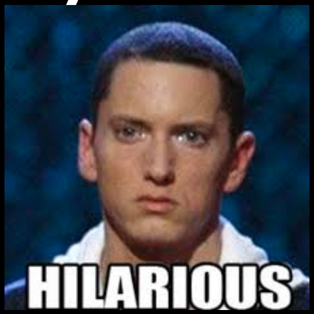
CSCI-351

Data communication and Networks

Lecture 16: PKI + DNSSEC

Warning: This may be hard to understand. Do not lose yourself during the class and keep asking questions



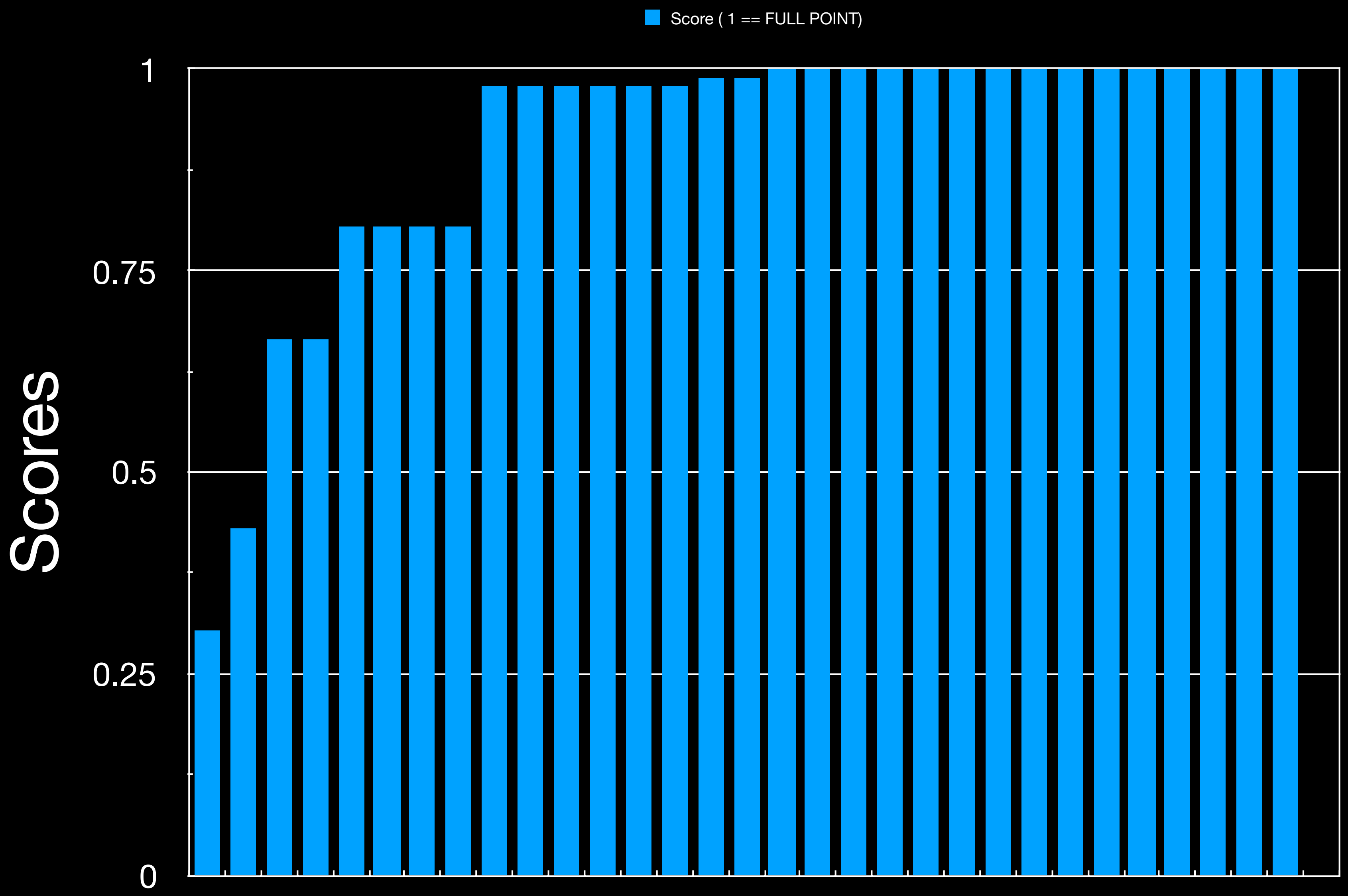
Project 4 Released

- DNSSEC Client

Final Schedule

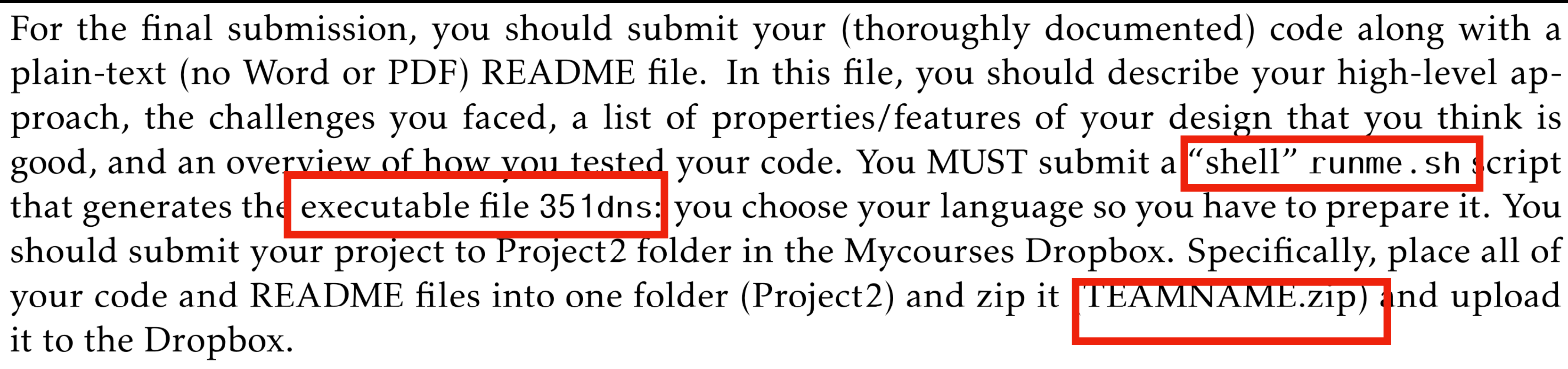
- 8:00am — 10:30am at December 13th
- Comprehensive

Project 3



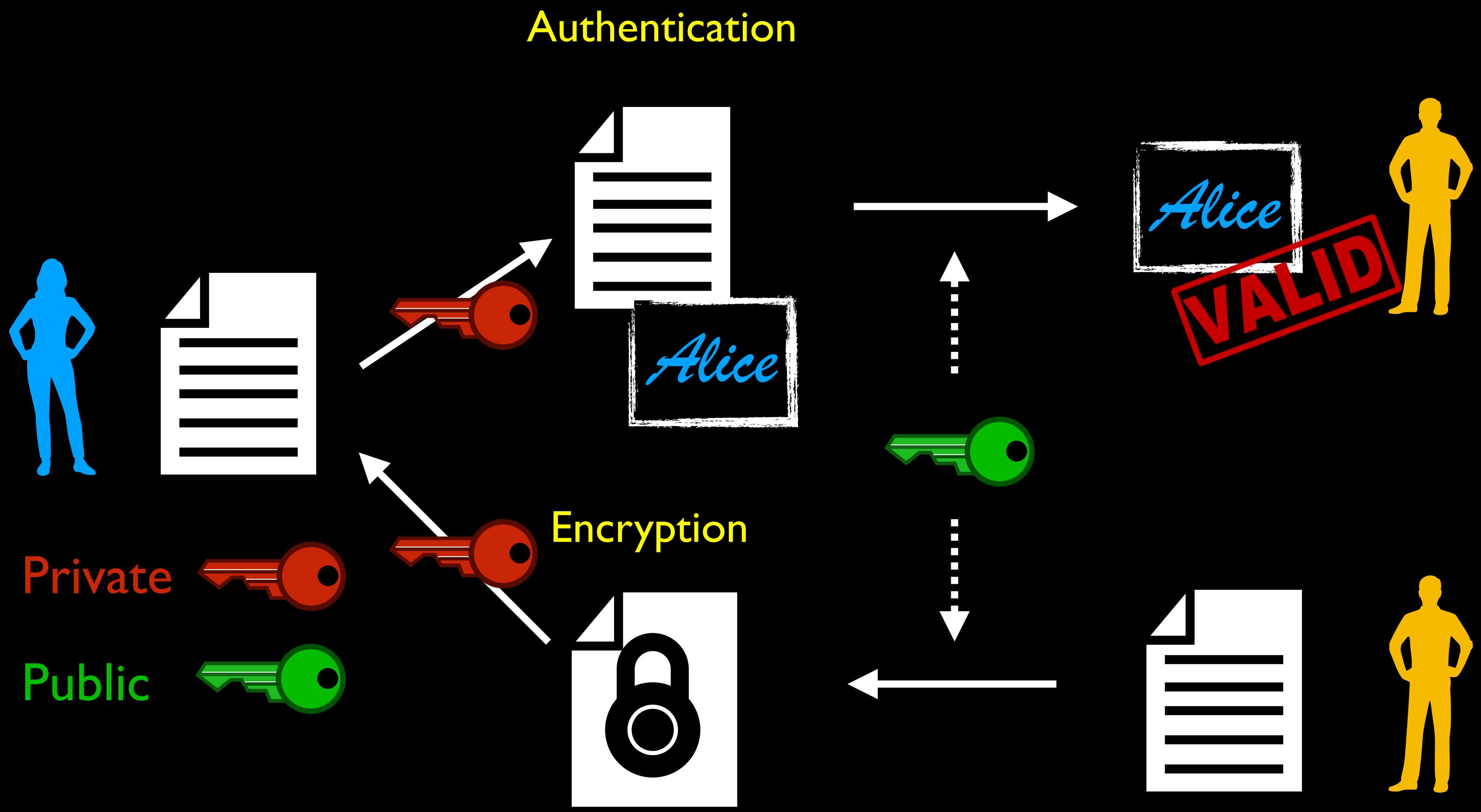
Will send you the feedbacks of Project 2 and 3 by the next class

Please

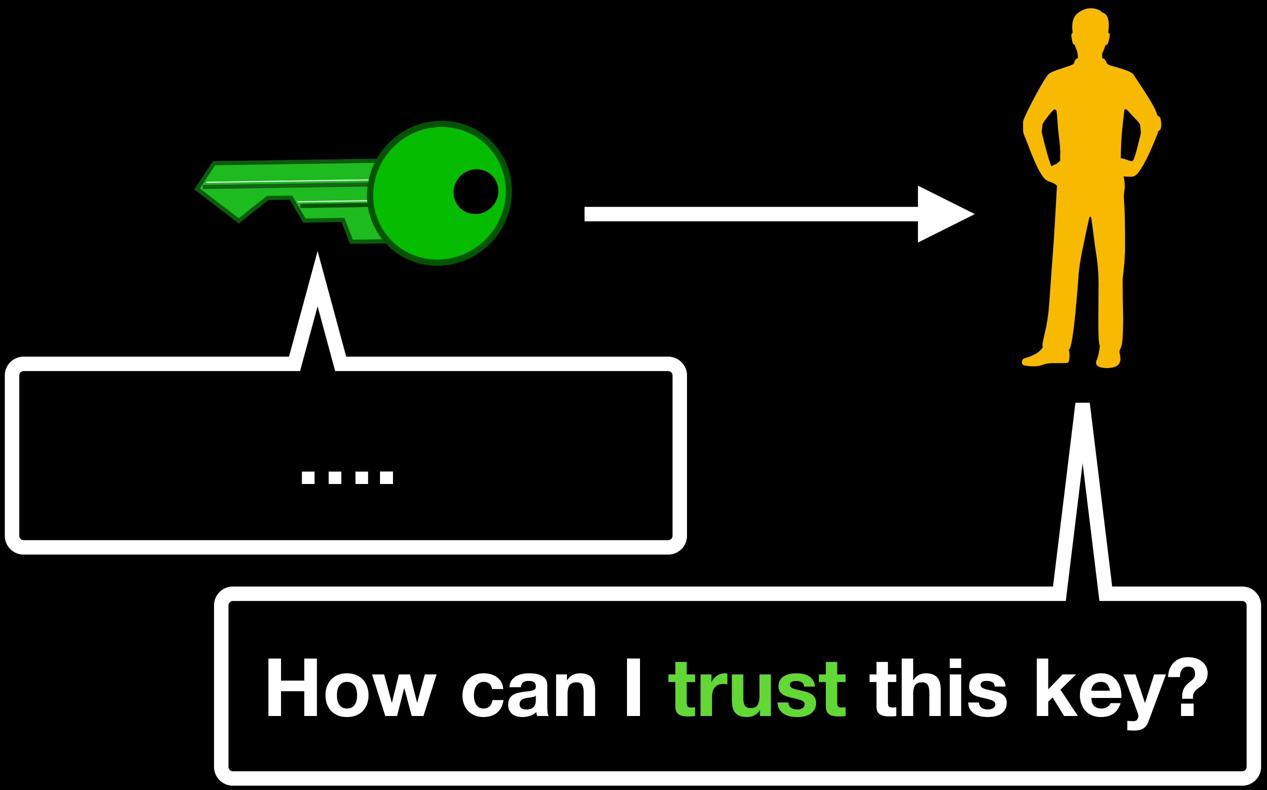


For the final submission, you should submit your (thoroughly documented) code along with a plain-text (no Word or PDF) README file. In this file, you should describe your high-level approach, the challenges you faced, a list of properties/features of your design that you think is good, and an overview of how you tested your code. You MUST submit a "shell" `runme.sh` script that generates the executable file `351dns:` you choose your language so you have to prepare it. You should submit your project to Project2 folder in the Mycourses Dropbox. Specifically, place all of your code and README files into one folder (Project2) and zip it (TEAMNAME.zip) and upload it to the Dropbox.

Public Key Cryptography



Public Key Infrastructure



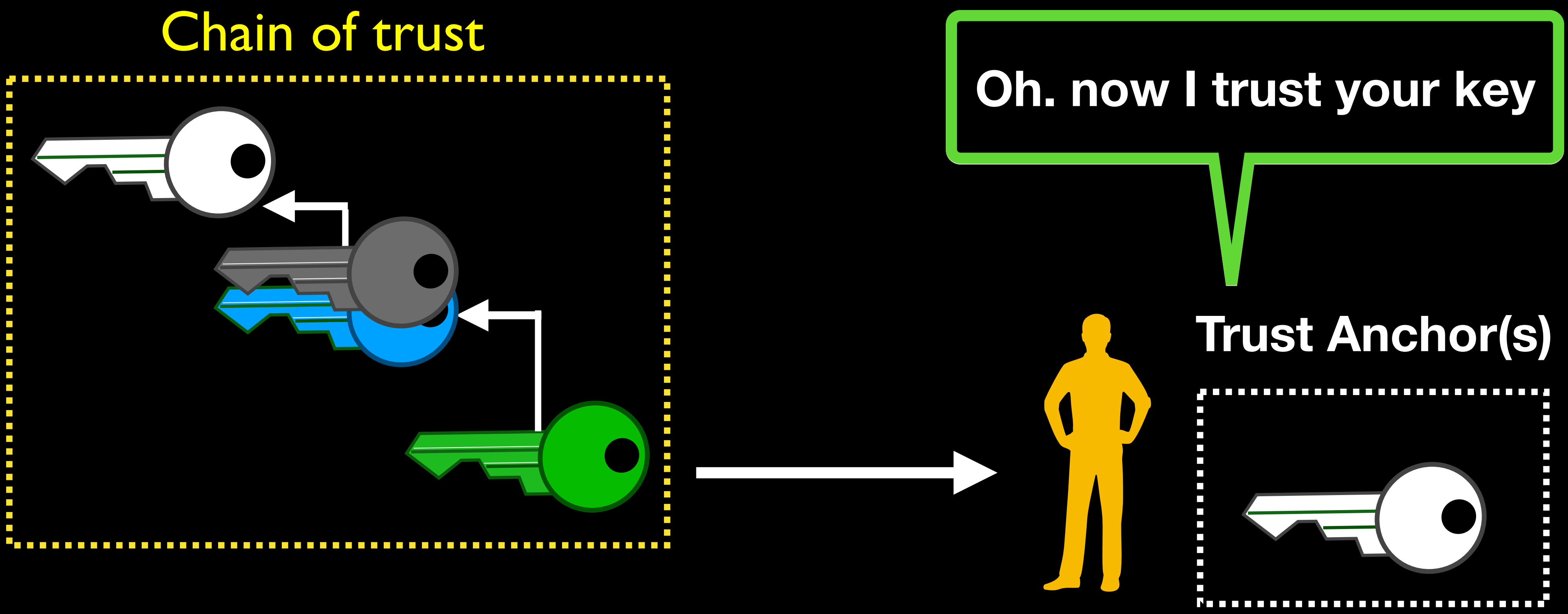
....

How can I **trust** this key?

PKI

Public Key Infrastructure (PKI) supports the (1) distribution and (2) identification of public key

Hierarchical
Public Key Infrastructure



Chain of trust

Oh. now I trust your key

Trust Anchor(s)

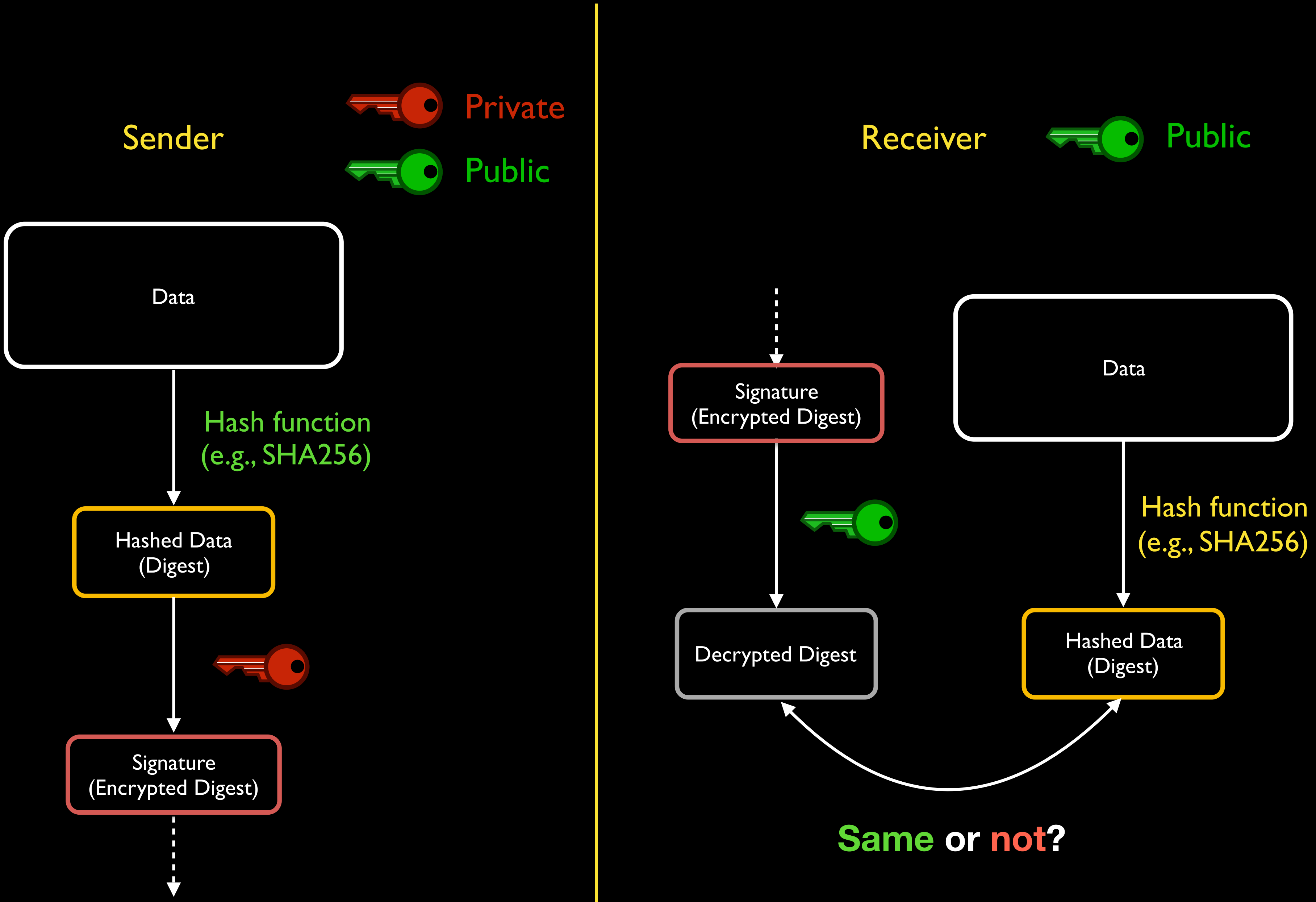
Hierarchical PKI

Many secure protocols in the Internet rely on hierarchical PKI

Something to plug (1)
New course – Spring 2019

- I'll be teaching a new (Graduate-Level) Seminar Course in the Spring 2019
  - GCCIS-CSCI-759 Topics In System
  - Title: Public Key Infrastructure and Network Security
- Security is really important! (who doesn't say..)

Again,
Signing and verification process



Sender

Private

Public

Data

Hash function
(e.g., SHA256)

Hashed Data
(Digest)

Signature
(Encrypted Digest)

Receiver

Public

Signature
(Encrypted Digest)

Data

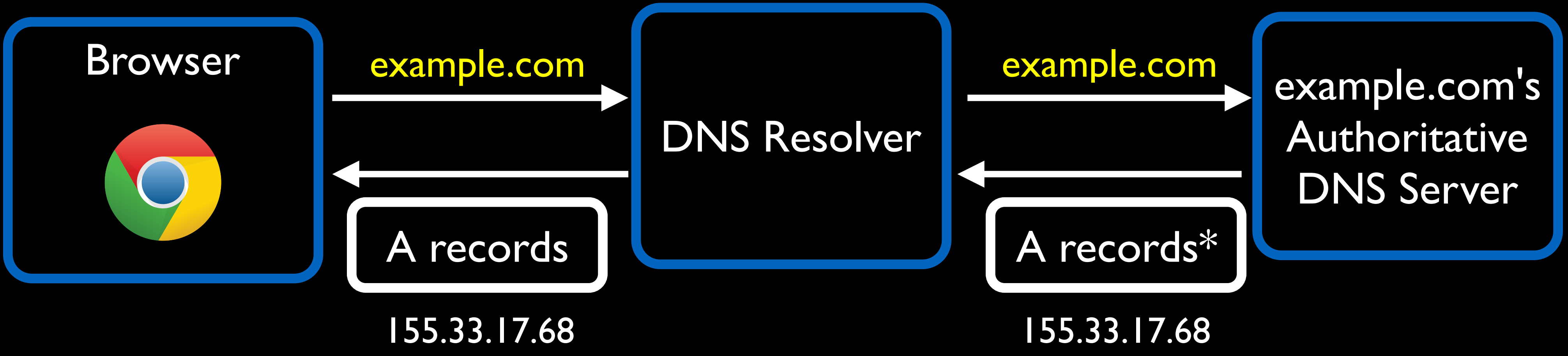
Hash function
(e.g., SHA256)

Decrypted Digest

Hashed Data
(Digest)

Same or **not**?

Domain Name System (DNS)



Browser

example.com

DNS Resolver

example.com

example.com's Authoritative DNS Server

A records

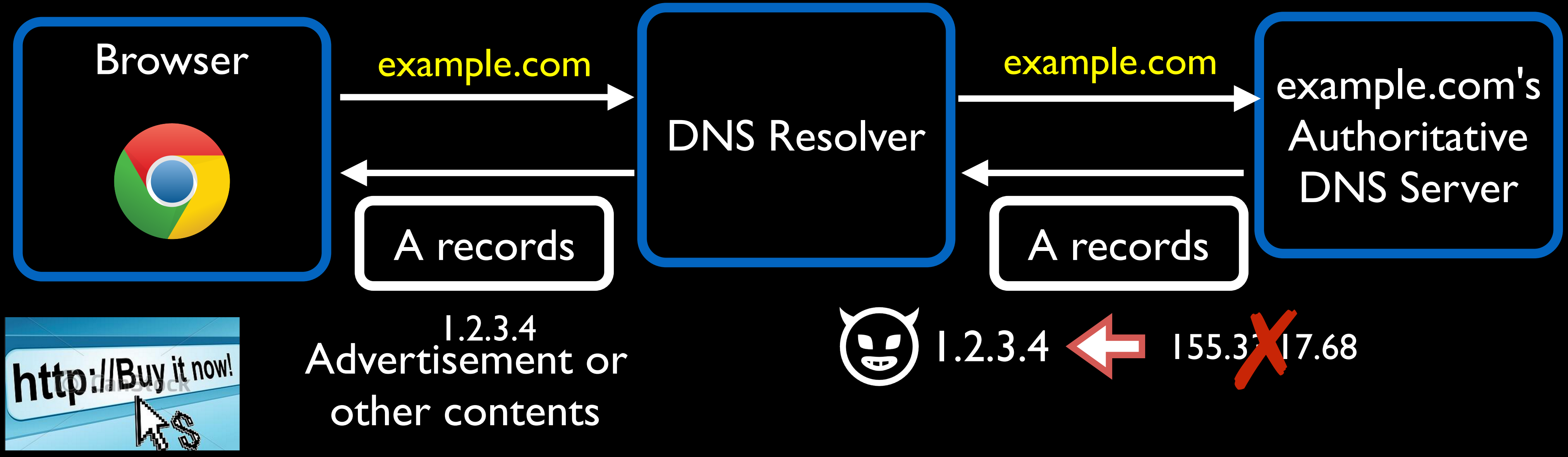
155.33.17.68

A records*

155.33.17.68

*A record: one of the DNS records that contains IP addresses of a domain name

DNS Spoofing



Browser

example.com

A records

DNS Resolver

example.com

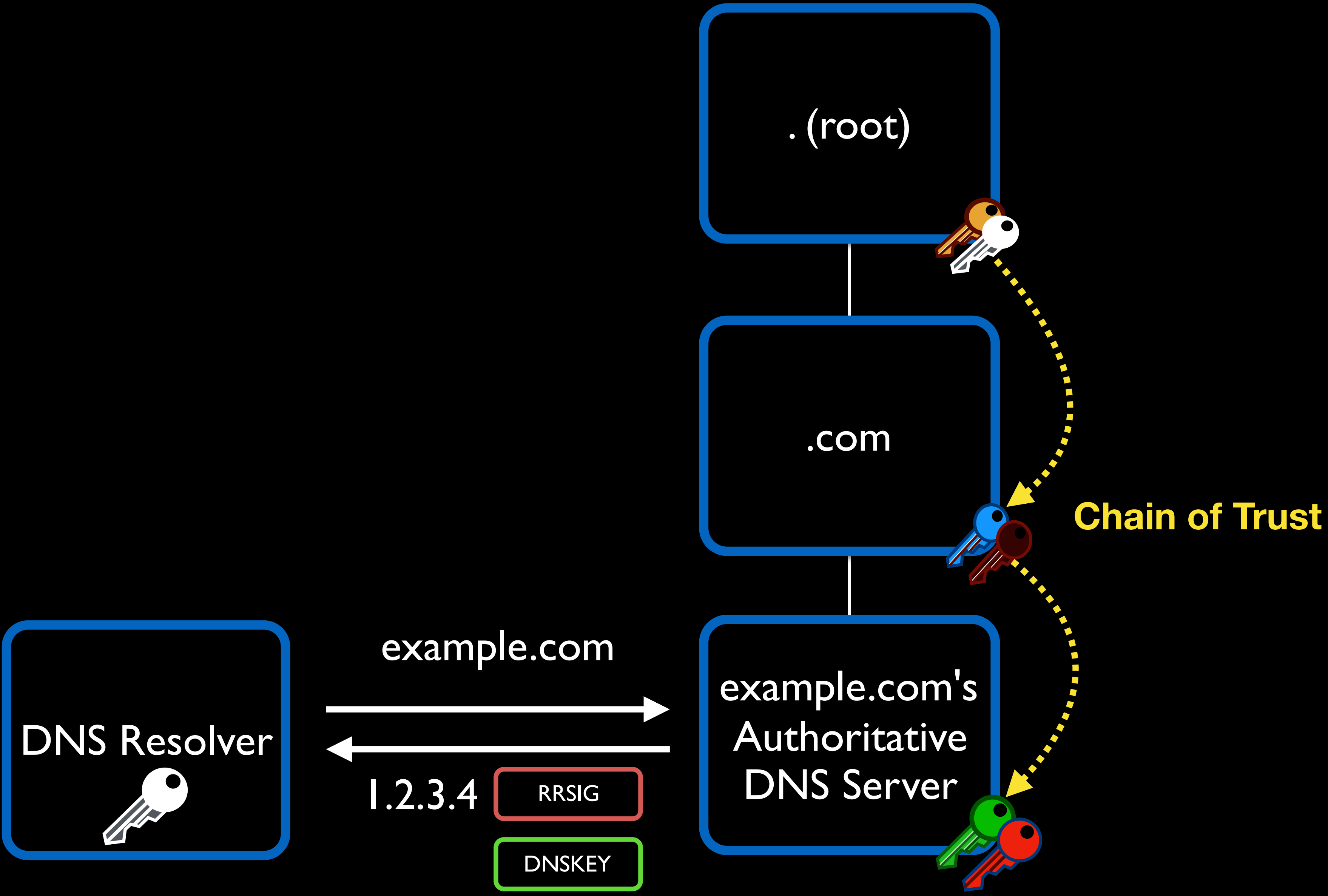
example.com's Authoritative DNS Server

A records

1.2.3.4 ← ~~155.33.17.68~~

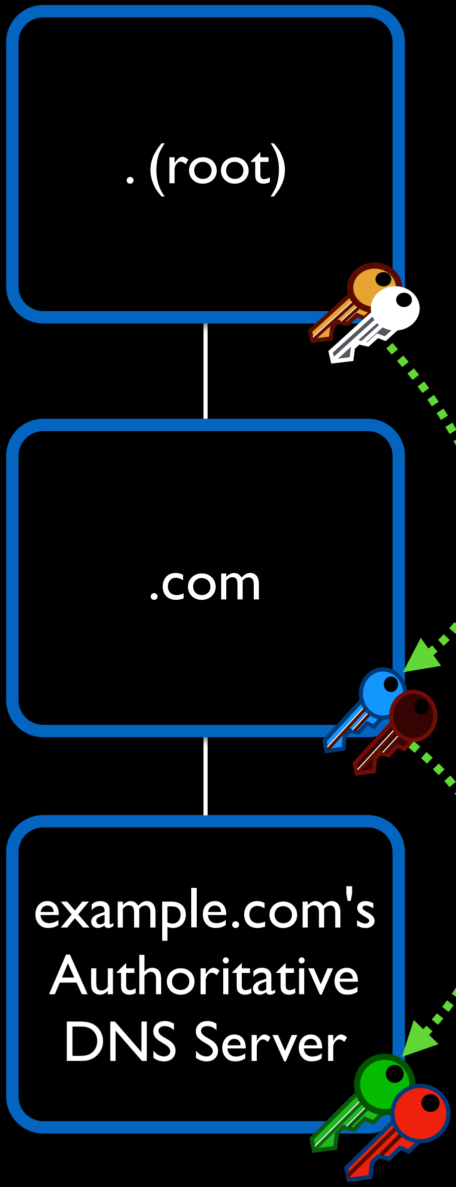
1.2.3.4
Advertisement or other contents

DNSSEC 101

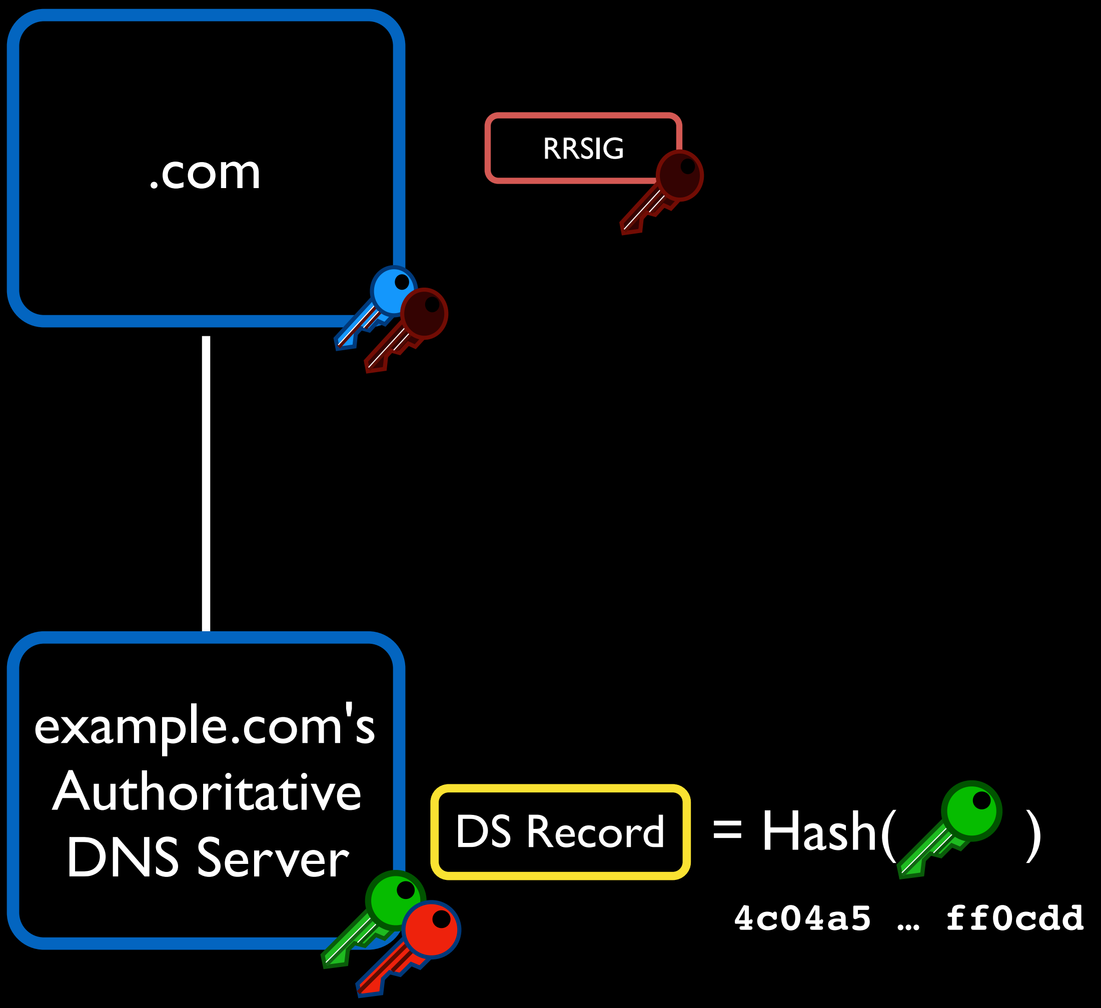


. (root)
.com
Chain of Trust
DNS Resolver
example.com
1.2.3.4
RRSIG
DNSKEY
example.com's Authoritative DNS Server

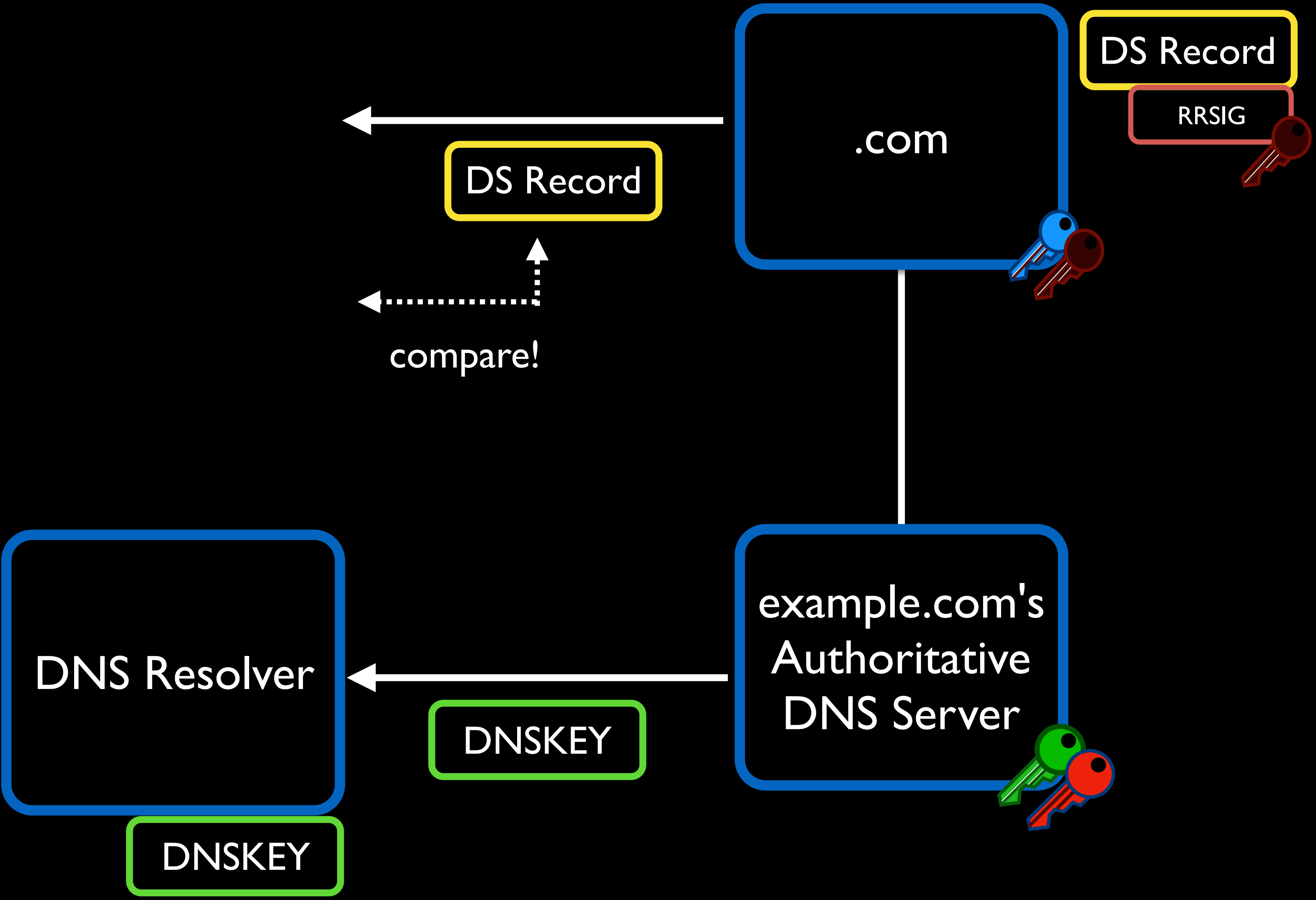
DNSSEC 101



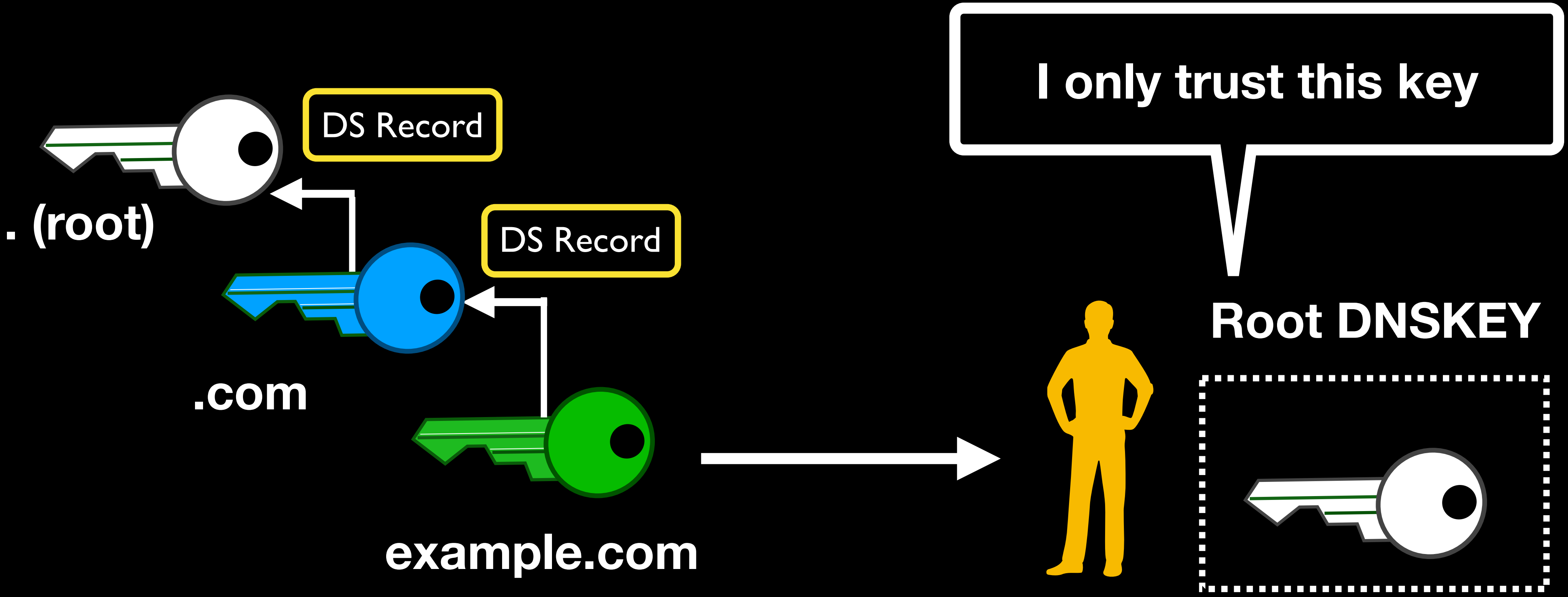
DNSSEC 101: Hierarchy Builds Trust



DNSSEC 101: Hierarchy Builds Trust



DNSSEC: Hierarchical PKI



DS Record

. (root)

DS Record

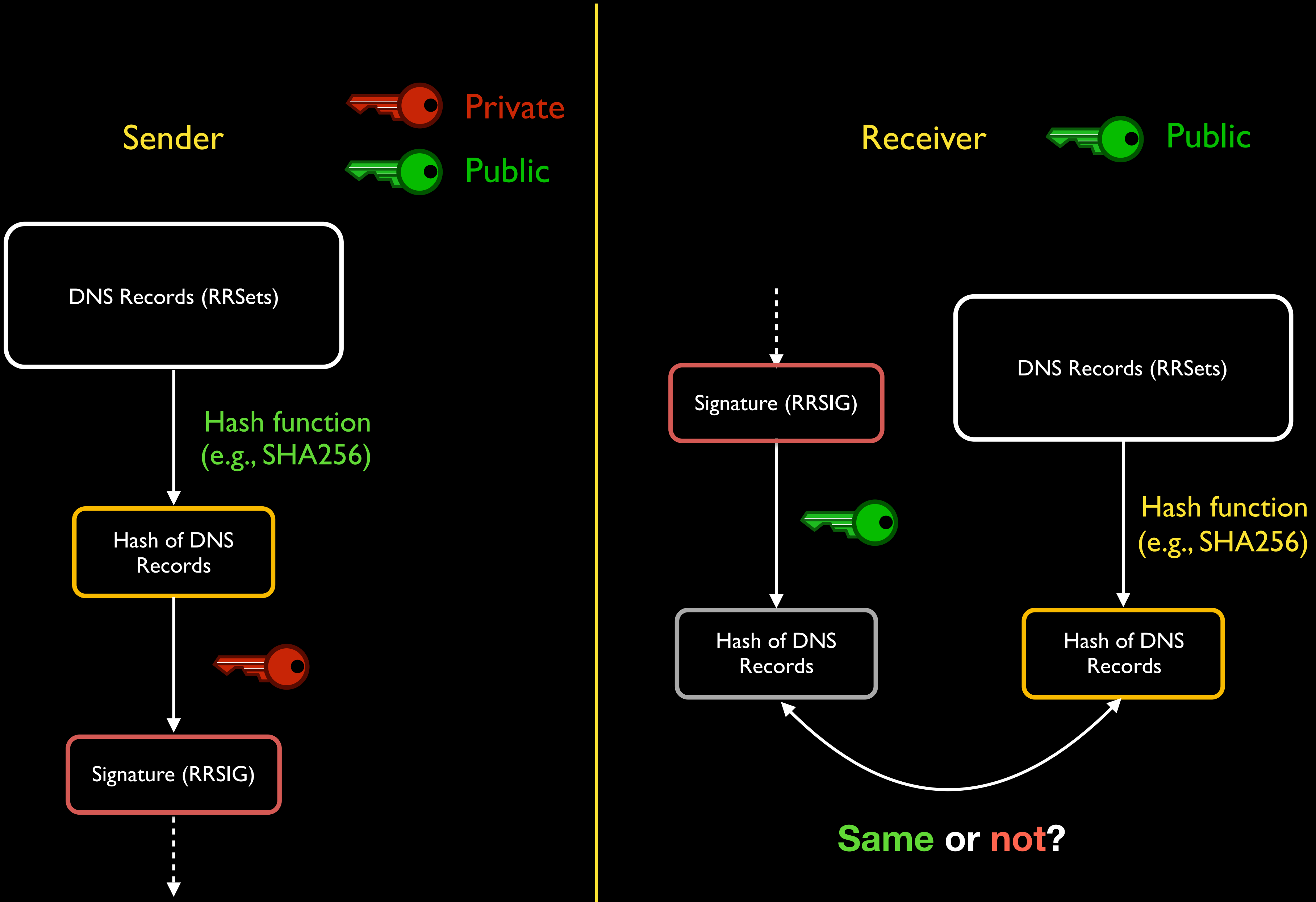
.com

example.com

I only trust this key

Root DNSKEY

Signing and verification process in DNSSEC



Sender

Private

Public

DNS Records (RRSets)

Hash function (e.g., SHA256)

Hash of DNS Records

Signature (RRSIG)

Receiver

Public

Signature (RRSIG)

DNS Records (RRSets)

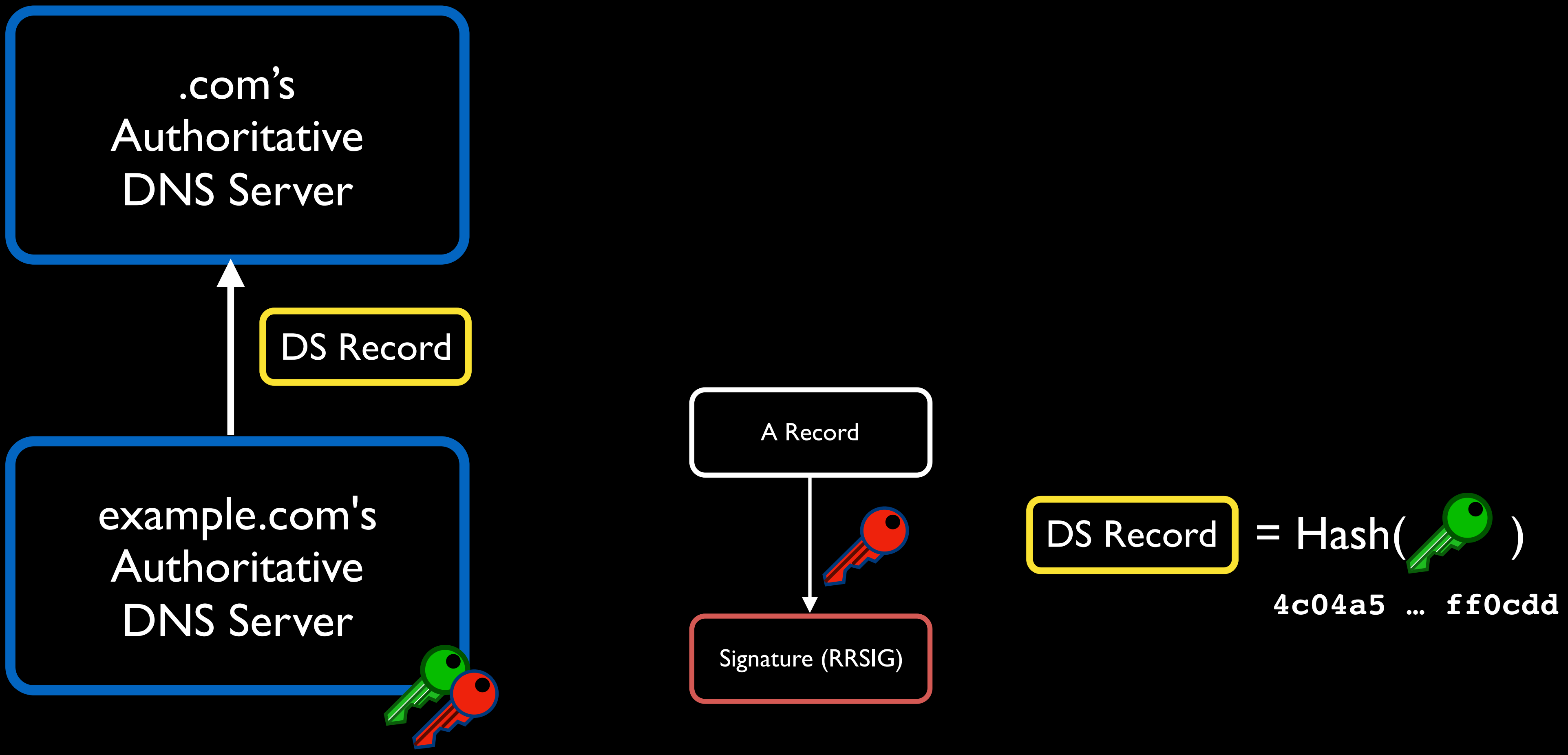
Hash function (e.g., SHA256)

Hash of DNS Records

Hash of DNS Records

Same or not?

Two DNSKEYs



.com's Authoritative DNS Server

DS Record

example.com's Authoritative DNS Server

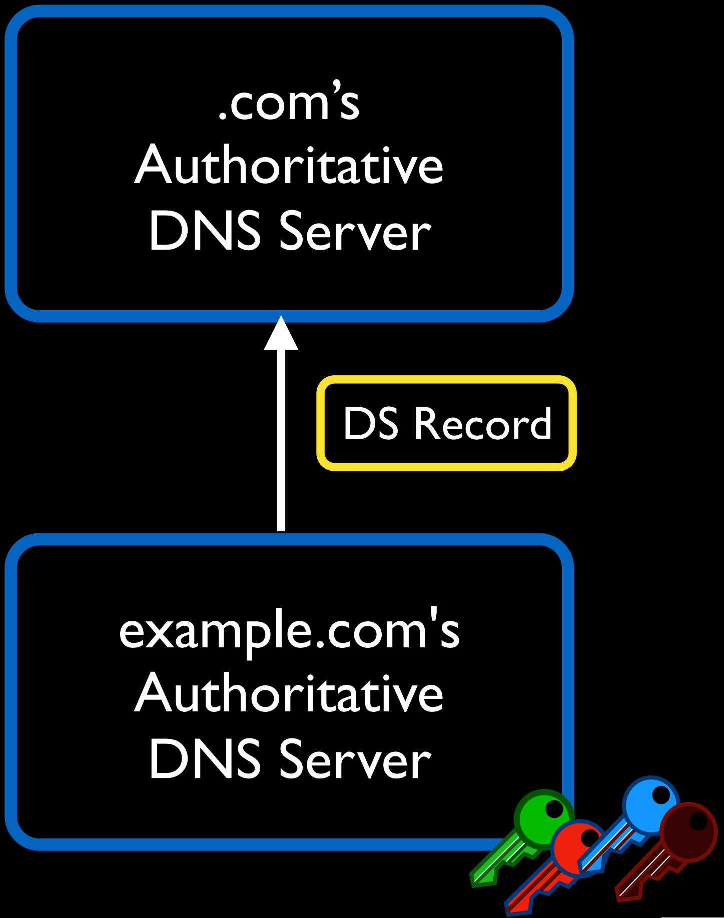
A Record

Signature (RRSIG)

DS Record = Hash( )

`4c04a5 … ff0cdd`

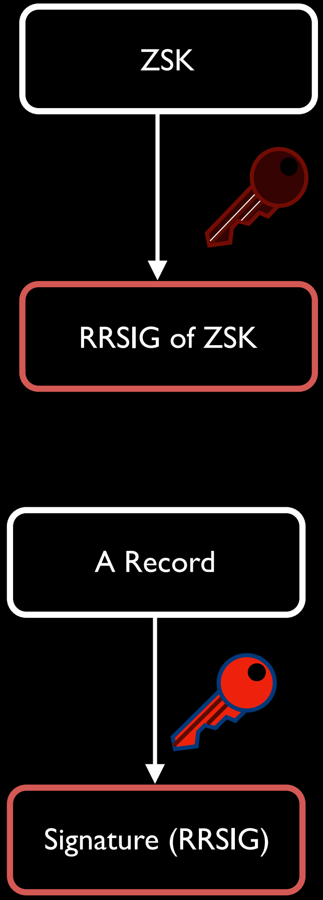
Two DNSKEYs



.com’s Authoritative DNS Server

DS Record

example.com's Authoritative DNS Server



ZSK

RRSIG of ZSK

A Record

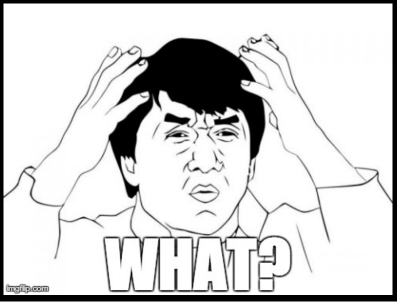
Signature (RRSIG)

DS Record = Hash(🔑)

`4c04a5 … ff0cdd`

🔑 Key Signing Key (KSK)

🔑 Zone Signing Key (ZSK)



Two DNSKEYs
Are you serious? Why?

example.com's
Authoritative
DNS Server

Key Signing Key (KSK)

Zone Signing Key (ZSK)

Only used to generate the signature of "ZSK"
=> Not heavily used
=> Stored in the offline storage (e.g., HSM)
=> More secure!

Frequently used to generate signatures for the DNS records
=> should be loaded on the memory
=> Not secure

Revisiting
3 Principles of Information Security

- Confidentiality
- Integrity
- Availability

Motivation of this research

Even though DNSSEC was introduced 20 years ago!

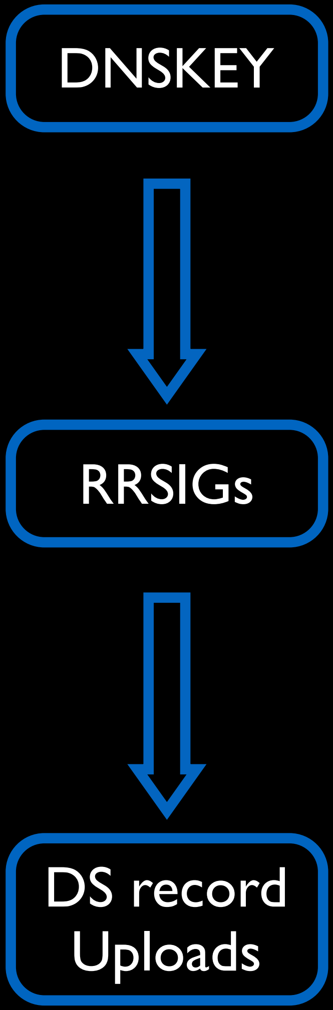
Research Questions

How **well** is today's DNSSEC PKI ecosystem **managed**?

If it is **not** managed well, then **why?**

How can we **improve** it?

How to Deploy DNSSEC (Correctly)



DNSKEY

RRSIGs

DS record Uploads

(1) Have DNSKEYs

(2) Generate Signatures

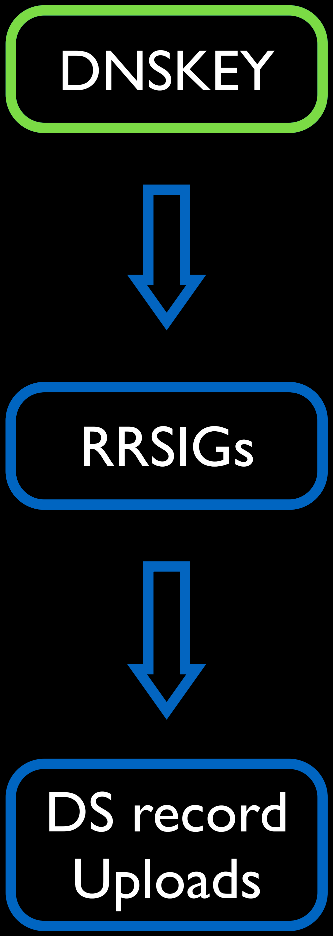
(3) Generate and upload DS record to the parent zone

Scanning All Domains

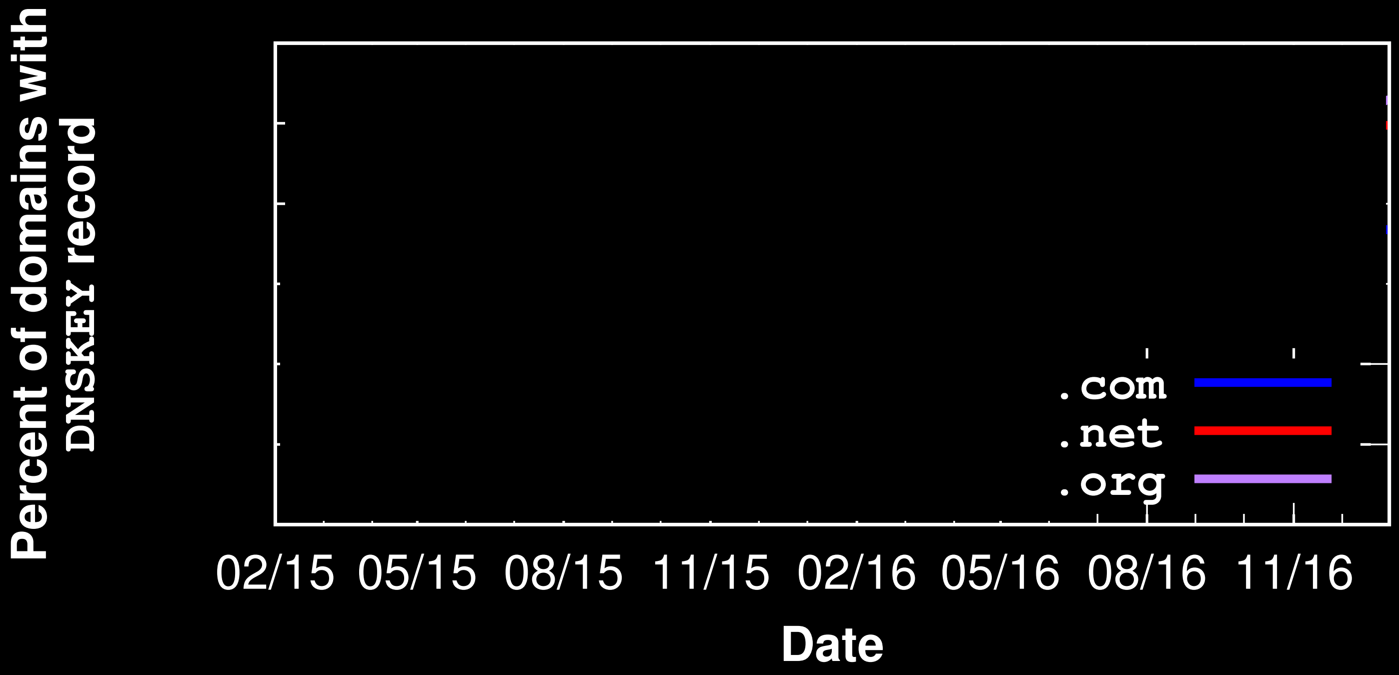
	Daily Scans
TLDs	.com, .org., .net
# of domains	147M domains
Interval	every day
Period	2015/03/01 ~ 2016/12/31

Over 750 billion DNS Records

How DNSSEC is deployed

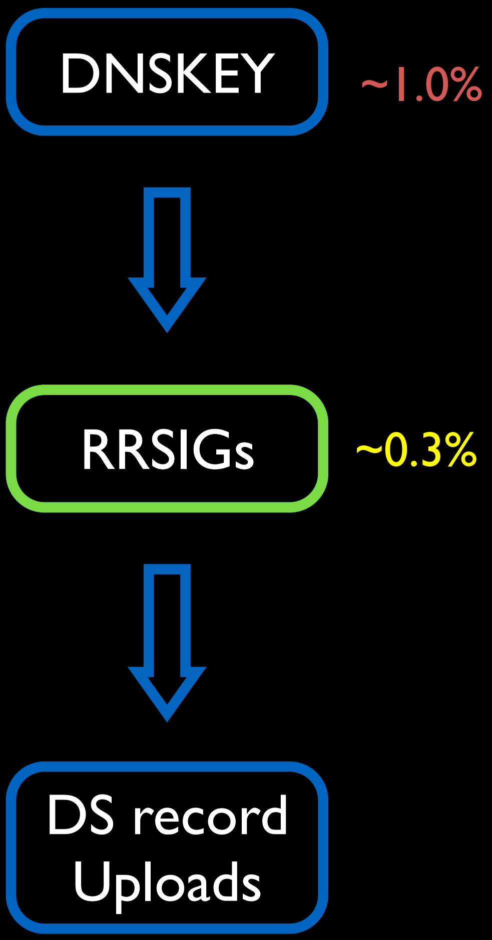


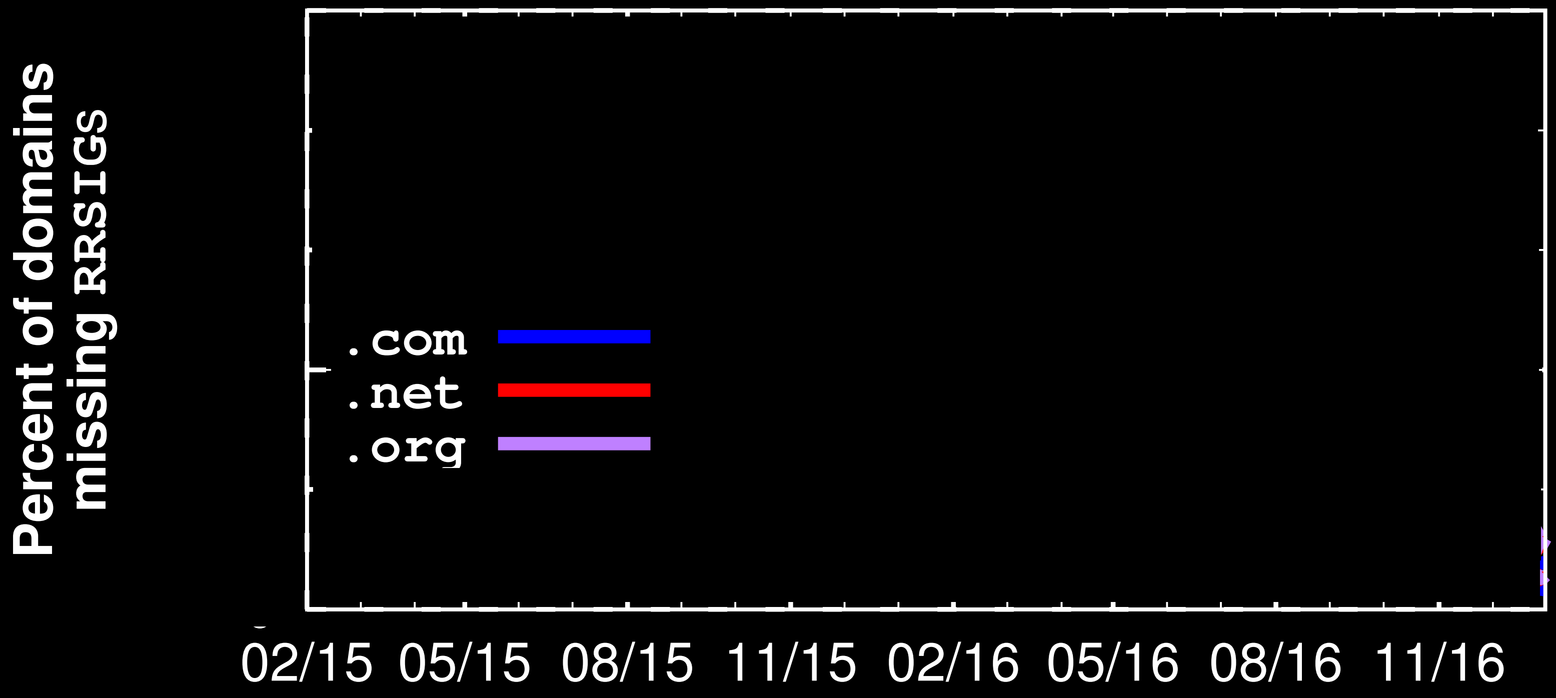
~1.0%



Deployment DNSSEC deployment is rare, but growing

Generating Signatures

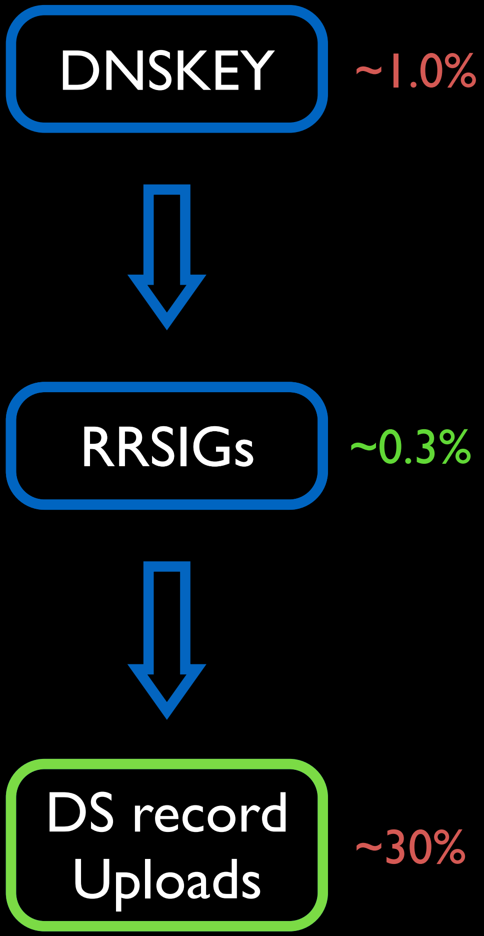




Missing RRSIGs

RRSIGs are rarely missing (0.3%)

Building a Chain of Trust



DNSKEY ~1.0%

RRSIGs ~0.3%

DS record Uploads ~30%

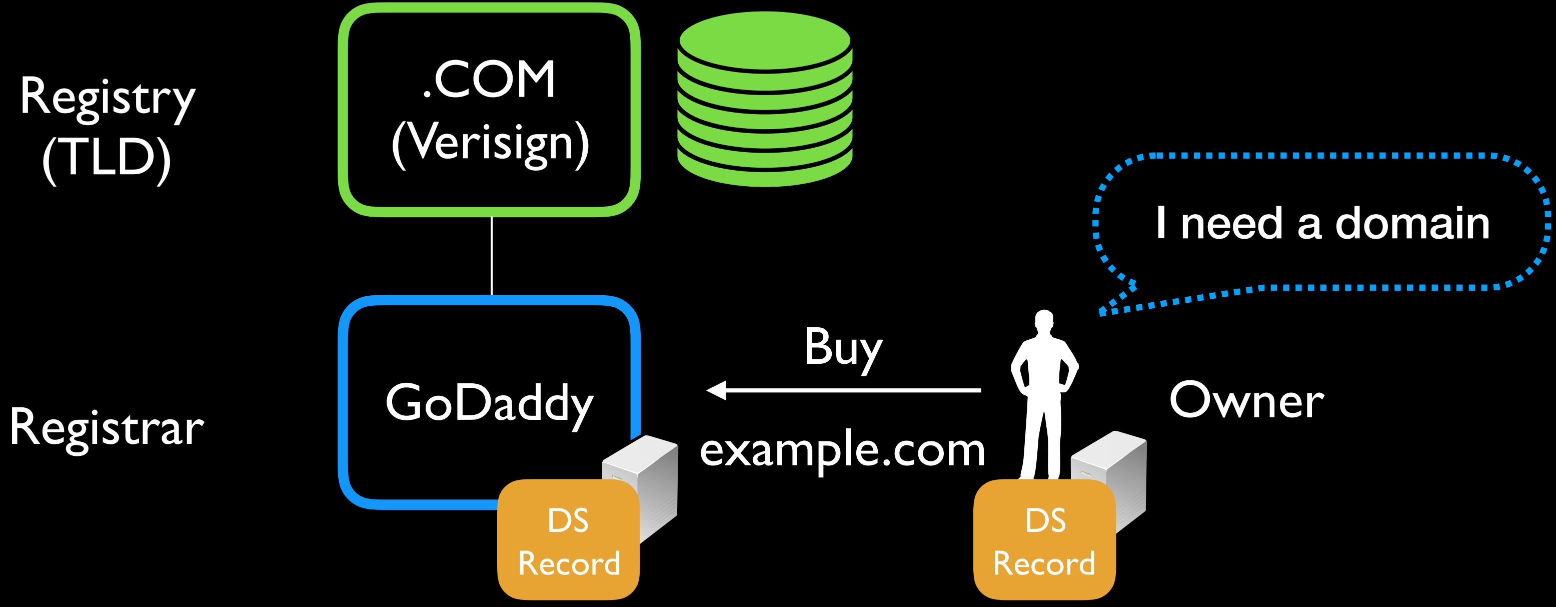
DS Records

Nearly 30% of domains DO NOT upload DS records!

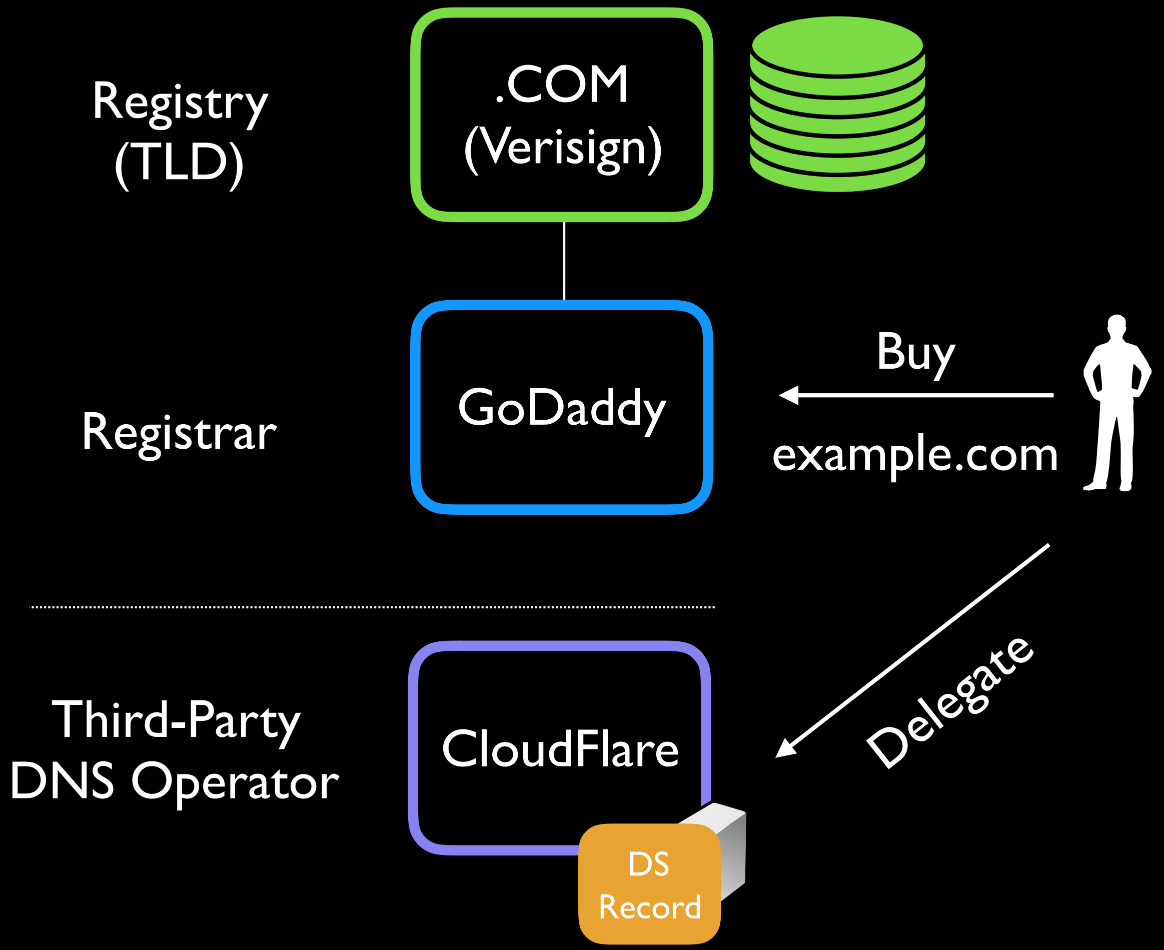
Why does DNSSEC deployment remain so small?

Why are 30% of domains w/o DS records?

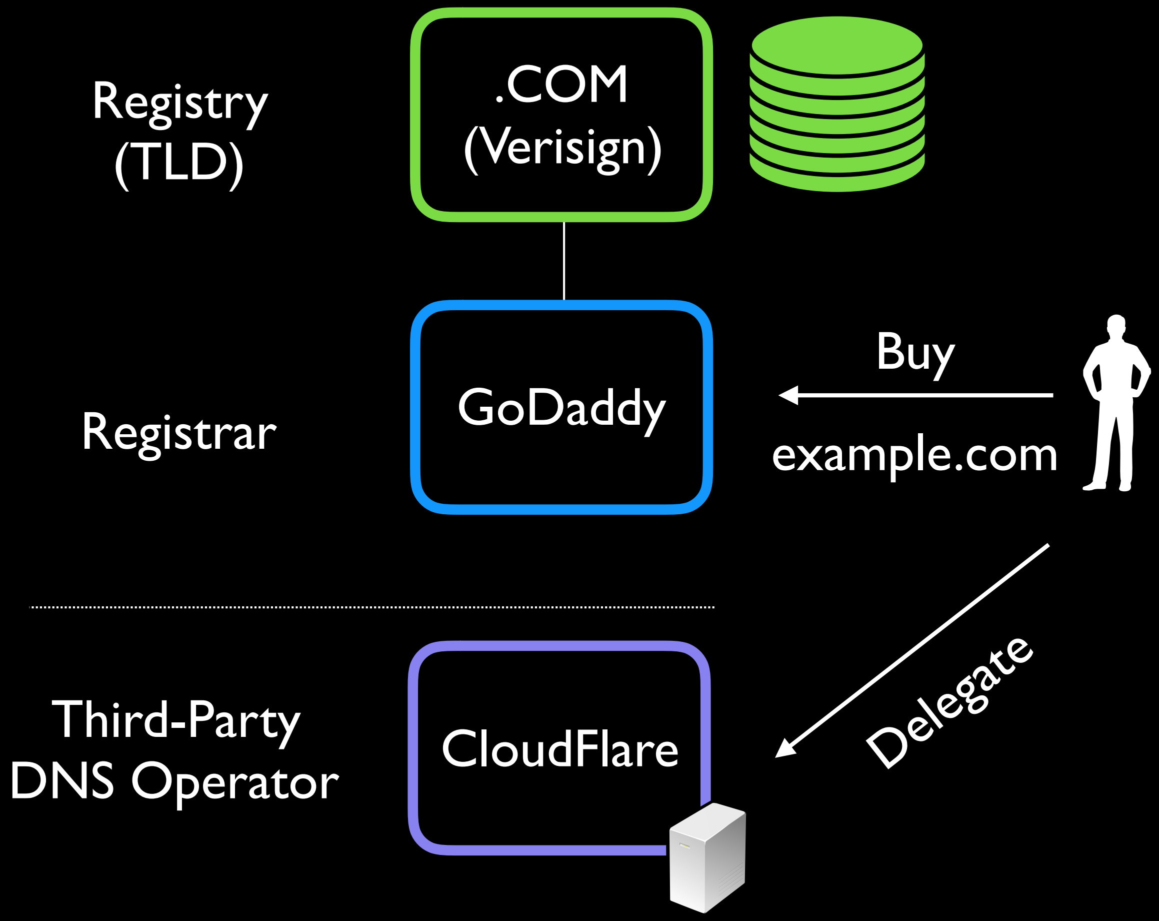
Deploying a DNSSEC on Your Server



Third Party DNS Operator



Third Party DNS Operator



Registry
(TLD)

.COM
(Verisign)

Registrar

GoDaddy

Buy

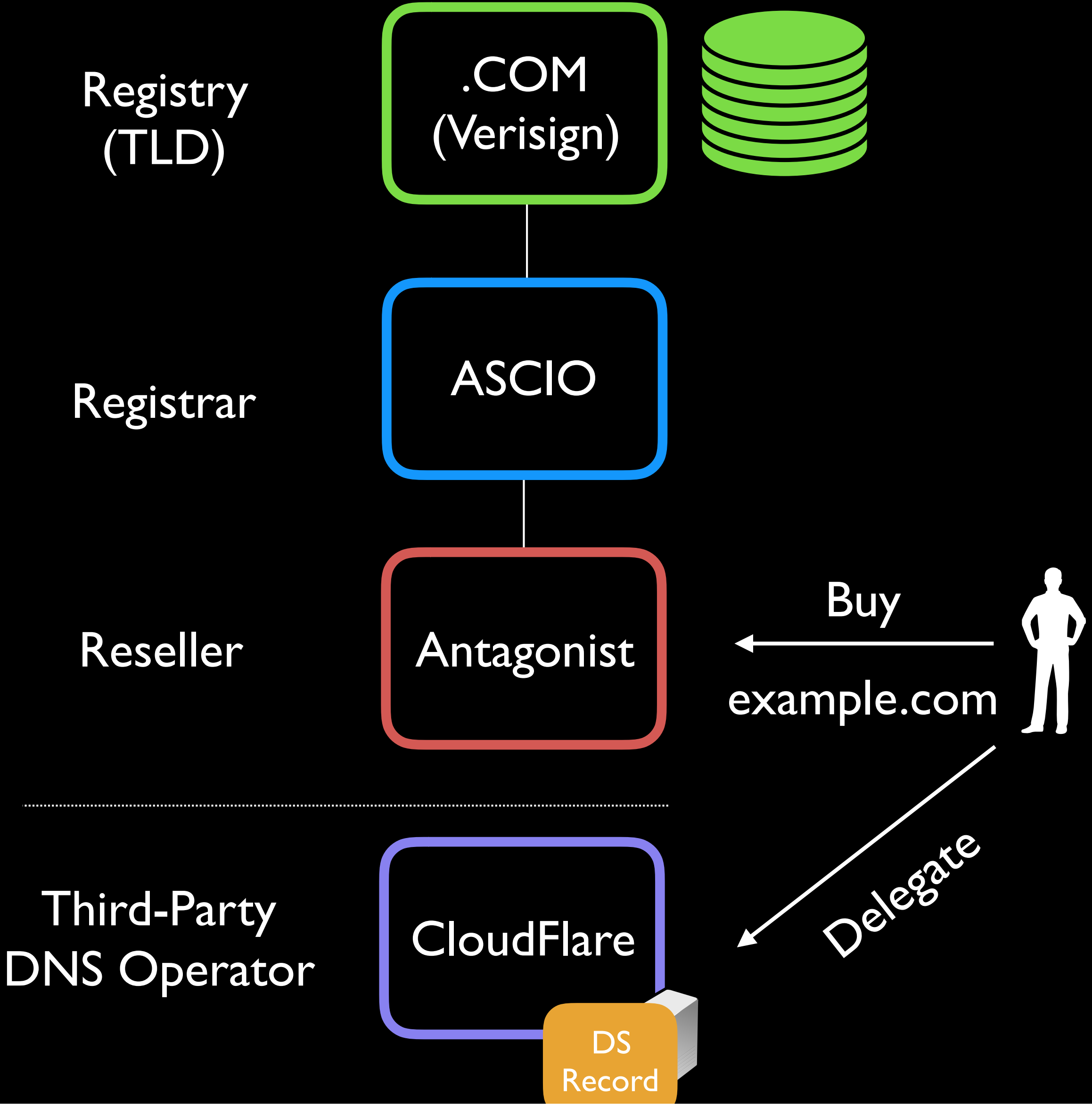
example.com

Third-Party
DNS Operator

CloudFlare

Delegate

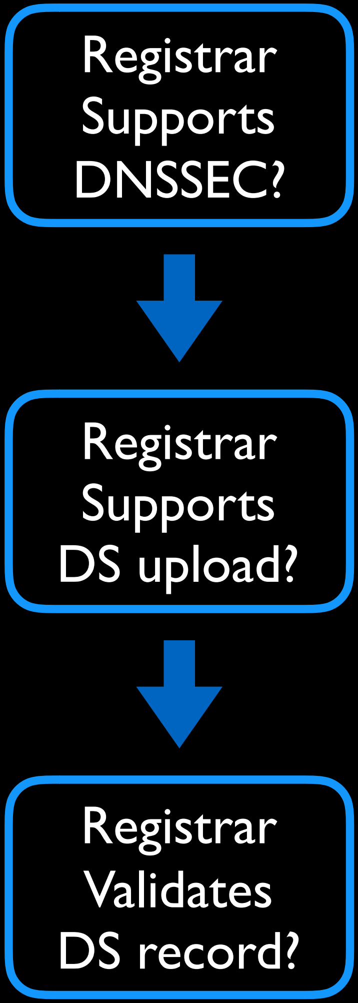
Reseller


Registry
(TLD)
.COM
(Verisign)
Registrar
ASCIO
Reseller
Antagonist
Buy
example.com
Delegate
Third-Party
DNS Operator
CloudFlare
DS
Record

Checking Registrar’s DNSSEC Policy

Registrar
DNS Operator

Owner
DNS Operator

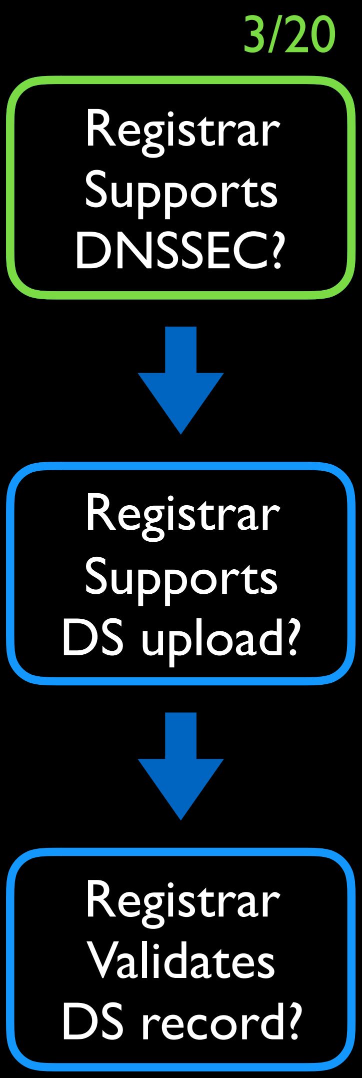


Registrar
Supports
DNSSEC?

Registrar
Supports
DS upload?

Registrar
Validates
DS record?

Popular Registrar’s DNSSEC Policy



3/20

Registrar Supports DNSSEC?

Registrar Supports DS upload?

Registrar Validates DS record?

Registrar (Authoritative Nameserver)	Registrar DNS Operator
GoDaddy (domaincontrol.com)	●
NameCheap (registrar-servers.com)	⚠
OVH (ovh.net)	●
HostGator (hostgator.com)	✗
Amazon (aws-dns)	✗
Google (googledomains.com)	✗
123-reg (123-reg.co.uk)	✗
RightSide (name.com)	✗
eNom (name-services.com)	✗
NameBright (namebrightdns.com)	✗
DreamHost (dreamhost.com)	✗
The others (10 registrars)	✗

⚠ *Some nameservers don’t support DNSSEC*

Anecdotal Examples

Experiment	Result
We saw the DNSKEY deployed (but not DS records) so asked why you don't upload DS records.	[1] They removed a DNSSEC menu [2] "*Most people do not understand DNS, so imagine the white faces when I mention DNSSEC*"
We asked a registrar to upload a DS record by email from the different email address than the one that registered	It was installed successfully
We asked a registrar to upload a DS record to our domain via web live chat	It was installed on *someone else's* domain due to a mistake by the customer service agent

Details of the Last Example

3:45:32 PM tijay hg-dnssec.com 3600 IN DS 2371 13 2 129f34c04ac58ece5218b9894148304a736a63757f58ff0cddd9b8df4989

3:56:05 PM Jeniffer S Awesome! one moment

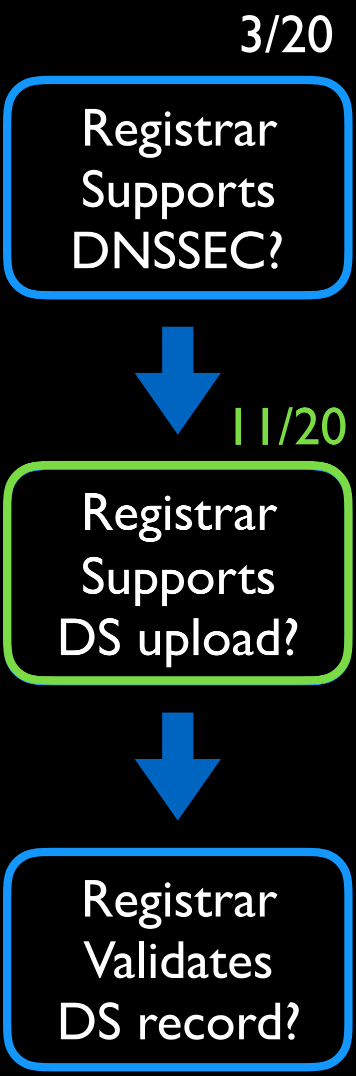
3:56:09 PM Jeniffer S I have now save the request information! Manage DNSSEC paananenmusic.com Record added successfully. It can take 4-8 hours for DNS to propagate

3:57:19 PM tijay paananenmusic.com?

3:57:28 PM tijay my domain is hg-dnssec.com?

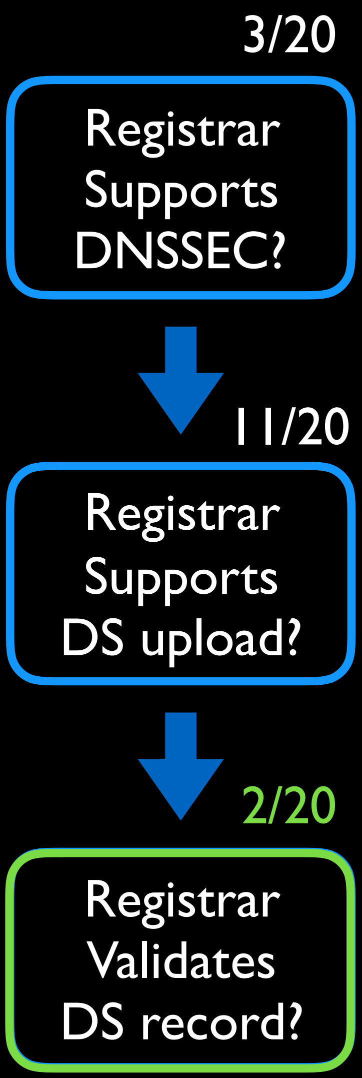
3:58:41 PM Jeniffer S I apologize, you are right, silly me, one moment

Popular Registrar’s DNSSEC Policy


3/20
Registrar Supports DNSSEC?
11/20
Registrar Supports DS upload?
Registrar Validates DS record?

Registrar (Authoritative Nameserver)	Owner DNS Operator	
	DS Upload	
	Web	Email
GoDaddy (domaincontrol.com)	●	—
NameCheap (registrar-servers.com)	●	—
OVH (ovh.net)	●	—
HostGator (hostgator.com)	●	—
Amazon (aws-dns)	●	—
Google (googledomains.com)	●	—
123-reg (123-reg.co.uk)	●	—
RightSide (name.com)	●	—
eNom (name-services.com)	✗	●
NameBright (namebrightdns.com)	✗	●
DreamHost (dreamhost.com)	✗	●
The others (10 registrars)	✗	✗

Popular Registrar's DNSSEC Policy



3/20

Registrar Supports DNSSEC?

11/20

Registrar Supports DS upload?

2/20

Registrar Validates DS record?

Registrar (Authoritative Nameserver)	Owner DNS Operator DS Upload		DS Validation
	Web	Email	
GoDaddy (domaincontrol.com)	●	—	✗
NameCheap (registrar-servers.com)	●	—	✗
OVH (ovh.net)	●	—	●
HostGator (hostgator.com)	●	—	✗
Amazon (aws-dns)	●	—	✗
Google (googledomains.com)	●	—	✗
123-reg (123-reg.co.uk)	●	—	✗
RightSide (name.com)	●	—	✗
eNom (name-services.com)	✗	●	✗
NameBright (namebrightdns.com)	✗	●	✗
DreamHost (dreamhost.com)	✗	●	●
The others (10 registrars)	✗	✗	✗

Summary: Registrar's DNSSEC Support

	DNS Operator	# of Registrar	What this means to you
Support DNSSEC?	Registrar	3/20	If you don't want to run your own name server, most of the time, you CAN'T deploy DNSSEC (17/20)
	Owner	11/20	If you do want run your own nameserver, still you CAN'T deploy DNSSEC for 9/20
Check DS Validation	Owner	2/11	If you happen to upload an incorrect DS record, your domain will be inaccessible

Why are DNSSEC support of registrars so rare?

Cost of Managements

<table>
<tr><th></th><th>DNS</th><th>DNSSEC</th></tr>
<tr><td><b># of Records</b></td><td colspan="2">DNSSEC introduces
much more records
(e.g., need signatures for each record)</td></tr>
<tr><td><b>Size of Records</b></td><td colspan="2">Signatures are usually 3~6 times larger
than non-DNSSEC records*</td></tr>
<tr><td><b>Management</b></td><td>-</td><td>Strong Key
Unique Key
Rollover</td></tr>
</table>

Operational Cost

Operational cost of DNSSEC is higher than that of DNS

*DNSSEC and Its Potential for DDoS Attacks (IMC’14)

Case Study: Registrar's Policy

	Registrar DNS Operator		Owner DNS Operator	
	Support DNSSEC	Pricing	Support DNSSEC	Pricing
# of registrars	3	Free: 2	11	Free
		Paid: 1		

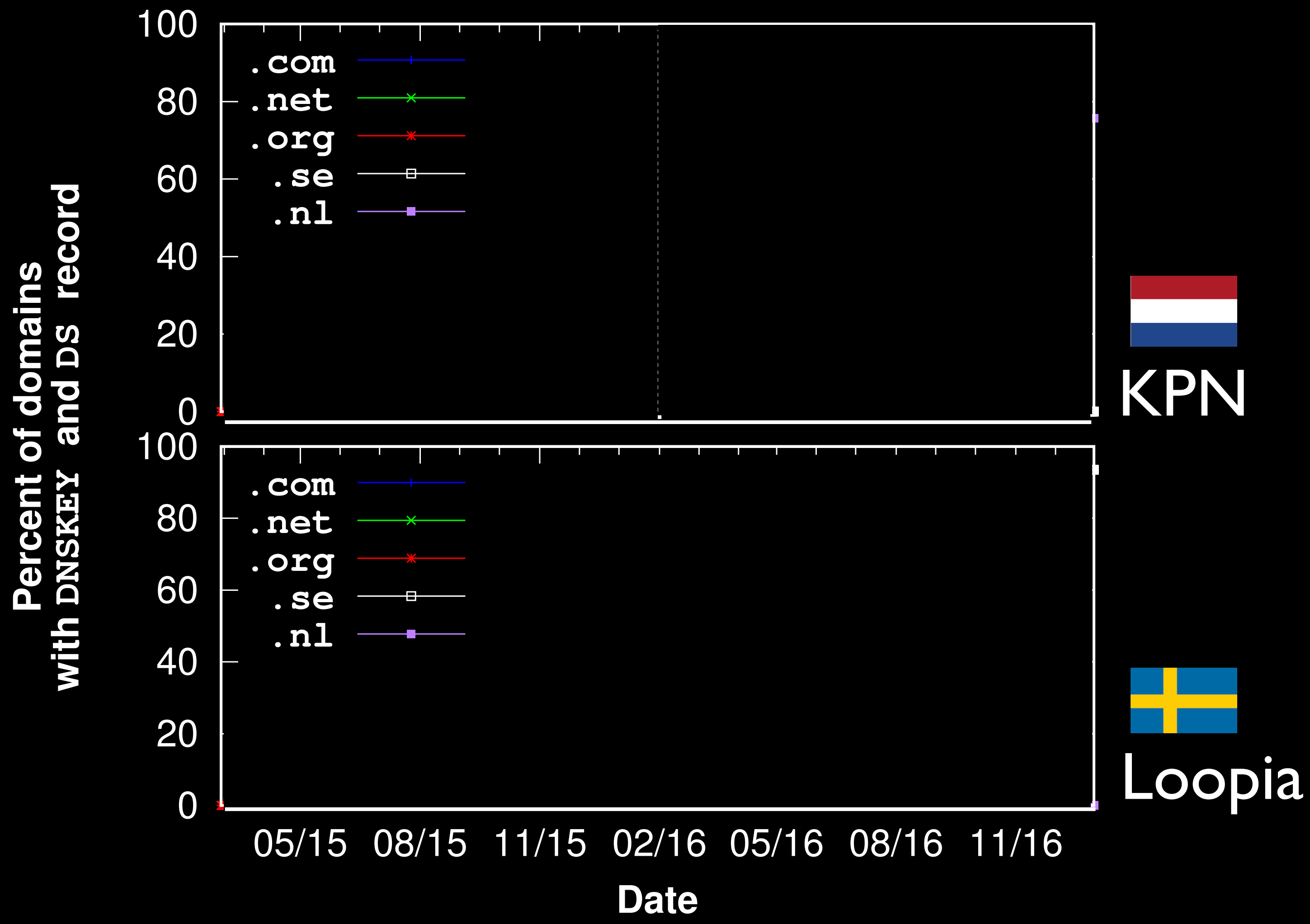
Registrars manage all DNS records

Registrars DO NOT need to manage DNS records at all

Scanning All Domains

TLD	Measurement Period (Daily Scan)	Domains	
		Total	Percent w/ DNSKEY
.com	2015/03/01 ~ 2016/12/31	118,147,199	0.7%
.net	2015/03/01 ~ 2016/12/31	13,773,903	1.0%
.org	2015/03/01 ~ 2016/12/31	9,682,750	1.1%
.nl	2016/02/09 ~ 2016/12/31	5,674,208	51.6%
.se	2016/06/07 ~ 2016/12/31	1,388,372	46.7%

Case Study: Financial Incentives

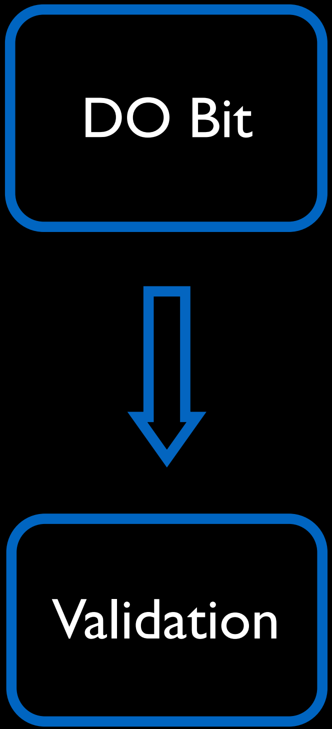


Financial Incentive

Financial gain is a huge incentive for deploying DNSSEC to certain domains

DNSSEC Resolvers

Correct Deployment for Resolvers



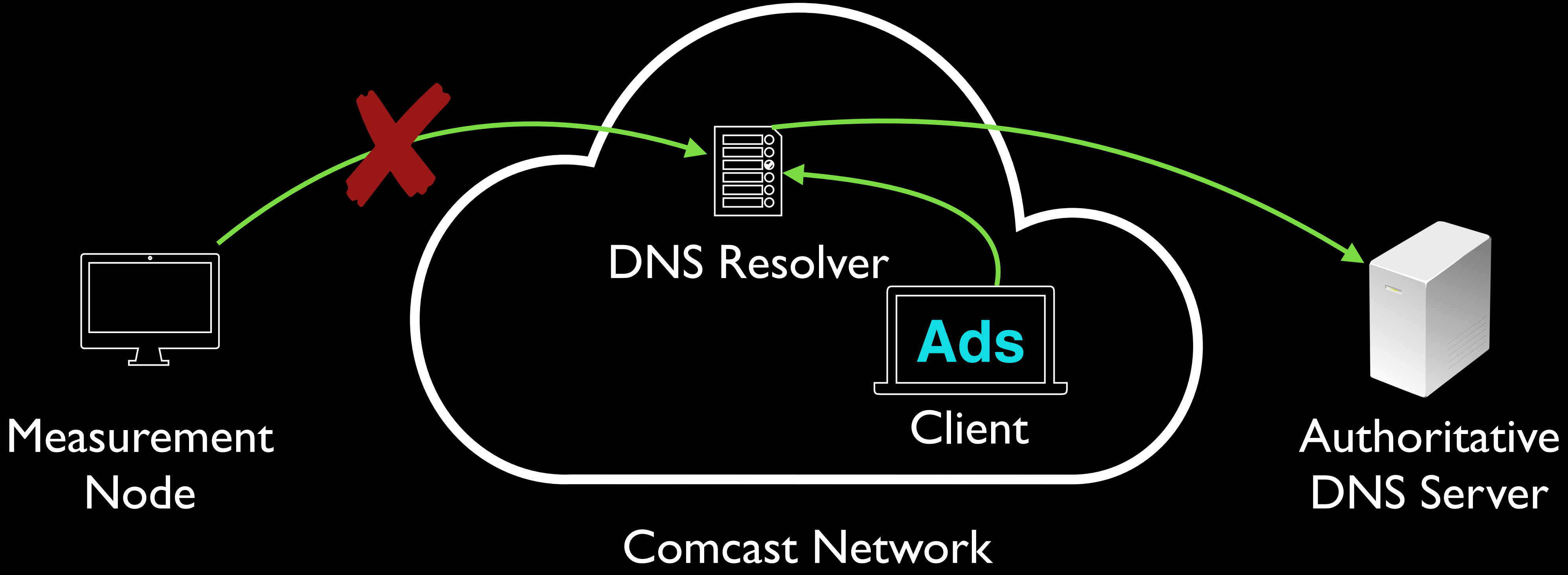
DO Bit

(1) DNSSEC OK bit in the header

Validation

(2) Validate DNSSEC Records

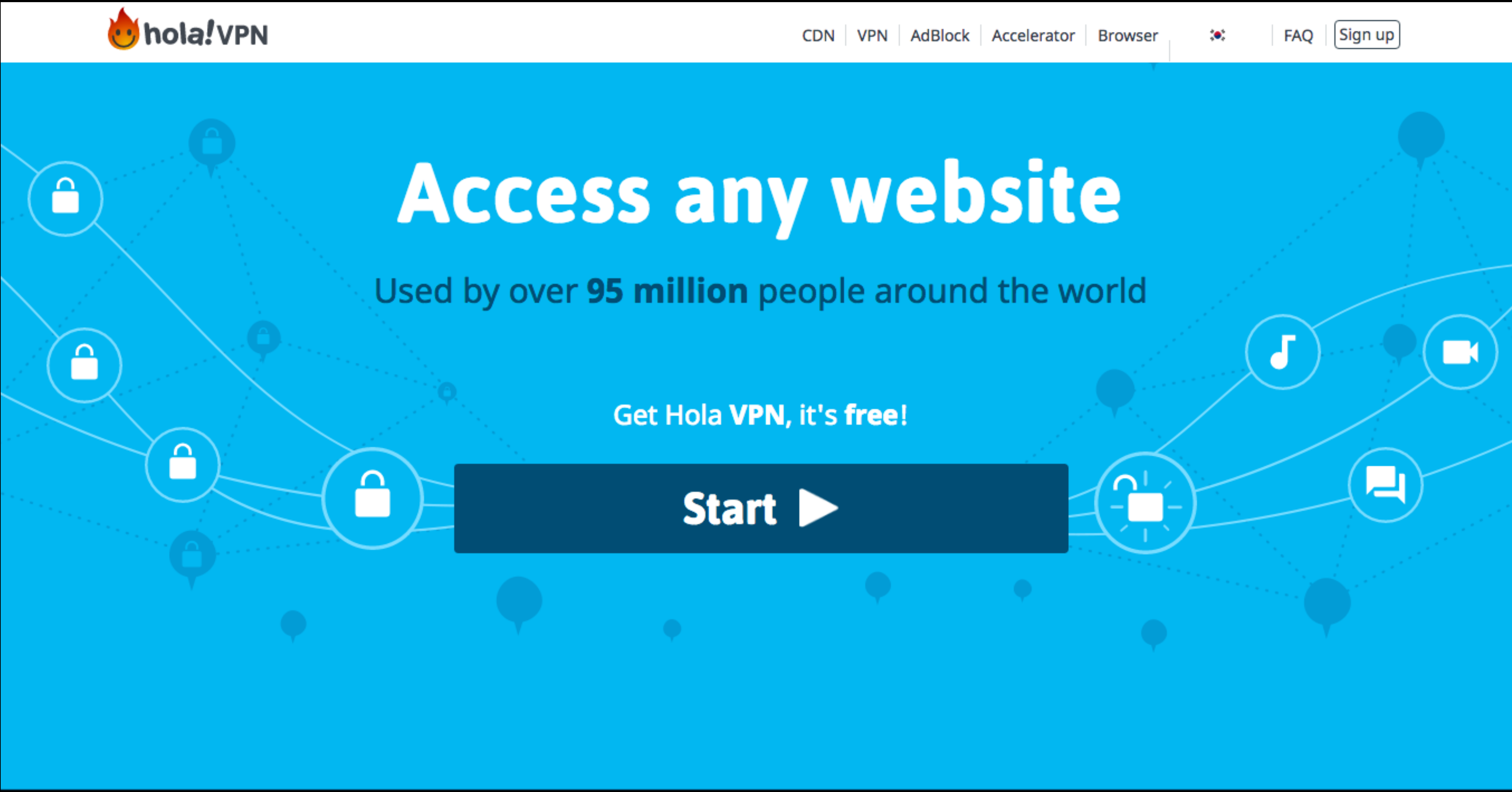
Measuring DNS resolver



No Control over the node

Not Reproducible

Hola Unblocker



hola!VPN

CDN | VPN | AdBlock | Accelerator | Browser | FAQ | Sign up

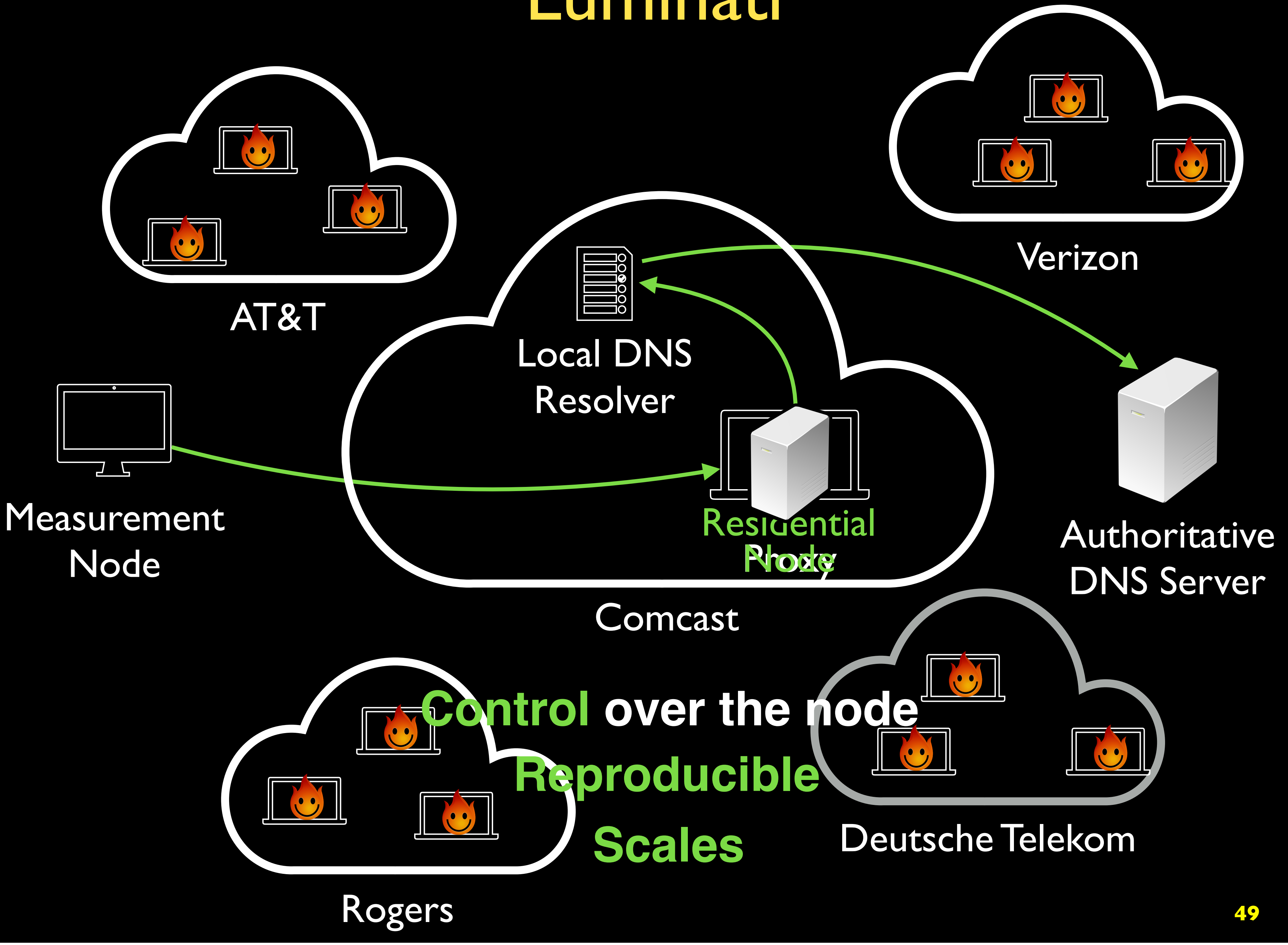
Access any website

Used by over **95 million** people around the world

Get Hola **VPN**, it's **free**!

Start ▶

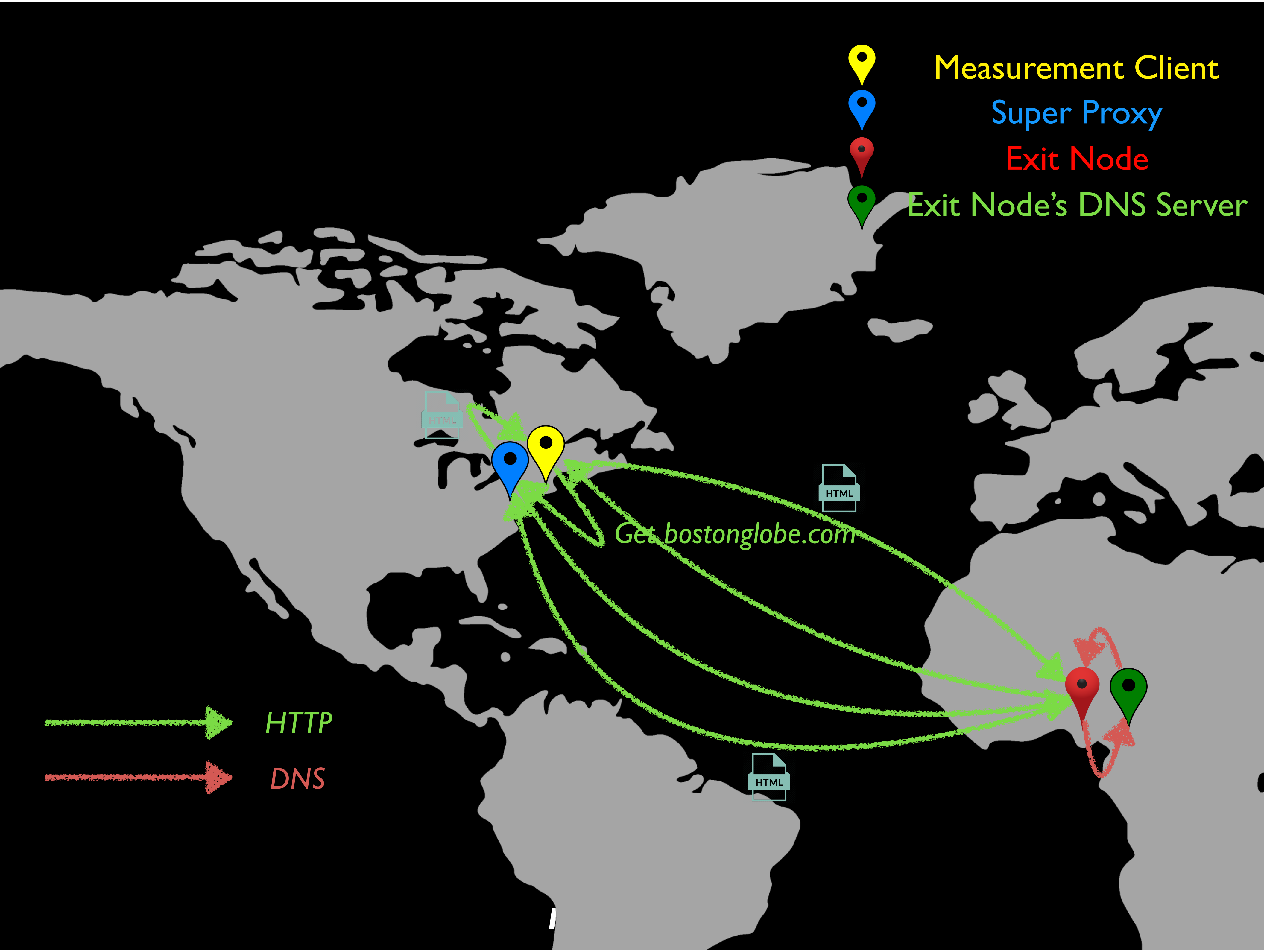
Luminati



Control over the node

Reproducible

Scales



Measurement Client

Super Proxy

Exit Node

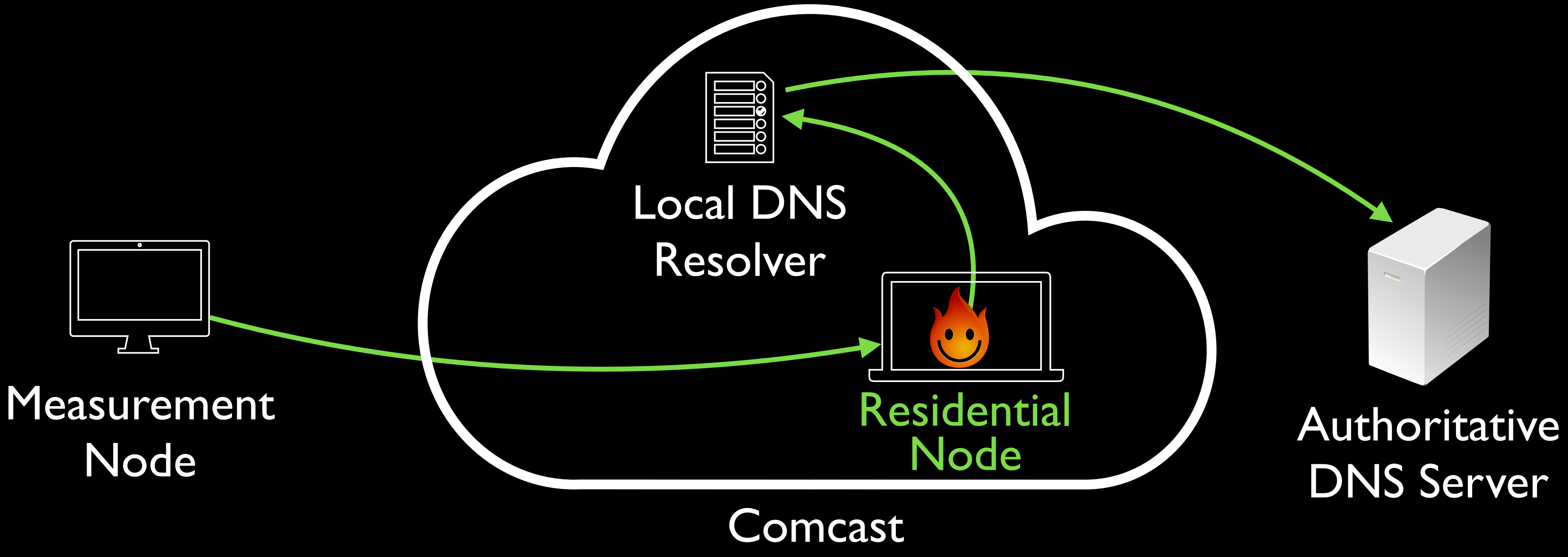
Exit Node’s DNS Server

Get bostonglobe.com

HTTP

DNS

Luminati

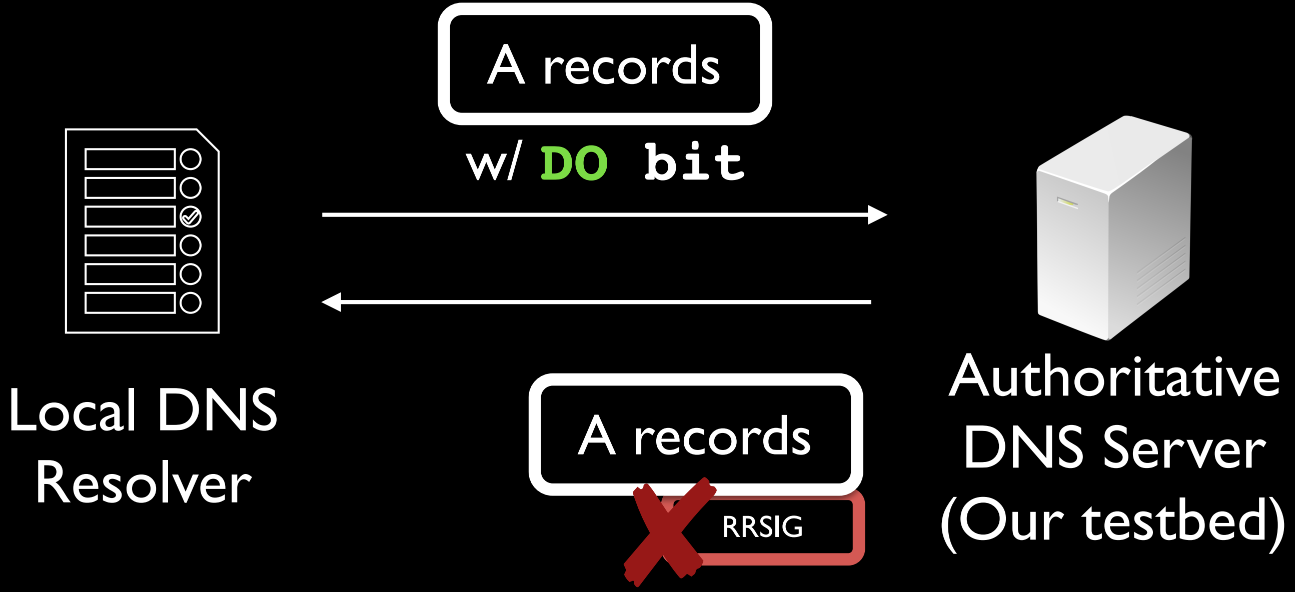


Control over the node

Reproducible

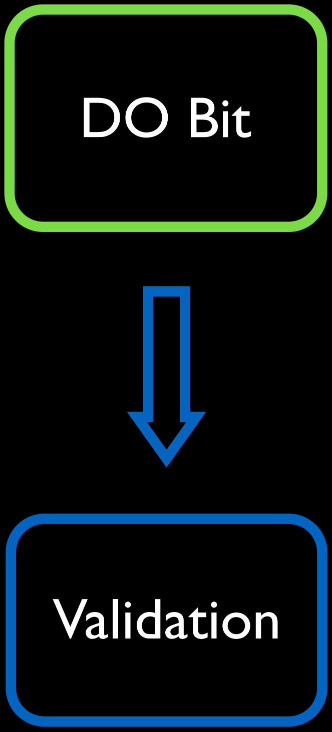
Scales

Methodology



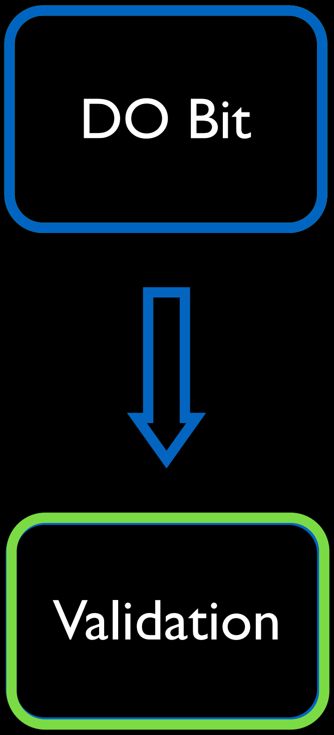
+ 8 other scenarios of incorrect DNSSEC records

Resolvers w/ DO Bit



- 4,427 resolvers
- 83% of them are DO-bit enabled

Resolvers w/ DO Bit



- 4,427 resolvers
- 83% of them are DO-bit enabled

- 3,635 (82%) fail to validate DNSSEC records

  Time Warner Cable Internet

  Rogers Cable Communications

- 543 (12.2%) correctly validate DNSSEC records

  Comcast

  Google

Open Resolver Tests

Provide	DO Bit	Requested		Validated?
		DS	DNSKEY	
Verisign	YES	YES	YES	YES
Google	YES	YES	YES	YES
DNSWatch	YES	YES	YES	YES
DNS Advantage	YES	YES	YES	YES
Norton ConnectSafe	YES	YES	YES	YES