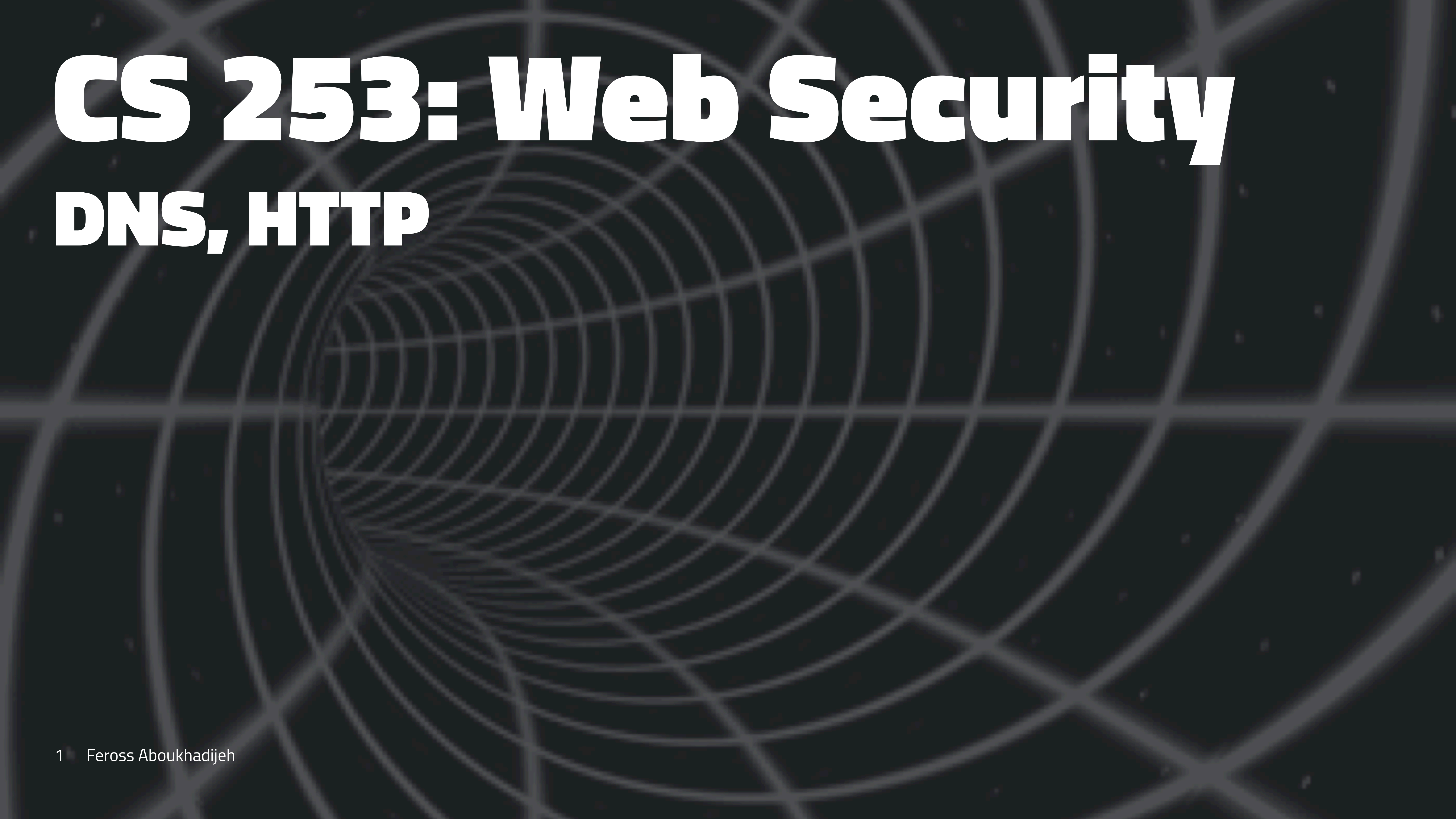


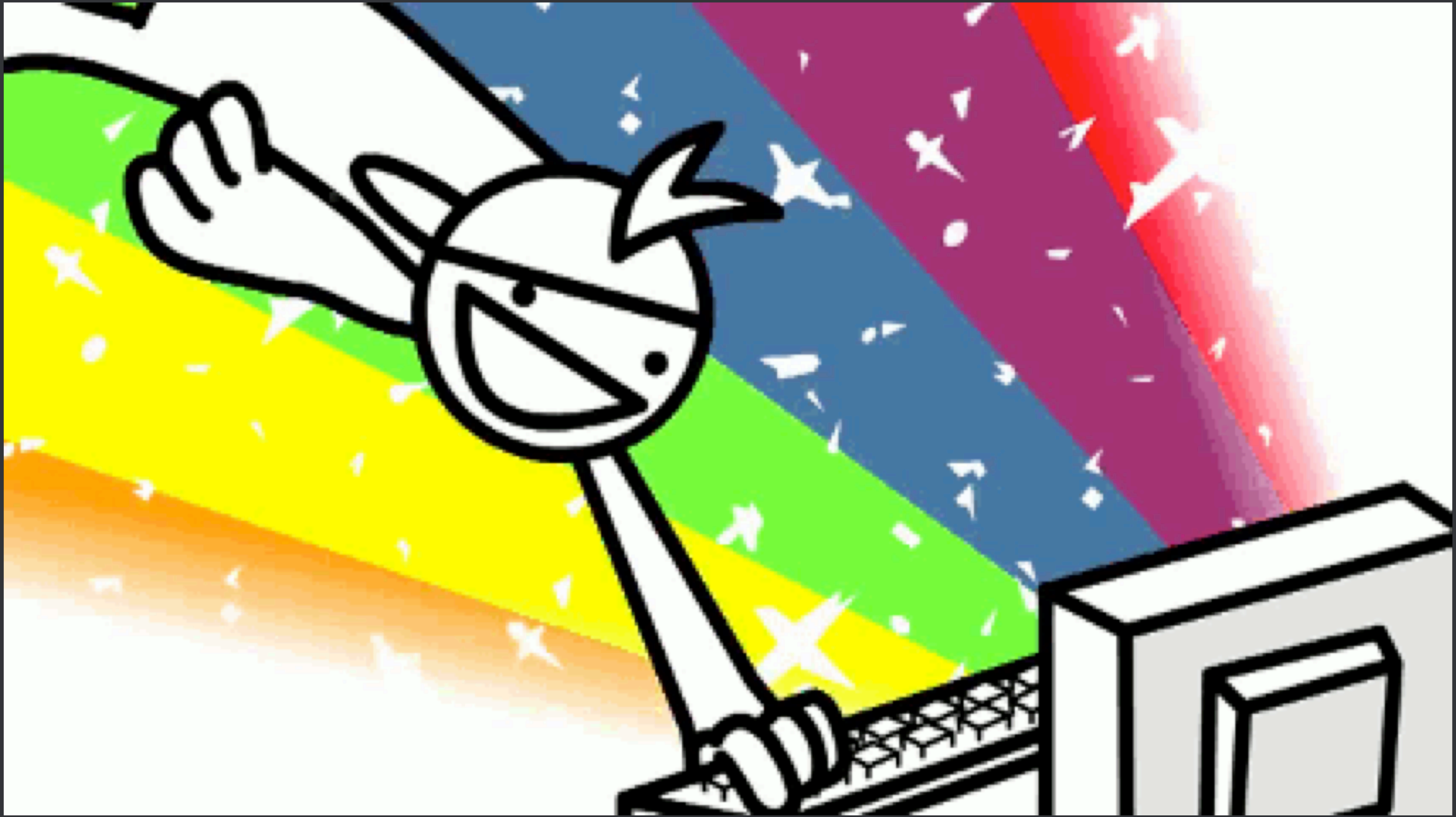
CS 253: Web Security

DNS, HTTP

Admin

- Assignment 0 is out!

What happens when you type a URL and press enter?



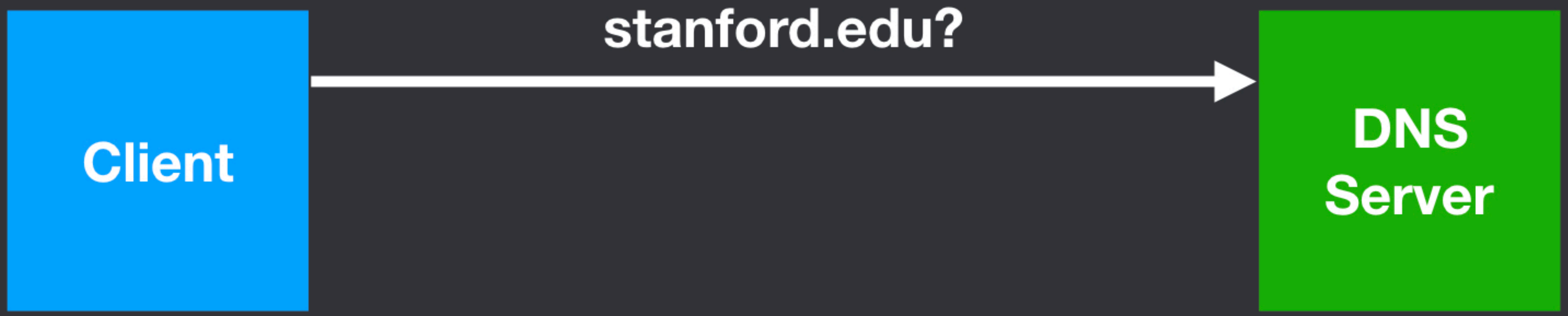
Domain Name System (DNS)

DNS

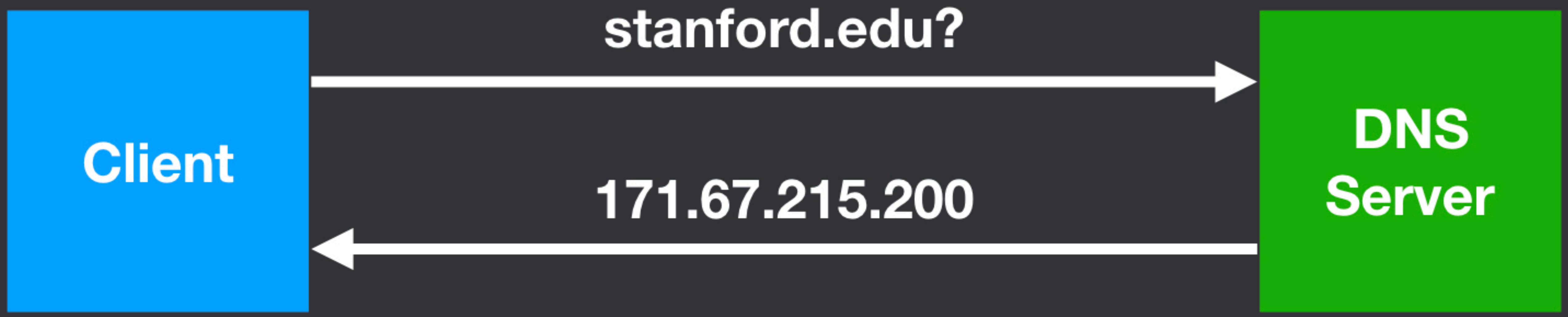
Client

DNS Server

DNS

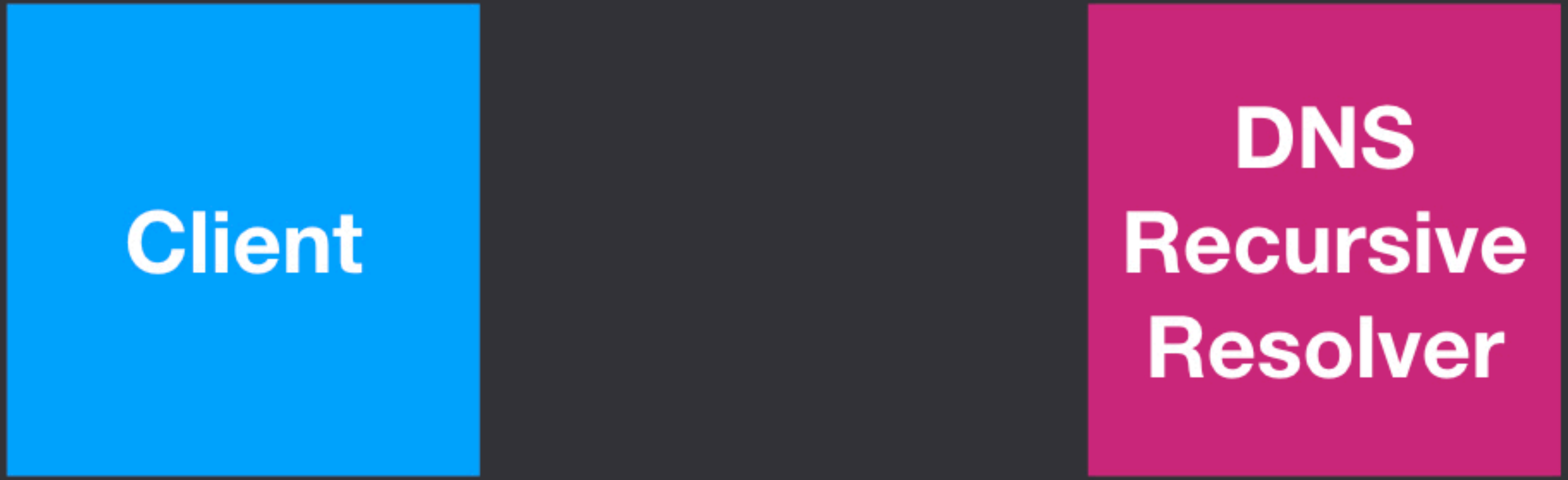


DNS



How does the "DNS server" work?

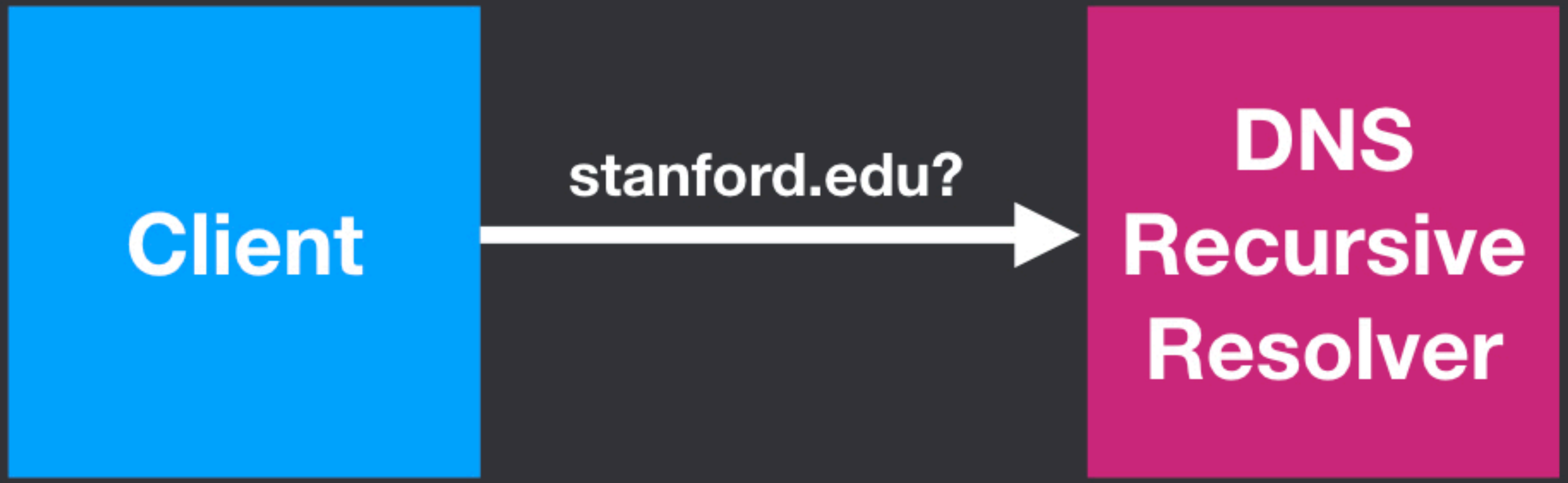
DNS



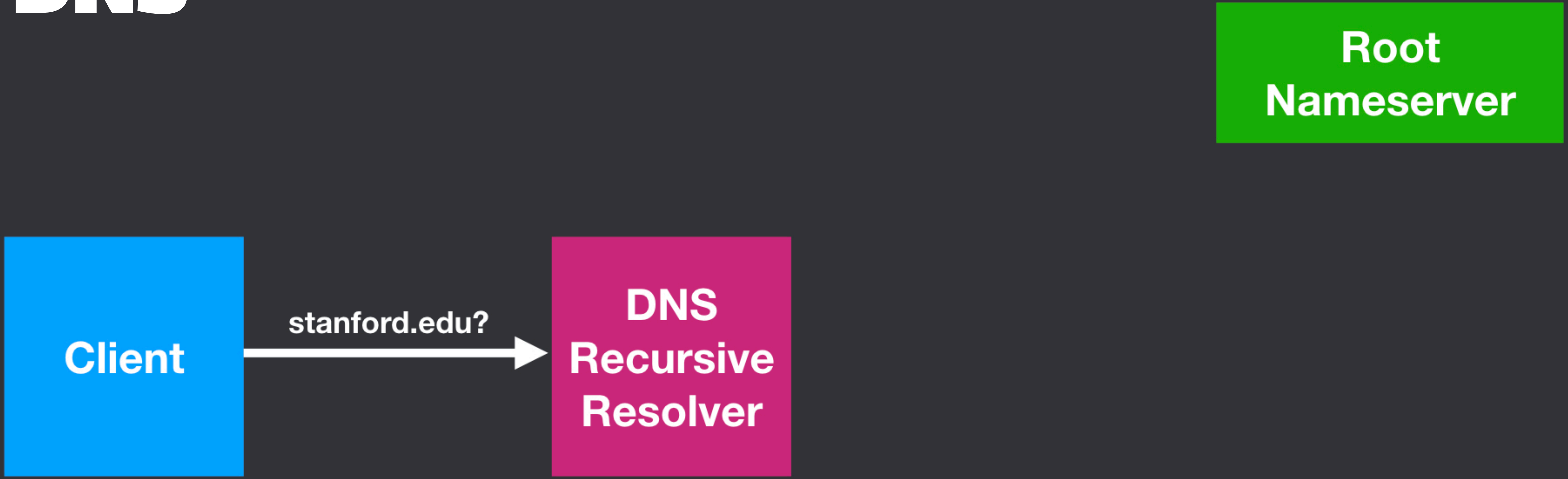
Client

DNS Recursive Resolver

DNS



DNS



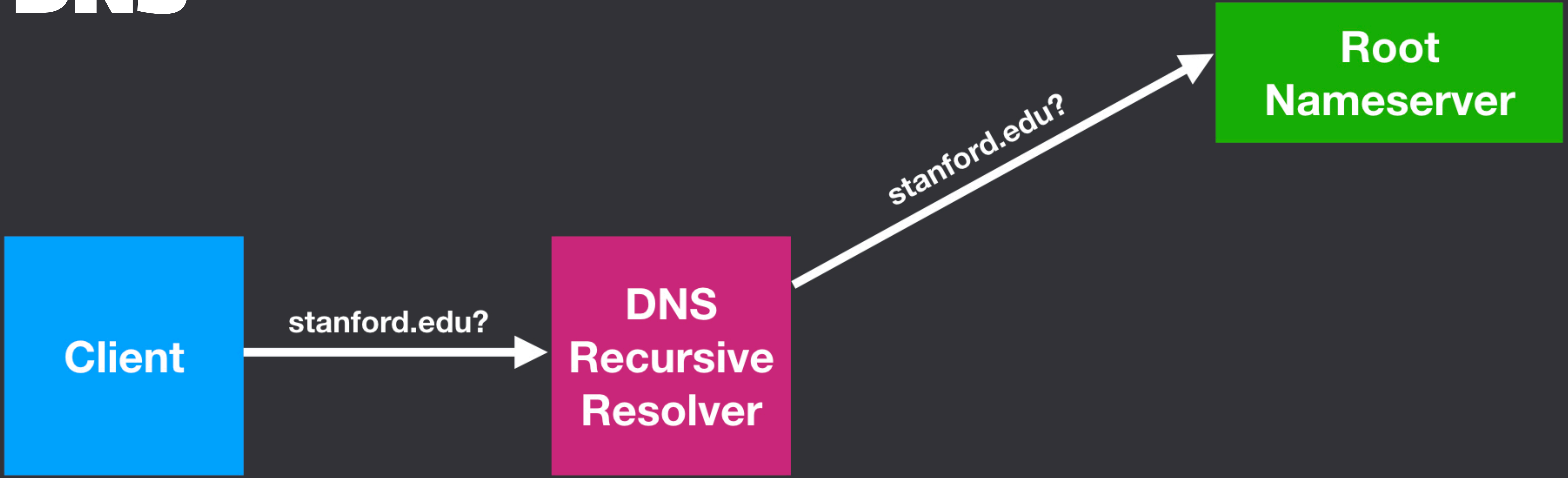
Root Nameserver

Client

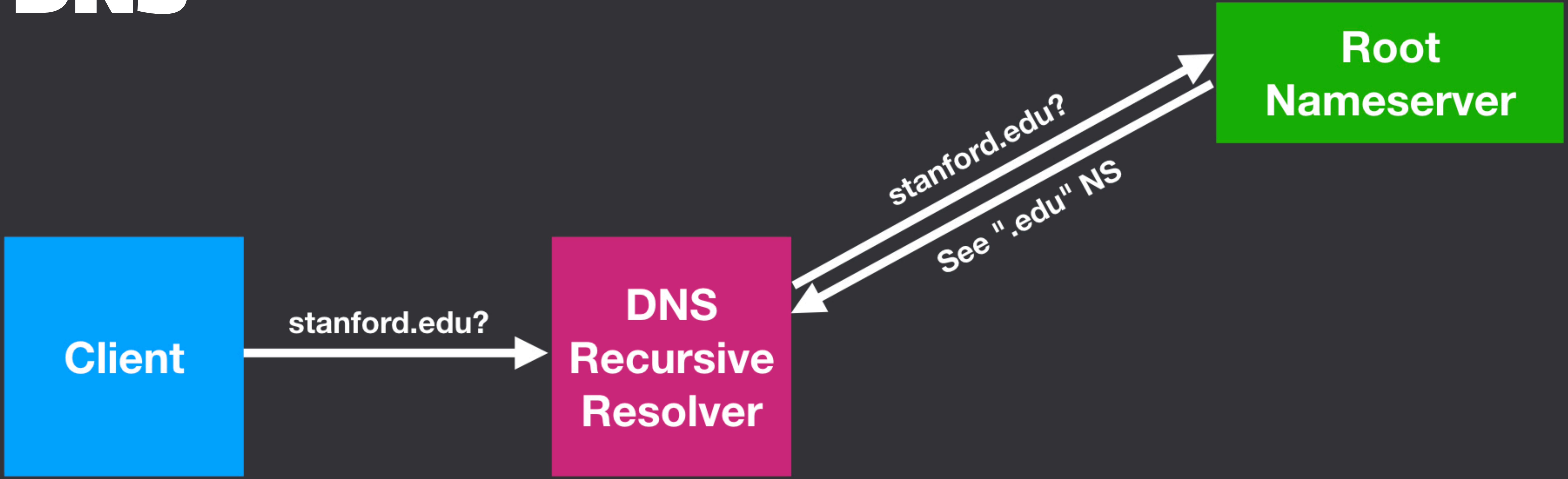
stanford.edu?

DNS Recursive Resolver

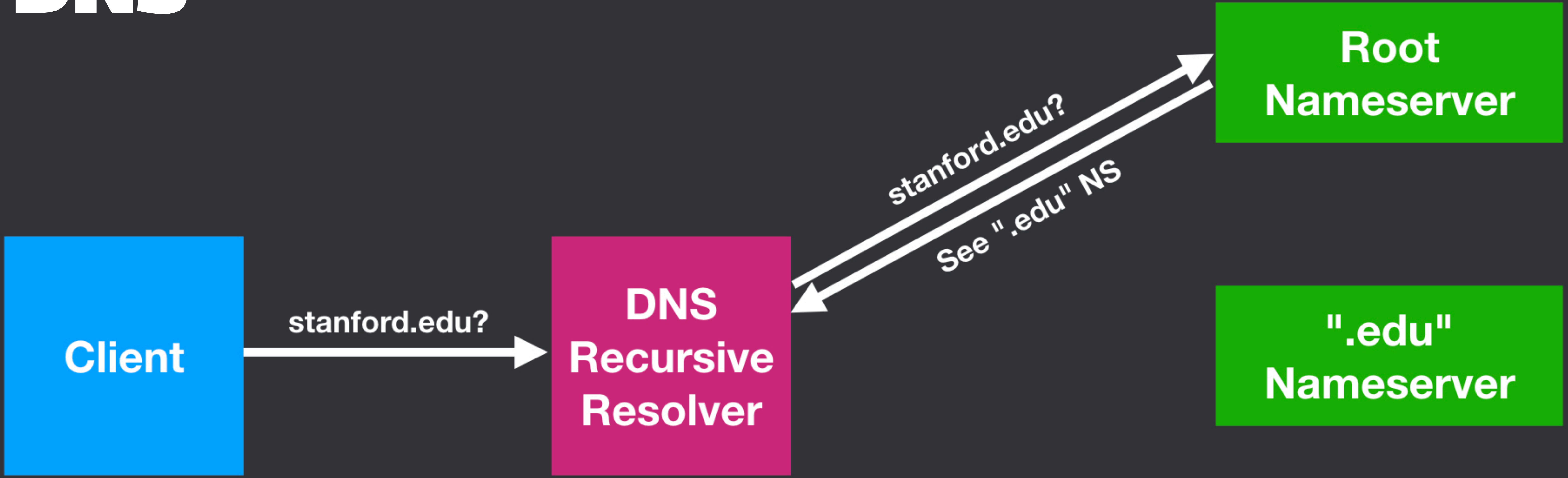
DNS


Root Nameserver
stanford.edu?
Client
stanford.edu?
DNS Recursive Resolver

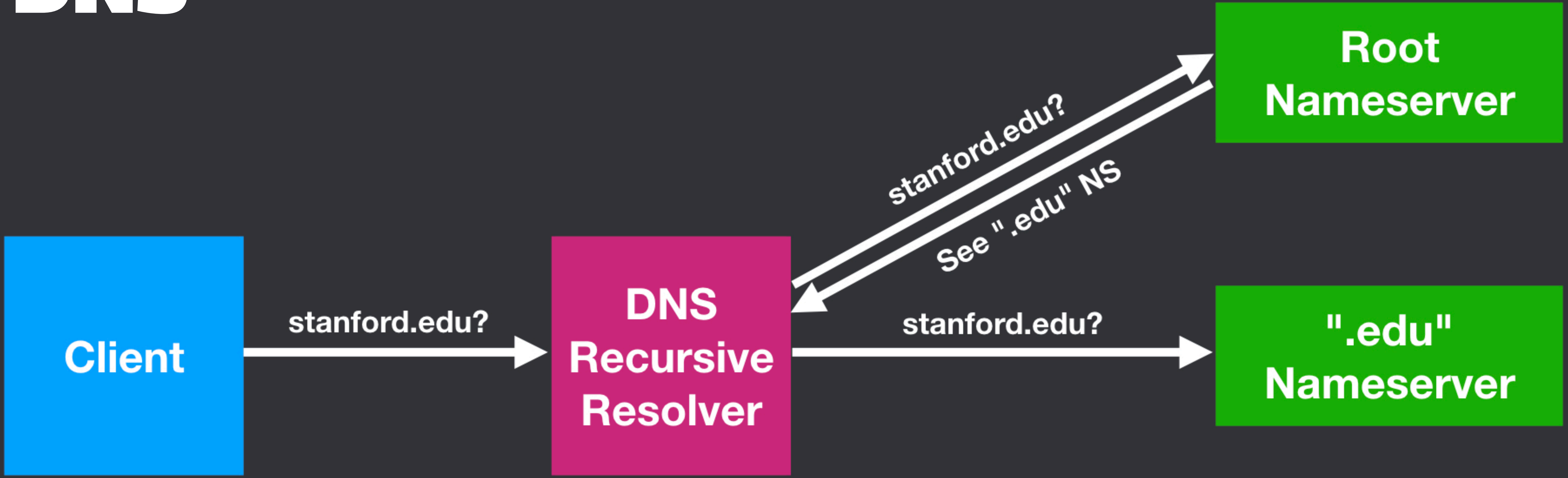
DNS


Client
stanford.edu?
DNS Recursive Resolver
stanford.edu?
See ".edu" NS
Root Nameserver

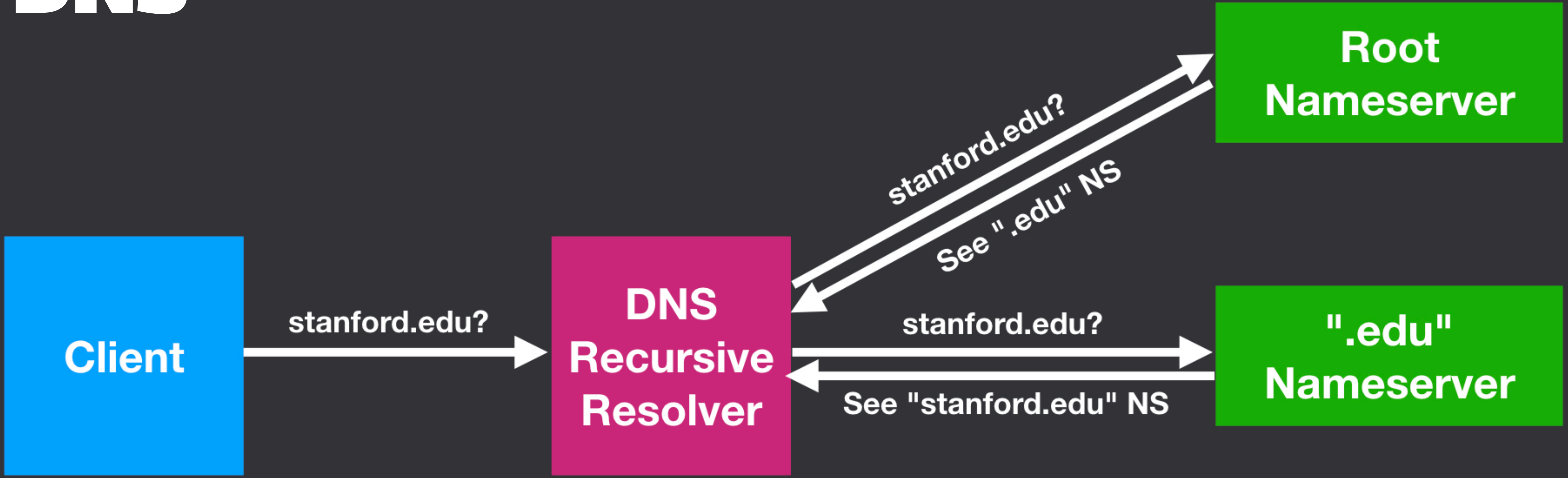
DNS


Root Nameserver
stanford.edu?
See ".edu" NS
Client
stanford.edu?
DNS Recursive Resolver
".edu" Nameserver

DNS


Root Nameserver
stanford.edu?
See ".edu" NS
Client
stanford.edu?
DNS Recursive Resolver
stanford.edu?
".edu" Nameserver

DNS



Root Nameserver

stanford.edu?

See ".edu" NS

Client

stanford.edu?

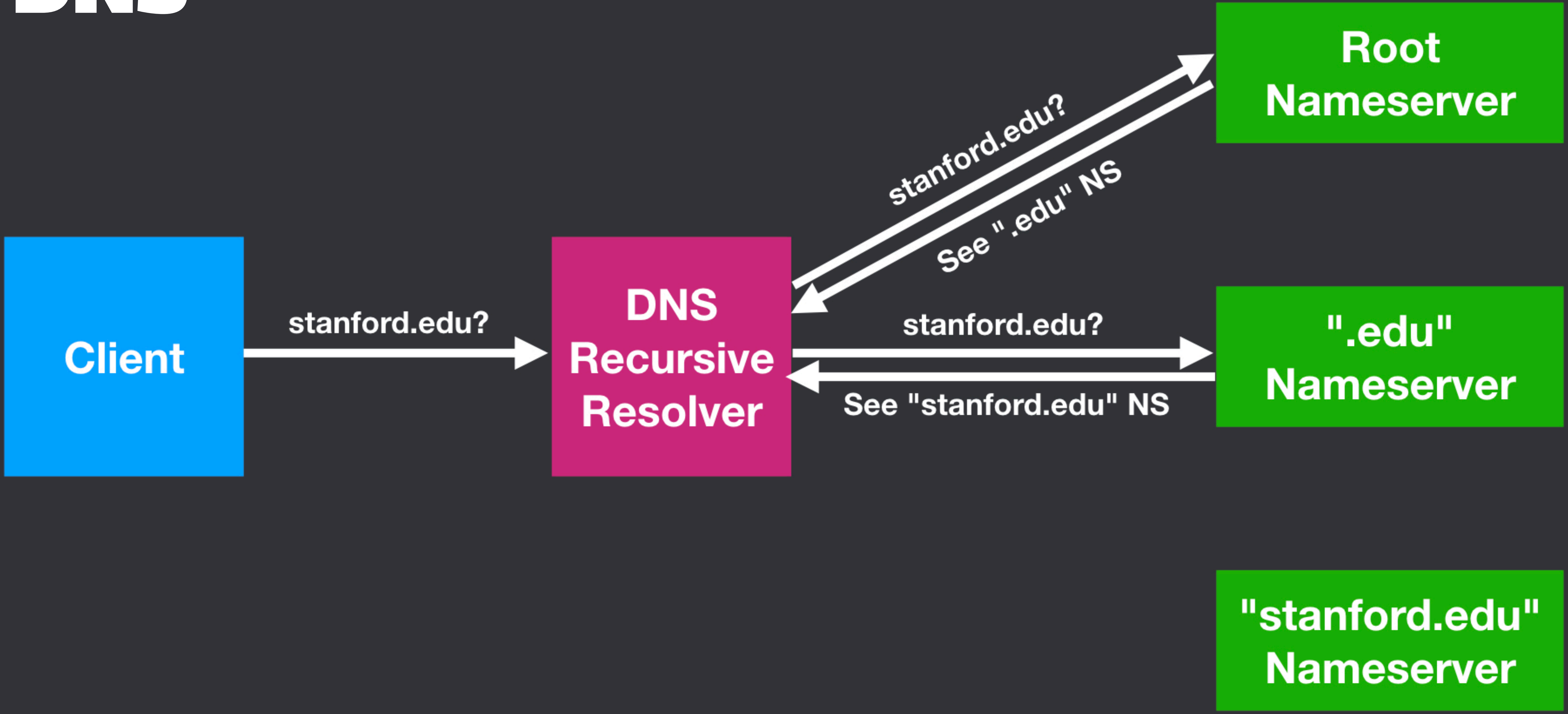
DNS Recursive Resolver

stanford.edu?

See "stanford.edu" NS

".edu" Nameserver

DNS



Client

stanford.edu?

DNS Recursive Resolver

stanford.edu?

See ".edu" NS

Root Nameserver

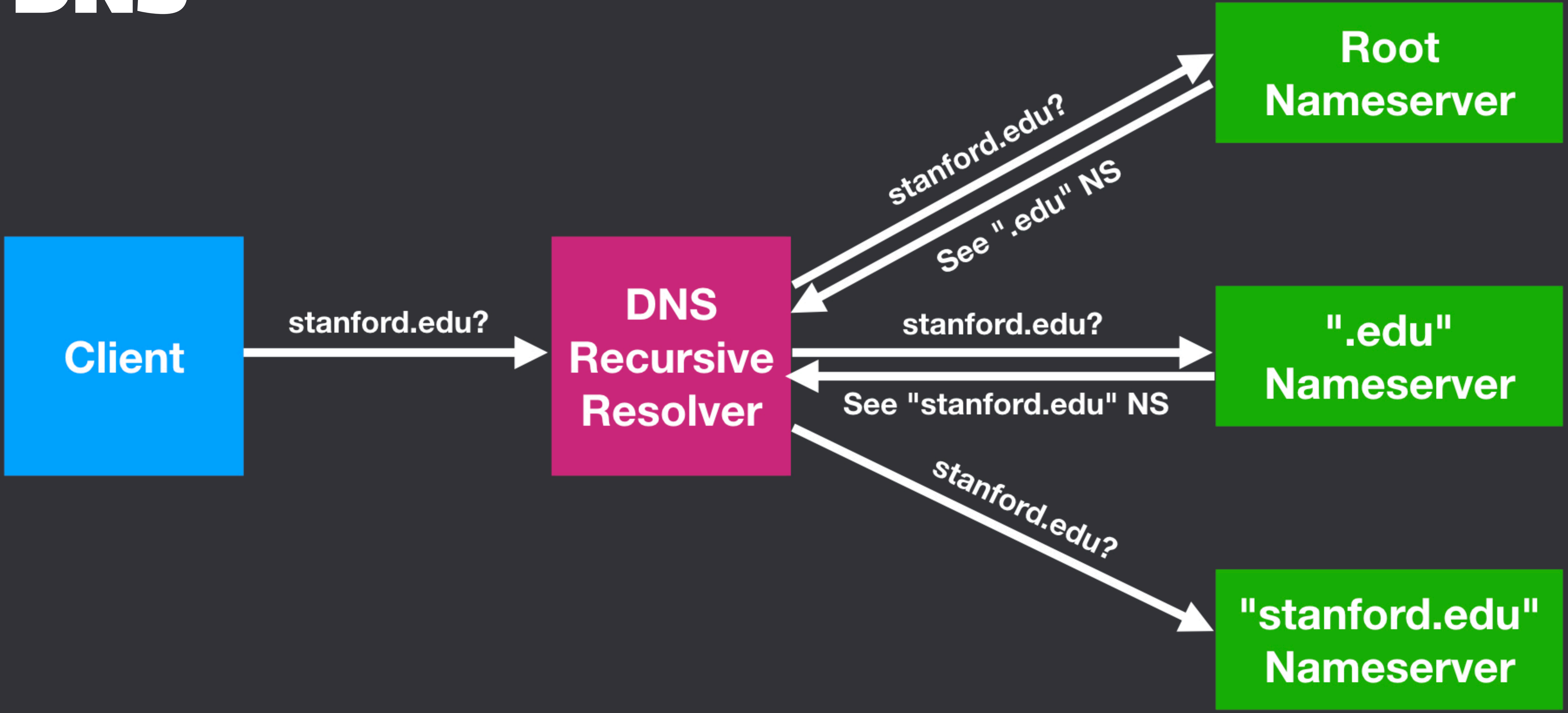
stanford.edu?

See "stanford.edu" NS

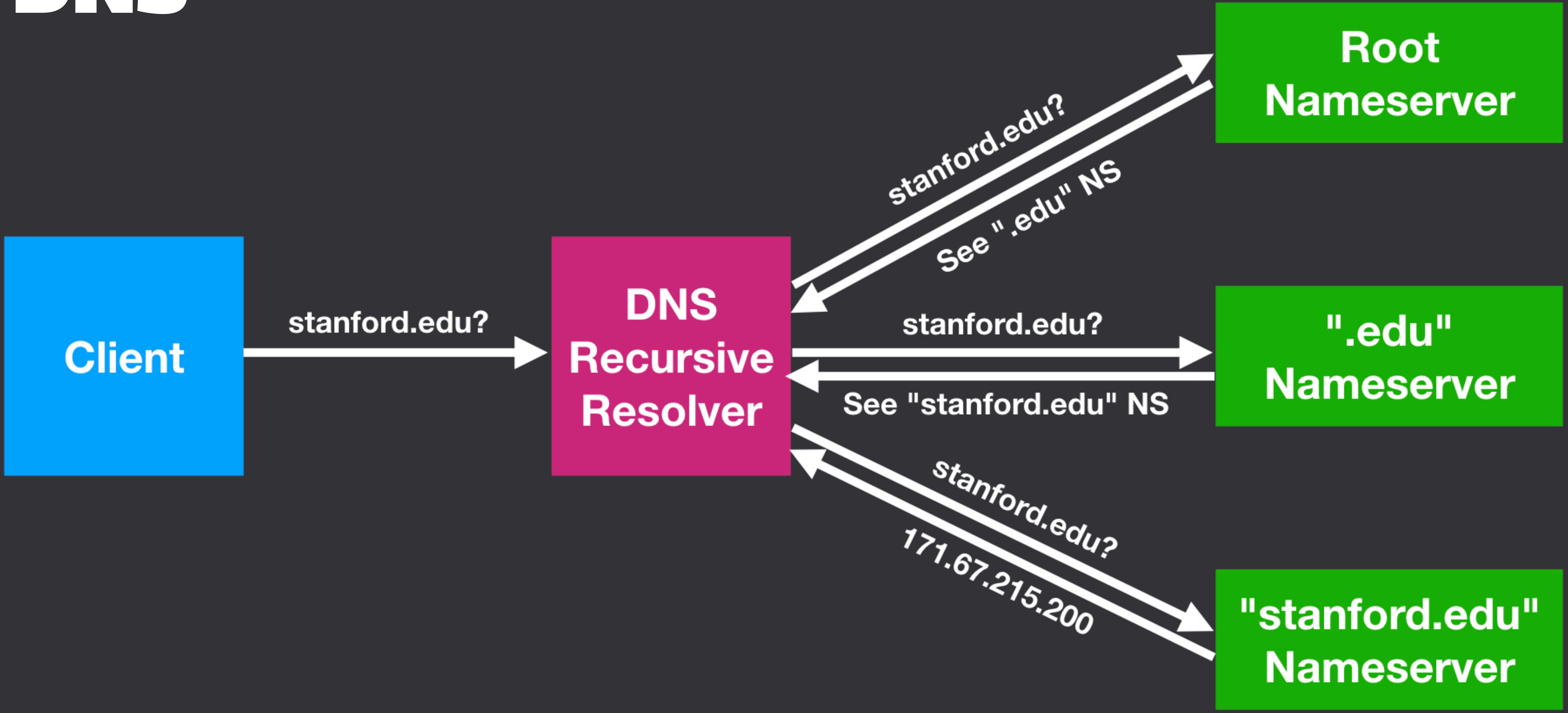
".edu" Nameserver

"stanford.edu" Nameserver

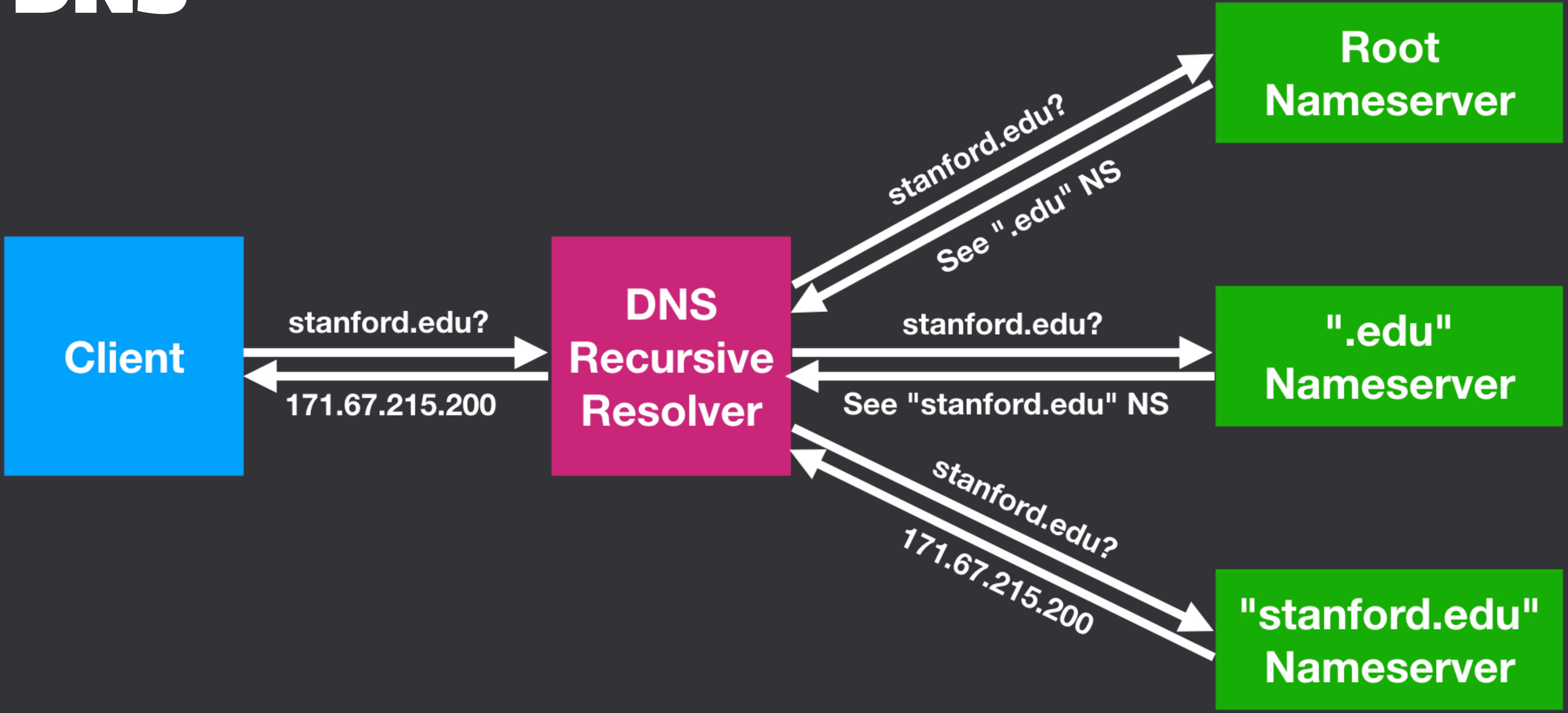
DNS


Client
stanford.edu?
DNS Recursive Resolver
stanford.edu?
See ".edu" NS
Root Nameserver
stanford.edu?
See "stanford.edu" NS
".edu" Nameserver
stanford.edu?
"stanford.edu" Nameserver

DNS


Root Nameserver
stanford.edu?
See ".edu" NS
Client
stanford.edu?
DNS Recursive Resolver
stanford.edu?
".edu" Nameserver
See "stanford.edu" NS
stanford.edu?
171.67.215.200
"stanford.edu" Nameserver

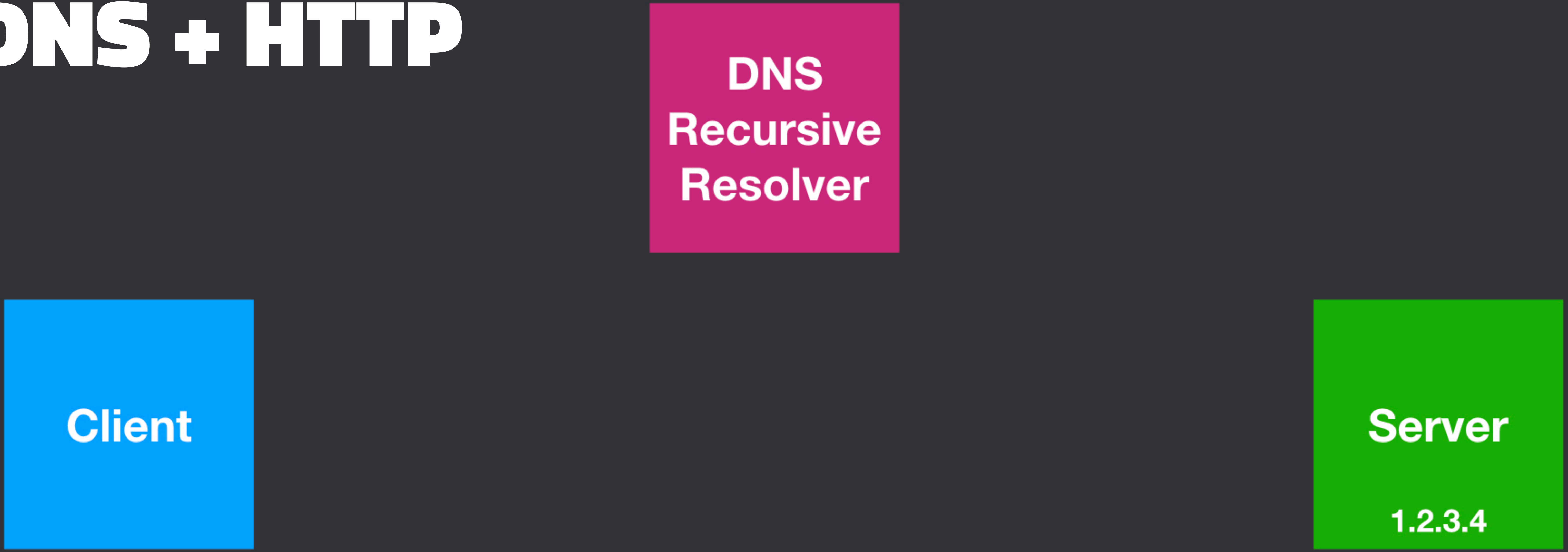
DNS


Root Nameserver
stanford.edu?
See ".edu" NS
Client
stanford.edu?
171.67.215.200
DNS Recursive Resolver
stanford.edu?
See "stanford.edu" NS
".edu" Nameserver
stanford.edu?
171.67.215.200
"stanford.edu" Nameserver

What happens when you type a URL and press enter?

1. **Client** asks **DNS Recursive Resolver** to lookup a hostname (`stanford.edu`).
2. **DNS Recursive Resolver** sends DNS query to **Root Nameserver**
   - **Root Nameserver** responds with IP address of **TLD Nameserver** (".edu" Nameserver)
3. **DNS Recursive Resolver** sends DNS query to **TLD Nameserver**
   - **TLD Nameserver** responds with IP address of **Domain Nameserver** ("stanford.edu" Nameserver)
4. **DNS Recursive Resolver** sends DNS query to **Domain Nameserver**
   - **Domain Nameserver** is authoritative, so replies with server IP address.
5. **DNS Recursive Resolver** finally responds to **Client**, sending server IP address (171.67.215.200)

DNS + HTTP



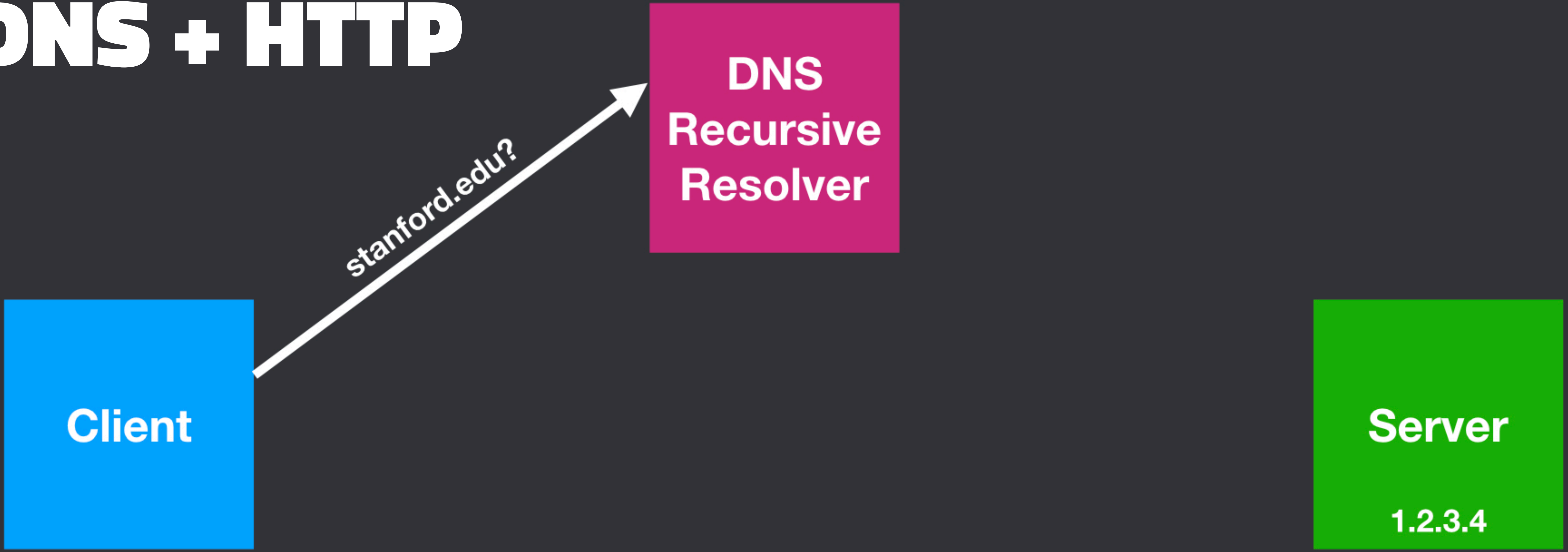
DNS Recursive Resolver

Client

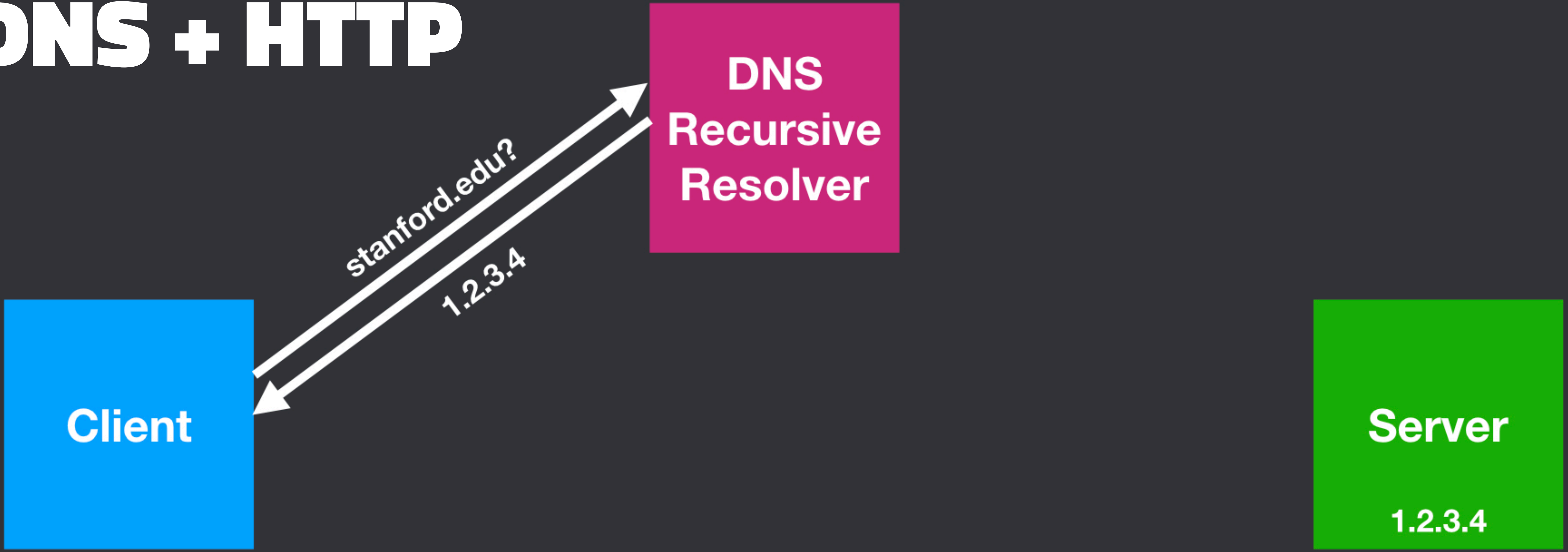
Server

1.2.3.4

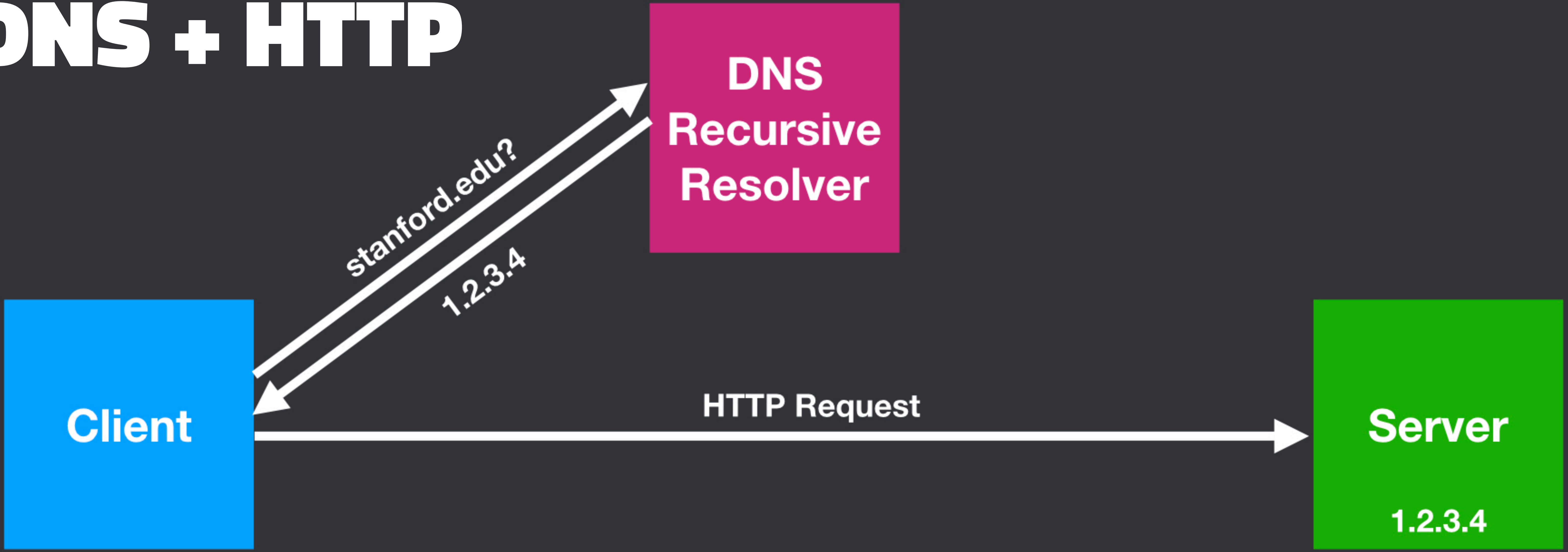
DNS + HTTP



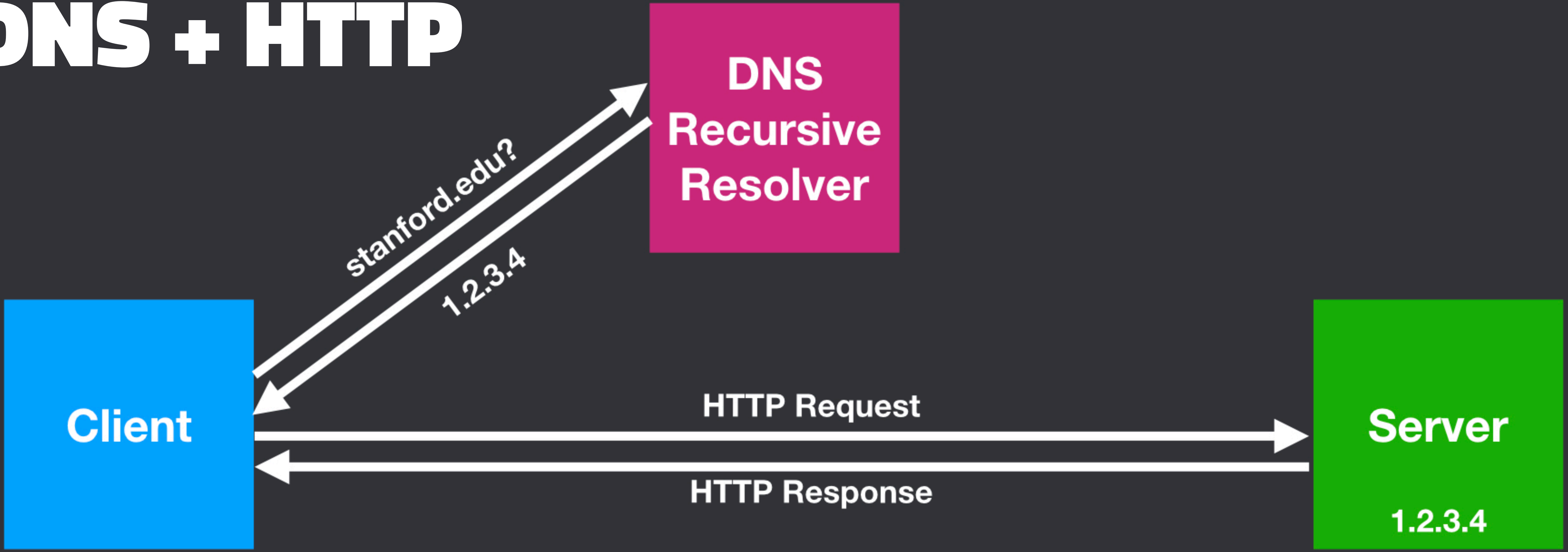
DNS + HTTP


DNS Recursive Resolver
stanford.edu?
1.2.3.4
Client
Server
1.2.3.4

DNS + HTTP


DNS
Recursive
Resolver
stanford.edu?
1.2.3.4
Client
HTTP Request
Server
1.2.3.4

DNS + HTTP

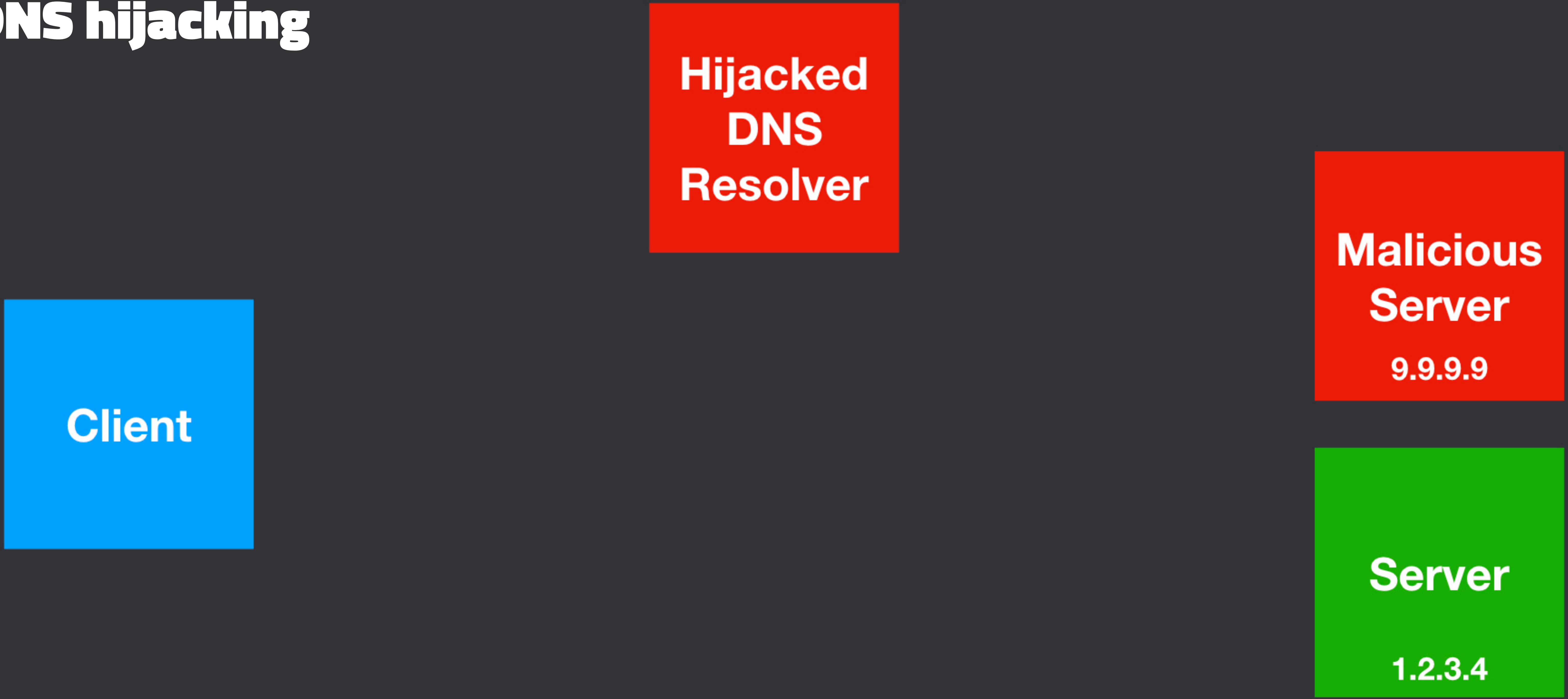

DNS
Recursive
Resolver
stanford.edu?
1.2.3.4
Client
HTTP Request
HTTP Response
Server
1.2.3.4

Attacks on DNS

DNS hijacking

- Attacker changes target DNS record to point to attacker IP address
  - Causes all site visitors to be directed to attacker's web server
- Motivation
  - Phishing
  - Revenue through ads, cryptocurrency mining, etc.
- How do they do it?

DNS hijacking



Hijacked DNS Resolver

Malicious Server

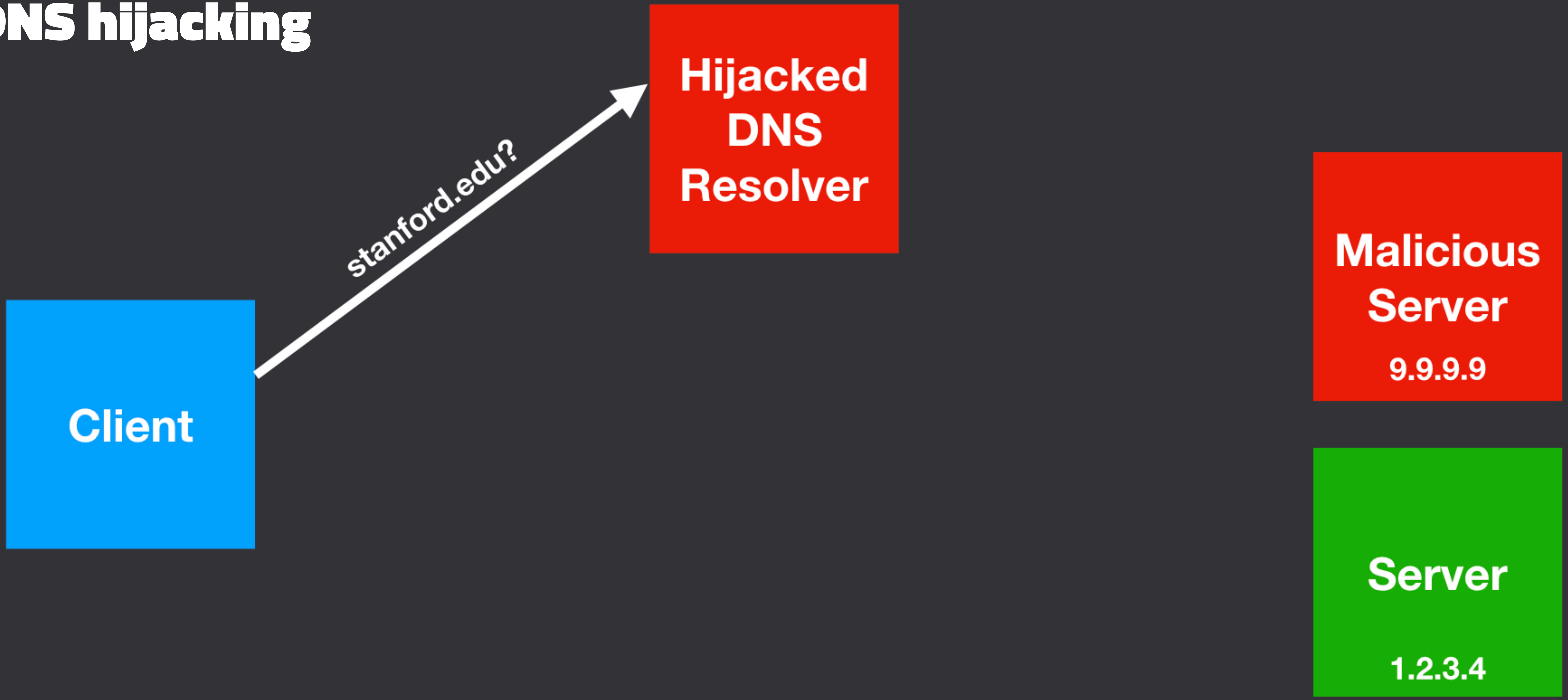
9.9.9.9

Client

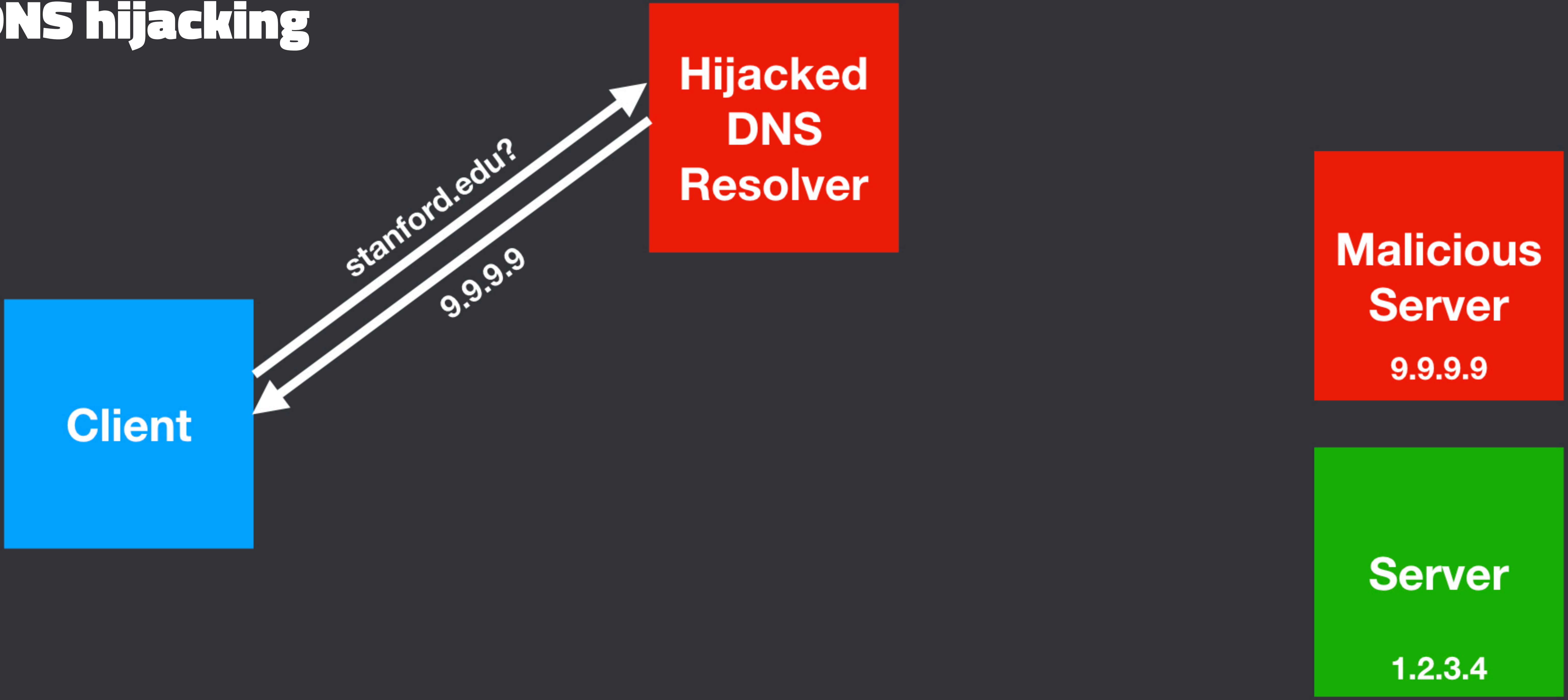
Server

1.2.3.4

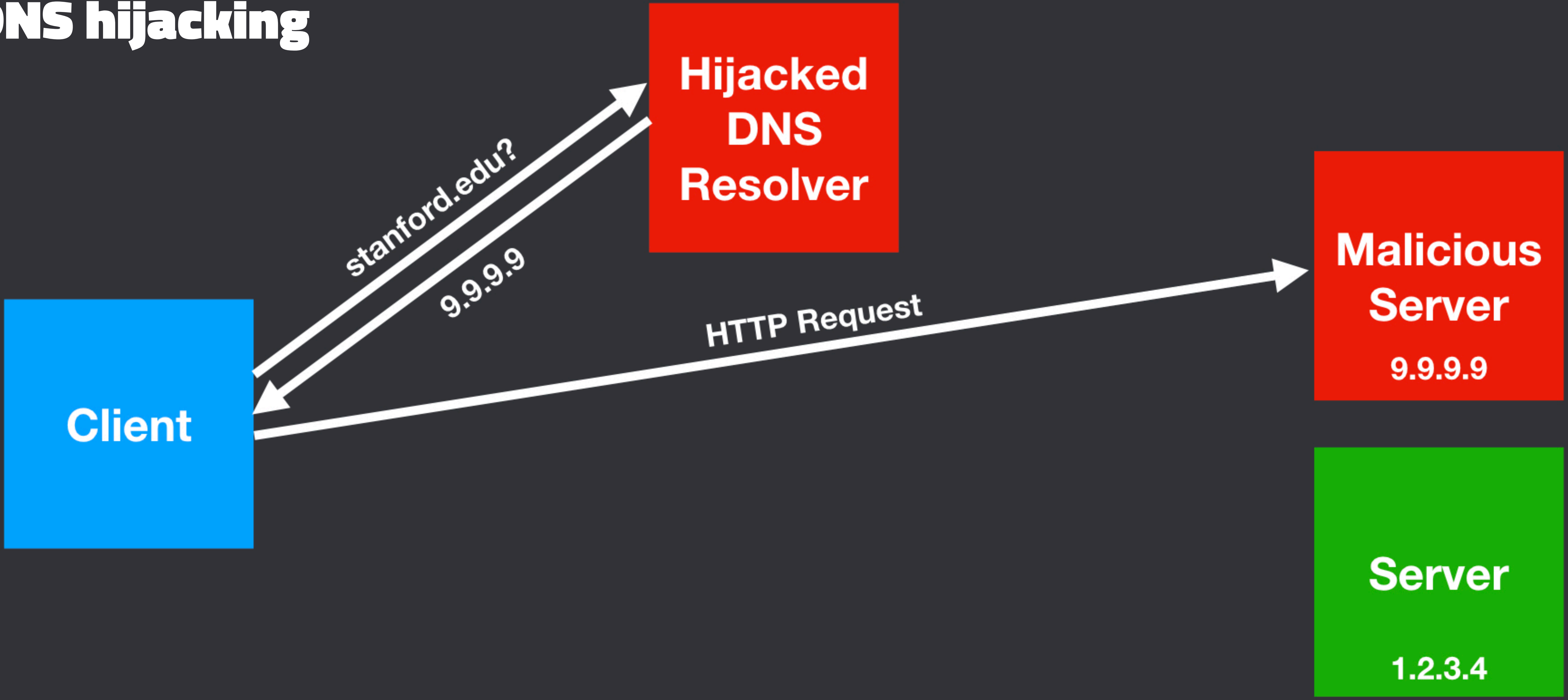
DNS hijacking



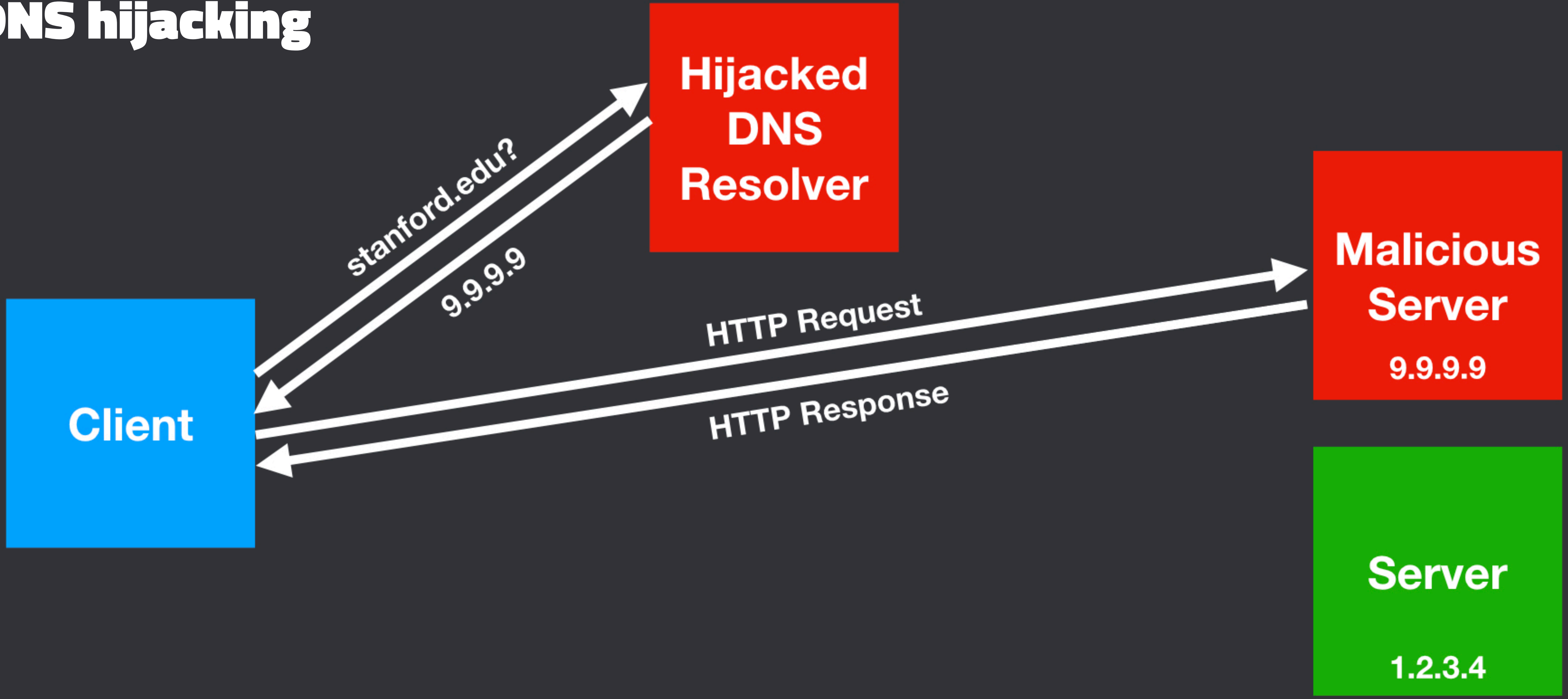
DNS hijacking



DNS hijacking

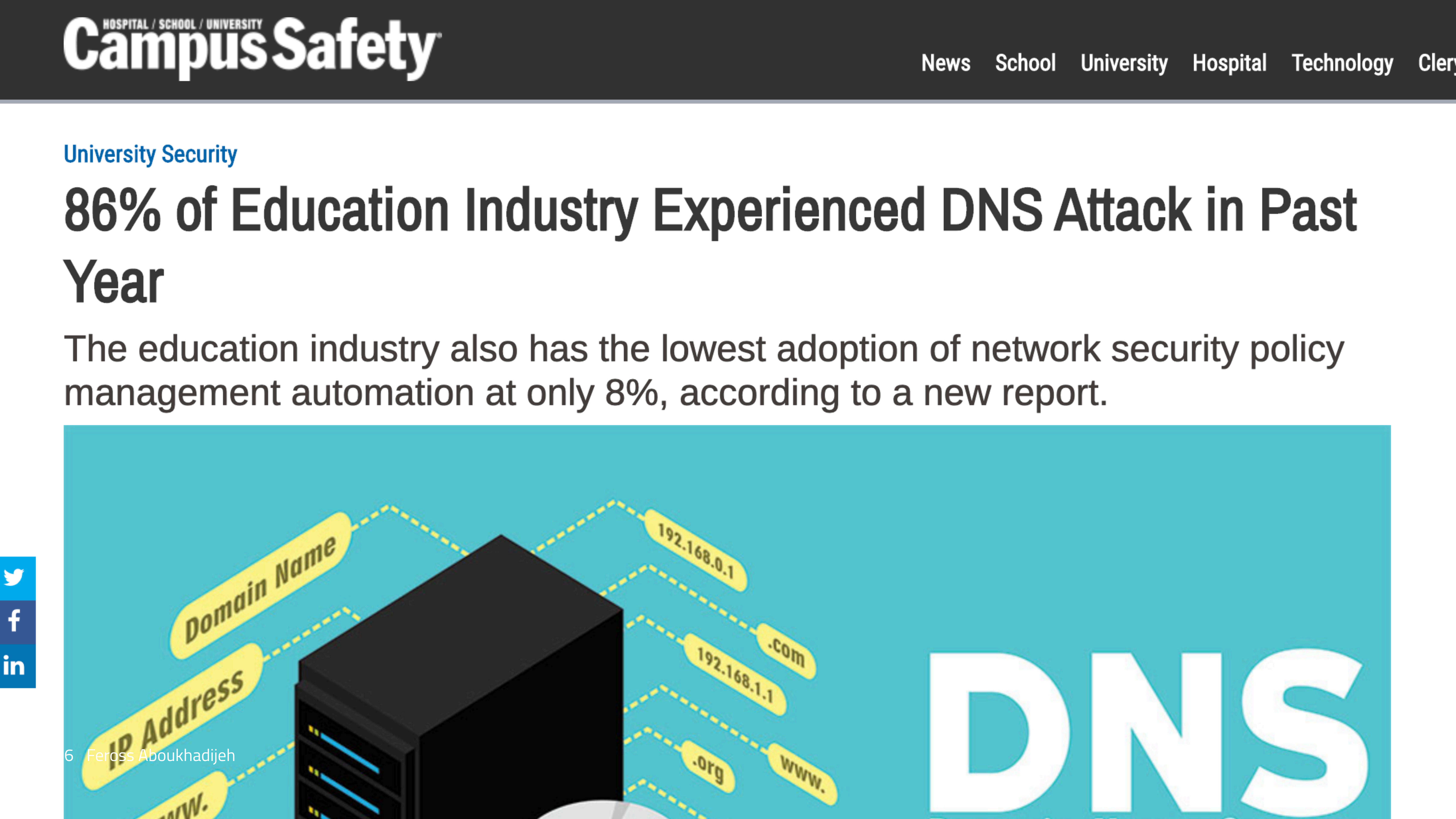


DNS hijacking



DNS hijacking vectors

- Hijacked recursive DNS resolver (shown previously)
- Hijacked DNS nameserver
- Compromised user account at DNS provider
- Malware changes user's local DNS settings
- Hijacked router

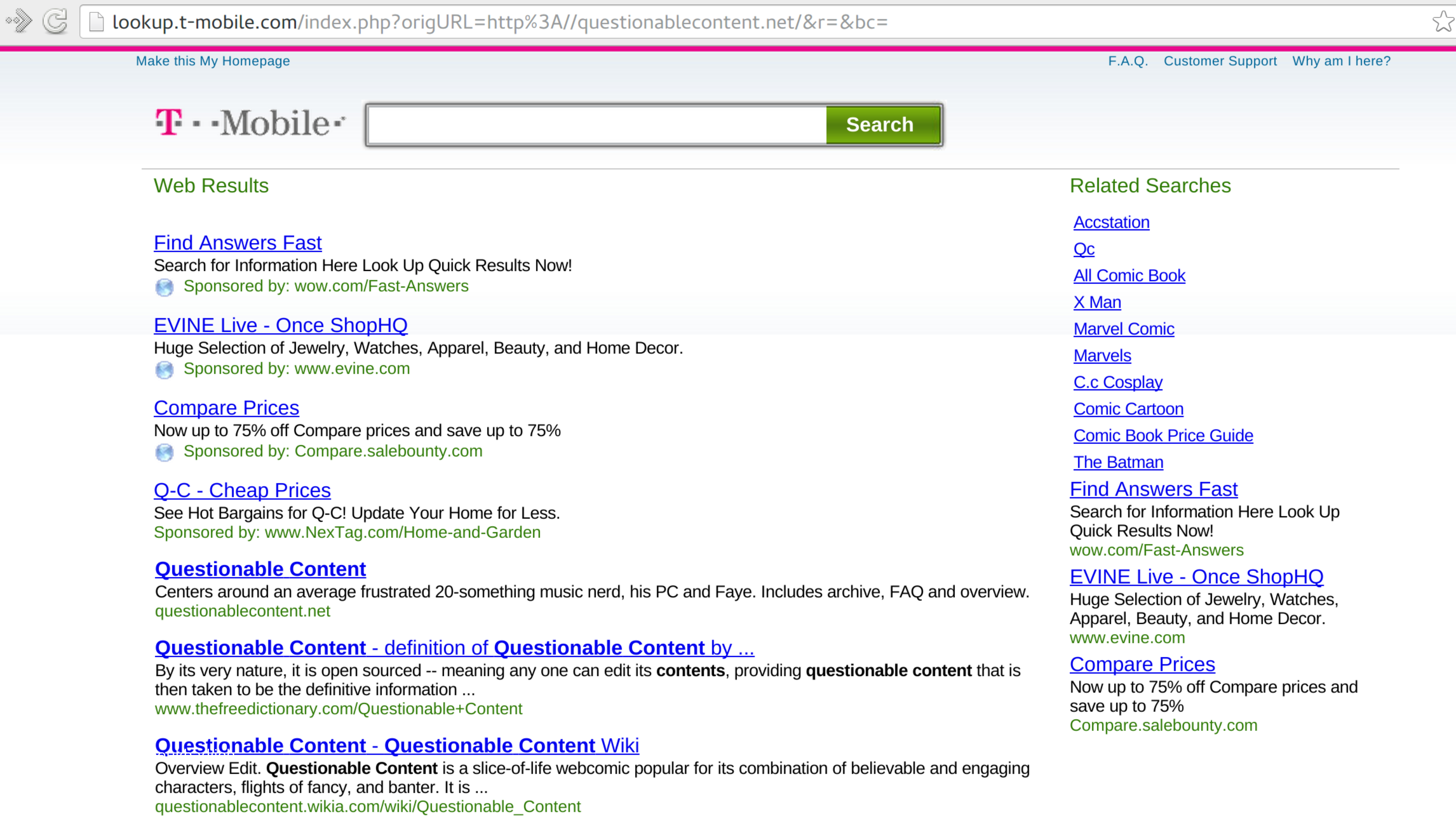


HOSPITAL / SCHOOL / UNIVERSITY Campus Safety

University Security

86% of Education Industry Experienced DNS Attack in Past Year

The education industry also has the lowest adoption of network security policy management automation at only 8%, according to a new report.



lookup.t-mobile.com/index.php?origURL=http%3A//questionablecontent.net/&r=&bc=

Make this My Homepage

F.A.Q. Customer Support Why am I here?

Web Results

[Find Answers Fast](#)

Search for Information Here Look Up Quick Results Now!

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[EVINE Live - Once ShopHQ](#)

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[Compare Prices](#)

Now up to 75% off Compare prices and save up to 75%

Sponsored by: Compare.salebounty.com

[Q-C - Cheap Prices](#)

See Hot Bargains for Q-C! Update Your Home for Less.

Sponsored by: www.NexTag.com/Home-and-Garden

Questionable Content

Centers around an average frustrated 20-something music nerd, his PC and Faye. Includes archive, FAQ and overview.

questionablecontent.net

Questionable Content - definition of **Questionable Content** by ...

By its very nature, it is open sourced -- meaning any one can edit its **contents**, providing **questionable content** that is then taken to be the definitive information ...

www.thefreedictionary.com/Questionable+Content

Questionable Content - **Questionable Content** Wiki

Overview Edit. **Questionable Content** is a slice-of-life webcomic popular for its combination of believable and engaging characters, flights of fancy, and banter. It is ...

questionablecontent.wikia.com/wiki/Questionable_Content

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- X Man
- Marvel Comic
- Marvels
- C.c Cosplay
- Comic Cartoon
- Comic Book Price Guide
- The Batman

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www.evine.com

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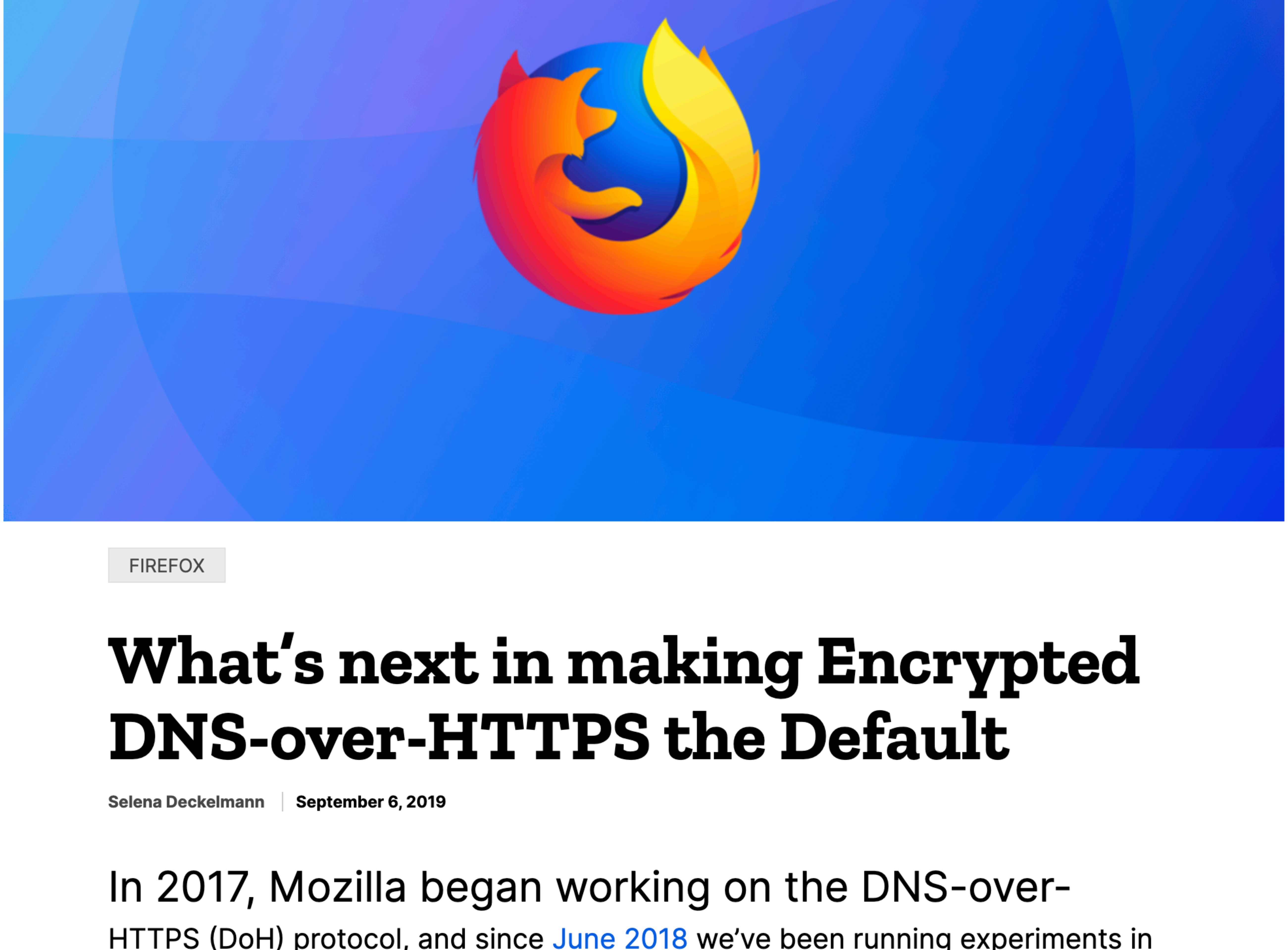
Compare.salebounty.com

DNS privacy

- Queries are in plaintext
- ISPs have been known to sell this data
- **Pro tip:** Consider switching your DNS settings to `1.1.1.1` or another provider with a good privacy policy



FIREFOX

What's next in making Encrypted DNS-over-HTTPS the Default

Selena Deckelmann | September 6, 2019

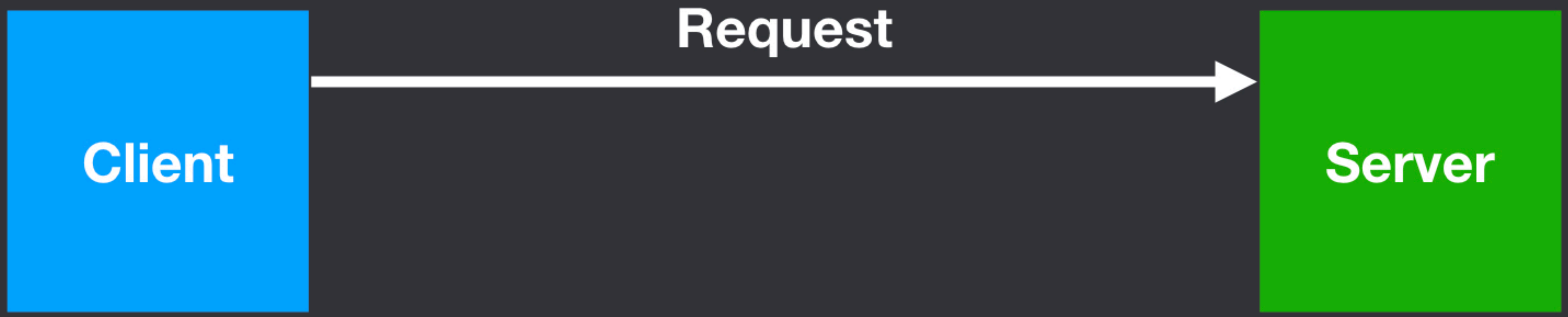
In 2017, Mozilla began working on the DNS-over-HTTPS (DoH) protocol, and since June 2018 we've been running experiments in

What happens when you type a URL and press enter?

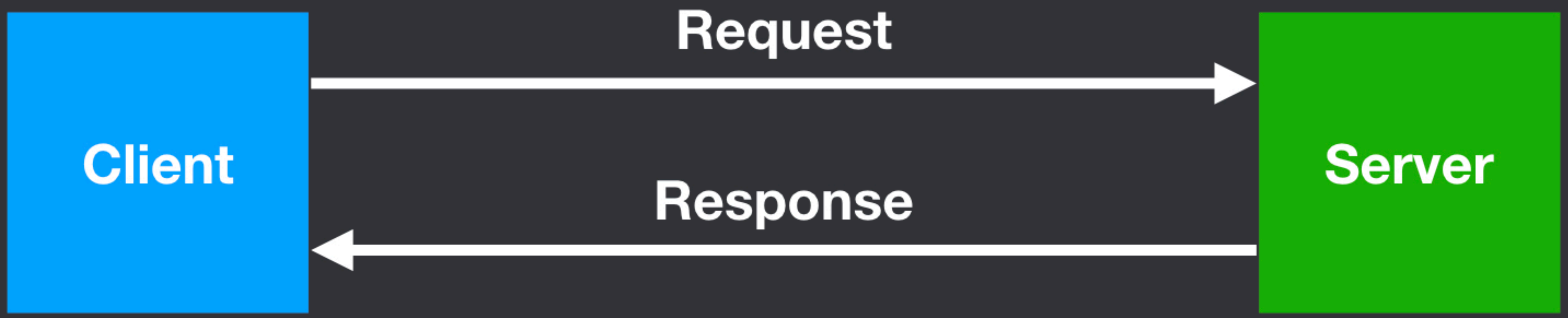
HTTP

Client
Server

HTTP



HTTP



Demo: Make an HTTP request

Demo: Make an HTTP request

```
curl https://twitter.com

curl https://twitter.com > twitter.html
open twitter.html
```

HTTP request

```
GET / HTTP/1.1
Host: twitter.com
User-Agent: Mozilla/5.0 ...
```

```
GET / HTTP/1.1
```

Method

Path

Protocol Version

HTTP response

```
HTTP/1.1 200 OK
Content-Length: 9001
Content-Type: text/html; charset=UTF-8
Date: Tue, 24 Sep 2019 20:30:00 GMT

<!DOCTYPE html ...
```

```
HTTP/1.1 200 OK
```

Protocol Version

Status Code

Status Message

HTTP

- **Client-server model** - Client asks server for resource, server replies
- **Simple** - Human-readable text protocol
- **Extensible** - Just add HTTP headers
- **Transport protocol agnostic** - Only requirement is reliability
- **Stateless** - Two requests have no relation to each other

HTTP is stateless?

- Obviously, we interact with "stateful" servers all the time
- "Stateless" means the HTTP protocol itself does not store state
- If state is desired, is implemented as a layer on top of HTTP

HTTP Status Codes

- **1xx** - Informational ("Hold on")
- **2xx** - Success ("Here you go")
- **3xx** - Redirection ("Go away")
- **4xx** - Client error ("You messed up")
- **5xx** - Server error ("I messed up")

HTTP Success Codes

- **200 OK** - Request succeeded
- **206 Partial Content** - Request for specific byte range succeeded

Range Request

```
GET /video.mp4 HTTP/1.1
Range: bytes=1000-1499
```

Response

```
HTTP/1.1 206 Partial Content
Content-Range: bytes 1000-1499/1000000
```

HTTP Redirection Codes

- **301 Moved Permanently** - Resource has a new permanent URL
- **302 Found** - Resource temporarily resides at a different URL
- **304 Not Modified** - Resource has not been modified since last cached

HTTP Client Error Codes

- **400 Bad Request** - Malformed request
- **401 Unauthorized** - Resource is protected, need to authorize
- **403 Forbidden** - Resource is protected, denying access
- **404 Not Found** - Ya'll know this one

HTTP Server Error Codes

- **500 Internal Server Error** - Generic server error
- **502 Bad Gateway** - Server is a proxy; backend server is unreachable
- **503 Service Unavailable** - Server is overloaded or down for maintenance
- **504 Gateway Timeout** - Server is a proxy; backend server responded too slowly

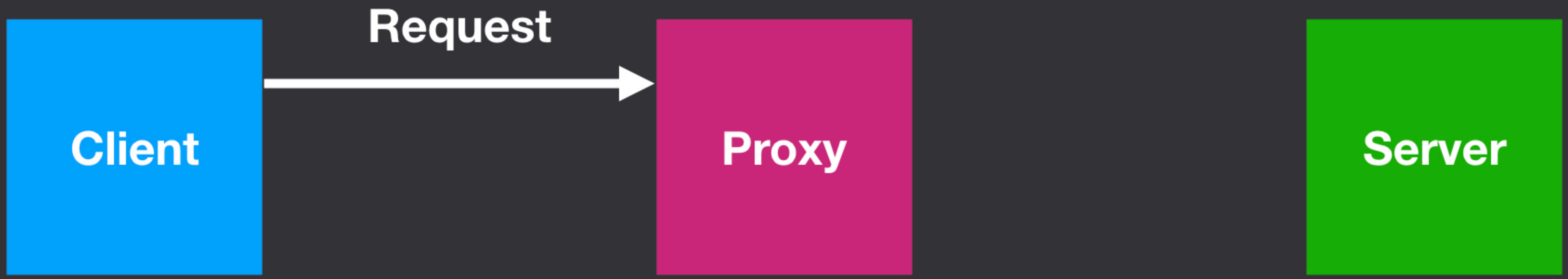
HTTP with a proxy server

Client

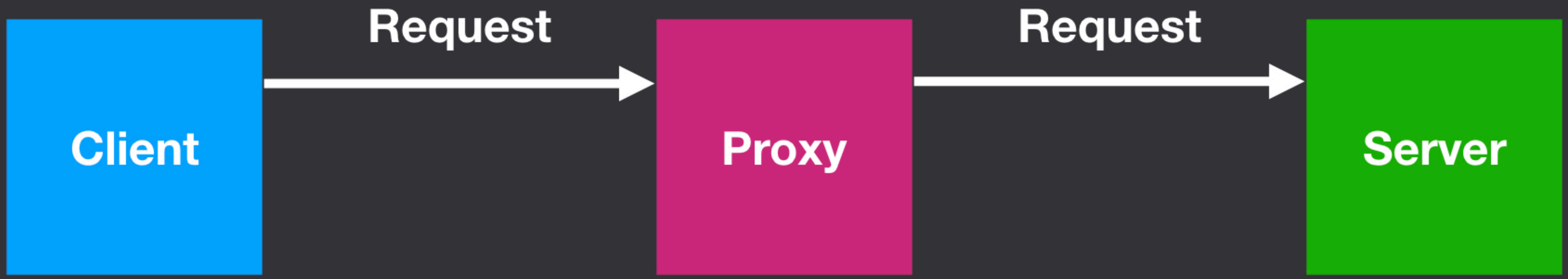
Proxy

Server

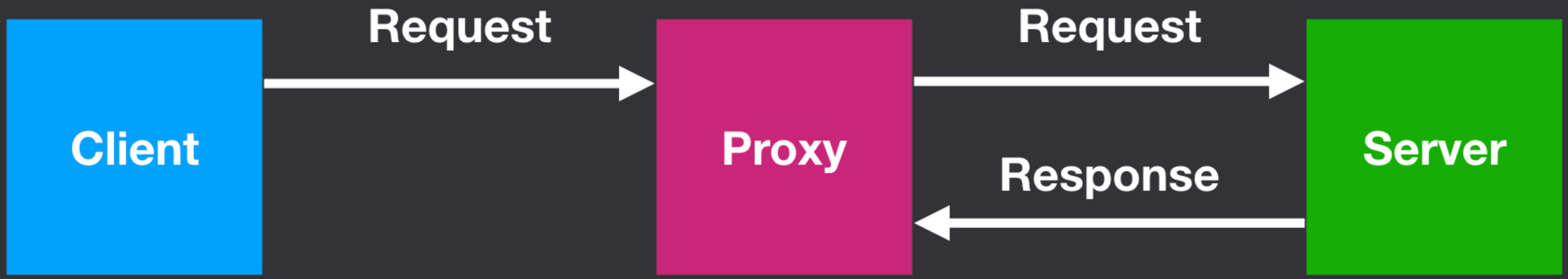
HTTP with a proxy server



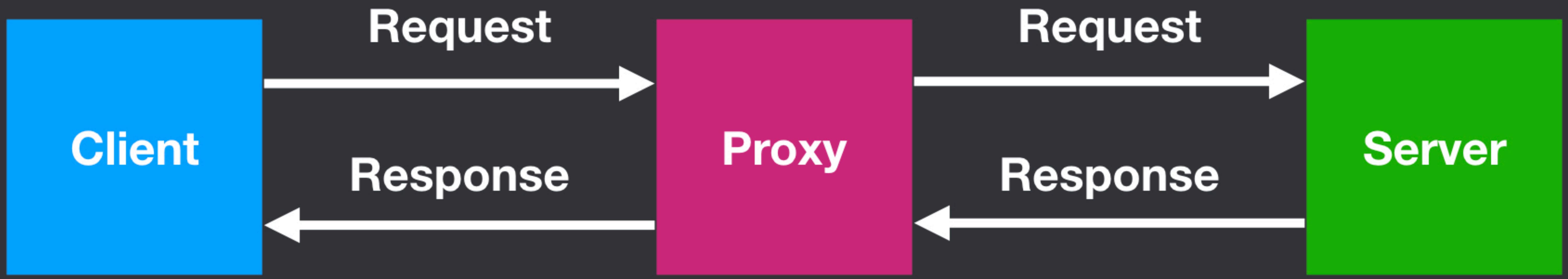
HTTP with a proxy server



HTTP with a proxy server



HTTP with a proxy server



HTTP proxy servers

- Can cache content
- Can block content (e.g. malware, adult content)
- Can modify content
- Can sit in front of many servers ("reverse proxy")

HTTP request

```
GET / HTTP/1.1
Host: example.com
User-Agent: Mozilla/5.0 ...
```

```
Host: example.com
```

Header Name

Header Value

HTTP headers

- Let the client and the server pass additional information with an HTTP request or response
- Essentially a map of key-value pairs
- Allow experimental extensions to HTTP without requiring protocol changes

Useful HTTP request headers

- `Host` - The domain name of the server (e.g. `example.com`)
- `User-Agent` - The name of your browser and operating system
- `Referer` - The webpage which led you to this page (misspelled)
- `Cookie` - The cookie server gave you earlier; keeps you logged in
- `Range` - Specifies a subset of bytes to fetch

Useful HTTP request headers (pt 2)

- **`Cache-Control`** - Specifies if you want a cached response or not
- **`If-Modified-Since`** - Only send resource if it changed recently
- **`Connection`** - Control TCP socket (e.g. **`keep-alive`** or **`close`**)
- **`Accept`** - Which type of content we want (e.g. **`text/html`**)
- **`Accept-Encoding`** - Encoding algorithms we understand (e.g. **`gzip`**)
- **`Accept-Language`** - What language we want (e.g. **`es`**)

Demo: Make an HTTP request with headers

Demo: Make an HTTP request with headers

```
curl https://twitter.com --header "Accept-Language: es" --silent | grep JavaScript

curl https://twitter.com --header "Accept-Language: ar" --silent | grep JavaScript
```

Demo: User-Agent Examples

HTTP response

```
HTTP/1.1 200 OK
Content-Length: 9001
Content-Type: text/html; charset=UTF-8
Date: Tue, 24 Sep 2019 20:30:00 GMT

<!DOCTYPE html ...
```

Useful HTTP response headers

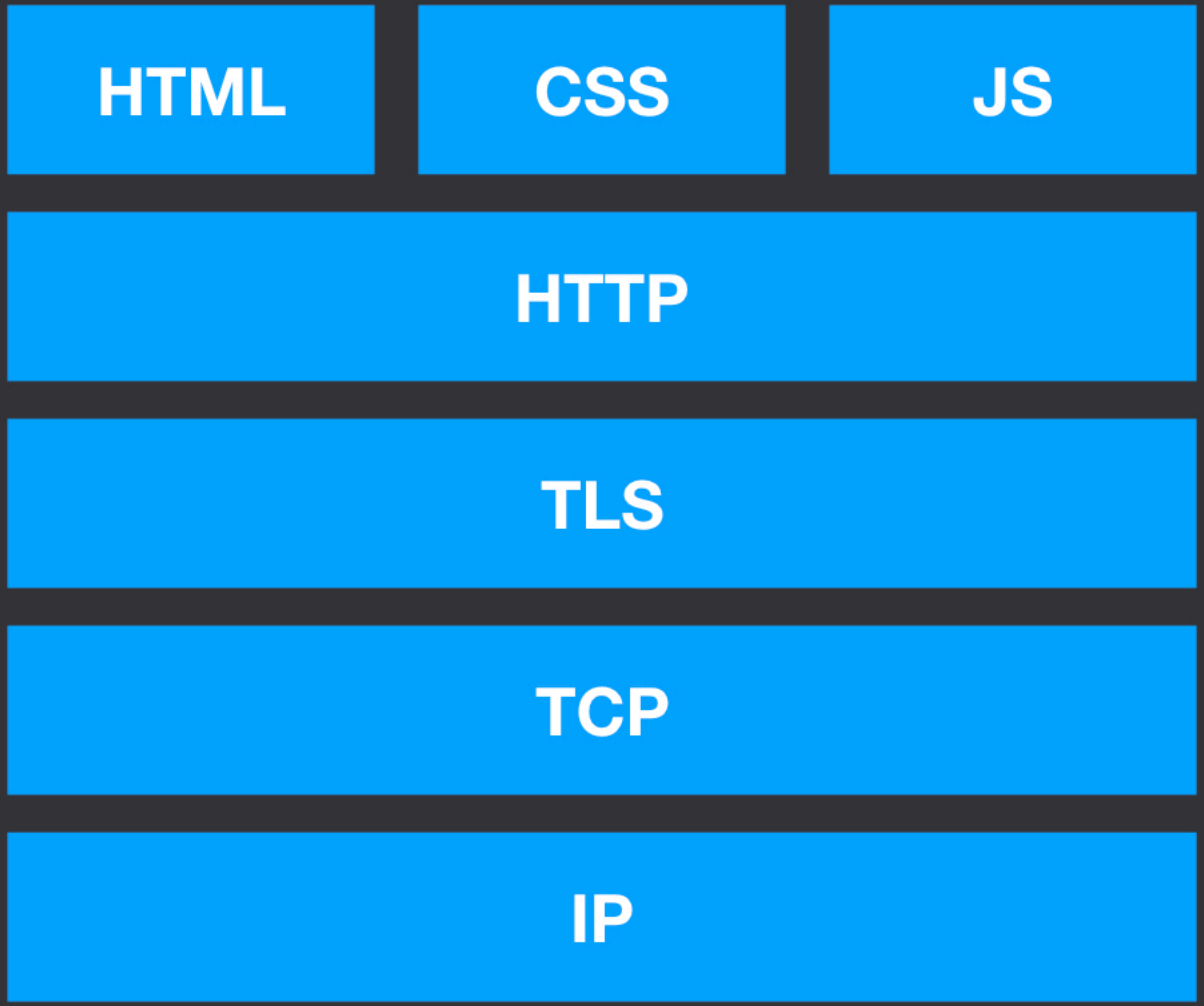
- **`Date`** - When response was sent
- **`Last-Modified`** - When content was last modified
- **`Cache-Control`** - Specifies whether to cache response or not
- **`Expires`** - Discard response from cache after this date
- **`Set-Cookie`** - Set a cookie on the client
- **`Vary`** - List of headers which affect response; used by cache

Vary on user language

```
HTTP/1.1 200 OK
Cache-Control: public, max-age=31536000
Vary: Accept-Langauge
```

Useful HTTP response headers (pt 2)

- `Location` - URL to redirect the client to (used with 3xx responses)
- `Connection` - Control TCP socket (e.g. `keep-alive` or `close`)
- `Content-Type` - Type of content in response (e.g. `text/html`)
- `Content-Encoding` - Encoding of the response (e.g. `gzip`)
- `Content-Language` - Language of the response (e.g. `ar`)
- `Content-Length` - Length of the response in bytes



HTML

CSS

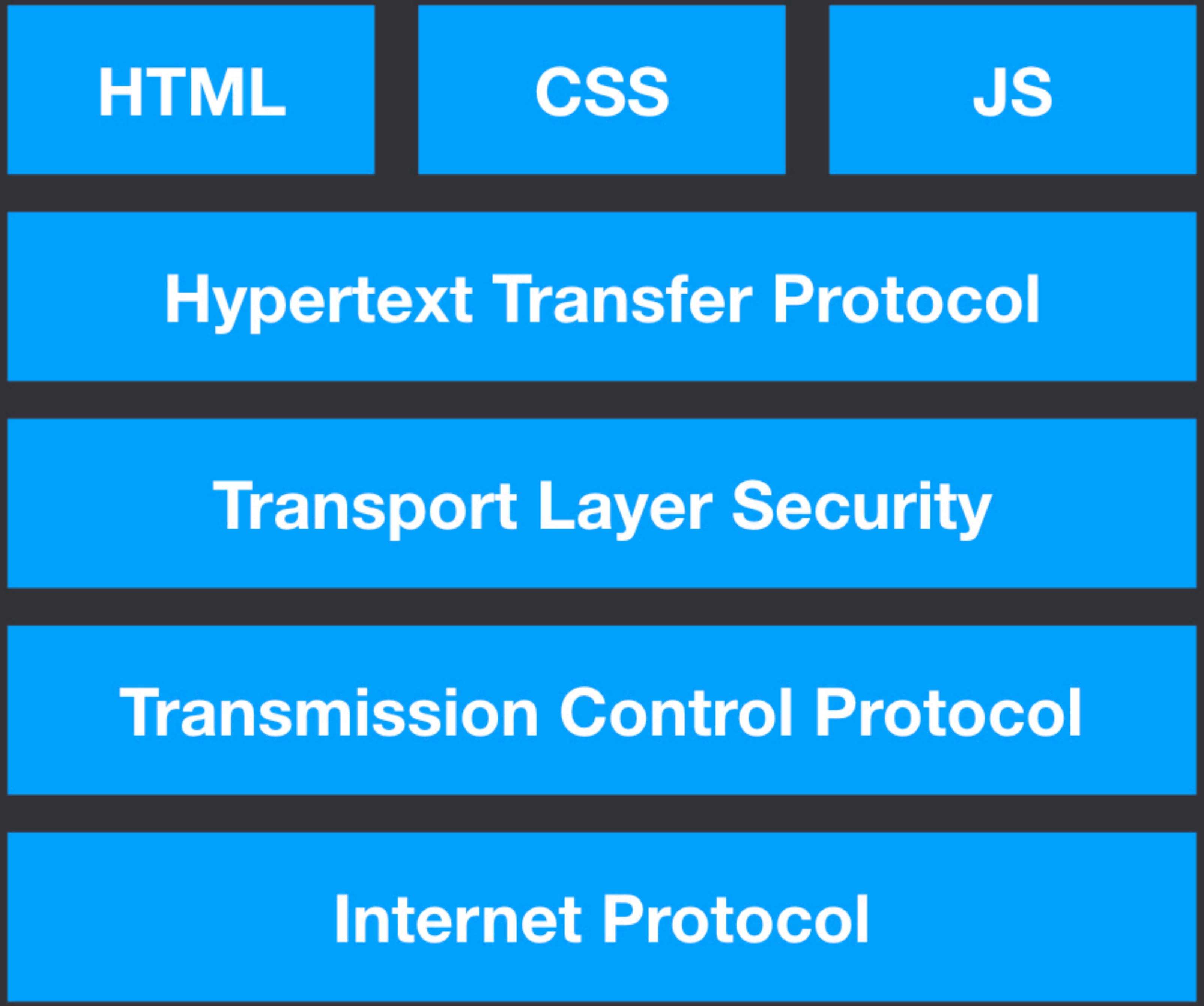
JS

HTTP

TLS

TCP

IP



HTML

CSS

JS

Hypertext Transfer Protocol

Transport Layer Security

Transmission Control Protocol

Internet Protocol

Demo: Implement an HTTP client

- Not magic!
- Steps:
    - Open a TCP socket
    - Send HTTP request text over the socket
    - Read the HTTP response text from the socket

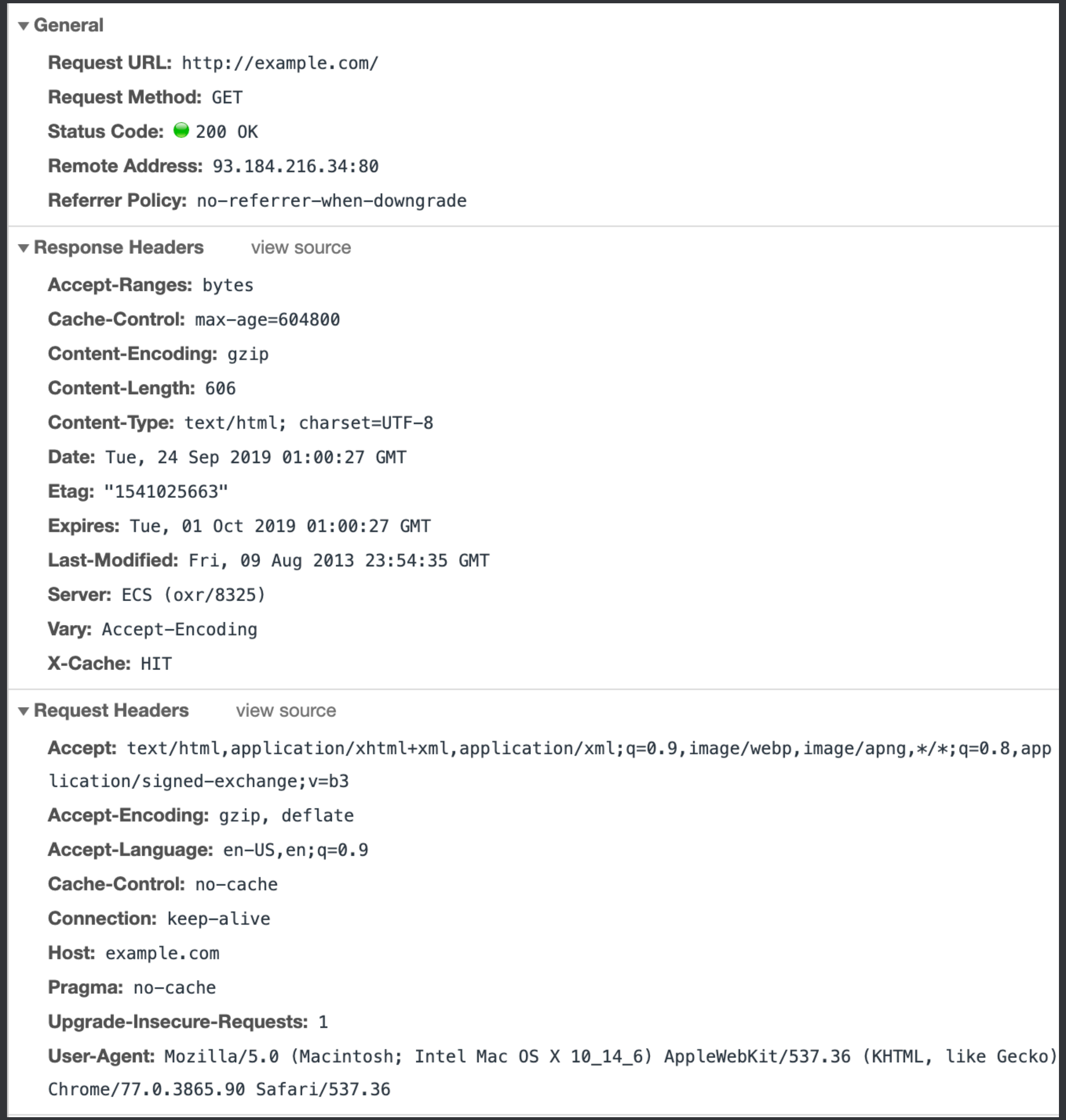
Implement an HTTP client

```
const net = require('net')

const socket = net.createConnection({
  host: 'example.com',
  port: 80
})

const request = `
GET / HTTP/1.1
Host: example.com

`.slice(1)

socket.write(request)
socket.pipe(process.stdout)
```

Implement an HTTP client (take 2)

```
const dns = require('dns')
const net = require('net')

dns.lookup('example.com', (err, address) => {
  if (err) throw err

  const socket = net.createConnection({
    host: address,
    port: 80
  })

  const request = `
GET / HTTP/1.1
Host: example.com

`.slice(1)

  socket.write(request)
  socket.pipe(process.stdout)
})
```

Demo: Chrome DevTools



▾ General

Request URL: `http://example.com/`

Request Method: `GET`

Status Code: ● `200 OK`

Remote Address: `93.184.216.34:80`

Referrer Policy: `no-referrer-when-downgrade`

▾ Response Headers

Accept-Ranges: `bytes`

Cache-Control: `max-age=604800`

Content-Encoding: `gzip`

Content-Length: `606`

Content-Type: `text/html; charset=UTF-8`

Date: `Tue, 24 Sep 2019 01:00:27 GMT`

Etag: `"1541025663"`

Expires: `Tue, 01 Oct 2019 01:00:27 GMT`

Last-Modified: `Fri, 09 Aug 2013 23:54:35 GMT`

Server: `ECS (oxr/8325)`

Vary: `Accept-Encoding`

X-Cache: `HIT`

▾ Request Headers

Accept: `text/html,application/xhtml+xml,application/xml;q=0.9,image/webp,image/apng,*/*;q=0.8,application/signed-exchange;v=b3`

Accept-Encoding: `gzip, deflate`

Accept-Language: `en-US,en;q=0.9`

Cache-Control: `no-cache`

Connection: `keep-alive`

Host: `example.com`

Pragma: `no-cache`

Upgrade-Insecure-Requests: `1`

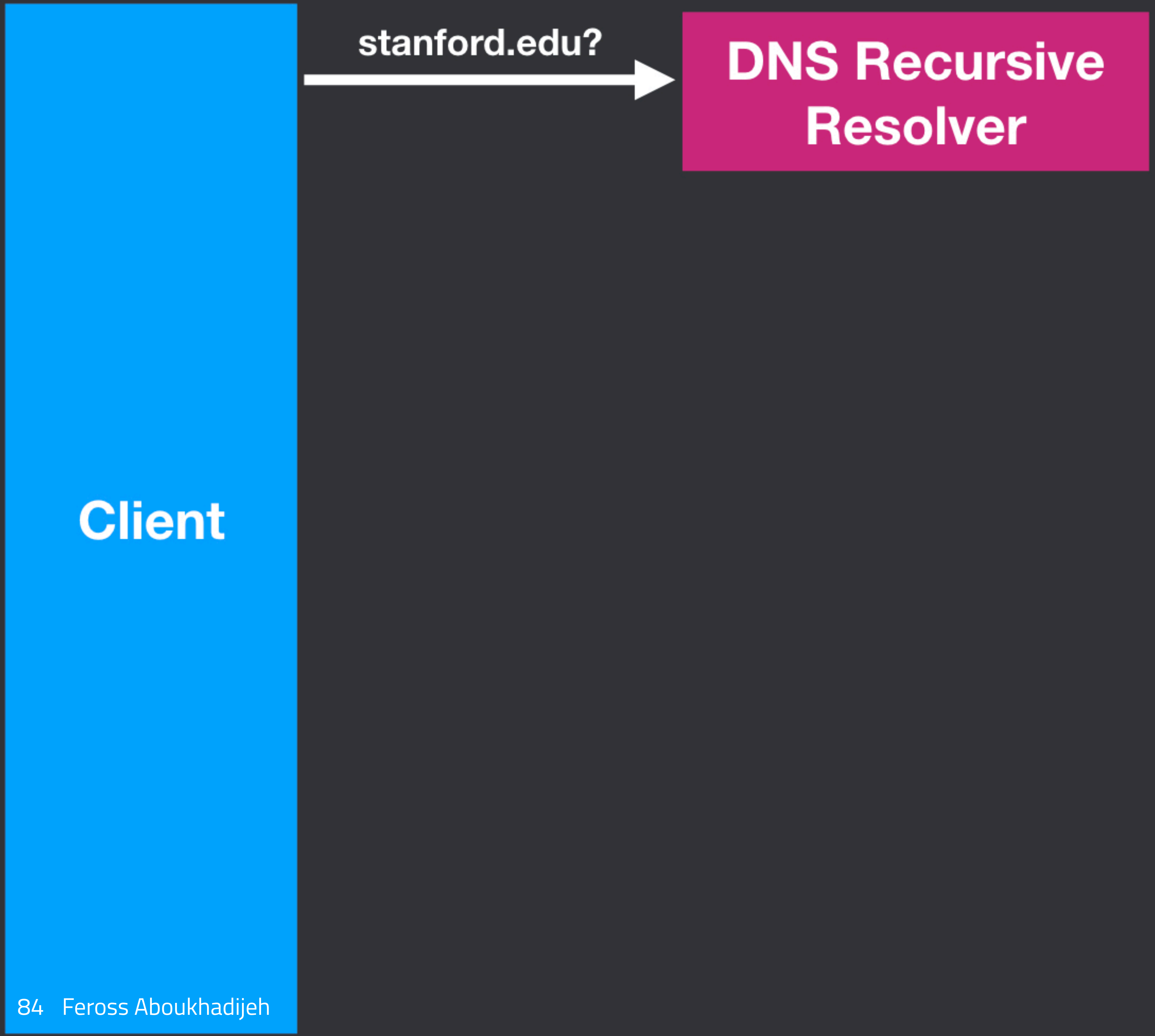
User-Agent: `Mozilla/5.0 (Macintosh; Intel Mac OS X 10_14_6) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/77.0.3865.90 Safari/537.36`

What happens when you type a URL and press enter?

1. Perform a **DNS lookup** on the hostname (**`example.com`**) to get an IP address (**`1.2.3.4`**)
2. Open a **TCP socket** to **`1.2.3.4`** on port **`80`** (the HTTP port)
3. Send an **HTTP request** that includes the desired path (**`/`**)
4. Read the **HTTP response** from the socket
5. Parse the HTML into the DOM
6. Render the page based on the DOM
7. Repeat until all external resources are loaded:
   - If there are pending external resources, make HTTP requests for these (run steps 1-4)
   - Render the resources into the page

Client

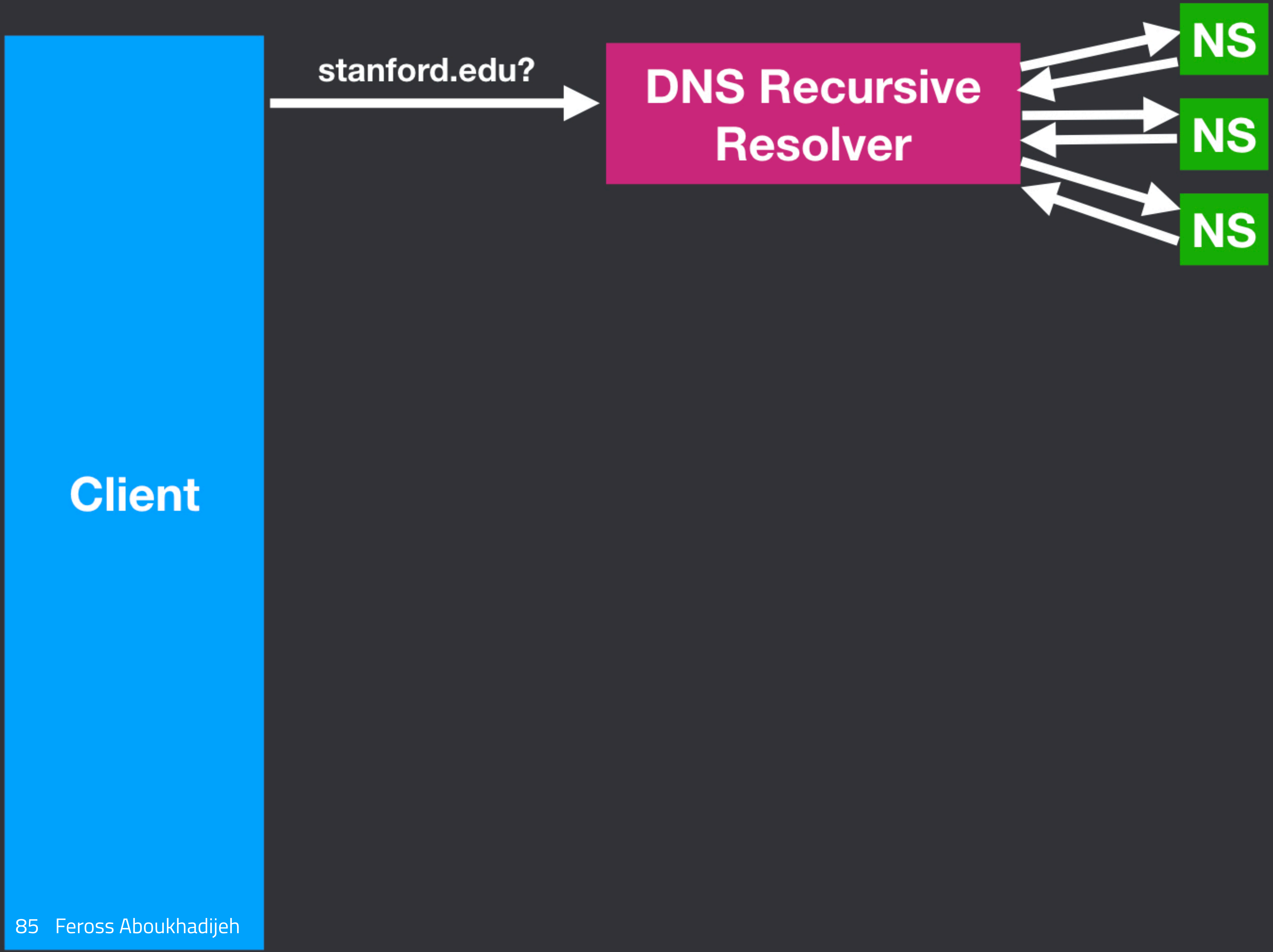
DNS Recursive Resolver

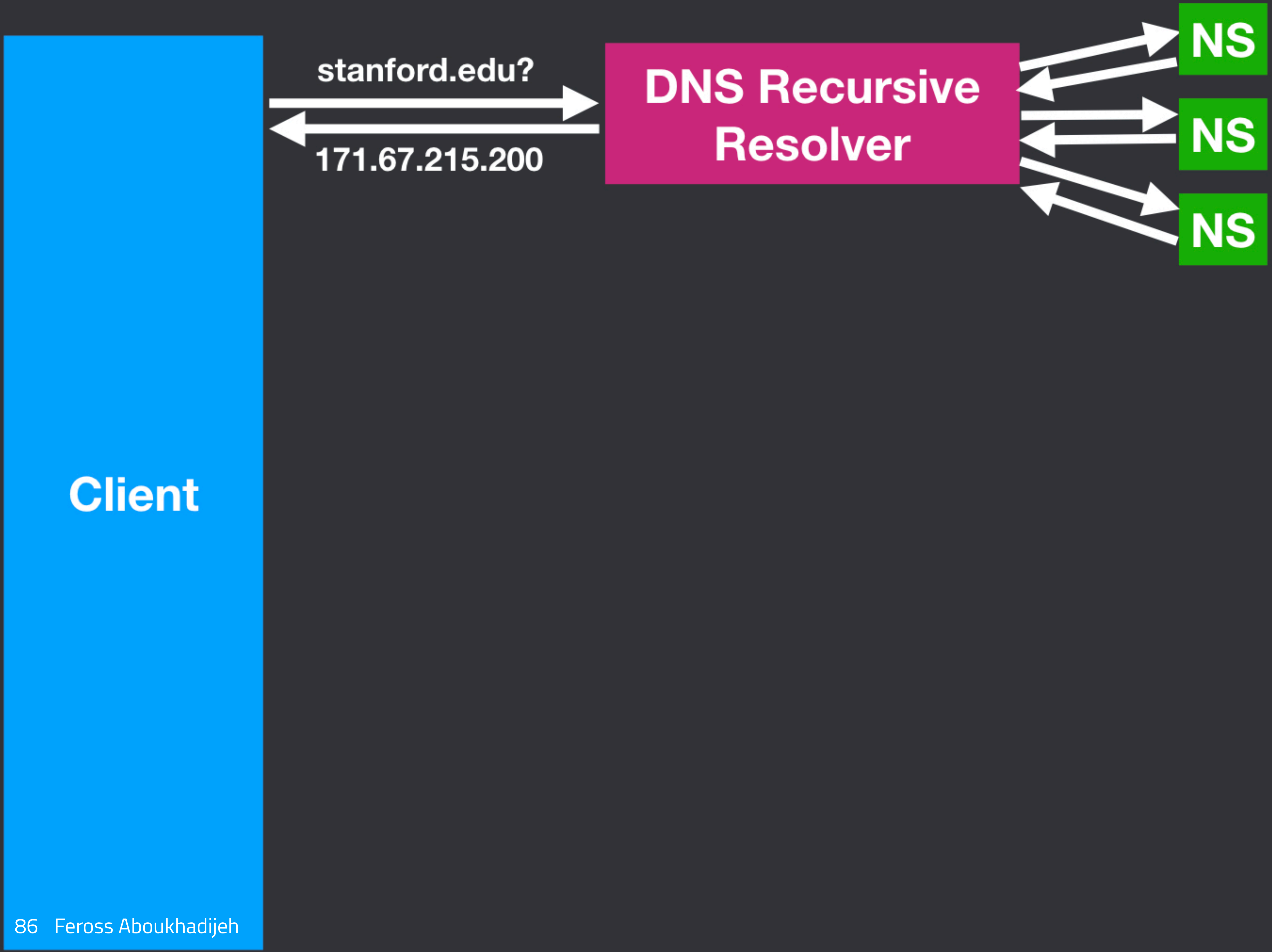


Client

stanford.edu?

DNS Recursive Resolver


stanford.edu?
DNS Recursive Resolver
NS
NS
NS
Client



Client

stanford.edu?

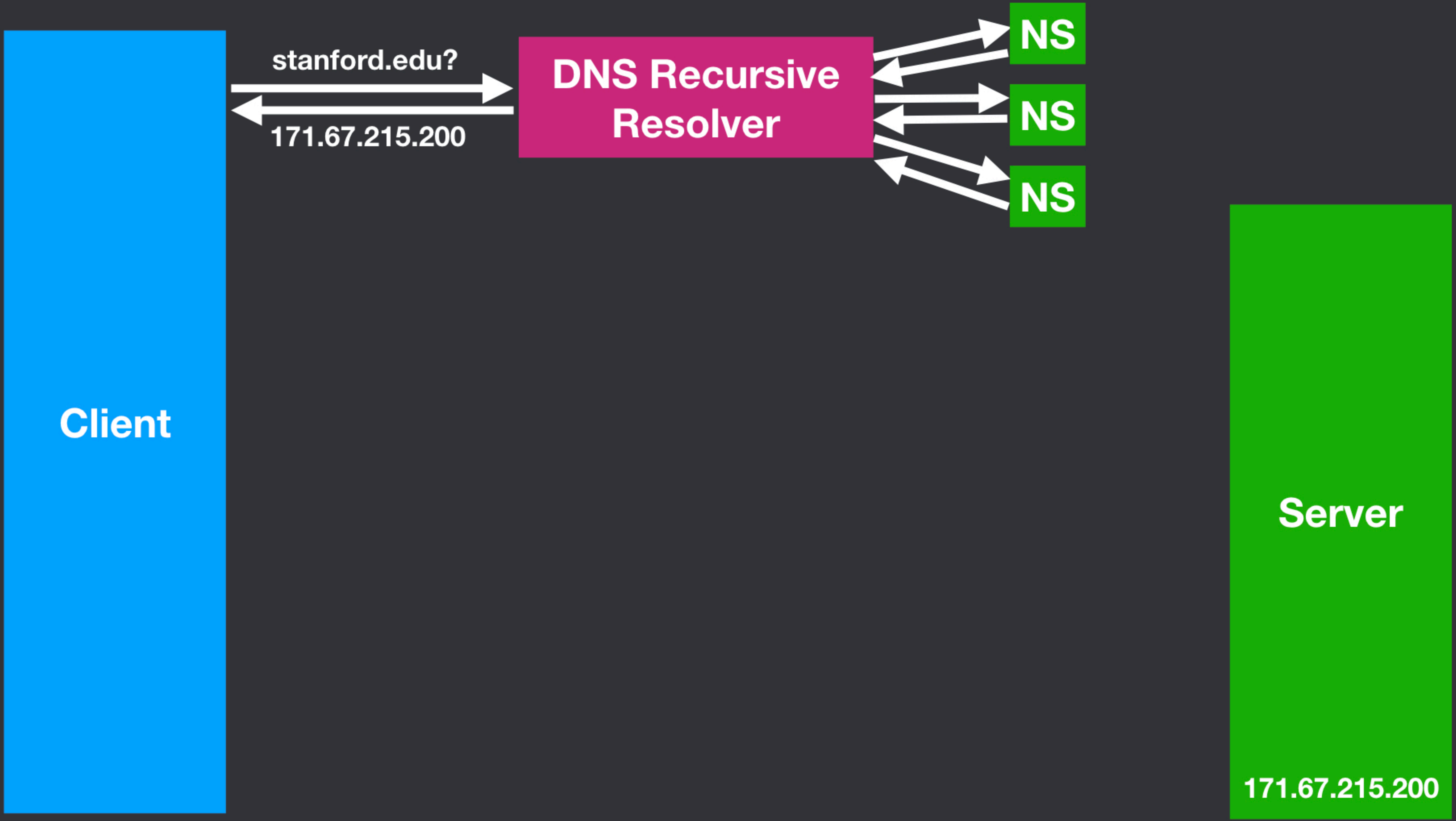
171.67.215.200

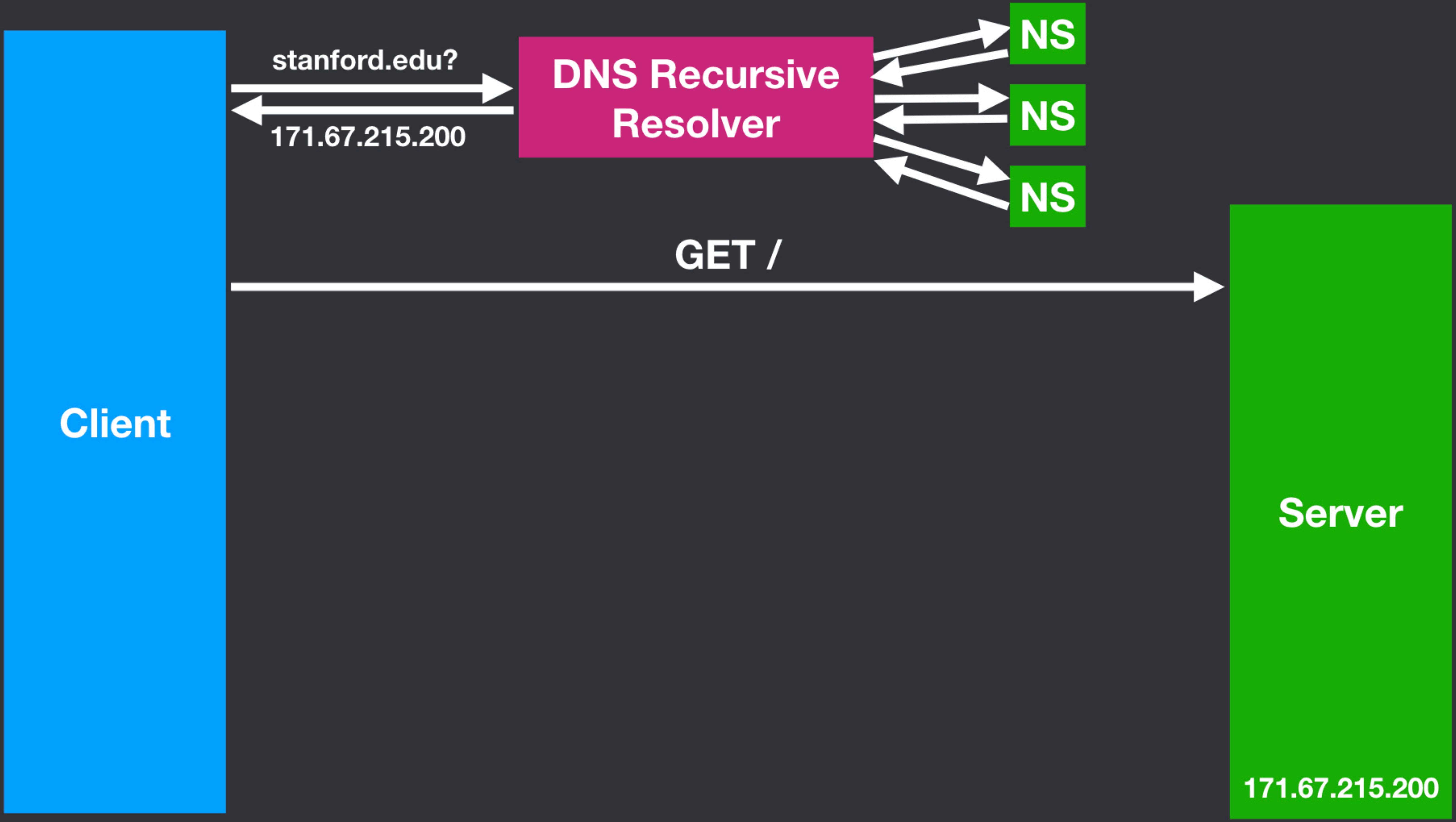
DNS Recursive Resolver

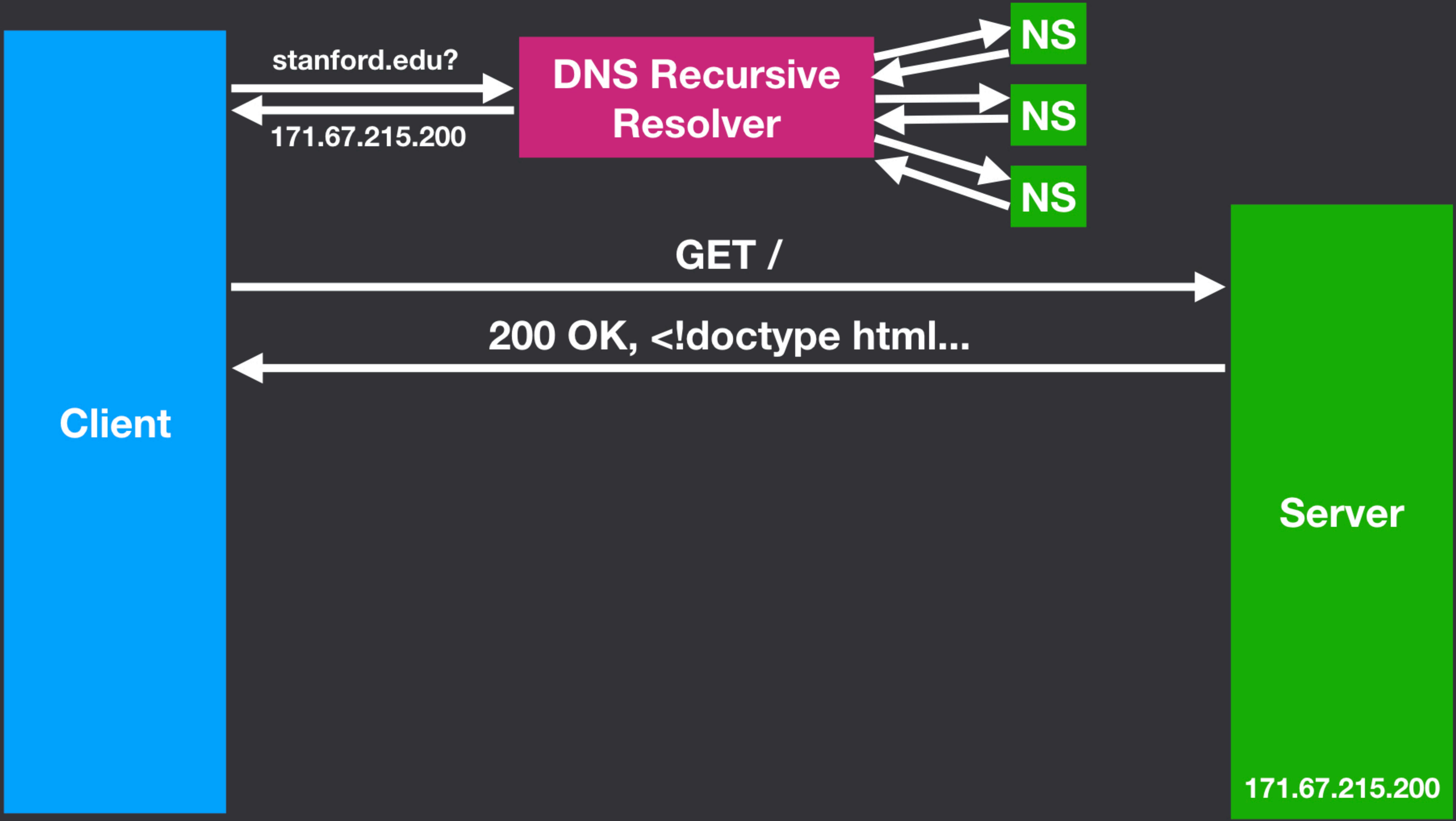
NS

NS

NS


Client
stanford.edu?
171.67.215.200
DNS Recursive Resolver
NS
NS
NS
Server
171.67.215.200


stanford.edu?
171.67.215.200
DNS Recursive Resolver
NS
NS
NS
GET /
Client
Server
171.67.215.200



Client

stanford.edu?

171.67.215.200

DNS Recursive Resolver

NS

NS

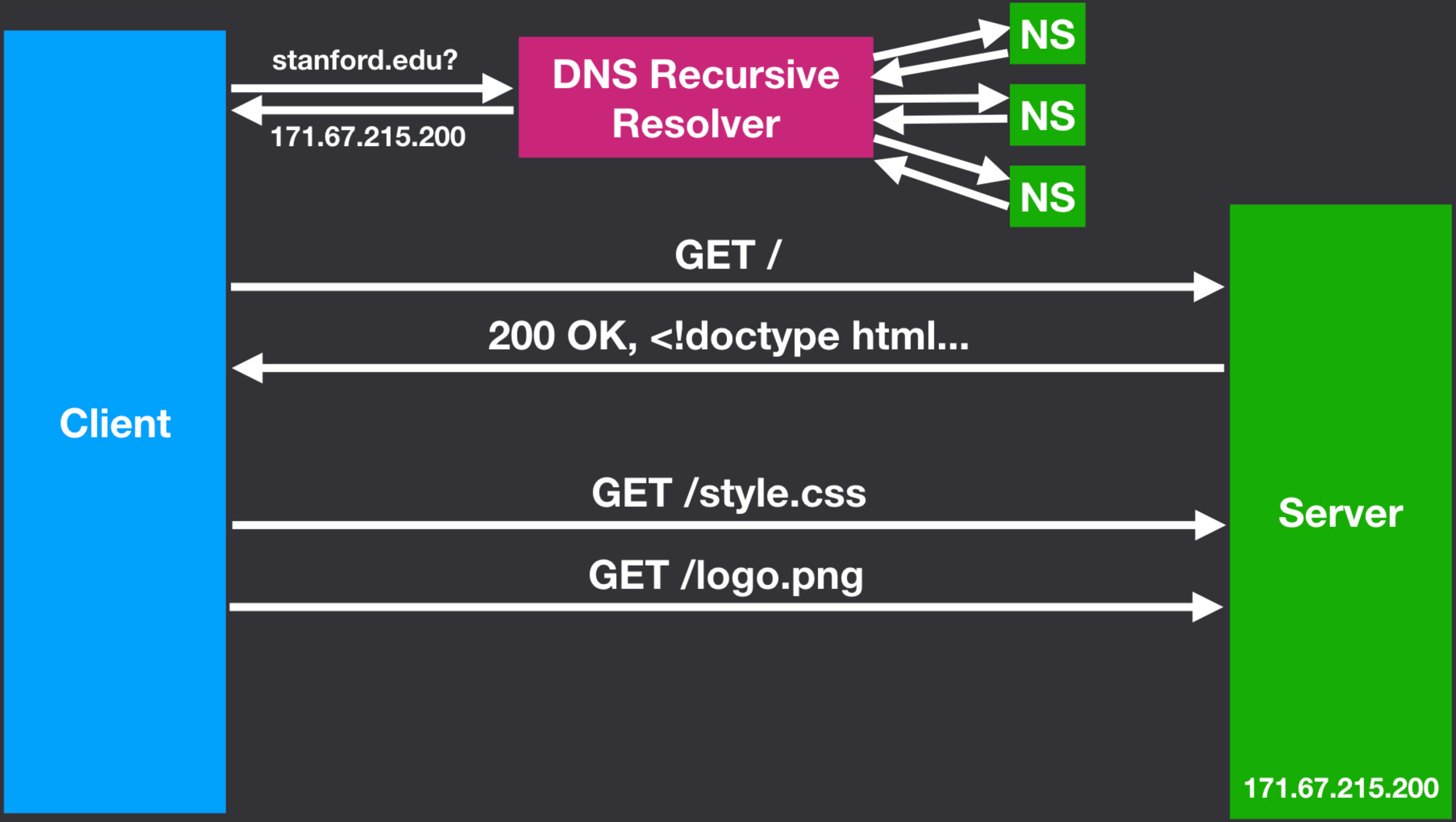
NS

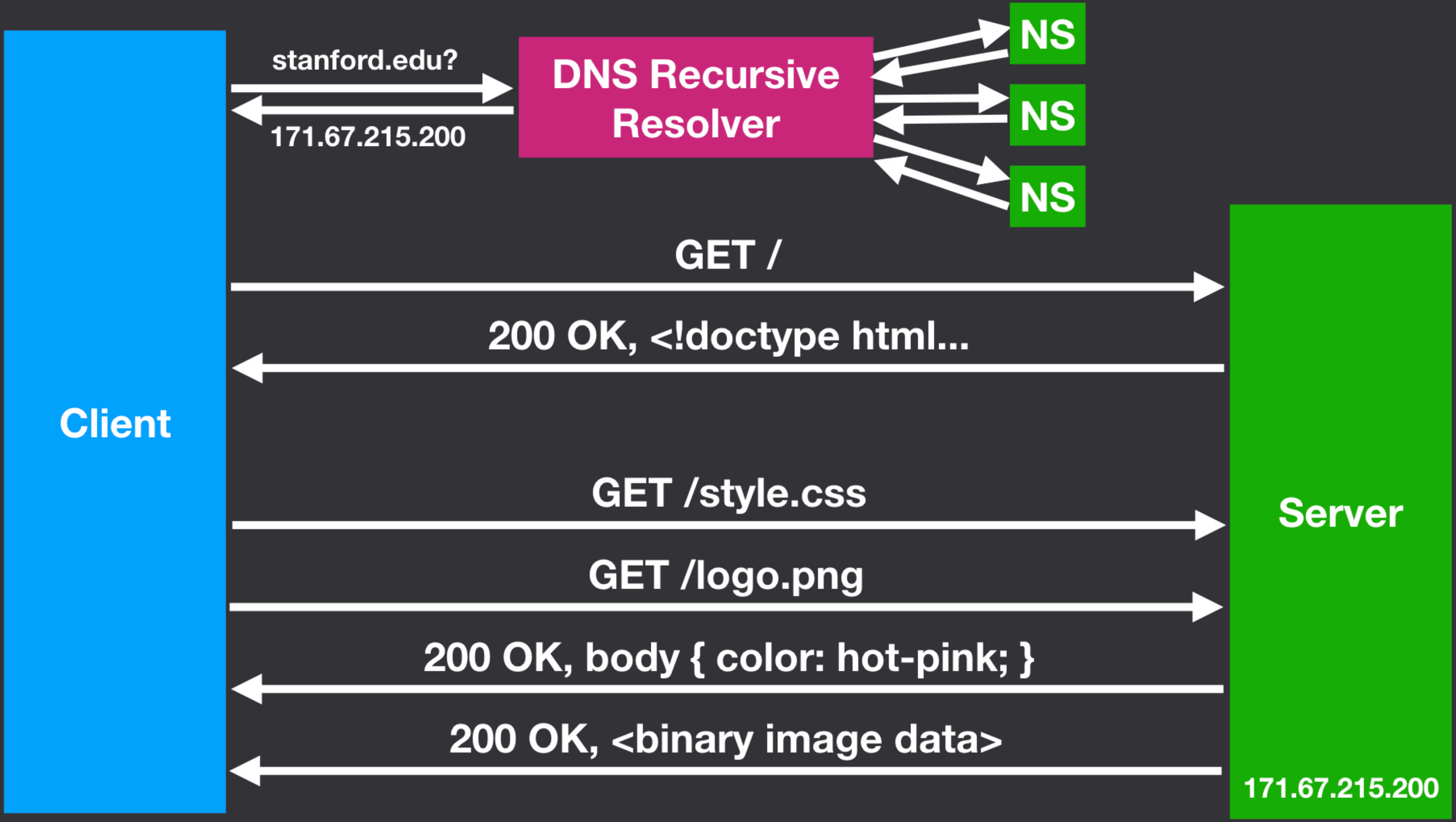
GET /

200 OK, <!doctype html...

Server

171.67.215.200

stanford.edu?
171.67.215.200
DNS Recursive Resolver
NS
NS
NS
Client
GET /
200 OK, <!doctype html...
GET /style.css
GET /logo.png
Server
171.67.215.200


stanford.edu?
171.67.215.200
DNS Recursive Resolver
NS
NS
NS
GET /
200 OK, <!doctype html...
Client
GET /style.css
GET /logo.png
200 OK, body { color: hot-pink; }
200 OK, <binary image data>
Server
171.67.215.200

END