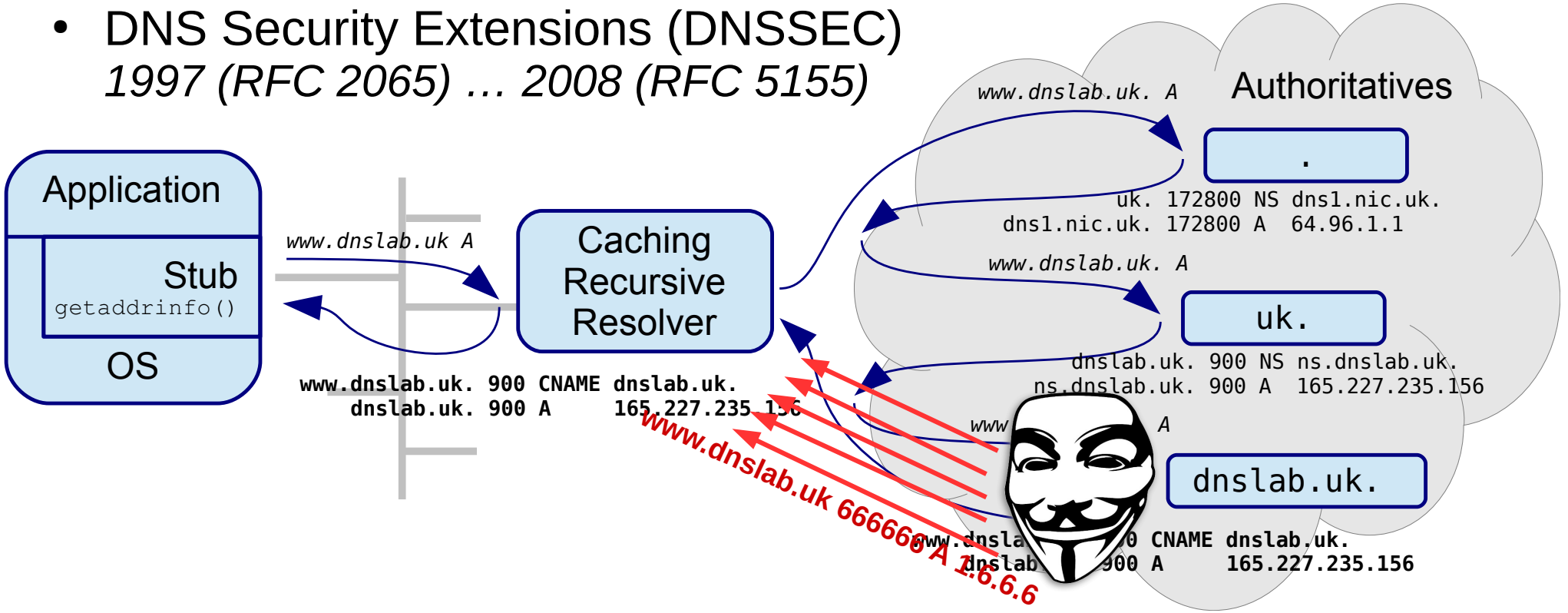
Hands on DNS Vulnerabilities

Online for NOMINET
20-24 September 2021

Domain Name System - security

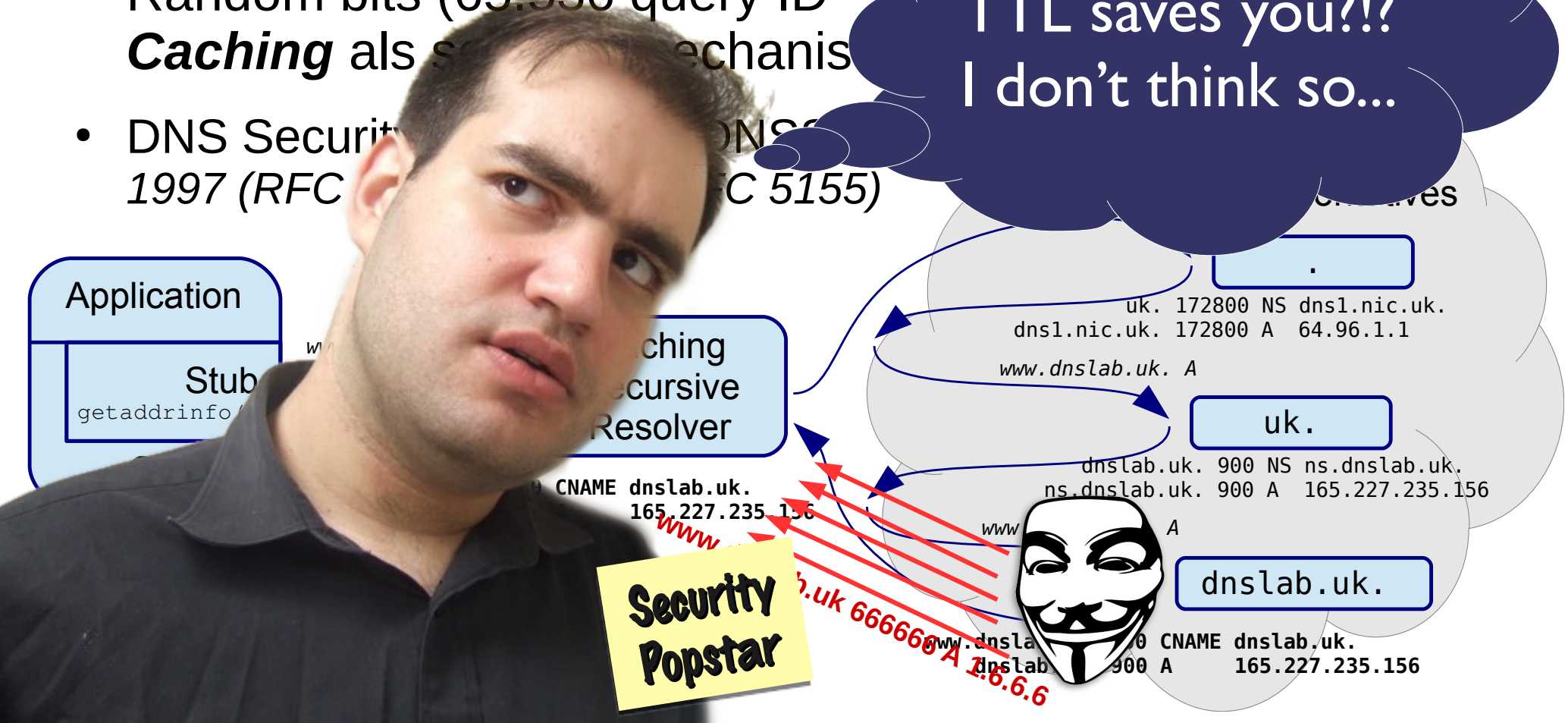
- Random bits (65.536 query ID * source ports) & ***Caching*** as security mechanism
- DNS Security Extensions (DNSSEC)
  1997 (RFC 2065) … 2008 (RFC 5155)



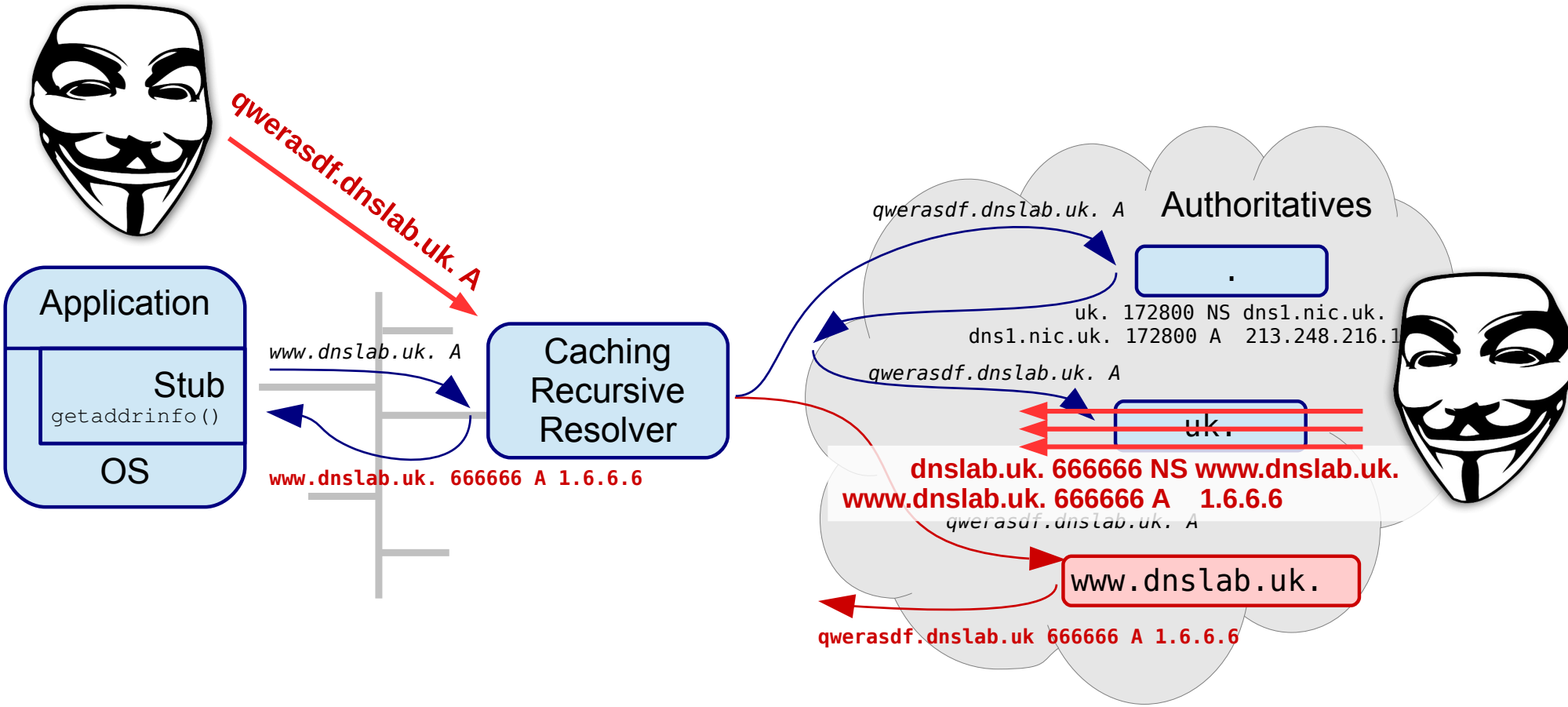
Domain Name System

- Random bits (65.536 query ID * 6
  Caching als s echanis
- DNS Securit DNS
  1997 (RFC C 5155)

TTL saves you?!?
I don't think so...



Domain Name System - security



Domain Name System - security

# Bits	50% chance	5% chance	Method
16	10 seconds	1 second	Query ID
26	2.8 hours	17 minute	1024 source ports
34	28 days	2.8 days	All source ports + 2 bits server selection
44	288444 days	2844.4 days	0x20 hack

Domain Name System - security

- Help with spoofing DNS responses

Fragmentation Considered Poisonous

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Abstract

ent practical *poisoning* and *name-server block-*
s on standard DNS resolvers, by *off-path,*
dversaries. Our attacks exploit large DNS
hat cause IP fragmentation; such long re-
creasingly common, mainly due to the use

narios, where DNSSEC is partially or

sary that is able to send spoofed packets (but not to intercept, modify or block packets). The most well known is Kaminsky's DNS poisoning attack [21], which was exceedingly effective against many resolvers at the time (2008). Kaminsky's attack, and most other known DNS poisoning attacks, allows the attacker to cause resolvers to provide incorrect (poisoned) responses to DNS queries of the clients, and thereby 'hijack' a domain name. We

Domain Name System - security

- Help with spoofing DNS responses

attacker ICMP frag needed→ authoritative

Offsets	Octet	0								1								2								3								
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
0	0	v4				IHL = 20				TOS								Total Length = 56																IP Header
4	32	IPID																x	DF	MF	Frag Offset													
8	64	TTL								Protocol = 1								IP Header Checksum																
12	96	Source IP = 6.6.6.6																																
16	128	Destination IP = 2.2.2.2																																
20	160	Type = 3								Code = 4								ICMP Checksum																ICMP Header
24	192	Unused																MTU = 100																
28	224	v4				IHL = 20				TOS								Total Length = 76																IP Header
32	256	IPID																x	DF	MF	Frag Offset													
36	288	TTL								Protocol = 17								IP Header Checksum																
40	320	Source IP = 2.2.2.2																																
44	352	Destination IP = 7.7.7.7																																
48	384	Source Port = 53																Destination Port = 12345																UDP Header
52	416	Length = 56																UDP Checksum = 0																

ent practical *p*
s on standa
dversaries.
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poisoning attacks, allows the attacker to cause resolvers to provide incorrect (poisoned) responses to DNS queries of the clients, and thereby 'hijack' a domain name. We

Domain Name System - security

- Help with spoofing DNS responses

1e fragment
authoritative → resolver

Offsets	Octet	0								1								2								3							
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	v4				IHL = 20				TOS								Total Length = 85															
4	32	IPID = 23456																x	DF	MF	Frag Offset = 0											
8	64	TTL								Protocol = 17								IP Header Checksum															
12	96	Source IP = 2.2.2.2																															
16	128	Destination IP = 7.7.7.7																															
20	160	Source Port = 53																Destination Port = 12345															
24	192	Length = 65																UDP Checksum = 0x14de															
28	224	TXID = 76543																QR	Opcode = 0			AA	TC	RD	RA	Z			RCODE = 0				
32	256	Question Count = 1																Answer Record Count = 1															
36	288	Authority Record Count = 0																Additional Record Count = 1															
40	320	4								m								a								i							
44	352	l								4								v								i							
48	384	c								t								2								i							
52	416	m								0								Type = A															
56	448	Class = IN																Name (Pointer)															
60	480	Type = A																Class = IN															
64	512	TTL																															

IP Header | UDP Header | DNS Header | Question Section | Answer Section

2e fragment
attacker → resolver

Offsets	Octet	0								1								2								3							
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	v4				IHL = 20				TOS								Total Length = 85															
4	32	IPID = 23456																x	DF	MF	Frag Offset = 48											
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12	96	Source IP = 2.2.2.2																															
16	128	Destination IP = 7.7.7.7																															
20	160	Data Length = 4																IPv4 Address															
24	192	= 2.2.2.2																Name = 0								Type							
28	224	= OPT								UDP Payload Size = 4096																EXTENDED-RCODE = 0							
32	256	Version = 0								DO	Z															Data Length							
36	288	= 0																															

IP Header | Answer Section | Additional Section

sary that is able to send spoofed packets (but not to intercept, modify or block packets). The most well known is Kaminsky's DNS poisoning attack [21], which was exceedingly effective against many resolvers at the time (2008). Kaminsky's attack, and most other known DNS poisoning attacks, allows the attacker to cause resolvers to provide incorrect (poisoned) responses to DNS queries of the clients, and thereby 'hijack' a domain name. We

Domain Name System - security

- Help with spoofing DNS responses

DNS Cache Poisoning Attack Reloaded: Revolutions with Side Channels

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ABSTRACT

In this paper, we report a series of flaws in the software stack that leads to a strong revival of DNS cache poisoning — a classic attack which is mitigated in practice with simple and effective randomization-based defenses such as randomized source port. To successfully poison a DNS cache on a typical server, an off-path adversary would need to send an impractical number of 2^{32} spoofed responses simultaneously guessing the correct source port (16-bit) and transaction ID (16-bit). Surprisingly, we discover weaknesses that allow an adversary to "divide and conquer" the space by guessing the source port first and then the transaction ID (leading to only $2^{16} + 2^{16}$ spoofed responses). Even worse, we demonstrate a number of ways an adversary can extend the attack window which drastically improves the odds of success.

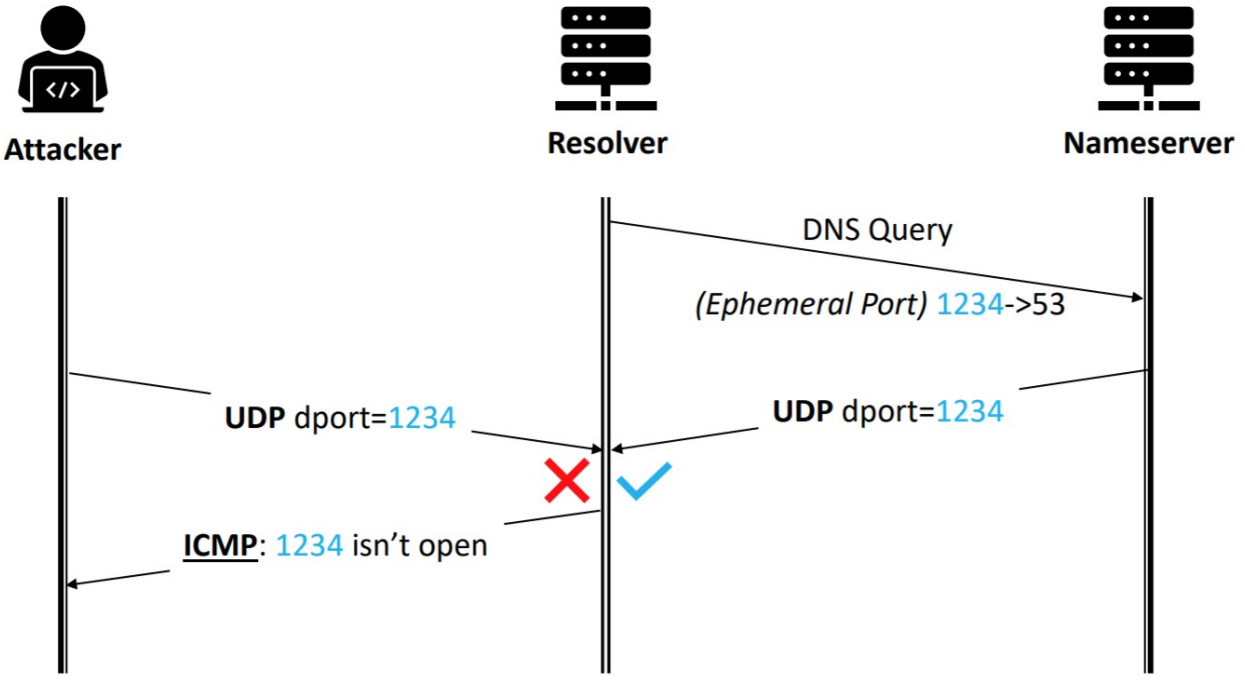
ACM Reference Format:
Keyu Man, Zhiyun Qian, Zhongjie Wang, Xiaofeng Zheng, Youjun Huang, and Haixin Duan. 2020. DNS Cache Poisoning Attack Reloaded: Revolutions with Side Channels. In *Proceedings of the 2020 ACM SIGSAC Conference on Computer and Communications Security (CCS '20), November 9–13, 2020, Virtual Event, USA.* ACM, New York, NY, USA, 14 pages. https://doi.org/10.1145/3372297.3417280

1 INTRODUCTION

Domain name system (DNS) is an essential part of the Internet, originally designed to translate human-readable names to IP addresses. Nowadays, DNS has also been overloaded with many other security critical applications such as anti-spam defenses [38], routing security (e.g., RPKI) [10]. In addition, DNS also plays a crucial role in bootstrapping trust for TLS. TLS certificates are now commonly

Domain Name System - security

Port Inference: Ephemeral Ports



Domain Name System - security

bits	50% chance	5% chance	Method
~~16~~	~~10 seconds~~	~~1 seconde~~	~~Query ID~~
~~26~~	~~2,8 uur~~	~~17 minutes~~	~~1024 source ports~~
2	0 seconds	0 seconds	~~All source ports~~ 2 bits server selection
~~44~~	~~288444 days~~	~~2844.4 days~~	~~0x20 hack~~
5	0 seconds	0 seconds	IP ID

Domain Name System - security

bits	50% chance	5% chance	Method
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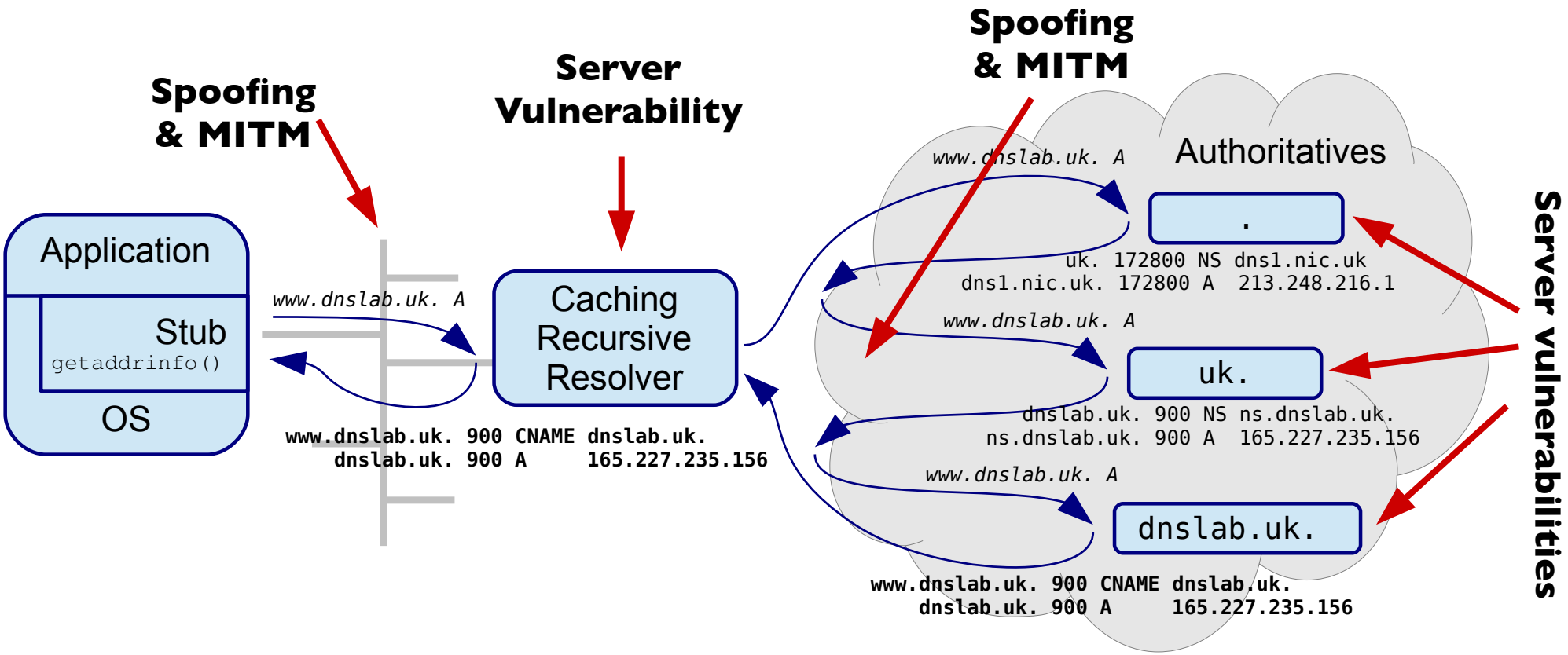
~~44~~	~~288444 days~~	~~2844.4 days~~	~~0x20 hack~~
5	0 seconds	0 seconds	IP ID
69	2,928,370,544 year	292,837,054 year	IPv6 /64 source address

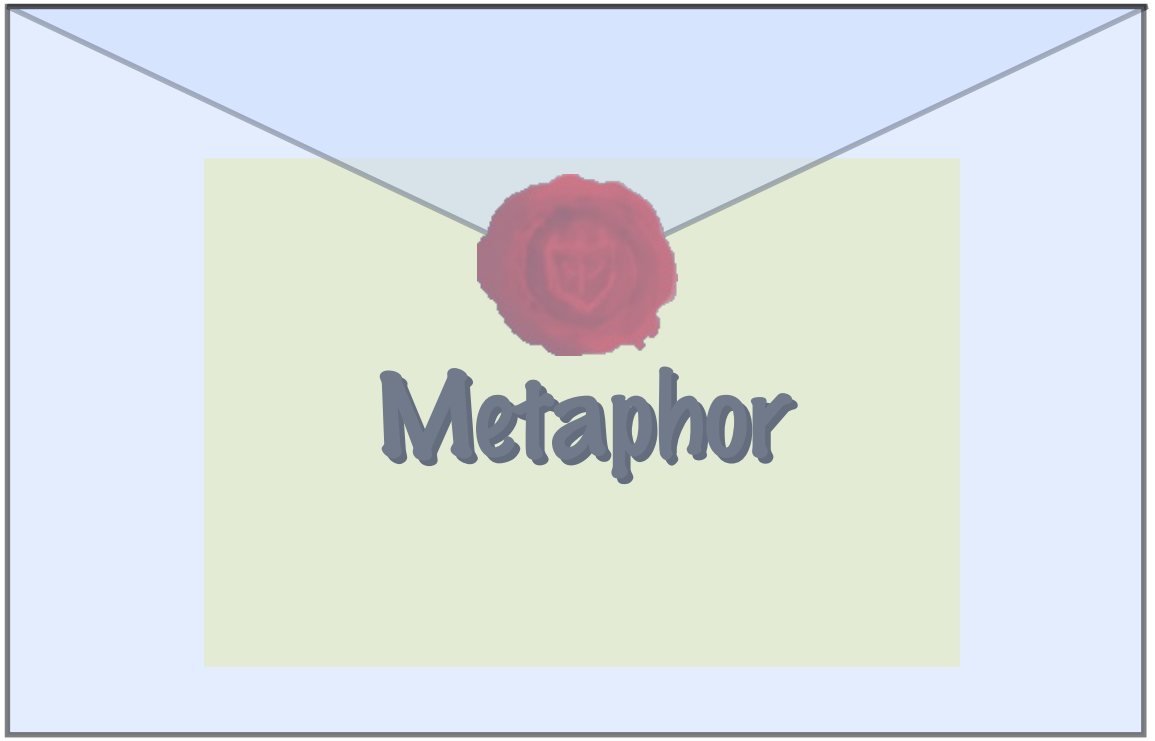
Domain Name System - security

- It's not just spoofing



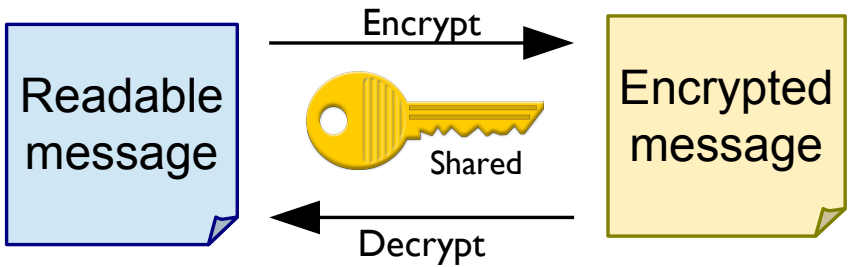
DNS Security Extensions (DNSSEC)

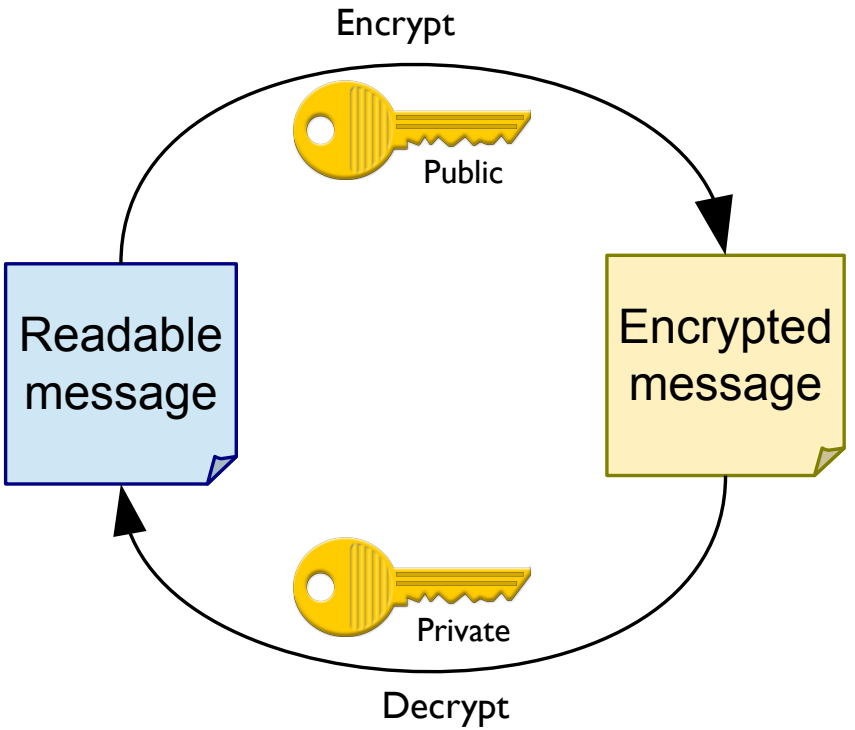
- end-to-end security on top of DNS



DNS Security Extensions (DNSSEC)

Refresher Public Key Crypto

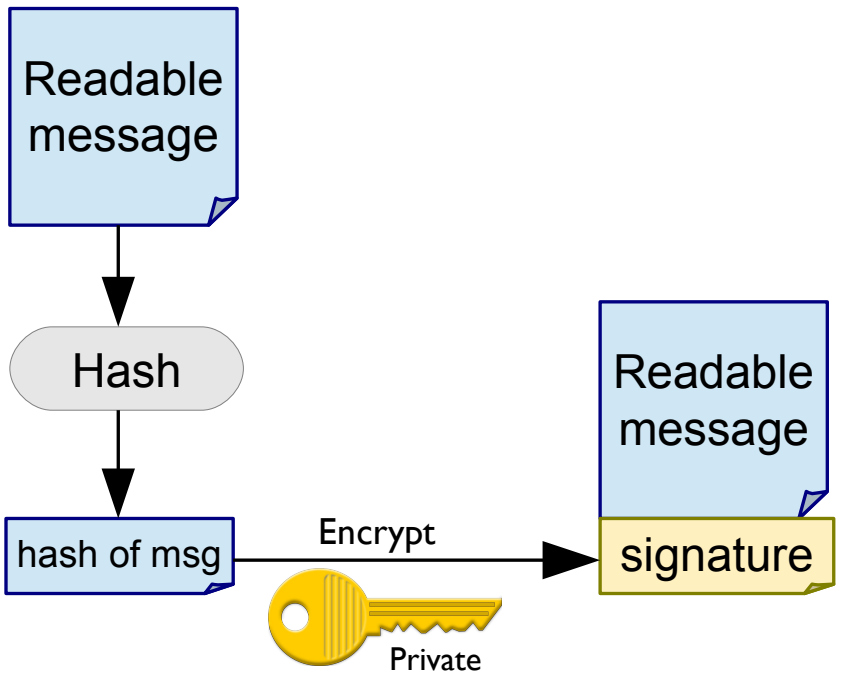




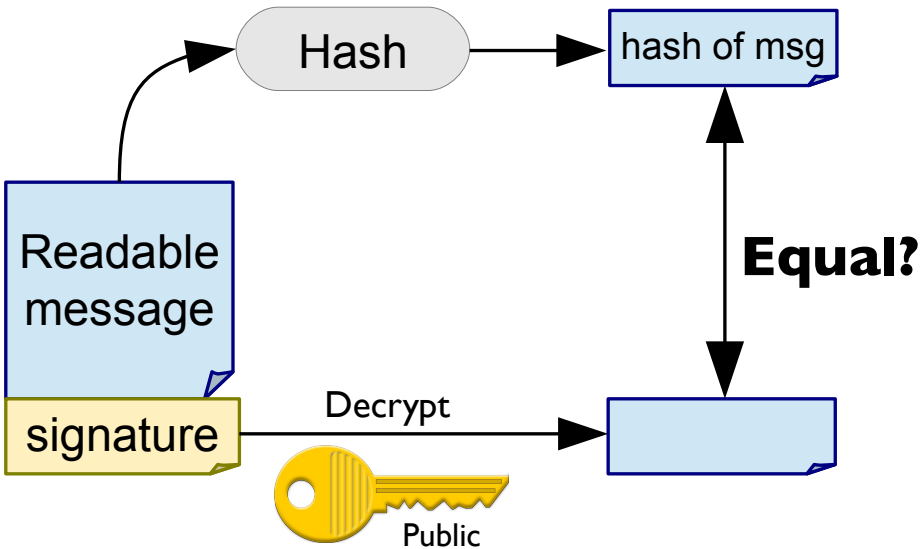
- Symmetric encryption
- Asymmetric encryption

DNS Security Extensions (DNSSEC)

Public Key Crypto – Signing



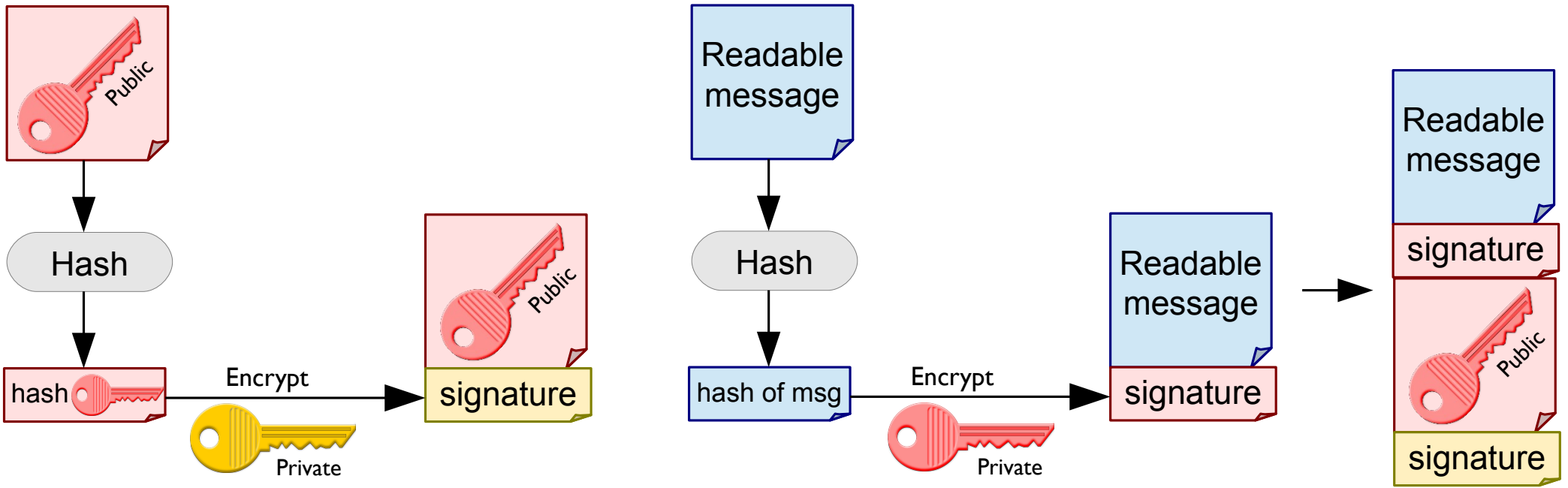
- Create signature

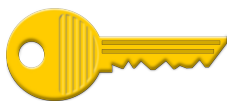
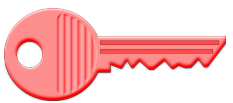
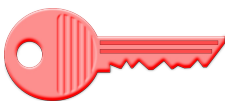


- Verify signature

DNS Security Extensions (DNSSEC)

Public Key Crypto – Delegating Authority



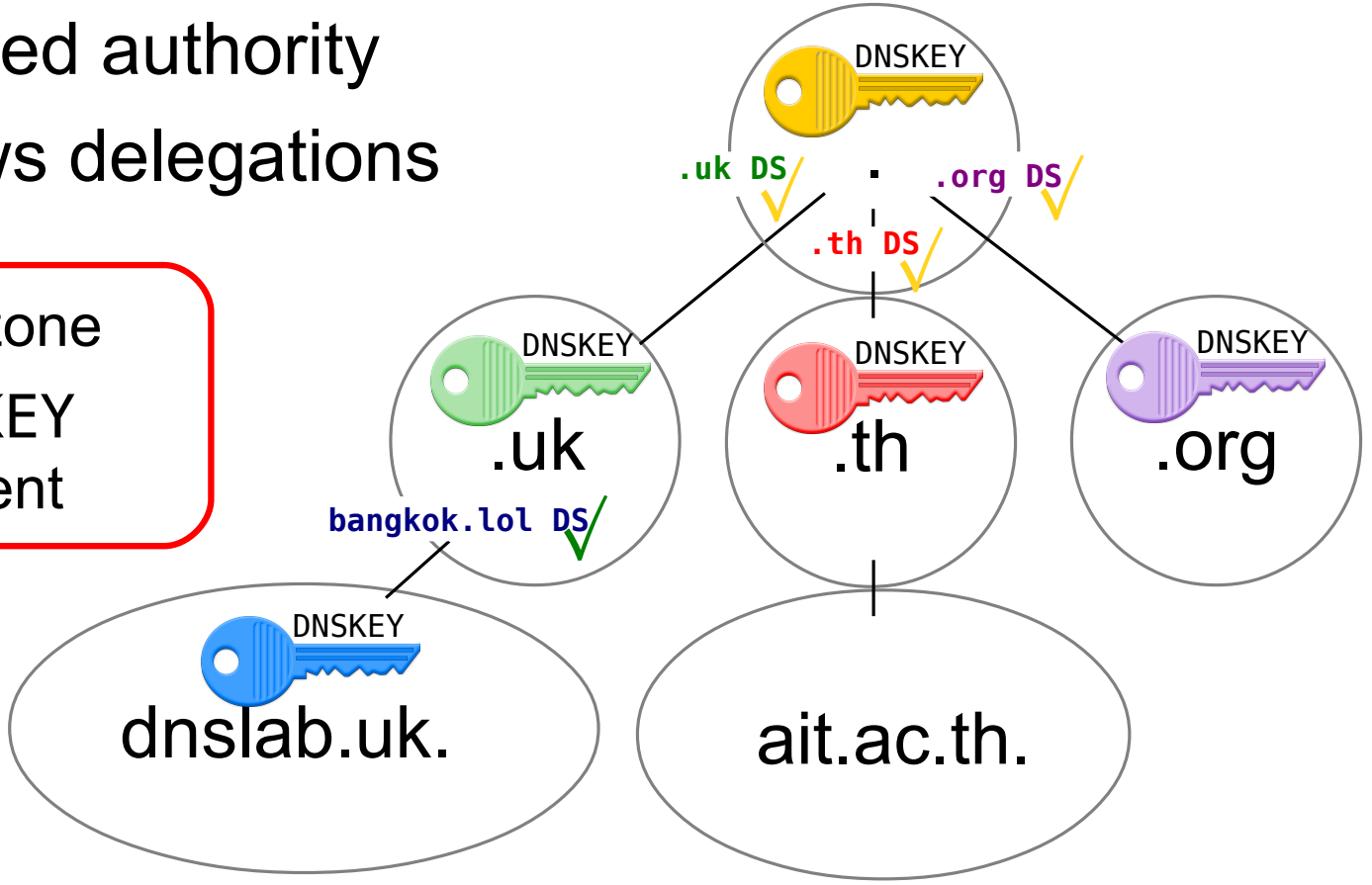
- Building the chain of trust
   authorizes 
-  signs the message

DNS Security Extensions (DNSSEC)

Chain of Trust

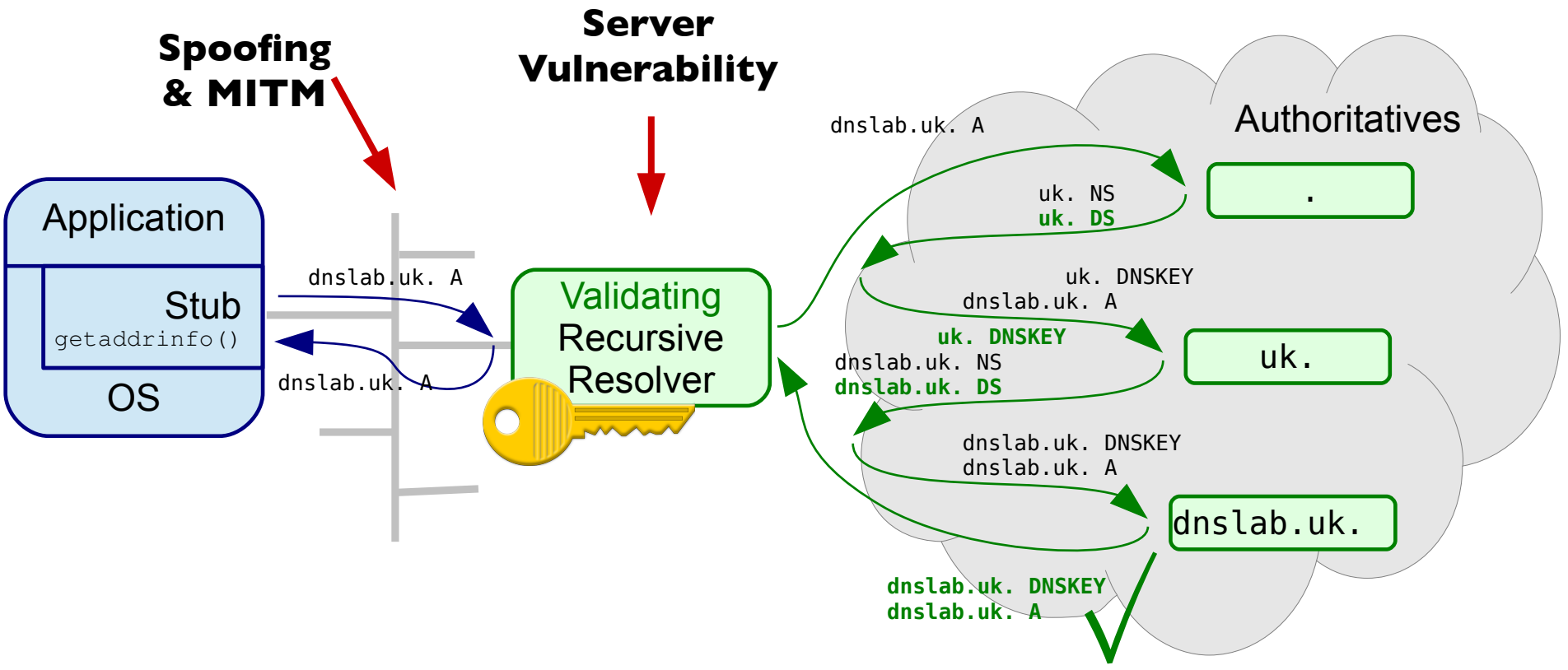
- Zones with distributed authority
- Chain of trust follows delegations

- DNSKEY Public key of zone
- DS Hash of DNSKEY signed by parent



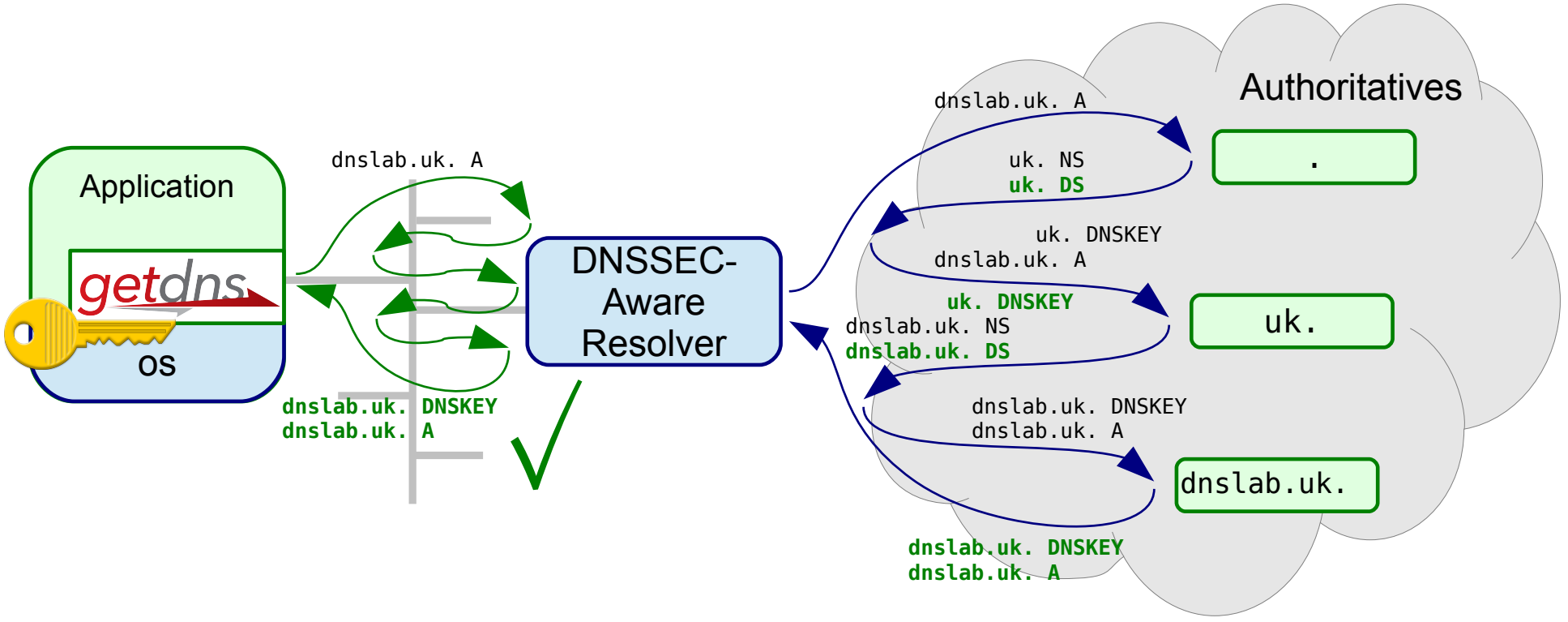
DNS Security Extensions (DNSSEC)

Validation



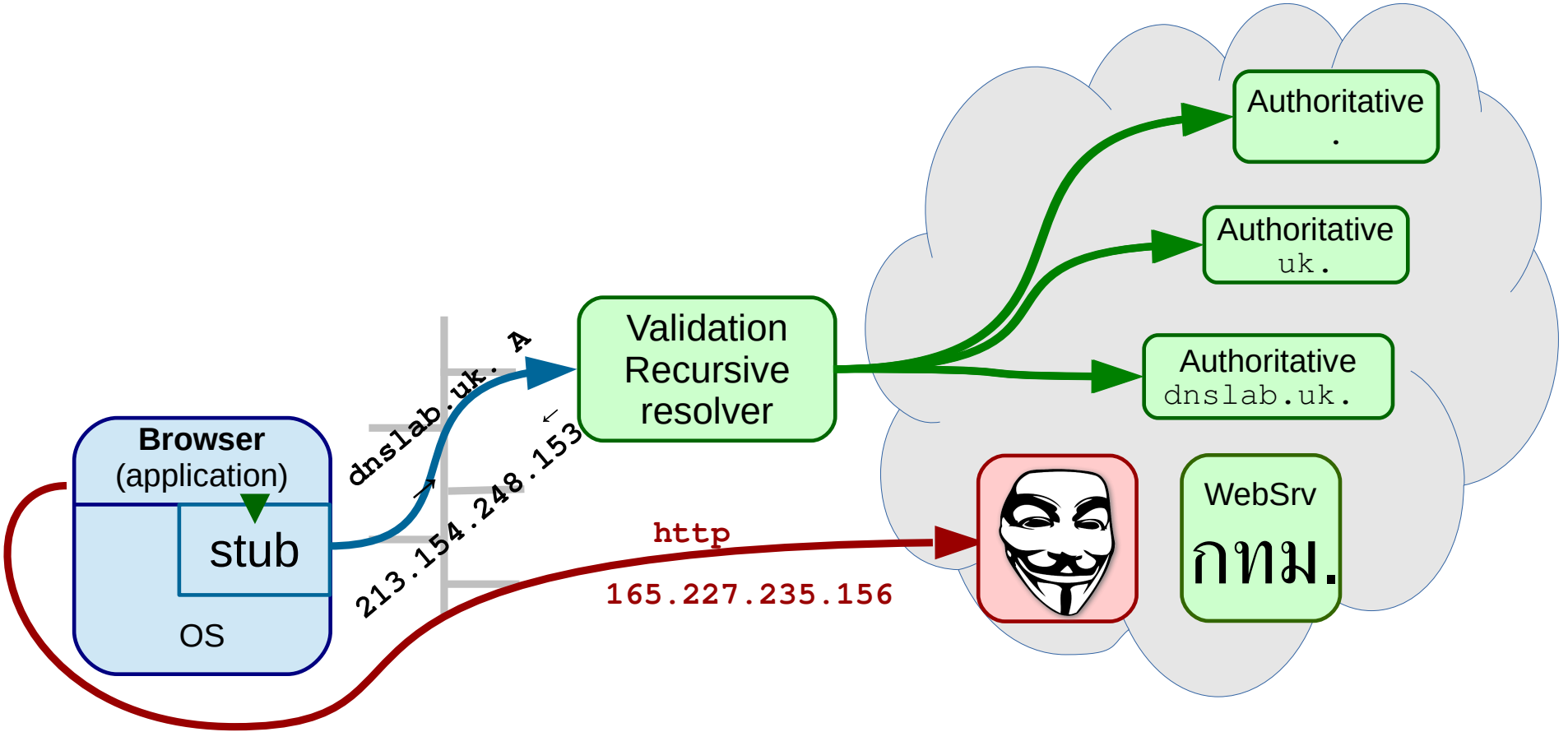
DNS Security Extensions (DNSSEC)

end-to-end validation



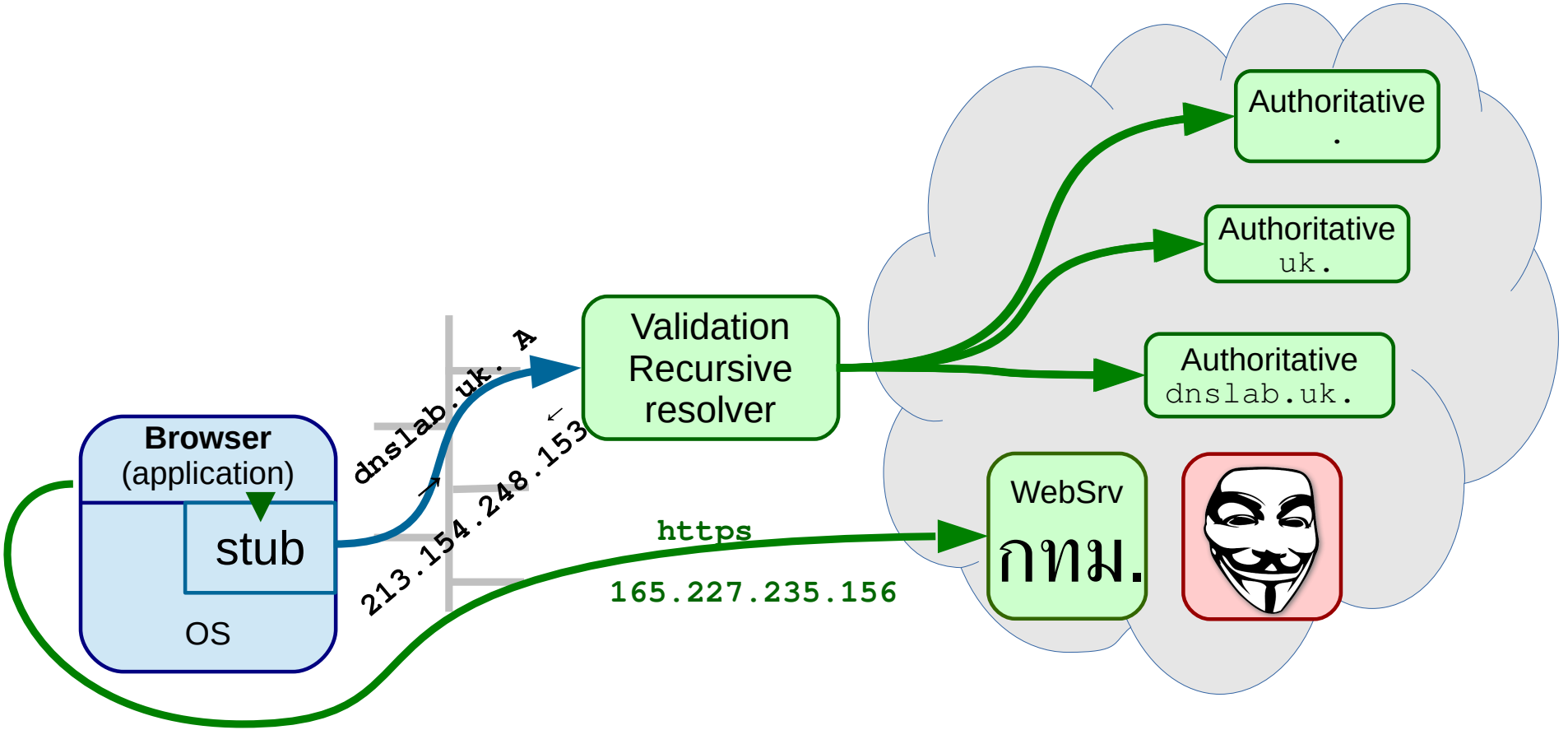
DNS Security Extensions (DNSSEC)

does not protect against MITM



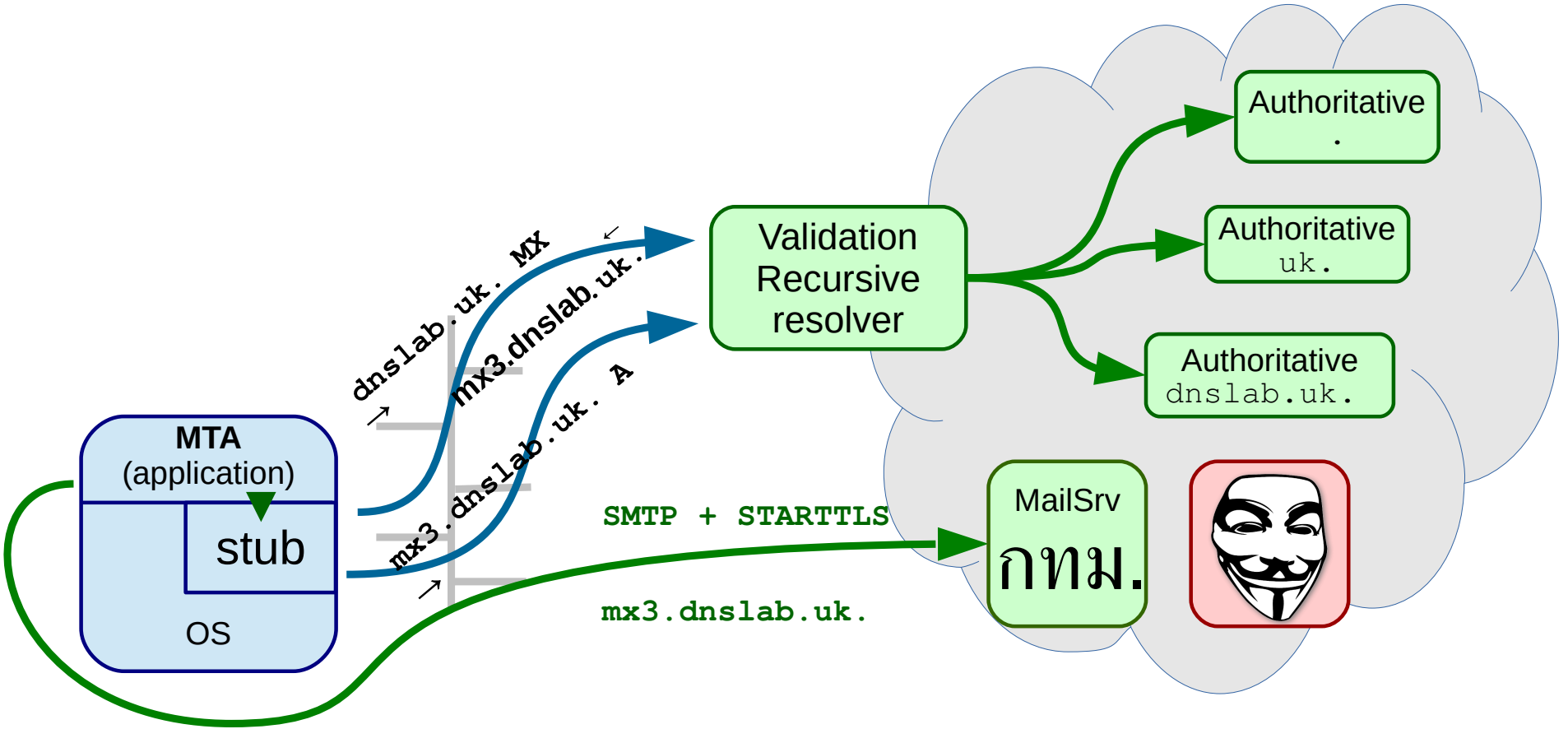
DNS Security Extensions (DNSSEC)

does not protect against MITM – TLS does!



DNS Security Extensions (DNSSEC)

still needed for referrals

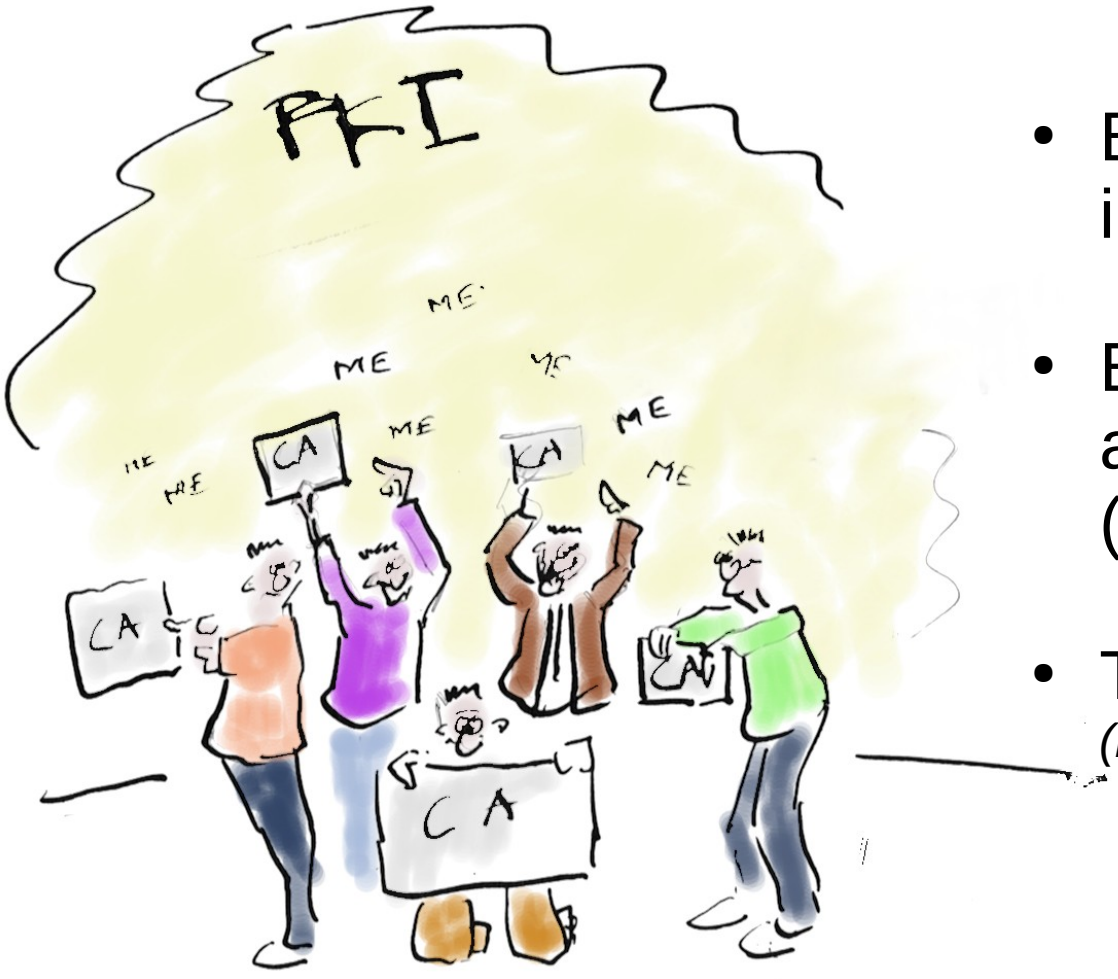


DNSSEC for Applications
for TLS

- Transport Layer Security (TLS) uses
  both asymmetric and symmetric encryption
- A symmetric key is sent encrypted with remote public key

- How is the remote public key authenticated?

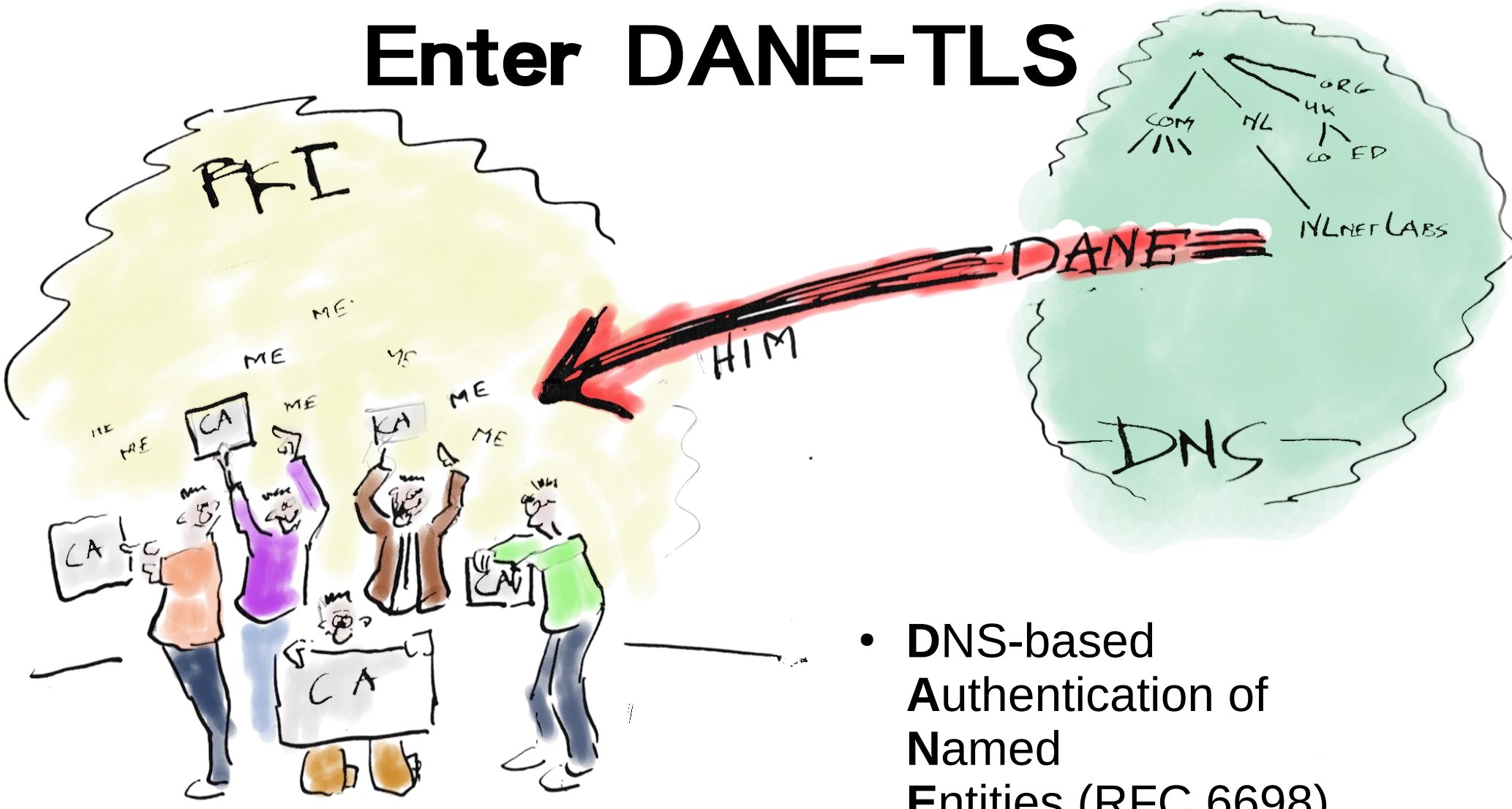
TLS without DNSSEC



Cartoon by Kloot

- By the Certificate Authorities in OS and/or browser
- Each CA is authorized to authenticate for **any** name (weakest link problem)
- There are more than 1500 CAs
  (in 2010, see https://www.eff.org/observatory)

Enter DANE-TLS

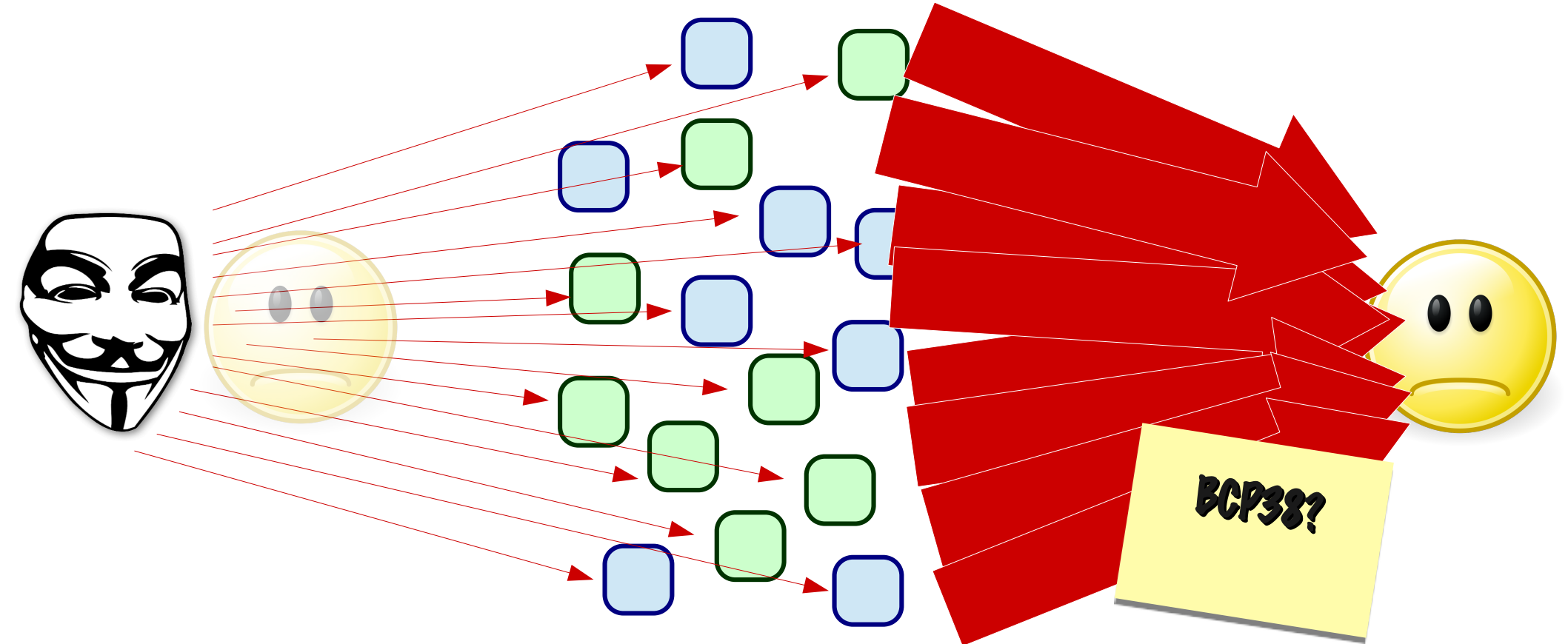


Cartoon by Kloot

- **D**NS-based **A**uthentication of **N**amed **E**ntities (RFC 6698)

DNS Security Extensions (DNSSEC)

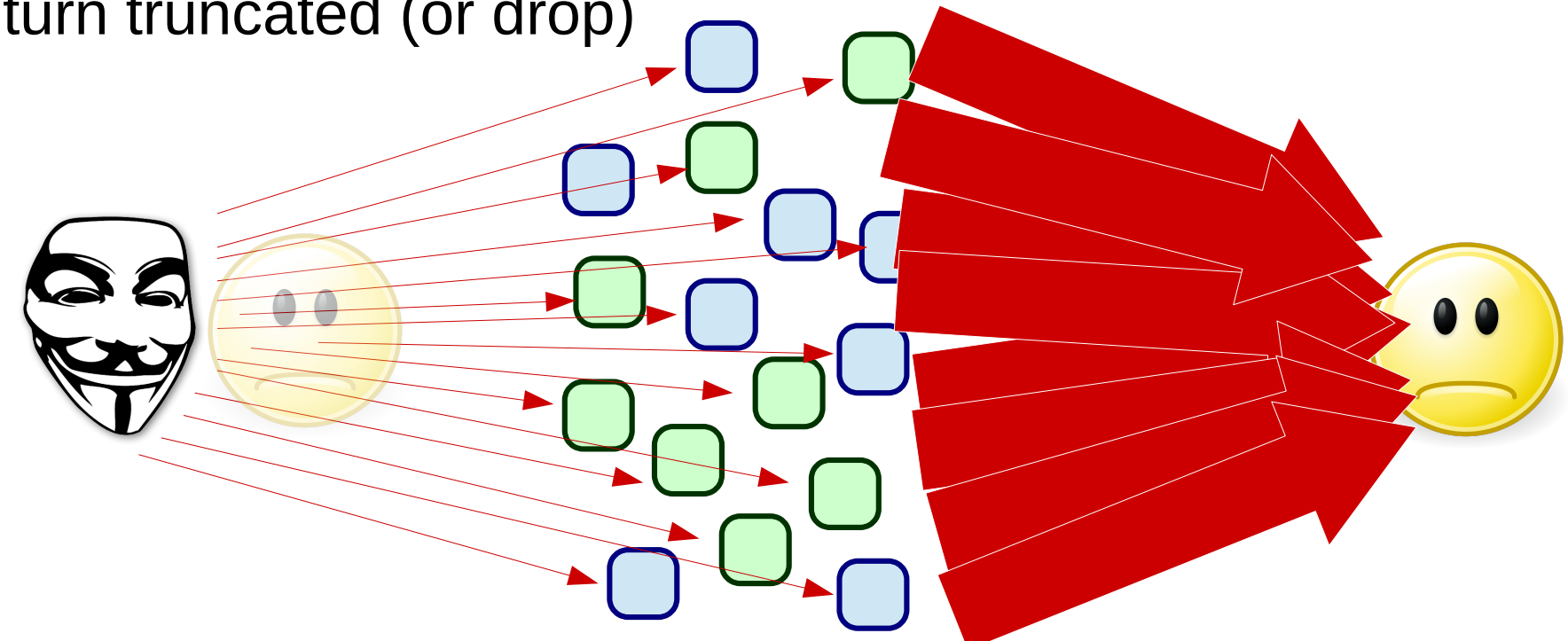
consequence of UDP, worse with DNSSEC



DNS Security Extensions (DNSSEC)

Query Rate Limiting (a.k.a. RRL)

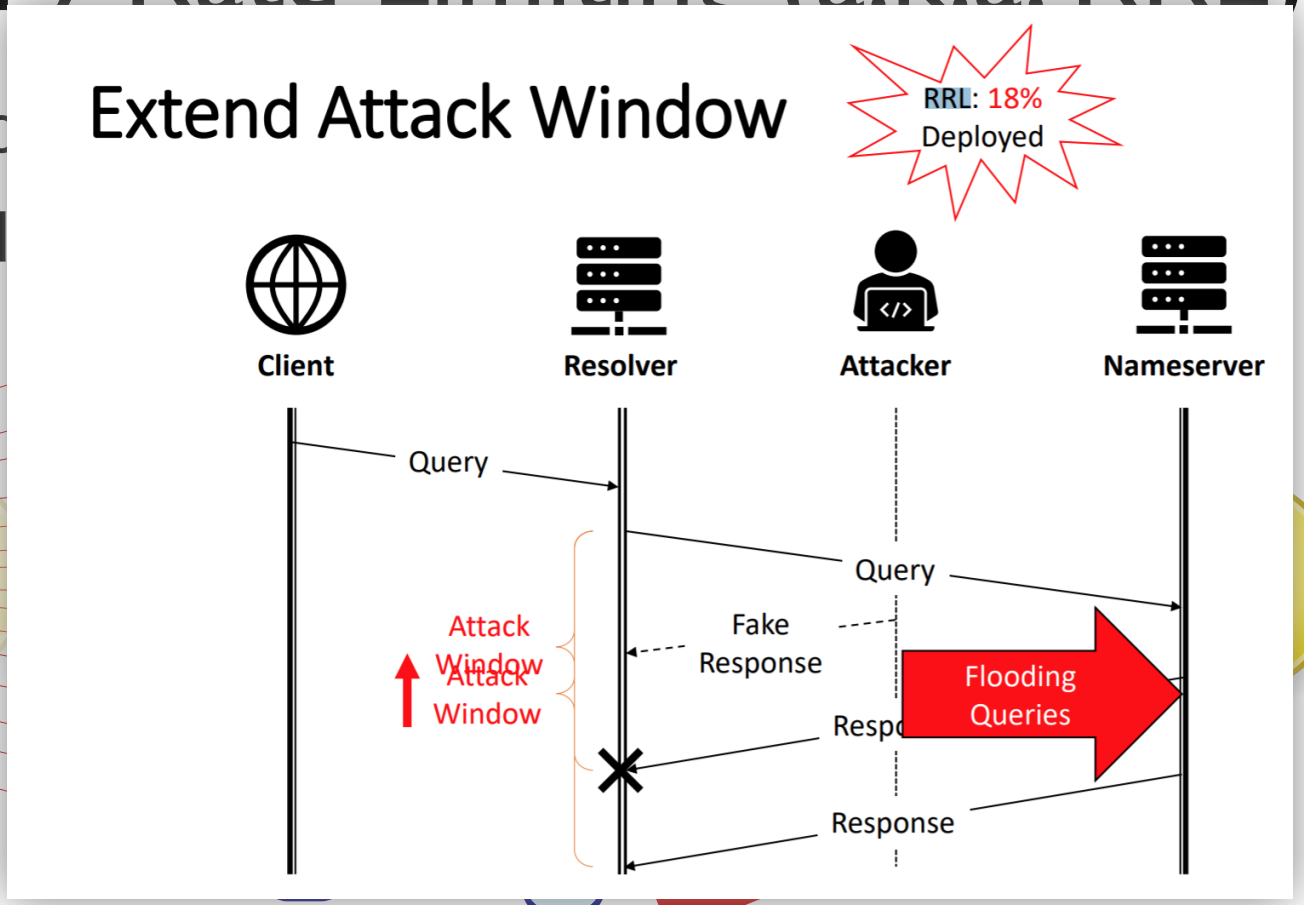
- When Queries per Second > X (from certain source IP or Prefix)
- Then Return truncated (or drop)



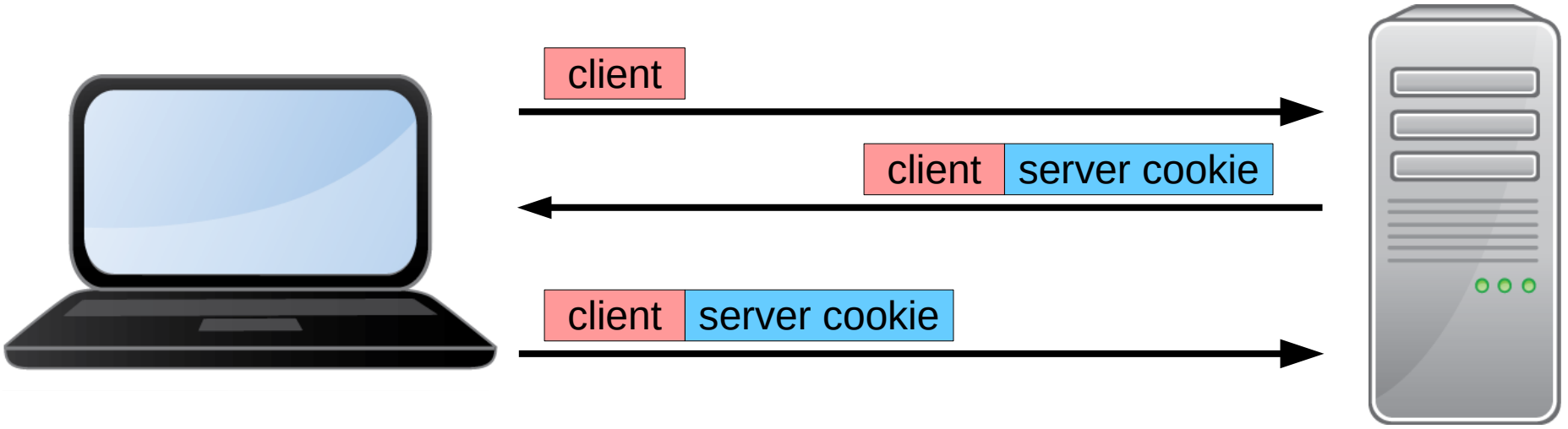
DNS Security Extensions (DNSSEC)

Query Rate Limiting (a.k.a. RRL)

- When er Sec
  ed



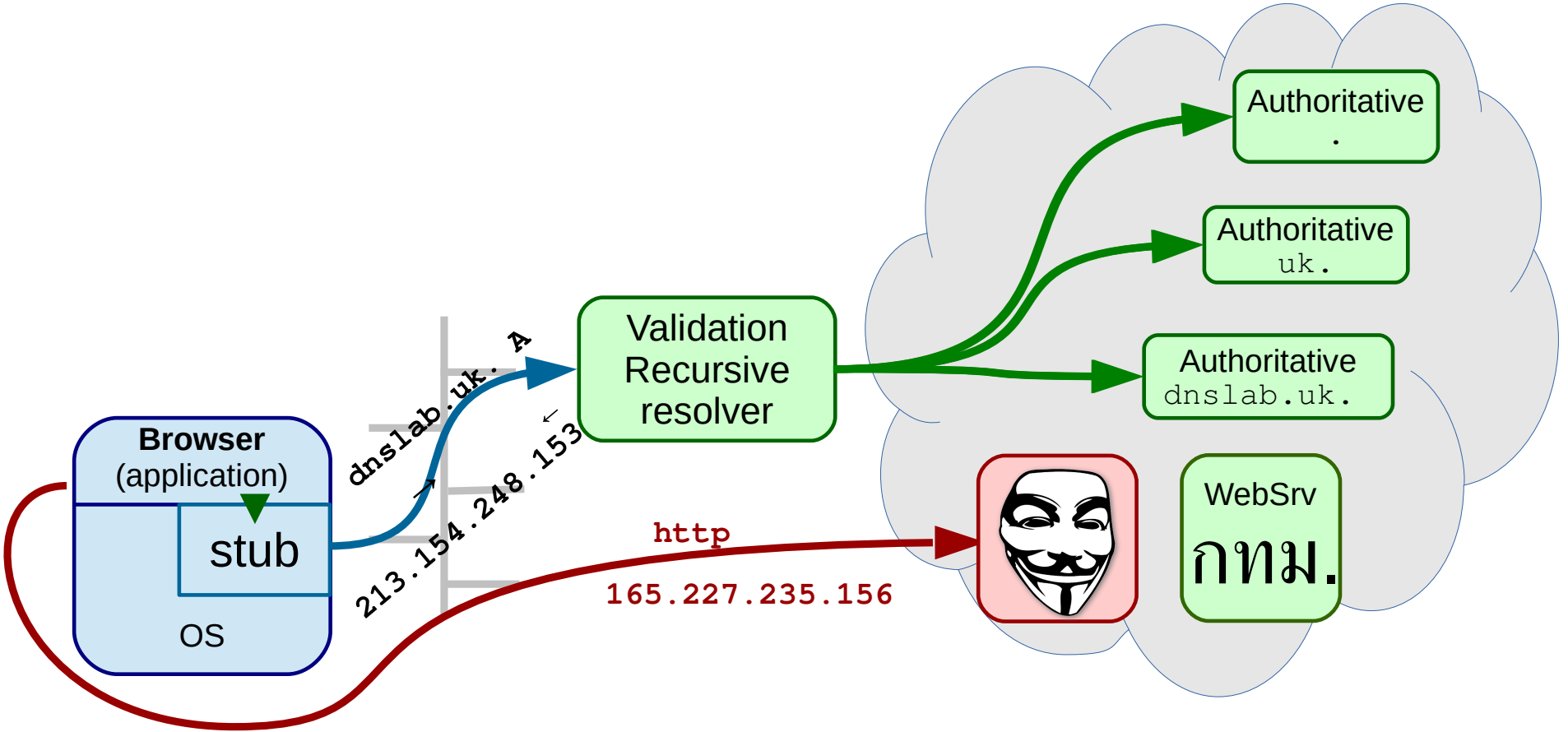
DNS Cookies Operation



- Valid Server Cookie? Large answers
- Valid Server Cookie? RRL Disabled!

DNS Security Extensions (DNSSEC)

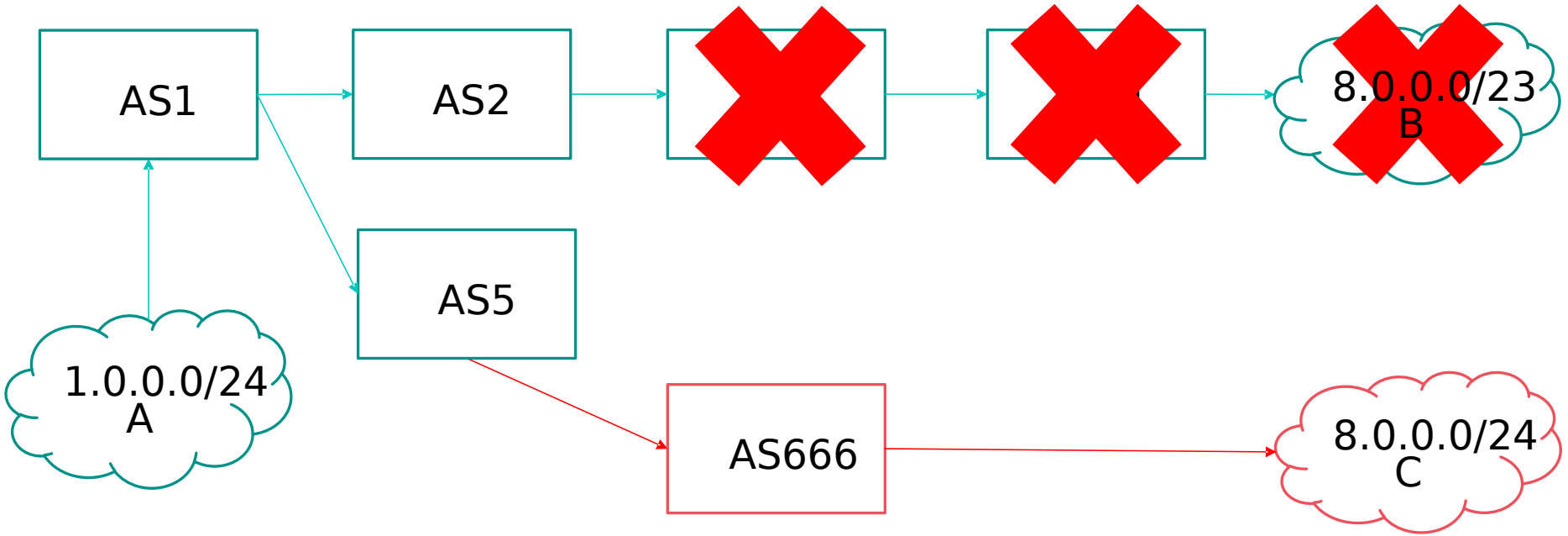
does not protect against MITM



RPKI 101

- DNSSEC protects against address forgery
- But the address $_{32}$ can be trivially hijacked

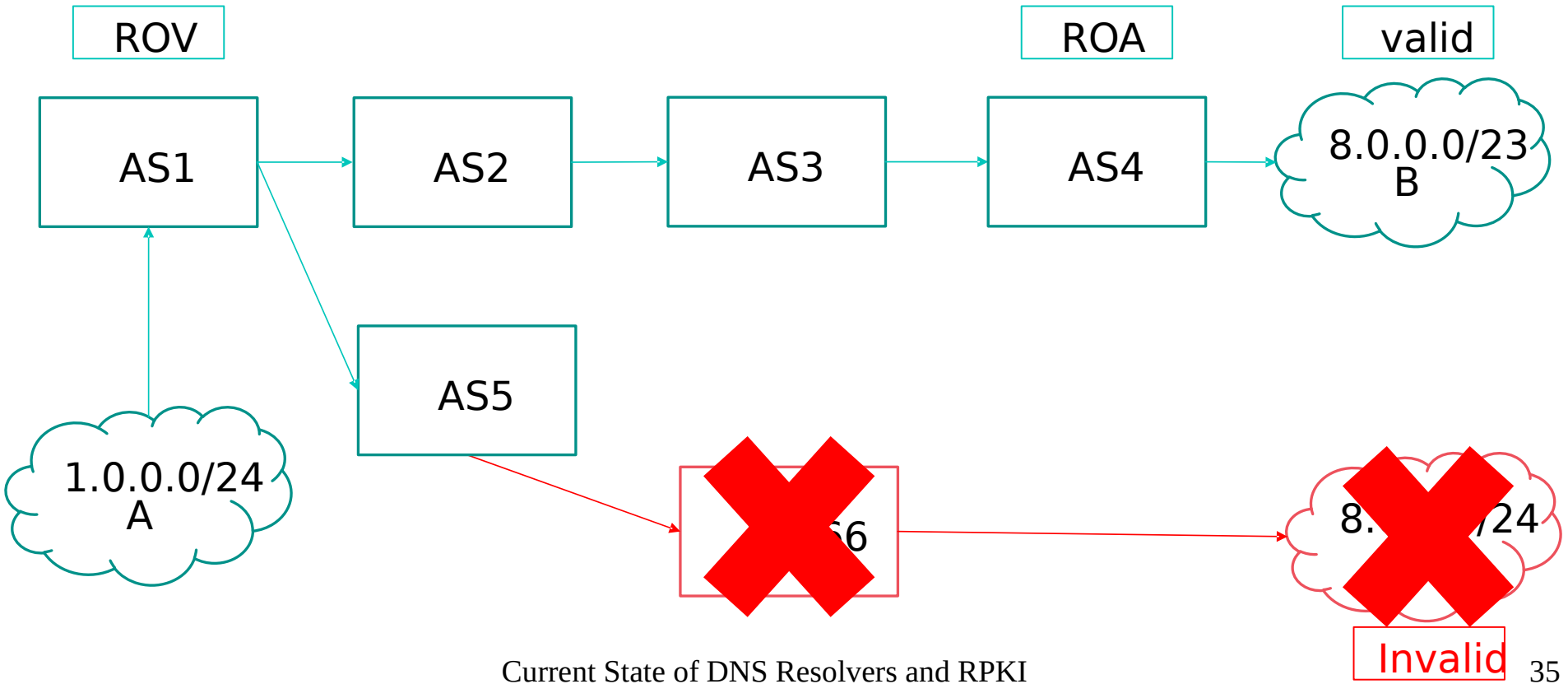
RPKI 101



RPKI 101

- DNSSEC protects against address forgery
- But the address can be trivially hijacked
- RPKI to the rescue

RPKI 101

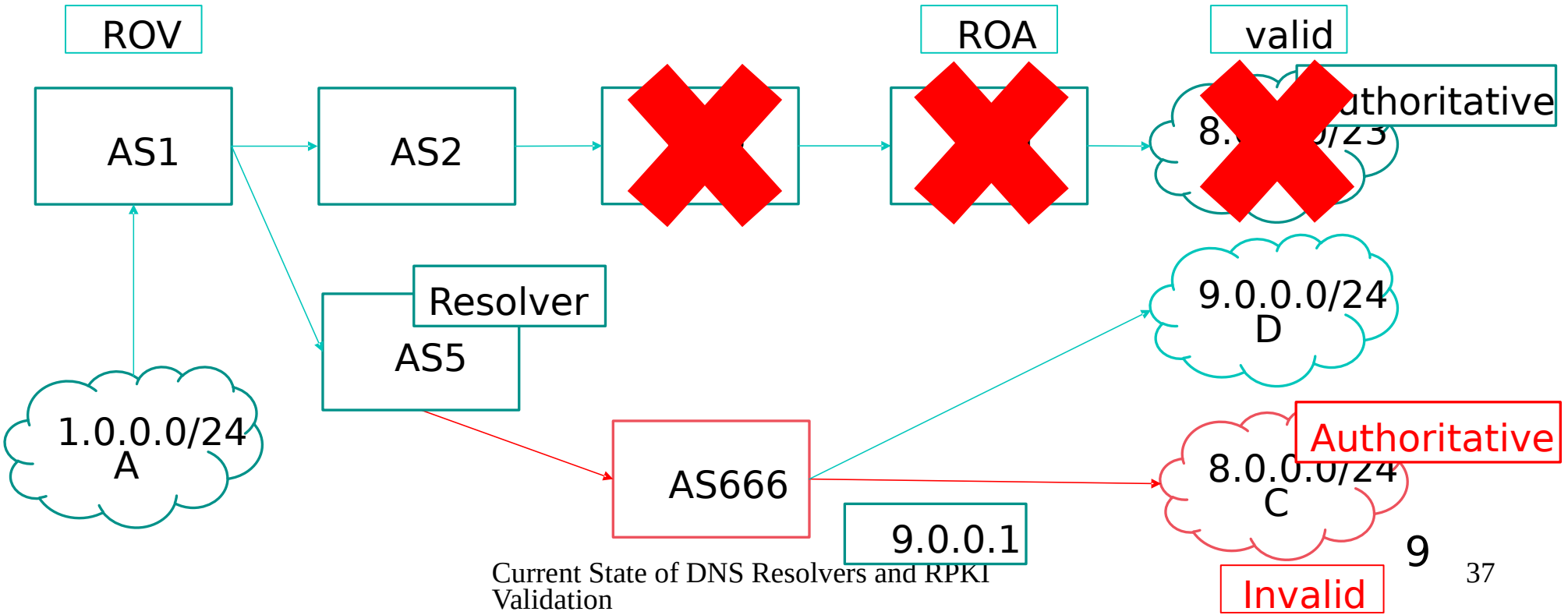


RPKI 101

- What does this have to do with DNS Resolvers?

RPKI 101

- What does this have to do with DNS?



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internetsociety.org/blog/2018/04/amazons-route-53-bgp-hijack/

Internet Society

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What Happened? The Amazon Route 53 BGP Hijack to Take Over Ethereum Cryptocurrency Wallets

By Aftab Siddiqui

Senior Manager, Internet Technology - Asia-Pacific

Yesterday, we published a blog post sharing the news and some initial details about Amazon's DNS route hijack event to steal Ethereum cryptocurrency from myetherwallet.com. In this post, we'll explore more details about the incident from the BGP hijack's perspective.

Lab time!

- Hands on: https://dnslab.uk/
- 5. Turning your recursive resolver into a validating resolver

Photo by Alex Kondratiev on Unsplash