GOOGLE ADWORDS

Optimizing Online Advertising

15.071x – The Analytics Edge

Google Inc.

- Provides products and services related to the Internet
  - Mission: "… to organize the world's information and make it universally accessible and useful."
- Most widely known for its search engine (www.google.com)
  - User enters a query; Google returns links to websites that best fit query

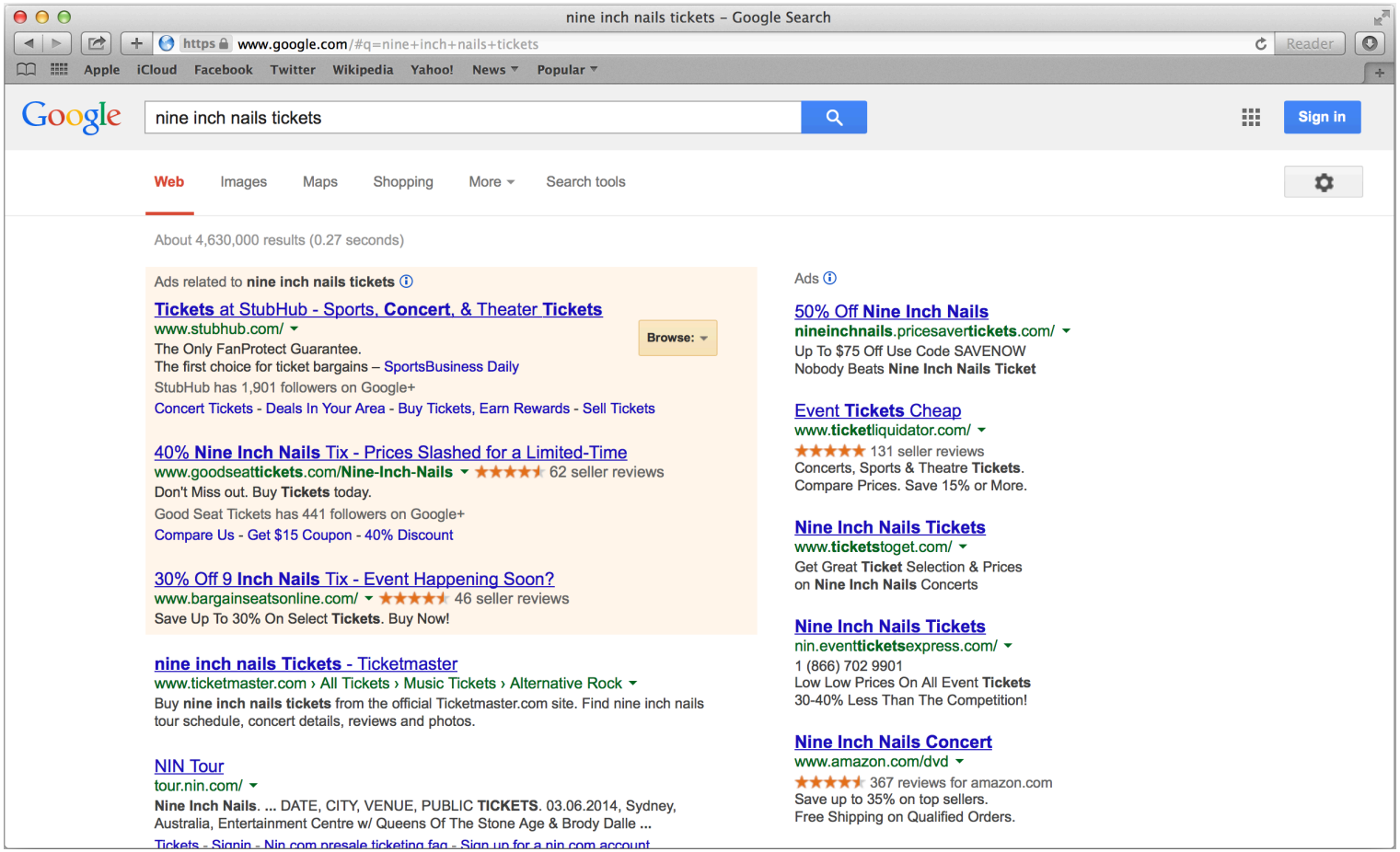
History of Google

- 1996 – Sergei Brin and Larry Page, graduate students at Stanford, working on a research project
  - How to measure importance of any webpage using links on the internet
- 1998 – Incorporated Google as a company and received first funding; database of 60 million webpages
- 2004 – Initial Public Offering
- 2007 – Google acquires YouTube and other companies
- 2013 – **More than 1 billion unique monthly visitors**

Google's Business Model

- Google search engine is free to use, so how does Google make money?
- Answer: **online advertising**

Example of Sponsored Ads



Google Advertising - AdWords

- Why do companies advertise on Google?
  - Google receives heavy traffic
  - Search pages are formatted in a very clean way
  - Companies can choose which types of queries their ads will be displayed for; better targeting
- 97% of Google's revenues come from AdWords

How does Advertising on Google work?

1. Advertisers place bids for different queries in an auction
2. Based on bids and *quality score* (fit of advertiser and ad to the queries), Google decides price-per-click of each advertiser and each query
3. Google then decides how often to display each ad for each query

Price-per-click (PPC)

- For each query, Google decides each advertiser's **price-per-click (PPC)**
  - How much advertiser pays Google when user clicks ad for that query
- Each advertiser also specifies a **budget**
  - Each time user clicks on advertiser's ad, budget is depleted by PPC amount

Example of price-per-click

Advertiser	Query 1 ("4G LTE")	Query 2 ("largest LTE")	Query 3 ("best LTE network")
AT&T	$5	$5	$20
T-Mobile	$10	$5	$20
Verizon	$5	$20	$25

Advertiser	Budget
AT&T	$170
T-Mobile	$100
Verizon	$160

-T--Mobile--

$100

5 × $10 = -$50

$50

Click-through Rate (CTR)

- Advertiser only pays Google if the user *clicks* on the ad
- The probability that a user clicks on an advertiser's ad is the **click-through rate (CTR)**
  - Can also think of as "clicks per user"

Example of click-through rate

Advertiser	Query 1 ("4G LTE")	Query 2 ("largest LTE")	Query 3 ("best LTE network")
AT&T	0.10	0.10	0.08
T-Mobile	0.10	0.15	0.10
Verizon	0.10	0.20	0.20

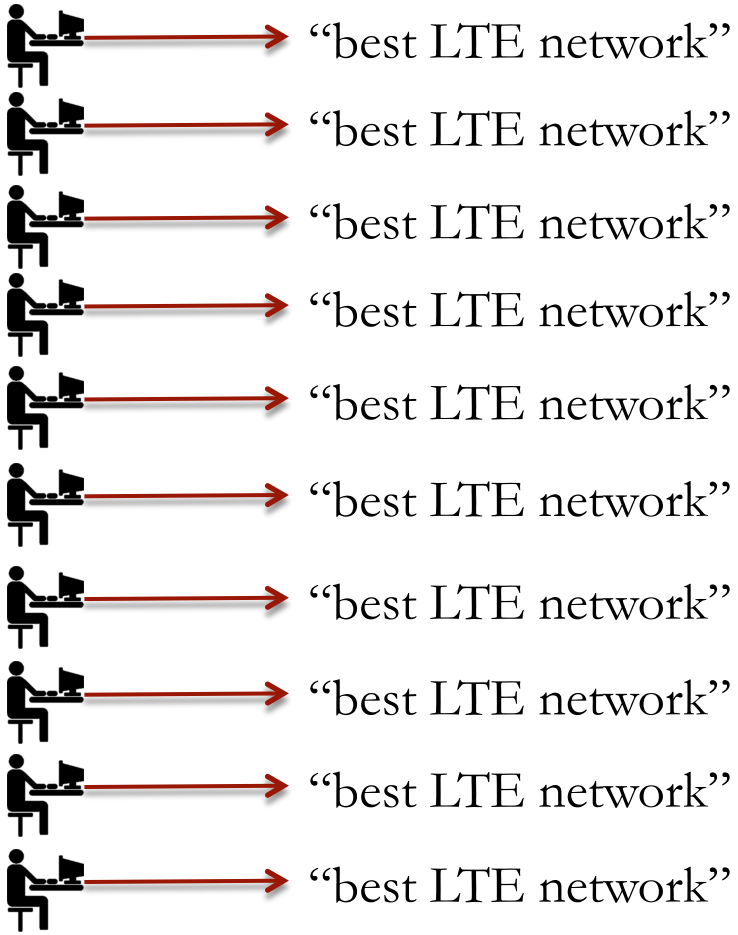
50 users x 0.08 = 4 users

100 users x 0.08 = 8 users

Average Price Per Display

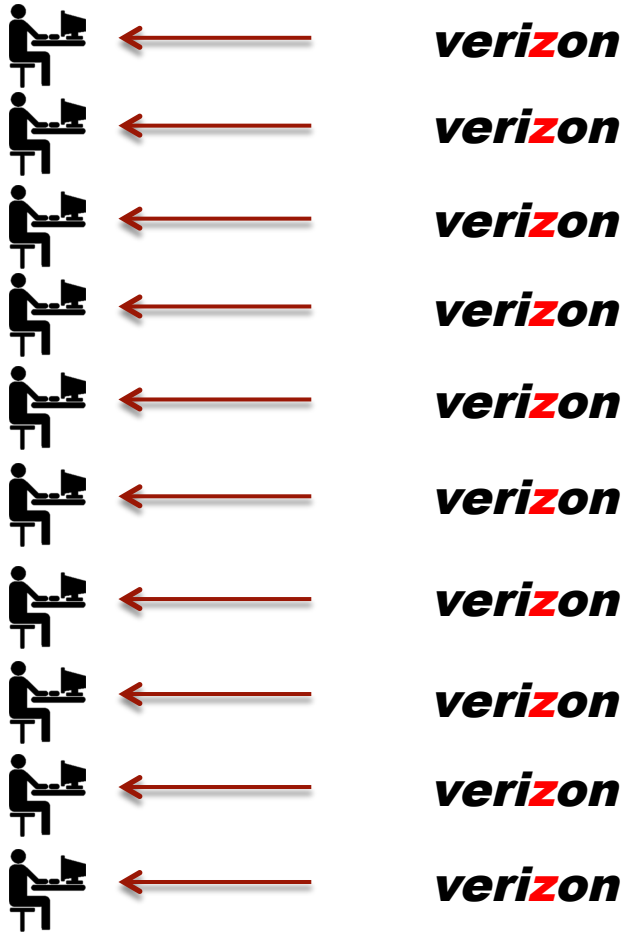
- Average amount that an advertiser pays each time its ad is shown is **PPC x CTR**

How average price per display works



Suppose 10 users search for "best LTE network"

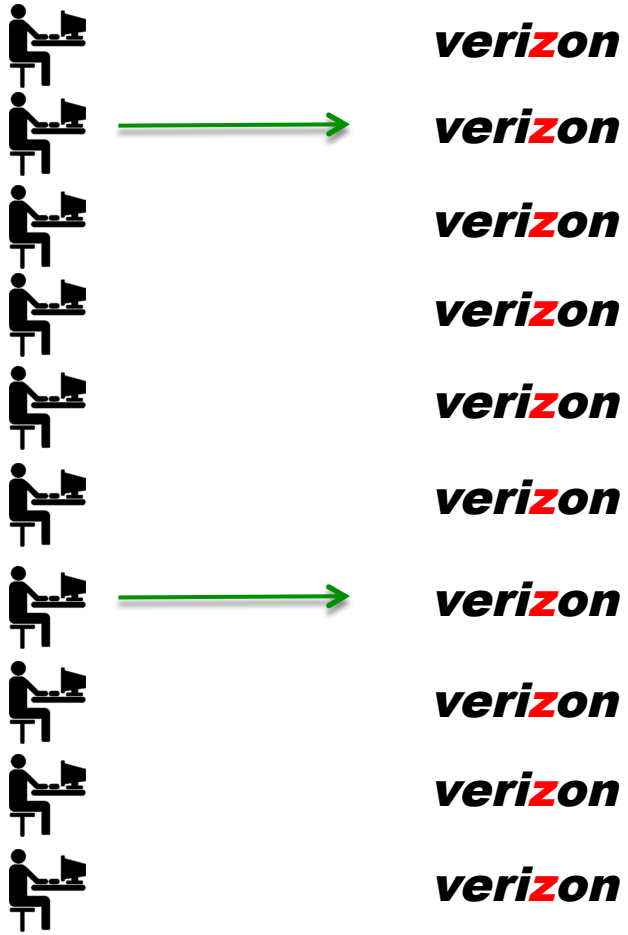
How average price per display works



Google decides to display Verizon's ad

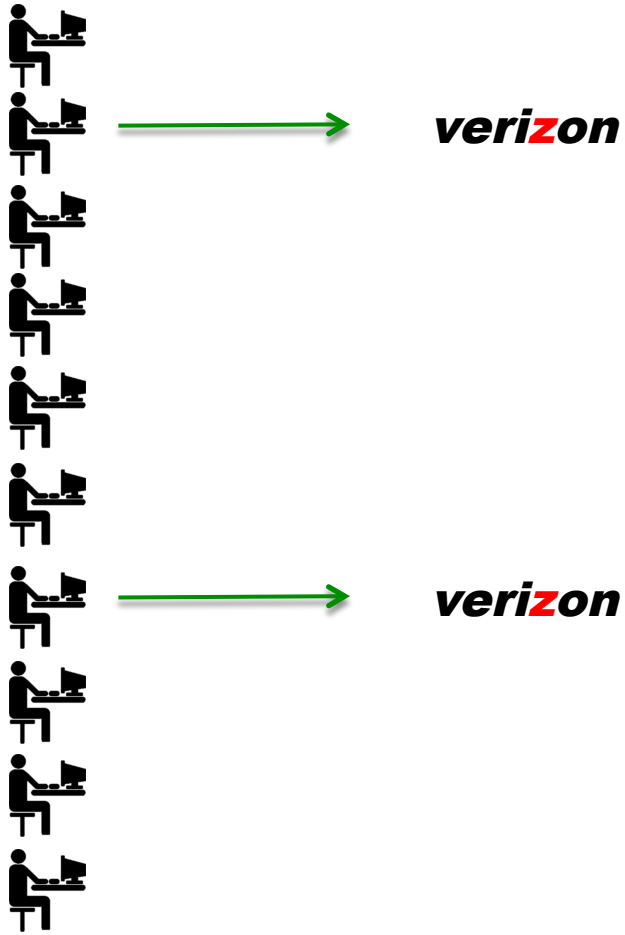
verizon

How average price per display works



CTR of Verizon and "best LTE network" is 0.2, so only 2 users click on the ad

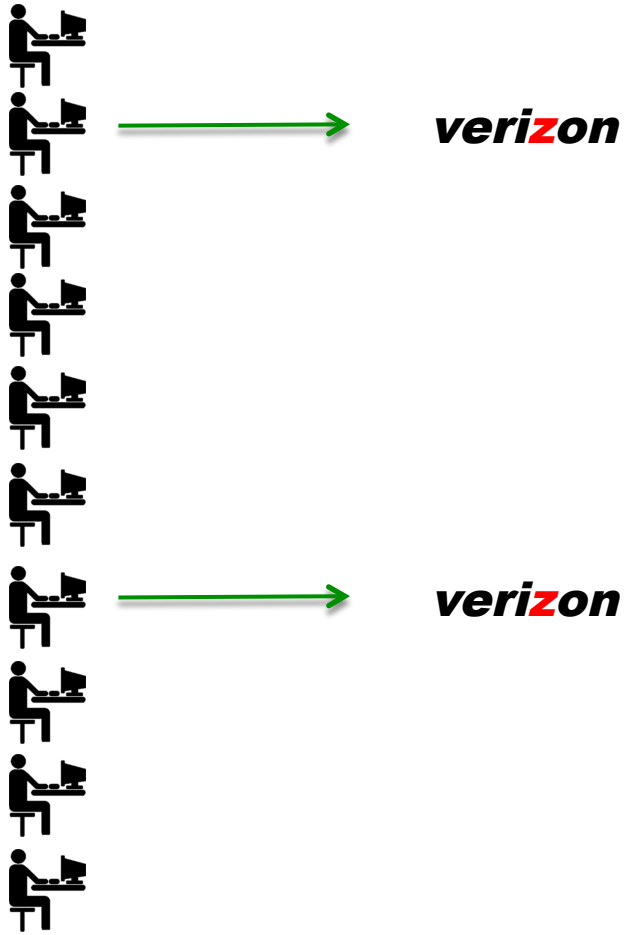
How average price per display works



Verizon pays PPC for each user:

$$\begin{aligned} & 2 \text{ clicks} \\ \times\ & \$25 \text{ per click} \\ = \ & \$50 \end{aligned}$$

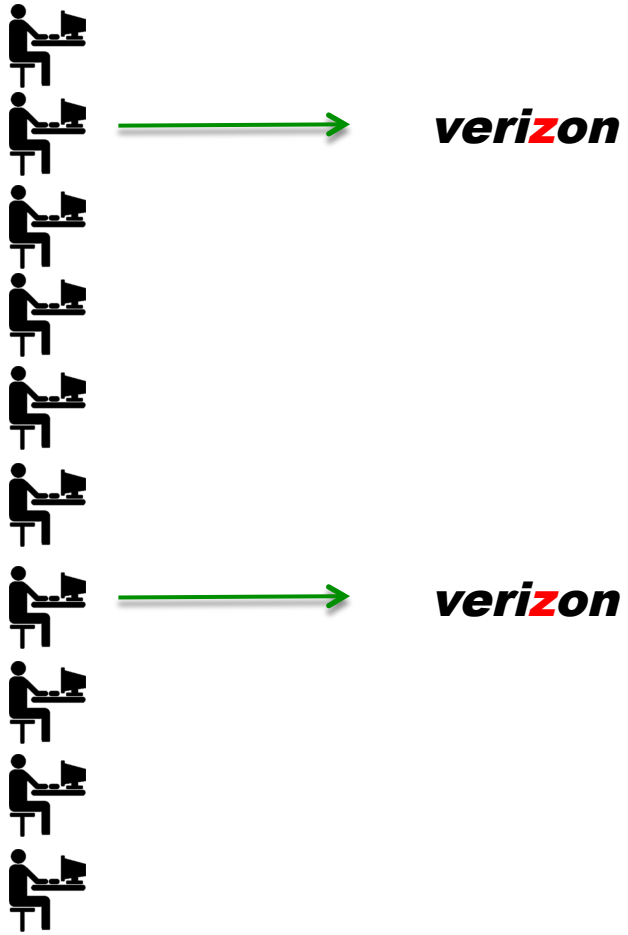
How average price per display works



Verizon pays on average per user/ display:

$$\$50$$
$$\div 10 \text{ displays}$$
$$= \$5 \text{ per display}$$

How average price per display works



This is exactly the PPC multiplied by the CTR:

$25 per click

$\times$ 0.20 clicks per user

$=$ $5 per user/display

Average price per display for example

Advertiser	Query 1 PPC ("4G LTE")	Query 2 PPC ("largest LTE")	Query 3 PPC ("best LTE network")
AT&T	$5	$5	$20
T-Mobile	$10	$5	$20
Verizon	$5	$20	$25

Advertiser	Query 1 CTR ("4G LTE")	Query 2 CTR ("largest LTE")	Query 3 CTR ("best LTE network")
AT&T	0.10	0.10	0.08
T-Mobile	0.10	0.15	0.10
Verizon	0.10	0.20	0.20

Average price per display for example

Advertiser	Query 1 APPD ("4G LTE")	Query 2 APPD ("largest LTE")	Query 3 APPD ("best LTE network")
AT&T	$0.50	$0.50	$1.60
T-Mobile	$1.00	$0.75	$2.00
Verizon	$0.50	$4.00	$5.00

Query estimates

- Google does not control how many times a query will be requested – driven by users!
- For each query, Google has estimate of number of times query will be requested over a given day

Example of query estimates

Query	Est. # of Requests
"4G LTE"	140
"largest LTE"	80
"best LTE network"	80

Google's problem

- **How many times to display each ad for each query to maximize revenue**

Google's problem

- Objective:
  - Maximize revenue
- Decision:
  - For each advertiser and query, number of times ad will be displayed for that query
- Constraints:
  - Average amount paid by each advertiser cannot exceed budget
  - Total ads for given query cannot exceed estimated number of requests for that query

Problem data

Advertiser	Avg. $ / Query 1 Ad Display	Avg. $ / Query 2 Ad Display	Avg. $ / Query 3 Ad Display
AT&T	$0.50	$0.50	$1.60
T-Mobile	$1.00	$0.75	$2.00
Verizon	$0.50	$4.00	$5.00

Advertiser	Budget
AT&T	$170
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Query	Est. # of Requests
Q1 ("4G LTE")	140
Q2 ("largest LTE")	80
Q3 ("best LTE network")	80

Modeling the problem

- Decision variables:

x_{A1} x_{A2} x_{A3} x_{T1} x_{T2} x_{T3} x_{V1} x_{V2} x_{V3}

- Revenue to Google under ad strategy:

$0.50\,x_{A1} + 0.50\,x_{A2} + 1.60\,x_{A3} + 1.00\,x_{T1} + \ldots + 5.00\,x_{V3}$

- Amount advertiser AT&T pays in ad strategy:

$0.50\,x_{A1} + 0.50\,x_{A2} + 1.60\,x_{A3} \leq 170$

- Number of times ad strategy uses query 2:

$x_{A2} + x_{T2} + x_{V2} \leq 80$

Let's do it in LibreOffice

Extensions to the problem

- Slates/positions
- Personalization
- Other issues
  - Estimating CTRs
  - How should advertisers bid?

Slates/positions

- Search result page has space for more than one ad
- **Slate**: combination of ads
- Many possible slates: which ones to display?

$X_{advertiser,\ query}$ X_{A1} X_{T1} X_{V1}

$X_{slate,\ query}$ X_{AT1} X_{AV1} X_{TV1}

X_{TA1} X_{VA1} X_{VT1}

↑↑

Personalization

- In addition to the query, Google can use other information to decide which ad to display:
  - IP address/geographic location
  - Previous Google searches/browser activity on Google
- How do we account for this?

$X_{advertiser,\ query}$ X_{A1p_1}

$X_{advertiser,\ query,\ user\ profile}$

p_1 p_2 p_3

AdWords at Google's scale

- We studied a small instance of the ad allocation problem
  - 3 bidders, 3 queries
- We saw how an optimization solution increases revenue by 16% over "common-sense" solution
- In reality, problem is *much* larger
  - Hundreds to thousands of bidders, over $40 billion
  - Gains from optimization at this scale become *enormous*