Market Design

COMPSCI323: Computational Microeconomics

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- Market design objectives
- Market matching
- Role of prices in market clearing
- GSP auction (if time)
- Market design for two-sided service platforms (if time)

Market Design

"Market design is a kind of economic engineering"

- Microeconomics (Economics)
- Algorithms (Computer Science)
- Optimization (Operations Research)

Market Design

"Who Gets What - and Why"

- Market-clearing
  - Matching
  - Pricing
  - Value

Market-clearing in large markets with diversely held information is only possible with data-driven algorithmic solutions

Market Matching for Ads

Up to 10 billion impressions processed daily

Whole matching process takes no more than 100 miliseconds.
impression, SSP, adX (auction start), DSP (info gathering),
adX (bidding), ad loading

Dynamic matching problem with large state space

Note: analogy to financial markets
(Digital ads market smaller in $volume, but large in the #items transacted)

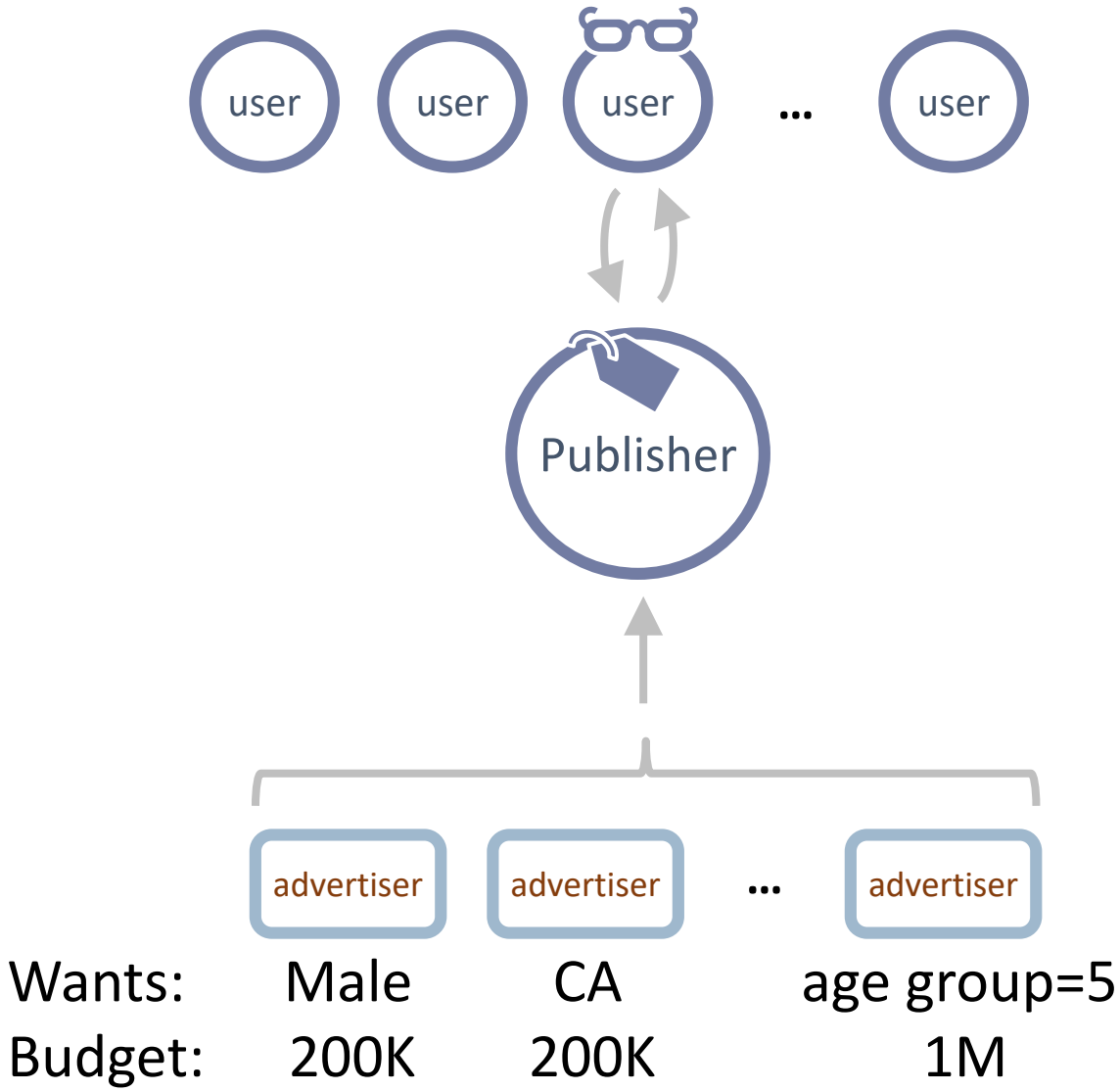
Optimal ad campaign portfolio, forwards, options, hedging, etc.

Consequence of a complex market. Nothing specific to ads.

Market Design Objectives

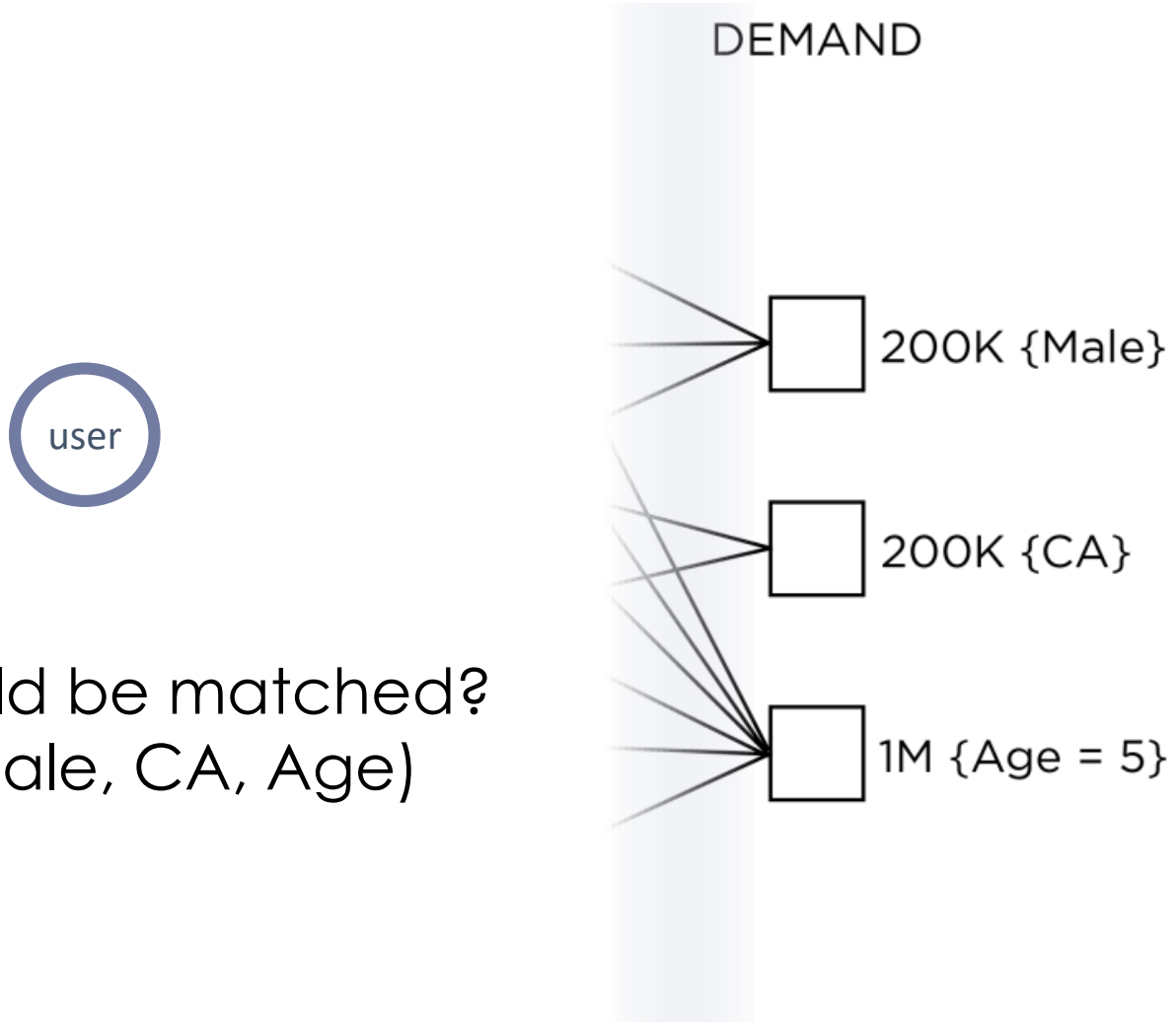
- Liquidity (#of trades)
- Profit maximization (maximize own payoff)
- Efficiency (maximize overall gains of trade)
- Stability (protect functioning of the market)

Market Matching for Ads



Who are the users?
Who will be the next user?
What is known about them?

Market Matching for Ads

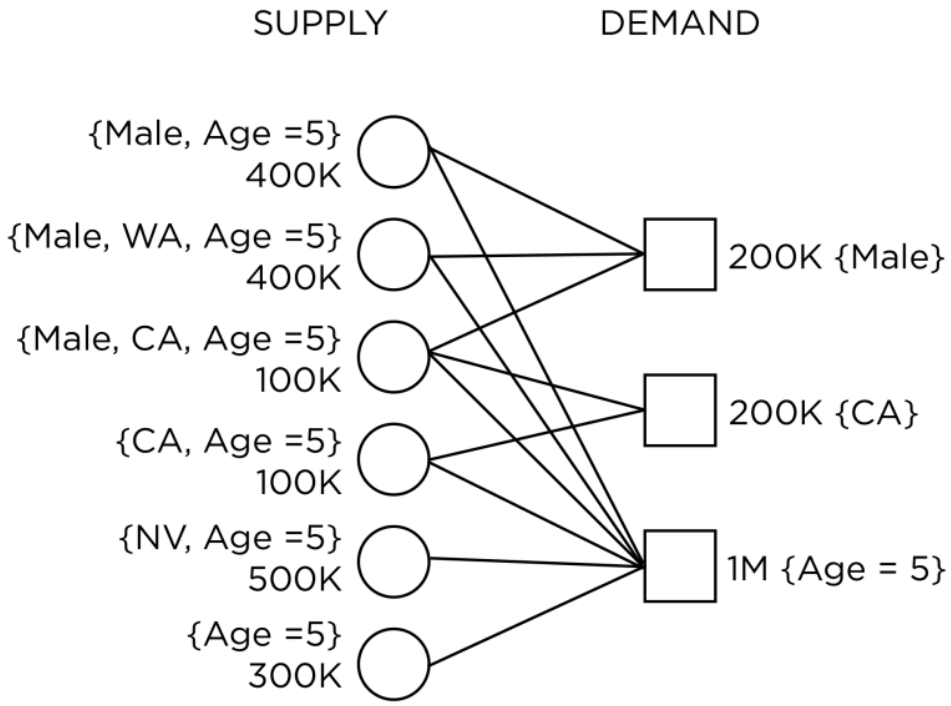


Which advertiser should be matched?
(even if known, say, Male, CA, Age)

At what price?

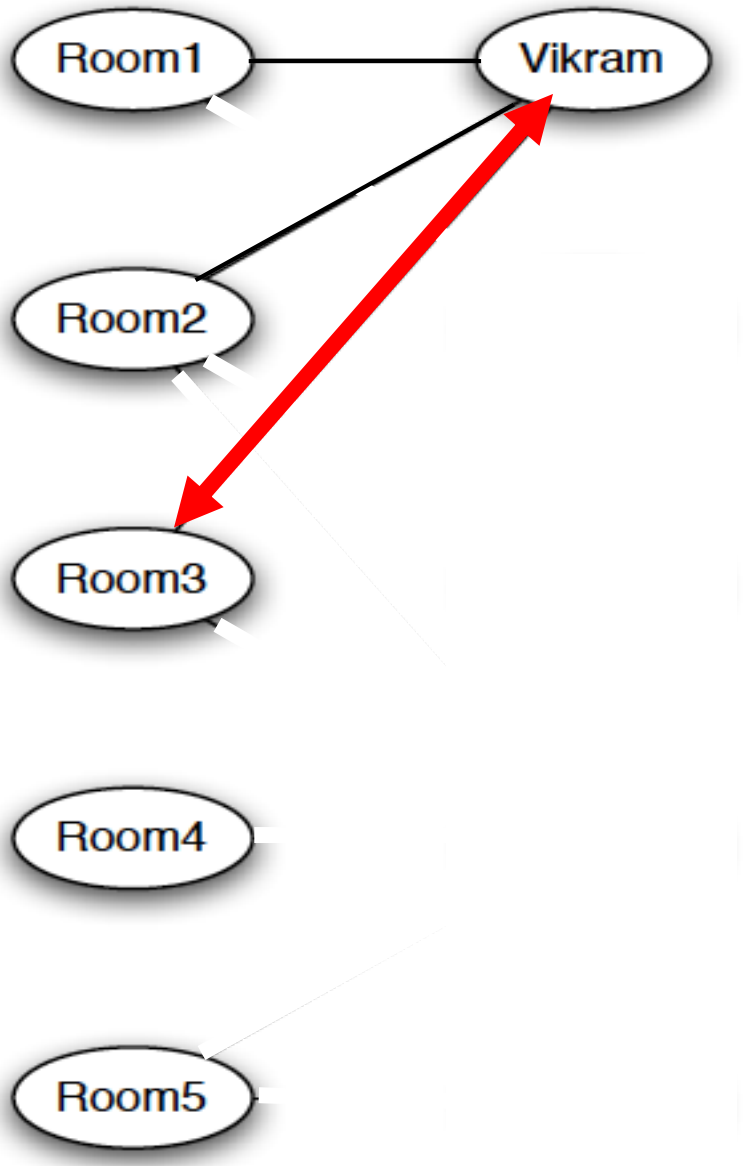
Decision-making under (future supply) uncertainty

Digital Ad Matching



Suppose you travelled to the future.
Suppose you know everything about these users, i.e., you know both sides of the market.

Matching



Myopic approach:

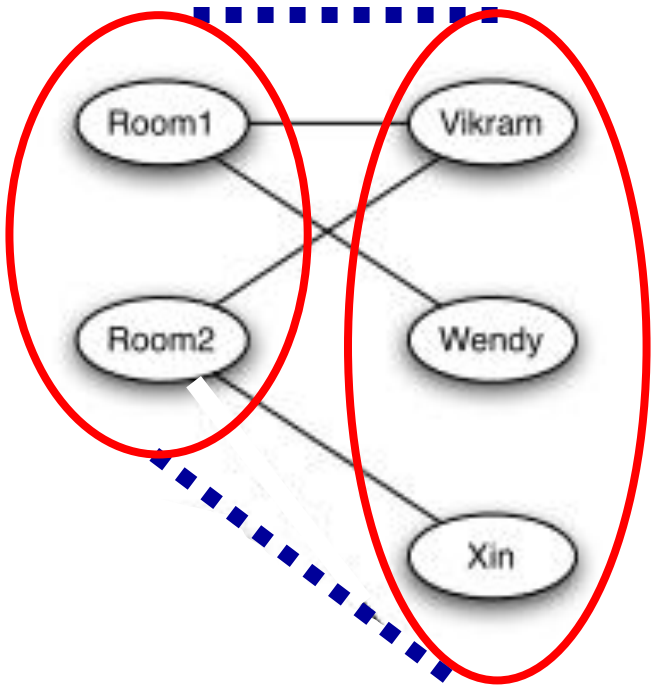
Easy

Suboptimal

Could do better: (also "easy" in computational sense)

Problematic if decisions made dynamically.

Matching: Perfect or Constricted Set

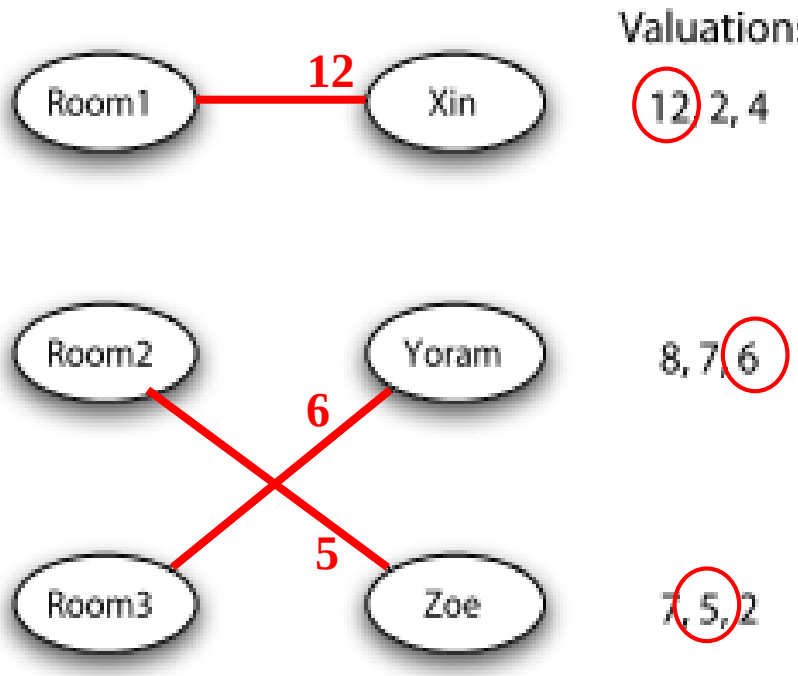


An obstacle to a perfect match:

Constricted Set

If no perfect matching, there exists a constricted set (bottleneck)

Matching with Valuations



Maximize overall value

Computationally "easy" (but not myopic)

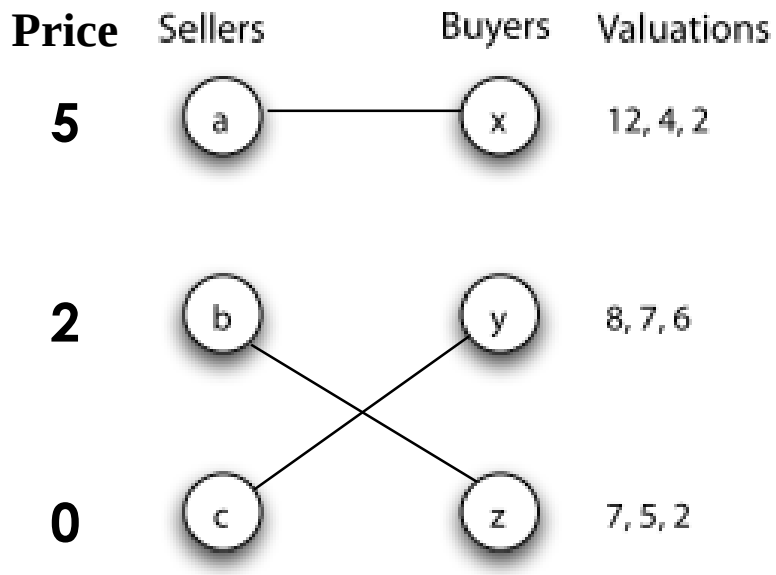
Max weight matching

12+6+5=23

Maximizing overall value does not maximize value for each individual participant.

- Raises market participation concerns
- Invites strategizing, misreporting, etc.
- Hurts market functioning: could lead to unraveling

Market-Clearing Prices

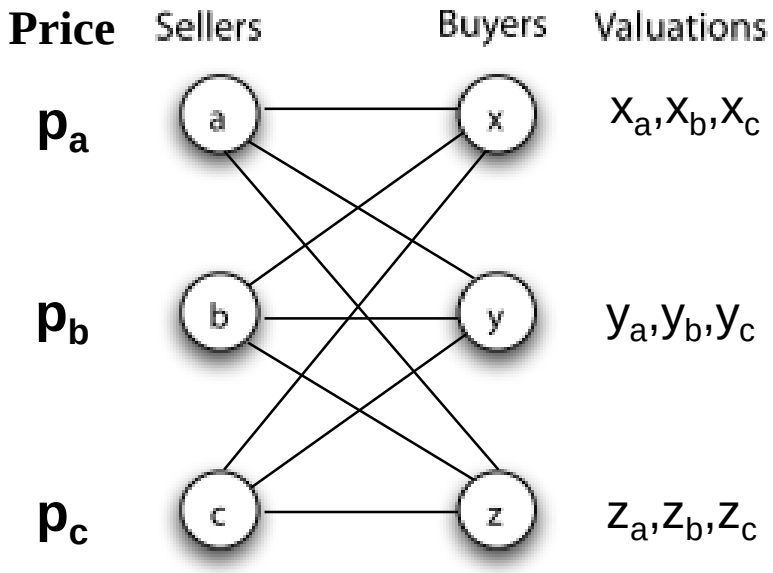


Every buyer wants the item that maximizes their payoff:
value-price

Overall value:
(12-5)+(5-2)+(6-0) (buyers)
+5 +2 +0 (sellers)
=23

Market-clearing prices:
- Maximize overall value
- Maximize buyer payoff

Market-Clearing Prices



Market-clearing prices:

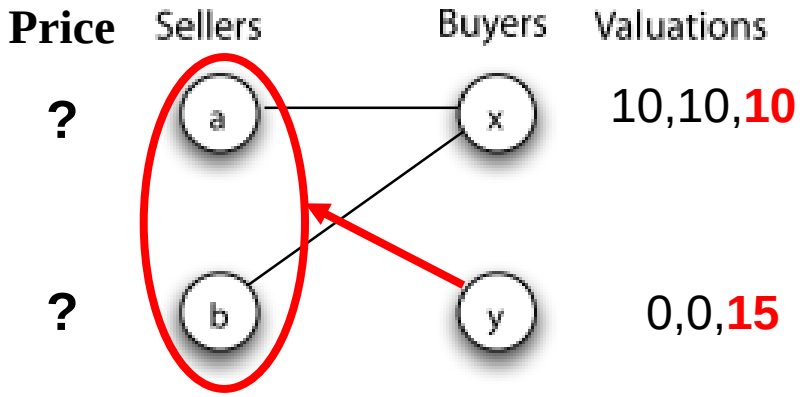
- Maximize overall value
- Maximize buyer payoff
- Not unique
- Differ across items

Do they always exist?

For any set of buyer valuations for items, market-clearing prices exist.

- "easy" to compute (not myopic)
- could choose to optimize buyer (or seller) payoffs only
- can't do it in general with a single price.

Market-Clearing Prices

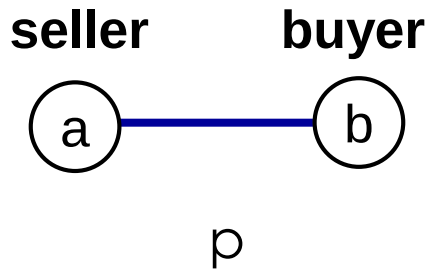


- Market-clearing item prices might not exist
  Need bundle prices
  (exponentially many, "hard" to compute)

- Even bundle prices might not clear the market.
  Need non-anonymous prices
  (price discrimination by buyer identity)

Serious fairness, regulatory, etc. issues

Trade



Buyer payoff: b-p
Seller payoff: p-a
Gains of trade: (b-p)+(p-a)= b-a

Gains of trade is the difference between buyer's and seller's valuations (or zero if trade not possible)

- Note: price is transactional

Market design objectives:

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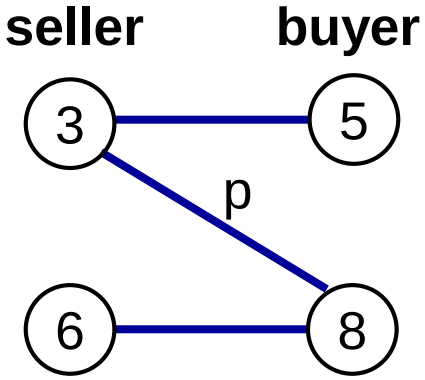
- Profit maximization (maximize own payoff)
- Efficiency (maximize overall gains of trade)
- Stability (protect functioning of the market)

Trade



Buyer payoff: (8-p)
Seller payoff: (p-3)
Gains of trade: (8-p)+(p-3)=8-3=5

Objective: maximize overall gains of trade

Any p in [3,8] works.

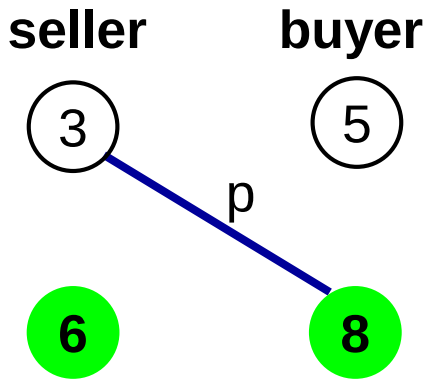
p=3 maximally favors buyer side

p=8 maximally favors seller side

p=5.5 splits gains of trade evenly across two sides

(Note: could be more than one trade with possibly different transaction prices)

Trade



Buyer payoff: (8-p)
Seller payoff: (p-3)
Gains of trade: (8-p)+(p-3)=8-3=5

Objective: maximize overall gains of trade

Who gets the items?

Those who value the items the most.

- **Allocative efficiency**

Market Design Objectives

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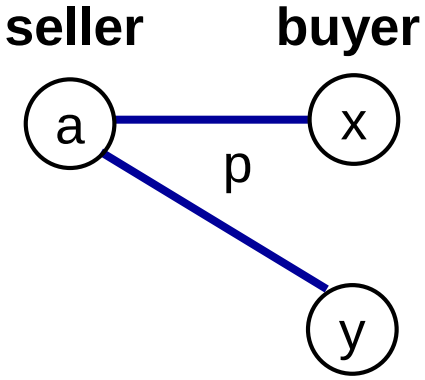
Ensure that everyone has an incentive to participate:

- should not be able to get a better deal elsewhere

Market-Clearing



Who should get the item?
At what price?

Buyers might not want to reveal their values.

Auctions to the rescue:

Dutch ~ 1st Price Auction

- buyers should not report truthfully
- complicated equilibrium bidding strategies

English ~ 2nd Price Auction
(a.k.a. Vickrey Auction)

- truthful report is a dominant (and simple) strategy

Generalizing Vickrey

- Generalizes for multiple items, buyers valuing bundles.

  "Vickrey-Clarke-Groves (VCG) mechanism"

  efficient, truthful reporting dominant strategy

  However:

  - Unreasonable informational demand on buyers
  - Computationally hard (understatement)
  - Accentuated revenue deficiency

- Important (but incorrect) "generalization"

  Generalized Second Price Auction

Click-Through Rate (CTR)

- Webpage real estate:

  location, location, location!

- CTR: a measure of quality of the location

  #clicks / #pageviews

- Fixed ad slots:

  Top > … > Side Top > … > Side Bottom

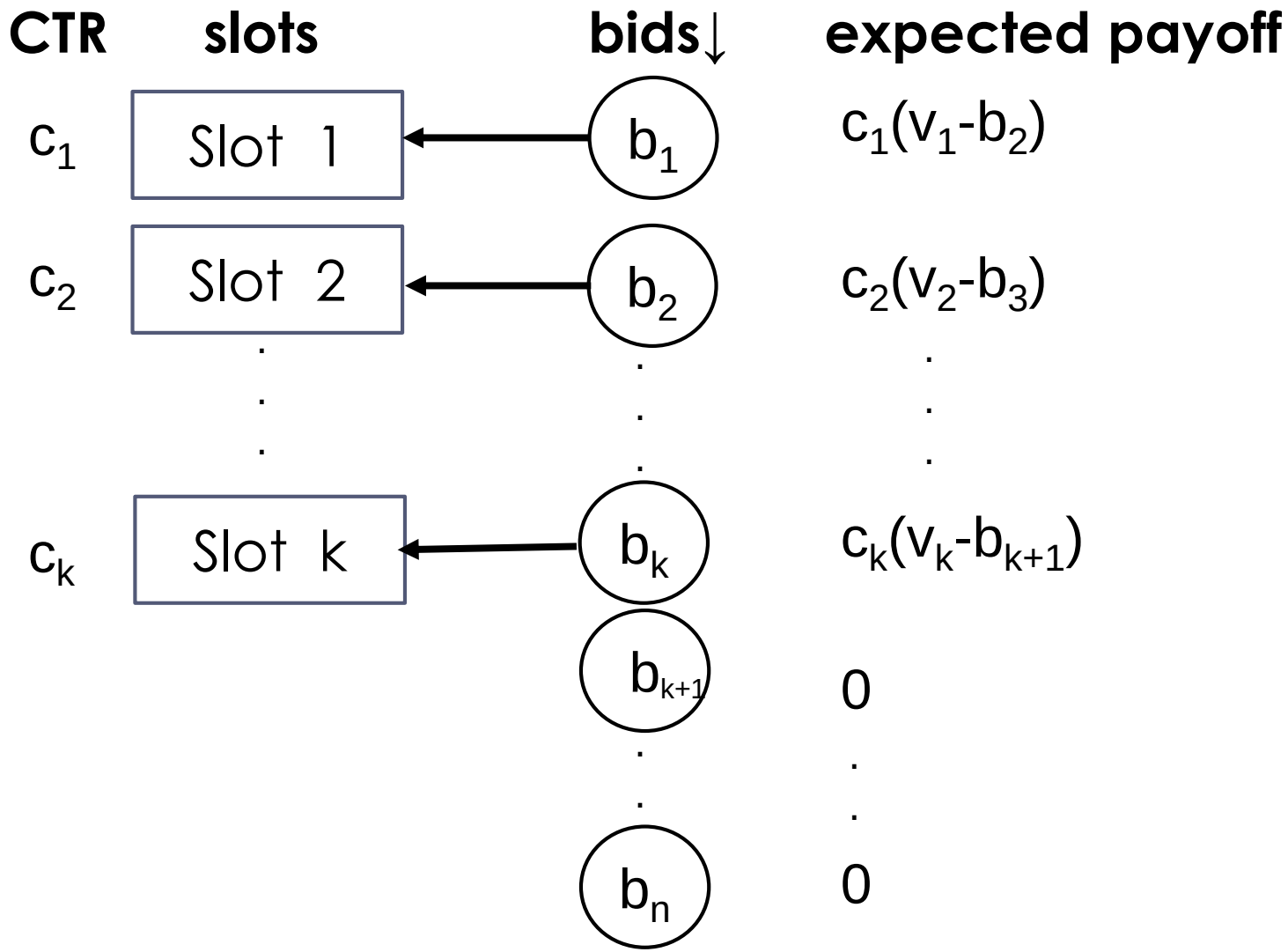
  CTR: c_T > … > c_{ST} > … > c_{SB}

- Advertiser value:

  v if click,

  0 if no click.

GSP Auction


CTR
slots
bids↓
expected payoff
c_1
Slot 1
b_1
$c_1(v_1-b_2)$
c_2
Slot 2
b_2
$c_2(v_2-b_3)$
c_k
Slot k
b_k
$c_k(v_k-b_{k+1})$
b_{k+1}
0
b_n
0

GSP Auction

- Highest bidder gets top ad slot,
  pays 2nd highest bid value (only if user clicks)
- 2nd highest bidder gets second ad slot,
  pays 3rd highest bid value (only if user clicks)

…

In practice, some additional enhancements:

- Bidder specific CTRs
- Bids adjusted for advertiser "quality": q*b
  (low quality bidders have to bid higher)
- Reserve prices
- Advertiser budgets
- Bidding on keyword combos, negative keywords, etc.

GSP Auction

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  pays 2nd highest bid value (only if user clicks)
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…

If only two slots: exactly 2nd Price (Vickrey) auction.

- Efficiency?

- Truthful reports?

Digital Ad Markets

- If valuations known: market-clearing prices

- If valuations private:
  - Vickrey computationally intractable
    - communications burden on bidders
    - non-transparent
  - GSP not truthful

- If buyers have budgets, or value bundles:
  - Hard market design problem

Emergence of multiple markets

heterogeneous advertiser valuation structures

fragmented supply (webpages with ad slots)

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Some practical obstacles

- Heterogeneity of goods
- Heterogeneity of market participants' preferences
- Multiple demand (demand for bundles)
- "Incumbent" market-clearing practices
- Constraints due to outdated regulation and "customary" ways of conducting (similar) business.

Market Design for Two-Sided Service Platforms

Data-driven Technologies

- Market matching
- Pricing
- Ease of use (both sides), transaction costs
- Assurances/Trust/Quality

How to Match Riders and Drivers?

How many blocks radius?

Should the closest driver be matched with the request?

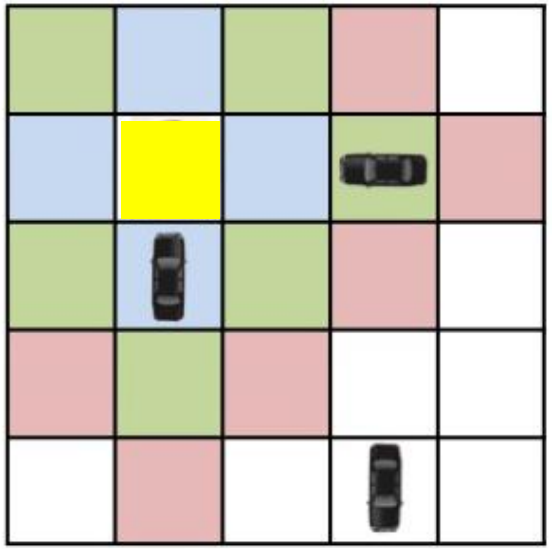
Perhaps (define “closest”)

Depends on the state of the system:

- supply/demand forecast
- typical driver route/pattern
- typical rider/driver behavior
- rider/driver ratings

Note: asymmetric information

- rider does not see all drivers
- driver does not know dest.



Hard optimization problem

- dynamic updates
- flexibility of (not) matching

Competitive advantage in technology

Surge Pricing?

Why even get in the middle and set prices?

Price-gauging?

Allows for dynamic management of the supply

Increase number of matches (liquidity)

Improving market efficiency

Role of Ratings

Driver ratings:

Quality assurance and trust-building

In general, ratings are central to recommendation and feedback systems in online marketplaces (e.g., managing and exploiting long tail).

Rider ratings:

Different policies, even among ride-hailing platforms

Market Design for Two-Sided Service Platforms

- Data-driven dynamic market matching is a technological competitive advantage.
- Surge pricing dynamically manages supply. Improves (likelihood of) matches and market efficiency.
- Ratings ensure quality/assurance/trust for both market sides.

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