

A complex network diagram with numerous nodes and edges, rendered in shades of pink and red, forming a dense web-like structure.

DCS/CSCI 2350:
Social & Economic Networks

Sponsored Search Markets
Reading: Chapter 15 [EK]
Video Lecture:
<http://bit.ly/vcg-gsp>

Mohammad T. Irfan

1

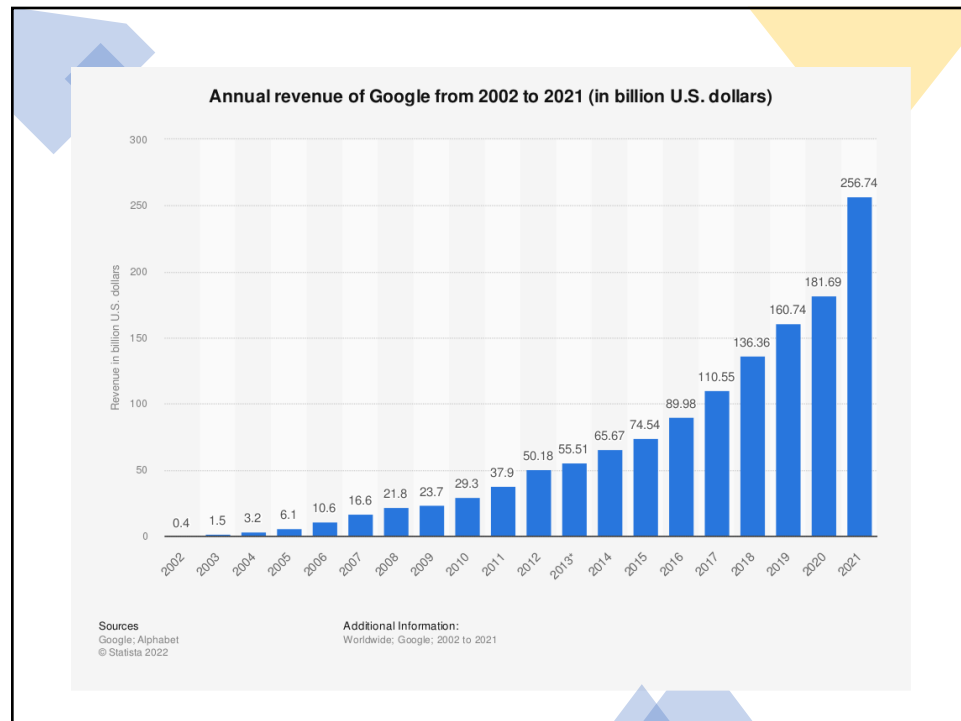
A vertical strip of a network diagram, showing a portion of the dense web-like structure of nodes and edges in pink and red.

How does Google/Microsoft/... make money from web search?

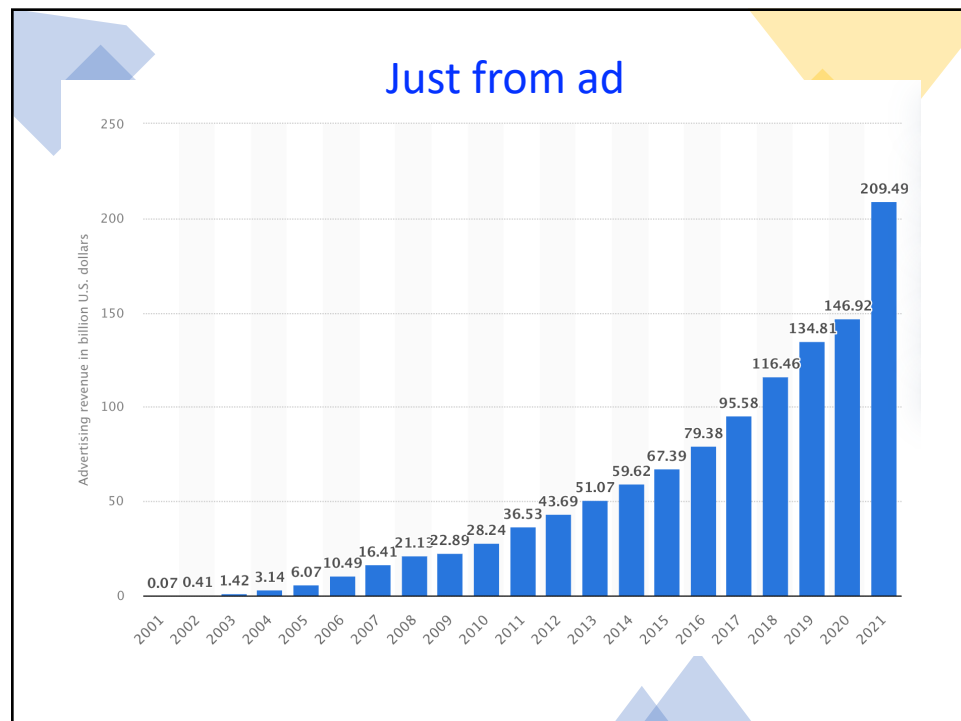
Connection with

- *Auctions (last topic)*
- *Matching markets (next topic)*

3



4



5



6

Agenda

- Brief history
- Conventions
- Vickrey-Clarke-Groves (VCG) auction
- Generalized second-price (GSP) auction

7

Search market

- Early days: TV model
 - Yahoo! negotiates deal with advertisers
 - Shows the ad a certain number of times
 - Effective?
- Since year ~2000
 - Keyword based advertising by Overture (bought out by Yahoo! in 2003 for \$1.63B)
 - New market

8

Conventions

1. Pay per click
 - Advertisers pay Google on per click basis
 - How much?
2. Price setting by auction
 - Fixed price for keywords doesn't work. Why?
 - Main challenge in auction: multiple ad spots

9

Preliminaries 1

- Search keyword (e.g., pizza)
- Multiple ad slots

Slot	Ad
1	?
2	?
3	?

10

Preliminaries 2

Click-through-rate (CTR) of a slot

- # of clicks/hr for that slot
- Assumptions
 - Advertisers know CTR
 - CTR solely depends on the slot, not on the ad

CTR	Slot
10 clicks/hr	1
5 clicks/hr	2
2 clicks/hr	3

11

Preliminaries 3

Revenue/click

- Advertisers get some revenue/click
- Assumption
 - Solely depends on the advertiser, not on the slot
 - Private information

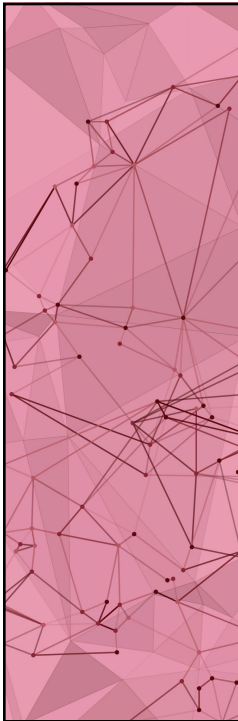
Advertiser	Revenue/Click
x	\$3/click
y	\$2/click
z	\$1/click

12

First-price auction?

- Did not work
 - Underbidding
 - Turbulent market
- Second-price auction for multiple items?

14



Vickrey-Clarke-Groves (VCG) mechanism

15

William Vickrey Facts



Photo from the Nobel
Foundation archive.

William Vickrey
The Sveriges Riksbank Prize in Economic Sciences in
Memory of Alfred Nobel 1996

Born: 21 June 1914, Victoria, BC, Canada

Died: 11 October 1996, Harrison, NY, USA

Affiliation at the time of the award: Columbia University,
New York, NY, USA

Prize motivation: “for their fundamental contributions to
the economic theory of incentives under asymmetric
information”

Prize share: 1/2

<https://www.nobelprize.org/>

16

VCG mechanism

Alternative view of second-price auction

1. Outcome maximizes **social welfare** (sum of valuations)
2. Winner is charged the **harm** they cause to the other bidders
 - Winner blocks the 2nd highest bidder (not 3rd, 4th, etc.)
 - Therefore, winner pays the harm = 2nd highest bid

17

How to calculate harm?

Harm caused by a bidder:

Increase in how much others **get** in an alternative universe where that bidder is not there

18

VCG price = harm

Each bidder pays the harm they cause to the other bidders

harm = total amount everyone would've been better off if that bidder were not there

19

VCG example

CTR #clicks/hr	Slot	Advertiser	Revenue/Click \$/click	Valuation \$/hr
10	1	x	3	30, 15, 6
5	2	y	2	20, 10, 4
2	3	z	1	10, 5, 2

} Private information of the advertisers

↓

Slot	Advertiser	Valuation \$/hr
1	x	30, 15, 6
2	y	20, 10, 4
3	z	10, 5, 2

How much should x, y, and z pay?

23

Slot	Advertiser	Valuation \$/hr
1	x	30, 15, 6
2	y	20, 10, 4
3	z	10, 5, 2

With x

Slot	Advertiser	Valuation \$/hr
1		
2	y	20, 10, 4
3	z	10, 5, 2

Without x

y 's increase in valuation = $20 - 10 = 10$
 z 's increase in valuation = $5 - 2 = 3$

 Harm caused by x = $10 + 3 = 13$

Similarly:

Harm caused by y = z 's increase in valuation = $5 - 2 = 3$ (x still gets 1 in y's absence)

Harm caused by z = 0 (x and y are unchanged in z's absence)

24

Steps of VCG mechanism

1. Ask bidders to submit valuations (CTR $\times$ revenue/click)
 - Valuations are independent and private
 - Truth-telling is a dominant strategy
2. Choose an assignment that maximizes social welfare (i.e., sum of valuations)
3. Charge bidders their respective VCG price (harm calculation)

25

VCG pros and cons

- Pros
 - Unique outcome
 - Maximizes social welfare
 - Bidders will submit their true valuations
- Cons
 - Complex for bidders
 - Difficult to explain an outcome to bidders

27

[Superficially] Generalized
Second-Price (GSP) Auction

29

GSP auction

1. Each advertiser bids a single number:
\$ per click
2. Google gives the i -th slot to the i -th highest bidder, who pays the bid of $(i+1)$ -st highest bidder

30

Analysis

- Varian (2007), Edelman, Ostrovsky, Schwartz (2007)
- Game
 - Players: bidders or advertisers
 - Strategy: bid amount
 - Payoff: revenue – price paid
- Nash equilibrium
 - Nobody has any incentive to change the bid unilaterally

31

Examples

- Bidders may gain more by lying
- Multiple Nash equilibria possible
- Comparison with VCG

32

Comparison:
VCG vs GSP

33

VCG example

CTR #clicks/hr	Slot	Advertiser	Revenue/Click \$/click	Valuation \$/hr
10	1	x	3	30, 15, 6
5	2	y	2	20, 10, 4
2	3	z	1	10, 5, 2



Slot	Advertiser	Valuation \$/hr
1	x	30, 15, 6
2	y	20, 10, 4
3	z	10, 5, 2

How much should x, y, and z pay?

34

Slot	Advertiser	Valuation \$/hr
1	x	30, 15, 6
2	y	20, 10, 4
3	z	10, 5, 2

Slot	Advertiser	Valuation \$/hr
1		
2	y	20, 10, 4
3	z	10, 5, 2

With x

Without x

y's increase in valuation = $20 - 10 = 10$

z's increase in valuation = $5 - 2 = 3$

Harm caused by x = $10 + 3 = 13$

Similarly:

Harm caused by y = z's increase in valuation = $5 - 2 = 3$ (x still gets 1 in y's absence)

Harm caused by z = 0 (x and y are unchanged in z's absence)

35

GSP example

CTR #clicks/hr	Slot	Advertiser	Revenue/Click \$/click	Bid \$/click
10	1	x	3	2
5	2	y	2	1
2	3	z	1	0.5



Slot	Advertiser	Payoff \$/hr
1	x	$(3-1) \times 10 = 20$
2	y	$(2-0.5) \times 5 = 7.5$
3	z	$(1-0) \times 2 = 2$

36

GSP pros

- Single item: GSP = VCG = 2nd price auction
- Pros
 - Easy to understand (contrast w/ VCG)
 - Nash equilibrium always exists
 - One Nash eq. maximizes social welfare

37

GSP cons

- Cons (for multiple items or slots)
 - Bidders may not be truthful (contrast w/ VCG)
 - May not optimize social welfare (contrast VCG)
 - Multiple Nash equilibrium possible (contrast VCG)
- Maximizes Google's revenue? **Maybe!**