

Modern Web Protocols Part 2

cs249i

Where we left off...

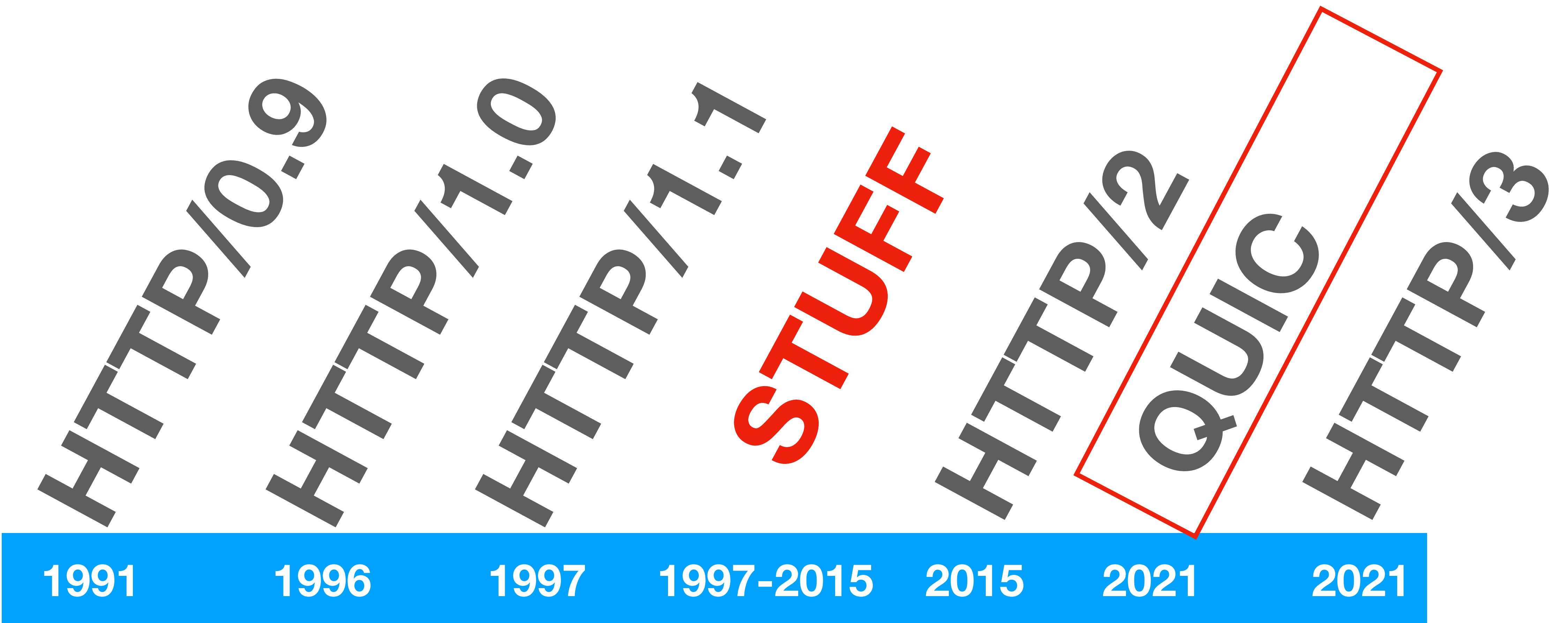
A History of Web Protocols

- HTTP/1.x has lots of problems
 - Standard request / response paradigm + HoL blocking made it difficult to scale to support increasingly complex modern websites
 - Solutions to this problem (e.g., HTTP pipelining) ran into serious deployment challenges which never let it take off
- HTTP/2 was created to solve lots of these problems
 - Implemented a new abstraction (e.g., byte streams, frames, messages) and fixed lots of challenges
 - But still suffers from HoL blocking, just at the TCP layer instead of the HTTP layer

Lingering Questions

- Q1: How many HPACK tables are there at once?
 - There is a pair of static / dynamic tables generated *per HTTP/2 connection*.
 - Size restraints make this feasible (but are tunable by client / server in settings frames)
 - If two mutually distrustful clients are using the same HTTP/2 connection, they can probe dynamic table state (and potentially leak client information)
- Q2: Can Server Push be used as a notification system?
 - No, the browser doesn't expose server push in JavaScript, see Push API instead

A History of Web Protocols



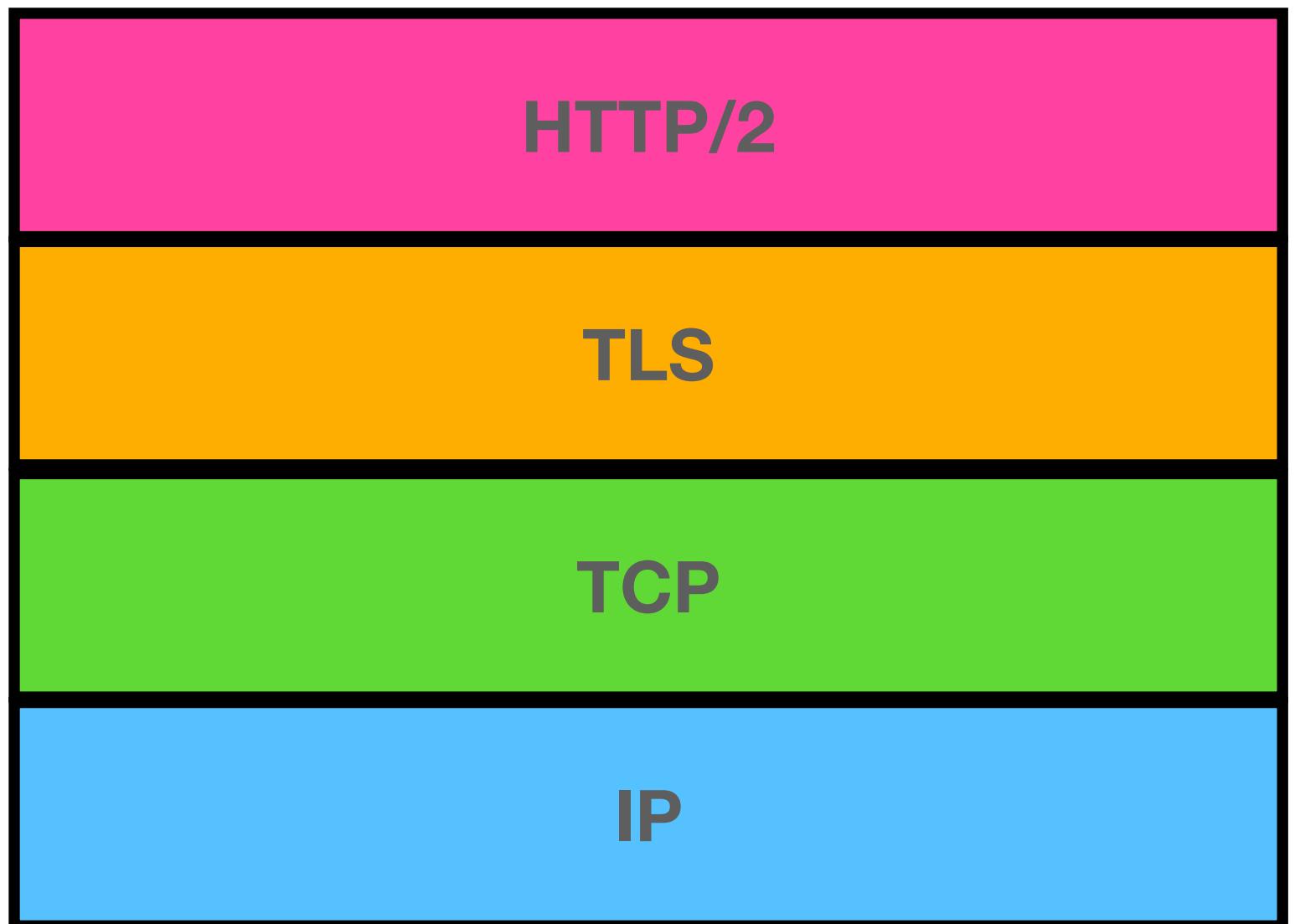
QUIC

A New Way Forward

- A core problem with HTTP up to this point is a fundamental limitation of *reliable transport over TCP*
 - We want to have reliability guarantees, but the way this is implemented in the layering model (e.g., in TCP) makes it such that applications don't have flexibility to define what reliability means!
- We could try to change TCP?
 - But that requires updating every router in the world. Way too hard.
- QUIC idea: What if we re-envisioned what we needed from lower network layers?

QUIC

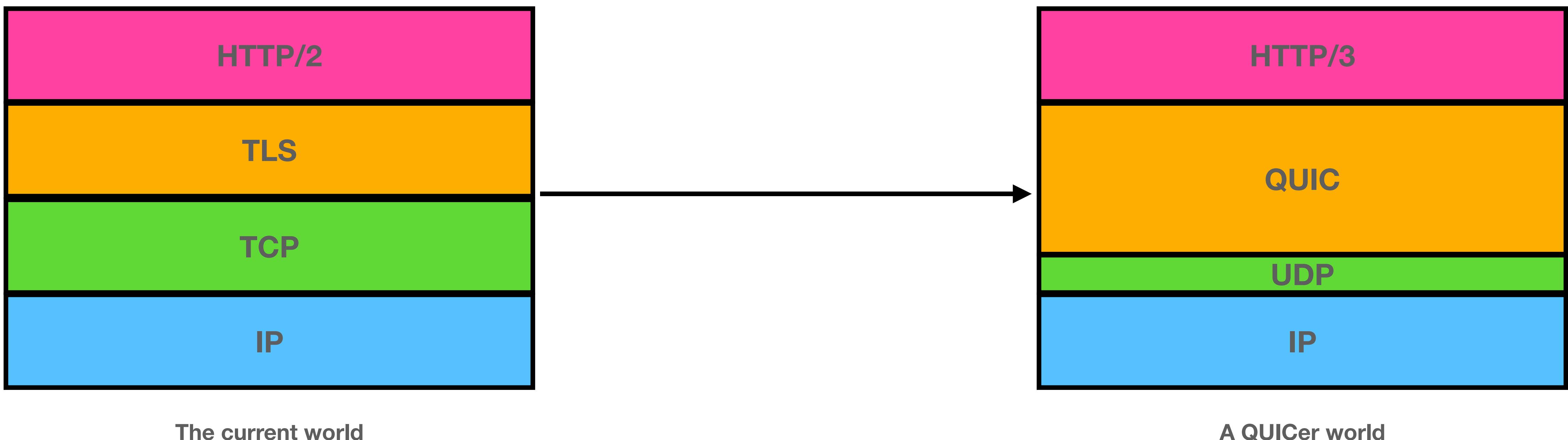
A New Transport Layer



The current world

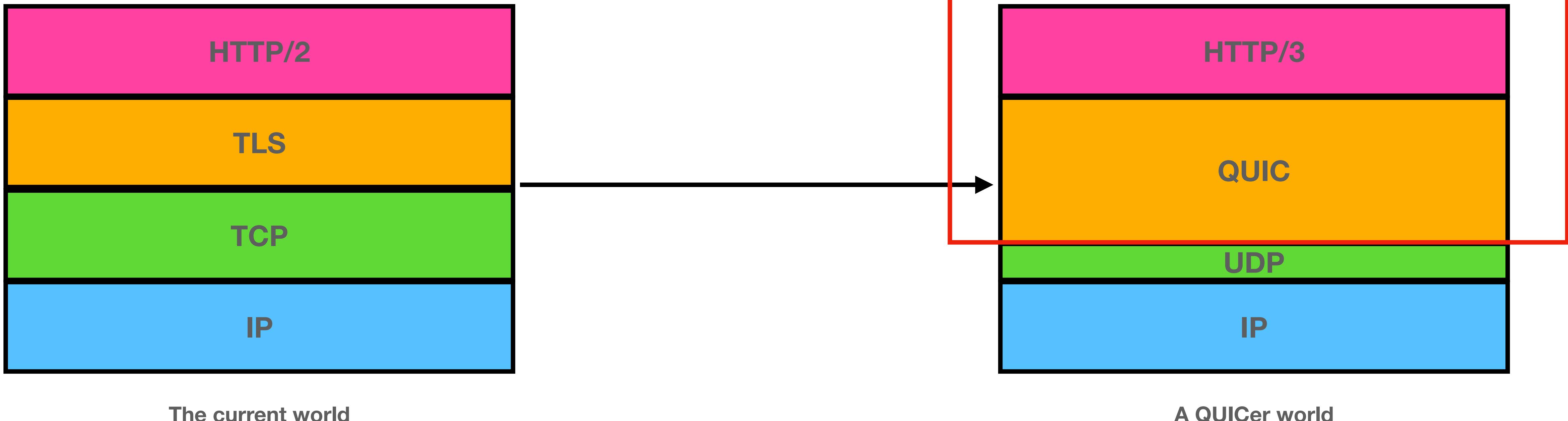
QUIC

A New Transport Layer



QUIC

A New Transport Layer



QUIC

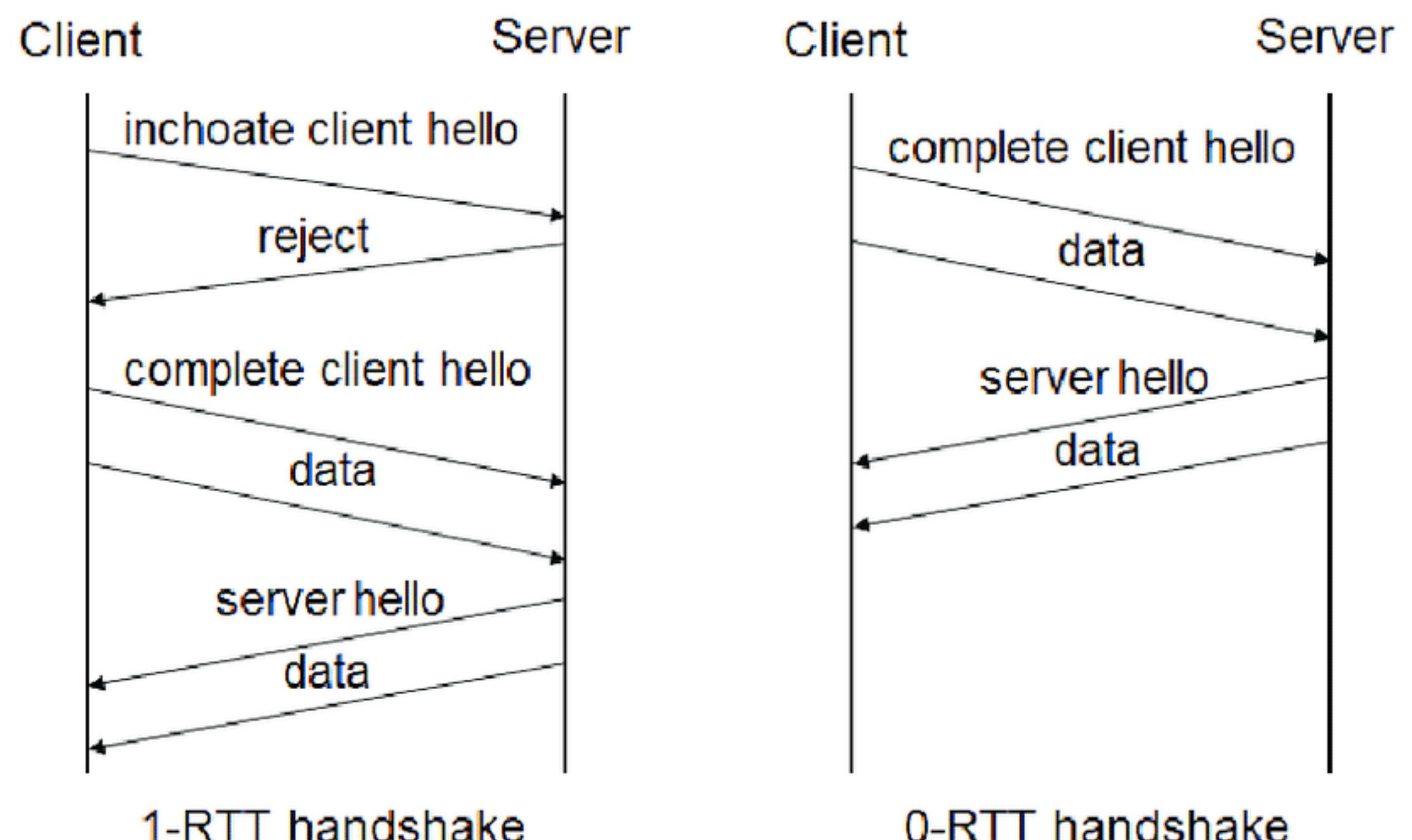
Design Goals

- A new, reliable transport layer
- Easily deployable and evolvable
 - Make this something that exists in userspace and something that doesn't require us to update every router ever
- Security by default
 - Build in encryption, integrity checks, and authentication into the transport layer itself
- Reduce unnecessary delays imposed by strict layering
 - Handshake delays (e.g., TLS handshake), HoL blocking (HTTP, TCP)

QUIC

Establishing a Connection

- The first time a client wants to communicate with a server, it send an *inchoate client hello* in cleartext, which will initiate a REJ (reject) from the server
 - The server will send back a number of details, including a certificate chain (for server authentication), long term keying materials, and other server metadata
- The client will then use the server information provided to send a *complete client hello*, and immediately start sending encrypted data with non forward-secure keys
- Server sends back *server hello*, with ephemeral forward-secure public keying material
- Client *caches* server details (based on origin), so for any future connection, the client can simply use the server block data to send encrypted messages moving forward. This is known as a **0-RTT protocol**.



QUIC

Two Types of Headers

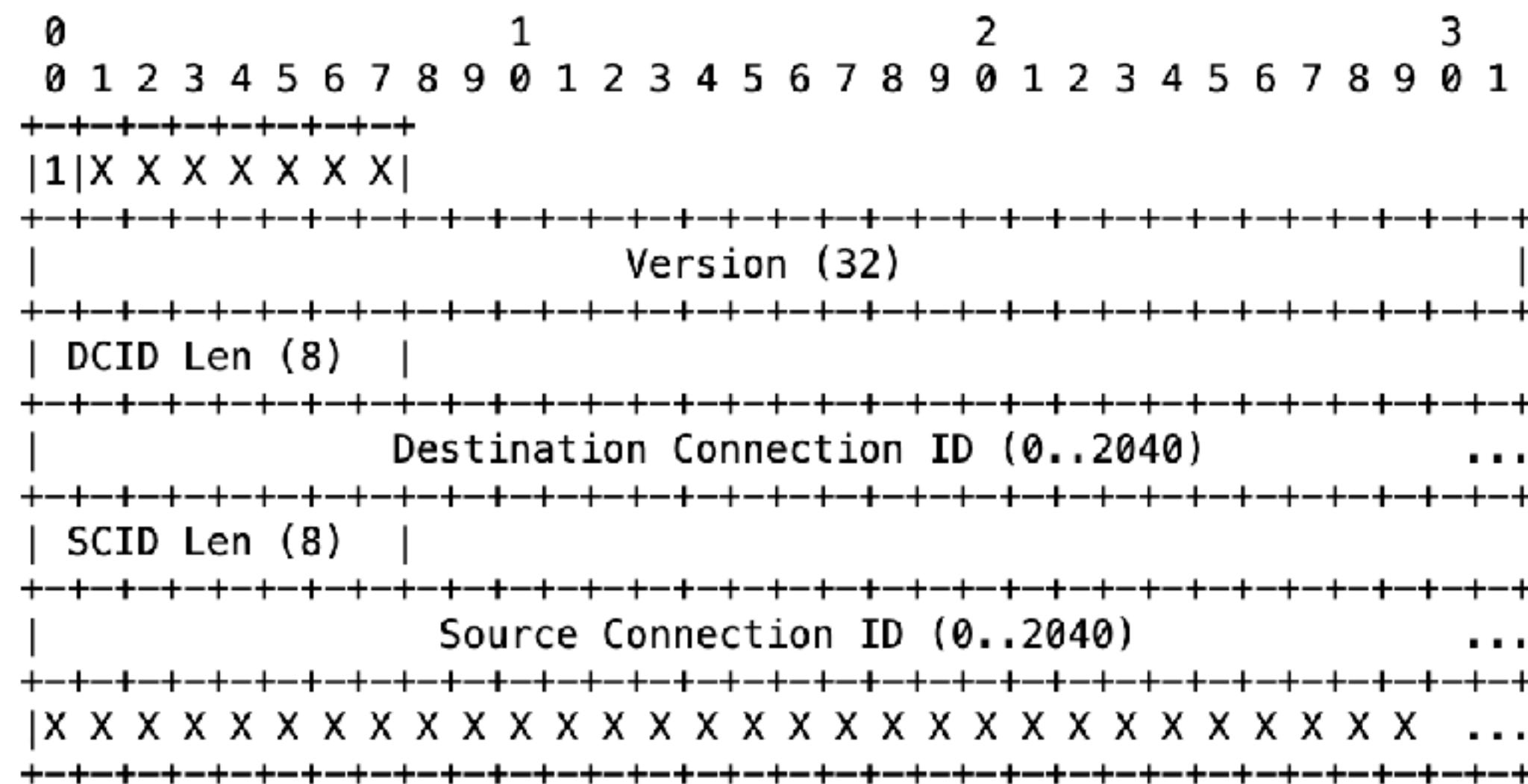
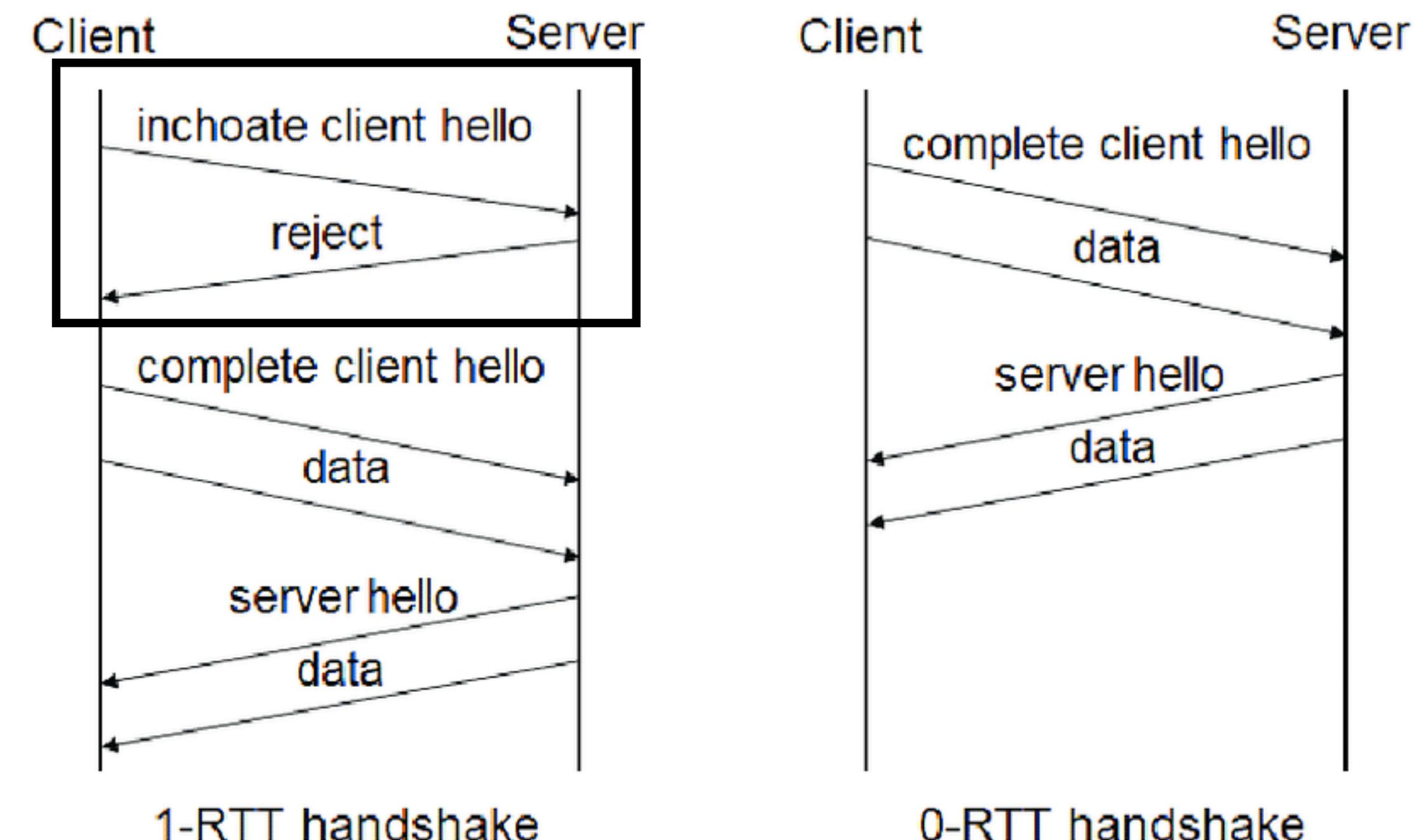


Figure 1: QUIC Long Header



QUIC

Two Types of Headers

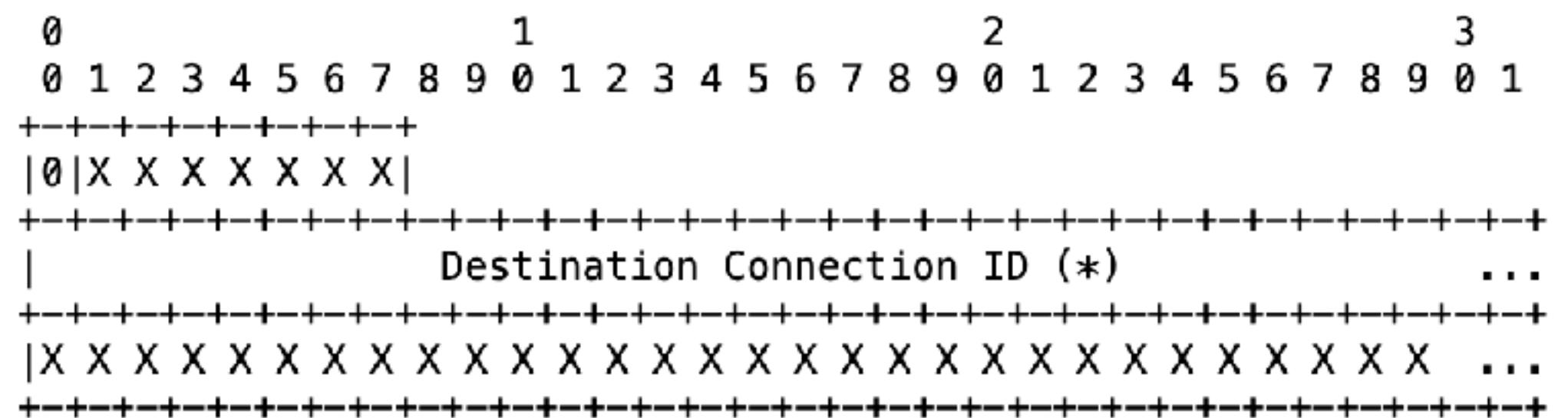
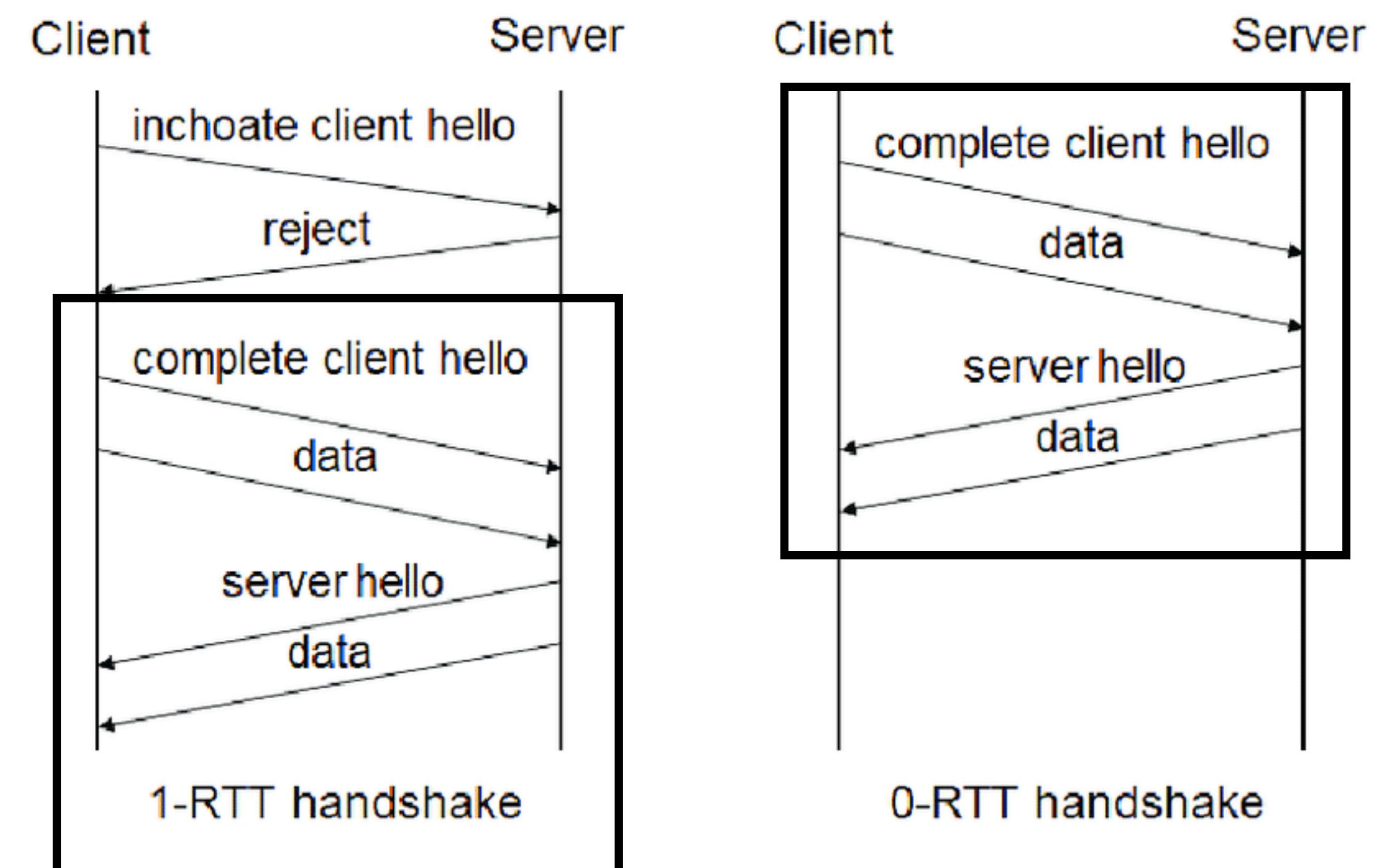


Figure 2: QUIC Short Header



QUIC

Encrypt as much as possible

HTTP w/ TLS + TCP

source port	destination port	
sequence number		
acknowledgement number		
hlen	flags	window
checksum	urgent pointer	
[options]		
type	version	length
length		
application data (HTTP headers and payload)		

HTTP w/ QUIC

source port	destination port
length	checksum
01SRRKPP	[dest connection id]
packet number	
application data (HTTP headers and payload)	

QUIC

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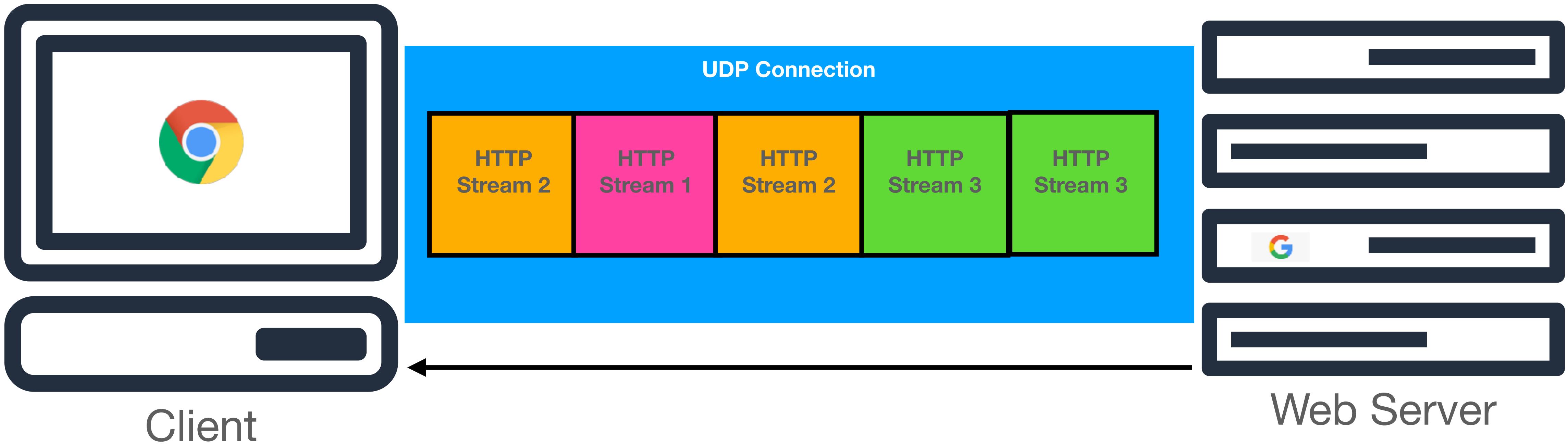
HTTP w/ QUIC

source port	destination port
	length
01S	[dest connection id]

QUIC

Maintaining the Stream Abstraction

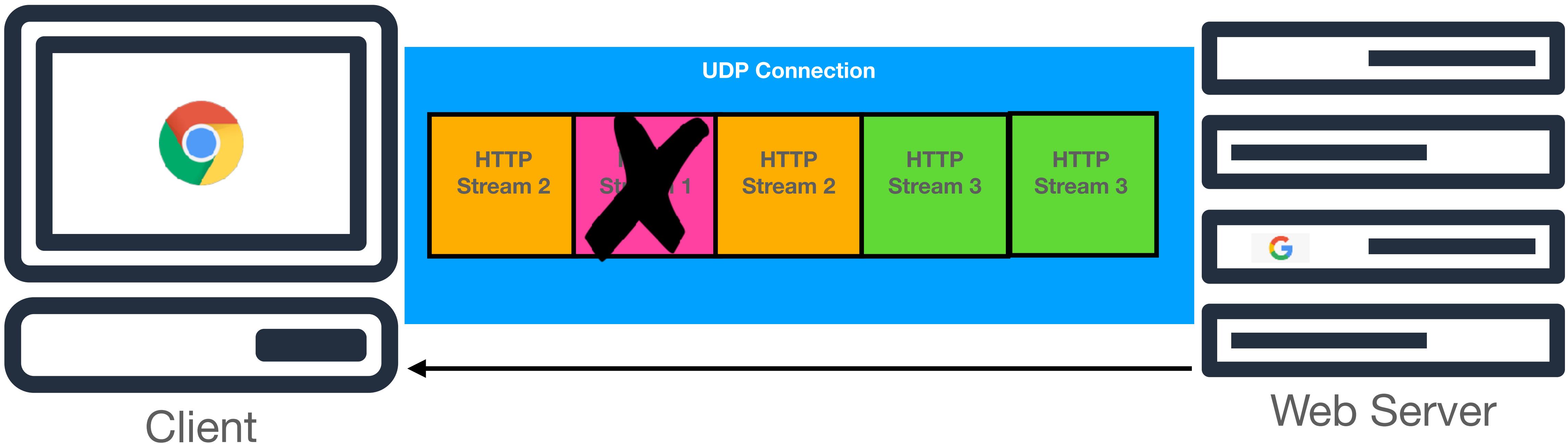
- QUIC uses the idea of a stream (with a `stream_id`) as a baseline abstraction for sending data between two endpoints, similar to HTTP/2



QUIC

Maintaining the Stream Abstraction

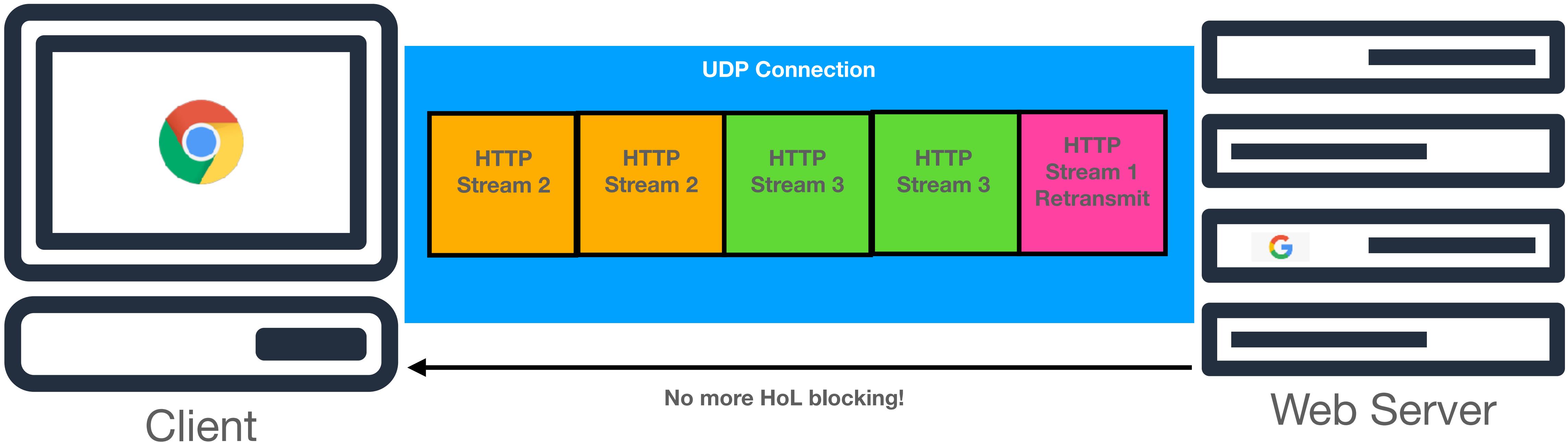
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TCP vs. QUIC

Recovering from Losses

- TCP uses sequence numbers + acknowledgement numbers to identify whether or not a packet has been lost, and needs to be retransmitted
 - Unfortunately, sequence numbers mean two things: reliability **and** the order at which the bytes are supposed to be delivered to the receiver
 - On top of this, TCP retransmissions use the *same* sequence number, so it becomes very hard to know whether an ACK was sent for first transmission or a retransmission
 - TCP conflates transmission ordering AND delivery ordering in one number

TCP vs. QUIC

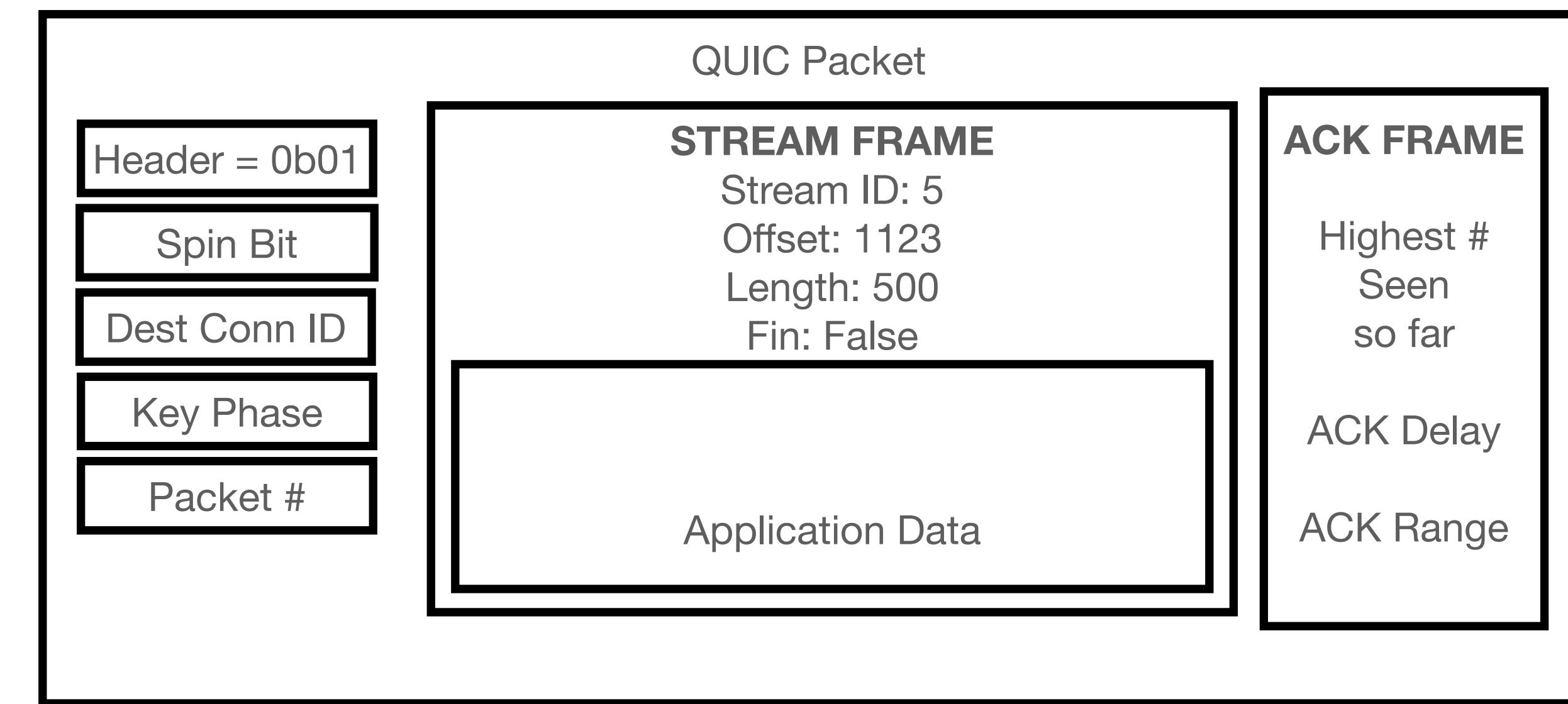
Recovering from Losses

- QUIC decouples transmission and delivery ordering through its use of *streams*
 - Each packet contains a packet number, which is **unique and monotonically increasing, even on retransmission**
 - Clients will ACKNOWLEDGE packet numbers, and the server can identify if an outstanding packet has not been acknowledged... you can find the details at the link below
 - Each frame in a stream contains a *stream offset*, which alerts the client of how to properly reorder the packets on the delivery side
- Enables simpler loss detection than TCP

QUIC

Packetization

- Packets can contain multiple types of frames (e.g., Stream frames, ACK frames, crypto frames)
- Stream frames contain stream IDs and *offsets* for the receiver to re-order out-of-order packets
- ACK frames contain acknowledgements for the highest packet number we've seen so far, and a range for what packets we've acked so far



QUIC

Connection Rebinding

- Because QUIC connections are over UDP, they can persist *beyond traditional network boundaries*, like your home NAT
 - No more resetting connection when your underlying network changes
- QUIC does this through the use of several unique variable length Connection IDs to identify the connection, with a protocol in place to verify the connection through a network change
- See RFC for notes on address spoofing + off-path packet attackers (something they've considered!)

QUIC

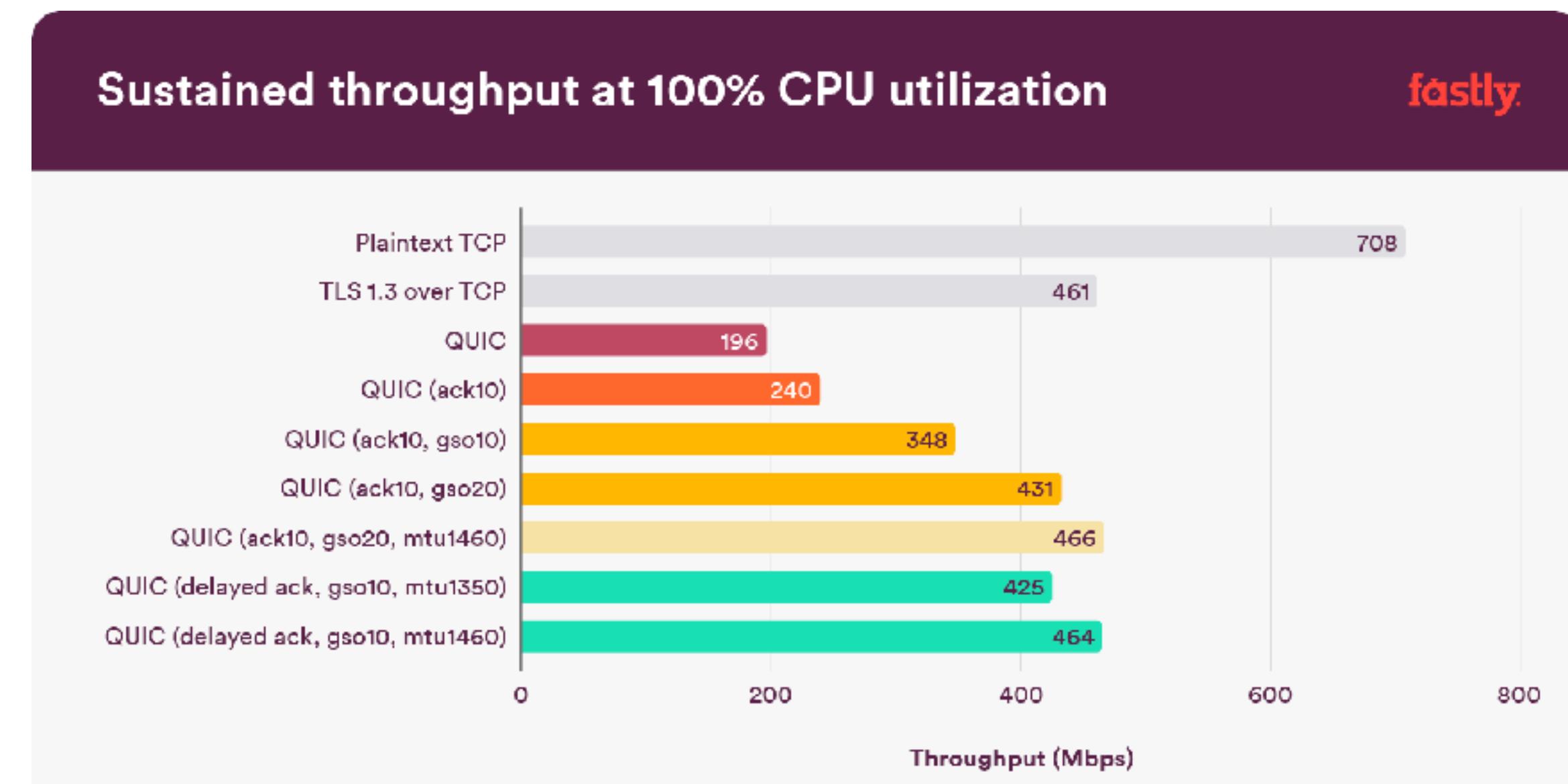
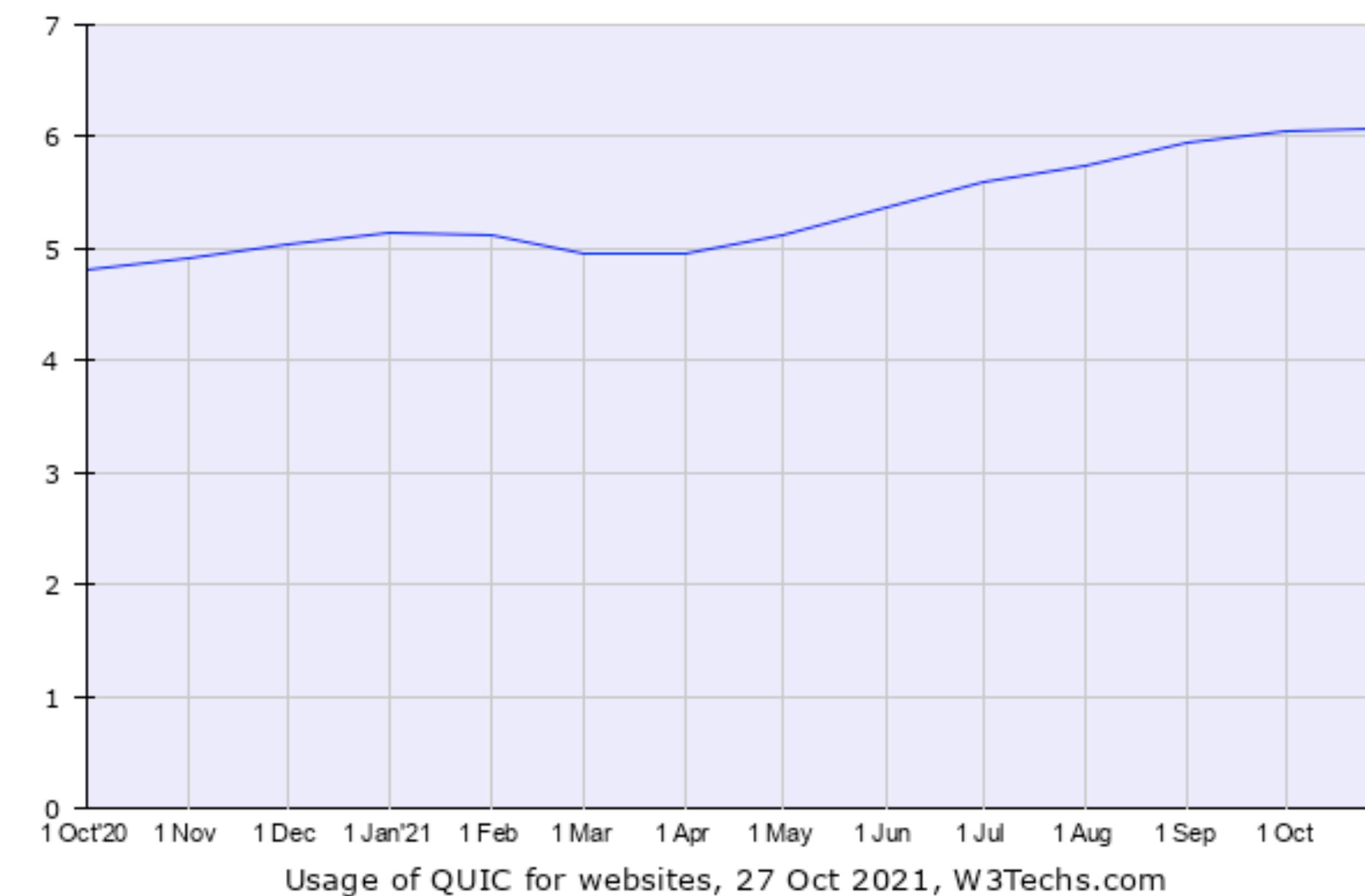
NATs, Middleboxes, Deployment Challenges

- Typically, NATs keep track of TCP connections by using a 5-tuple (`src_port`, `src_ip`, `dst_port`, `dst_ip`, `protocol`), and can maintain state because they have access to TCP headers
- Not all NATs speak QUIC yet, and even if they did, header information is encrypted, so they default to processing UDP packets, which could cause short timeouts and routing issues
- UDP-based protocols are susceptible to *reflection attacks*, where attackers use UDP servers with spoofed source ports to amplify their attack, and QUIC can be asymmetric on *inchoate client hello*
 - This is why QUIC has a REJ packet to start, but this increases the number of round trips required on initial connection. Probably a decent trade off.

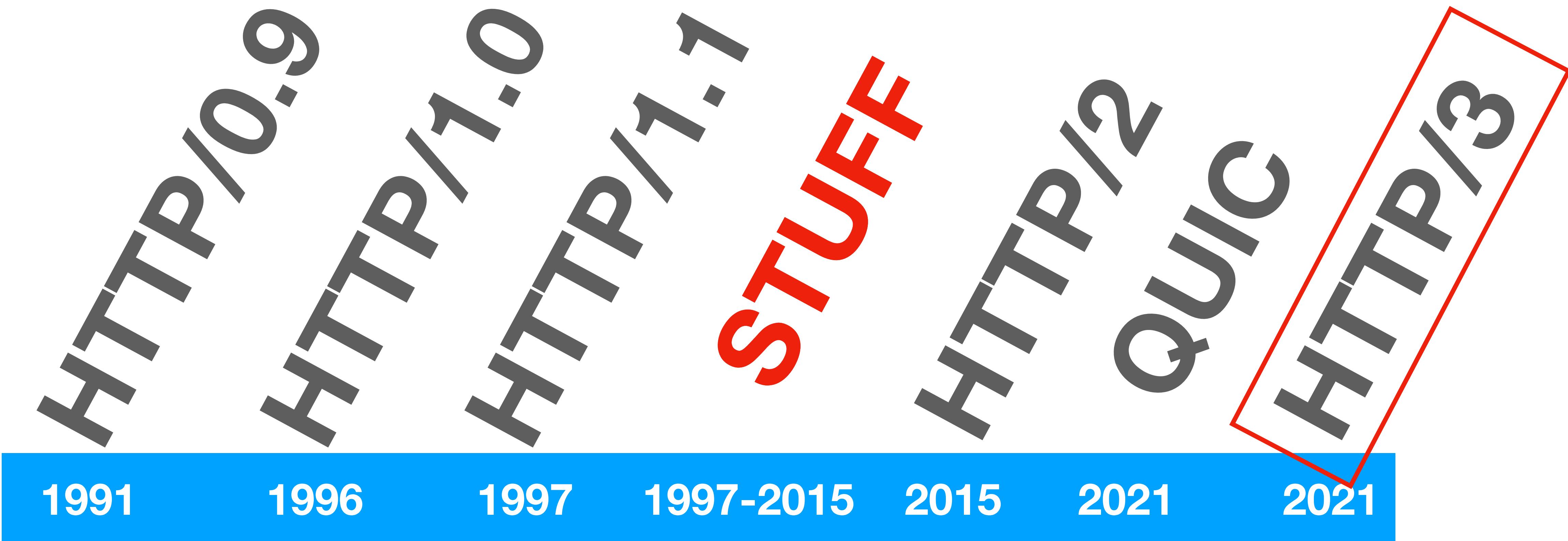
QUIC Deployment

QUICly eating the world

- QUIC was officially ratified by the IETF in May 2021 (RFC 9000)
- QUIC support already existed in Chrome for a while, but is now available in Firefox as well
- QUIC is being deployed everywhere
 - 6% of websites use QUIC, but will grow post RFC ratification
 - Google apps all use QUIC, 75% of Facebook uses QUIC
 - Some ISPs have reported that **20% of their packets were over QUIC**
- With appropriate tuning in high performance benchmarks, QUIC is so far as good as TLS 1.3 over TCP



A History of Web Protocols



HTTP/3 is HTTP over QUIC!

HTTP/3

Building HTTP over QUIC

- Still being iterated on by IETF (no RFC number yet)
- HTTP/3 uses the same abstraction as HTTP/2 (e.g., streams, frames, etc.), except it utilizes these streams as supported by QUIC rather than implementing on top of TCP
- This causes some notable new challenges:
 - HPACK, the clever header encryption scheme, cannot be enforced anymore without causing HoL blocking (recall that headers MUST appear before response data in HTTP/2)
 - HTTP/2 enjoyed stream prioritization, which is hard to implement in the transport layer on top of everything else

HTTP/3 vs. HTTP/2

Notable Changes?

- HPACK is updated to QPACK, which is designed to allow for out-of-order header data (and updating dynamic tables accordingly)
 - Essentially, adds more ability for client to control when to use a dynamic table entry – no need to wait to update an entry or read a table entry before processing a request
- Removed stream prioritization altogether!
 - Deemed too challenging to use for clients and offered little guarantees anyway, so it is being discussed independently

Recap

- The web has drastically changed over time, with developers doing more than ever before and websites becoming increasingly complex
 - But for a long time, our protocols didn't match the growing complexity of the world
- New protocols like SPDY, HTTP/2 were useful in working within our paradigm, but there is **change** afoot!
 - People are not liking TCP as much, and companies like Google are starting to throw their weight around in envisioning a new future for layering requirements
- We are redefining “end-to-end” abstractions... let's see how it goes :)

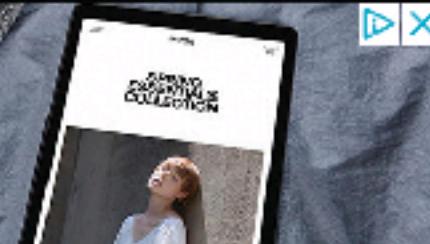
Web Content

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Modern Websites

Third Party Resources

- Modern websites rely on many different types of *third-party resources* to provide services to keep their websites functional
 - Third party resources are ones served by external parties – so for example, if you are on [cnn.com](#), any resource served from a domain that is NOT [cnn.com](#) (e.g., [doubleclick.com](#), [google-analytics.com](#))
 - These resources could be anything from static images to JavaScript libraries to analytics, advertising, the list goes on...



- AddThis
- Adform
- Adition
- Adobe Audience M...
- Adobe Experience ...
- Aggregate Knowle...
- Amazon Advertising
- AppNexus
- Bidswitch
- Bidtellect
- BlueKai
- Bombora
- Bounce Exchange
- ChartBeat
- Criteo
- Datalogix
- DoubleClick
- Drawbridge
- Eyeota
- Facebook Connect
- FreeWheel
- Google Ads Measu...
- Google Adsense
- Google Dynamic R...
- Google Safeframe
- Google Tag Manag...
- Index Exchange
- Integral Ad Science
- LiveRamp
- Lotame
- MediaMath
- NetRatings SiteCe...
- OneTag
- OpenX
- Optimizely
- Outbrain
- Outbrain Amplify
- PowerLinks
- PubMatic
- Quantcast
- RTB House
- Rubicon
- Salesforce DMP
- ScoreCard Researc...
- Simpli.fi
- Smaato
- SOASTA mPulse
- SpotX
- Tapad
- TradeDesk



PODCAST: Tug of War | TRENDING: World Series | Pope and Biden | Tuesday elections | Halloween train attack | Economic bills | G20 summit | Box office |

Trump escalates January 6 cover-up



ANALYSIS
The former President is trying to keep the House select committee probing January 6 from seeing a list of documents as he ramps up his political comeback

KFILE Trump lawyer said 'courage and the spine' would help Pence send election to the House in comments before January 6

► Brian Stelter's ominous prediction: Imagine it's 2022 and ...

January 6 committee is losing patience with Trump's former chief of staff Mark Meadows as it seeks his testimony

Washington Post report rebuts the January 6 alt-reality that Tucker Carlson promotes

Biden says US 'continuing to suffer' from Trump's decision to pull out of Iran nuclear deal



LIVE UPDATES

Astros top Braves 9-5 in World Series Game 5

- **Trivia:** Can you name the only player to play in all 3 cities that the Braves have called home?
- **Analysis:** The Braves may win the World Series. But they're striking out with some fans



Students are fed up with raging adults at school board meetings

- A Texas lawmaker is investigating 850 books on race and gender that could cause 'discomfort' to students
- **Opinion:** When parents scream at school board meetings, how can I teach their children?



Southwest launches investigation into pilot reportedly using anti-Biden phrase on flight

- Reporter reveals what Lindsey Graham said during January 6 riot

White House press secretary tests positive for Covid, last saw Biden Tuesday

BREAKING Japan's Fumio Kishida defies expectations as ruling party keeps majority

Aurora borealis puts on a gorgeous show

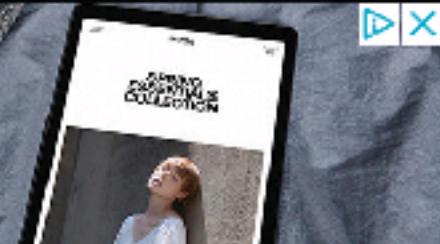
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Police investigating desecration of Torah scroll at fraternity

COP26 climate talks off to an ominous start after weak G20 leaders' meeting

► Video shows passengers fleeing knife attack on train





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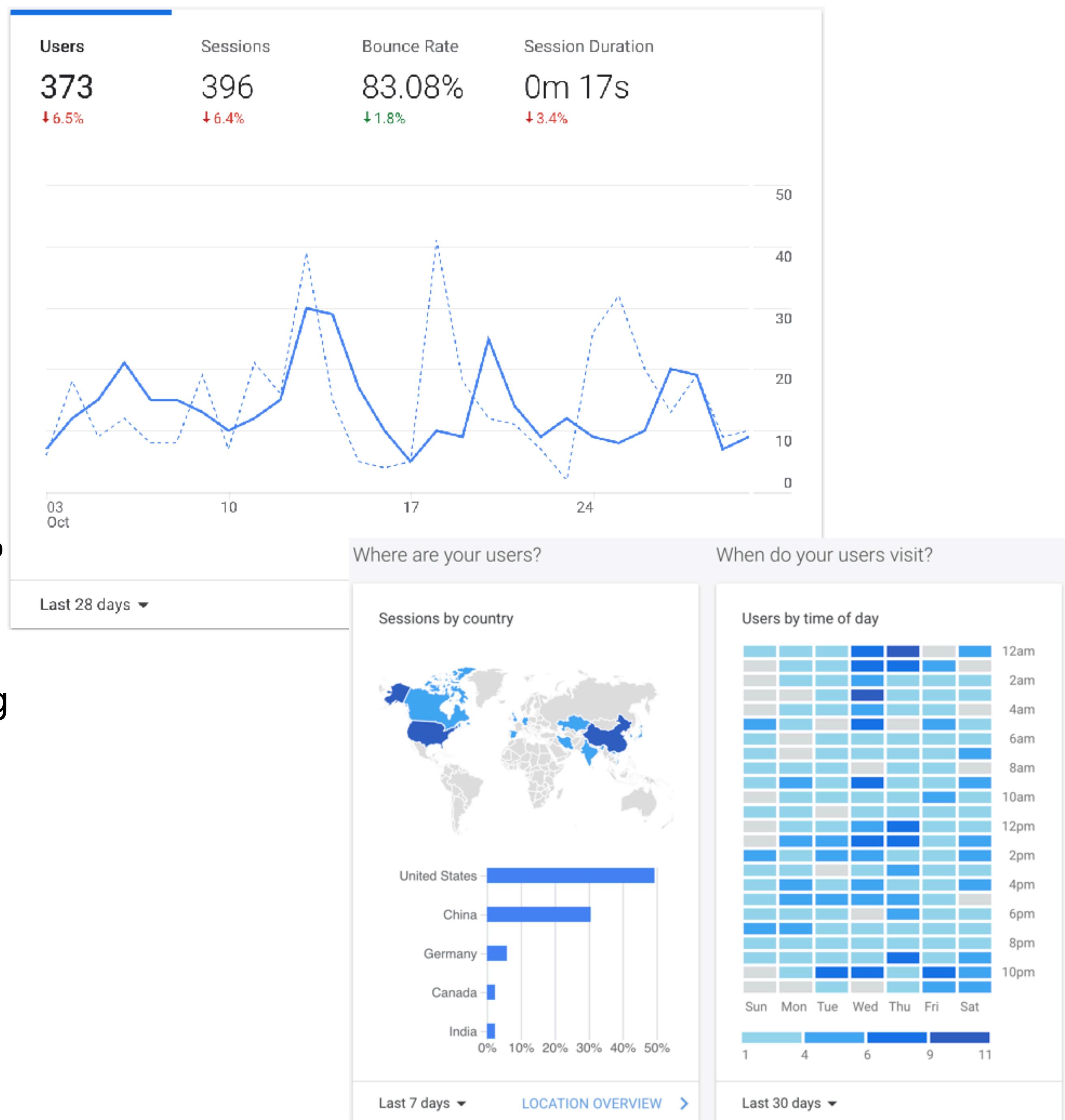
64 Trackers

- AddThis
- Adform
- Adition
- Adobe Audience M...
- Adobe Experience ...
- Aggregate Knowle...
- Amazon Advertising
- AppNexus
- Bidswitch
- Bidtellect
- BlueKai
- Bombora
- Bounce Exchange
- ChartBeat
- Criteo
- Datalogix
- DoubleClick
- Drawbridge
- Eyeota
- Facebook Connect
- FreeWheel
- Google Ads Measu...
- Google Adsense
- Google Dynamic R...
- Google Safeframe
- Google Tag Manag...
- Index Exchange
- Integral Ad Science
- LiveRamp
- Lotame
- MediaMath
- NetRatings SiteCe...
- OneTag
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Modern Websites

Analytics

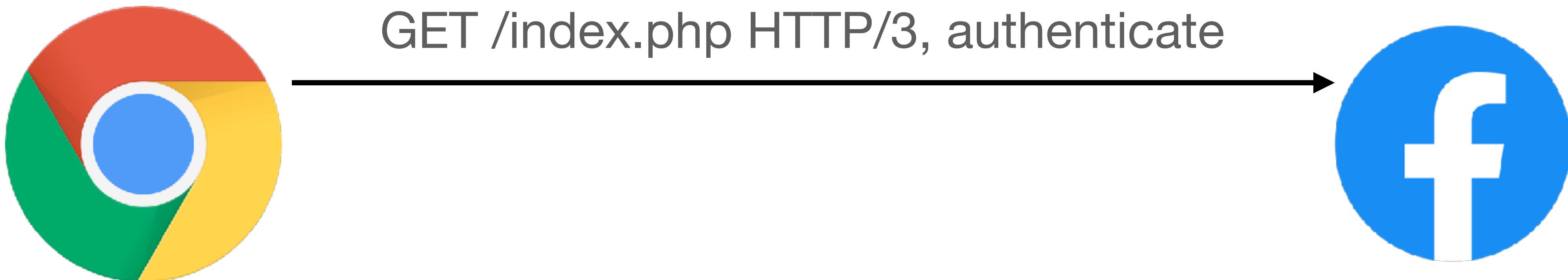
- Many websites rely on analytics on their users to continue to improve their services
 - For example, Google provides Google Analytics, which appears on an estimated 70% of the top websites
- As an analytics user, you can see where your clients are connecting from, you can see how long they spent on the page, what devices they're connecting from, and a ton of other interesting details
 - These are typically scoped to a single request, but in recent years, companies have been expanding the scope of what they know about users...



Web Tracking

Cookies and Code

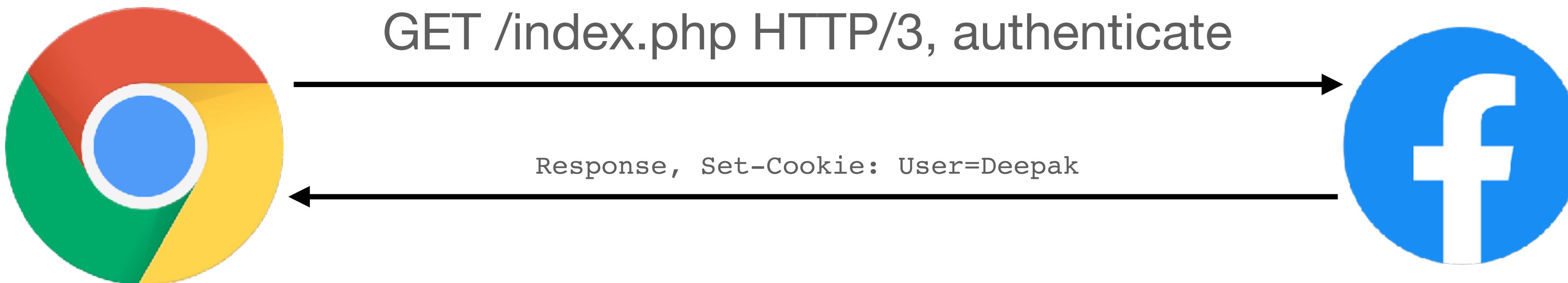
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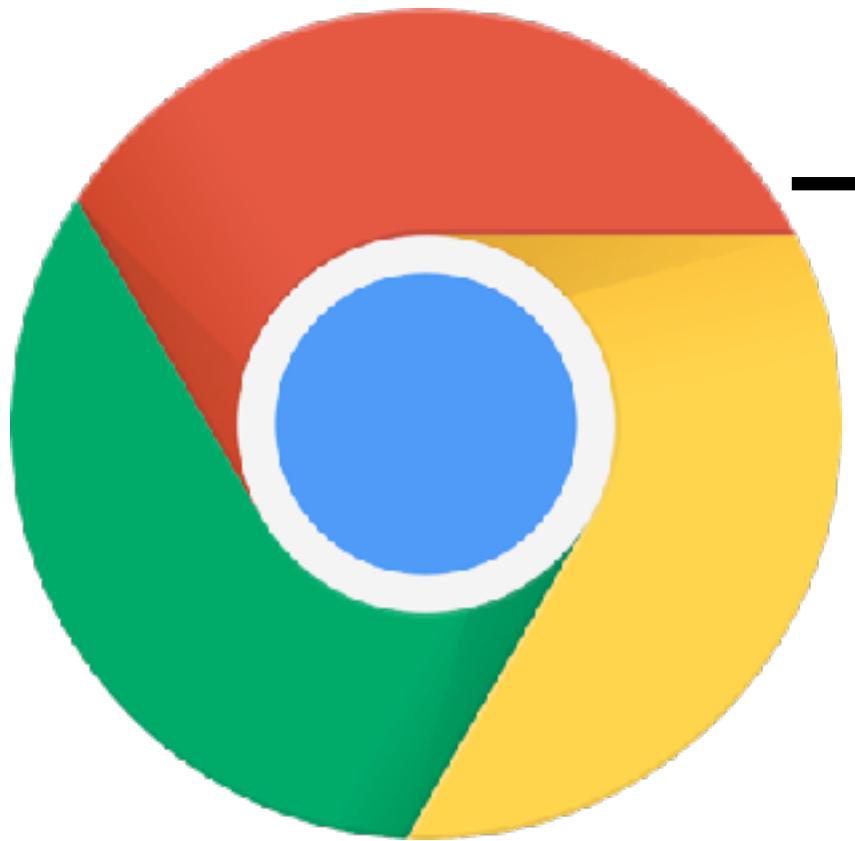
Web Tracking

Cookies and Code

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- Once a cookie is set, the browser attaches a cookie to every subsequent request sent out for that particular domain
 - Cookies are by default scoped to the first-party domain that set the cookie
 - No other domains can read the cookie value!
- ...then how does web tracking work?

Web Tracking

Cookies and Code



GET / HTTP/3

A screenshot of a web browser window displaying a news article from CNN. The page is heavily laden with tracking code, as indicated by the numerous small icons and text labels on the right side of the interface. These labels include "64 Trackers", "SQUARESPACE", "Set up an online store and start selling today.", "START YOUR FREE TRIAL", "LIVE TV Edition", "PODCAST: Tug of War | TRENDING: World Series | Pope and Biden | Tuesday elections | Halloween train attack | Economic bills | G20 summit | Box office", "Trump escalates January 6 cover-up", "Astros top Braves 9-5 in World Series Game 5", "Southwest launches investigation into pilot reportedly using anti-Biden phrase on flight", "Students are fed up with raging adults at school board meetings", and "White House press secretary tests positive for Covid, last saw Biden Tuesday". The browser's status bar shows "64 Trackers" and a list of tracking companies: AddThis, Adform, Adition, Adobe Experience M..., Adobe Experience ..., Aggregate Knowle..., AppNexus, Bidswitch, Bidtellect, Blurred, Bombers, Bounce Exchange, Chartbeat, Criteo, Datalogix, DoubleClick, Drawbridge, Eyeota, Facebook Connect, FreeWheel, Google Measure..., Google Adsense, Google Analytics R..., Google Selfserve, Google Tag Manager, Index Exchange, Integral Ad Science, LiveRamp, Lotame, MediaMath, NetRatings SiteCe..., OneTag, OpenX, Optimizely, Outbrain, Outbrain Amplify, Powertags, RubMetrics, Quantcast, RTB House, Rubicon, Salesforce DMP, ScoreCard Research, Simpli.fi, Smasht, SOASTA mPulse, Tapad, TradeDesk.

Web Tracking

Cookies and Code



GET / HTTP/3

GET /facebook-like.js HTTP/3

A screenshot of a web browser window displaying a news article from CNN. The browser's developer tools are open, specifically the Network tab, which shows two requests being made:

- A main request for the page content: "GET / HTTP/3".
- A script request for a Facebook-like.js file: "GET /facebook-like.js HTTP/3".

On the right side of the browser window, a sidebar titled "64 Trackers" lists numerous tracking companies and services, including AddThis, Adform, Adobe Experience, Amazon Advertising, AppNexus, Bidswitch, Doubleclick, Drawbridge, Eyeota, Facebook Connect, FreeWheel, Google Adsense, Google Analytics, Google Selfserve, Google Tag Manager, Index Exchange, Integral Ad Science, LiveRamp, Lotame, MediaMath, Nielsen SiteC, OneTag, OpenX, Optimizely, Outbrain, Outbrain Amplify, Powertech, Quantcast, RTB House, Rubicon, ScoreCard Research, Simpli.fi, Smasht, SOASTA mPulse, SportX, Tapad, and TradeDesk. A large thumbs-up icon is visible in the bottom right corner of the browser window.

Web Tracking

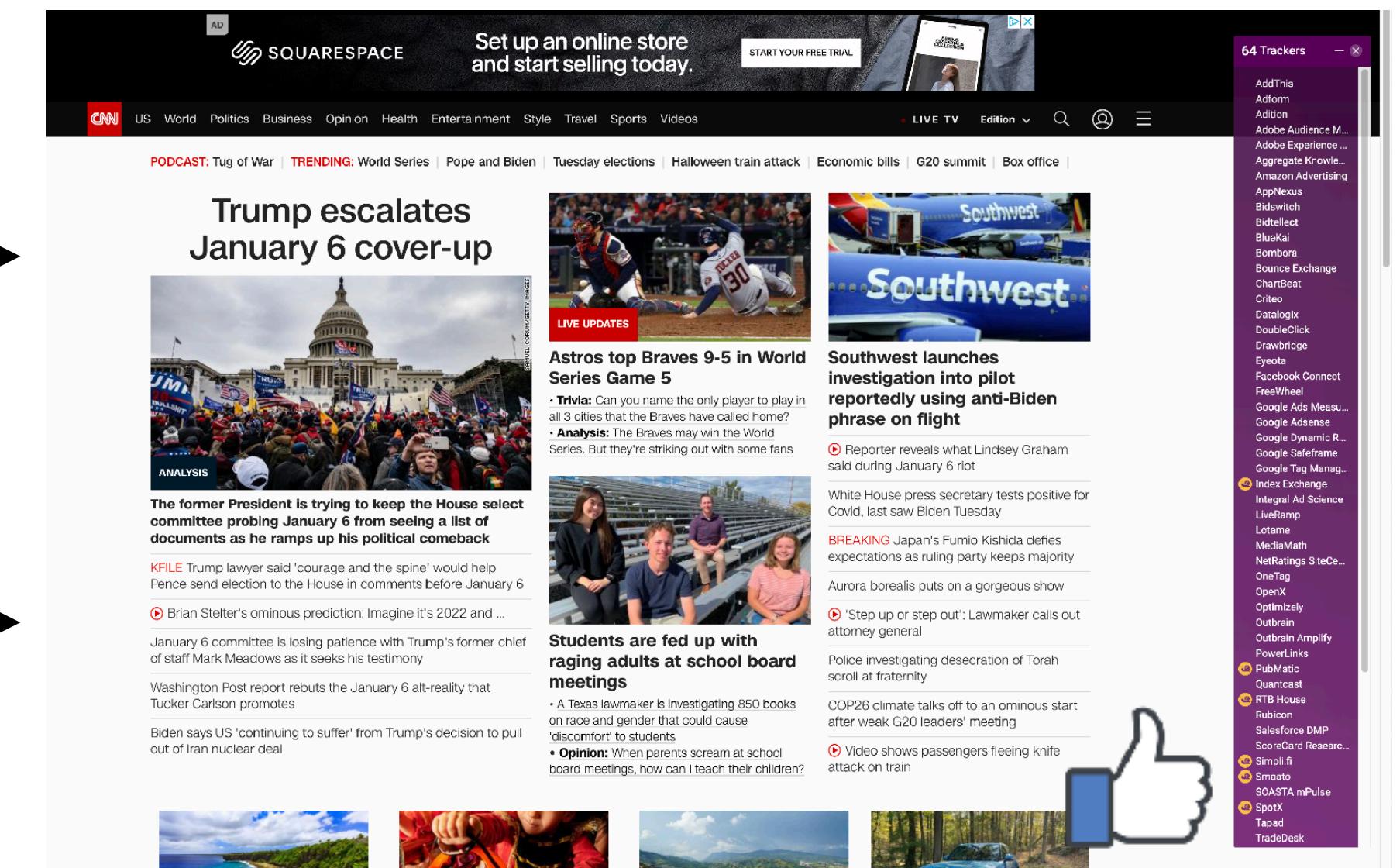
Cookies and Code



GET / HTTP/3

GET /facebook-like.js HTTP/3

Cookie: User=Deepak, Referer=cnn.com



- With this request, companies can link your cookie to your browsing data (e.g., through Referer header, Host headers, Origin, or just JavaScript)

Web Tracking

Browser Fingerprinting

- Websites can also fingerprint you effectively with *browser fingerprinting*, which is a technique that leverages all your settings to identify you, and stores this in a cookie on your browser
 - <https://iamunique.org>
 - So long as JavaScript can run (by third-parties), you run the risk of being “followed” on the web

```
{  
  "user-agent": "Mozilla/5.0 (Macintosh; Intel Mac OS X 10.15; rv:93.0) Gecko/20100101 Firefox/93.0",  
  "accept": "text/html,application/xhtml+xml,application/xml;q=0.9,image/avif,image/webp,*/*;q=0.8",  
  "accept-encoding": "gzip, deflate, br",  
  "accept-language": "en-US,en;q=0.5",  
  "upgrade-insecure-requests": "1",  
  "referer": "https://amiunique.org/",  
  "userAgent-js": "Mozilla/5.0 (Macintosh; Intel Mac OS X 10.15; rv:93.0) Gecko/20100101 Firefox/93.0",  
  "platform": "MacIntel",  
  "cookies": "yes",  
  "timezone": 420,  
  "languages-js": "en-US,en",  
  "ad": "no",  
  "doNotTrack": "NC",  
  "navigator_properties": [  
    "vibrate",  
    "javaEnabled",  
    "getGamepads",  
    "getVRDisplays",  
    "mozGetUserMedia",  
    "sendBeacon",  
    "requestMediaKeySystemAccess",  
    "registerProtocolHandler",  
    "taintEnabled",  
    "un沉没的  
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  "accept-encoding": "gzip, deflate, br",  
  "accept-language": "en-US,en;q=0.5",  
  "upgrade-insecure-requests": "1",  
  "referer": "https://amiunique.org/",  
  "userAgent-js": "Mozilla/5.0 (Macintosh; Intel Mac OS X 10.15; rv:93.0) Gecko/20100101 Firefox/93.0",  
  "platform": "MacIntel",  
  "cookies": "yes",  
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  "doNotTrack": "NC",  
  "navigator_properties": [  
    "vibrate",  
    "javaEnabled",  
    "getGamepads",  
    "getVRDisplays",  
    "mozGetUserMedia",  
    "sendBeacon",  
    "requestMediaKeySystemAccess",  
    "registerProtocolHandler",  
    "taintEnabled",  
    "un沉没的  
  ]  
}
```

Web Tracking

Prevalence of Major Companies

- Major companies have large presences on the web, and as a result, can see the majority of websites that you visit
 - Google appears on 82.2% of the Top 1M (by AS), because of analytics and advertising services
 - Facebook appears on 34.1%, to enable social sharing + tracking

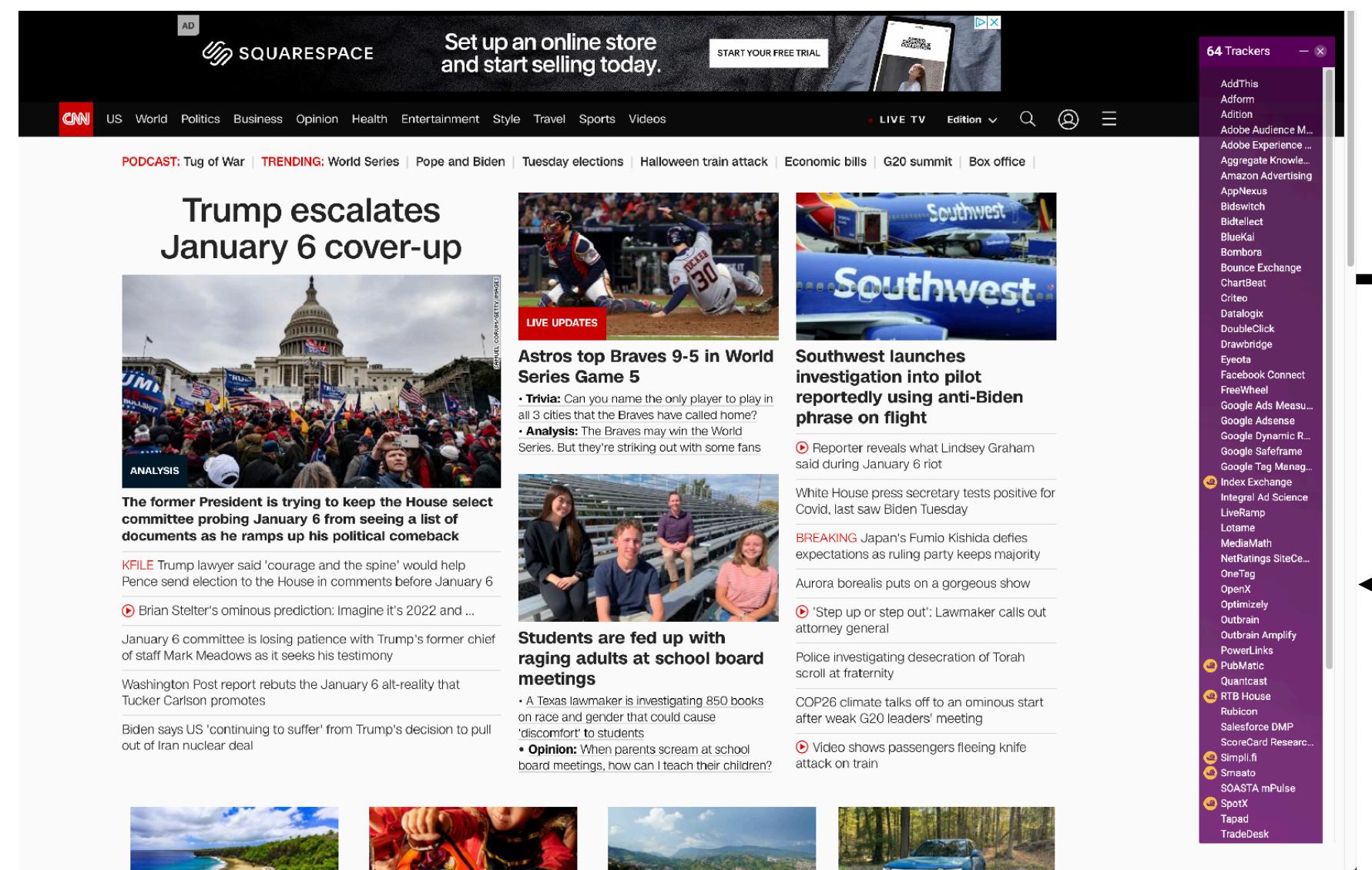
Company	Prevalence on Top 1M
Google	82.2%
Facebook	34.1%
Amazon	32.6%
Cloudflare	30.7%
Akamai	20.3%
MaxCDN	19.0%
Edgecast	17.9%
Fastly	15.5%
SoftLayer	11.8%
Twitter	11.2%

Web Tracking

Cookie Syncing

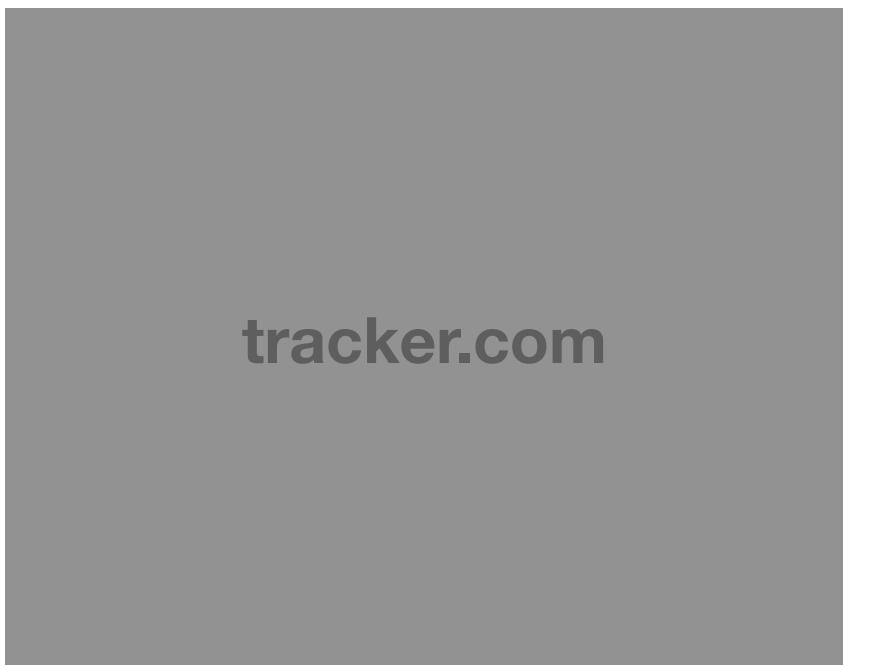
- Even if a company is not available on every website, companies often times *share* cookie information
 - “Cookie Synchronization: Everything You Always Wanted to know but were afraid to ask” – WebConf 2019
- Core idea is simple: If you have a collaboration agreement with another third-party, you simply *redirect* requests to them upon receiving requests

Web Tracking Cookie Syncing

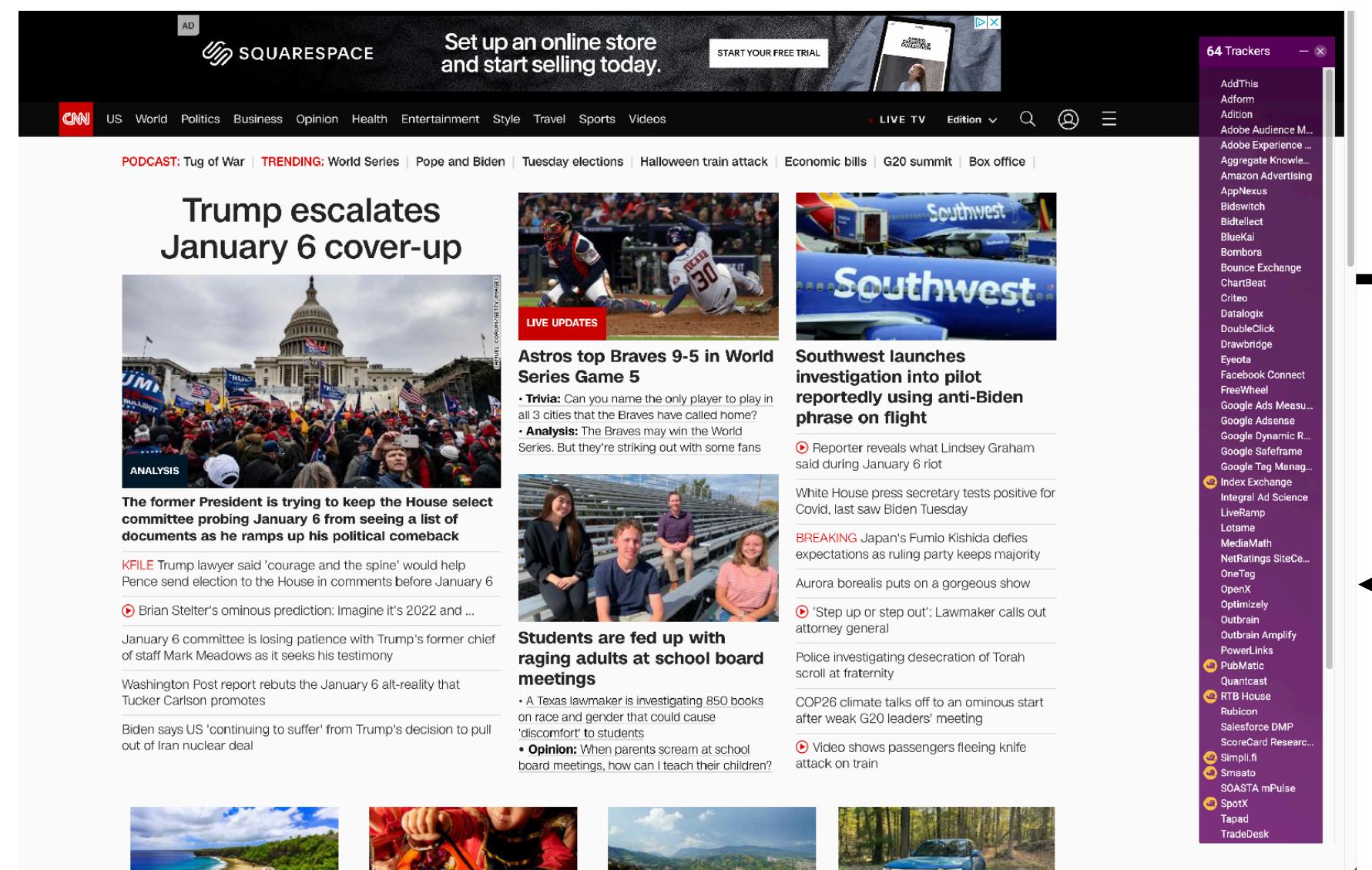


GET tracker.com/pixel.jpg

Response, Set-Cookie: User=user123



Web Tracking Cookie Syncing



GET advertiser.com/pixel.jpg

Response, Set-Cookie: User=userABC



Web Tracking Cookie Syncing

Monday, November 1, 2023
Today's Paper

U.S. INTERNATIONAL CANADA ESPAÑOL P.R.

PLAY THE CROSSWORD Account

50PF 5P 2P
Nasdaq +0.2% +

The New York Times

World U.S. Politics N.Y. Business Opinion Tech Science Health Sports Arts Books Style Food Travel Magazine T Magazine Real Estate Video

LIVE

Climate Change Is 'Ravaging the World,' Biden Tells Summit

António Guterres, the U.N. secretary general, opened the conference with a blistering critique of the world's failure to unite to address global warming.

"We are standing at an inflection point in world history," President Biden said in a speech, calling the need for action a moral imperative. Here's the latest.

How much are countries pledging to reduce emissions?

China

Current
1.5°C compatible
Historical emissions

1850 2030

President Biden will try to assure skeptics that the U.S. is serious about climate action.

Europe is worried that the costs of climate action could set off a populist backlash.

Once a leading polluter, the U.K. is now trying to lead on climate change.

LIVE

Supreme Court Is Hearing Oral Arguments on Texas Abortion Law

The question for the justices is whether abortion providers and the Biden administration are entitled to challenge the law. Listen and follow our analysis.

Global Virus Death Toll Passes 5 Million

Experts say that the official toll is an undercount, as many covid-19 deaths accurately.

Jen Psaki, the White House press secretary, tested positive for the coronavirus.

TAP TO UNMUTE

This is live audio coverage of the Texas-abortion law case.

The court is hearing arguments in two different challenges. Listen

PLAY THE CROSSWORD Account

50PF 5P 2P
Nasdaq +0.2% +

The TV Hit That Wasn't

There was hype for the FX series "Impeachment: American Crime Story." But it won't be available on any major streaming platform for another 10 months.

A man sitting in front of a television set.

He ran in the first New York City Marathon. Next week, he'll run in the 50th.

A pair of N.F.L. teams made big impressions in Week 8. Here's what we learned from Sunday's games.

Opinion

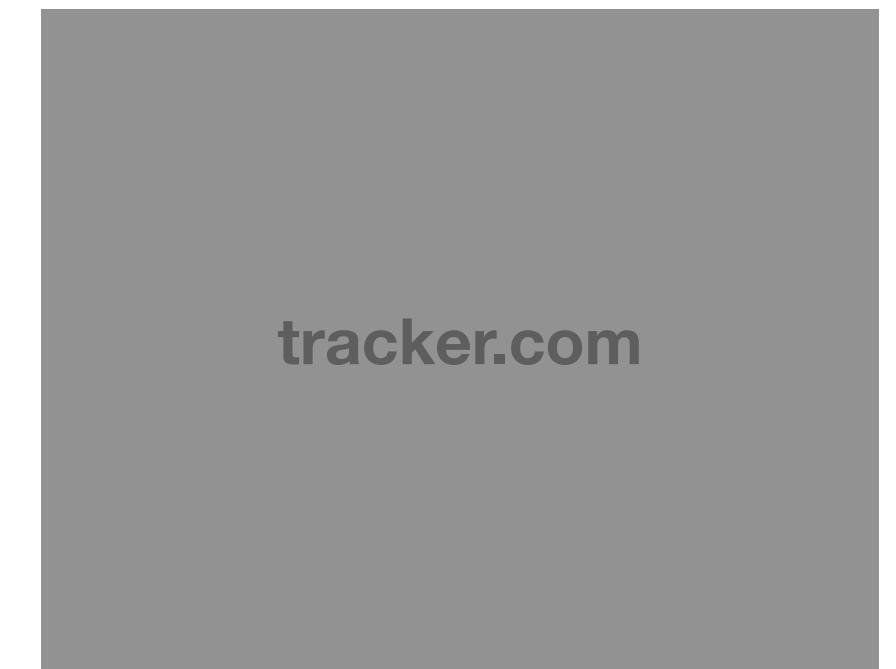
KATHRYN KOLBERT AND JULIE E. KAY

Roe Is as Good as Gone. It's Time for a New Strategy.

MARGARET RENKL

I Just Turned 60, but I Still Feel 22

GET tracker.com/pixel.jpg, cookie=user123



advertiser.com

Web Tracking Cookie Syncing

The New York Times homepage featuring a chart titled "How much are countries pledging to reduce emissions?" showing China's historical and projected emissions from 1850 to 2030. The chart highlights a sharp increase in historical emissions followed by a plateau and a projected rise towards 2030.

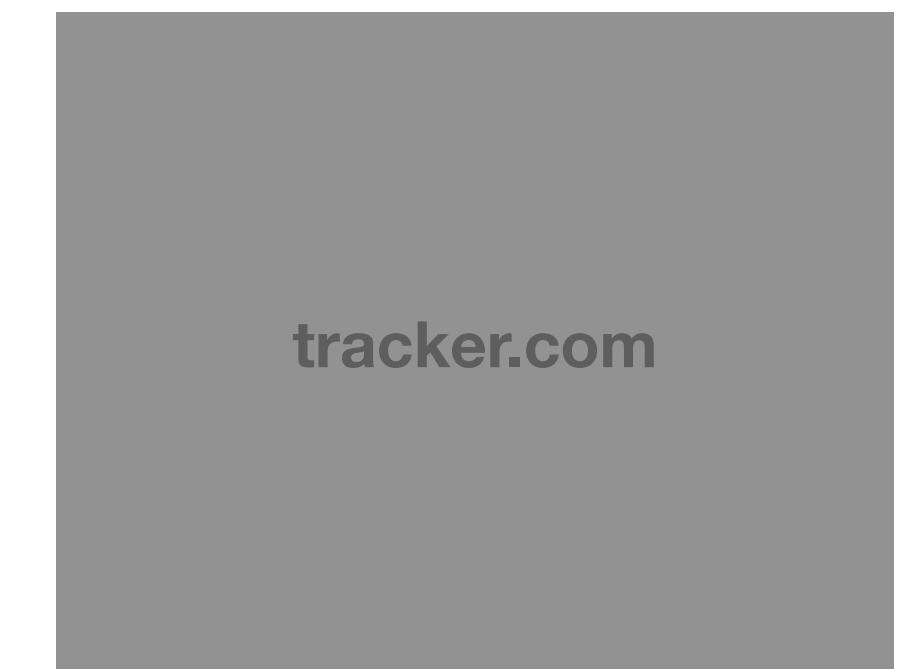
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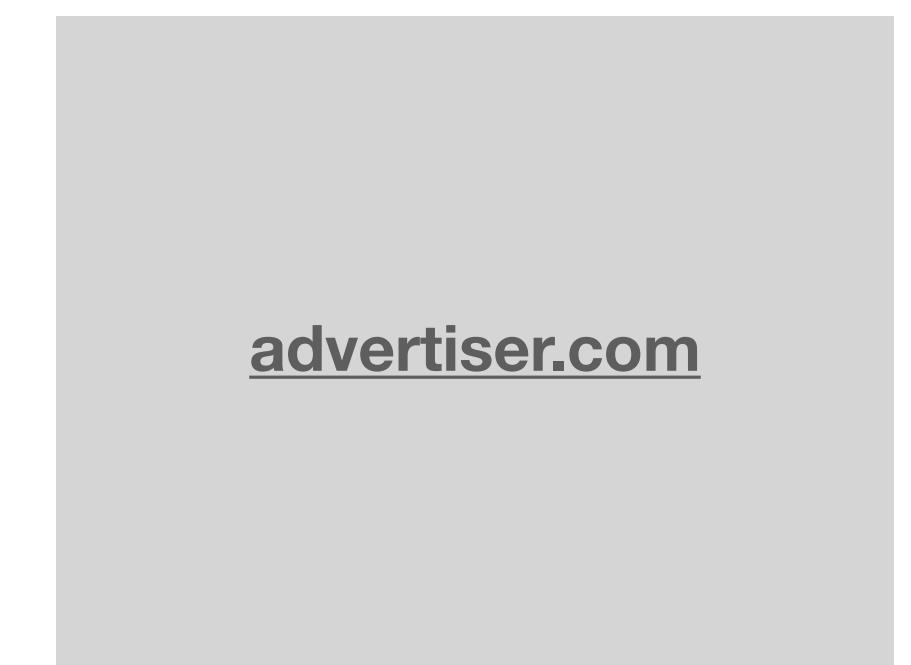
LIVE
Global Virus Death Toll Passes 5 Million
Experts say that the official toll is an undercount, as many covid-19 deaths accurately.

GET tracker.com/pixel.jpg, cookie=user123

REDIRECT, advertiser.com?syncID=user123&publisher=nytimes.com



advertiser.com



Web Tracking Cookie Syncing

The New York Times homepage features a prominent chart titled "How much are countries pledging to reduce emissions?" focusing on China. The chart shows historical emissions from 1850 to 2010, followed by a sharp rise in "Current Pledged" emissions reaching 12 GtCO₂ by 2030, which is described as "1.5°C compatible". Below the chart, a live update discusses Biden's speech at a climate summit.

LIVE
Climate Change Is 'Ravaging the World,' Biden Tells Summit
António Guterres, the U.N. secretary general, opened the conference with a blistering critique of the world's failure to unite to address global warming.
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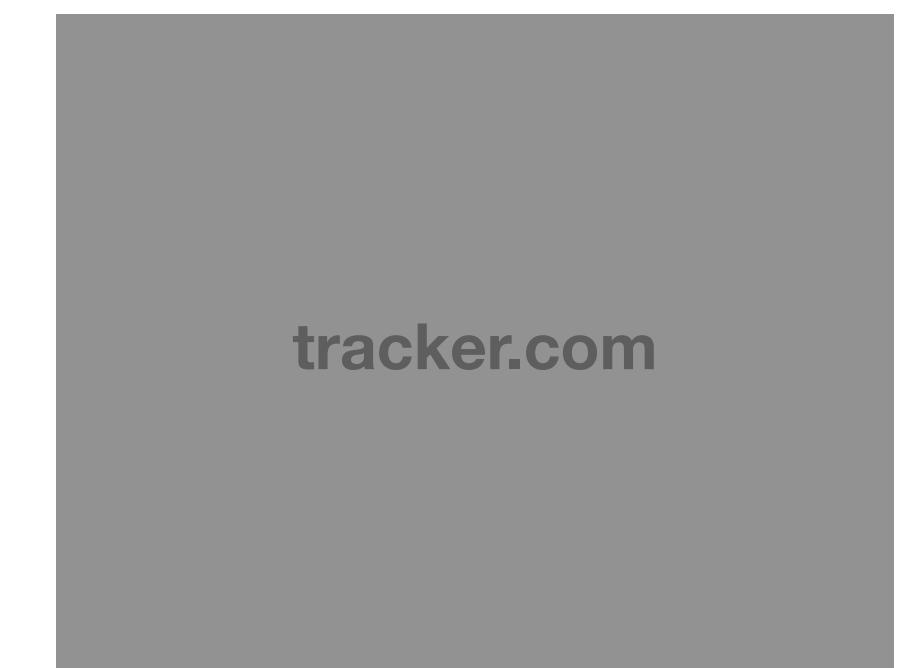
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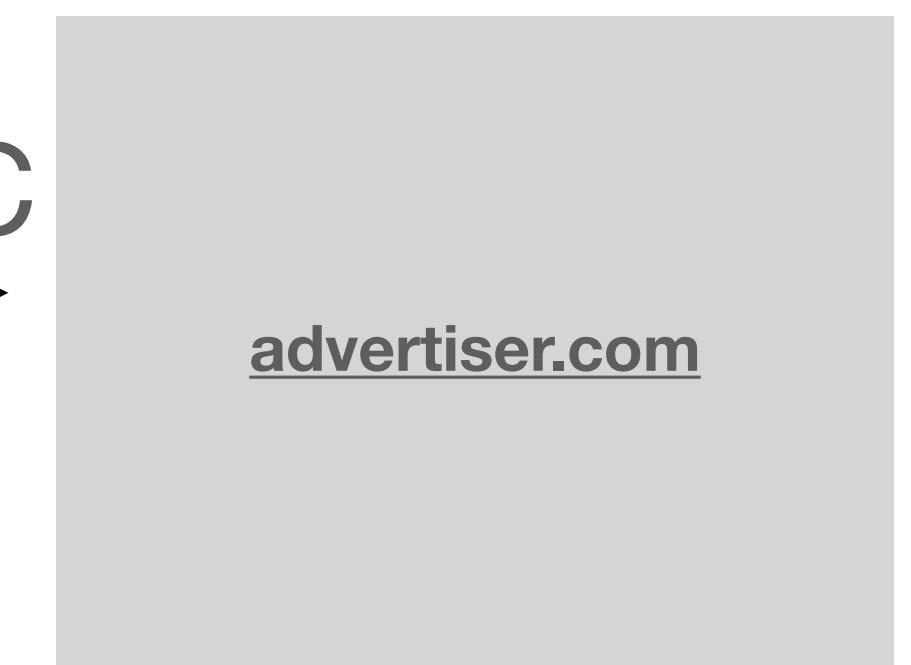
GET tracker.com/pixel.jpg, cookie=user123

REDIRECT, advertiser.com?syncID=user123&publisher=nytimes.com



GET syncID=user123, cookie=userABC

advertiser.com



Web Tracking Cookie Syncing

The screenshot shows the homepage of The New York Times. At the top, there are navigation links for U.S., INTERNATIONAL, CANADA, ESPAÑOL, and P.R. Below that, it says "Monday, November 1, 2023" and "Today's Paper". There are also links for PLAY THE CROSSWORD and ACCOUNT.

The main headline is "Climate Change Is 'Ravaging the World,' Biden Tells Summit". A sub-headline reads: "António Guterres, the U.N. secretary general, opened the conference with a blistering critique of the world's failure to unite to address global warming. 'We are standing at an inflection point in world history,' President Biden said in a speech, calling the need for action a moral imperative. Here's the latest."

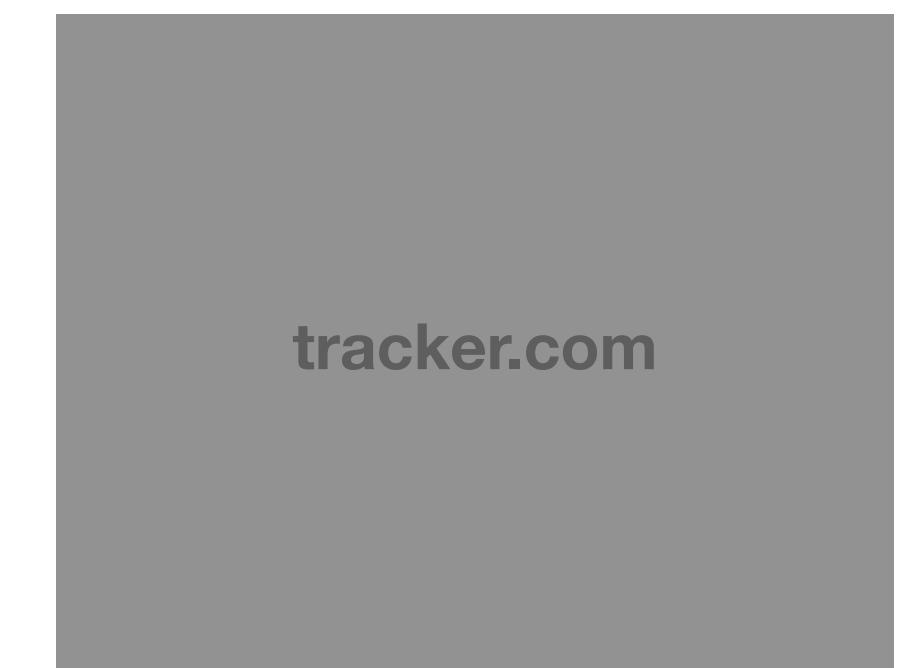
A chart titled "How much are countries pledging to reduce emissions?" shows China's historical emissions from 1850 to 2030. It highlights a sharp increase starting around 2000, with a yellow line labeled "Current" and a blue line labeled "Pledged". The blue line ends at the year 2030 with the text "1.5°C compatible".

Other news items include:

- "President Biden will try to assure skeptics that the U.S. is serious about climate action."
- "Europe is worried that the costs of climate action could set off a populist backlash."
- "Once a leading polluter, the U.K. is now trying to lead on climate change."
- "Supreme Court Is Hearing Oral Arguments on Texas Abortion Law" (with a live video link).
- "Global Virus Death Toll Passes 5 Million" (with a live video link).
- "Jen Psaki, the White House press secretary, tested positive for the coronavirus."

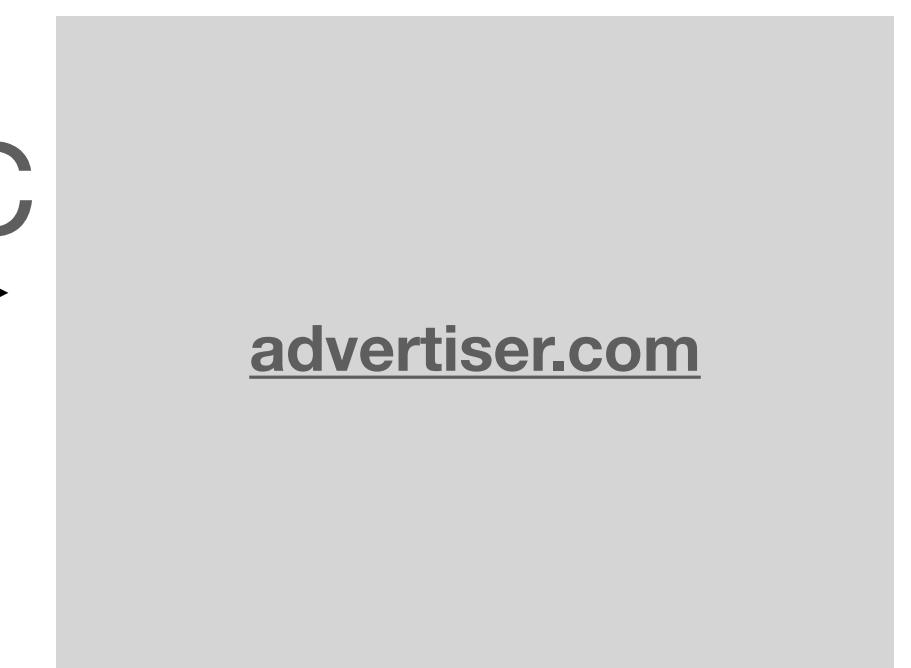
GET tracker.com/pixel.jpg, cookie=user123

REDIRECT, advertiser.com?syncID=user123&publisher=nytimes.com



GET syncID=user123, cookie=userABC

advertiser.com



- Third-parties with cookie syncing is enabled on 78% of modern websites :(

Web Tracking

Cookie Ghostwriting

- Not all first-party cookies *should* be treated the same!

Web Tracking Cookie Ghostwriting

- Not all first-party cookies *should* be treated the same!

The screenshot shows the homepage of The New York Times on Monday, November 1, 2022. At the top, there are navigation links for U.S., INTERNATIONAL, CANADA, ESPAÑOL, and 中文. Below that is a search bar and a crossword puzzle link. On the right side, there's a weather forecast for New York City: 59°F, 51°/32°, and a stock market tick for Nasdaq at +0.2%.

The main headline is "Climate Change Is 'Ravaging the World,' Biden Tells Summit". A graph titled "How much are countries pledging to reduce emissions?" compares historical emissions from 1850 to projected emissions by 2030 for China, showing a sharp increase from 12 GtCO₂ to 1.5°C compatible levels. Other news items include "Europe is worried that the costs of climate action could set off a populist backlash.", "Once a leading polluter, the U.K. is now trying to lead on climate change.", "President Biden will try to assure skeptics that the U.S. is serious about climate action.", and "He ran in the first New York City Marathon. Next week, he'll run in the 50th."

On the left, there's a live video feed of the Supreme Court hearing oral arguments on Texas Abortion Law, with a button to "TAP TO UNMUTE". Other live sections include "Global Virus Death Toll Passes 5 Million" and "Jon Psaki, the White House press secretary, tested positive for the coronavirus".

GET tracker.com/script.js



Web Tracking Cookie Ghostwriting

- Not all first-party cookies *should* be treated the same!

The screenshot shows the homepage of The New York Times on Monday, November 1, 2022. At the top, there are navigation links for U.S., INTERNATIONAL, CANADA, ESPAÑOL, and 中文. Below that is a search bar and account options. The main headline is "Climate Change Is 'Ravaging the World,' Biden Tells Summit". A chart titled "How much are countries pledging to reduce emissions?" compares historical emissions from 1850 to projected emissions by 2030 for China, showing a sharp increase from historical levels to current and pledged projections. Other news items include "Europe is worried that the costs of climate action could set off a populist backlash.", "Once a leading polluter, the U.K. is now trying to lead on climate change.", "President Biden will try to assure skeptics that the U.S. is serious about climate action.", and "Supreme Court is Hearing Oral Arguments on Texas Abortion Law". There are also sections for "Global Virus Death Toll Passes 5 Million" and "Joe Biden's First 100 Days". The footer includes a "TODAY'S PAPER" link and a "NYT+ \$10/MO" offer.

GET tracker.com/script.js

tracker.com

document.cookie = "user=userABC"

script.js

Web Tracking Cookie Ghostwriting

- 42% of identifier cookies are *ghostwritten* in modern websites

The screenshot shows the homepage of The New York Times on Monday, November 1, 2022. The main headline is "Climate Change Is 'Ravaging the World,' Biden Tells Summit". Below it is a chart titled "How much are countries pledging to reduce emissions?" comparing historical emissions from 1850 to projected emissions by 2030 for China, the U.K., and the world. The chart shows a sharp increase in emissions starting around 1950, with a projected line for China reaching nearly 12 GtCO₂ by 2030. A callout highlights the difference between "Current" and "Pledged" projections. Other news items include "President Biden will try to assure skeptics that the U.S. is serious about climate action.", "Europe is worried that the costs of climate action could set off a populist backlash.", "Once a leading polluter, the U.K. is now trying to lead on climate change.", "He ran in the first New York City Marathon. Next week, he'll run in the 50th.", "A pair of N.F.L. teams made big impressions in Week 8. Here's what we learned from Sunday's games.", "The Supreme Court has revised its procedures in a bid to tame interruptions during oral arguments.", "Roe Is as Good as Gone. It's Time for a New Strategy.", "I Just Turned 60, but I Still Feel 22.", and "Global Virus Death Toll Passes 5 Million". The weather forecast for New York is 59°F / 37° / 32° with a -0.2% chance of rain.

GET tracker.com/script.js

tracker.com

document.cookie = "user=userABC"

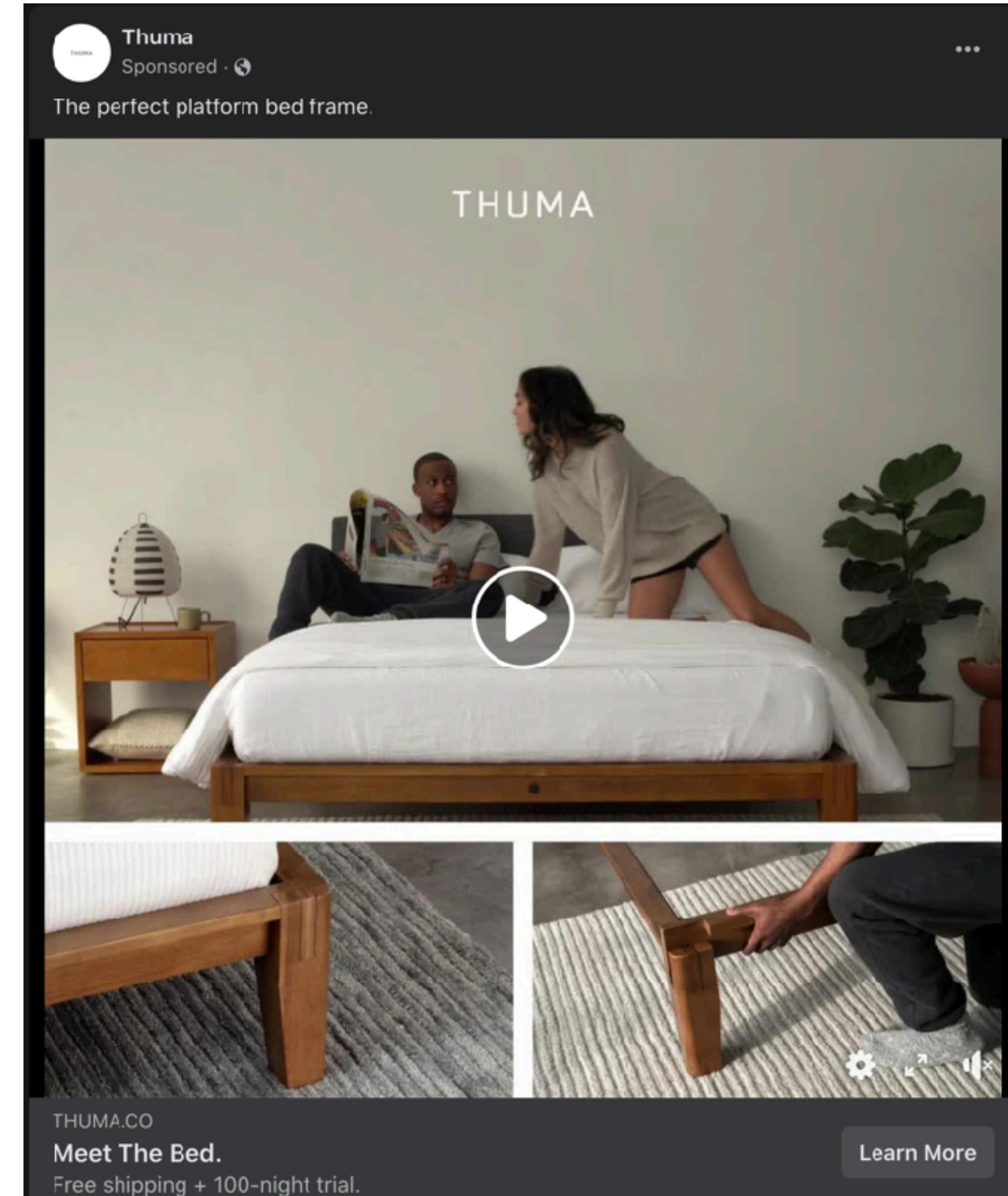
advertiser.com

Why is there so much tracking?

Online Advertising

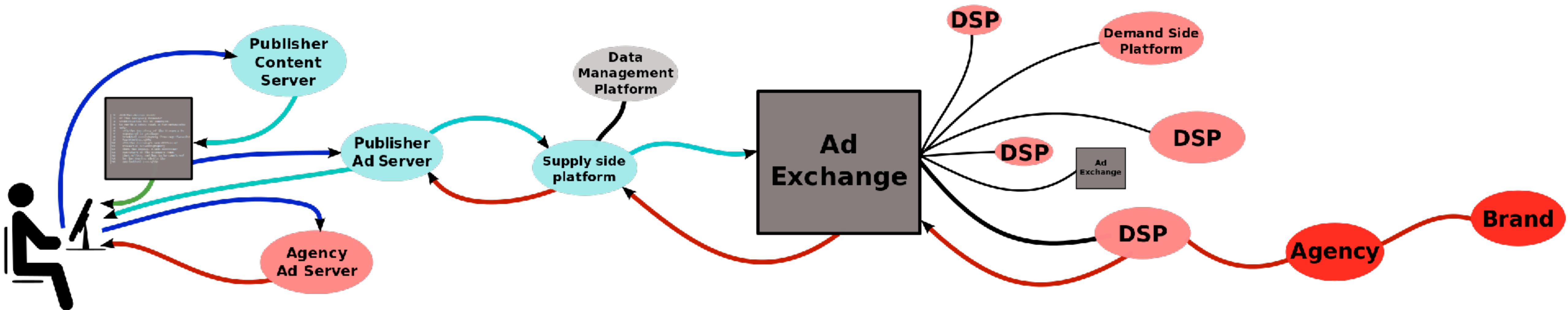
The Best Thing Since Sliced Bread! Available for \$4.99 at your local Costco.

- Companies typically track you around the web to build profiles for *targeted advertising*
 - The more targeted your advertising, the more revenue you can make from advertisers who are potentially willing to give you more money to sell the ad spot
 - Useful for advertisers to know if people with your browsing habits, your properties, your whatever are browsing on the web



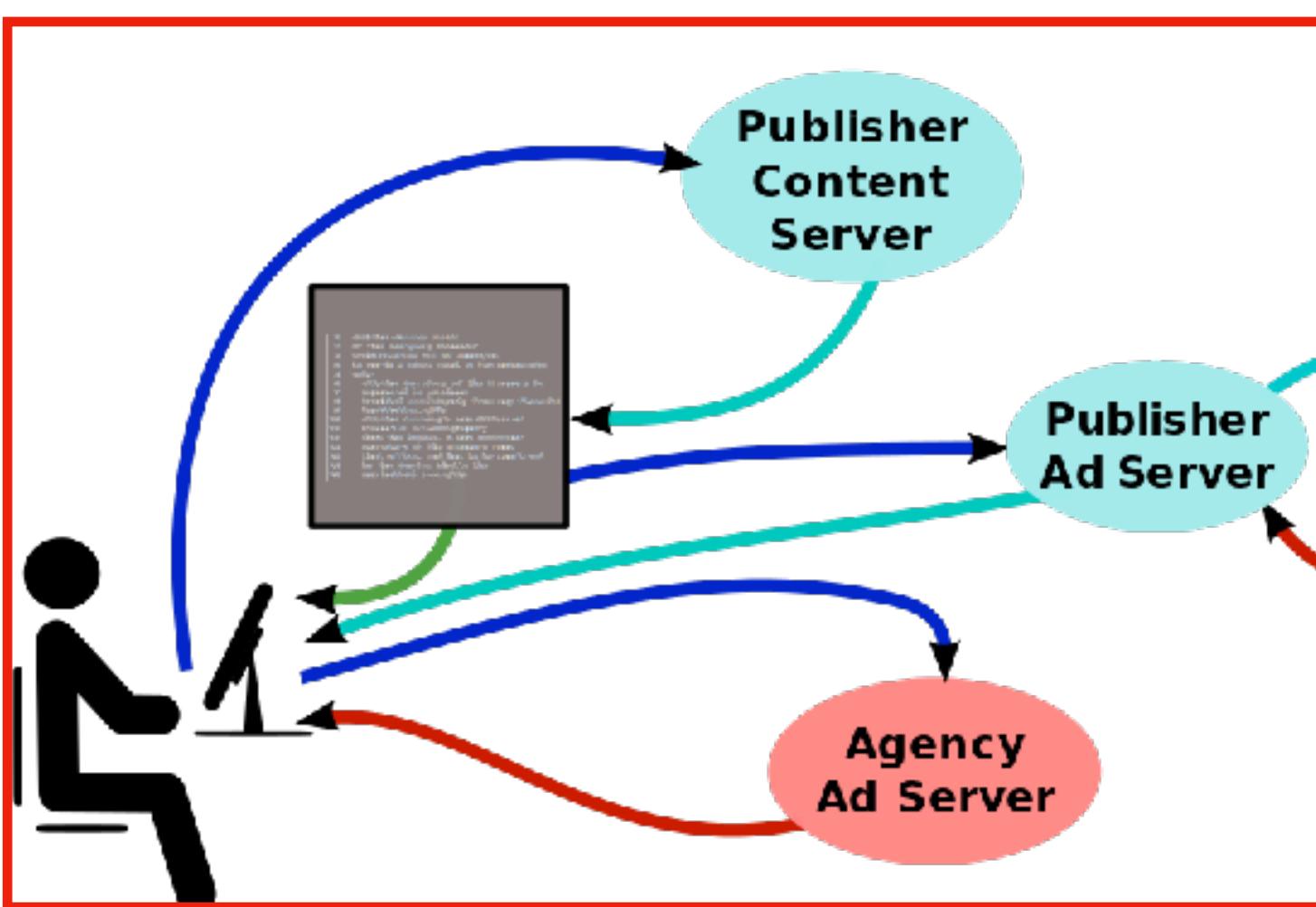
Online Advertising

The Many Internet Players in Advertising



Online Advertising

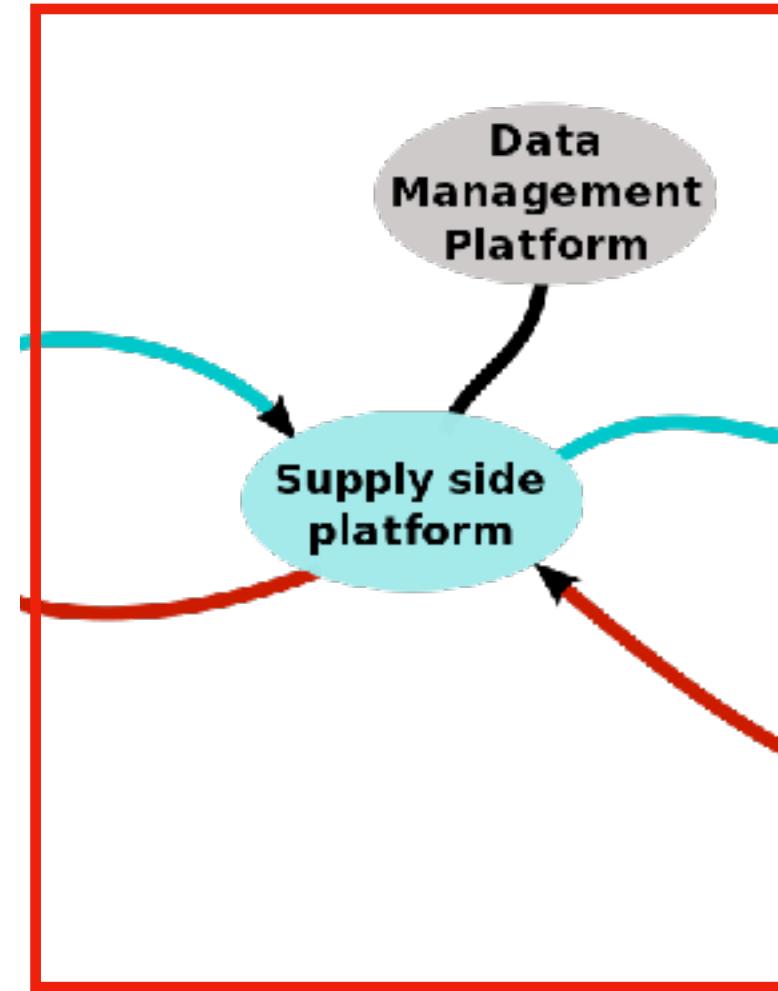
Publishers



- Publishers (e.g., nytimes.com, cnn.com, other websites) often have advertising space that they are hoping to make revenue off of
- In some cases, publishers have explicit agreements with companies and can sell their space that way

Online Advertising

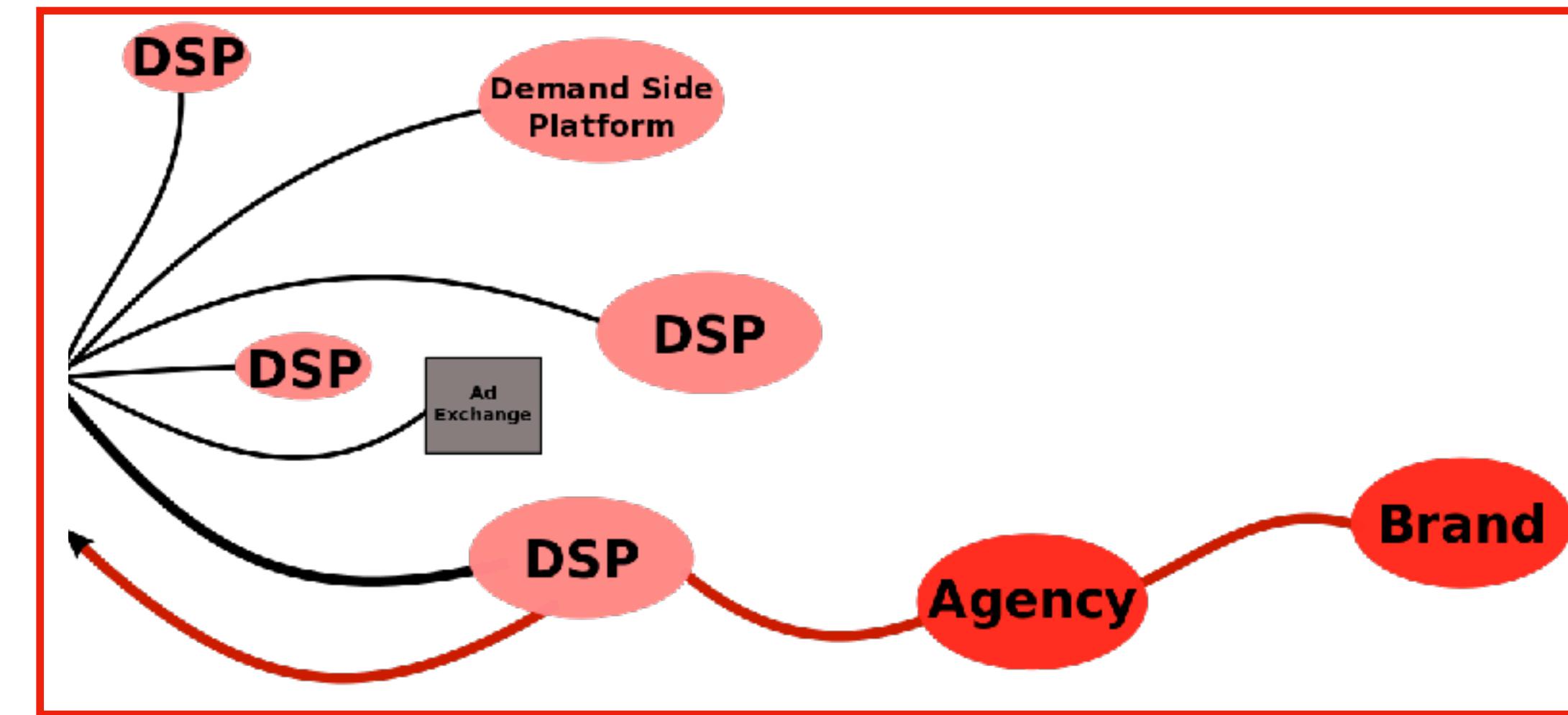
Supply Side Platforms



- If a publisher wants to place the ad spot on the open advertising market, they typically go through an intermediary called a Supply Side Platform (SSP)
 - Examples: Pubmatic, Rubicon Project, Verizon Media, etc.
 - This aggregates information about the client (through a DMP) and participates in ad exchange

Online Advertising

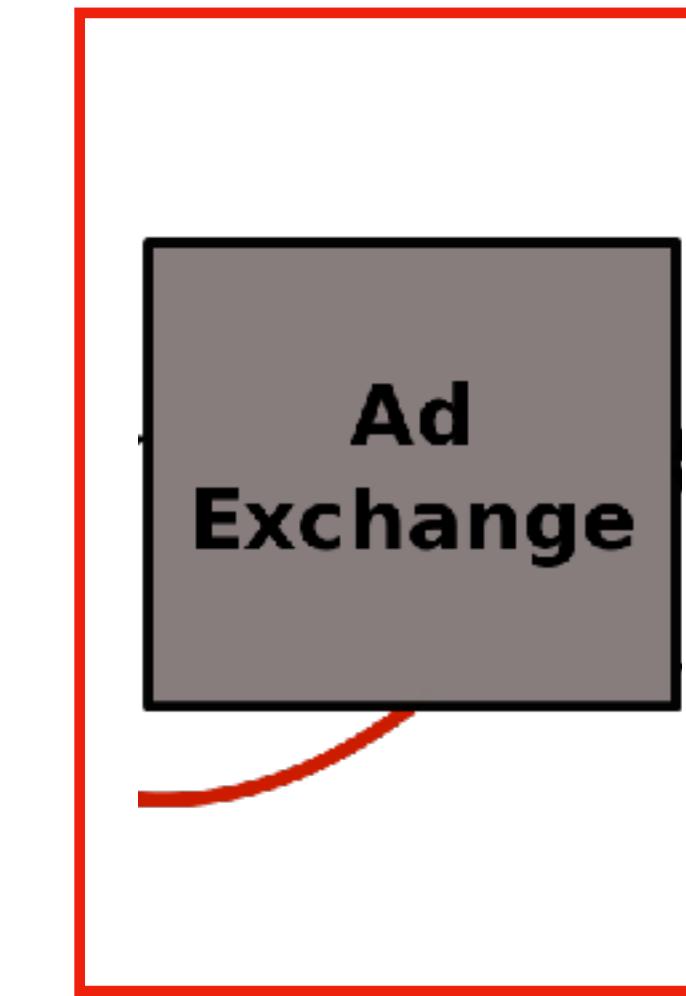
Demand Side Platforms



- On the other end of the pipeline, you have advertisers
- There are analogous entities called demand side platforms, which participate in Real-Time Bidding, which is a real-time auction for ad space (examples: Google DoubleClick, QuantCast, Criteo, Adform)
 - Typically happens in < 100ms

Online Advertising

Ad Exchanges



- Advertising exchanges receive spots from supply side, and facilitate real time bidding from the demand side based on properties of the ad spot
 - Examples: Google DoubleClick, Facebook Exchange, PubMatic, Microsoft Advertising

Online Advertising

Bid Requests

```
"site": {
    "id": "1234",
    "name": "Example Site",
    "domain": "examplesitedomain.com",
    "mobile": 1,
    "amp": 0,
    "pub": {
        "id": "9876",
        "name": "Example Publisher, Inc.",
        "domain": "examplepubdomain.com"
    }
},
"user": {
    "id": "a0af45c77890045deec100acb8443baff57c",
    "consent": "ihdknkhkq8y",
    "buyeruid": "fcd4282456238256034abcdef220d9aa5892",
    "yob": 1990,
    "gender": "F",
    "ext": {
        "consented_providers_settings": {
            "consented_providers": [
                1,
                52,
                45,
                23
            ]
        }
    }
},
"device": {
    "type": 4,
    "ifa": "8846d6fa10008bceaaaf322908dfcb221",
    "ip": "1.2.3.4",
    "ua": "Mozilla/5.0 (Macintosh; U; Intel Mac OS X 10.6; en-US; rv:1.9.2.16) Gecko/20110319 Firefox/3.6.16",
    "make": "Apple",
    "model": "iPhone",
    "hwv": "6s",
    "os": 13,
    "osv": "11.4.1",
    "mccmn": "310-005",
    "geo": {
        "lat": 40.7128,
        "lon": -74.0060
    }
}
```

[https://
protocol.bidswitch.com/
rtb/request-
examples.html](https://protocol.bidswitch.com/rtb/request-examples.html)

Online Advertising

Bid Response

```
{  
    "id": "d7d1e107-987h",  
    "cur": "usd",  
    "ext": {  
        "protocol": "6.0"  
    },  
    "seatbid": [  
        {  
            "seat": "4",  
            "bid": [  
                {  
                    "id": "qwerty-098765",  
                    "item": "asdf-7890",  
                    "price": 1.45,  
                    "cid": "app-mraid-campaign-3442",  
                    "burl": "https://adserver.com/winnnotice?impid=102&winprice=${AUCTION_PRICE}",  
                    "macro": [  
                        {  
                            "key": "TIMESTAMP",  
                            "value": "1127987134"  
                        }  
                    ],  
                    "ext": {  
                        "agency_id": "agency_123",  
                        "advertiser_name": "example advertiser"  
                    },  
                    "media": {  
                        "ad": {  
                            "id": "creative_id_1234",  
                            "adomain": [  
                                "example.com",  
                                "example.io"  
                            ],  
                            "cat": [  
                                "cat_1",  
                                "cat_2"  
                            ],  
                            "lang": "en",  
                            "attr": [  
                                3,  
                                7  
                            ]  
                        }  
                    }  
                }  
            ]  
        }  
    ]  
}
```

[https://
protocol.bidswitch.com/
rtb/response-
examples.html](https://protocol.bidswitch.com/rtb/response-examples.html)

Online Advertising

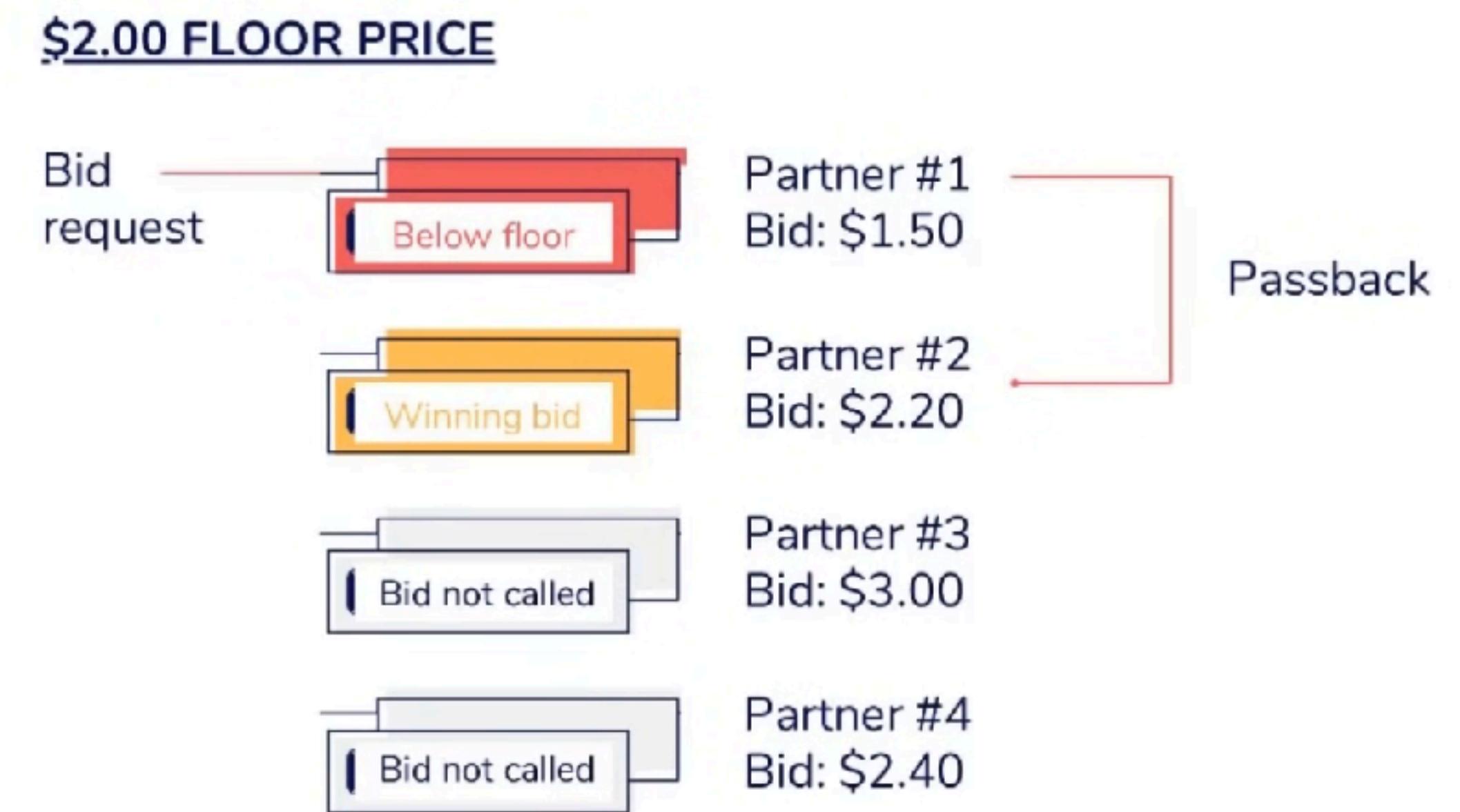
Bidding for Ad Spots

- 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
 - Header bidding

Online Advertising

Waterfall Bidding

- Publishers would pre-define a hierarchy of advertising networks that they wanted to ask in order (e.g., in a waterfall) about any given advertising spot
- Publishers would then set a floor bid rate that they needed for the ad spot
 - The first network to fulfill the floor would win the spot, but floor price goes down with lower priority
- Problems:
 - Slow (serial computation)
 - Anti-competitive!
 - Google had both an SSP and a DSP, which often meant they got first pick at ad spots



Online Advertising

Header Bidding

- Every DSP is offered the auction at the *same time*, and DSPs are incentivized to provide their true value for the advertising spot (theoretically)
 - This typically happens in 100 – 200ms
- Two options:
 - Client-side header bidding (happens in JavaScript), potentially makes the page slower, but have finer grained access to cookies
 - Server-side header bidding (happens in the SSP), can be faster, but requires cookie syncing, could make things slower

When the business model ***is*** the privacy violation

APRIL 12, 2018 BY [ARVIND NARAYANAN](#)

BRACE YOURSELVES

REGULATION IS COMING

Regulation

GDPR, CCPA

- We've seen a big regulation push in the last five years around issues of online privacy and tracking
 - General Data Protection Regulation (GDPR), is an EU law on data protection and privacy for the European Economic Area
 - California Consumer Privacy Act (CCPA) is a state statute which aims to enhance consumer protections for Californians
 - Both of these laws mandate all kinds of rules for the storing of personally identifiable data (e.g., IP addresses, cookies!), how long these things can be stored about users on the server side, etc.

Regulation

Cookie Banners

- If you use cookies, you must:
 - Inform users that your site/app uses cookies
 - Explain how cookies work and what the site uses them for
 - Obtain informed consent **prior** to storing those cookies on the user's device
- Need to provide users a **clear** and **easy** way to opt-out of cookie-tracking on a website
 - Steep fines (4% of annual revenue) if you do not comply
- Unfortunately, cookie-banners are being designed in terrible ways... and consent is broken

