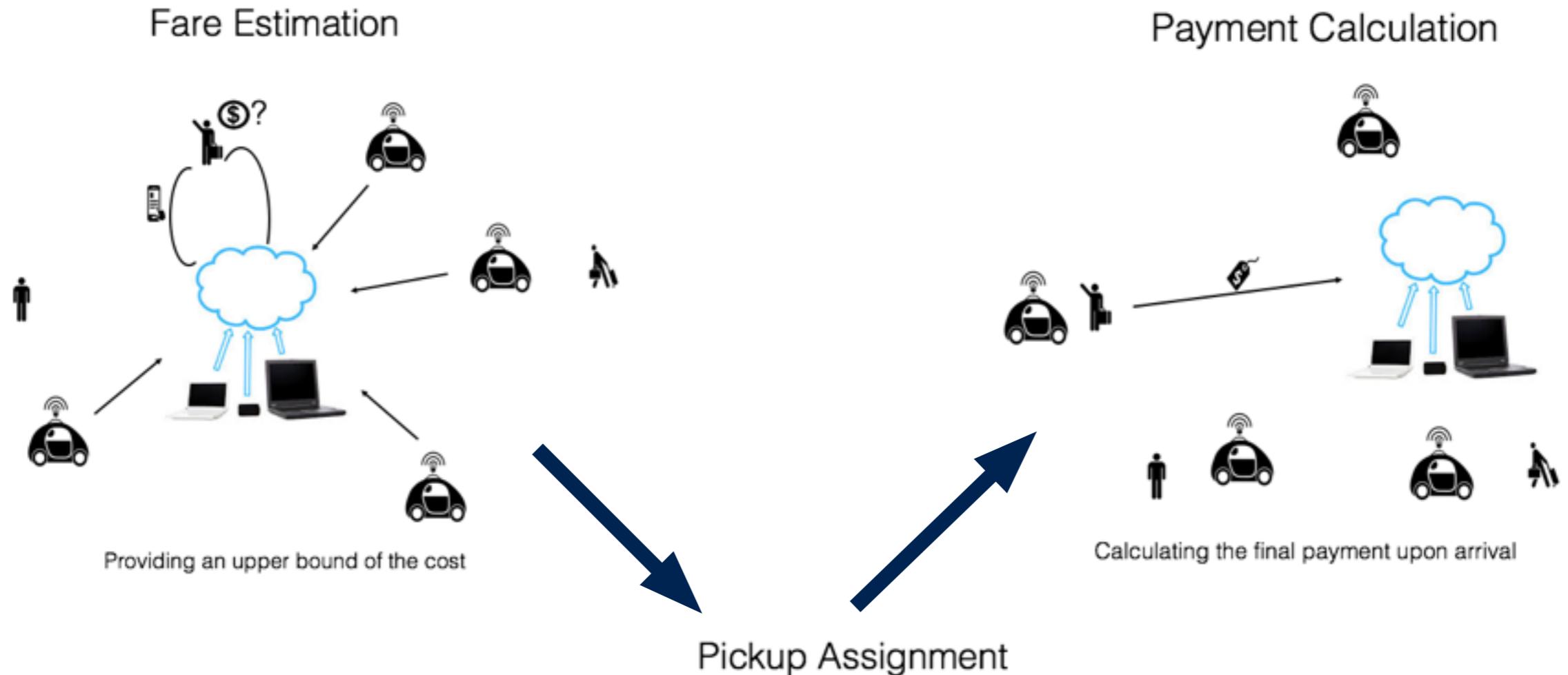
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Autonomous Mobility-on-Demand Systems



A Post-Price Online Mechanism for RideSharing



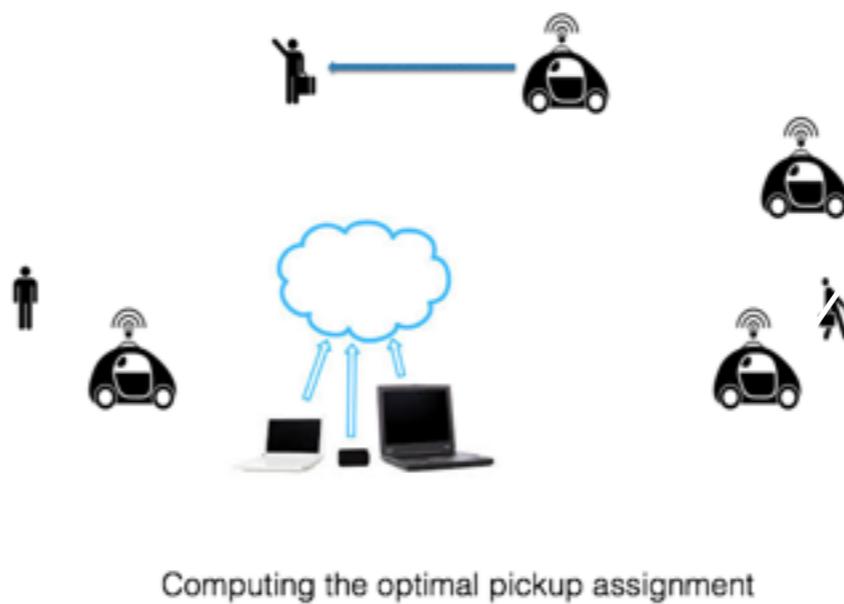
Objective:

To minimize the operational cost per unit demand.

Properties:

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

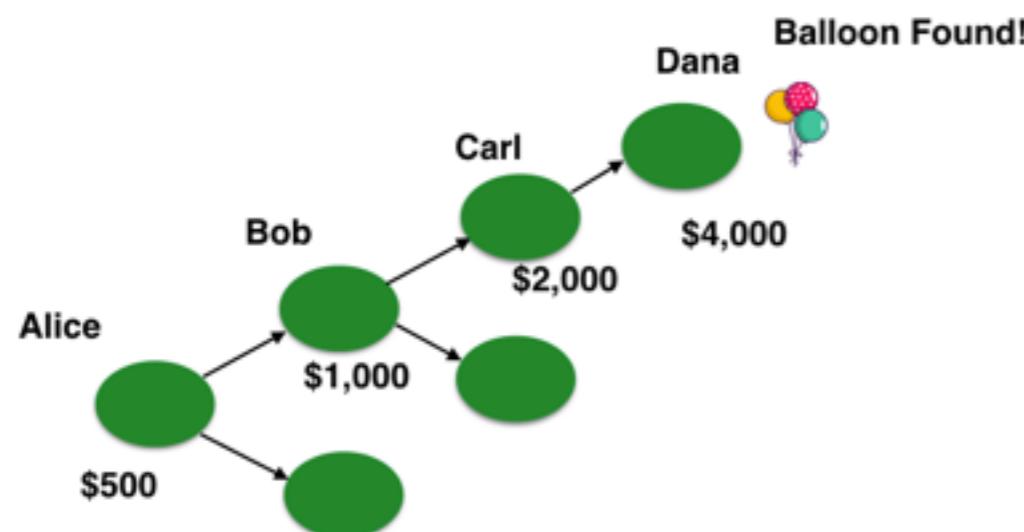
(Shen, Lopes, Crandall IJCAI'16)



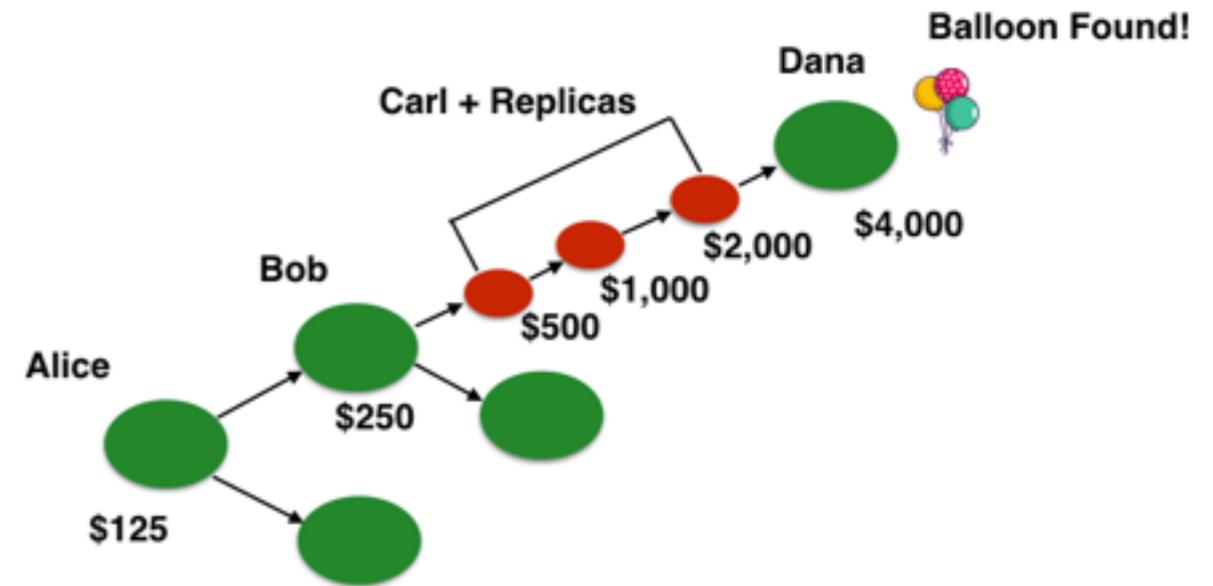
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Counteracting False-Name Attacks



(a) Honest diffusion



(b) Diffusion with manipulations

- **Multi-Winner Contests Mechanism:**

- Use the post-price mechanism to determine 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 conduct a contest among the players in the same subgraph and assign the rewards proportionally.

Counteracting Collusion

Generalized Contest Mechanism:

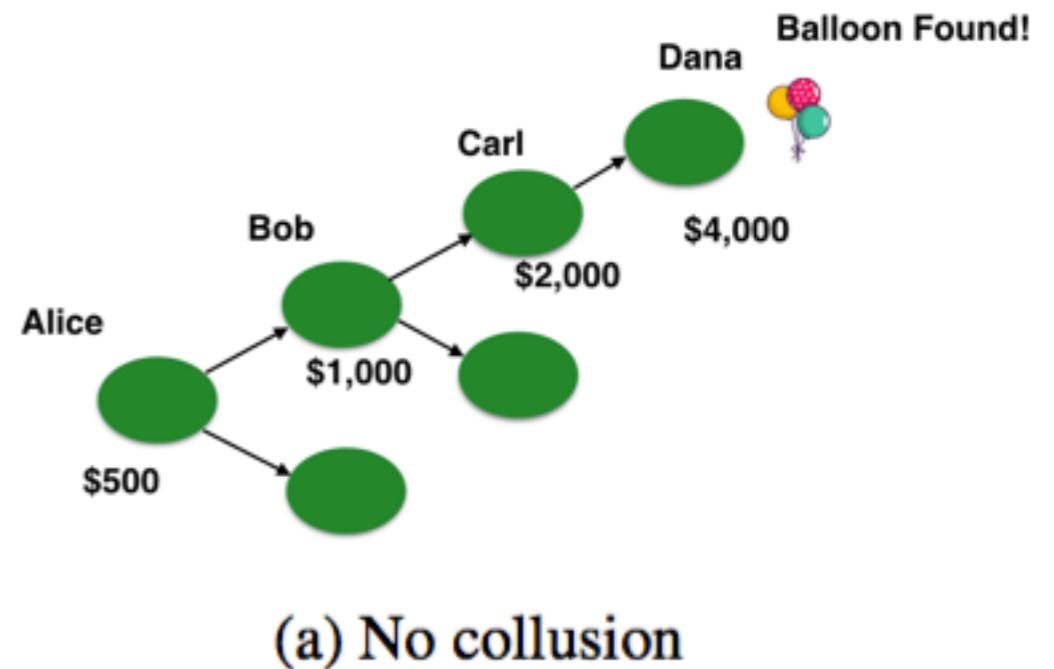
-Use a superadditive function to determine the virtual credits

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

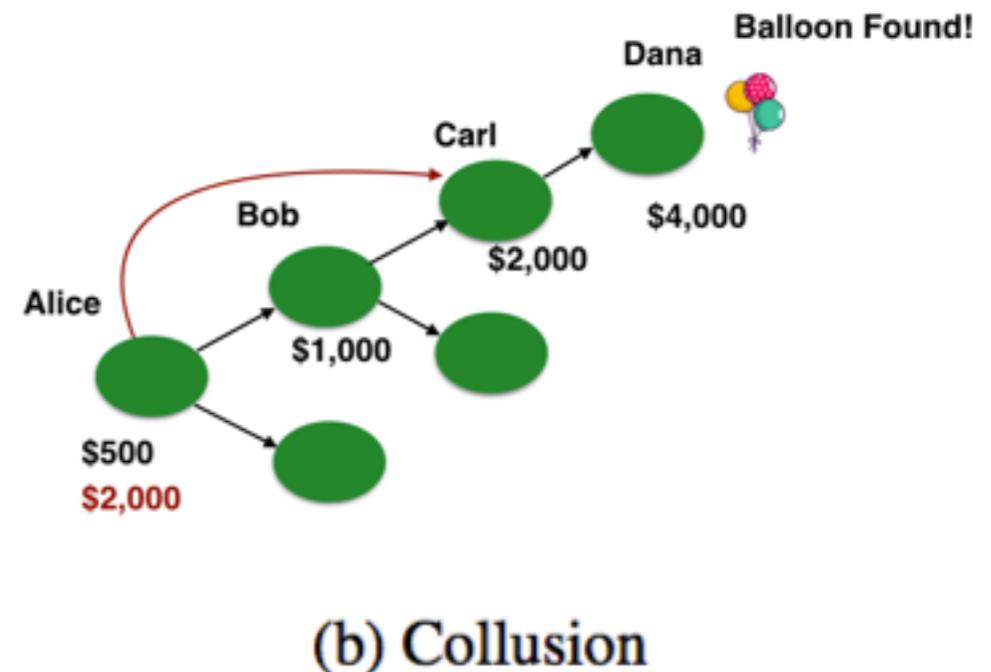
-Use an increasing and bounded function to cap the total diffusion rewards of a referral

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

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



(a) No collusion



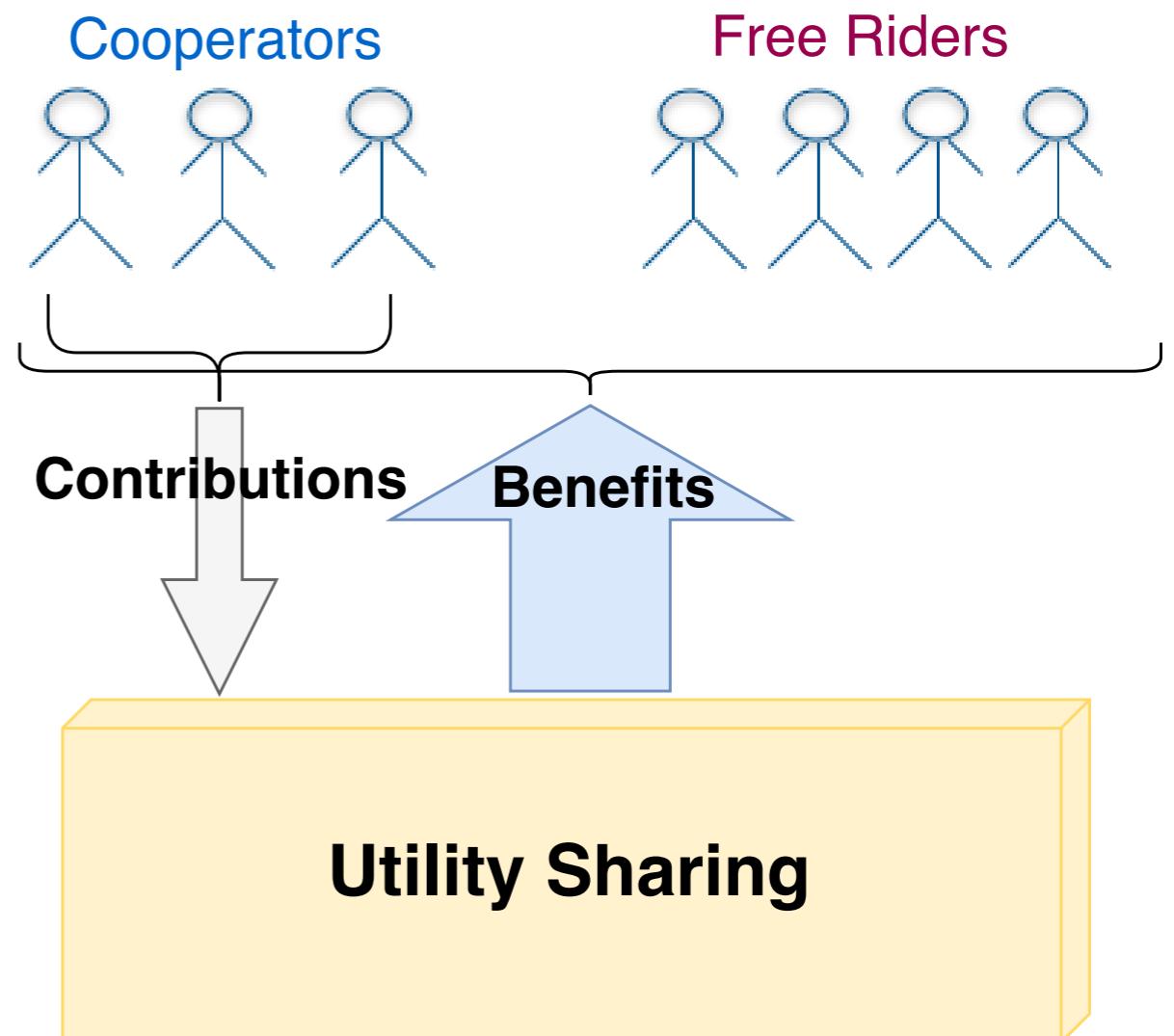
(b) Collusion

Countering Free Riding

Sequential Contest Mechanism:

- Conduct a sequential contest to attract players to contribute
- Select a private threshold to terminate the contest
- Reward the players that have made contributions before the termination of the contest

The Free Rider Problem



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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

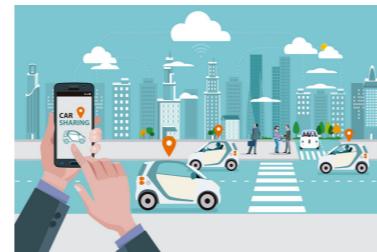
Approach: using contests to increase competitions

Results: robust to false-name attacks, collusion, free riding

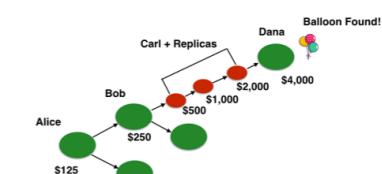
Crowdfunding



Ridesharing



Countering Manipulation



Future Directions

- **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 open source software development
 - Cybersecurity: eliminate/reduce the incentives of attacks
 - Cyber-Physical Systems: coordinate societies of autonomous machines

Thank You!

Q & A