CLOUDFLARE

January 9th
2015

Universal SSL

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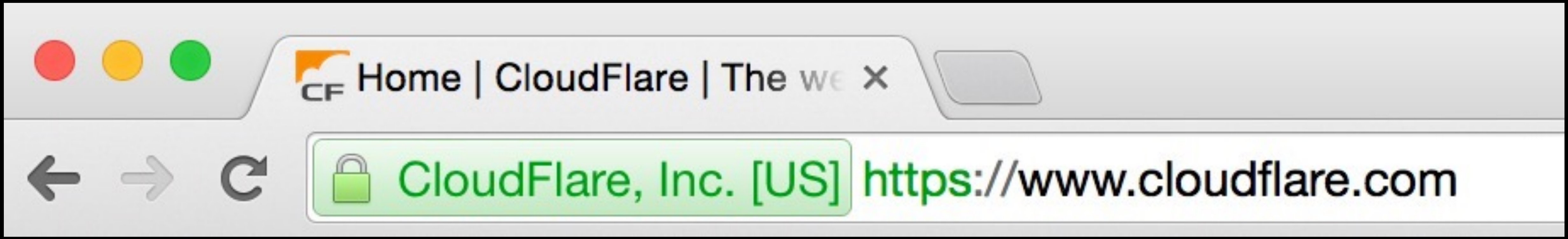
Real Real World Crypto: HTTPS



Home | CloudFlare | The we

CloudFlare, Inc. [US] https://www.cloudflare.com

HTTPS Myths

- Only for banking
- Only for authentication
- Too hard

HTTPS is used for

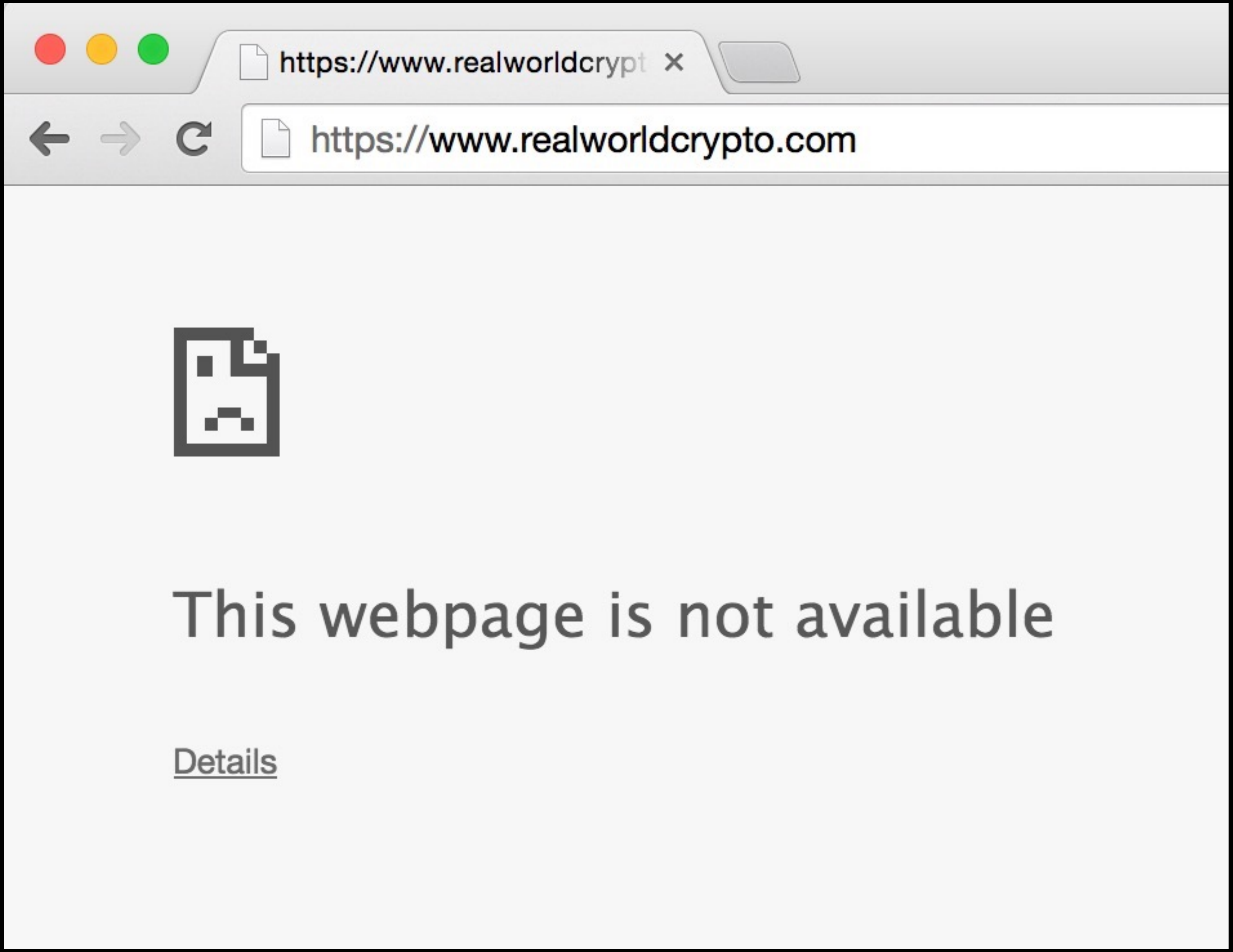
- Visitor privacy
- Invasive intermediaries
- SEO?

First some good news…

realworldcrypto.com

does *not* have any TLS vulnerabilities

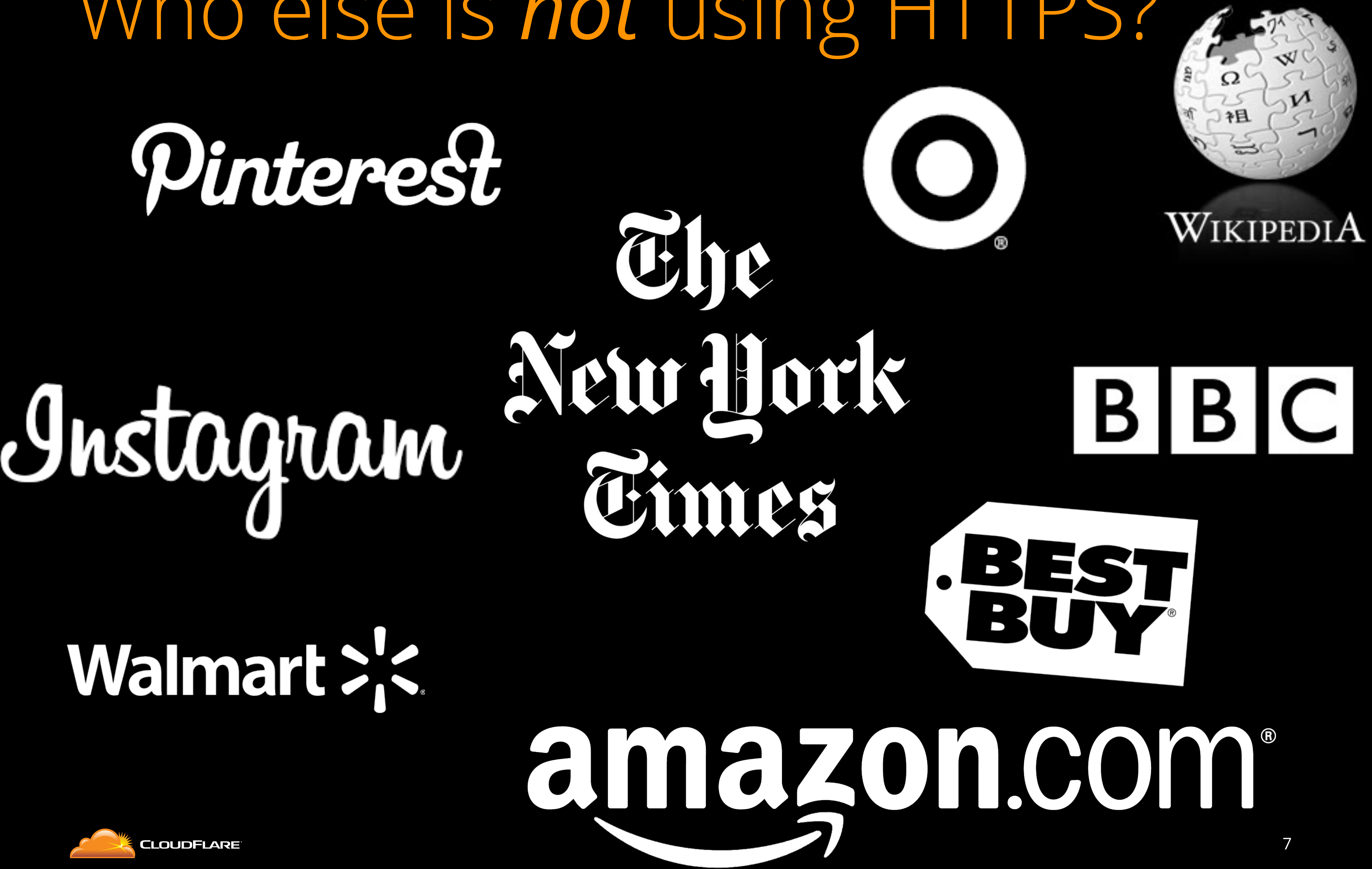
The bad news



This webpage is not available

Details

Who else is ***not*** using HTTPS?



And at the low end...

- Personal sites
- Small businesses
- Shared hosting (Github pages, etc.)

WHY U NO HTTPS?

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Reasons at high end

- Sysadmin time/training
- Business process and risk
- Vendor cost (CDN, Hardware)
- Third party liability
- Mixed content warnings from ads

Reasons at low end

- Certificates cost money
- Hosting provider capabilities
- Setting up HTTPS is complicated
- Fixing vulnerabilities

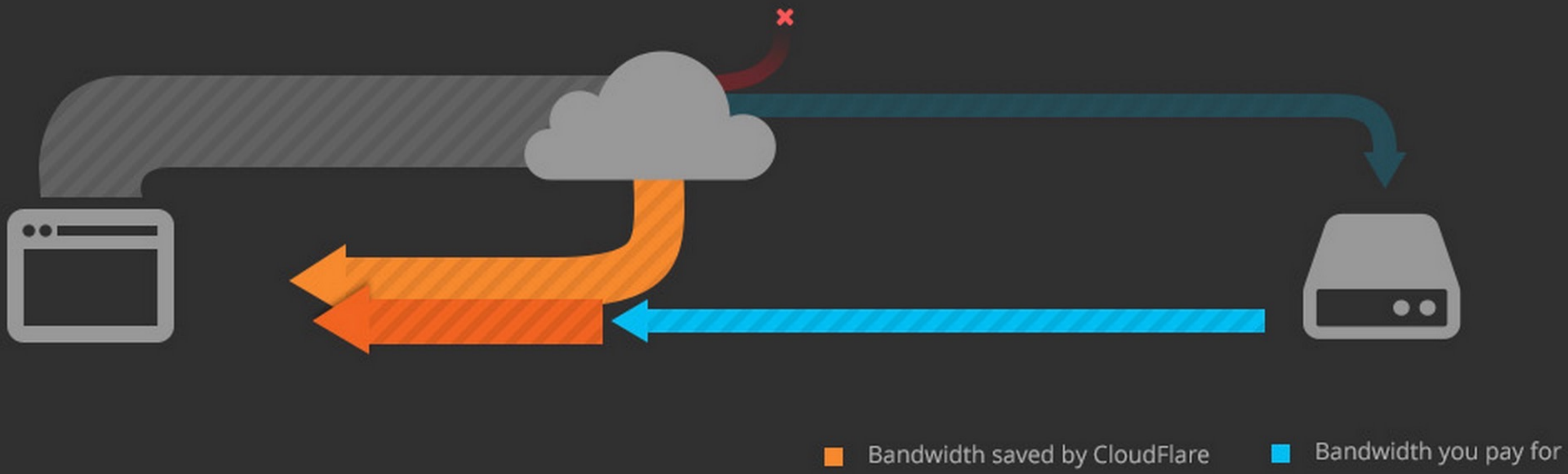
Goal

Get more sites on HTTPS

How?

HTTPS as a service

CloudFlare Reverse Proxy



Potential issues

- Certificate Management
- Scaling
- Performance

Problem

Certificate Management

Solution

Automated Certificate Issuance

How does a CA validate a site?

- Domain validation (DV)
- Organization validation (OV)
- Extended validation (EV)

How does a CA validate a site?

- Domain validation (DV)
    - WHOIS email
    - DNS
    - HTTP

Whois email

```
$ whois realworldcrypto.com
The Registry database contains ONLY .COM, .NET, .EDU domains and
Registrars.
Domain Name: realworldcrypto.com
Registry Domain ID: 1839854081_DOMAIN_COM-VRSN
Registrar WHOIS Server: whois.register.com
Registrar URL: http://www.register.com
Updated Date: 2013-12-20T05:00:00Z
Creation Date: 2013-12-20T16:52:54Z
Registrar Registration Expiration Date: 2023-12-20T05:00:00Z
Registrar: Register.com, LLC.
Registrar IANA ID: 9
Admin Name: Dan Boneh
…
Admin Email: dabo@cs.stanford.edu
```

DNS Validation

- If you control DNS, you control the site
- Add a TXT record to DNS with token from CA

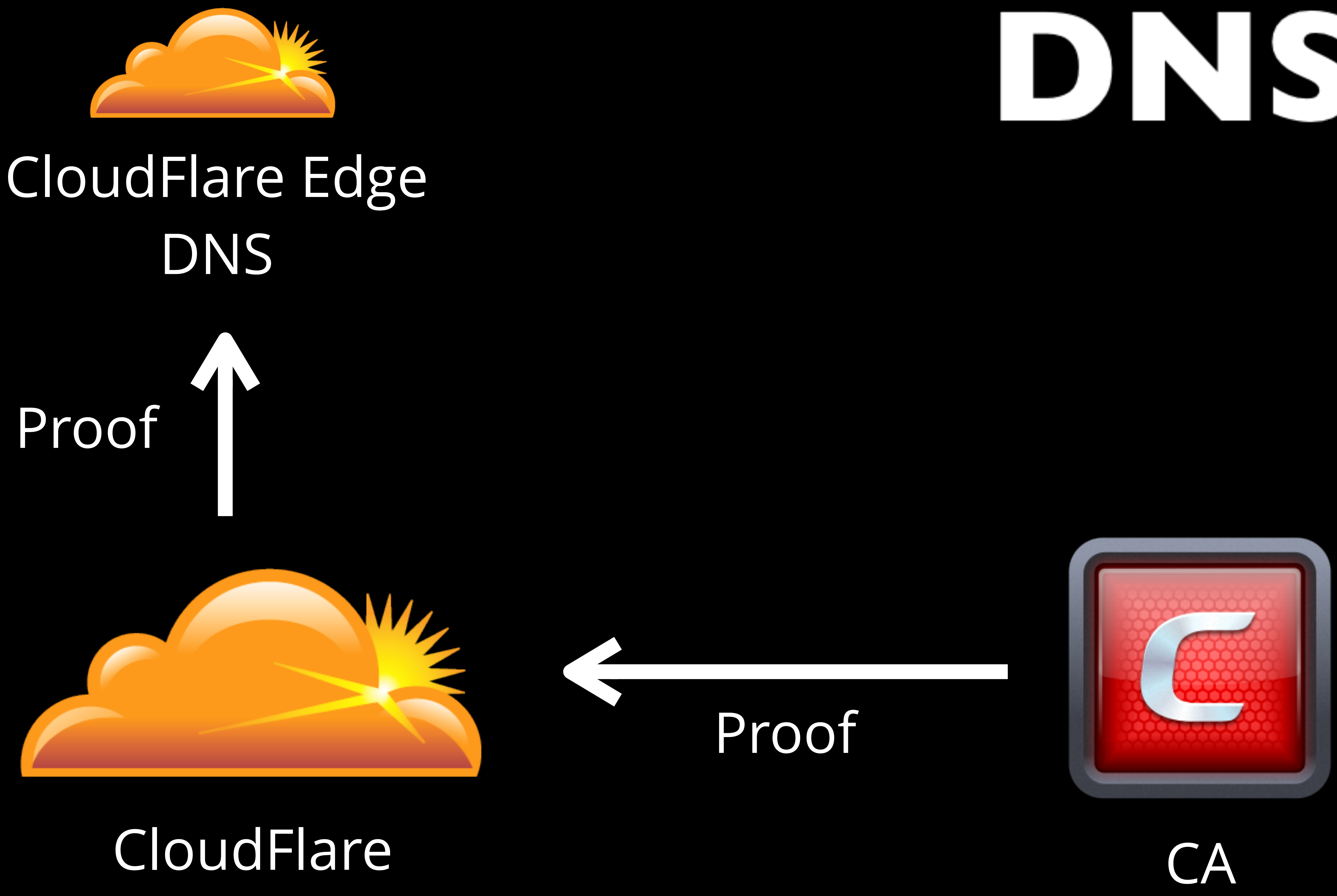
```
$ dig realworldcrypto.com TXT

realworldcrypto.com. 14399 IN TXT "google-site-
verification=8-V5SmsK-pBf9PLCE49ACqFCX4qymWylbNVFaIDbtXc"
```

HTTP Validation

- If you control page content, you control the site
- Add a meta-tag to HTML

```
<meta name=“validator” content=“...”>
```

DNS



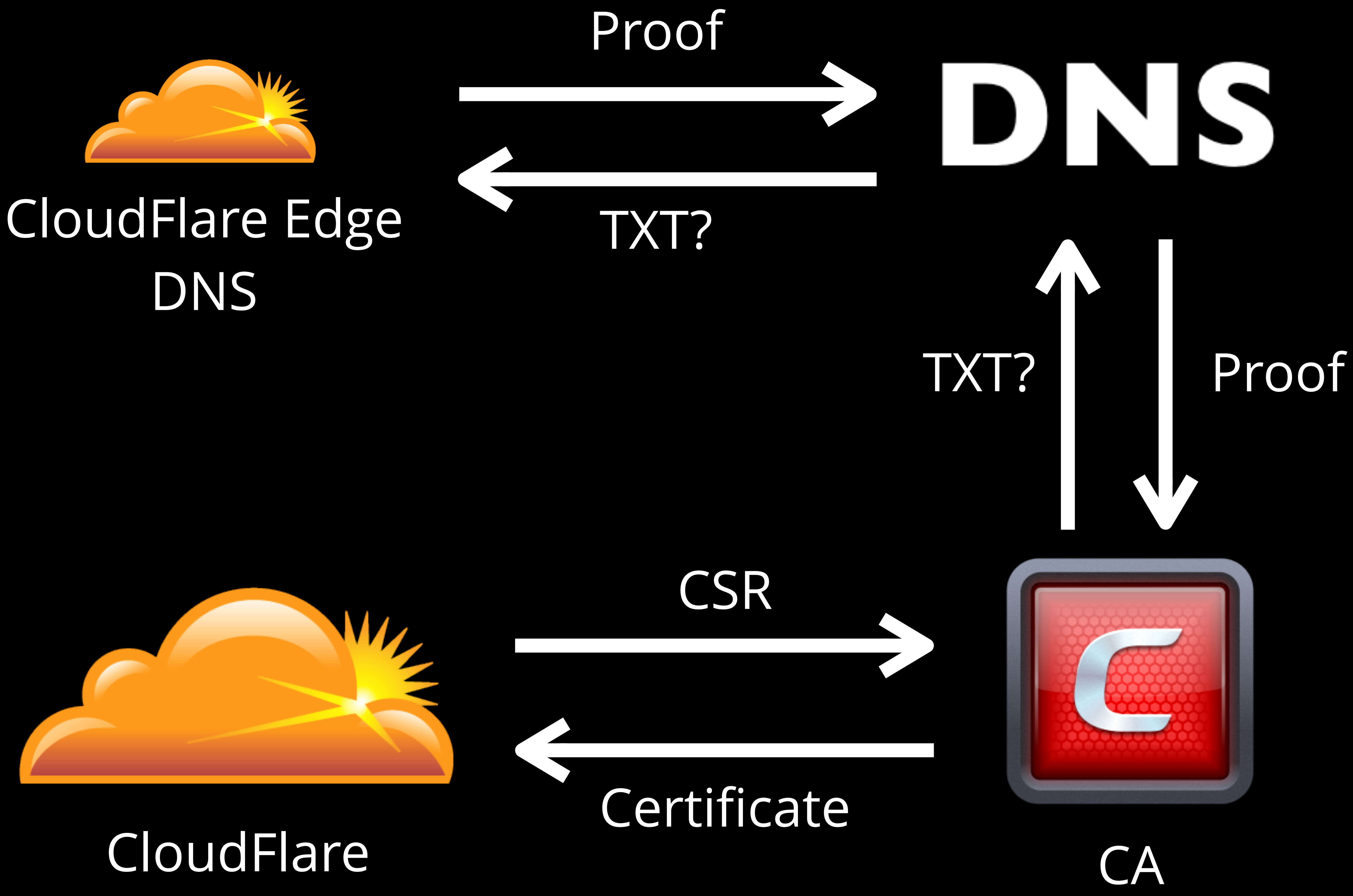
CloudFlare Edge DNS

Proof

CloudFlare

Proof

CA



Proof

DNS

TXT?

CloudFlare Edge DNS

TXT?

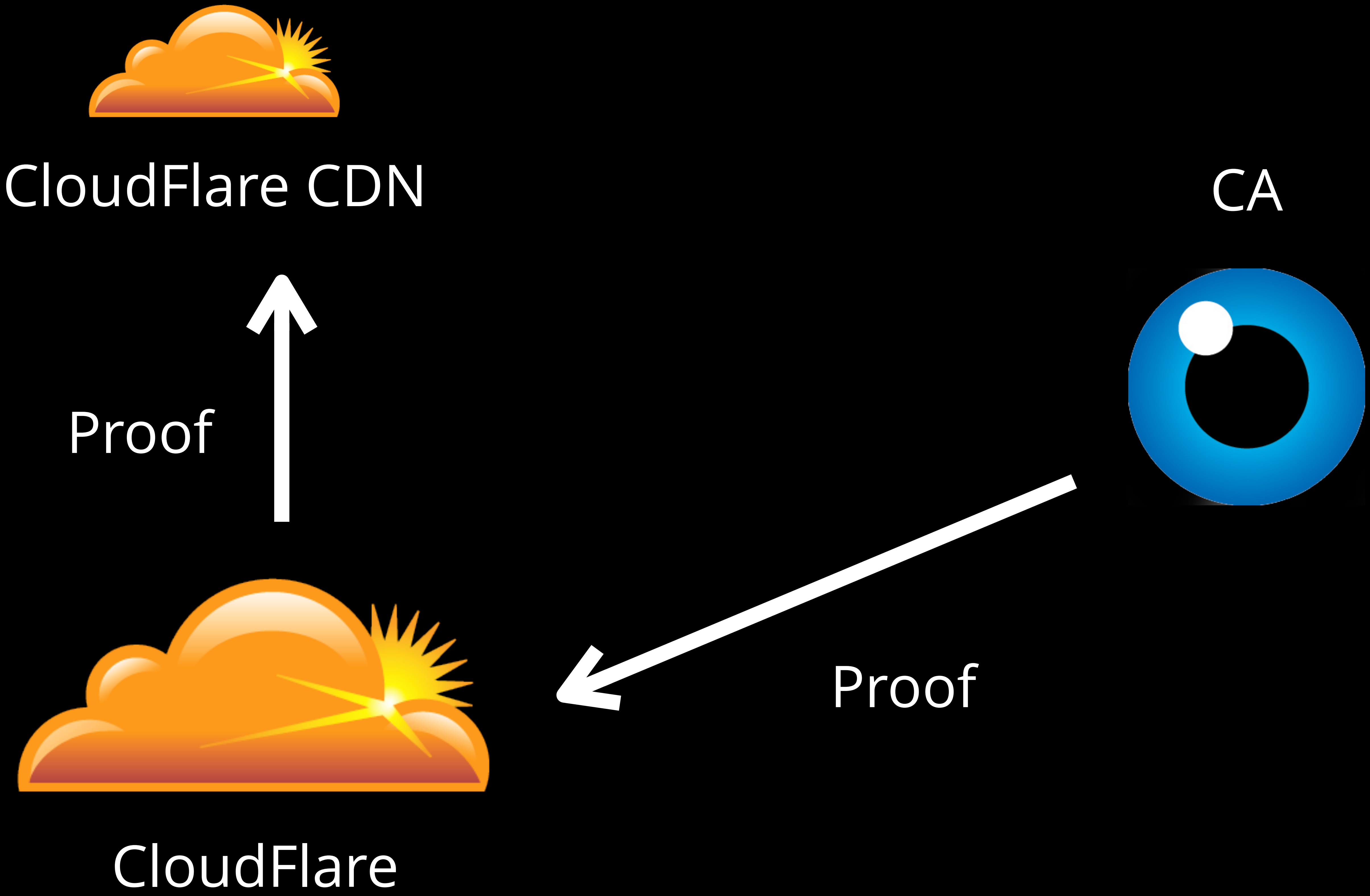
Proof

CSR

Certificate

CloudFlare

CA



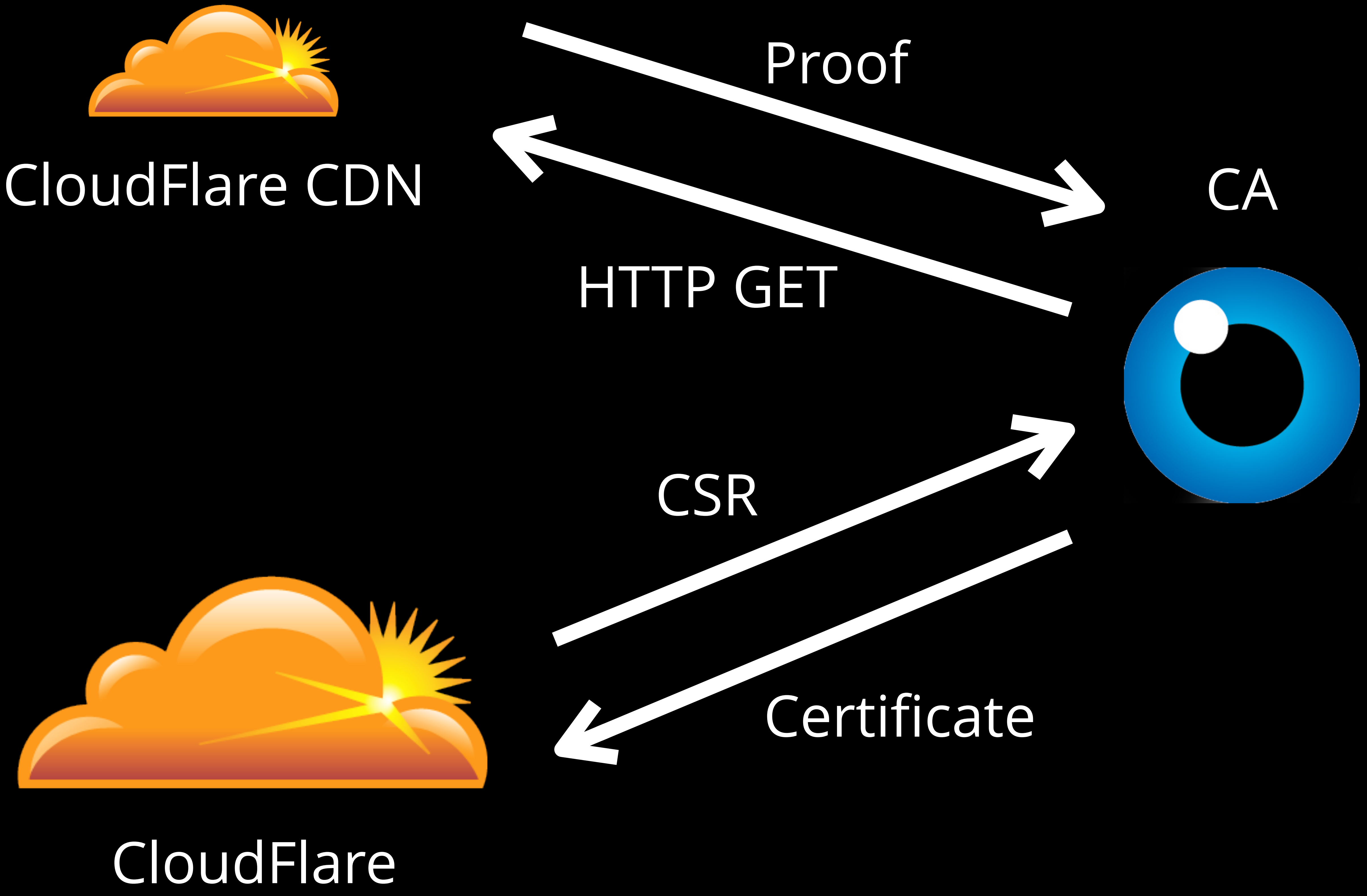
CloudFlare CDN

CA

Proof

Proof

CloudFlare


Proof
CloudFlare CDN
CA
HTTP GET
CSR
Certificate
CloudFlare

Problem

Certificate Management

✓

Problem

Scaling

Customer Power Law

High-end enterprises	1,000s
Businesses with budgets	10,000s
Cost sensitive sites	100,000s
Free customers	1,000,000s

All numbers approximate

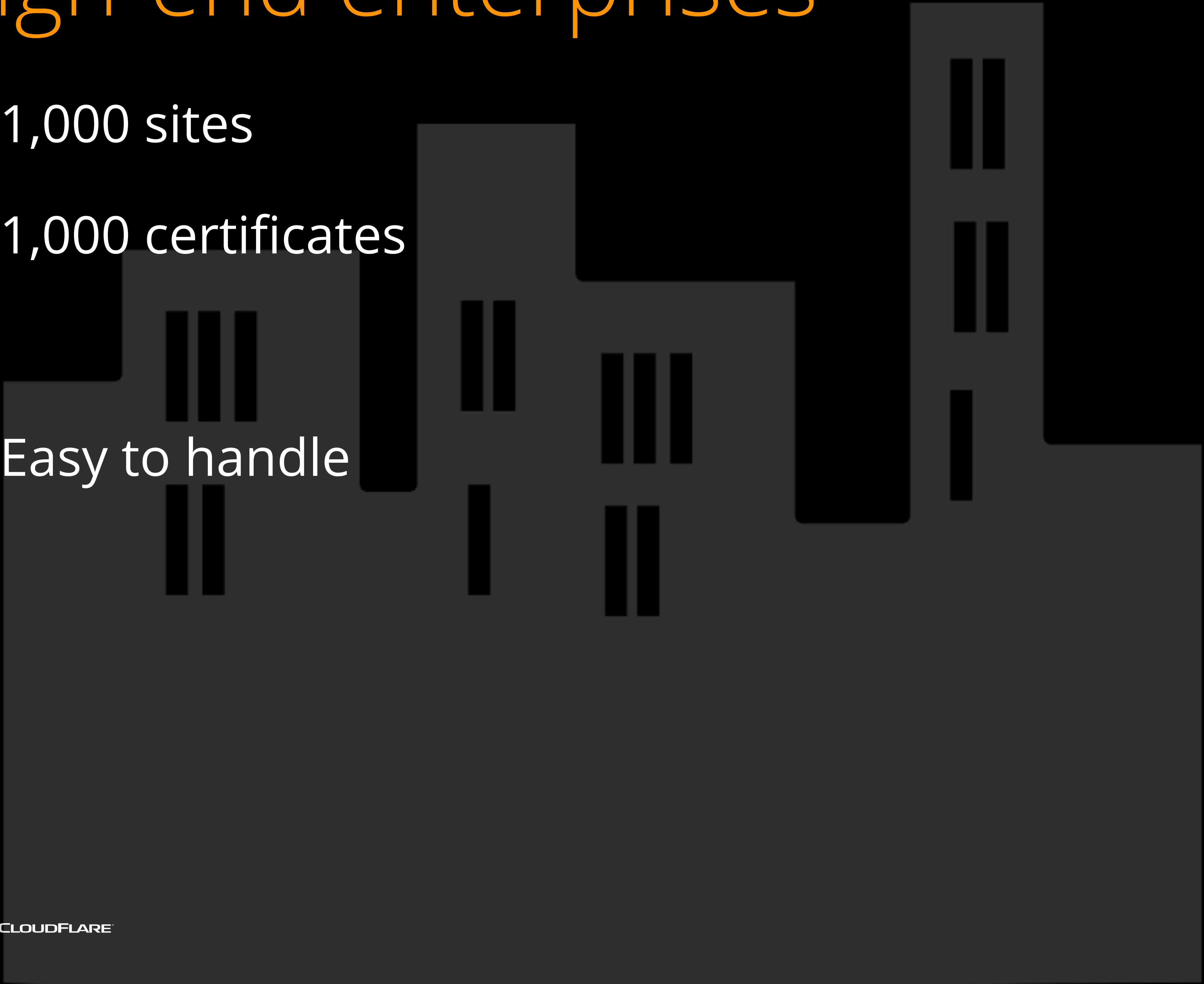
for illustration

Assumptions

- One IP address per site

- Web server can handle around 10,000 certificates
- Service owns 10,000 IPv4 addresses

High-end enterprises



- 1,000 sites
- 1,000 certificates
- Easy to handle

Third party liability?

- Keyless SSL
  - Keep private key on premises
  - Open signing oracle to proxy
  - Proxy splits handshake

Hello! Let’s start a encrypted conversation using TLS 1.2.

I want to talk to bank.com
I know the following cipher suites:
- ECDHE and RSA with 128bit AES in GCM mode and SHA256
- RSA with 128bit AES in GCM mode and SHA256
Here’s a randomly chosen number:
3d86a5..04

Hi there, I think we can chat.

Let’s use the cipher:
RSA with 128bit AES in GCM mode and SHA256
Here’s my random number:
ca35f0..13
Here’s my certificate chain:
[bank.com’s certificate]

This certificate checks out: it was issued to bank.com and digitally signed by a certificate authority I trust.
Here’s a secret encrypted with the RSA public key I took from your certificate:
[encrypted pre-master secret]
We can both derive the same key using this secret and the random numbers we exchanged.

Hey, you’re the one with the key for bank.com, can you decrypt this for me?
[encrypted pre-master secret]

Sure, here’s the
decrypted message:
[pre-master secret]

I have decrypted the secret and derived the key.
From now on let’s use the key to encrypt what we say.

[It’s so great to speak privately]
[Can you get me the current balance of my checking account?]

[Sure thing, you have $12.05 left in that account]

Keyless SSL

Example handshake performance

No proxy:	895ms
Proxy with keyless:	346ms
Proxy with key:	149ms

Businesses with budgets

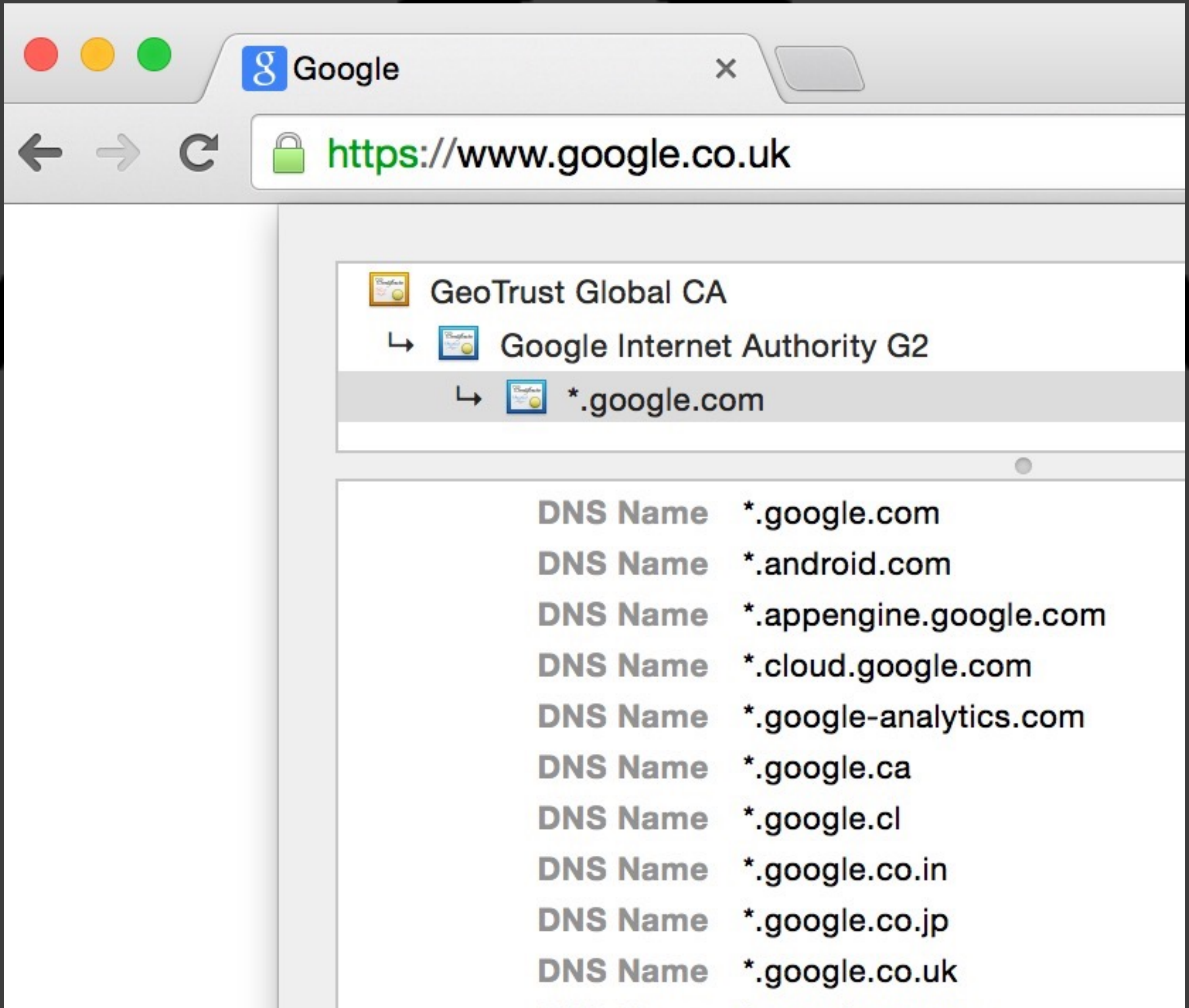
- 10,000 sites
- 10,000 certificates
- Near capacity for stock web server

Cost sensitive sites

- 100,000 sites
- 100,000 certificates
- This begins to get tricky

Subject Alternative Names

- Associate values to a certificate (DNS Name, IP)



GeoTrust Global CA
↳ Google Internet Authority G2
↳ *.google.com

DNS Name	*.google.com
DNS Name	*.android.com
DNS Name	*.appengine.google.com
DNS Name	*.cloud.google.com
DNS Name	*.google-analytics.com
DNS Name	*.google.ca
DNS Name	*.google.cl
DNS Name	*.google.co.in
DNS Name	*.google.co.jp
DNS Name	*.google.co.uk

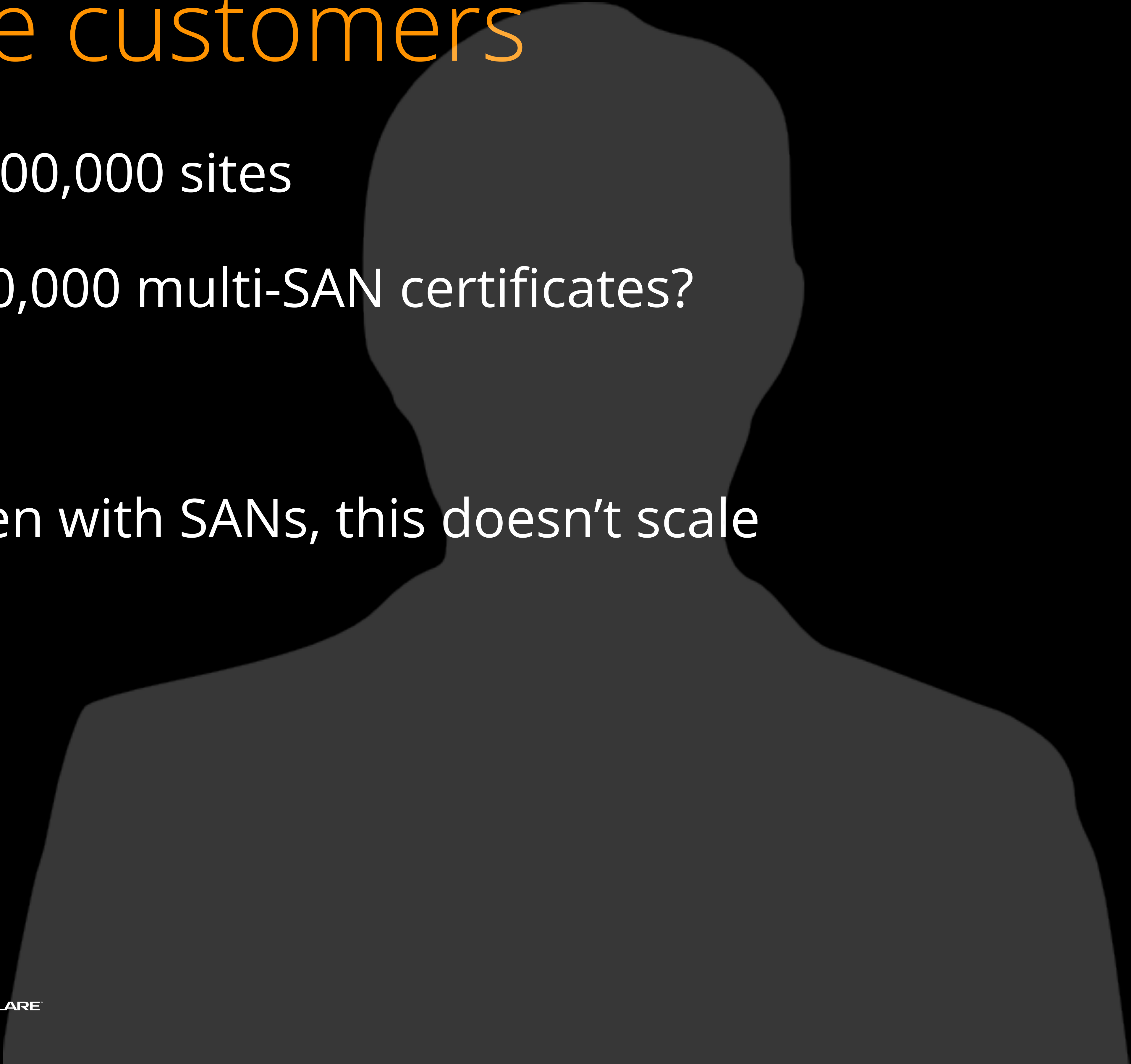
Solution to certificate problem

- Put multiple sites on same SAN
- ~40 or so SANs before performance is affected
- Sites can't spoof each other: managed key

Cost sensitive sites

- 100,000 sites
- 10,000 multi-SAN certificates
- Acceptable web server

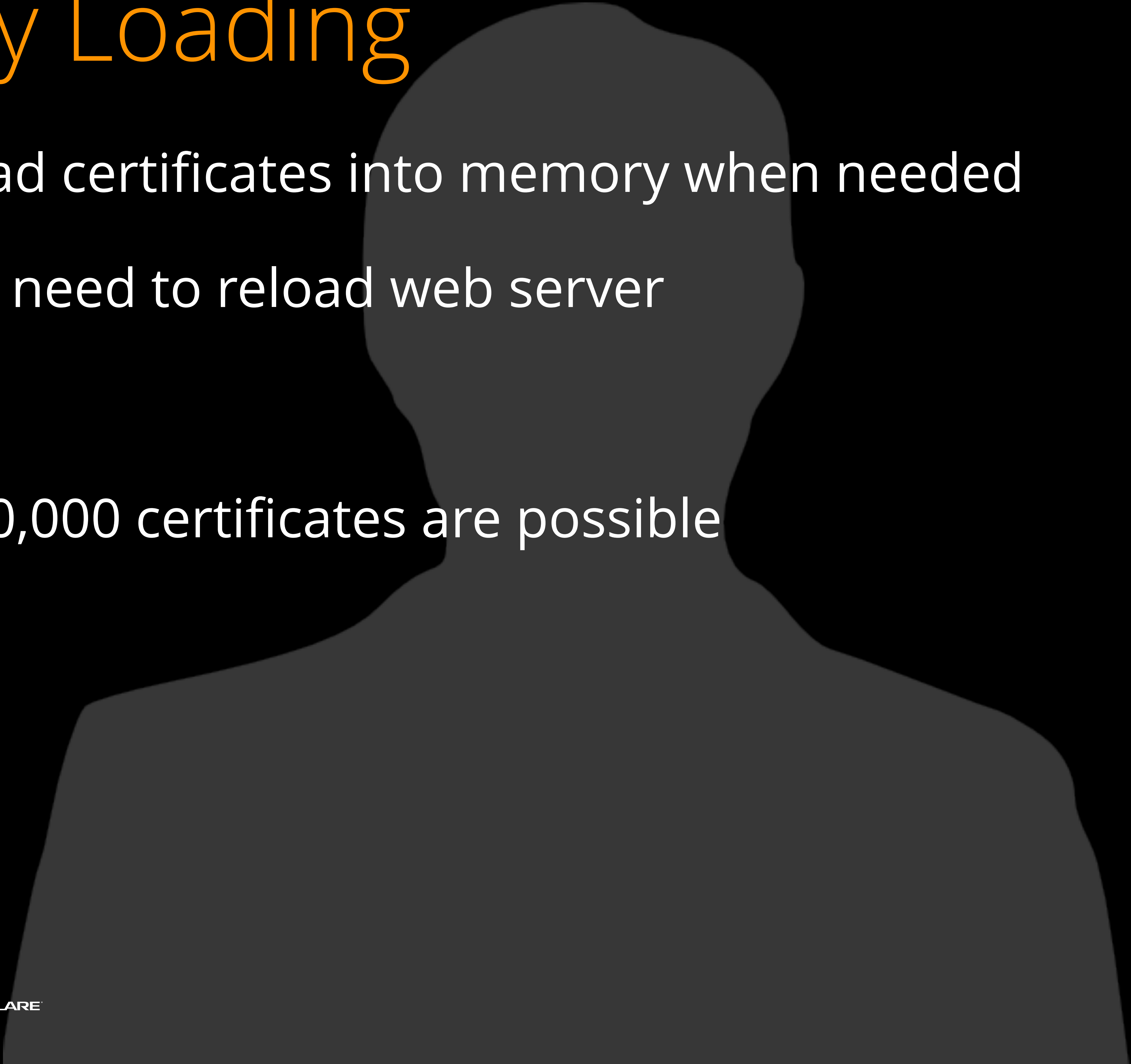
Free customers



- 1,000,000 sites
- 100,000 multi-SAN certificates?
- Even with SANs, this doesn't scale

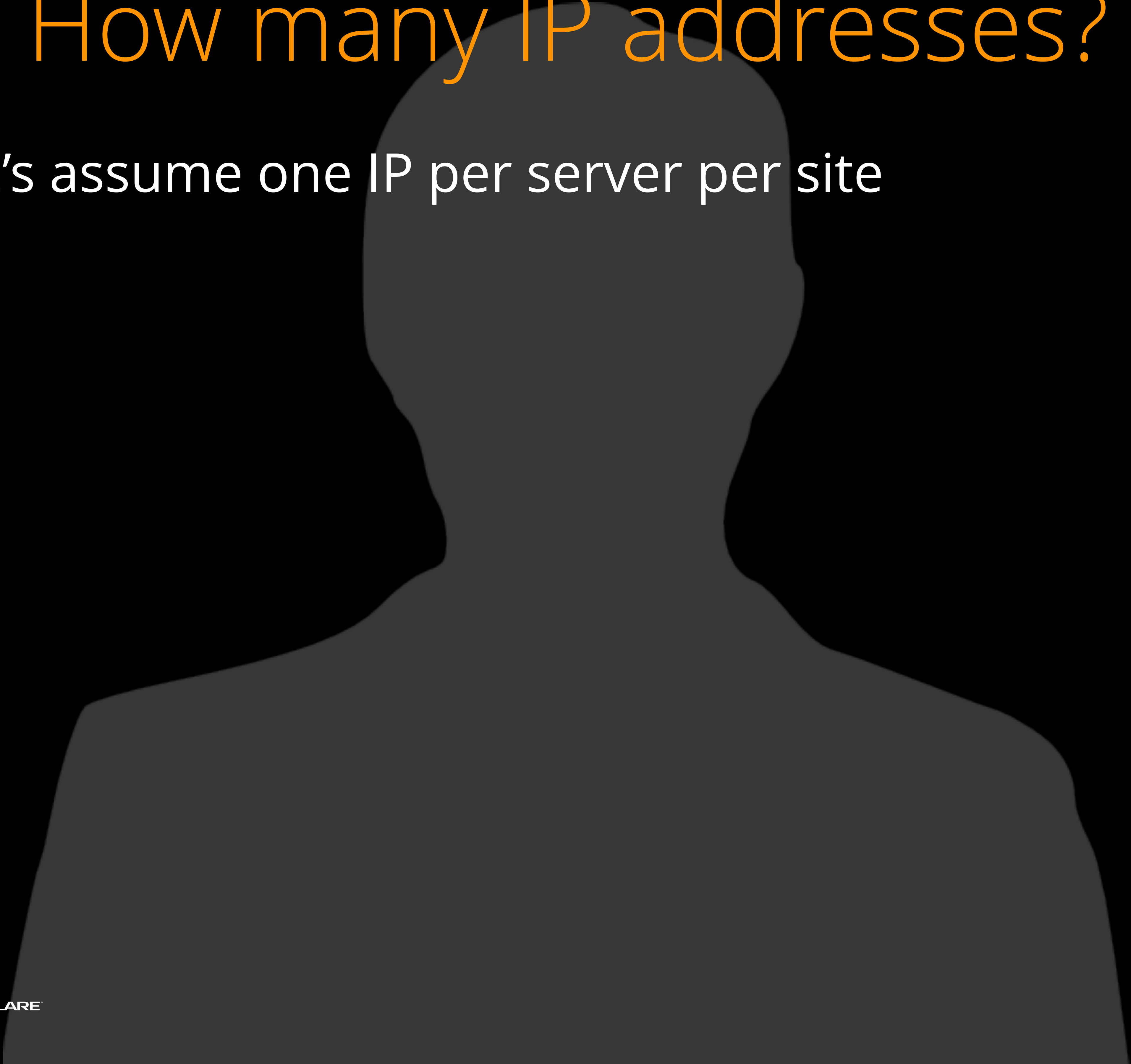
Lazy Loading

- Load certificates into memory when needed
- No need to reload web server
- 100,000 certificates are possible

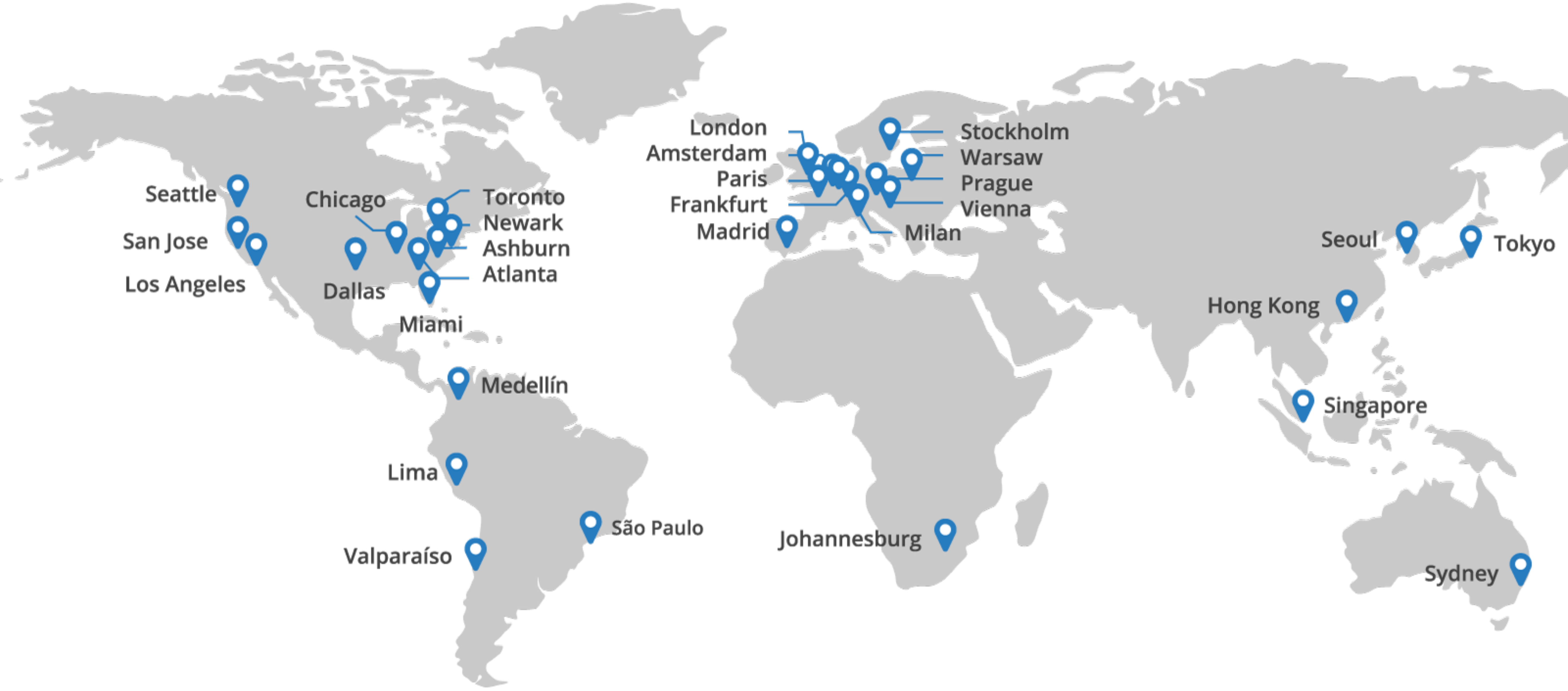


How many IP addresses?

- Let’s assume one IP per server per site



CloudFlare’s Global Network



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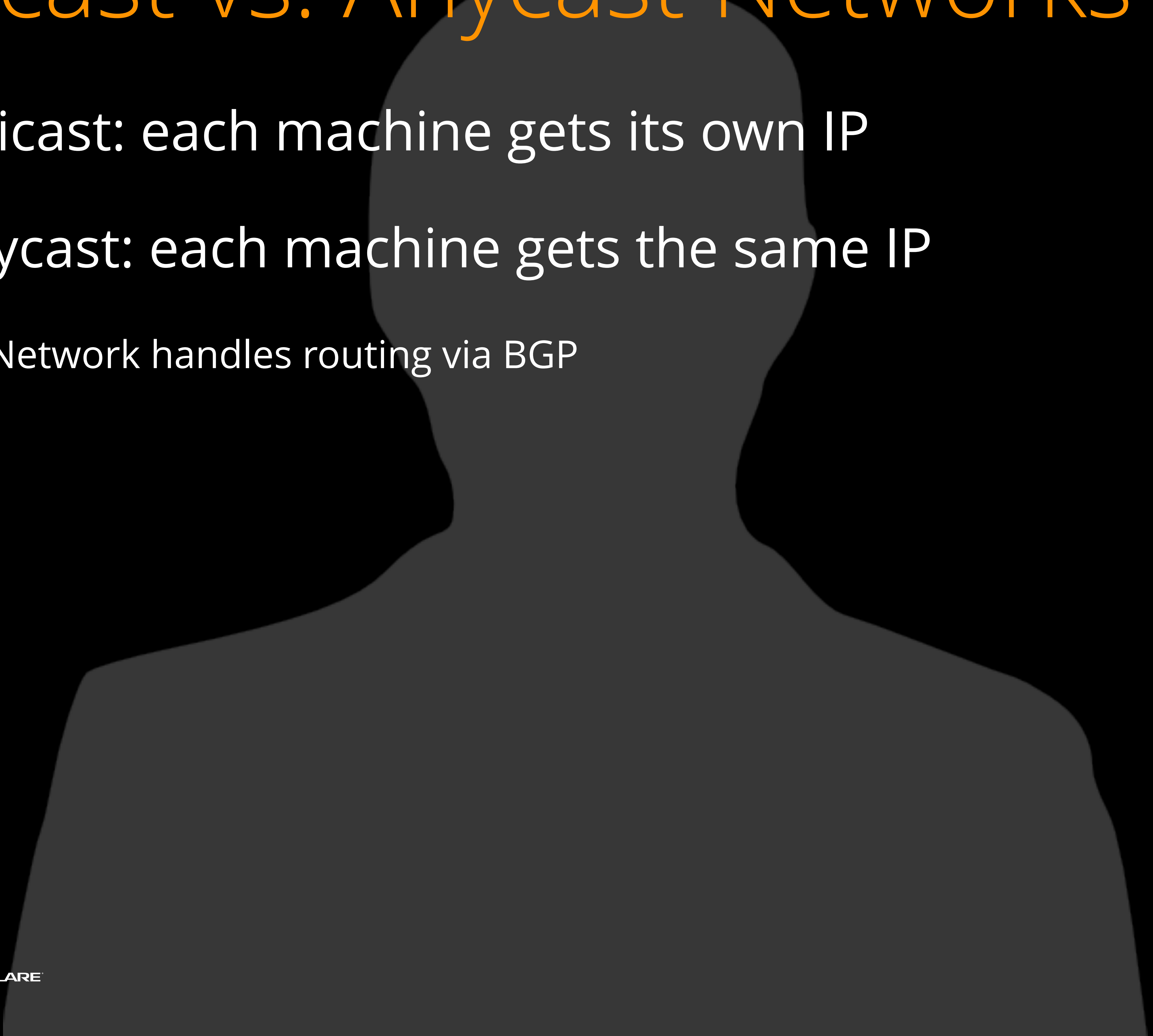
IP addresses needed

- 1 certificate per IP per PoP
- 100,000 certificates
- ~3 million IPs for 30 pops

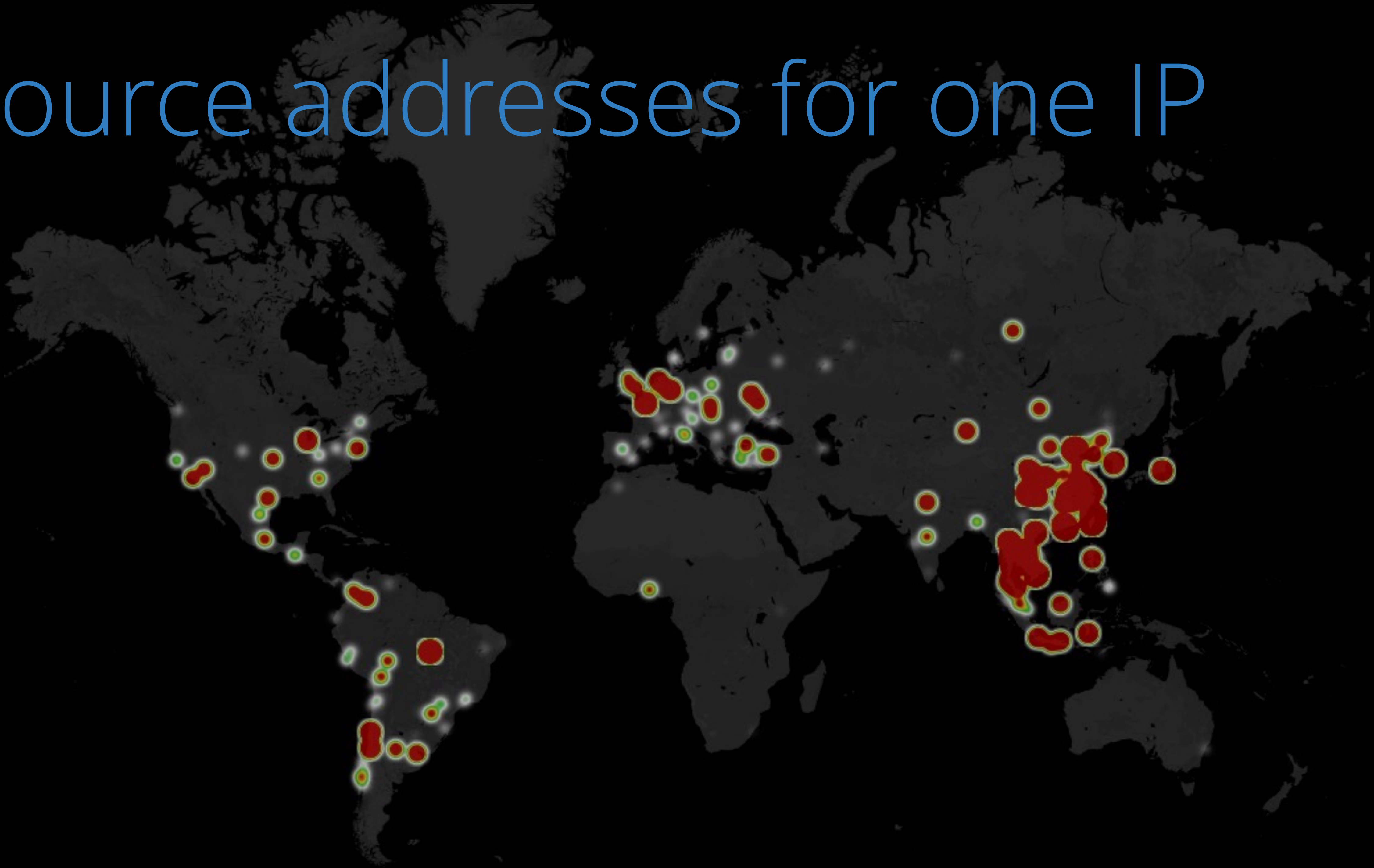
- CloudFlare only has ~1 million IP addresses
- Only ~16 million in a Class A network

Unicast vs. Anycast Networks

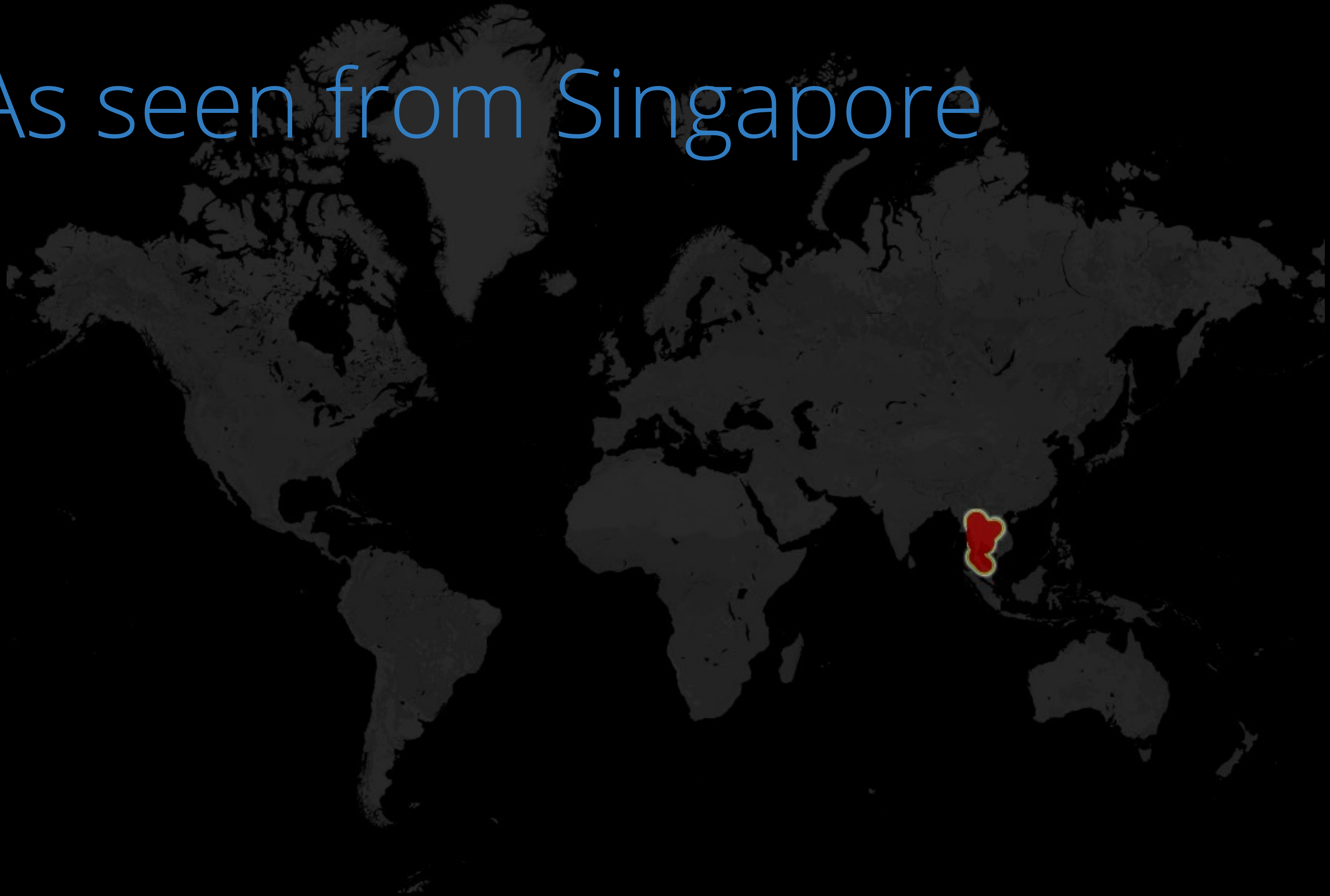
- Unicast: each machine gets its own IP
- Anycast: each machine gets the same IP
  - Network handles routing via BGP



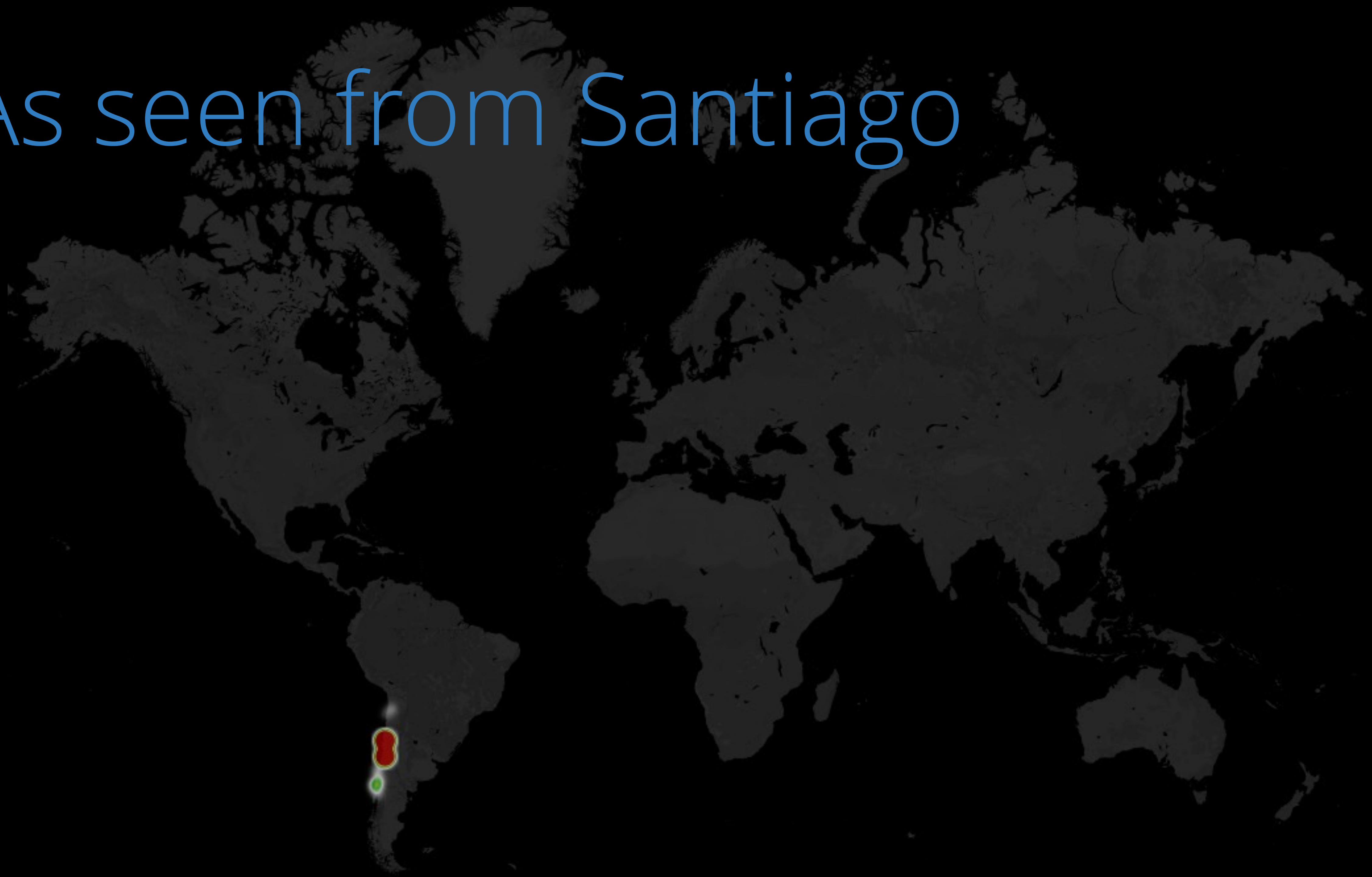
Source addresses for one IP



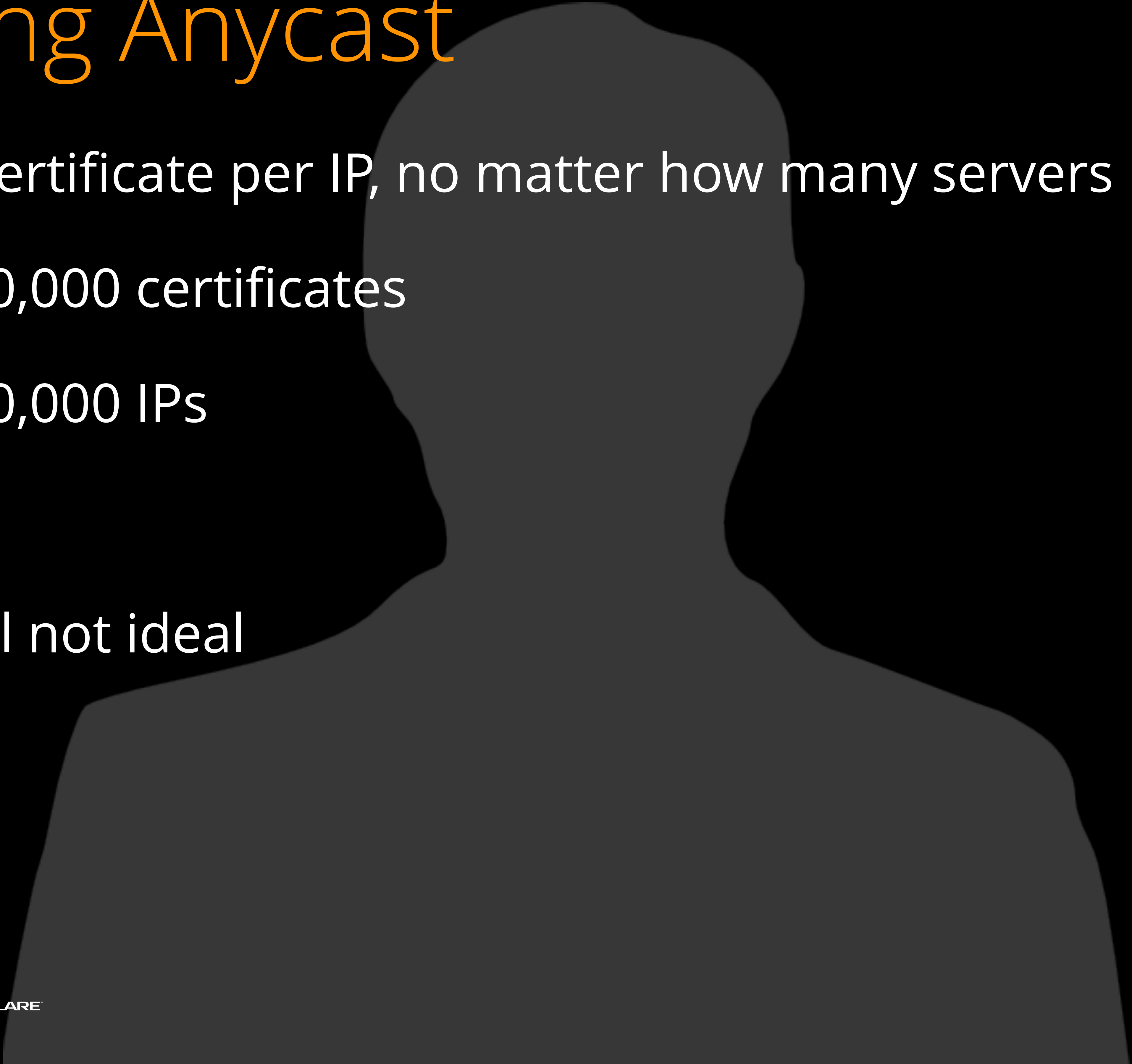
As seen from Singapore



As seen from Santiago



Using Anycast



- 1 certificate per IP, no matter how many servers
- 100,000 certificates
- 100,000 IPs
- Still not ideal

Solution

Server Name Indication

(SNI)

What is it?

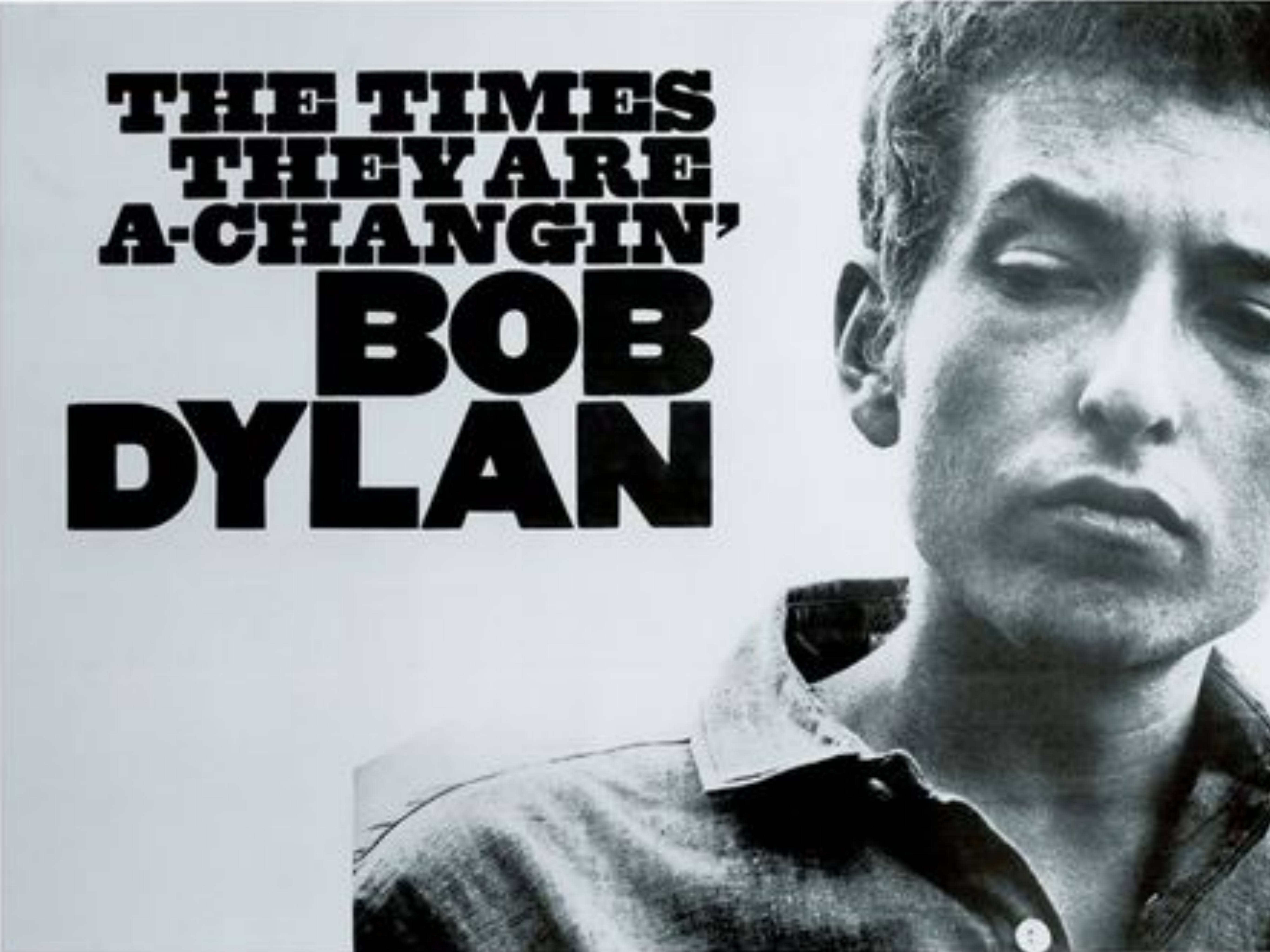
- TLS extension that adds the hostname to ClientHello
- Allows “virtual hosting”
- Multiple certificates behind one IP

Downside

- Not universally supported

SNI Support

	Windows XP	Android	iOS/MacOS
OS Browser	X	3.0+	iOS 4+ MacOS 10.5+
Chrome	3.0+	✓	✓
Firefox	2.0+	✓	✓


THE TIMES
THEY ARE
A-CHANGIN'
BOB
DYLAN

Meanwhile…

- Windows XP end of life
- Microsoft and Google dropping support for SHA-1
- POODLE exploit causes SSL v3.0 to be dropped

SHA-256 Support

	Windows XP	Android	iOS/MacOS
OS Browser	SP3	2.3+	iOS 3+ MacOS 10.5+
Chrome	26.0+ SP3	✓	✓
Firefox	1.5+	✓	✓

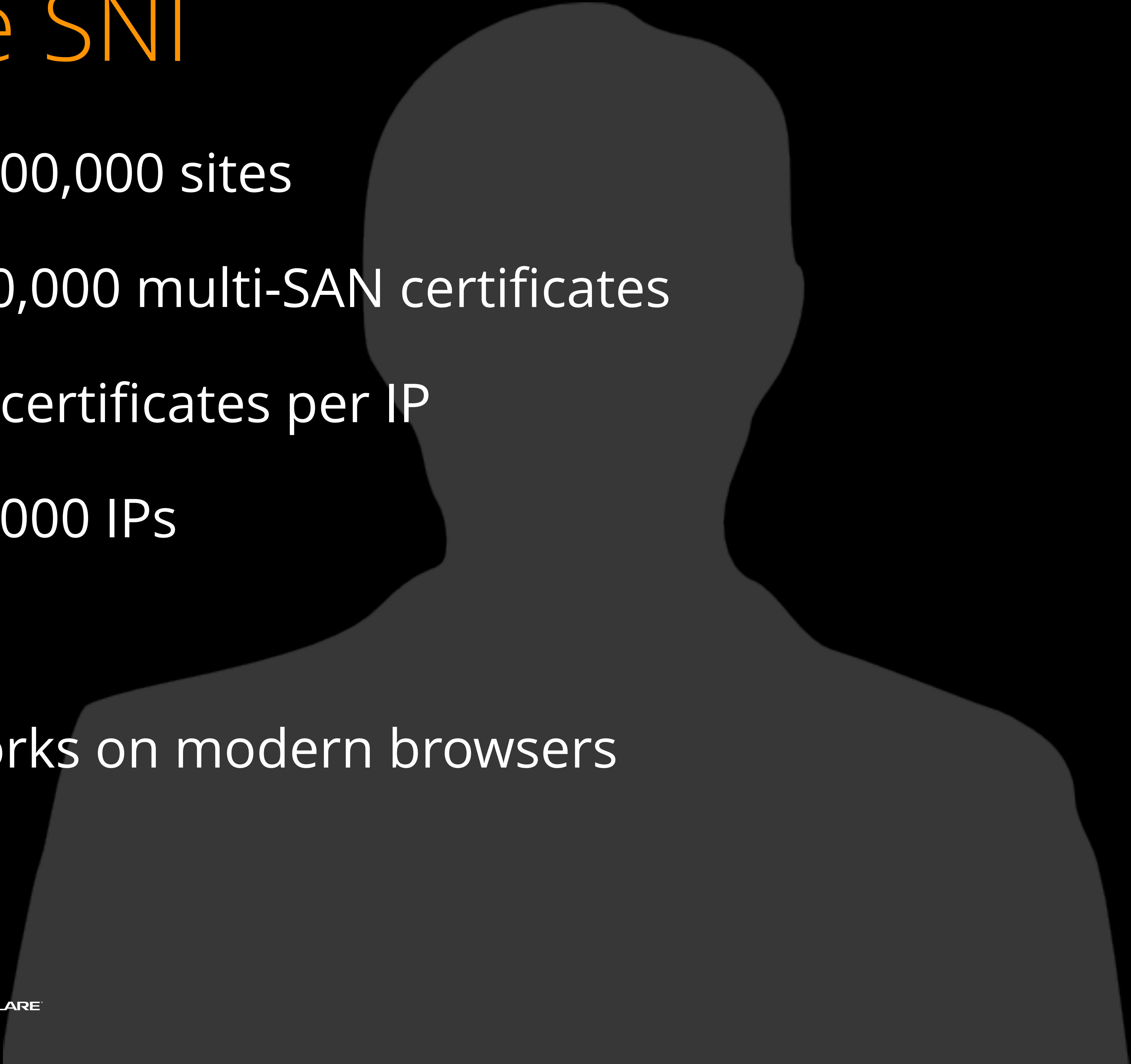
no SNI support, yes SHA-256

	Windows XP	Android	iOS/MacOS
OS Browser	XP SP3	2.3 only	iOS 3 only
Chrome	3.0+ SP2 3 – 25 SP3	N/A	N/A
Firefox	N/A	N/A	N/A

Use SNI

- 1,000,000 sites
- 100,000 multi-SAN certificates
- 10 certificates per IP
- 10,000 IPs

- Works on modern browsers



Problem

Scaling

✓

Problem

Performance

Potential performance issues

- Server CPU usage
- Handshake latency
- Is the site slower with HTTPS?

CPU utilization - bulk crypt

- Modern Intel CPUs have instructions for AES
  - Advanced Encryption Standard Instruction Set (AES-NI)
  - Carry-less Multiplication (CLMUL)
- ChaCha20/Poly1305 for mobile — soon
- Encrypt and decrypt at line rate

CPU utilization - handshake

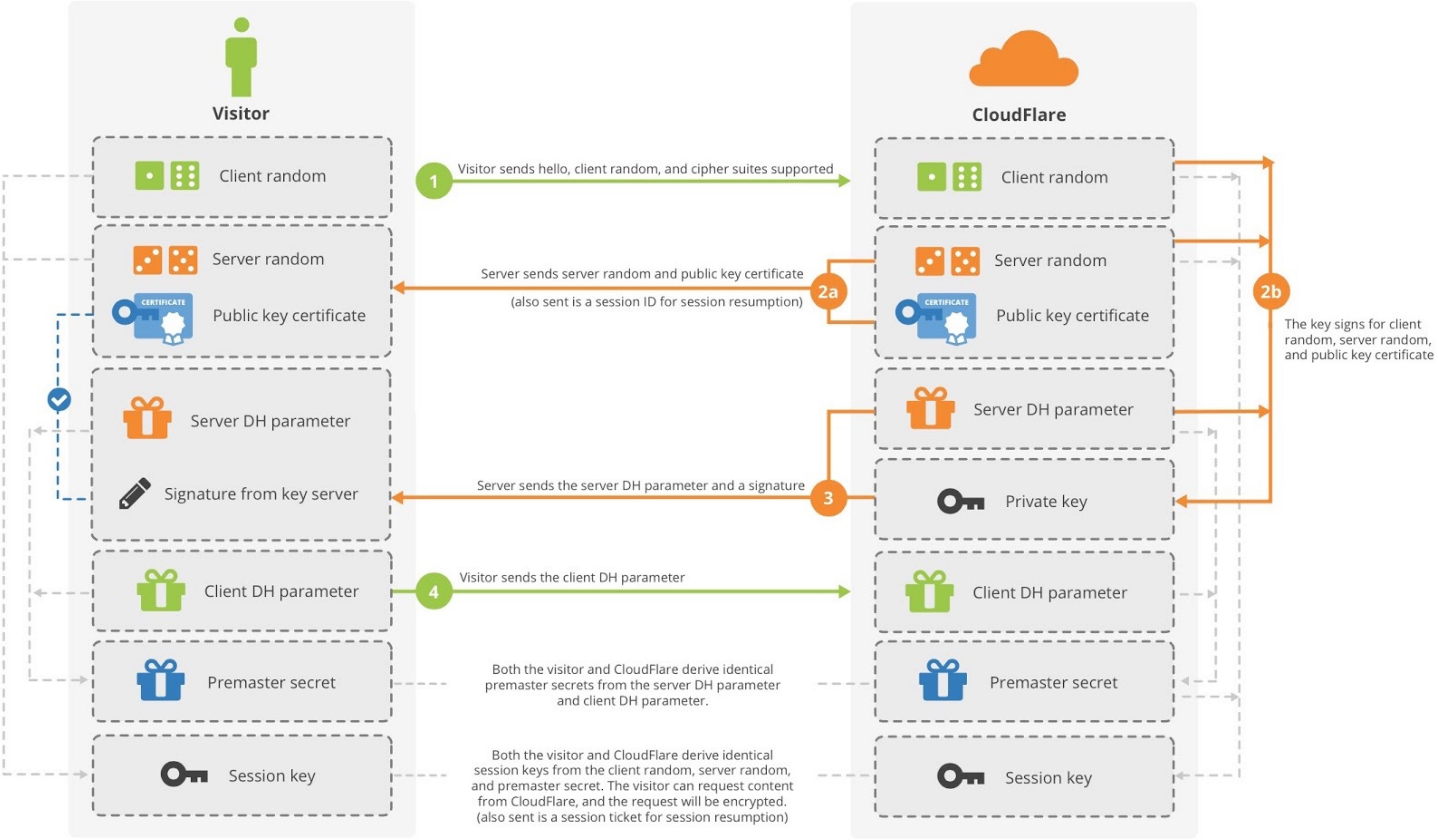
- Elliptic curve certificates
  - Assembly implementation of P256 in OpenSSL
  - 10x less computation than RSA on server side

Latency - handshake

- Session resumption
  - Session tickets, globally resumable
  - Session IDs, resumable within a PoP

SSL Handshake (Diffie-Hellman)

Handshake



Visitor

Client random

Server random

Public key certificate

Server DH parameter

Signature from key server

Client DH parameter

Premaster secret

Session key

CloudFlare

Client random

Server random

Public key certificate

Server DH parameter

Private key

Client DH parameter

Premaster secret

Session key

1 Visitor sends hello, client random, and cipher suites supported

2a Server sends server random and public key certificate

(also sent is a session ID for session resumption)

2b The key signs for client random, server random, and public key certificate

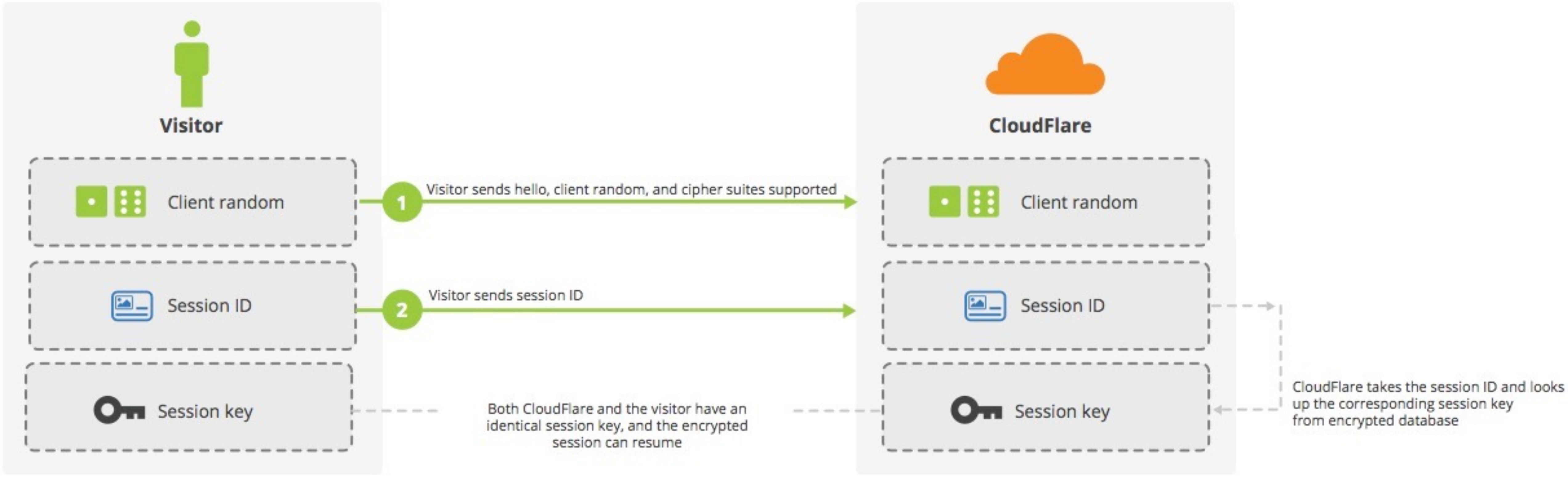
3 Server sends the server DH parameter and a signature

4 Visitor sends the client DH parameter

Both the visitor and CloudFlare derive identical premaster secrets from the server DH parameter and client DH parameter.

Both the visitor and CloudFlare derive identical session keys from the client random, server random, and premaster secret. The visitor can request content from CloudFlare, and the request will be encrypted. (also sent is a session ticket for session resumption)

Session resume with session ID



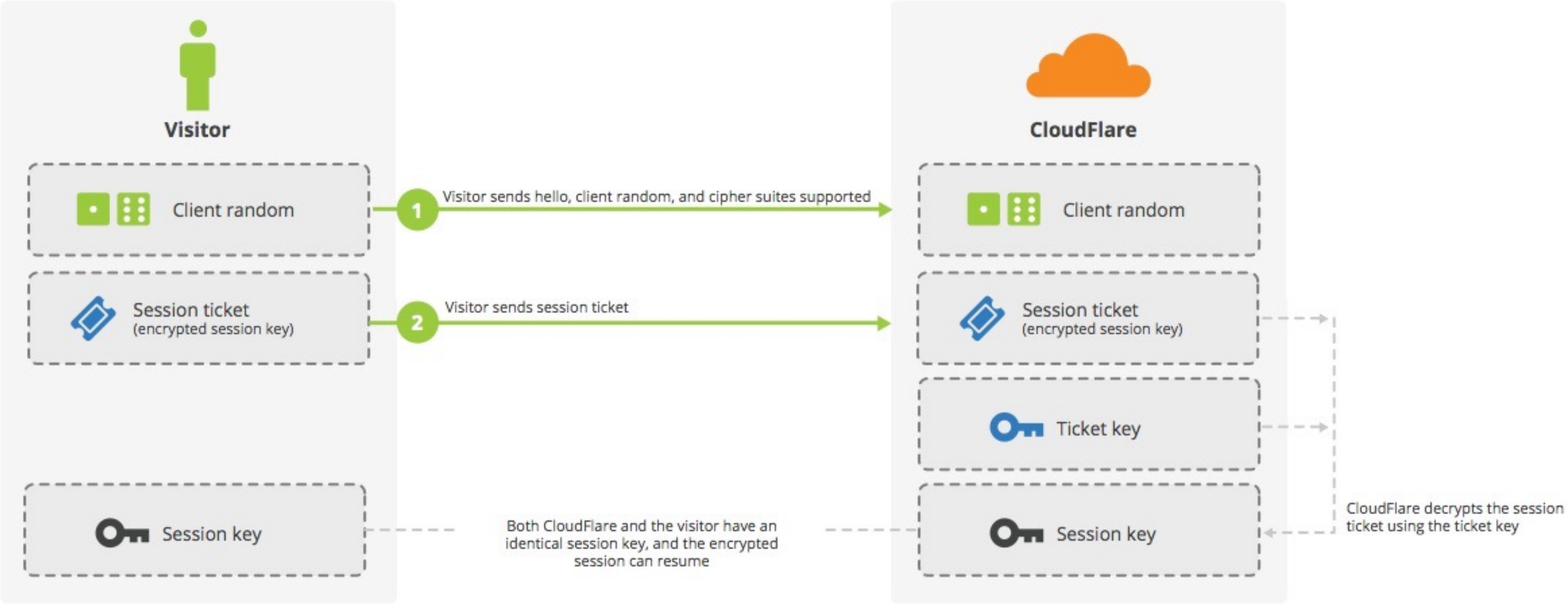
1 Visitor sends hello, client random, and cipher suites supported

2 Visitor sends session ID

CloudFlare takes the session ID and looks up the corresponding session key from encrypted database

Both CloudFlare and the visitor have an identical session key, and the encrypted session can resume

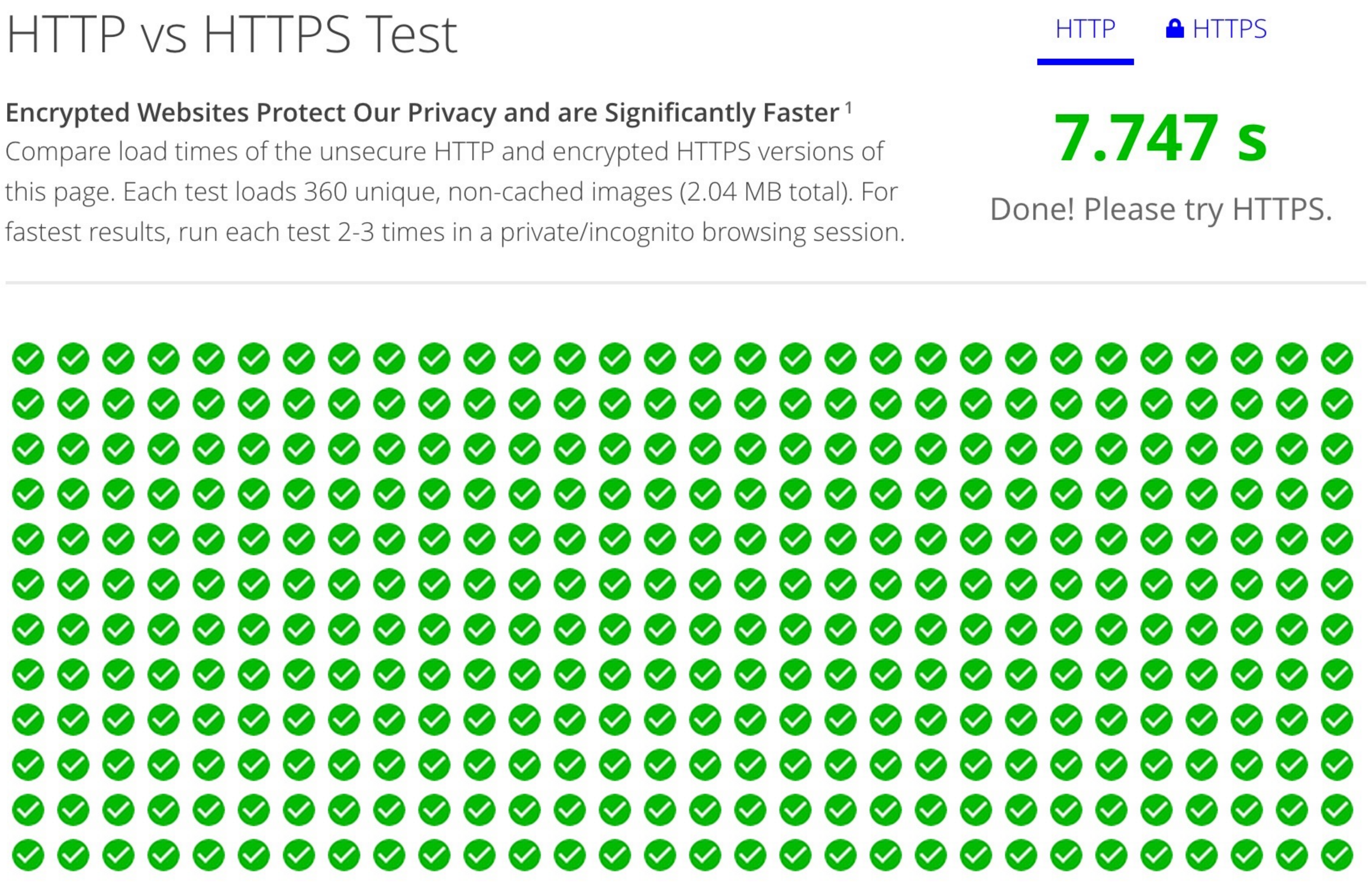
Session resume with session ticket



Visitor
CloudFlare
Client random
1
Visitor sends hello, client random, and cipher suites supported
Client random
Session ticket
(encrypted session key)
2
Visitor sends session ticket
Session ticket
(encrypted session key)
Ticket key
Session key
Both CloudFlare and the visitor have an identical session key, and the encrypted session can resume
Session key
CloudFlare decrypts the session ticket using the ticket key

Latency - HTTP

- Use SPDY



HTTP vs HTTPS Test

Encrypted Websites Protect Our Privacy and are Significantly Faster [1]
Compare load times of the unsecure HTTP and encrypted HTTPS versions of this page. Each test loads 360 unique, non-cached images (2.04 MB total). For fastest results, run each test 2-3 times in a private/incognito browsing session.

7.747 s

Done! Please try HTTPS.

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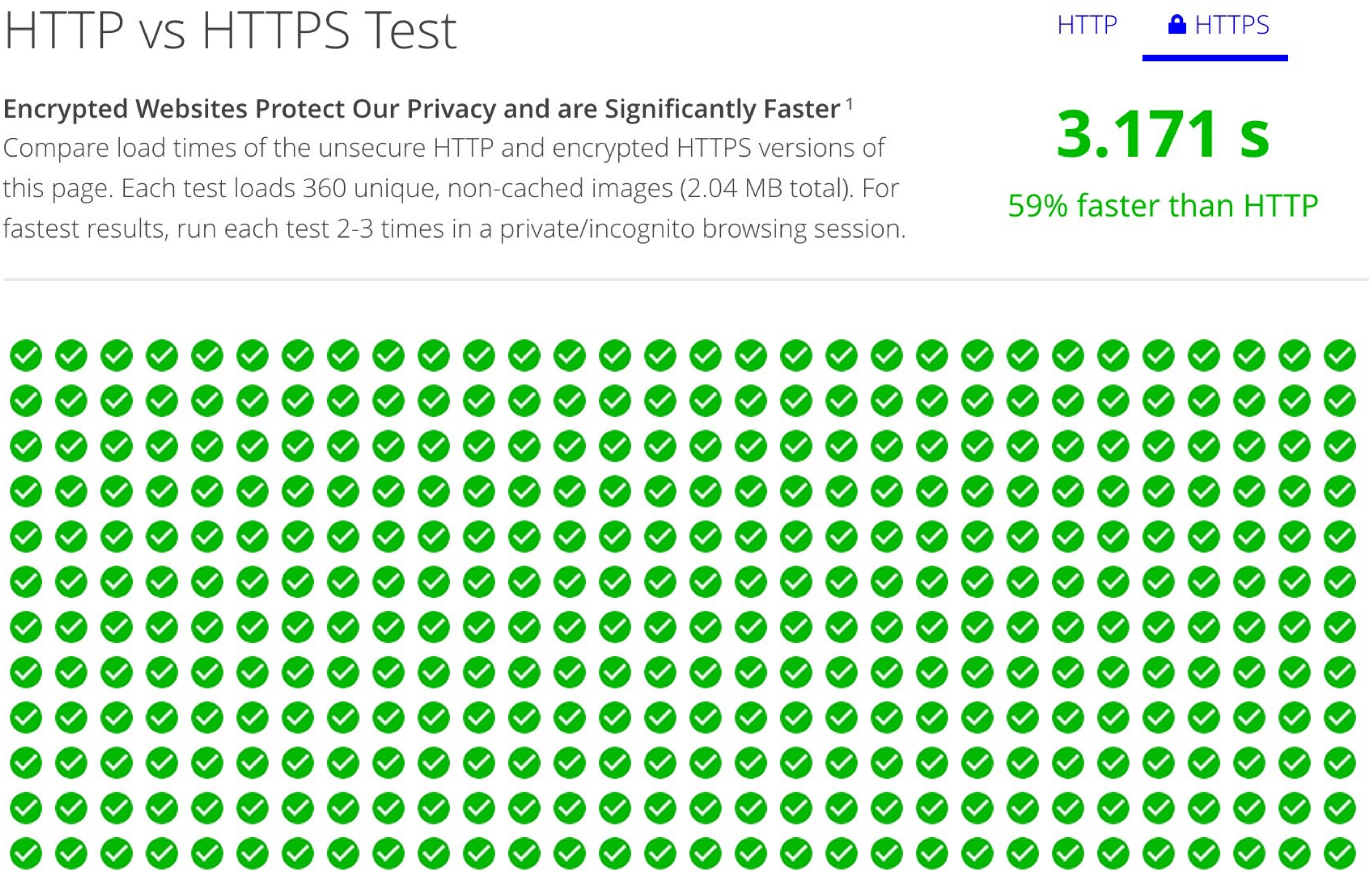

HTTP vs HTTPS Test

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Compare load times of the unsecure HTTP and encrypted HTTPS versions of this page. Each test loads 360 unique, non-cached images (2.04 MB total). For fastest results, run each test 2-3 times in a private/incognito browsing session.

3.171 s

59% faster than HTTP

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Problem

Performance

✓

Problems

- Certificate Management ✓
- Scaling ✓
- Performance ✓

UNIVERSAL SSL
EVERYBODY GETS SSL!
memegenerator.

Universal SSL

- No-hassle HTTPS
- ECDSA certificates
- SNI only
- ***Free*** and automatic

- Over a million new sites with HTTPS!

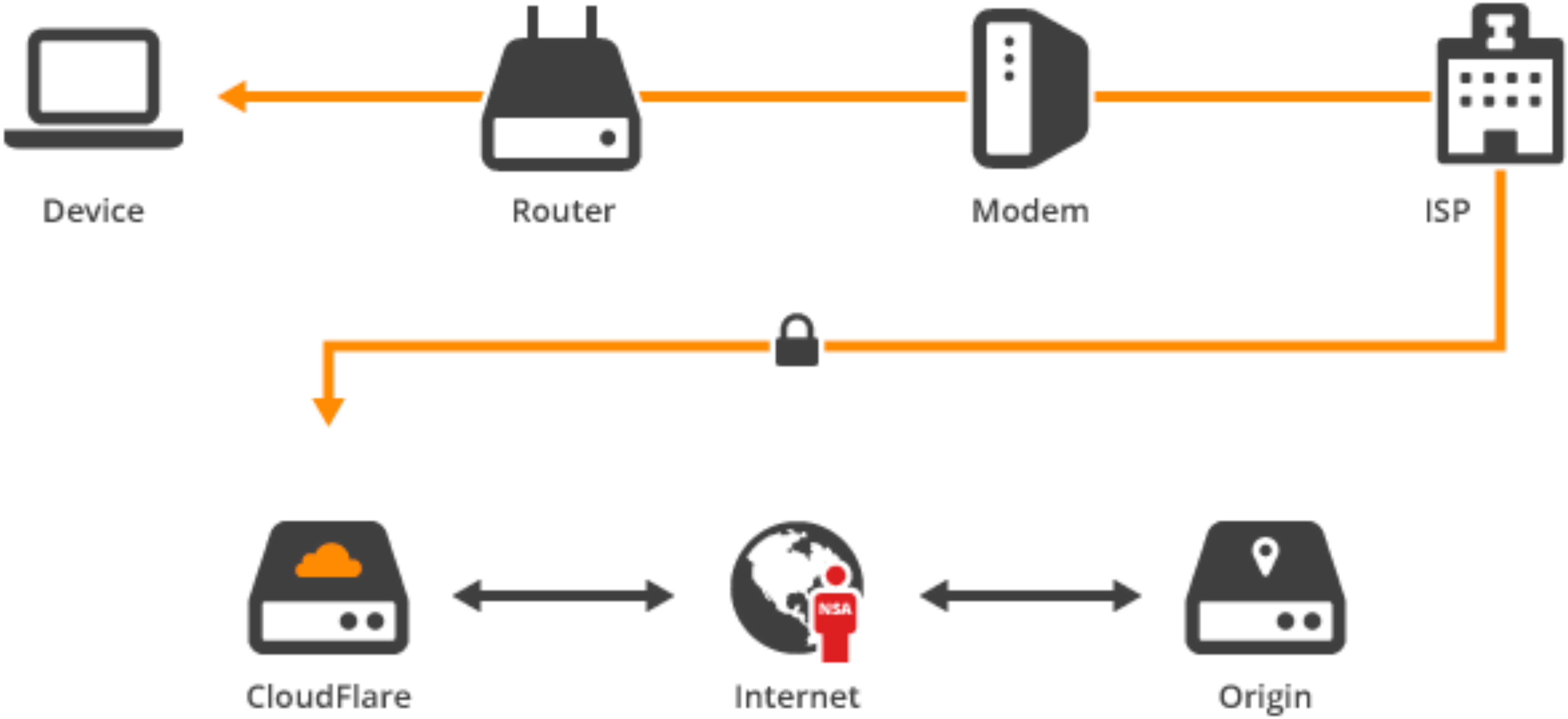
Universal SSL

- Modern browsers only

Some issues left to solve

- Back-end encryption
- Ad networks and mixed content warnings

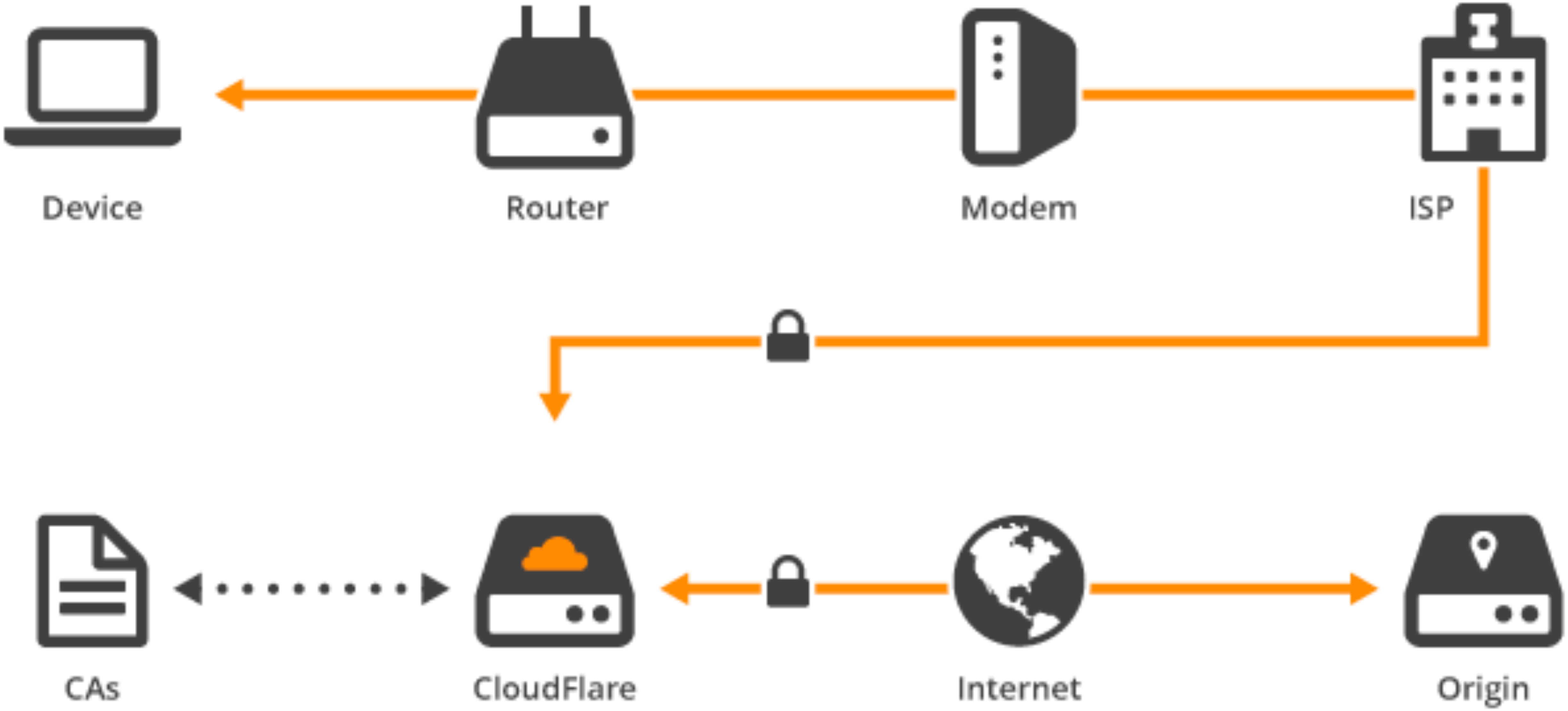
CloudFlare flexible SSL — front-end over TLS, back-end unencrypted



Automatic Back-end Encryption

- Automatic issuance of certificates for origin
- CloudFlare Origin CA
- Let’s Encrypt ???

CloudFlare full SSL (strict) — front-end over TLS, back-end over TLS (validated)



NSA monitoring foiled here!

Mixed content warnings

- Invite me back next year when we’ve fixed it

January 9th
2015

Universal SSL

Nick Sullivan
@grittygrease