

The changing face of web search



Prabhakar Raghavan

Yahoo! Research



Reasons for you to exit now ...

- I gave an early version of this talk at the Stanford InfoLab seminar in Feb
- This talk is essentially identical to the one I gave at STOC 2006 a month ago

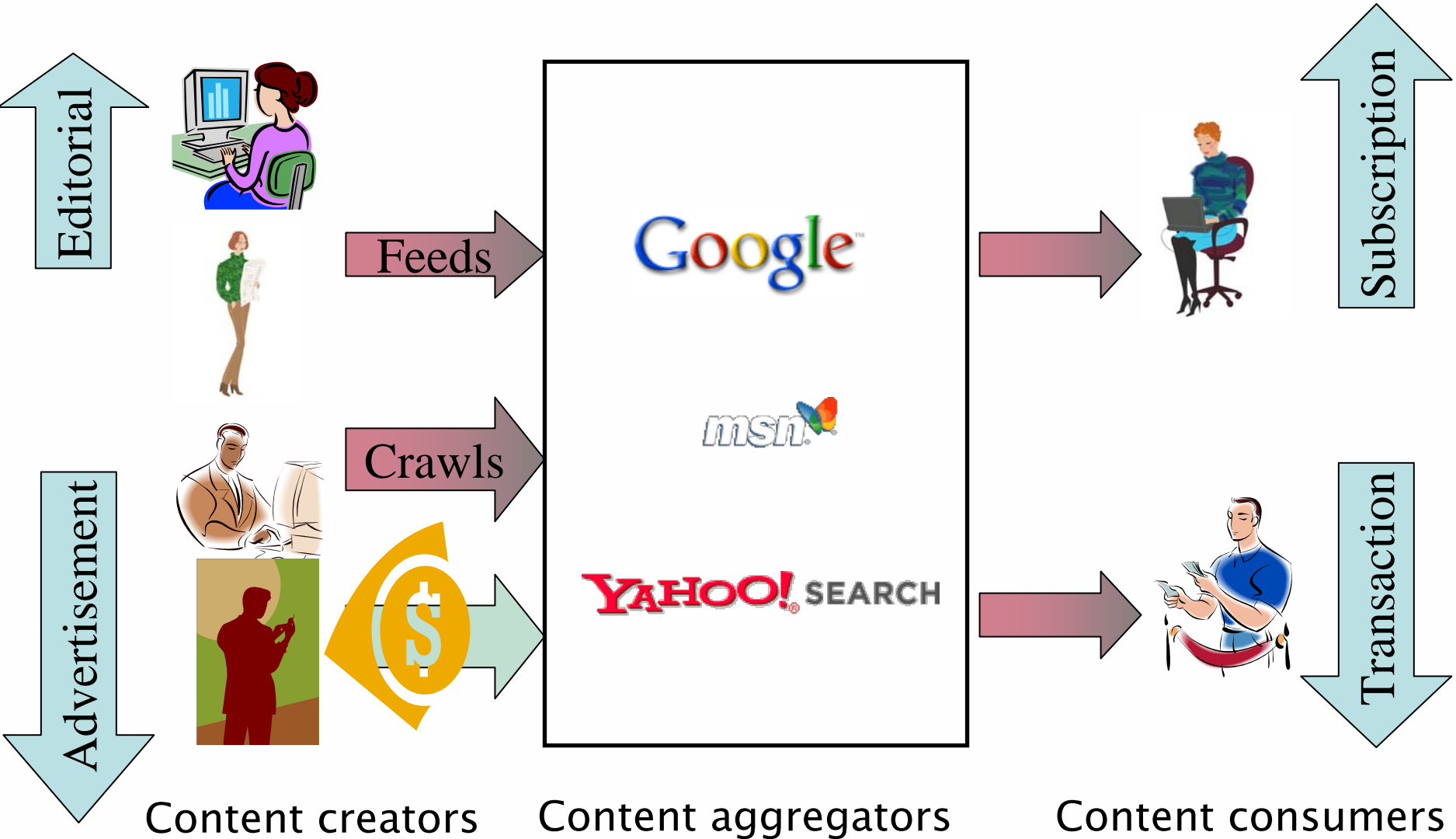


What is web search?

- Access to “heterogeneous”, distributed information
 - Heterogeneous in creation
 - Heterogeneous in accuracy
 - Heterogeneous in motives
- Multi-billion dollar business
 - Source of new opportunities in marketing
- Strains the boundaries of trademark and intellectual property laws
- A source of unending technical challenges



The coarse-level dynamics





Brief (non-technical) history

- Early keyword-based engines
 - Altavista, Excite, Infoseek, Inktomi, Lycos, ca. 1995-1997
- Paid placement ranking: Goto (morphed into Overture → Yahoo!)
 - Your search ranking depended on how much you paid
 - Auction for keywords: casino was expensive!



Brief (non-technical) history

- 1998+: Link-based ranking pioneered by Google
 - Blew away all early engines except Inktomi
 - Great user experience in search of a business model
 - Meanwhile Goto/Overture's annual revenues were nearing \$1 billion



Brief (non-technical) history

- Result: Google added “paid-placement” ads to the side, separate from search results
- 2003: Yahoo follows suit, acquiring Overture (for paid placement) and Inktomi (for search)



Web Images Groups News Froogle Local more »

nigritude ultramarine Search

Advanced Search Preferences

Results 1 - 10 of about 185,000 for nigritude ultramarine. (0.35 seconds)

Dash: Nigritude Ultramarine

... Just placed a link ... Cheers! ... Mar 1, 2006 - Similar pages

Nigritude Ultramarine FAQ

... frequently asked questions about nigritude ultramarine and ... Similar pages

Nigritude Ultramarine contest - Wikipedia, the free encyclopedia

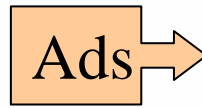
... competition by SearchGuild is widely acclaimed as ... Similar pages

slashdot | How To Get Googled, By Hook Or By Crook

... When ... Similar pages

Nigritude Ultramarine Search Engine Optimization Contest

... a new contest to rank tops for ... Similar pages



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Business Blogging Seminar

Coming to L.A. March 16 Top bloggers reveal key techniques www.blogbusinesssummit.com Los Angeles, CA

Full-Time SEO & SEM Jobs

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SEO Contests

Information on SEO Contests like the Nigritude Ultramarine contest. www.seo-contests.com/

The SEO Book

Nigritude Ultramarine & SEO secret Fun, free, raw, & different.



Music - Dance - Electronic Overstock.com



“Social” search

Is the Turing test always the
right question?

Photos: [Explore Flickr](#) • [Learn More](#)flickr BETATags / [jaguar](#) / clusters

SEARCH

(Or, try an [advanced search](#).)[car](#), [cars](#), [auto](#), [etype](#), [automobile](#), [classic](#), [vintage](#), [autoshow](#), [red](#), [show](#)[→ See more in this cluster...](#)[zoo](#), [animal](#), [cat](#), [animals](#), [bigcat](#), [seattle](#), [woodlandparkzoo](#), [sleep](#), [edinburgh](#), [caged](#)[→ See more in this cluster...](#)[guitar](#), [fender](#)[→ See more in this cluster...](#)[aircraft](#), [raf](#)[→ See more in this cluster...](#)These are the *most recent* photos tagged with [jaguar](#). [See more...](#)



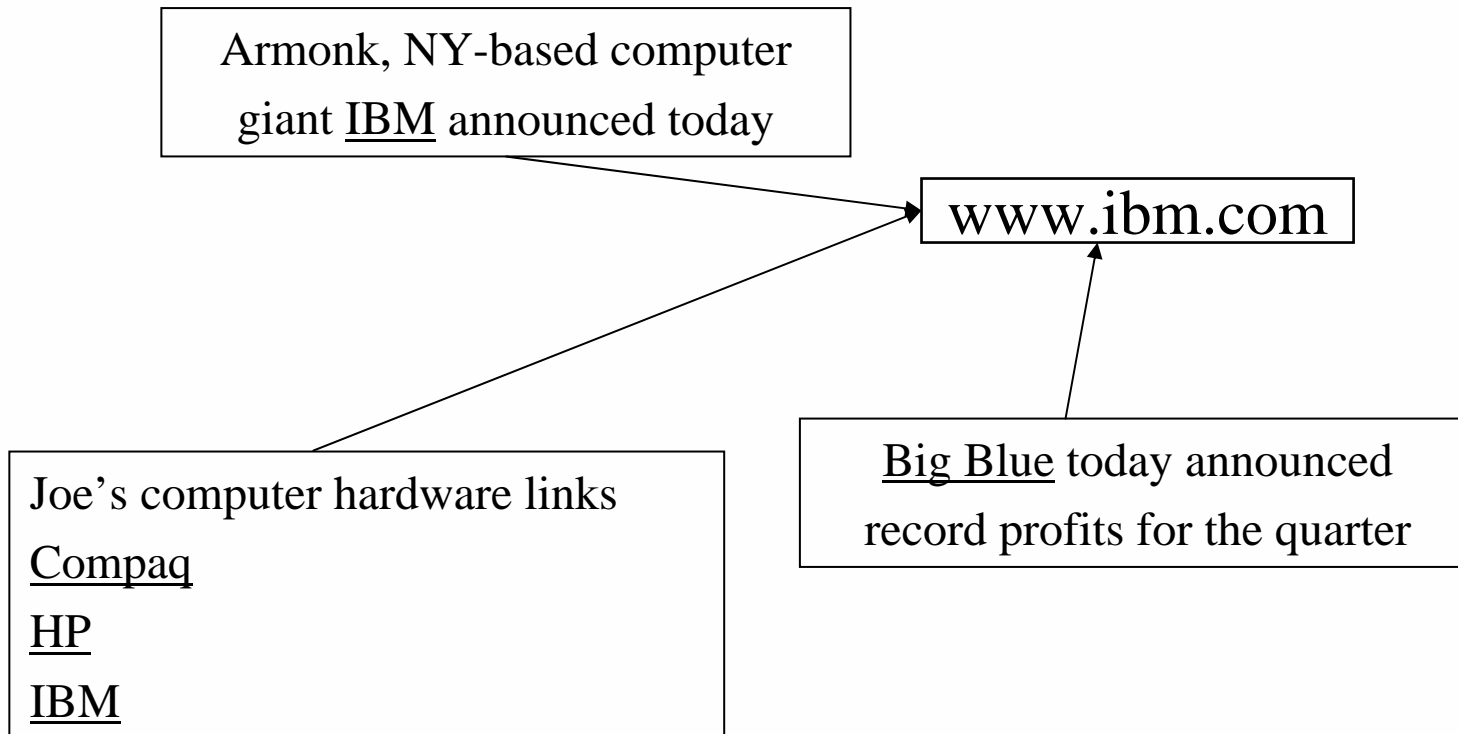
The power of social media

- Flickr – community phenomenon
- Millions of users share and tag each others' photographs (why???)
- The wisdom of the crowd can be used to search
- The principle is not new – anchor text used in “standard” search
- Don't try to pass the Turing test?



Anchor text

- When indexing a document D , include anchor text from links pointing to D .





Challenges in social search

- How do we use these tags for better search?
- How do you cope with spam?
- What's the ratings and reputation system?
- The bigger challenge: where else can you exploit the power of the people?
- What are the incentive mechanisms?
 - Luis von Ahn (CMU): The ESP Game



Ratings and reputation

- Node reputation: Given a DAG with
 - a subset of nodes called GOOD
 - another subset called BAD
 - Find a measure of goodness for all other nodes.
- Node pair reputation: Given a DAG with a real-valued *trust* on the edges
 - Predict a real-valued trust for ordered node pairs not joined by an edge



The ESP Game

As seen on CNN and newspapers around the world! beta

1 MILLION LABELS COLLECTED

TOP SCORES

HOW TO PLAY

New to the ESP Game?
[Sign up for FREE!](#)

common image

The screenshot shows the game interface with the following elements:

- Time Left:** 0:09
- The ESP Game** (Title)
- score:** 0077
- Taboo Words:** HOUSE, PLANT, ROOM
- Your Guesses:** CORRIDOR, COLUMNS
- Image:** A photograph of a hallway.
- Input Area:** "Your partner wants to pass" above "Type your next guess:" with a text input field.
- Buttons:** "Pass" (yellow) and "Flag" (orange).
- Progress Bar:** A horizontal bar with a slider and a red indicator.
- Footer:** © 2001-2003 Carnegie Mellon University. All rights reserved.

progress



Paid placement

What pays the bills



Generic questions

- Of the various advertisers for a keyword, which one(s) get shown?
- What do they pay on a click through?
- The answers turn out to draw on insights from microeconomics

to try: miele vacuum, miele appliances, miele dishwasher More...

Miele Vacuums and Appliances
www.factorydirectsuperstore.com
built-in appliances.

Miele Vacuums and Accessories
www.thinkvacuums.com Miele vacuum cleaners and accessories. Free shipping and no sales tax.

Free Next Day Express On Miele Vacuums
www.vac-cleaner.com Free gift-wrapping. All Miele vacuums models in stock.

Miele on Yahoo! Shopping
Top Categories: Dishwashers - Cooktops - Washers - Canister Vacuum Cleaners - Dryers
Yahoo! Shortcut - About

My Web Results for miele (7)

1. Miele USA
Subsidiary providing company, product and dealer information.
Category: Miele > Regional
www.mieleusa.com - 35k - Cached - More from this site - Save

2. Miele
Welcome to Miele the home of the very best appliances and kitchens in the world

SPONSOR RESULTS

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Call for trade pricing. Buy with confidence from Witbecks, 89 year...

www.witbeckappliance.com

Miele Vacuum Cleaners - Free Shipping

Extensive reviews, specifications and comparisons of Miele vacuums.

www.ristenbatt.com

Shop Miele Appliances

Find Miele home appliances, along with other great brands like...

www.us-appliance.com

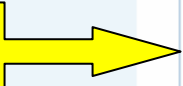
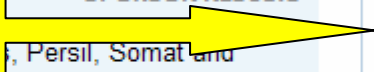
Miele at Best-Vacuum.com

6 months same as cash financing. Financing available and free...

www.best-vacuum.com

Ads go in slots like this one

and this one.





Advertisers generally prefer this slot

SPONSOR RESULTS

to this one.

Buy Miele Appliances - Free Delivery

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Miele Vacuum Cleaners - Free Shipping

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Miele Vacuums and Accessories

www.thinkvacuums.com Miele vacuum cleaners and accessories. Free shipping and no sales tax.

Free Next Day Express On Miele Vacuums

www.vac-cleaner.com Free gift-wrapping. All Miele vacuums models in stock.

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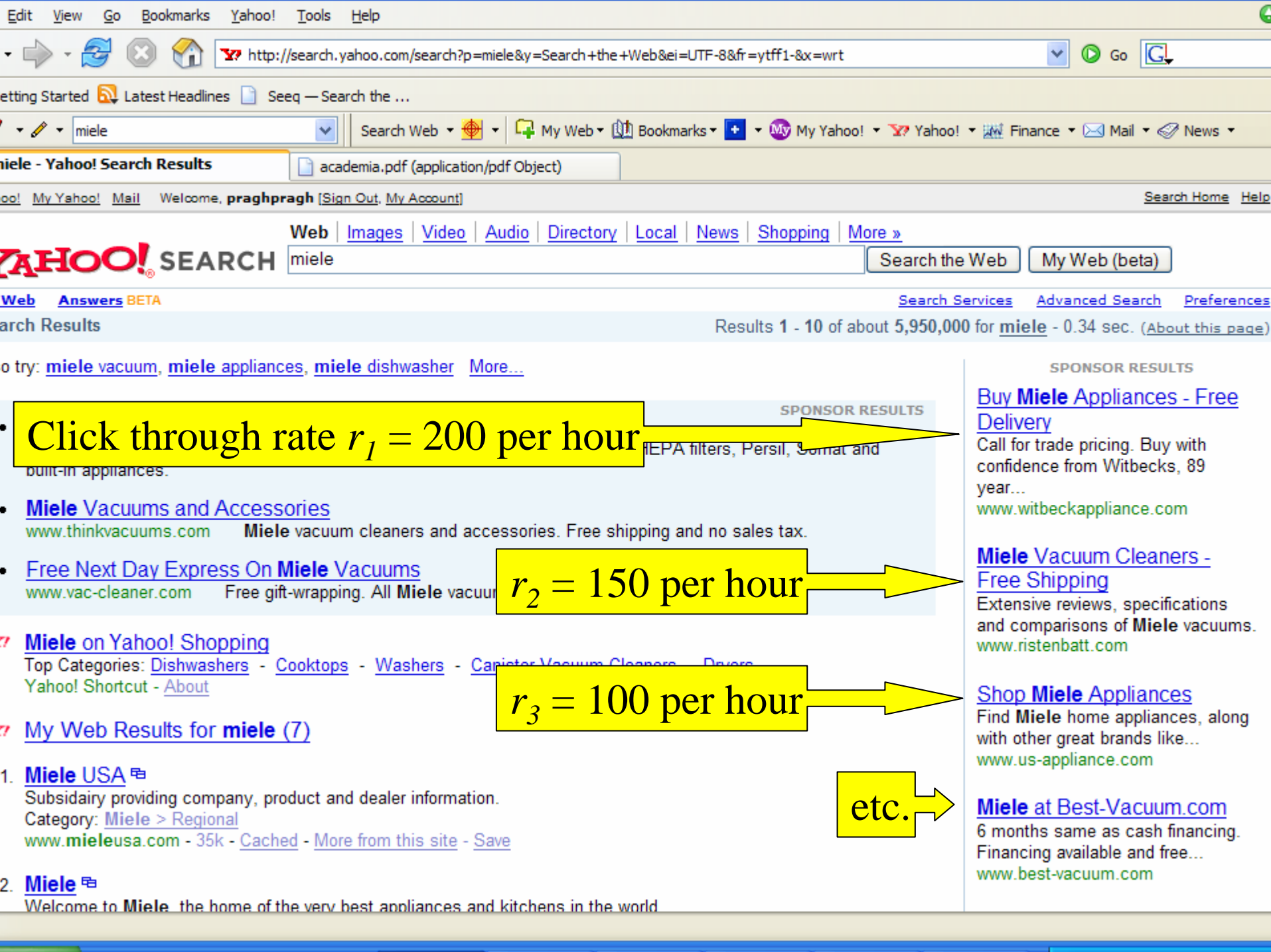
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Miele USA

Subsidiary providing company, product and dealer information.
Category: Miele > Regional
www.mieleusa.com - 35k - Cached - More from this site - Save

Miele

Welcome to Miele the home of the very best appliances and kitchens in the world



Click through rate $r_1 = 200$ per hour

$r_2 = 150$ per hour

$r_3 = 100$ per hour

etc.

- SPONSOR RESULTS
- [Buy Miele Appliances - Free Delivery](#)
Call for trade pricing. Buy with confidence from Witbecks, 89 year...
www.witbeckappliance.com
 - [Miele Vacuum Cleaners - Free Shipping](#)
Extensive reviews, specifications and comparisons of Miele vacuums.
www.ristenbatt.com
 - [Shop Miele Appliances](#)
Find Miele home appliances, along with other great brands like...
www.us-appliance.com
 - [Miele at Best-Vacuum.com](#)
6 months same as cash financing. Financing available and free...
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to try: miele vacuum, miele appliances, miele dishwasher More...

Miele Vacuums and Appliances

www.factor...
built-in app

Why did witbeckappliance win

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PA filters, Persil, Somat and

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Miele vacuum cleaners and accessories. Free shipping and no sales tax.

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Free gift-wrapping. All Miele vacuu

Miele on Yahoo! Shopping

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Yahoo! Shortcut - About

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www.mieleusa.com - 35k - Cached - More from this site - Save

2. Miele

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www.witbeckappliance.com

Miele Vacuum Cleaners - Free Shipping

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Find Miele home appliances, along with other great brands like...

www.us-appliance.com

Miele at Best-Vacuum.com

6 months same as cash financing. Financing available and free...

www.best-vacuum.com




First-cut assumption

- Click-through rate depends only on the slot, not on the advertisement
- In fact not true; more on this later.



Advertiser's value

- We assume that an advertiser j has a value v_j per click through
 - Some measure of downstream profit
- Say, click-through followed by
 - 96% of the time, no purchase
 - 0.7% buy Dishwasher, profit \$500
 - 1.2% buy Vacuum Cleaner, profit \$200
 - 2.1% buy Cleaning agents, profit \$1

 \$ 5.921



Example

- For the keyword *miele*, say an advertiser has a value of \$10 per click.
- How much should he bid?
- How much should he be charged?

The value of a slot for an advertiser, what he bids and what he is charged, may all be different.

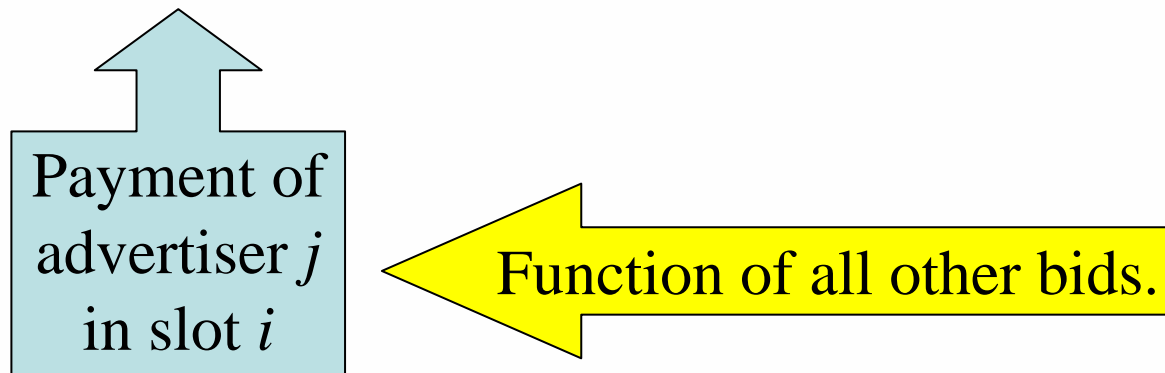


Advertiser's payoff in ad slot i

(Click-through rate) x (Value per click) –
(Payment to search engine)

$$= r_i v_j - (\textit{Payment to Engine})$$

$$= r_i v_j - p_{ij}$$





Two auction pricing mechanisms

Not truthful.

- First price: The winner of the auction is the highest bidder, and pays his bid.
- Second price: The winner is the highest bidder, but pays the *second-highest* bid.
- Engine decides and announces pricing.
- What should an advertiser bid?



Second-price = *Vickrey* auction

- Consider first a single advt slot
- Winner pays the second-highest bid
- Vickrey: *Truth-telling is a dominant strategy for each player (advertiser)*
 - No incentive to “game” or fake bids



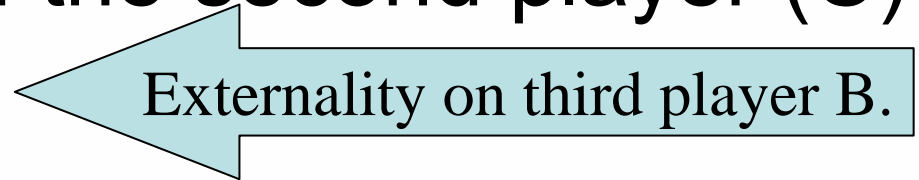
Auctions and pricing: multiple slots

- Overture's (→Yahoo!'s) model:
 - Ads displayed in order of decreasing bid
 - E.g., if advertiser A bids 10, B bids 2, C bids 4 – order ACB
- How do you price slots? Generalized Vickrey?
 - Generalized second-price (*GSP*)
 - Vickrey-Clark-Groves (*VCG*): each advertiser pays the *externality* he imposes on others



VCG pricing

- Suppose click rates are 200 in the top slot, 100 in the second slot
- VCG payment of the second player (C) is $2 \times 100 = 200$
- For the first player, $4 \times (200 - 100) + 200$



Generalized Second Price auction pricing

The image shows a screenshot of a Yahoo! search results page for the query "miele". The page displays search results for "miele" with a total of 5,950,000 results. The search results are sorted by relevance, and the top results are highlighted in blue. The search results include:

- Miele Vacuums and Appliances** (www.factorydirectsuperstore.com) - Full line of vacuums, bags, and built-in appliances.
- Miele Vacuums and Accessories** (www.thinkvacuums.com) - Miele vacuum cleaners and accessories. Free shipping and no sales tax.
- Free Next Day Express On Miele Vacuums** (www.vac-cleaner.com) - Free gift-wrapping.
- Miele on Yahoo! Shopping** - Top Categories: Dishwashers - Cooktops - Washers - Canister Vacuum Cleaners - Dryers.
- My Web Results for miele (7)**
- Miele USA** (www.mieleusa.com) - Subsidiary providing company, product and dealer information. Category: Miele > Regional.
- Miele** (www.miele.com) - Welcome to Miele, the home of the very best appliances and kitchens in the world.

On the right side of the page, there are sponsored results:

- Buy Miele Appliances - Free Delivery** (www.witbeckappliance.com) - Call for trade pricing. Buy with confidence from Witbecks, 89 year...
- Miele Vacuum Cleaners - Free Shipping** (www.ristenbatt.com) - Extensive reviews, specifications and comparisons of Miele vacuums.
- Shop Miele Appliances** (www.us-appliance.com) - Find Miele home appliances, along with other great brands like...
- Miele at Best-Vacuum.com** (www.best-vacuum.com) - 6 months same as cash financing. Financing available and free...

Annotations on the page illustrate a generalized second-price auction pricing mechanism:

- Pays 4**: A yellow box with an arrow pointing to the first search result, indicating the price paid is the second-highest bid.
- Bidder A, \$10**: A light blue box with an arrow pointing to the first search result, indicating the highest bid.
- Pays 2**: A yellow box with an arrow pointing to the second search result, indicating the price paid is the second-highest bid.
- Bidder C, \$4**: A light blue box with an arrow pointing to the second search result, indicating the second-highest bid.
- Bidder B, \$2**: A light blue box with an arrow pointing to the second search result, indicating the highest bid.



VCG and GSP

Edelman, Ostrovsky, Schwarz

- Truth-telling is a dominant strategy under VCG ...
- Truth-telling *not* dominant under GSP!

Aggarwal, Goel, Motwani (ACM EC 2006): give a truthful mechanism in a model that precludes VCG.



VCG and GSP

Edelman, Ostrovsky, Schwarz

- Static equilibrium of GSP is *locally envy-free*: no advertiser can improve his payoff by exchanging bids with advertiser in slot above.
- Depending on the mechanism, revenue varies: $GSP \geq VCG$.

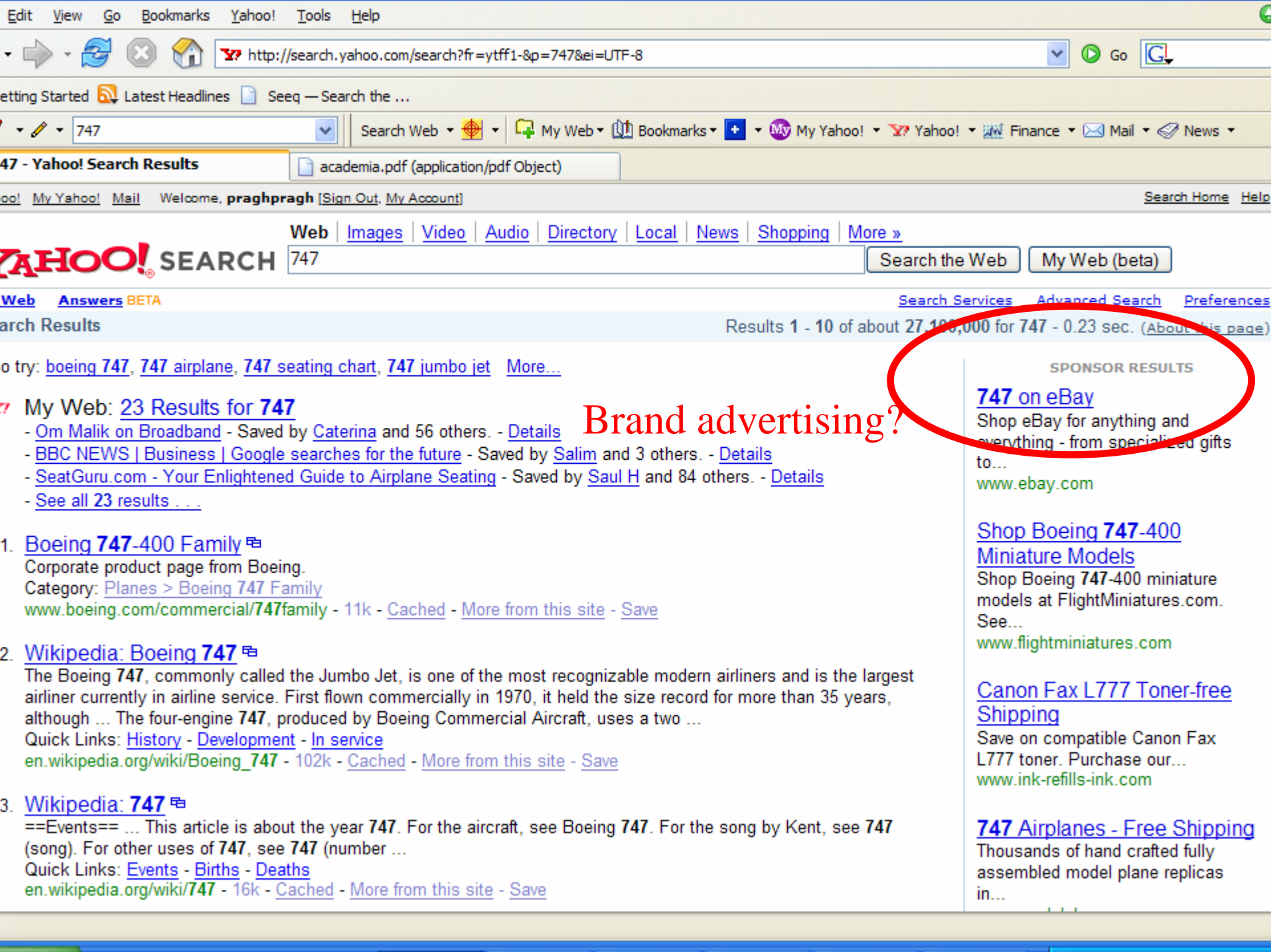


Locally envy-free mechanisms correspond to *Stable Marriage* solutions.



GSP for bid-ordering

- What's good about bid-ordering and GSP?
 - Advertisers like transparency
- What's wrong with bid-ordering?

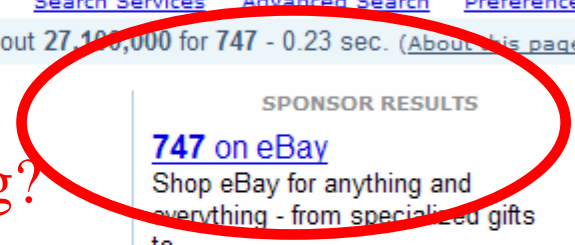


to try: boeing 747, 747 airplane, 747 seating chart, 747 jumbo jet More...

My Web: 23 Results for 747

- Om Malik on Broadband - Saved by Caterina and 56 others. - Details
- BBC NEWS | Business | Google searches for the future - Saved by Salim and 3 others. - Details
- SeatGuru.com - Your Enlightened Guide to Airplane Seating - Saved by Saul H and 84 others. - Details
- See all 23 results ...

Brand advertising?



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747 on eBay

Shop eBay for anything and everything - from specialized gifts to... www.ebay.com

Shop Boeing 747-400 Miniature Models

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Save on compatible Canon Fax L777 toner. Purchase our... www.ink-refills-ink.com

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1. Boeing 747-400 Family

Corporate product page from Boeing. Category: Planes > Boeing 747 Family www.boeing.com/commercial/747family - 11k - Cached - More from this site - Save

2. Wikipedia: Boeing 747

The Boeing 747, commonly called the Jumbo Jet, is one of the most recognizable modern airliners and is the largest airliner currently in airline service. First flown commercially in 1970, it held the size record for more than 35 years, although ... The four-engine 747, produced by Boeing Commercial Aircraft, uses a two ... Quick Links: History - Development - In service en.wikipedia.org/wiki/Boeing_747 - 102k - Cached - More from this site - Save

3. Wikipedia: 747

==Events== ... This article is about the year 747. For the aircraft, see Boeing 747. For the song by Kent, see 747 (song). For other uses of 747, see 747 (number ... Quick Links: Events - Births - Deaths en.wikipedia.org/wiki/747 - 16k - Cached - More from this site - Save

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Local area maps of the Palo Alto and surrounding areas.

[www.city.palo-alto.ca.us/maps/bayarea.html](#) - 6k - [Cached](#) - [More from this site](#) - [Save](#)7. [African Maps | Map Africa](#) African maps and information about African maps. ... sites, Links & Gateways, **Map** collecting, **Map** collections, **Map** societies, Marketplace, News (sources ... has sources for estimating **map** prices.[http://library.stanford.edu/depts/branner](#) ...[www-sul.stanford.edu/depts/ssrg/africa/map.html](#) - 92k - [Cached](#) - [More from this site](#) - [Save](#)8. [Stanford Zebrafish Genome Project](#) ... **STANFORD ZEBRAFISH GENOME PROJECT**. COMPARATIVE ANALYSIS ... collaboration with the Thisses, we have begun to determine the **map** locations of the transcripts they have characterized ...[zebrafish.stanford.edu/genome/Frontpage.html](#) - 8k - [Cached](#) - [More from this site](#) - [Save](#)9. [Stanford Digital Forma Urbis Romae Project Slab Map](#)

DIGITAL MAP OF THE SLABS OF THE FORMA URBIS ROMAE. Click on a slab to view fragments associated with it. ... relationship between the architecture depicted on the **Map** and the actual buildings on the ground is ... about the **Map** itself, refer to the **Map** page. **Stanford** Graphics. **Stanford** Classics ...

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Revenue ordering

- Simplified version of Google's ordering
 - Each ad j has an expected click-through denoted CTR_j
 - Advertiser j 's bid is denoted b_j
- Then, expected revenue from this advertiser is $R_j = b_{j+1} \times CTR_j$
- Order advertisers by R_j
 - Payment by GSP

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747 [Advanced Search](#)
[Preferences](#)

Results 1 - 10 of about 83,900,000 for 747. (0.10 seconds)

[Boeing: Commercial Airplanes - 747 Home](#)
 Boeing Announces First Engineering Releases for New 747-8 Family · Boeing Delivers
 Malaysia Airlines System's First 747-400 Freighter · Cargolux Expands ...
[www.boeing.com/commercial/747family/](#) - 12k - May 3, 2006 - [Cached](#) - [Similar pages](#)

[Boeing: Commercial Airplanes - 747 - About the 747 Family](#)
 The Boeing 747 Family -- The Right Choice for the Large Airplane Market. About the 747
 Family. Instantly recognized by passengers around the world, ...
[www.boeing.com/commercial/747family/background.html](#) - 26k - [Cached](#) - [Similar pages](#)
 [[More results from www.boeing.com](#)]

[Boeing 747 - Wikipedia, the free encyclopedia](#)
 Boeing 747, commonly called the Jumbo Jet, is one of the most ... The 747SP was the
 best-range airliner available until the 747-400 entered service ...
[wikipedia.org/wiki/Boeing_747](#) - 101k - May 3, 2006 - [Cached](#) - [Similar pages](#)

[Airliners.net: Boeing 747-400](#)
 747-400 is the latest, longest ranging and best selling model of the 747 family. Boeing
 introduced the 747-400 in October 1985 and the first development ...
[www.airliners.net/info/stats.main?id=100](#) - 27k - May 3, 2006 - [Cached](#) - [Similar pages](#)

[Boeing 747SP Website](#)
 Boeing 747SP Production List, Photo Gallery, Incident Reports, Current Status, News and
 much more.
[www.boeing747sp.com/](#) - 21k - May 3, 2006 - [Cached](#) - [Similar pages](#)

Sponsored Links

[747 On Sale](#)
 Chairs, Desks & Cabinets
 Everyday Low Prices.
[OfficeFurniture.BettyMills.com](#)

[Boeing™ 747-400 Model](#)
 Accurately detailed Boeing™ 747-400
 desktop display models
[www.FlightMiniatures.com](#)

[Boeing's Photo Collection](#)
 The world's leading source of
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 Everything to do with
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Search

Advanced Search Preferences

eb Results 1 - 10 of about 72,500,000 for stanford map. (0.24 seconds)

Page results for stanford map



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Whatever you're looking for you can get it on eBay. www.eBay.com

Stanford University: Campus Maps

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Stanford University: Directions to Campus

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3. Bus Parking. Visitor. Parking. Visitor Parking. Undergraduate ...
s.stanford.edu/images/03-04_Visitor-Map.pdf - Similar pages

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Still primitive understanding

- Advertisers' bids generally placed by robots
 - Currently approved by Engines
 - No room for coalitions
- Granularity of markets to bid on
- Pricing when the number of ad slots is variable 



Burgeoning research area

- Marketplace design
 - Multi-billion dollar business, growing fast
 - Interface of microeconomics and CS
- Many open problems, a few papers, some of them quite realistic

ACM EC Conf

WINE



Incentive networks

Joint w/Jon Kleinberg (FOCS 2005)

ask.

Ask a question on any topic and get answers from real people.

(you have **110** characters to work with)

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- Arts & Humanities
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 - Cars & Transportation
 - Computers & Internet
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-  [How do you get a bleach spot out of your pants?](#)
Asked by [girly_antagonist](#) - [Cleaning & Laundry](#) - 1 second ago
 -  [is there a home remedy forgetting rid of ants out side with out harming my dogs or plants?](#)
Asked by [cheetarajade](#) - [Other - Home & Garden](#) - 2 seconds ago
 -  [which poker site is the most profitable for a tournament player?](#)
Asked by [judas](#) - [Card Games](#) - 12 seconds ago
 -  [what is the website where you can play all those games? there is a new TV commercial about it...?](#)

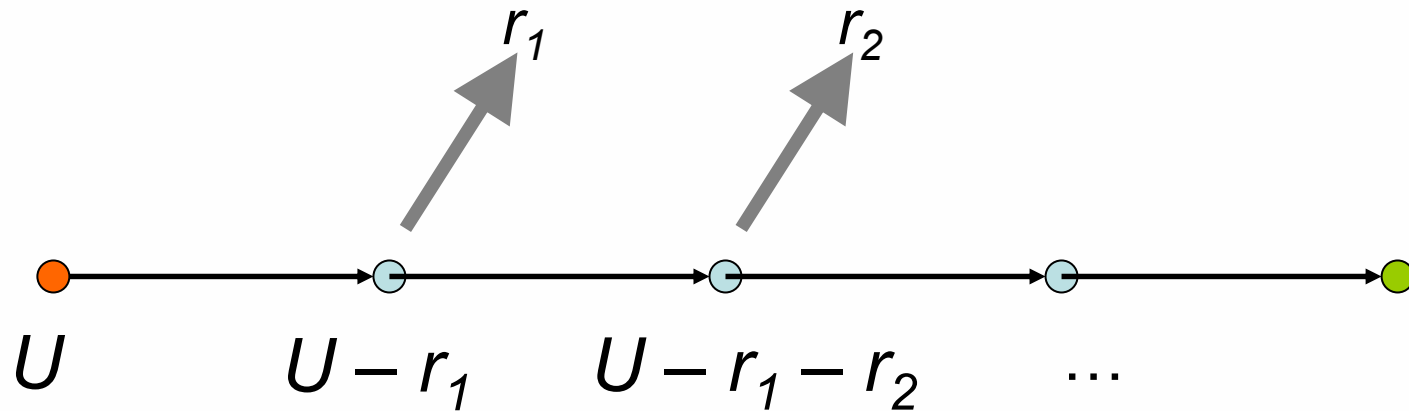


The power of the middleman

- Setting: you have a need
 - For information, for goods ...
- You initiate a request for it and offer a reward for it, to some person X
 - Reward = your value U for the answer
- How much should X “skim off” from your offered reward, before propagating the request?



Propagation



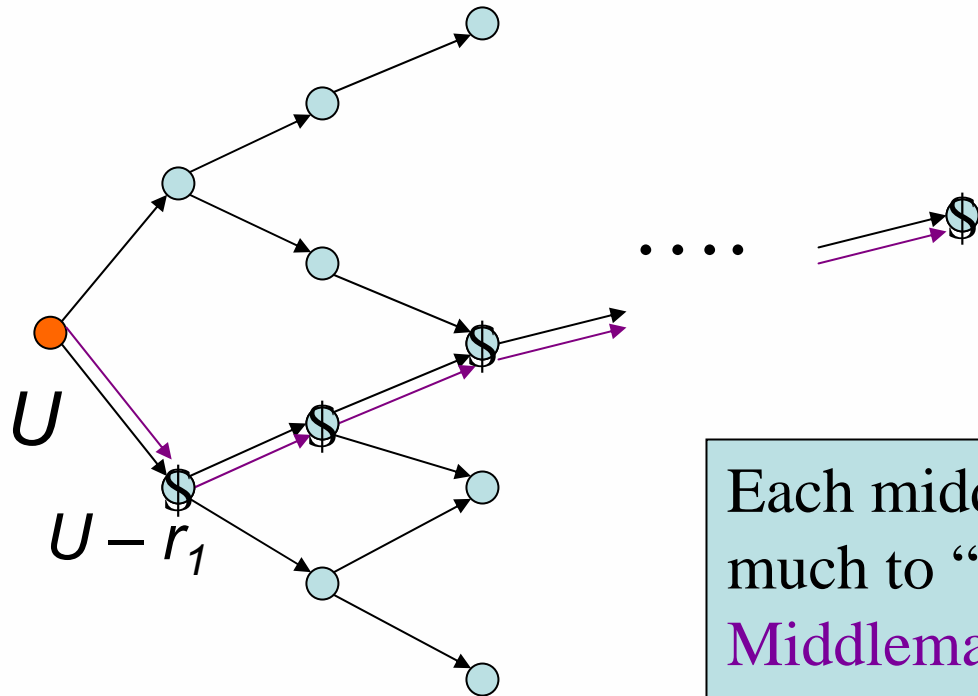
Request propagated repeatedly until it finds an answer.

Target not known in advance.

Middlemen get reward only if answer reached.



More generally



Each middleman decides how much to “skim off”.
Middleman only gets paid if on the path to the answer.

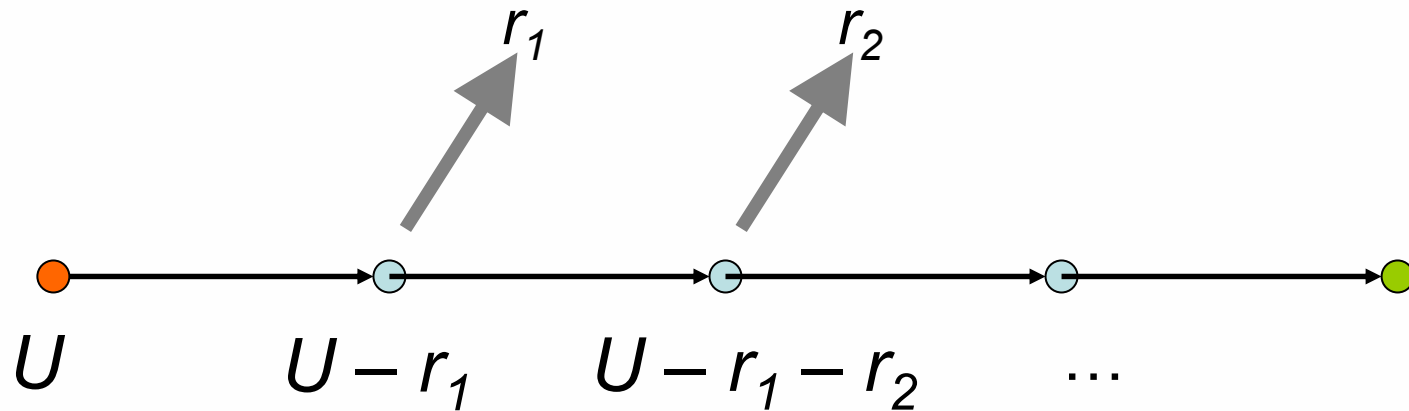


Rewards must be non-trivial

- We will assume that all the $r_i \geq 1$.
- Else, have a form of Zeno's paradox:
 - Source can get away with offering an arbitrarily small reward.
- Equivalently, nodes value their effort in participating.



Back to the line



Under *strategic* behavior by each player, how much should a player skim?

$n =$ answer *rarity*: probability a node has the answer = $1/n$, independently of other nodes.

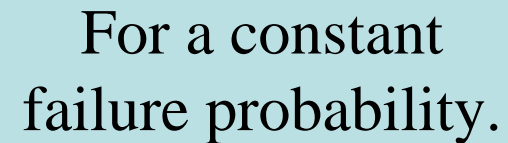


The bad news

- For rarity n , it takes about n hops to get to the answer.

- Initial reward must be exponential in n

–A very inefficient network.



For a constant failure probability.



Branching processes

- Branching process: a network where
- Each node has a number of descendants
- Number of descendants is a random variable X
 - drawn from a probability distribution
 - Expectation[X] = b



Branching processes

- Classical study of population dynamics and random graph evolution.
- Basic fact:
 - If $b < 1$, process dies out
 - If $b \geq 1$, process infinite.



Main results - unique Nash

- For $b < 2$, the initial investment must be exponential in the path length from the root to the answer.
- For $b > 2$, the initial investment is linear in the path length from the root to the answer.

Criticality at $b=2$.

Knowing fewer than 2 people is expensive.



Tempting conclusion

- (Sufficient) competition makes incentive networks efficient.
- But ... we haven't fully introduced competition yet.
 - On trees, we have a unique path from the origin to each node.



Many open questions

- Full model of competition
 - When does competition promote efficiency?
- Given a DAG, how does a node compute its strategy?



The net

- Web search is scientifically young
- It is intellectually diverse
 - The human element
 - The social element
- The science must capture economic, legal and sociological reality.

Thank you.



Questions?

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