CSE190/291
How The Web Tracks You / Targeted Advertising

Online Advertising, Part 1

UC San Diego

Housekeeping

General course things to know

- PA1 part 2 grades were released
- PA1 part 3 is due **today**… hope you got started
  - Basic idea is to build a simple classifier… you will use this in part 4
- PA1 part 4 is coming**…** you should get started
  - Everything that you have built so far will converge
  - **We are preemptively extending the deadline of Part 4 to 11/3 EOD.** The website and assignment will be updated accordingly

Housekeeping

General course things to know

- Pete Snyder, Principal Privacy Researcher at *Brave*, (a privacy oriented browser company) will be visiting us on **11/3,** in the CSE190 section
- The talk will (hopefully) be in-person, which will be great!
  - Come prepared with lots of questions about how Brave works and the online tracking ecosystem!



Brave

Housekeeping

General course things to know

- The midterm is coming: in class on **11/5**
- Basic structure:
  - Multiple choice — penalties for guessing
  - Short answer — write things
  - PA-style questions — **very** similar to your PAs!
- *We will release some sample questions next week!*
- **You must attend the section you are enrolled in. No exceptions.**

Previously on CSE190/CSE291…

- Stateful tracking, inferences, and a history of advertising…
  - All of this has led us to this moment: it’s time to learn how ads are actually placed
  - Note: This lecture will give you all the concepts you need in order to tackle part 4

Let’s do a recap (exam style)

- Let’s say someone is told to include the following line of code to their site:
  `<script src="https://jquery.com/min.js"></script>`
- What can the script do?
  - Read the page’s cookies
  - Modify variables the page stores on the client
  - Run on jquery.com's web server rather than in the user’s browser
  - Send data it collects to any destination on the web
  - Only read cookies scoped to jquery.com

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Let’s do a recap (exam style)

- Remember — including JavaScript on your page is *as if you wrote the JavaScript itself*
  - It has *all the privileges* that you have
- JavaScript can make web requests (we’ll see this again today!)

Let’s do a recap (exam style part 2)

- Which of the following components in a web application can *make* HTTP requests?
  - A script running in the browser
  - The browser itself
  - The web server
  - The root HTML page
  - A form on the page

Let’s do a recap (exam style part 2)

- Which of the following components in a web application can *make* HTTP requests?
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  - **The browser itself**
  - **The web server**
  - **The root HTML page**
  - **A form on the page**

A subtler point on clients and servers

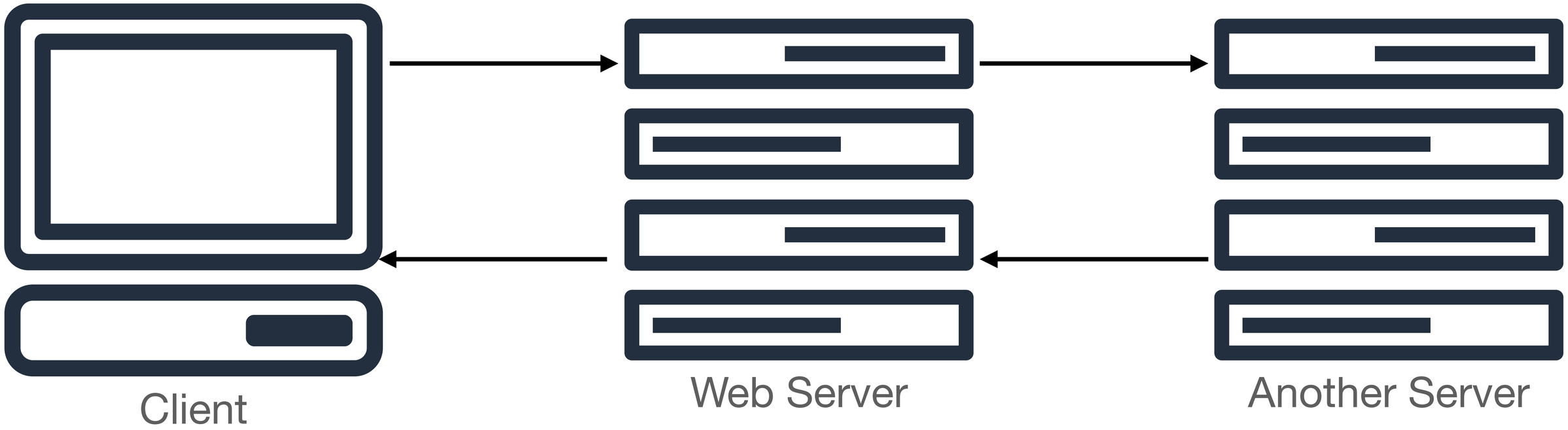


A subtler point on clients and servers



Servers can *sometimes* make HTTP requests (making them clients)

A subtler point on clients and servers



Examples?

A subtler point on clients and servers



Client

A subtler point on clients and servers

When did dinosaurs die?



Client

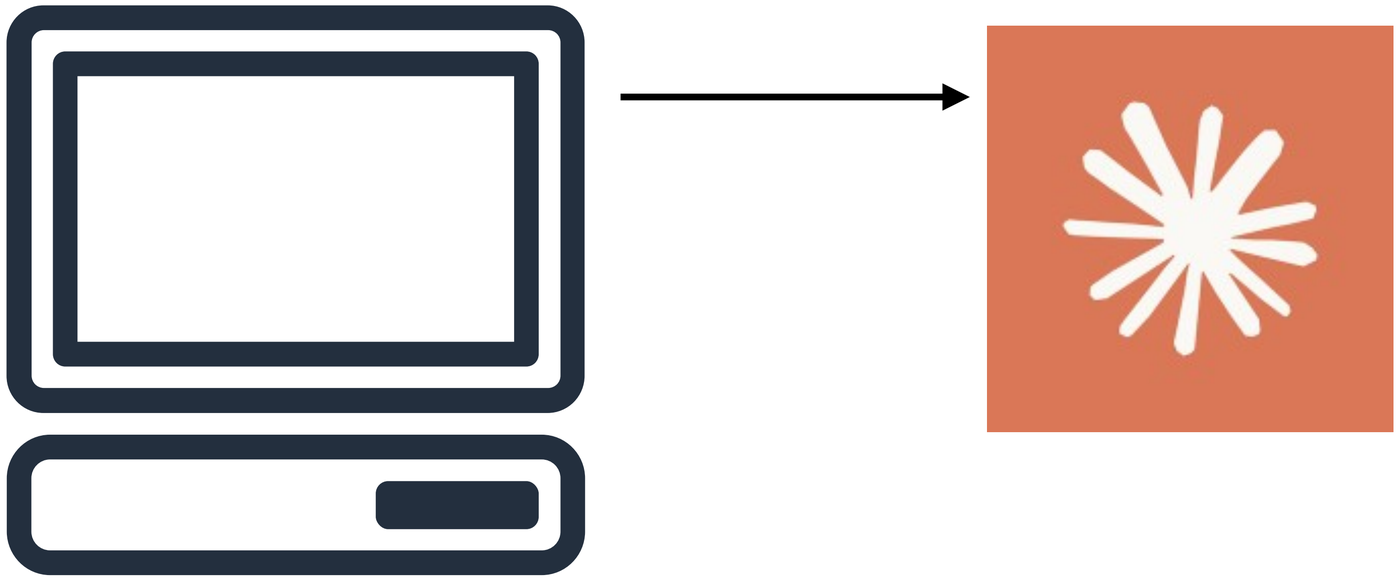


Claude

What protocol do you use when speaking to a chatbot?

A subtler point on clients and servers

When did dinosaurs die?



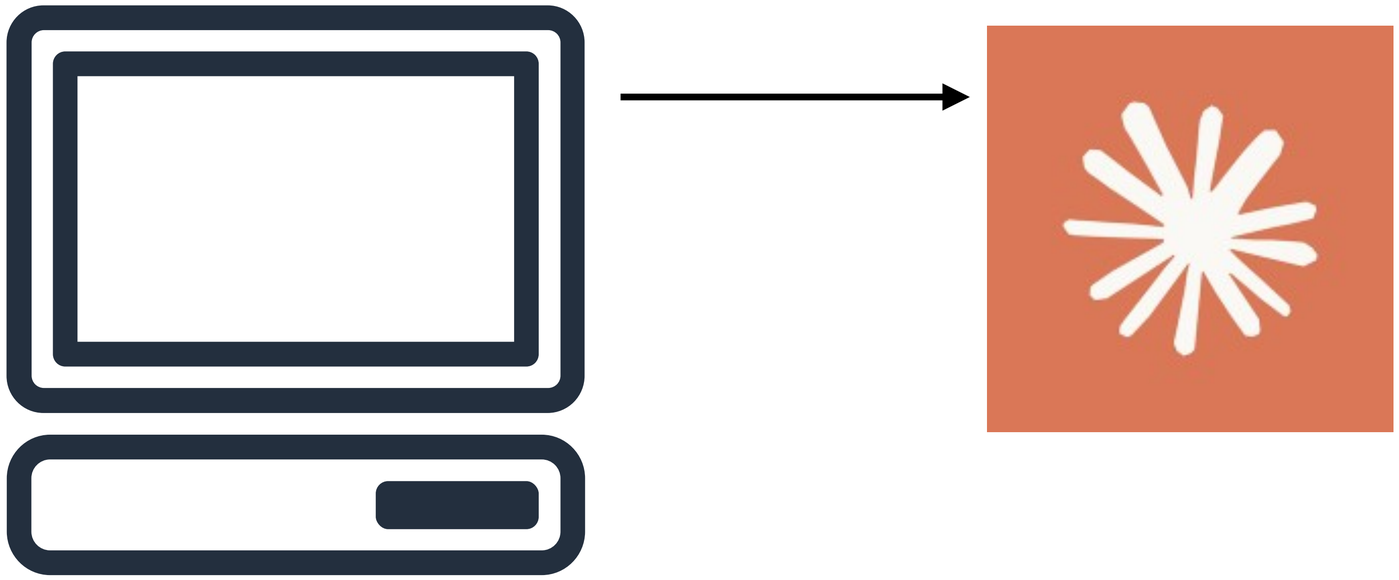
Client

Claude

What protocol do you use when speaking to a chatbot?
HTTP! So you are talking to Anthropic's web servers.

A subtler point on clients and servers

When did dinosaurs die?



Client

Claude

If Claude doesn’t “know,” where might it go…?

A subtler point on clients and servers

When did dinosaurs die?

`GET /search?q=dinosaurs`



Client



Claude might
request Wikipedia



Wikipedia

Here, Anthropic servers… are clients. Why?

A subtler point on clients and servers

When did dinosaurs die?

`GET /search?q=dinosaurs`



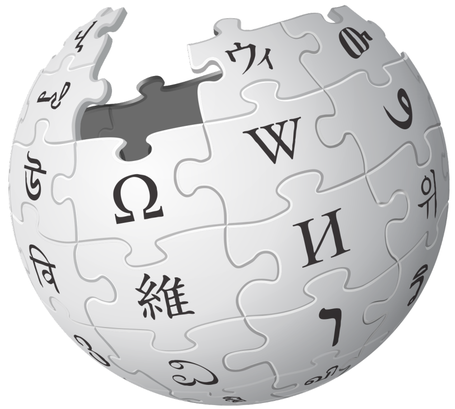
Client

66M years ago



Claude might request Wikipedia

66M years ago



Wikipedia

Remember: clients make requests, servers respond.
But, ultimately, everything is just software.

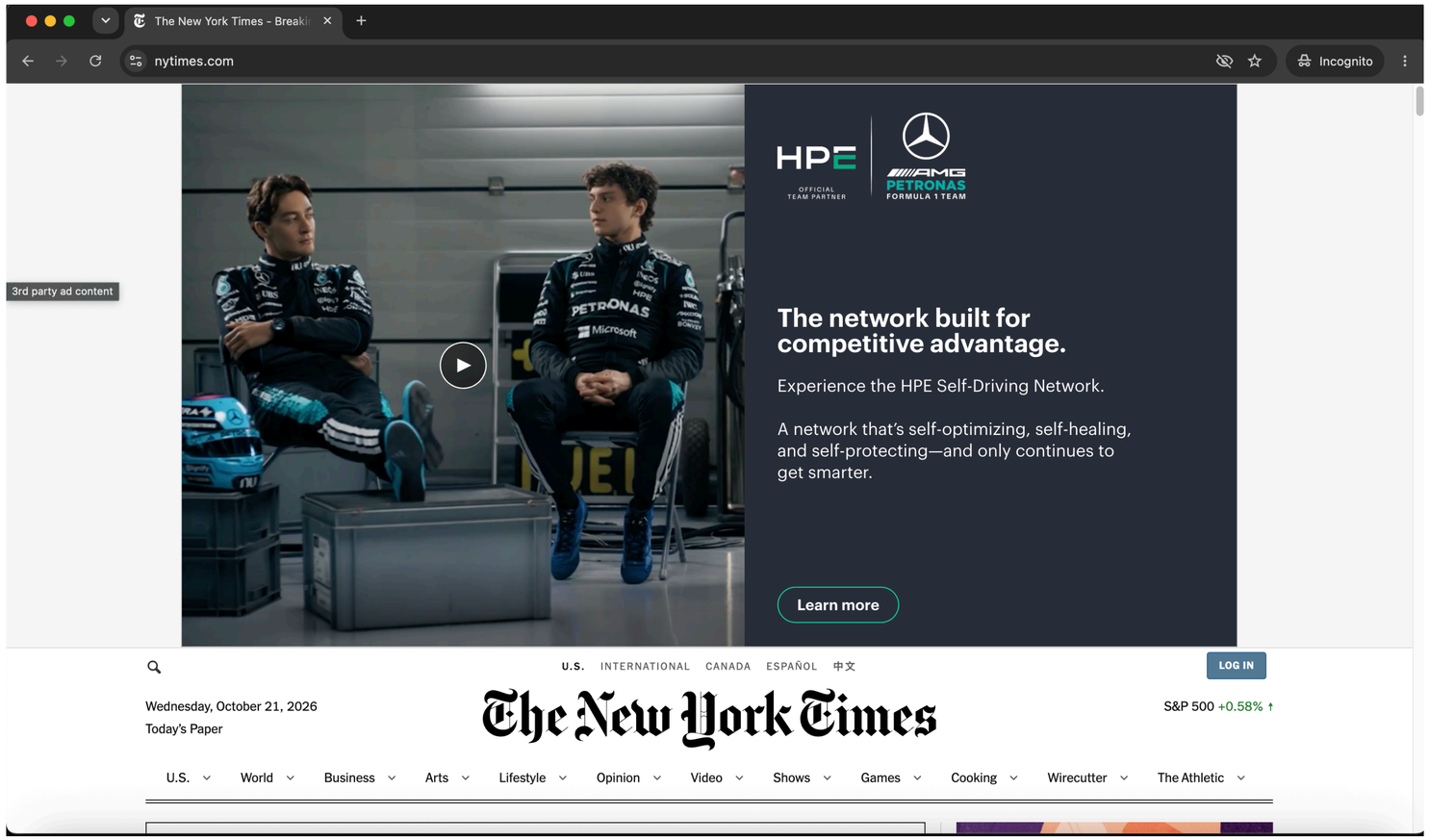
Today's lecture — Online Advertising, Part 1

Learning Objectives

- Learn about the digital advertising ecosystem writ large, the major players involved in advertising, supply, demand, and exchanges
- Learn about OpenRTB — the spec that defines how requests and responses work in online advertising
- Understand the idea of an *auction*, how auctions are embedded in online advertising, and the distinction between a first-price and second-price auction

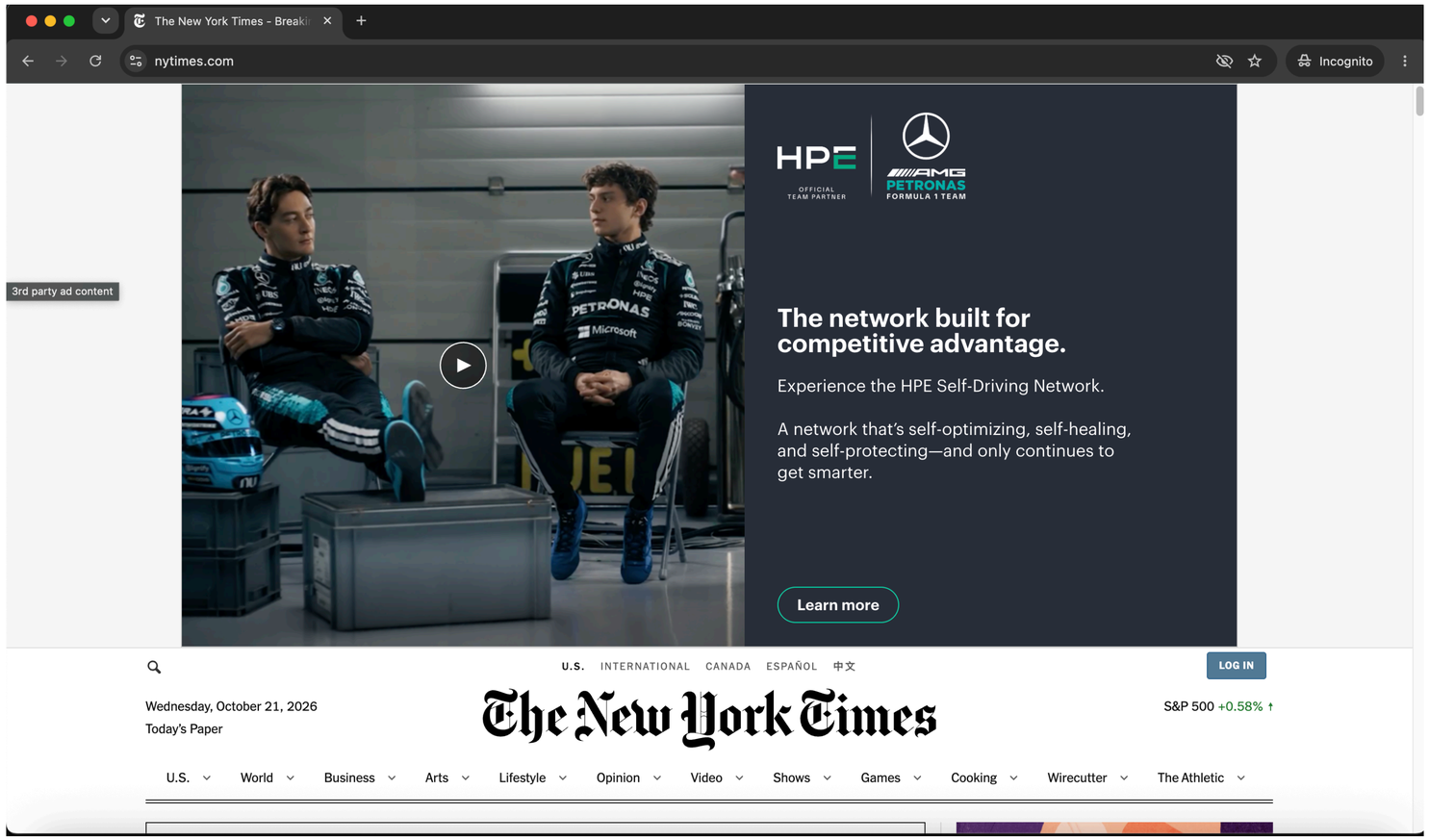
The Programmatic Ad Ecosytem

Here is an ad on the NYTimes



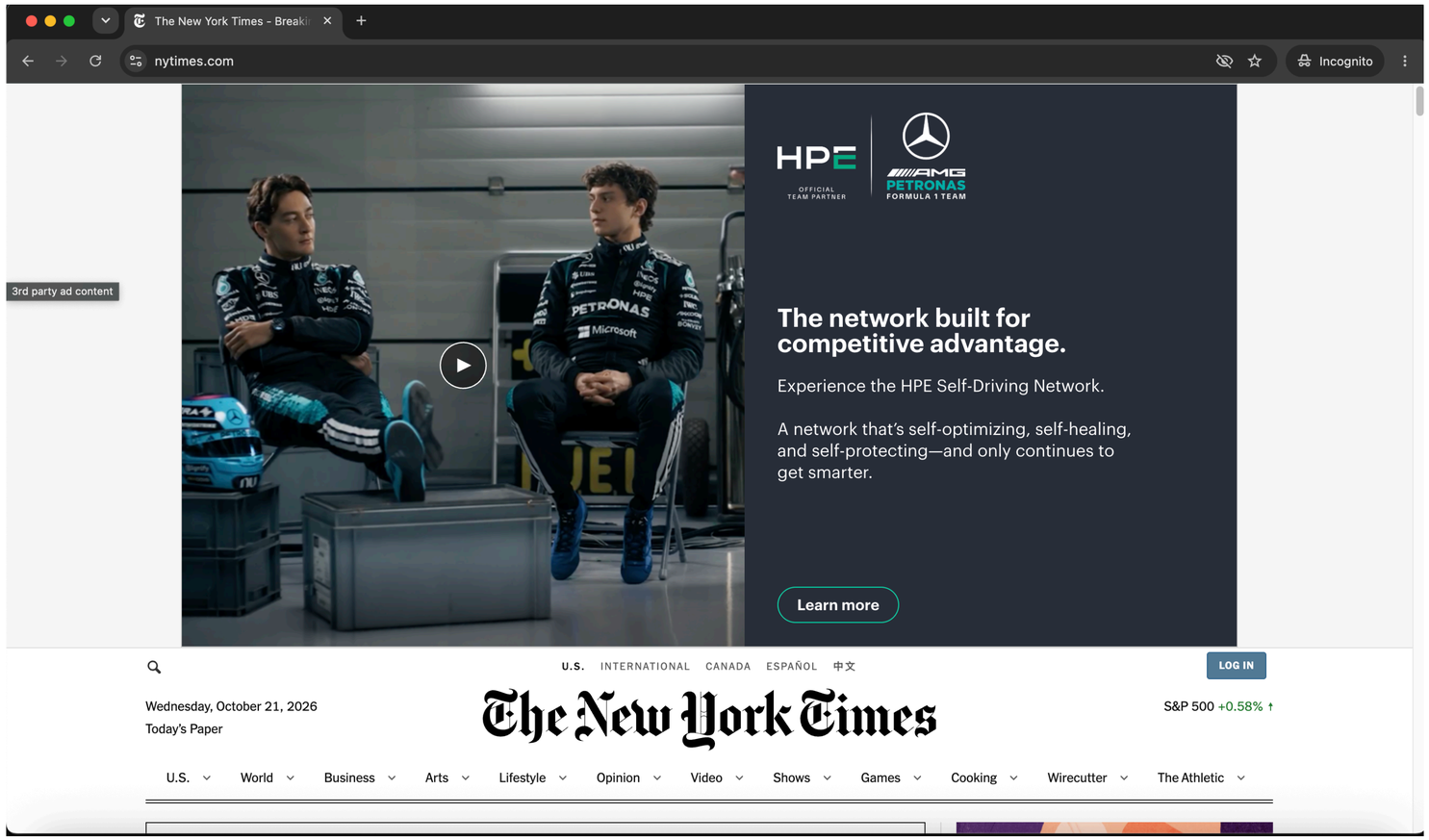
The ad ecosystem

- With a group, answer the following questions:
  - In an online advertising context, what is *supply*?
  - In an online advertising context, what is *demand*?



The ad ecosystem

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  - **In an online advertising context, what is *supply*?**
  - In an online advertising context, what is *demand*?



Ad Supply

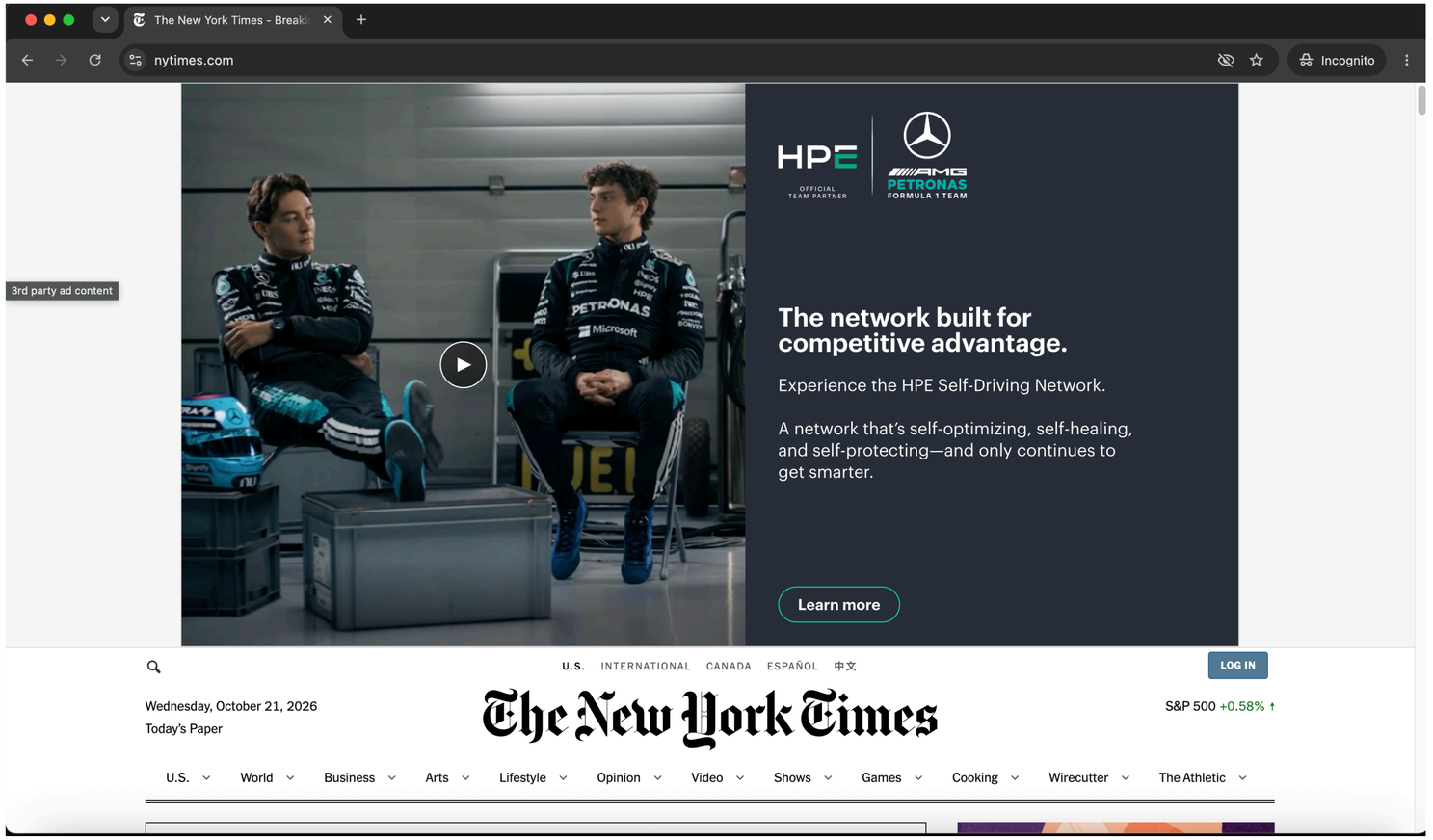
- On the web, ad *supply* are the “spots” to advertise
  - Who owns the supply?

Ad Supply

- On the web, ad *supply* are the “spots” to advertise
  - Who owns the supply?
- Web developers! Or platforms. Or publishers. Or…. lots of language to describe this, so if you’re reading about ad supply, expect all these terms

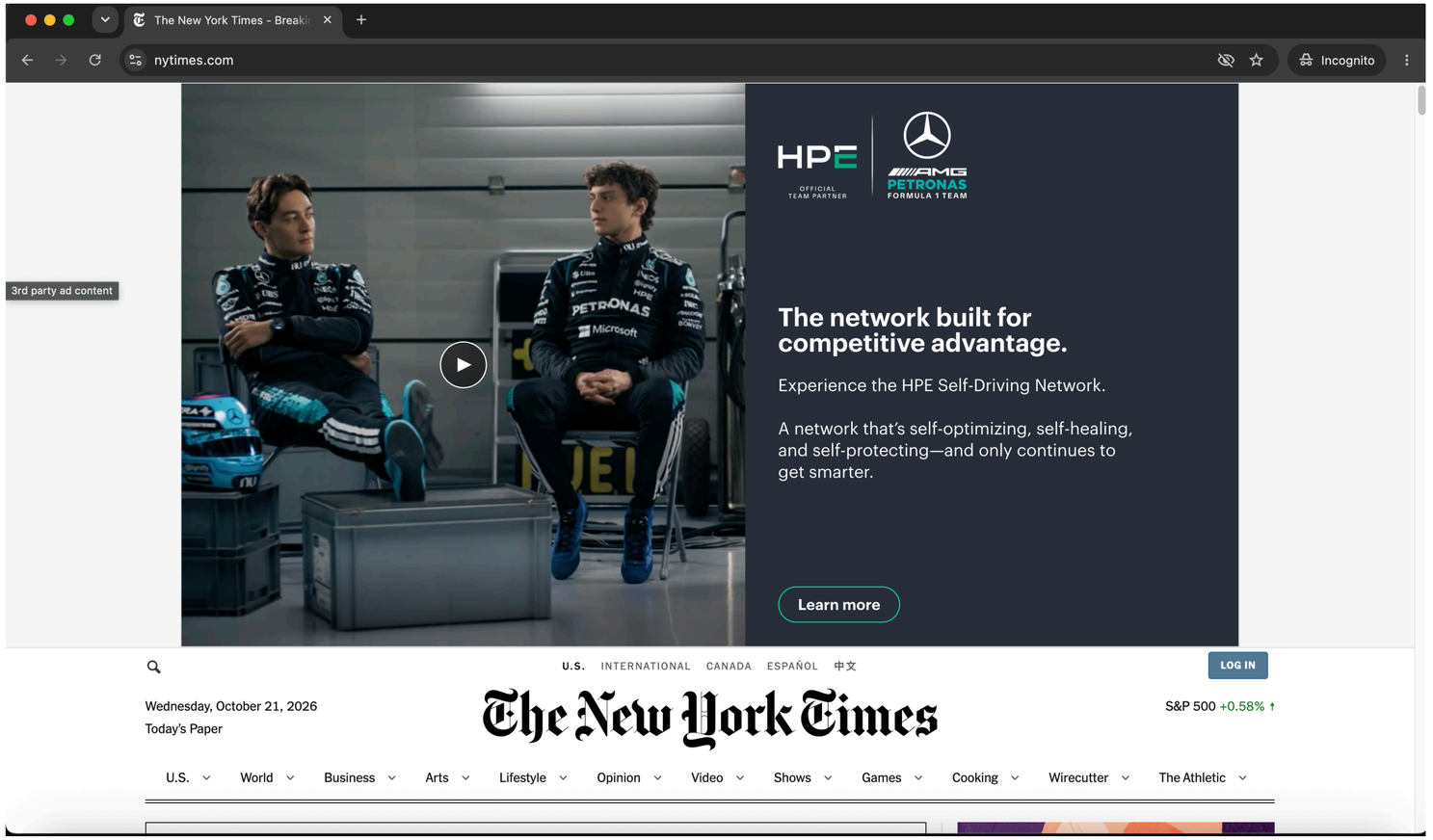
Back to the ad

- What are some properties that “describe” the supply?



Back to the ad

- What are some properties that "describe" the supply?
  - The domain that owns the supply (e.g., nytimes.com vs. cnn.com)
  - Where the ad is placed (topbar, sidebar, etc.)
  - The size of the ad
  - Minimum amount of $ you'll accept



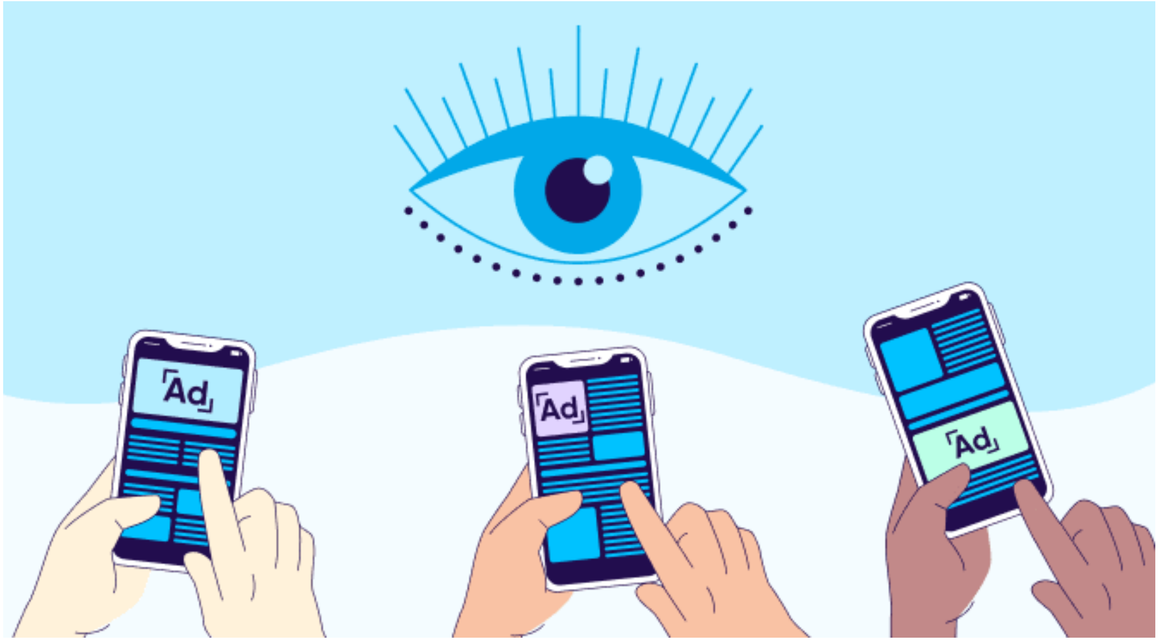
What’s in my supply?

- Impression
- Context
- Device
- User
- Source

What's in my supply?

- **Impression**
- Context
- Device
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- An "impression" is the ad slot itself — could be a banner ad, a video interstitial, or an embedded social media post
  - Format details (e.g., 250 x 350)
  - `bidfloor` (minimum bid amount)
  - `secure` (ad must be served via HTTPS)

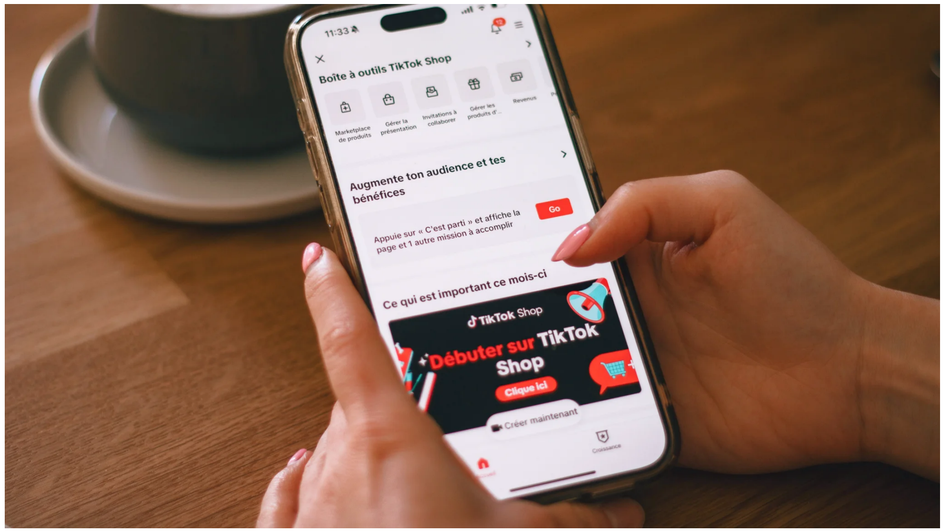




What's in my supply?

- Impression
- **Context**
- Device
- User
- Source

- Context is how the ad will be shown — either `site`, `app`, or `dooh`
  - Domain + page URL
  - Content details (title, genre, categories, language)
- Generally, in-app pays more (CPM ~$2), compared to site (CPM ~$1.5)



in-app advertising

What's in my supply?

- Impression
- Context
- **Device**
- User
- Source

- Device is — details about the device itself, like user-agent, IP, device type, OS, screen size, etc.
- Why might this matter?

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  - You might target *different people* with your ad if it's on mobile vs. app
  - Device type can be a proxy…

What's in my supply?

From Scroll to Sale: Exploring the Impact of Interaction Type and Device Price on TikTok Advertisements

Nazanin Sabri, Cat Mai, Haodi Zou, Isha Varada, Damon McCoy, Deepak Kumar, Kristen Vaccaro

Companies and brands increasingly use dynamic pricing, including targeting social media ads to users based on their income. In this work we audit TikTok's feed using 56 automated accounts, which collect data on over 80,000 videos, across two studies. We test the impact of device price on ad load and ad types, using 12 phones of low ($0-250$), medium ($400-650$), and high ($750-1,000+$) price as a proxy for income. We also test the impact of interaction type (i.e., like, comment, share), age, and gender on the frequency and content of ads. Overall, the ad load was 29.4%, but liking and sharing content increased ad load significantly. We also found that as accounts spend more time on TikTok, the ad load steadily increases. We found some evidence that device price impacts both ad load and content -- more expensive devices were targeted with fewer ads, while the least expensive devices received more discounts.

- User
- S
  - Why might this matter?

"… that users who do not have the means or desire to purchase more expensive devices may face a higher advertisement burden, with ads taking up more of their time and attention."

  - Device type can be a proxy…

What's in my supply?

- Impression
- Context
- Device
- **User**
- Source

- That's you
- Often will connect with what's called a "Data Management Platform" (DMP) or a "Customer Data Platform" (CDP) this is the entity that is storing the tracking data
- <u>More on this next time.</u>









What’s in my supply?

- Impression
- Context
- Device
- User
- **Source**

- Question: Does the NYTimes do its own advertising?

What's in my supply?

- Impression
- Context
- Device
- User
- **Source**

- Question: <u>Does the NYTimes do its own advertising? **No!**</u>
  - Relies on a *Supply Side Platform* (SSP) and *ad exchanges* to sell the spot
  - SSPs are pieces of software designed to **represent the supplier** in a real-time auction — source says where the supply is coming from

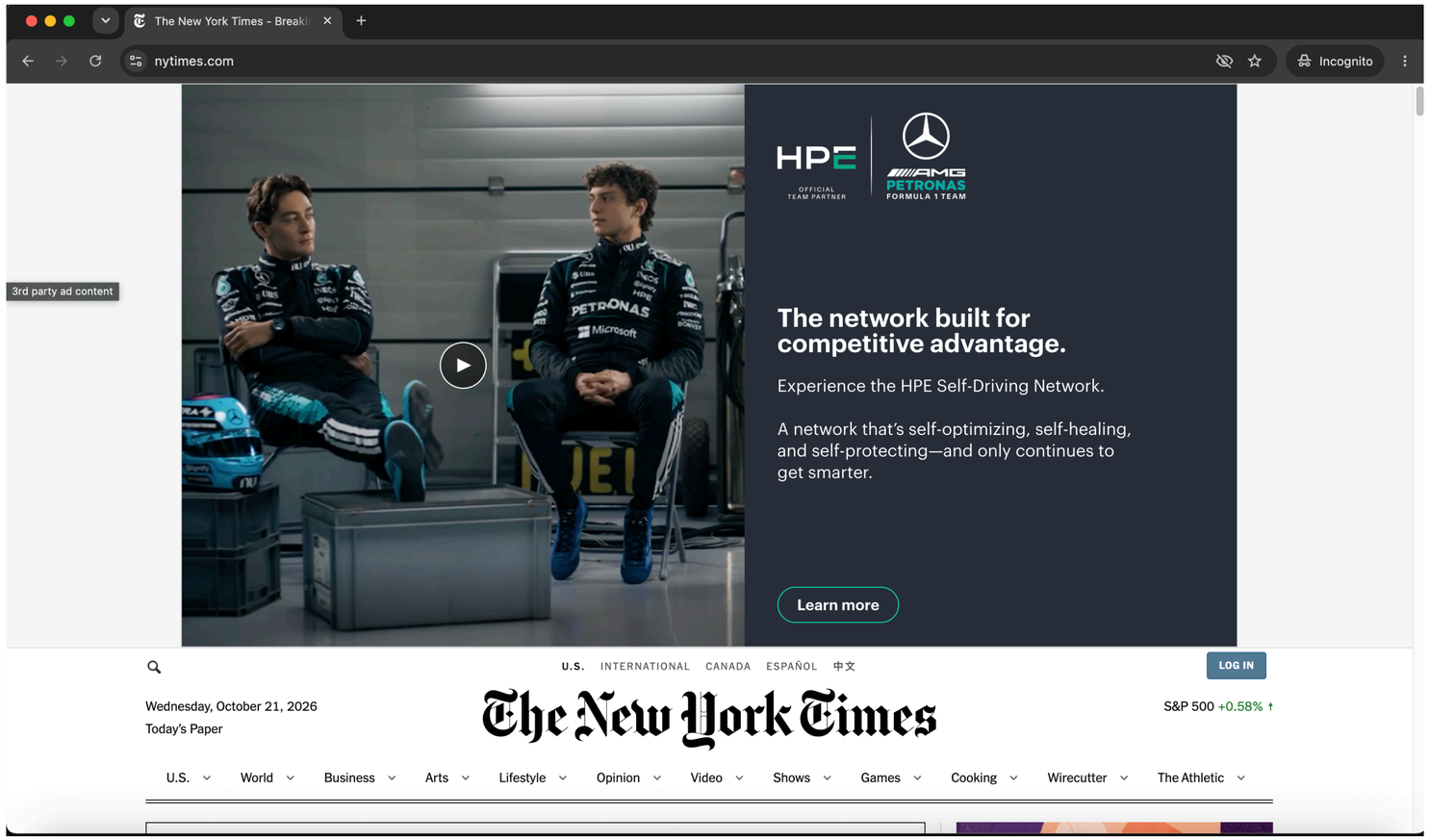






The ad ecosystem

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Ad Demand

- On the web, ad *demand* is created by *advertisers* seeking to advertise
- Advertisers work with a *demand side platform* (DSP) to try and get their ads placed in *favorable places*
- If you're an advertiser, what kinds of details would you surface to suppliers?

Ad Demand

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- Advertisers work with a *demand side platform* (DSP) to try and get their ads placed in *favorable places*
- If you're an advertiser, what kinds of details would you surface to suppliers?
  - How much you are willing to pay
  - Advertisement details (e.g., content, advertiser domain, language, dimensions)
  - The actual advertisement itself!

The players in generating demand

- Advertisers (brands) and their **agencies**
  - They run in-house buying teams called *trading desks*



old-school advertising
in Mad Men

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- These desks interact programmatically with Demand Side Platforms (DSPs) — software that represents the advertiser in an ad auction
  - Any guesses as to companies that run DSPs?



old-school advertising in Mad Men

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- These desks interact programmatically with Demand Side Platforms (DSPs) — software that represents the advertiser in an ad auction
  - Any guesses as to companies that run DSPs?
    - Google, Amazon, The Trade Desk… see a pattern?



old-school advertising in Mad Men

Placing an ad?

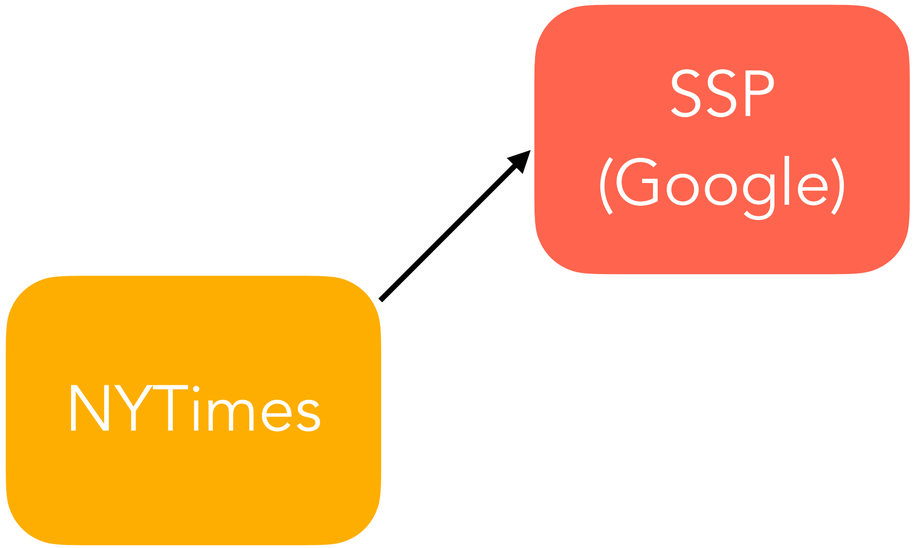
- With a group, answer the following questions:
  - Where does the initial request to place an advertisement come from? Who makes that request?
  - Where does that request go? Who services that request?
  - How does the *money* flow in this ecosystem? How does a publisher actually get *paid* for their ad spot?

Stepping through a programmatic ad placement

NYTimes

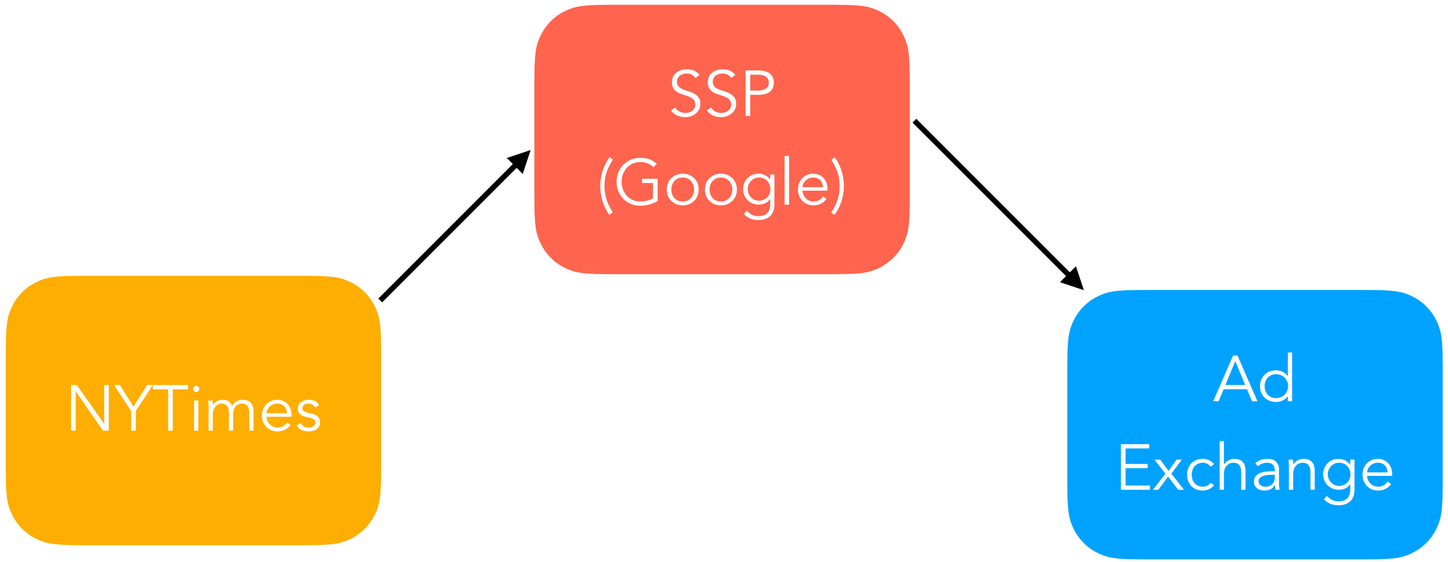
nytimes.com wants to sell an ad slot

Stepping through a programmatic ad placement



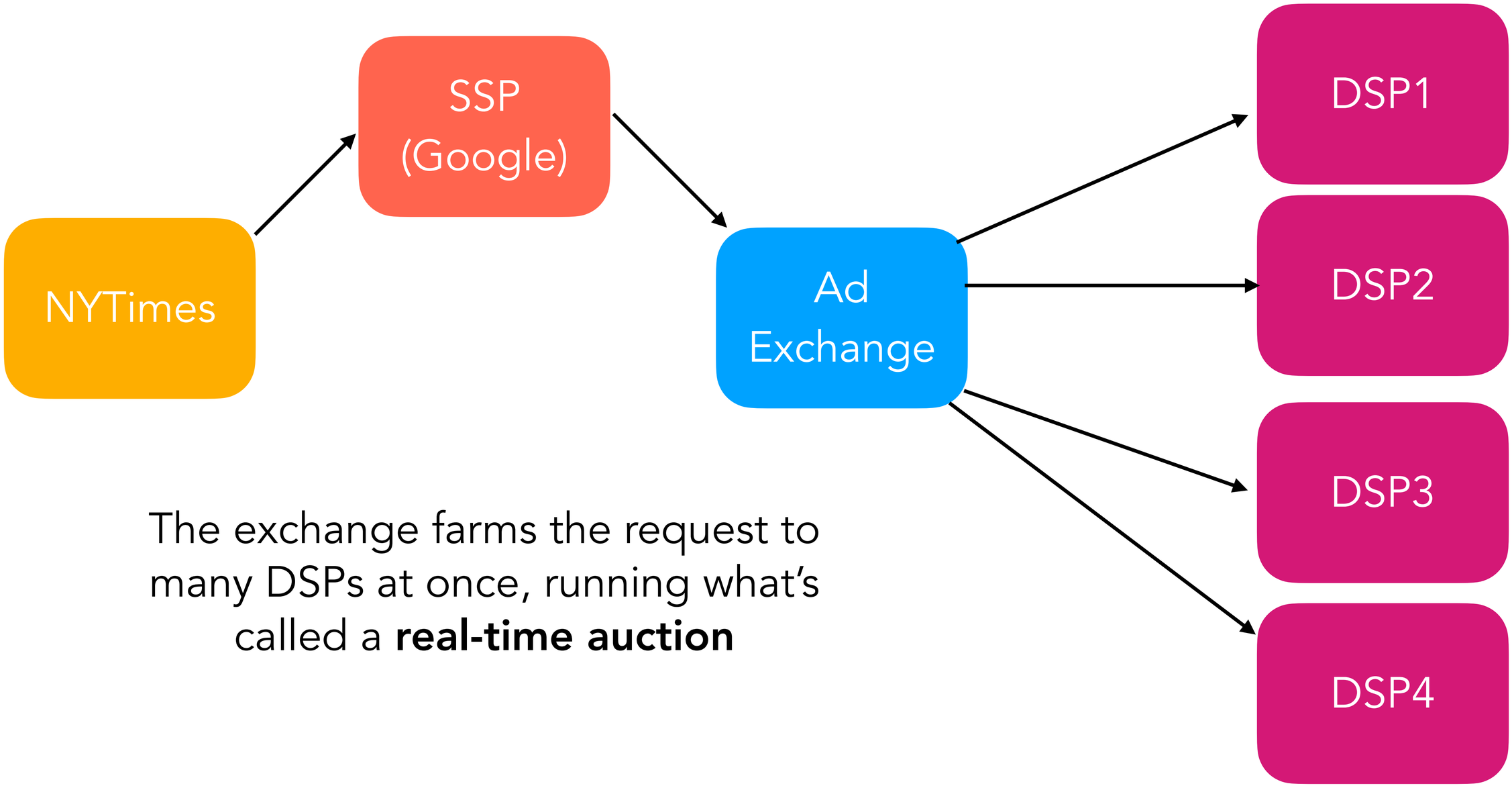
First, they talk to their SSP, providing details about the slot

Stepping through a programmatic ad placement



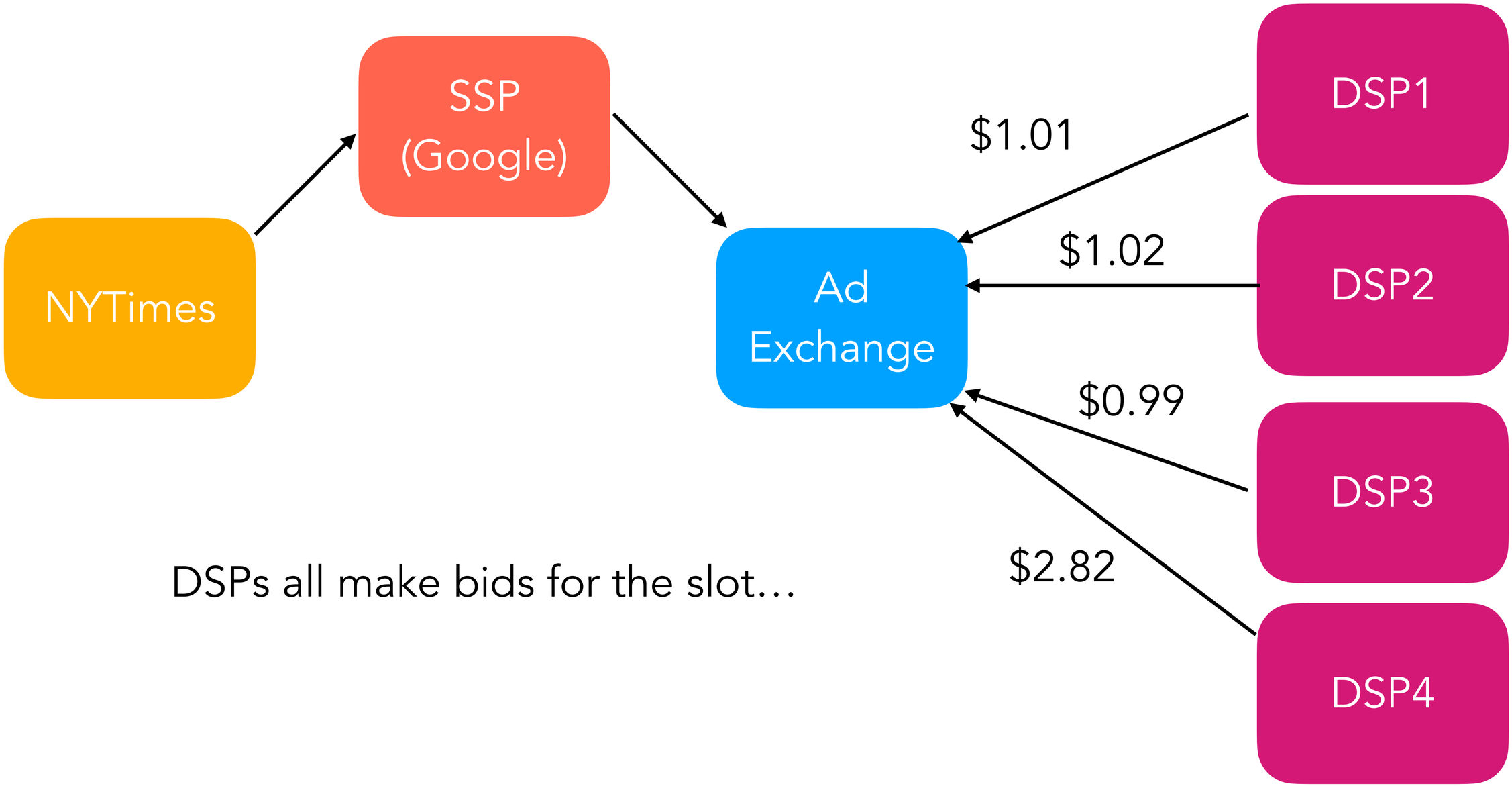
The SSP tells an *ad exchange*
about the slot

Stepping through a programmatic ad placement



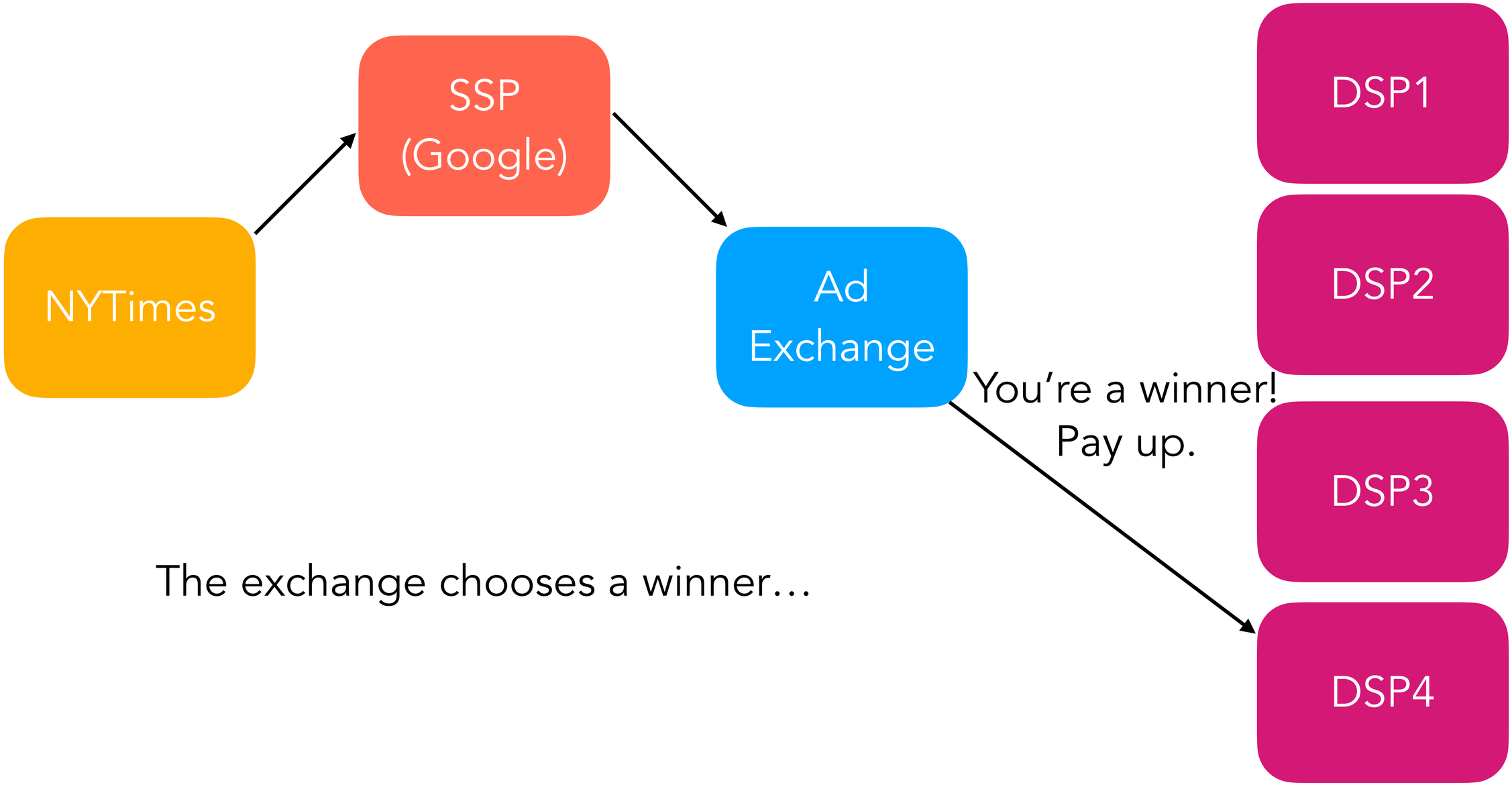
The exchange farms the request to many DSPs at once, running what's called a **real-time auction**

Stepping through a programmatic ad placement

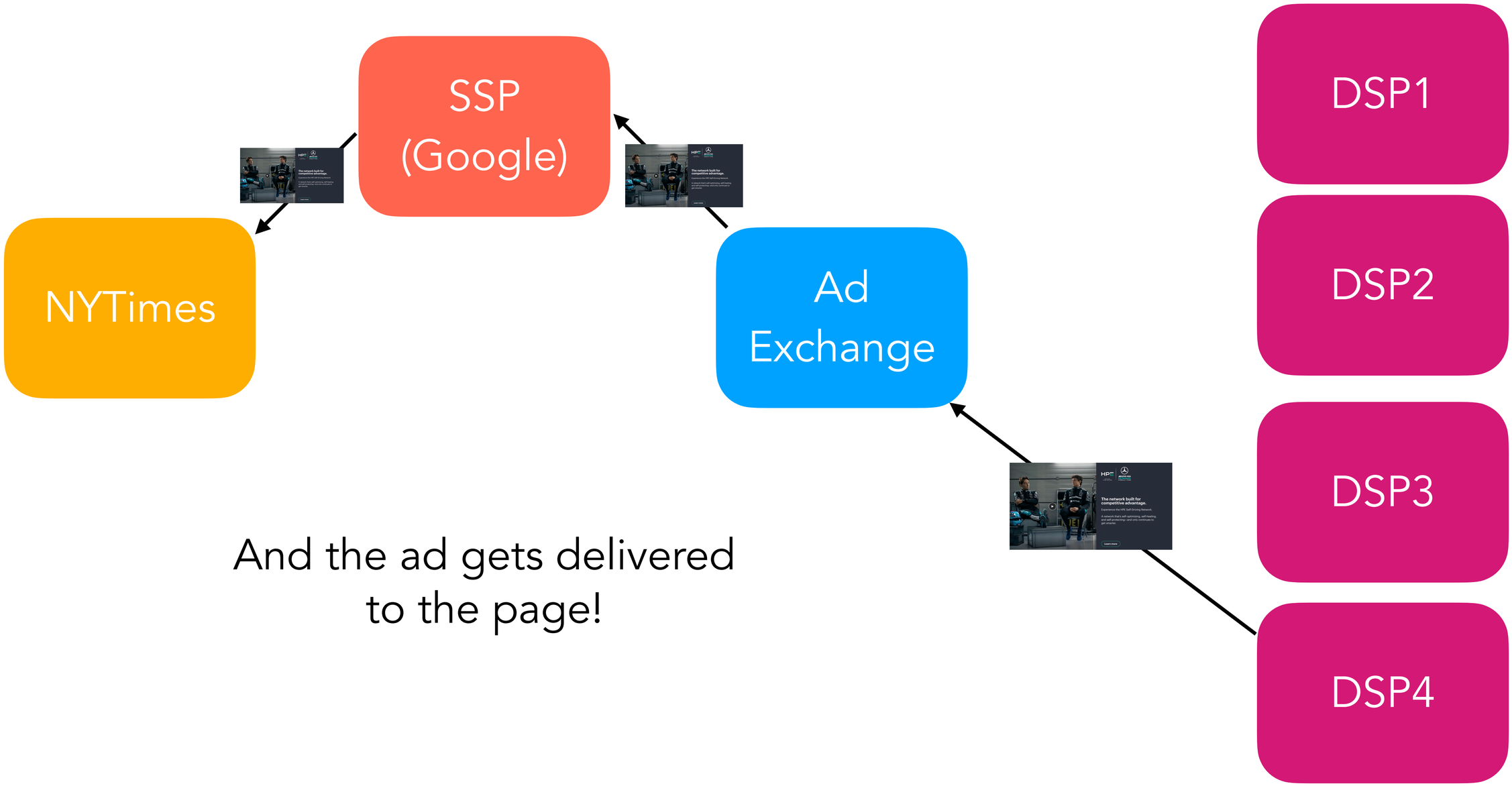


DSPs all make bids for the slot…

Stepping through a programmatic ad placement

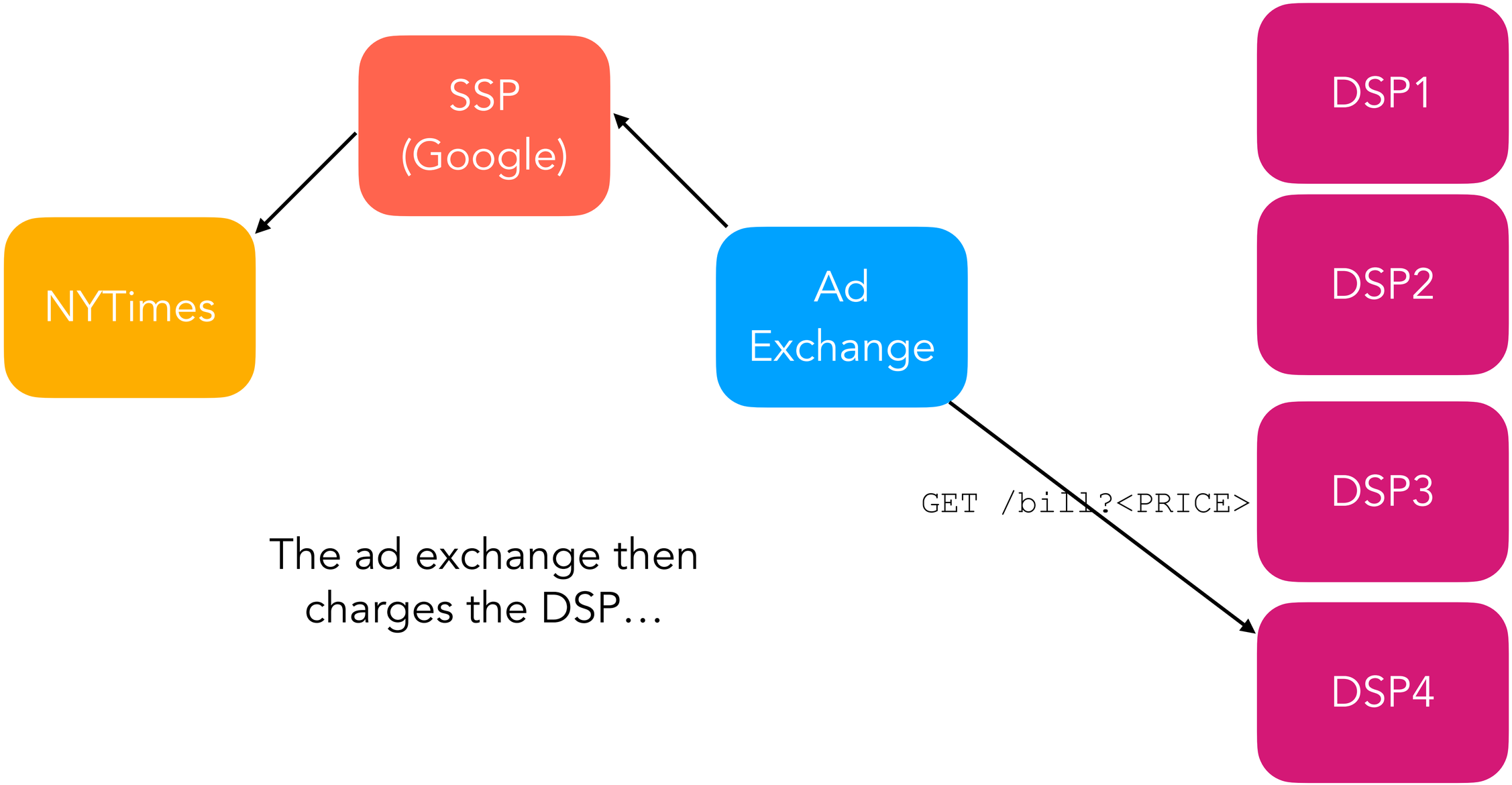


Stepping through a programmatic ad placement



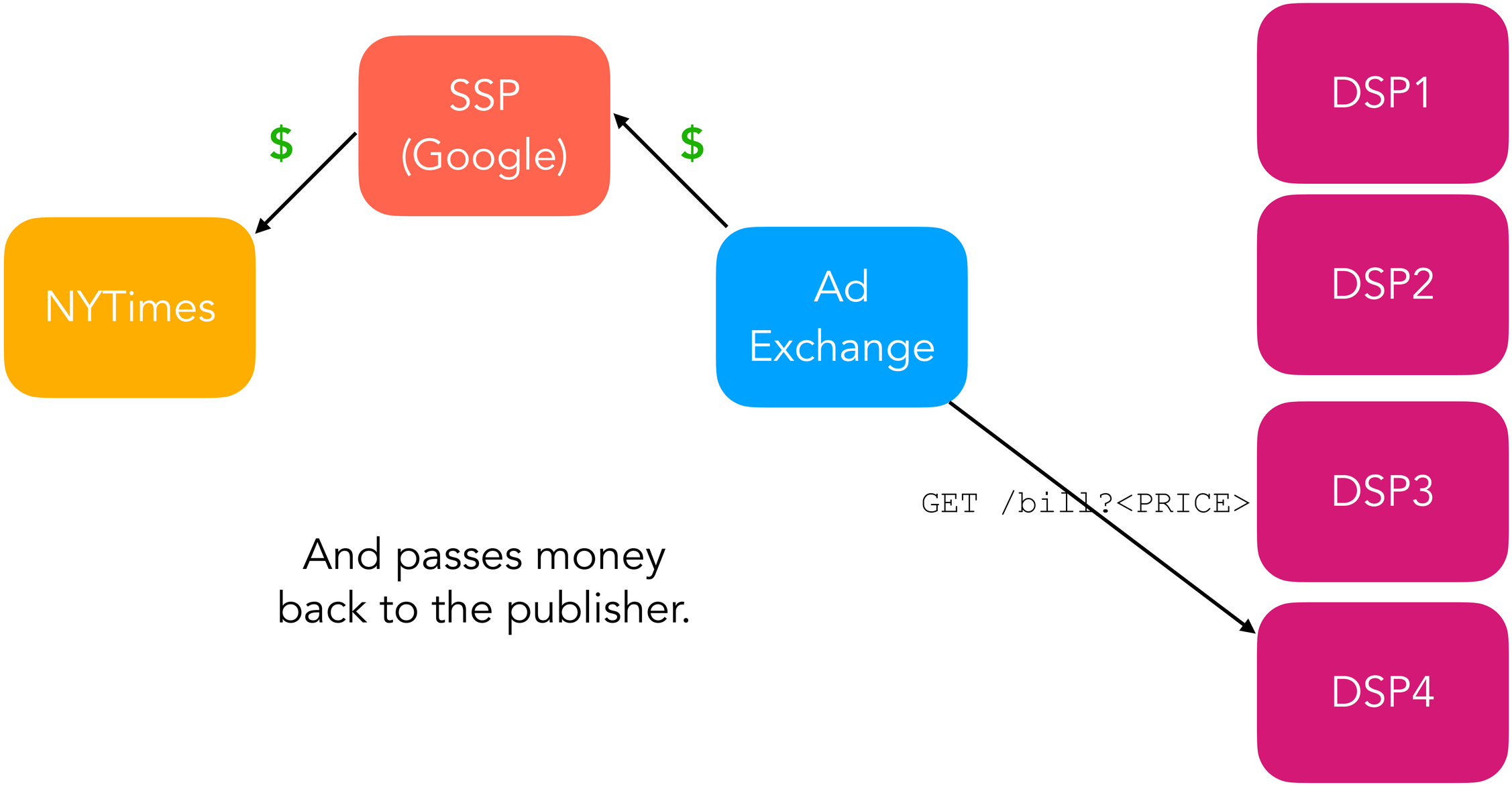
And the ad gets delivered to the page!

Stepping through a programmatic ad placement



The ad exchange then charges the DSP…

Stepping through a programmatic ad placement



And passes money
back to the publisher.

Questions about this process

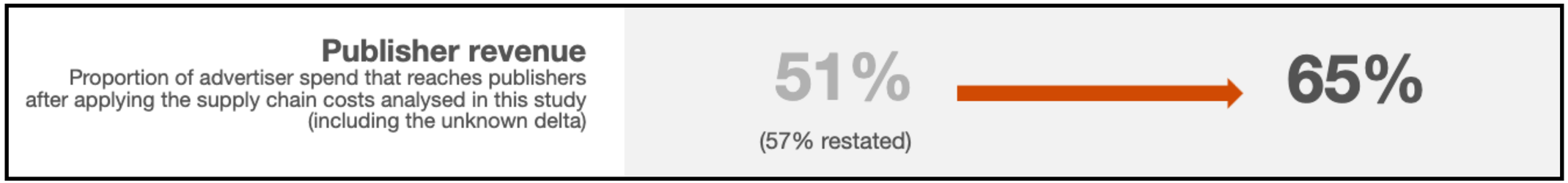
- How quickly does this **entire auction** happen?

Questions about this process

- How quickly does this **entire auction** happen?
  - 100 — 300ms. *Crazy fast!*
- Let’s say the CPM price an advertiser was willing to pay was $1. How much do you think gets back to the publisher?

Questions about this process

- How quickly does this **entire auction** happen?
  - 100 — 300ms. *Crazy fast!*
- Let's say the CPM price an advertiser was willing to pay was $1. How much do you think gets back to the publisher?



- If not to the publisher, where does the money go…?

https://www.isba.org.uk/system/files/media/documents/2023-01/ISBA%20%20PwC%20programmatic%20supply%20chain%20study%20II%20%28summary%29-%2018%20January%202023.pdf

Middlepeople (SSPs, DSPs, and Ad Exchanges)



Google Ad Exchange (AdX)

Magnite

amazon
publisher services

OpenX

PubMatic

…How is this allowed?



Google… wins, somehow?

Google escapes ad tech breakup in third Big Tech antitrust loss for US

By **Jody Godoy** and **Jonathan Stempel**

September 2, 2026 7:31 AM PDT · Updated September 2, 2026



FILE PHOTO: The Google logo is seen outside the company's offices in London, Britain, June 24, 2025. REUTERS/Carlos Jasso/File Photo/File Photo Purchase Licensing Rights

- Google was able to *keep* all their advertising properties (supply side, demand side, *and* exchange)… despite clear opportunity to rig pricing

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- How much money did Google make on advertising in 2025? Total revenue was ~$400B.

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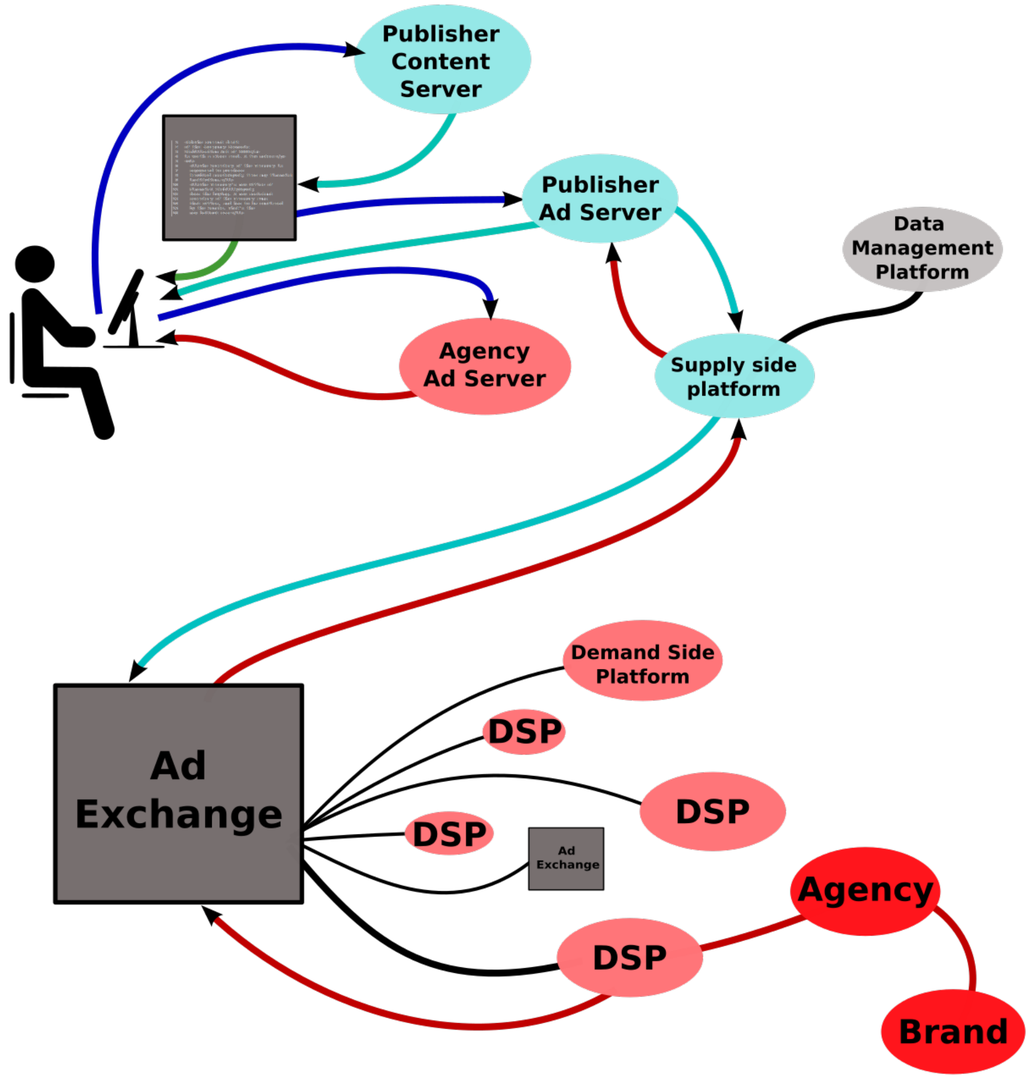


FILE PHOTO: The Google logo is seen outside the company's offices in London, Britain, June 24, 2025. REUTERS/Carlos Jasso/File Photo/File Photo Purchase Licensing Rights

- Google was able to *keep* all their advertising properties (supply side, demand side, *and* exchange)… despite clear opportunity to rig pricing
- How much money did Google make on advertising in 2025? Total revenue was ~$400B.
  - **$294.7B (74%!!!!!!!!)**

And by the way, it's actually way more complicated

- Such as…
  - Suppliers can make separate deals for ad placements
  - SSPs usually connect to **all ad exchanges at the same time** to find the most competitive price
  - There are thousands of DSPs that want to participate in advertising
  - Networking is a big deal (the closer you are to the exchange the better)
  - And so it goes….



OK, but, lots of questions…

- How does any of this stuff get encoded?
- How does the bidding *actually* happen programmatically?
- How does the auction work?
- And many more…

Implementing Programmatic Advertisements

Let’s design a protocol

- With people around you, take three minutes to list what an SSP must tell a DSP so it can decide what to bid.

The current way: IAB's OpenRTB Protocol

- The Interactive Advertising Bureau (IAB) is an org started in 1996 to support the budding online advertising economy

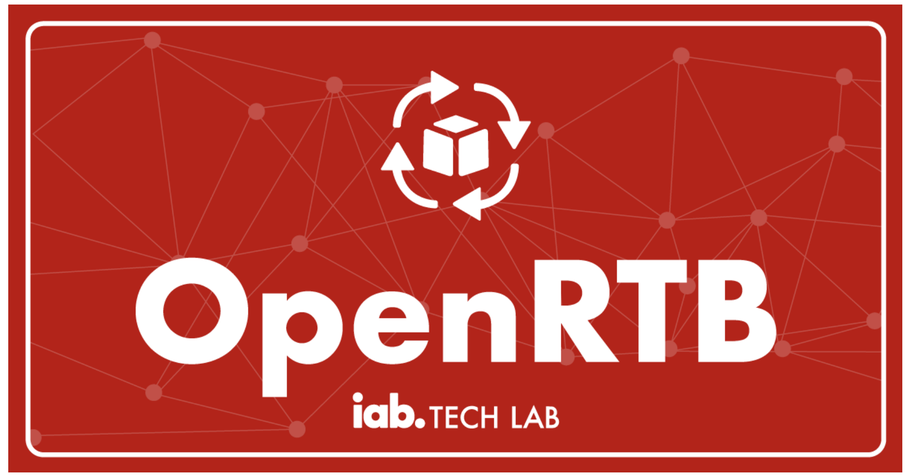


The current way: IAB's OpenRTB Protocol

- The Interactive Advertising Bureau (IAB) is an org started in 1996 to support the budding online advertising economy

- IAB built a protocol, called **OpenRTB** (real-time bidding), to standardize the advertising ecosystem

    - First version was released ~2010, but released as a full standard in 2012 (current version 2.6 is most used)



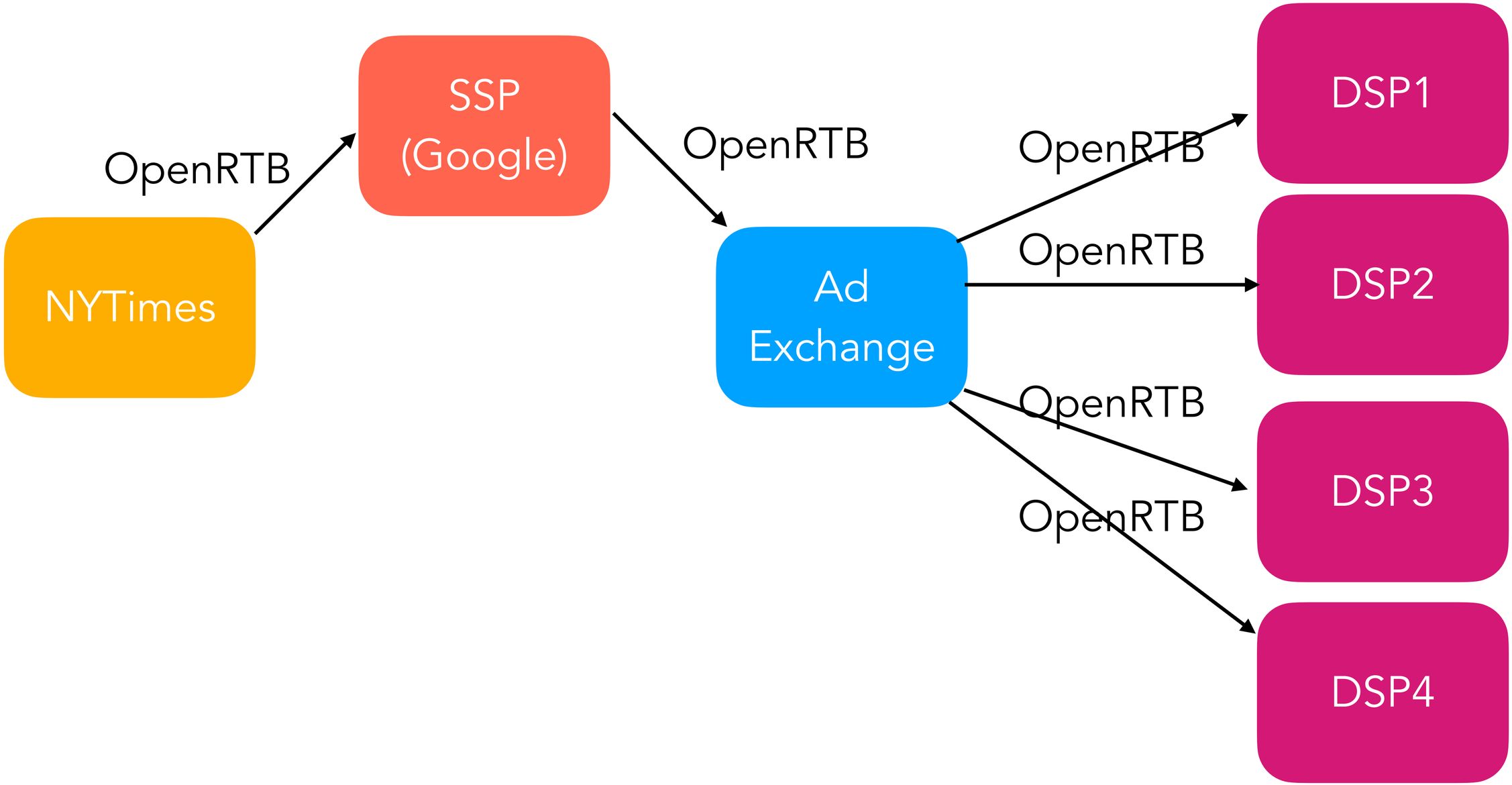
OpenRTB is JSON over HTTP

- The protocol is web native — meaning it is implemented on top of HTTP and uses JSON formatting
  - Is JSON a good choice for this?

OpenRTB is JSON over HTTP

- The protocol is web native — meaning it is implemented on top of HTTP and uses JSON formatting
  - Is JSON a good choice for this?
- Mixed bag. JSON is bloated (you duplicate a lot of data over the wire), but it is human-readable (which I guess is nice)
- **You will implement a very simple version of OpenRTB in PA1 part 4.**

OpenRTB runs the entire ecosystem



Recall: Clients and Servers

- Which of the following pieces of software can be considered an **OpenRTB client?**
  - The SSP
  - The DSP
  - The Ad Exchange
  - The publisher website
  - The advertiser’s trade desk software

Recall: Clients and Servers

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  - **The Ad Exchange**
  - **The publisher website**
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A Simple OpenRTB Request

```
{
  "id": "req-123", "at": 1, "tmax": 150,
  "imp": [{ "id": "1", "banner": { "w": 300, "h": 250 }, "bidfloor": 0.50 }],
  "site": { "domain": "news.example", "page": "https://news.example/sports/
game" },
  "device": { "ua": "Mozilla/5.0 ...", "ip": "203.0.113.0" },
  "user": { "buyeruid": "dsp-u-77f1" }
}
```

What do we know about this slot?

A Simple OpenRTB Request

```
{
  "id": "req-123", "at": 1, "tmax": 150,
  "imp": [{ "id": "1", "banner": { "w": 300, "h": 250 }, "bidfloor": 0.50 }],
  "site": { "domain": "news.example", "page": "https://news.example/sports/
game" },
  "device": { "ua": "Mozilla/5.0 ...", "ip": "203.0.113.0" },
  "user": { "buyeruid": "dsp-u-77f1" }
}
```

This is a banner ad, with size 250x300px

A Simple OpenRTB Request

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  "imp": [{ "id": "1", "banner": { "w": 300, "h": 250 }, "bidfloor": 0.50 }],
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}
```

The minimum amount the seller is willing to accept is a CPM of $0.5

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  "device": { "ua": "Mozilla/5.0 ...", "ip": "203.0.113.0" },
  "user": { "buyeruid": "dsp-u-77f1" }
}
```

The seller is selling on news.example, specifically the sports section

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```
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  "device": { "ua": "Mozilla/5.0 ...", "ip": "203.0.113.0" },
  "user": { "buyeruid": "dsp-u-77f1" }
}
```

The user has an identifier (likely, a cookie) and device information (including IP addresses!)

A Simple OpenRTB Request

```
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Question: why send this cookie value along?

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}
```

Question: why send this cookie value along?

Advertisers that this supplier has *cookie sync'd* with can send an even more specific targeted advertisement!

A Simple OpenRTB Response

```
{
  "id": "req-123",
  "seatbid": [{ "bid": [{
    "impid": "1", "price": 1.10,
    "adm": "<a href='...'><img src='...'></a>",
    "nurl": "https://dsp.example/win?p=${AUCTION_PRICE}"
  }]}]
}
```

What does this response seem to contain?

A Simple OpenRTB Response

```
{
  "id": "req-123",
  "seatbid": [{ "bid": [{
    "impid": "1", "price": 1.10,
    "adm": "<a href='...'><img src='...'></a>",
    "nurl": "https://dsp.example/win?p=${AUCTION_PRICE}"
  }]}]
}
```

The price that the bidder is willing to pay (CPM)

A Simple OpenRTB Response

```
{
  "id": "req-123",
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  }]}]
}
```

The advertisement itself! Rendered in HTML.

A Simple OpenRTB Response

```
{
  "id": "req-123",
  "seatbid": [{ "bid": [{
    "impid": "1", "price": 1.10,
    "adm": "<a href='...'><img src='...'></a>",
    "nurl": "https://dsp.example/win?p=${AUCTION_PRICE}"
  }]}]
}
```

A “notice URL,” telling the DSP that they won the auction, and at what price.

OpenRTB categories

- There are *lots* of fields, lots of ways to customize, for example… categories!

```
{
  "id": "req-002",
  "imp": [{ "id": "1", "banner": { "w": 300, "h": 250 } }],
  "site": {
    "domain": "sports.example",
    "page": "https://sports.example/running/marathon-training",
    "cattax": 7,
    "cat": ["483"],
    "pagecat": ["<ContentTax3.0 ID for Running>"]
  }
}
```

OpenRTB categories

- There are *lots* of fields, lots of ways to customize, for example… categories!

```
{
  "id": "req-002",
  "imp": [{ "id": "1", "banner": { "w": 300, "h": 250 } }],
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    "domain": "sports.example",
    "page": "https://sports.example/running/marathon-training",
    "cattax": 7,
    "cat": ["483"],
    "pagecat": ["<ContentTax3.0 ID for Running>"]
  }
}
```

There are taxonomies and categories of content, users, etc… everything you can possibly imagine

Aside — PA1 Part 4

- In part 4 of PA1, your goal will be to implement an **SSP** that interfaces with four **DSPs** that we run
  - You will have to try and get the “best” ads for your customer (Boogle), while navigating weird DSP logic, bad ads, shady stuff… and you’ll have to do it all in < 300ms
  - You will do this by running a real-time auction to try and make money for Boogle
  - You will implement a small version of OpenRTB

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  - You will implement a small version of OpenRTB

How do real-time auctions work…?

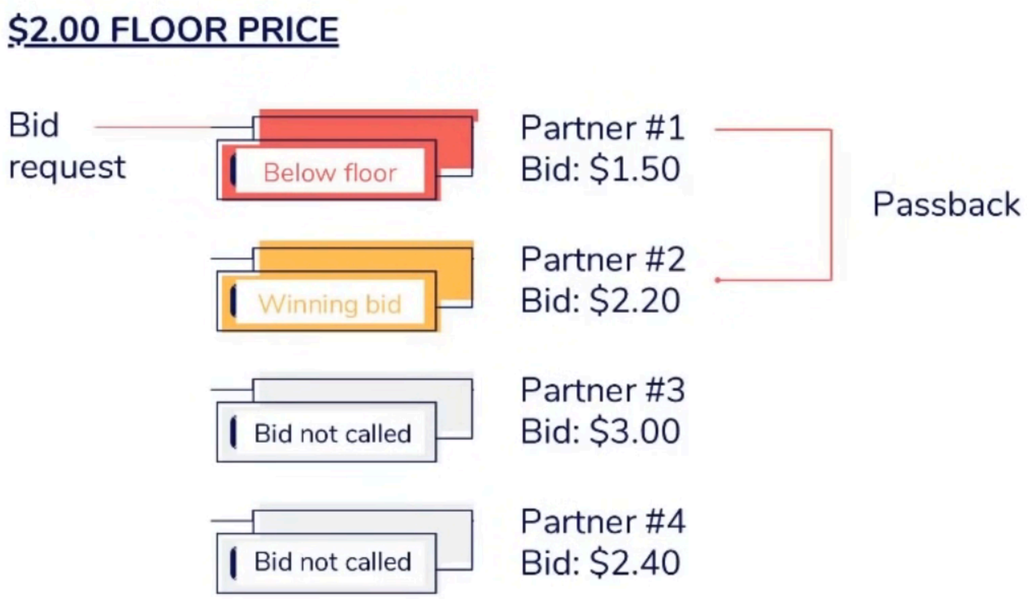
Real-time auctions

Bidding for ad spots

- **Real-time bidding** is an auction process that is kicked off when a publisher tells an advertising network that they have an open ad-spot with certain properties
- Two most widely used methods of auctioning
  - Waterfall bidding (old)
  - Header bidding (the newness)

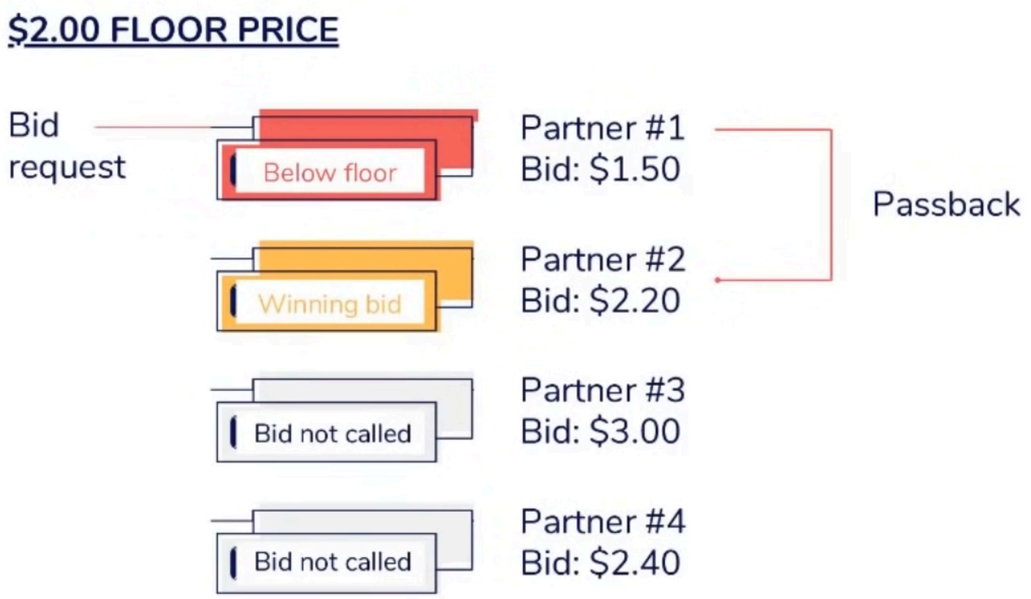
Waterfall Bidding

- Publishers pre-define a hierarchy of advertising networks (e.g., in a waterfall) about any spot
- Publishers set a floor that they needed for the ad spot
  - The first network to fulfill the floor would win the spot



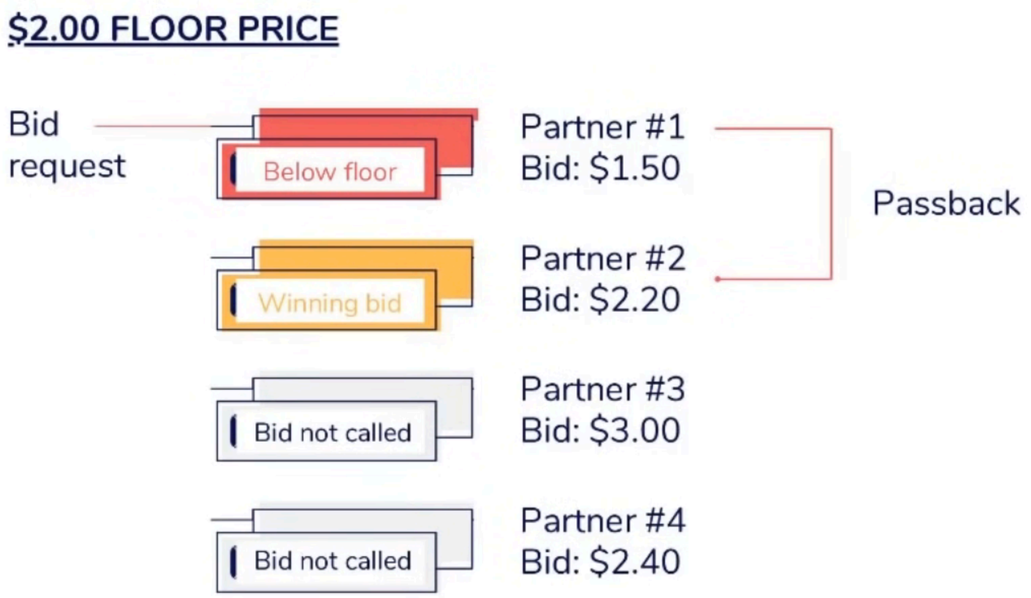
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- What problems might you see with waterfall bidding?



Waterfall Bidding

- Publishers pre-define a hierarchy of advertising networks (e.g., in a waterfall) about any spot
- Publishers set a floor that they needed for the ad spot
  - The first network to fulfill the floor would win the spot
- What problems might you see with waterfall bidding?
  - Slow (computation is serial)
  - Anti-competitive!
    - Google had both an SSP and a DSP, which often meant they got first pick at ad spots



Header Bidding

- Every DSP is offered an opportunity to bid at the *same time*
  - Why is this a good thing for competitiveness?

Header Bidding

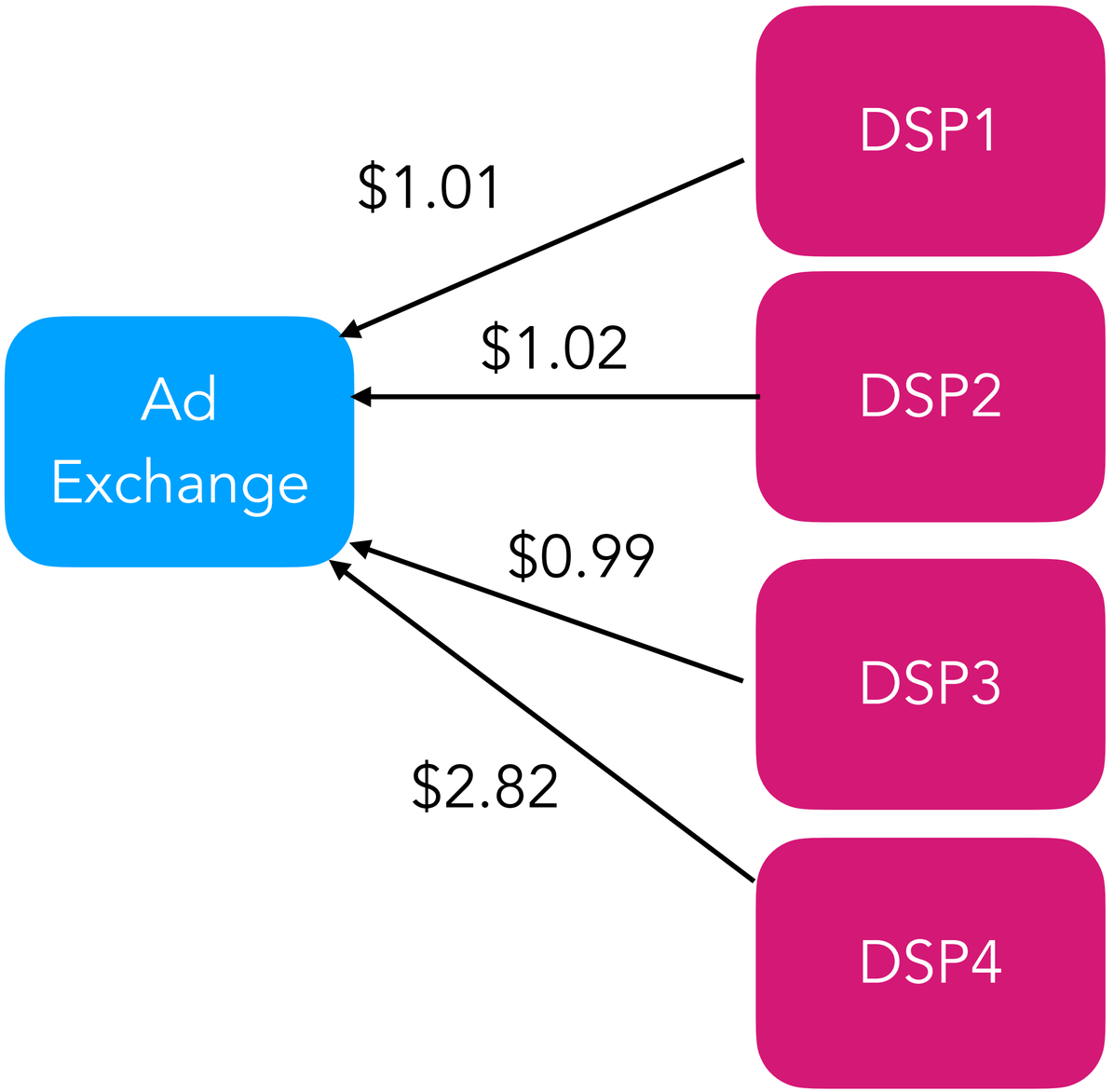
- Every DSP is offered an opportunity to bid at the *same time*
  - Why is this a good thing for competitiveness?
  - DSPs are incentivized to provide their true value for the advertising spot (theoretically)
- Two types of auctions you'll see in online advertising markets
  - Second-price auctions (Vickrey)
  - First-price auction

Second-Price Auction

- In a second-price auction, the **highest bidder** wins the auction, but only pays **the second-highest bid price** (+0.01)

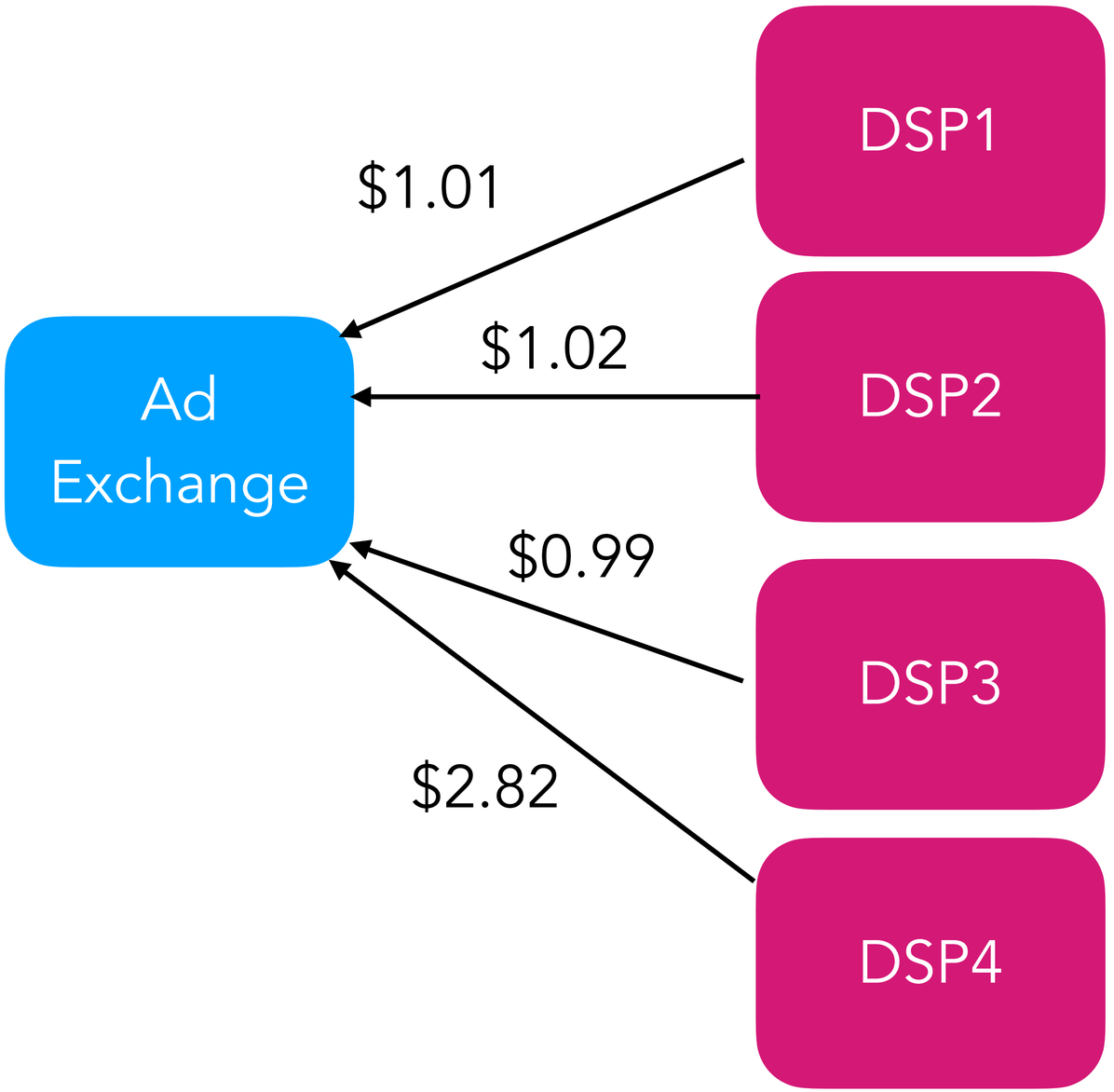
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- Which DSP should win the auction?



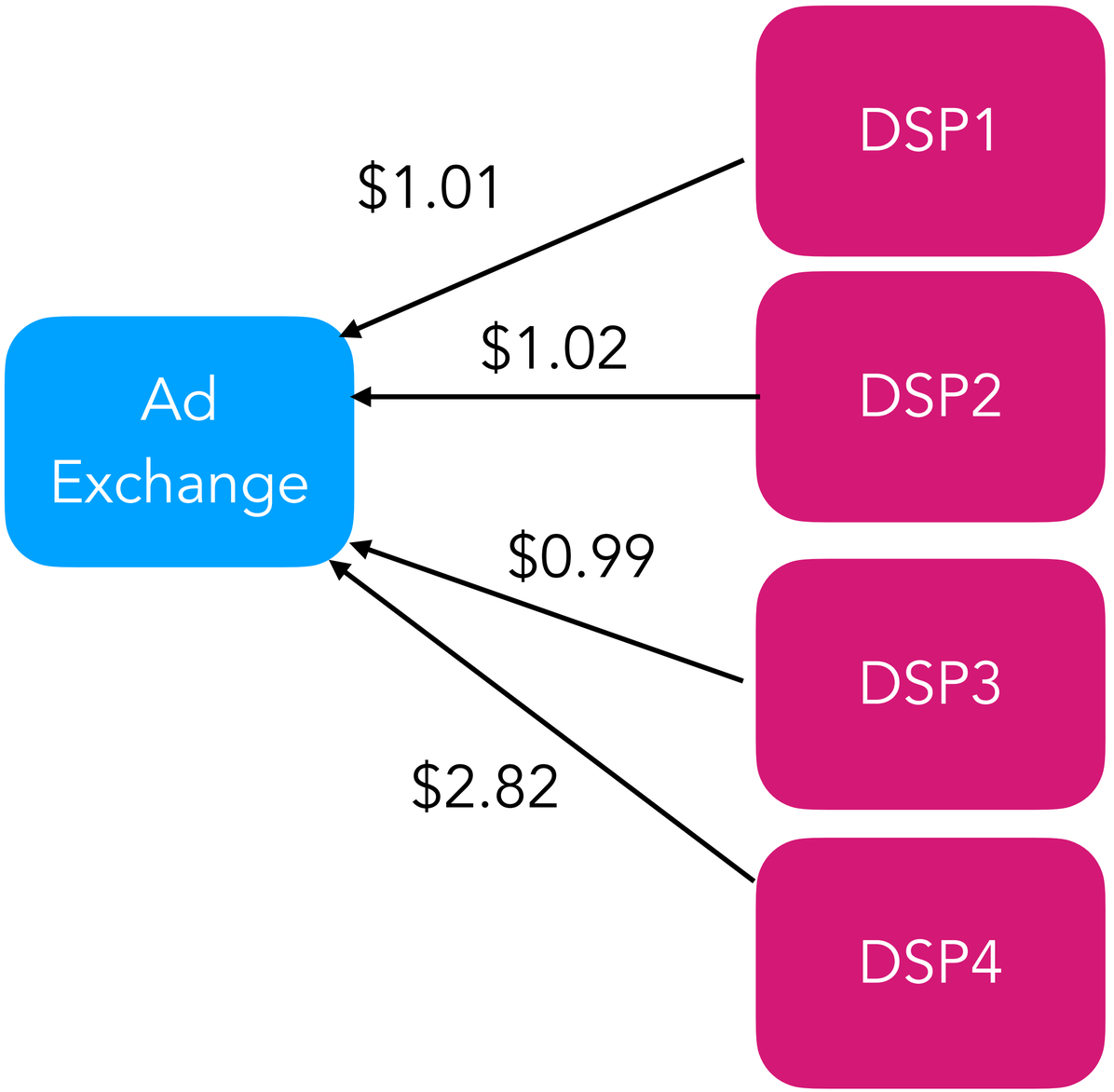
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- Which DSP should win the auction?
  - DSP4! How much should they pay?



Second-Price Auction

- In a second-price auction, the **highest bidder** wins the auction, but only pays **the second-highest bid price** (+0.01)
- Which DSP should win the auction?
  - DSP4! How much should they pay? **$1.03**



Second-Price Auction Economics

- A **dominant strategy** is one where your choice gives you the best likelihood of winning, regardless of what other entities (e.g., DSPs do)
- If you are a DSP, what is your dominant strategy?

Second-Price Auction Economics

- A **dominant strategy** is one where your choice gives you the best likelihood of winning, regardless of what other entities (e.g., DSPs do)
- If you are a DSP, what is your dominant strategy?
  - **Offer your true value!**
    - If you bid above your true value, you risk winning (and therefore paying out higher than your value)
    - If you bid below your true value, you risk losing at your profitable price

A shift in priorities

- Second-price auctions were the industry standard from 2009 — 2019ish — almost every single entity implemented them
- Nowadays, most everyone has shifted to a first-price auction.
  - What is a first-price auction?

A shift in priorities

- Second-price auctions were the industry standard from 2009 — 2019ish — almost every single entity implemented them
- Nowadays, most everyone has shifted to a first-price auction.
  - What is a first-price auction?
    - An auction where the highest bidder wins and pays they price that they bid!
- Why might the industry have moved to first-price auctions?

A humble ad exchange goes rogue

Google Misled Publishers and Advertisers, Unredacted Lawsuit Alleges

Details show Google employees fretting its ad tech auctions were 'untruthful' and based in 'insider information'

By Tripp Mickle and Keach Hagey
Updated Jan. 14, 2022 4:50 pm ET

Aa 88 Listen (2 min)

Google's Alleged Scheme to Corner the Online Ad Market

A newly unredacted legal filing sheds light on internal programs that antitrust enforcers argue advantaged Google at the expense of advertisers and publishers.

Questioning Second-Price Auctions in Ad Tech



Written by Matthew B. Wilson, December 21, 2018

Problems with first-price auctions

- What is the big problem with first-price auctions?
  - Bidders may end up overpaying when bidding their true value. Requires bidders to *guess* the right value… which means… **algorithms**

Enter: Bid shading!

- **Bid shading** is the process how advertisers *decide* how much to bid on an ad

- What's a simple bid shading algorithm?

Enter: Bid shading!

- **Bid shading** is the process how advertisers *decide* how much to bid on an ad
- What's a simple bid shading algorithm?
  - Take your true value and bid 0.9 * value
- There are **many** more complicated algorithms at play, complex ML, etc… lots of research here if you're interested!

Adaptive Bid Shading Optimization of First-Price Ad Inventory

NIKLAS KARLSSON and QIAN SANG

Bid Shading in The Brave New World of First-Price Auctions

Djordje Gligorijevic*, Tian Zhou*, Bharatbhushan Shetty, Brendan Kitts, Shengjun Pan, Junwei Pan and Aaron Flores
Yahoo Research, Verizon Media
Sunnyvale, CA, USA
{djordje.gligorijevic,tian.zhou,bharatbs,brendan.kitts,alanpan,jwpan,aaron.flores}@verizonmedia.com

An Efficient Deep Distribution Network for Bid Shading in First-Price Auctions

Tian Zhou, Hao He, Shengjun Pan, Niklas Karlsson, Bharatbhushan Shetty, Brendan Kitts, Djordje Gligorijevic, San Gultekin, Tingyu Mao, Junwei Pan, Jianlong Zhang and Aaron Flores
Yahoo Research, Verizon Media
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jonaspan@tencent.com,jianlong.zhang@gmail.com,aaron.flores@verizonmedia.com

Next time…

- We will continue down our exploration of the online advertising ecosystem, discussing trust + transparency, how user tracking plays a role, fraud, and fun stories of the online advertising ecosystem imploding on itself time and time again
- PA1 part 3 is due **tonight**! Good luck!
- PA1 part 4 is en route… get started early