RIPE NCC
RIPE NETWORK COORDINATION CENTRE

DNSSEC

Training Course

Training Services | RIPE NCC | November 2016

Schedule

09:00 - 09:30	**Coffee, Tea**
11:00 - 11:15	**Break**
13:00 - 14:00	**Lunch**
15:30 - 15:45	**Break**
17:30	**End**

Introduction

- **Name**
- **Number on the list**
- **Experience**
  - DNS
  - DNSSEC
  - Cryptography
- **Goals**

Overview

1. Introduction to DNS
   - *Exercise A: Creating a Zone file*
2. DNS Vulnerabilities
3. Introduction to Cryptography
4. Introduction to DNSSEC
5. New Resource Records for DNSSEC
   - *Exercise B: Update the zone file in Bind*
   - *Exercise C: Using DIG to Find Information*
6. Delegating Signing Authority
7. Setting up a Secure Zone
   - *Exercise D: Configure DNSSEC for the Domain*
8. Flags and Scenarios
9. Key Rollovers
10. DANE
11. Troubleshooting, Tips, Tricks
    - *Exercise E: Check and Troubleshoot DNSSEC*

Introduction to DNS

Section 1

In the Beginning…

- **The Internet was small**
  - fewer than 100 hosts
- **Everybody knew everybody else**
- **Centralised: host file distributed to everyone**
- **But it didn’t scale**

What is DNS ?

- Domain Name System
- RFC1035
- Distributed database
- Translation

    name -> IP address

    IP address -> name

What is DNS ?

- System to convert names to IP addresses:

www.ripe.net → 193.0.6.139

www.ripe.net → 2001:67c:2e8:22::c100:68b

What is DNS ?

Reverse DNS:

139.6.0.193.in-addr.arpa → www.ripe.net

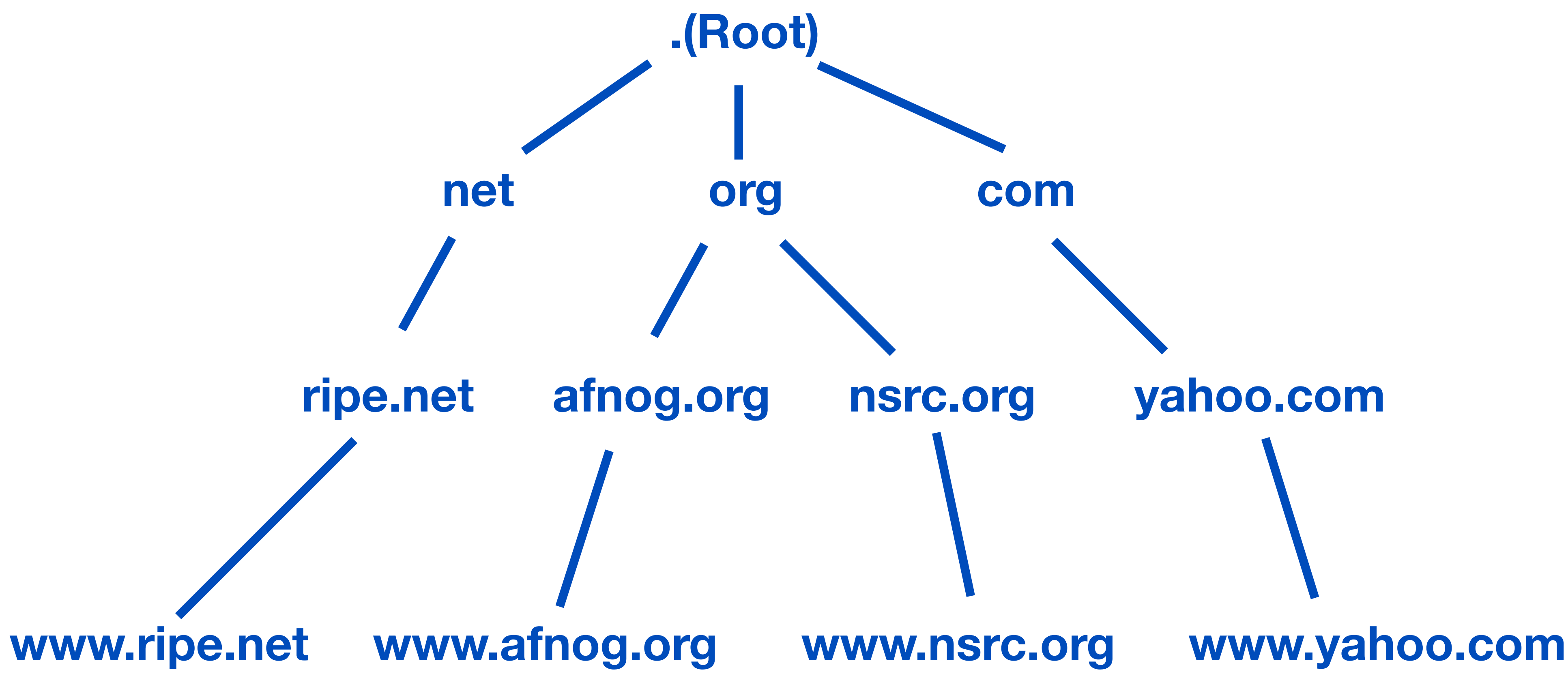
or

b.8.6.0.0.0.1.c.
0.0.0.0.0.0.0.0.2.2.0.0.8.e.
2.0.c.6.7.0.1.0.0.2.ip6.arpa → www.ripe.net

DNS

- **Case insensitive**
- **Transport is either UDP or TCP on port 53**
- **Indexed by “domain names”**
  - A “domain name” is a sequence of labels
    - www.ripe.net
    - emi.ac.ma

DNS is Hierarchical



- **DNS administration shared**
  - No single central entity administers all data
- **Delegation = distribution of administration**

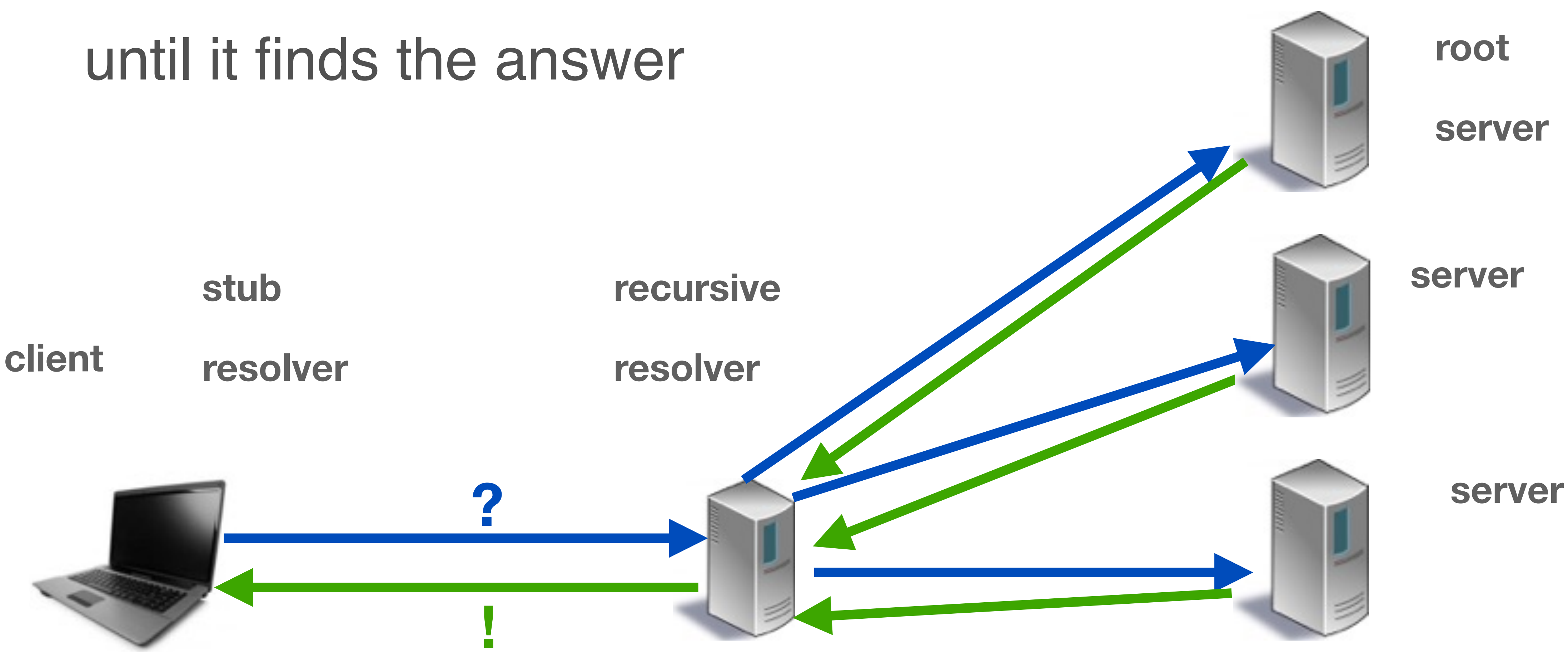
DNS is a Database

- **Contains different types of data:**
  - IP Addresses
  - Where to send email
  - Who is responsible
  - Geographical info
  - etc..

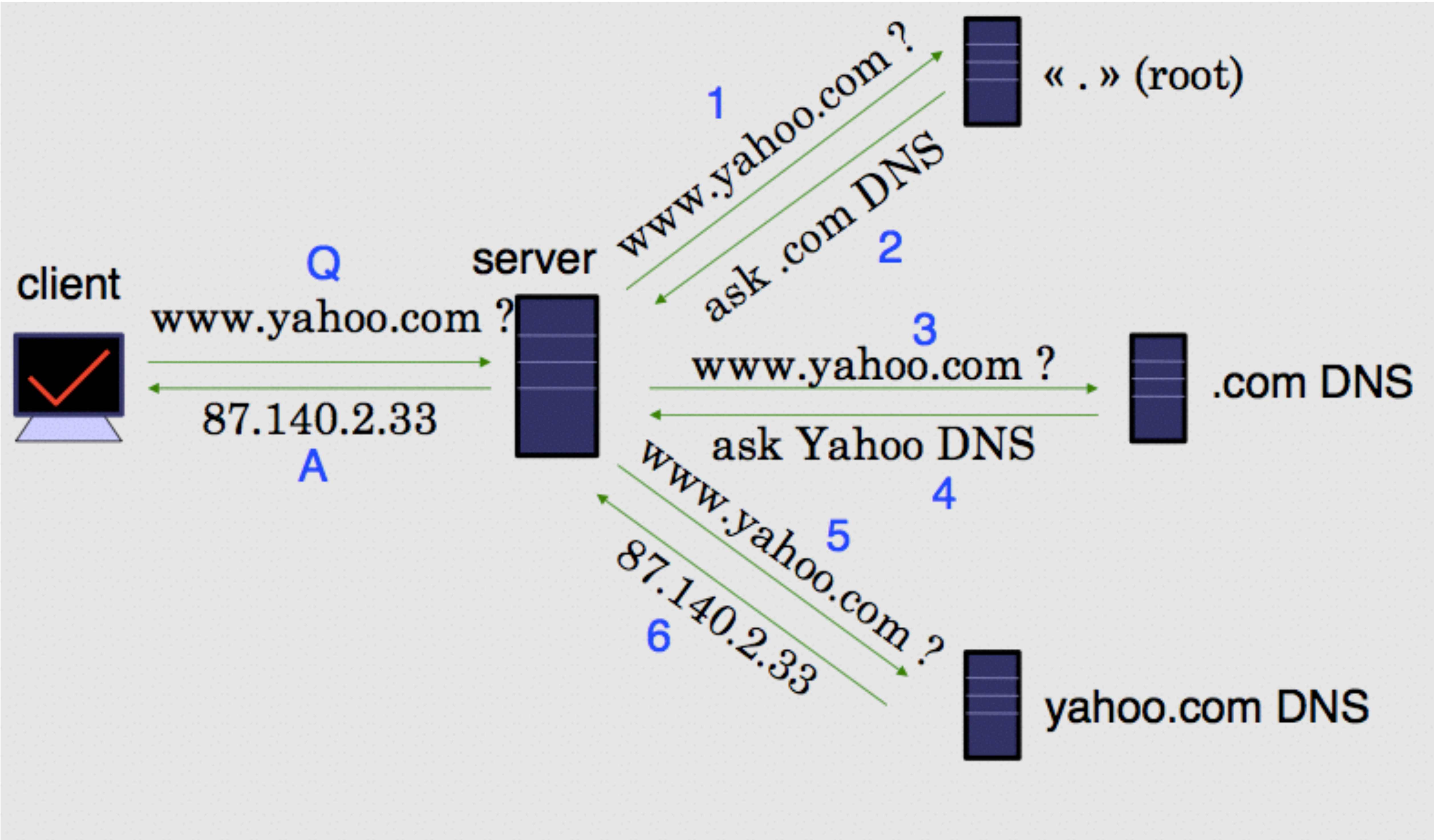
How Does DNS Work?

- Clients use **stub resolvers** and ask **recursive resolver** = this is a query
- recursive resolver will find answer on behalf of client
- recursive resolver keep asking servers top (root) to bottom

  until it finds the answer



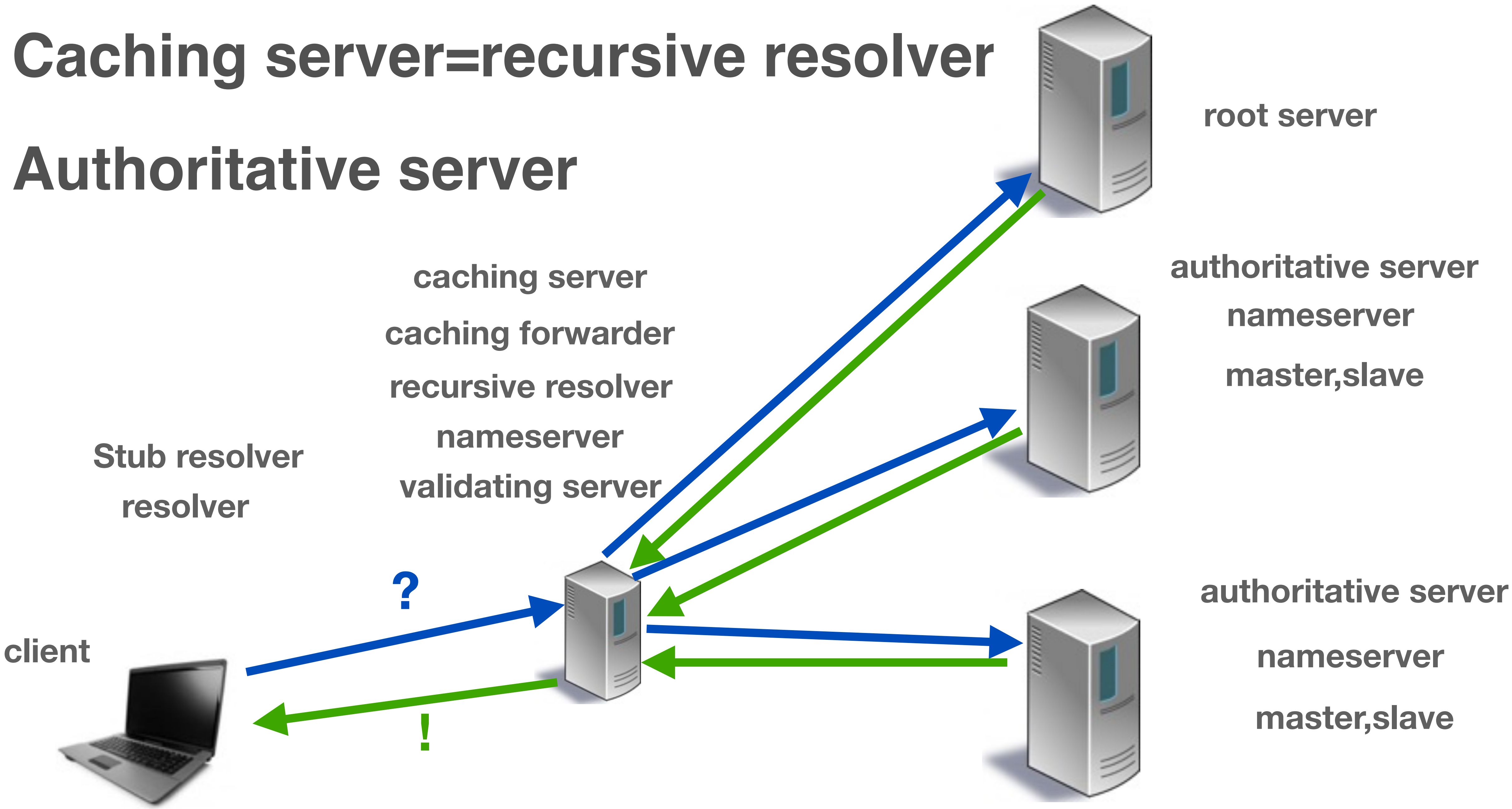
DNS Query



client
Q
www.yahoo.com ?
87.140.2.33
A
server
1
www.yahoo.com ?
ask .com DNS
2
« . » (root)
3
www.yahoo.com ?
ask Yahoo DNS
4
.com DNS
5
www.yahoo.com ?
6
87.140.2.33
yahoo.com DNS

Terminology

- Stub resolver
- Caching server=recursive resolver
- Authoritative server



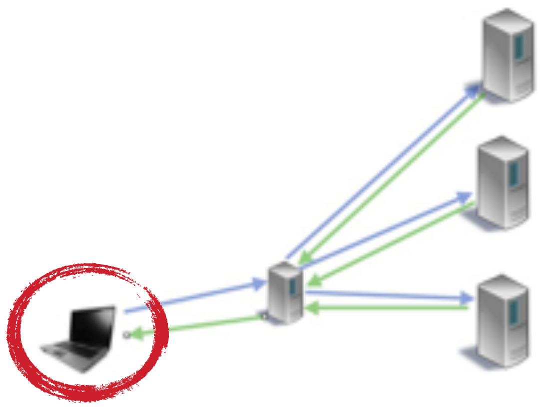
Recursion is Important

No single machine can have all the information in the world

How the Client Finds the Recursive Resolver

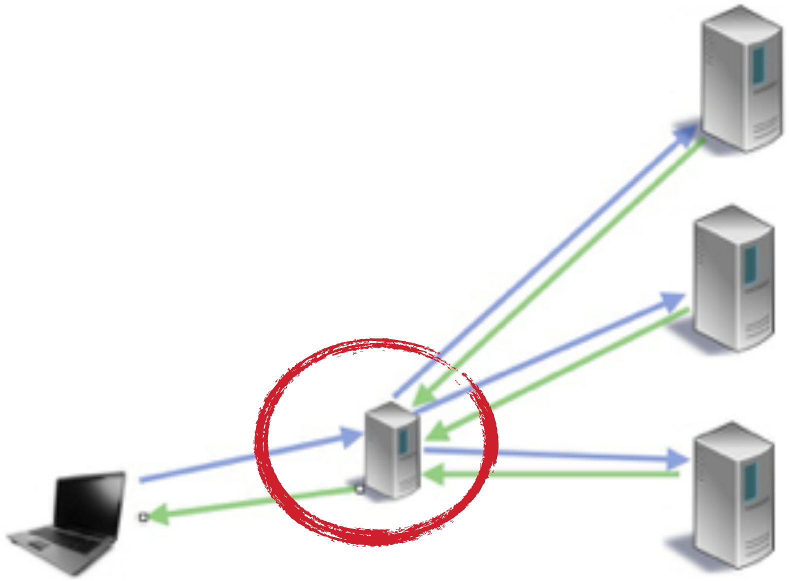
- **Client** (web browser, email …) uses OS's <u>stub resolver</u> to find **recursive resolver's** IP address

- The address of the resolver can be configured manually, or received via DHCP



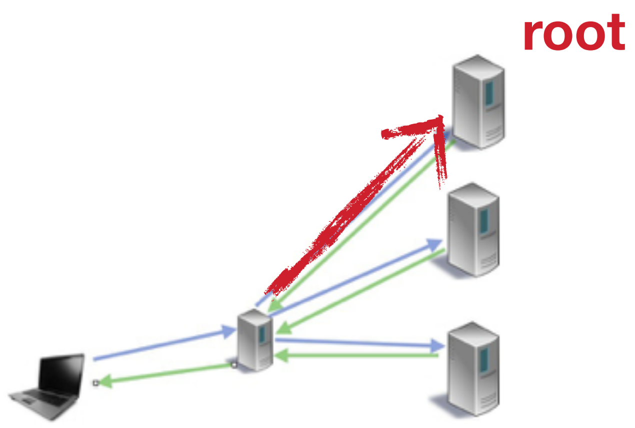
Recursive Resolver

- Queried by **stub resolvers** to resolve names
- They query the **authoritative servers** for the answer and serve it back
- Results are cached based on the Time To Live (TTL) in the zone
- Most famous resolver: 8.8.8.8



How Does a Recursive Resolver Find

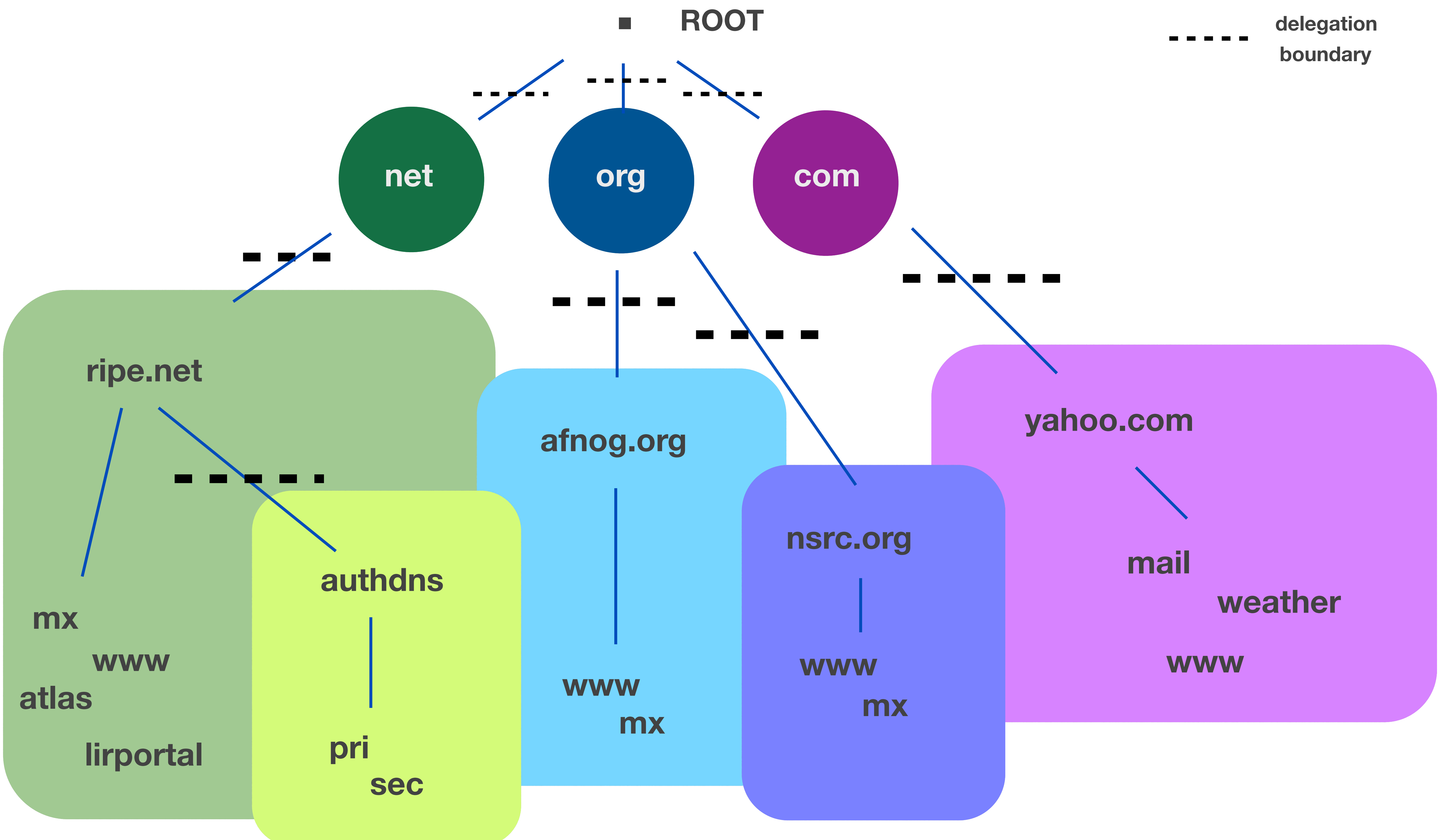
- First query to 192.112.36.4 (G.ROOT-SERVERS.NET.)
- How to reach root?
- Each **recursive resolver** has a list of root nameservers (A-M.ROOT-SERVERS.NET) and their IPs
- In BIND: `named.cache`



Root and TLDs

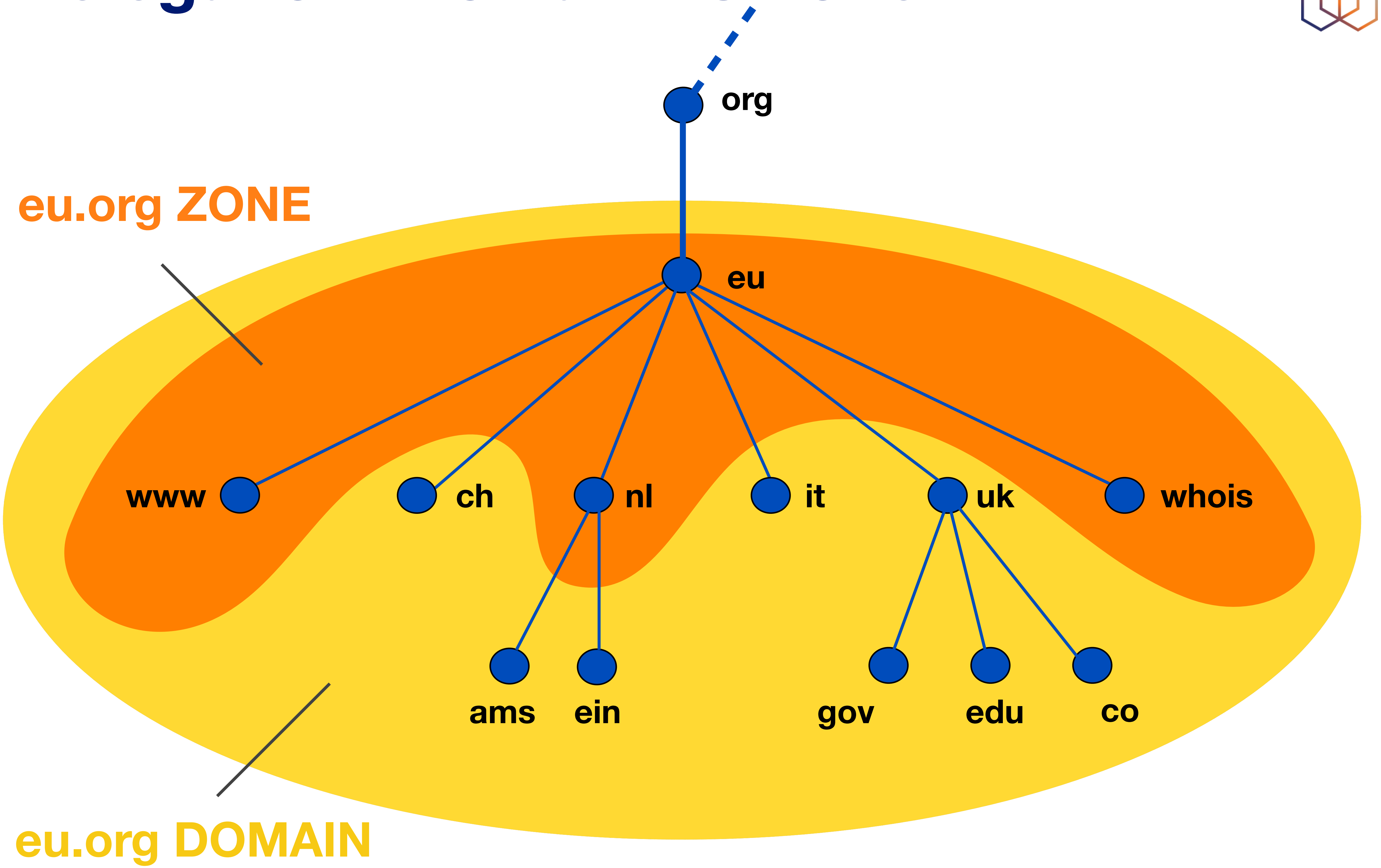
- **Top-bottom approach**
  - 13 Root servers
  - “Empty label” covers the “.” zone
- **Top level domains**
  - GTLD: Generic Top-Level Domain (.com, .net, .org, etc)
  - CCTLD: Country-Code Top-Level Domain (.it, .nl, .ch, etc)
  - New TLDs (.tourism, .newyork, .museum, etc…)
  - IDN: Internationalised Domain Names (ایران. .MOCKBA)

Delegation



. ROOT
delegation boundary
net
org
com
ripe.net
mx
www
atlas
lirportal
authdns
pri
sec
afnog.org
www
mx
nsrc.org
www
mx
yahoo.com
mail
weather
www

Delegation: Domain vs Zone



DNS Query

- **Every DNS Query consists of:**
  - qname: a domain name (i.e. www.ripe.net)
  - qtype: A, AAAA, MX, CNAME, PTR, SRV, TXT, NS
  - qclass: IN, CH, HS (only IN used today)
  - Flags: QR, RD, EDNS Opt, DO, AD, etc.

Resource record types

- SOA: Start of Authority
- NS: Name Server
- A: IPv4 address record
- AAAA: IPv6 address record
- CNAME: Canonical Name (i.e. Alias)
- MX: Mail Exchanger
- PTR: Pointer (for reverse DNS)

NS Record

- **Name Server record**
- **Delegates a DNS subtree from parent**
  - Lists the authoritative servers for the zone
- **Appears in both parent and child zones**
- **rdata contains hostname of the DNS server**

```
ripe.net. IN NS pri.authdns.ripe.net.
```

"owner",
child's domain

child's DNS server

A Record

- IPv4 Address Record
- rdata contains an IPv4 address

www.ripe.net. IN A 193.0.6.139

"owner"
host or domain

IPv4 address

AAAA Record

- IPv6 Address Record
- rdata contains an IPv6 address

```
www.ripe.net. IN AAAA 2001:67c:2e8:22::c100:68b
```

"owner"
host or domain

IPv6 address

CNAME Record

- **An “alias”**
  - maps one name to another (regardless of type)

- **rdata contains the mapped domain name (canonical name)**

```
website.ripe.net. IN CNAME www.ripe.net.
```

“owner”
host or domain

canonical name
“alias”

MX Record

- **Mail Exchanger: defines the host receiving mail**

```
ripe.net. IN MX 10 mail1.ripe.net.
ripe.net. IN MX 20 mail2.ripe.net.
```

preference — host receiving email

lower preference = higher priority

SOA Record (Start Of Authority)

- **Defines the start of a new zone**
  - also, important parameters for the zone
- **Always appears at the beginning of the zone**
- **Serial number should be incremented on zone content updates**

serial number

ripe.net. IN SOA pri.authdns.ripe.net. dns.ripe.net. 1399456383 3600 600 864000 300

Authority: Who Owns This Data

- Query the SOA (Start of Authority) for a domain:

```
# dig SOA <domain>
...
;; AUTHORITY SECTION:
<domain>. 860 IN SOA ns.<domain>. root.<domain>.
                     200702270 ; serial
                     28800       ; refresh
                     14400       ; retry
                     3600000   ; expire
                     86400       ; neg ttl
...
```

SOA
name of master server

RP
(responsible person's email)
Replace first "." by "@"

label

For replication between namservers

How often slave server checks master for new data

If refresh fails, how often retry

If master failed to answer for this long, don't hand out this data to clients

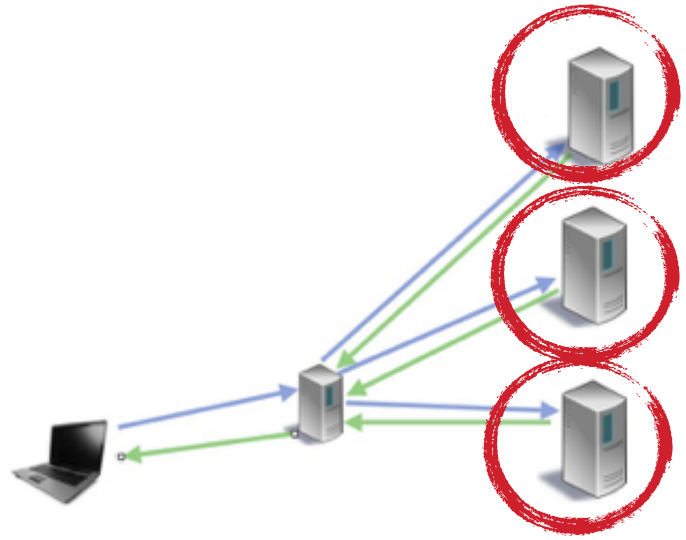
If you got a negative answer (record doesn't exist) when you query the zone file, chache it for so long

Authoritative Server

- **Records are in its zone file**
  - Type A, AAAA, MX, CNAME, etc.

- **Only answer queries for data under their authority**
  - Only if they have internal copy of the data

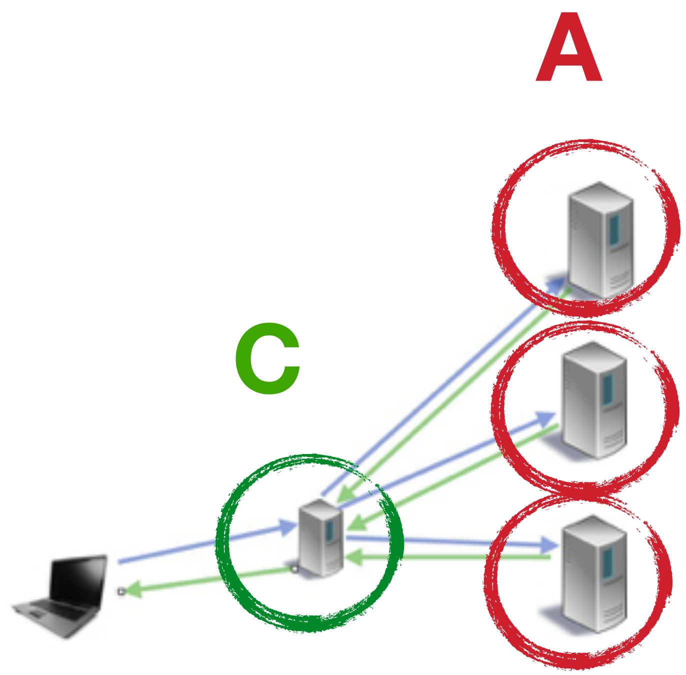
- **If can't answer, it points to authority**
  - but doesn't query recursively.



Caching vs Authoritative

- Caching: repeated query -> query time is lower
- Answers **cached** by recursive resolver
- TTL of answer: max time it can be cached

caching (recursive) server ⟷ authoritative server



Time to Live (TTL)

- How fresh is your data?
- TTL values decrement and expire
- Try asking for A record repeatedly:

```
# dig www.yahoo.com
```

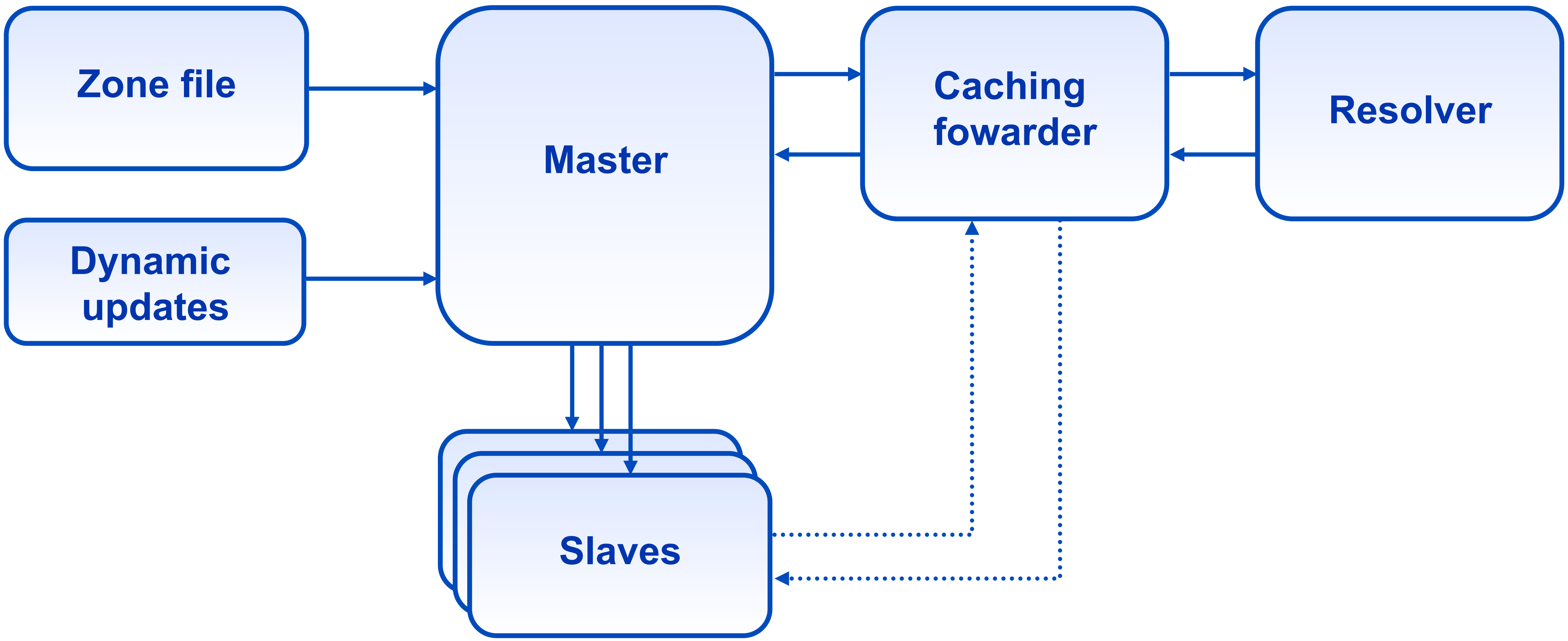
Creating a Zone File

Exercise A

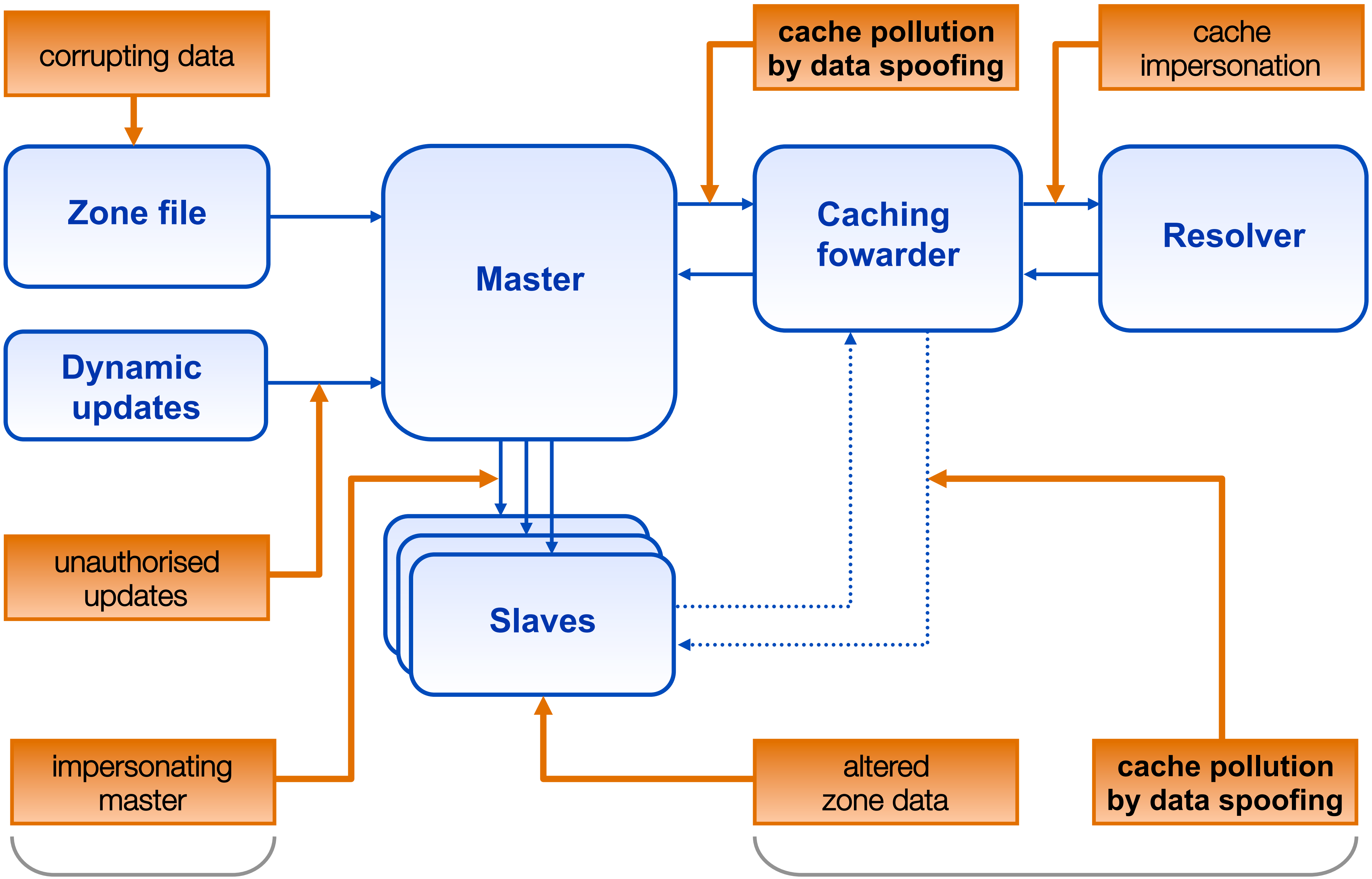
DNS Vulnerabilities

Section 2

DNS Data Flow

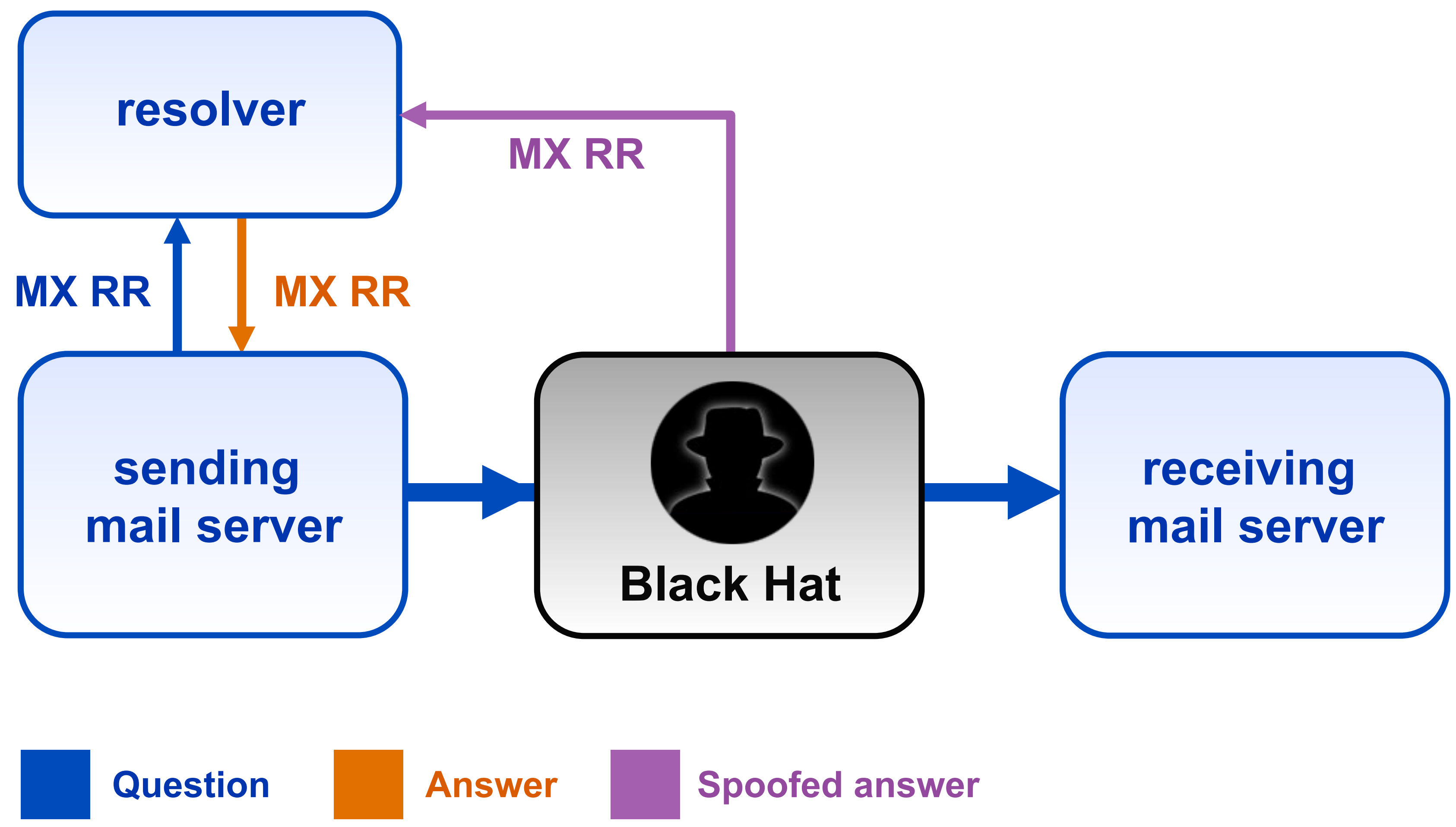


DNS Vulnerabilities



DNS Exploit Example

- Mail goes to the server in the MX resource record
- Path only visible in the email headers



Introduction to Cryptography

Section 3

Cryptography

- **A way to encrypt or hash some content**
  - Make it “secure” and/or verifiable
- **Intent is not always to hide the message**
  - For DNSSEC, goal is to verify the content
- **Different methods and keys**

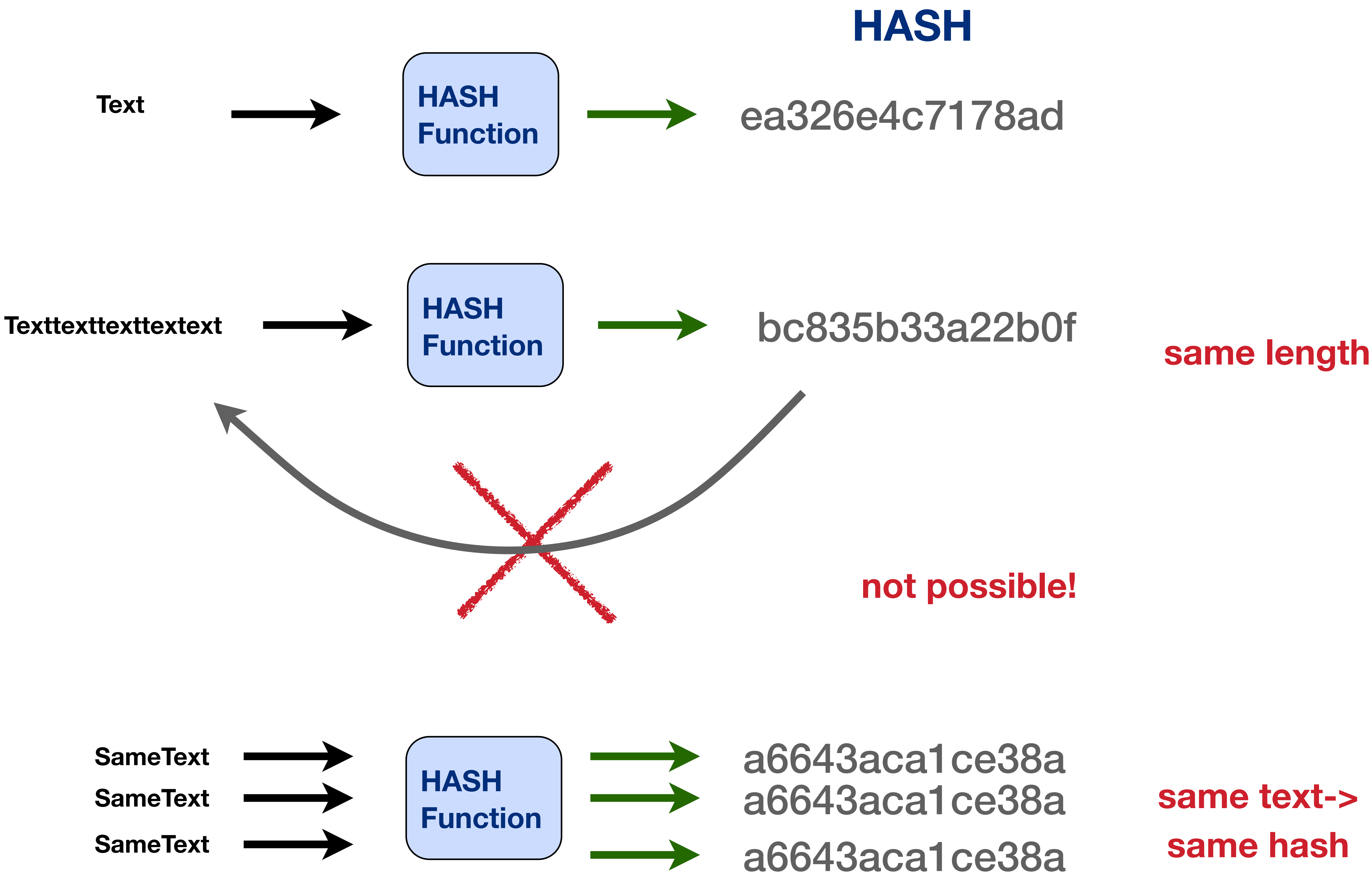
Hashes

- Turns a string into a different series of characters
- Fixed length

SHA256 ("This is the DNSSEC Course")
a8feb4dd098d86d1ea326e4c7178ad5dcbacacabb4df421
c0f4bbe04f28077a2

SHA256 ("This is the DNSSEC Course for LIRs")
74fda40946cb6bc835b3322bc0b0a6643aca1ce38af4f88c
a114edec859bec68

Hashes

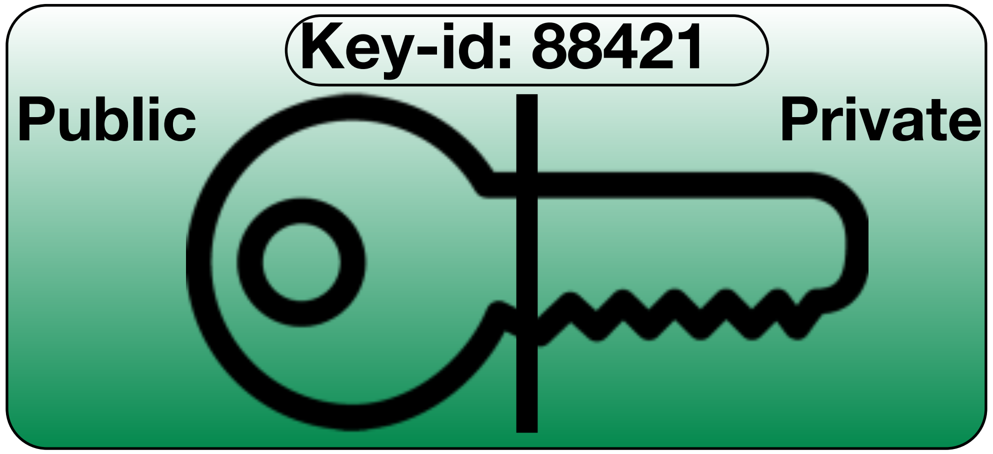

HASH
Text
HASH Function
ea326e4c7178ad
Texttexttexttextext
HASH Function
bc835b33a22b0f
same length!
not possible!
SameText
SameText
SameText
HASH Function
a6643aca1ce38a
a6643aca1ce38a
a6643aca1ce38a
same text->
same hash

Public Key Cryptography

- **Most commonly used cryptographic system**
- **Can guarantee security and authentication**
  - Via encryption
  - Via signatures
  - Or both

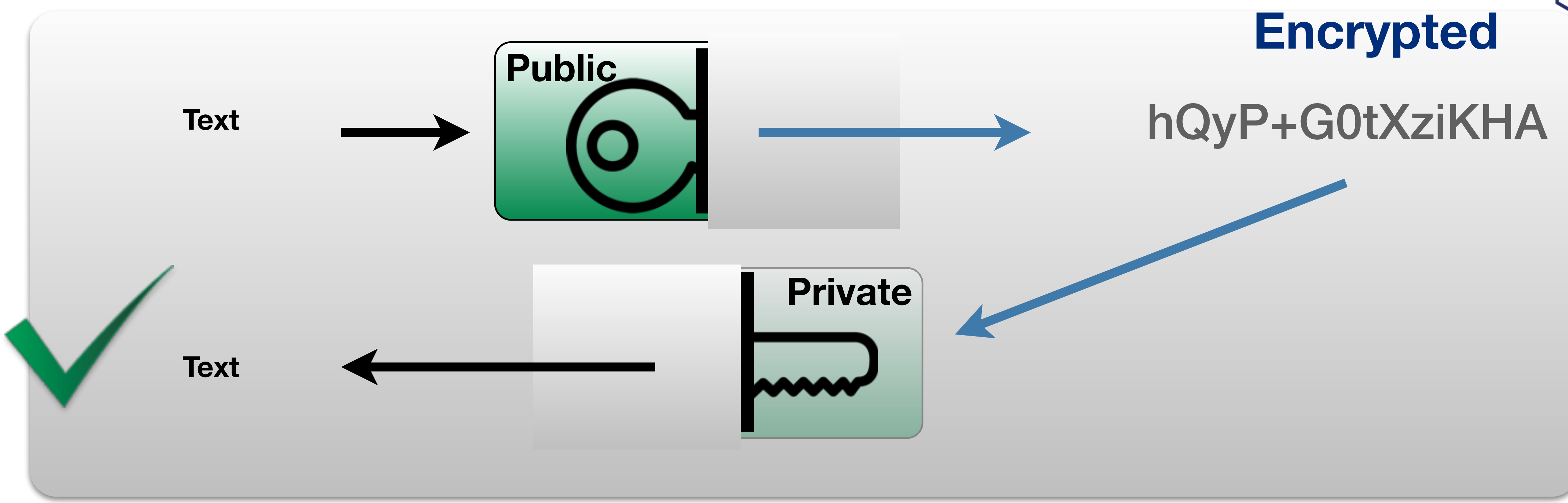
Encryption: Keys

- **Key pair**
  - One private
  - One public

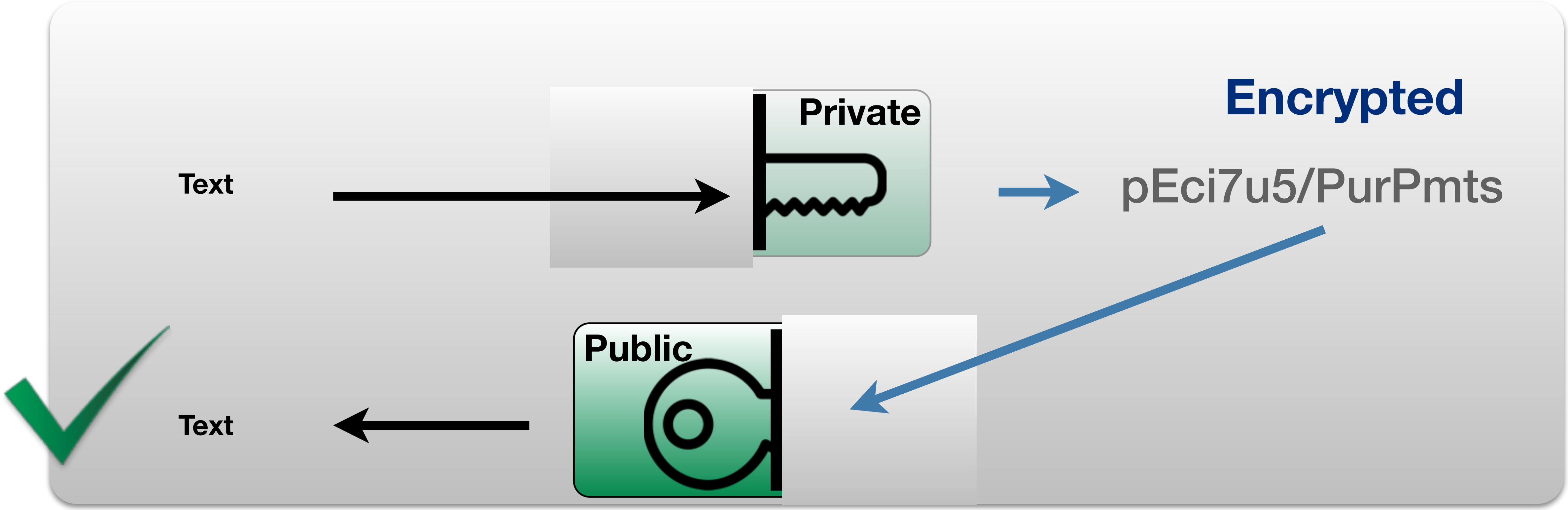


- **Content encrypted with one key, can only be decrypted with the other one**
  - A public key can “open” content encrypted with the private key, and viceversa

Encryption with Key Pair



OR:



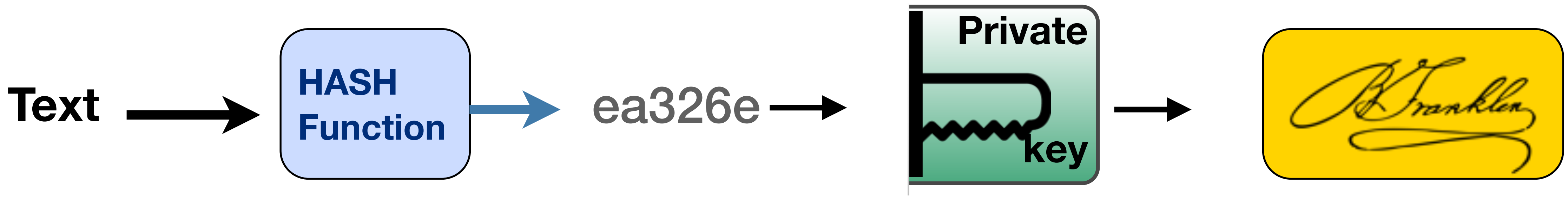
Digital Signatures

- If we combine **hashes** and public key **encryption**, we get a **digital signature**

- We generate a hash, then encrypt it with a key

Signature

Hashing + Encryption = Signature



(or with Public key)

Checking Authenticity of Signatures

- **Decrypt it,**
  - you get the hash
- **Hash original message again**
- **Compare it with the hash received**
- **If 2 hashes match, nobody tampered with the message**

Key Rollovers

- **Keys have to be changed regularly**
  - For security reasons
- **Key rollover = scheduled changing of keys**

Introduction to DNSSEC

Section 4

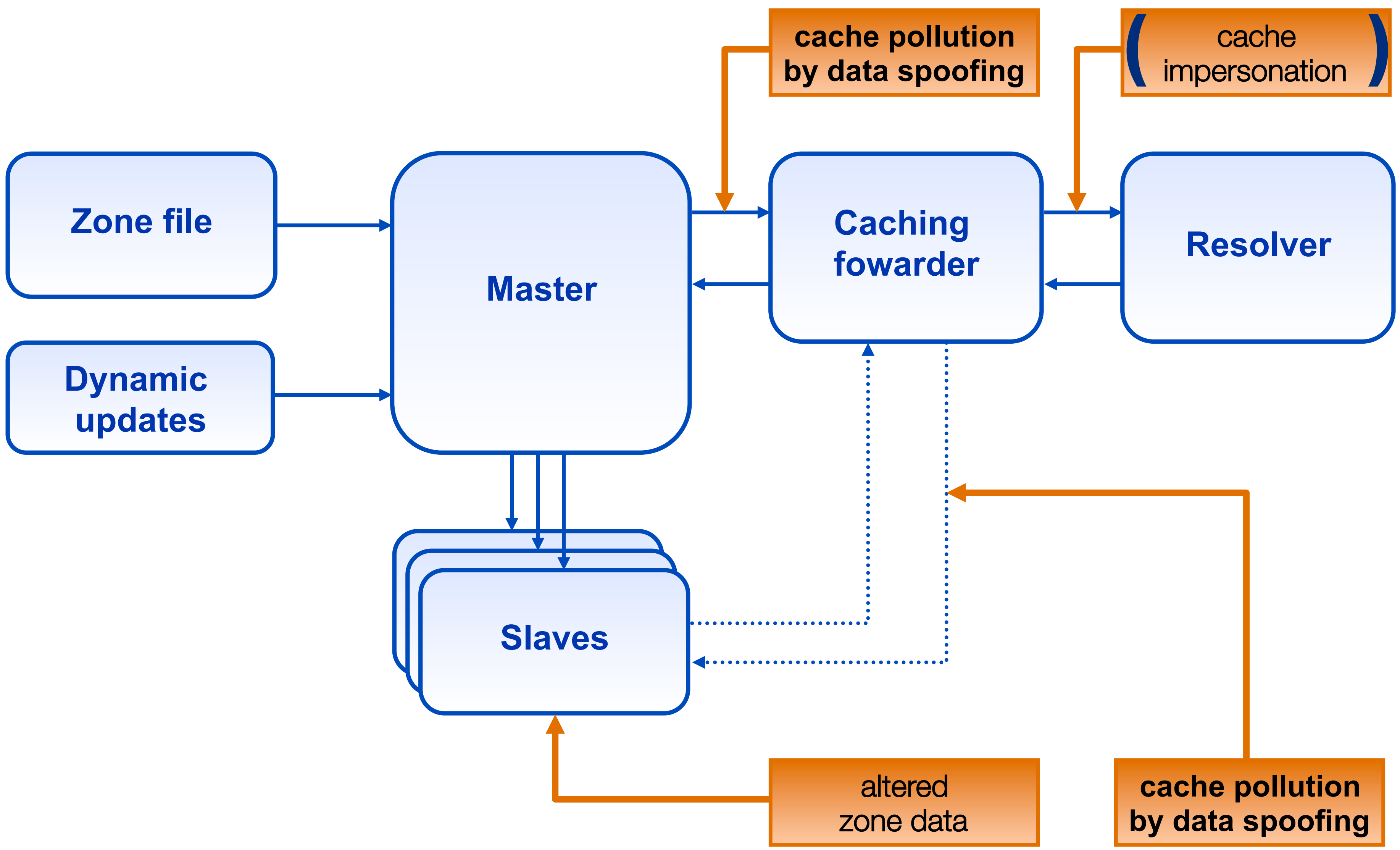
Basic DNS problems

- DNS is plain text
- Simple UDP, no sessions
- Tree structure with delegations
  - Each entity is responsible for a limited part of it
- Resolvers victims of attacks, hijacks and mistakes
- Trust is needed

DNSSEC

- DNS Security Extensions
- RFC4033
- Adds layers on top of DNS to make it verifiable
    - Adds new record types
    - Adds PKI
- Chain of trust to validate data

DNSSEC Protected Vulnerabilities



DNSSEC Summary

- Data authenticity and integrity by signing the Resource Records Sets with **private DNSKEY**
- You need **Public DNSKEY**s to verify the **RRSIG**s (signature)
- Children sign their zones with their **private key**
  - Parent guarantees authenticity of child's key by signing the hash of it (**DS**) (Delegation Signer)
- Repeat for parent …
  - …and grandparent
- Ideal case: one **public DNSKEY** distributed

DNSSEC Summary

ripe.net.

CHILD

www.ripe.net IN 900 **A 193.0.0.214** original DNS record
www.ripe.net IN 900 **RRSIG A** ... **26523 ripe.net.** ... signature

ripe.net IN 3600 **DNSKEY** 256 3 5 ... key
ripe.net IN 3600 **RRSIG DNSKEY** ... **26523 ripe.net.** ... signature

net.

PARENT

ripe.net IN 3600 **DS 26523** 5 1 ... hash of child's key
ripe.net IN 3600 **RRSIG DS** .... **573 net. ...** signature

Locally Configured Verifier (named.conf)

Config file on recursive resolver

trusted-keys { "ripe.net." 256 3 5 "..."; };

The Recursive Resolver's View

- So far we talked about authoritative servers
- Recursive resolver will query them for records and for authentication of records
- DNSSEC happens between server and resolver
  - Security status of records
  - Security status determines what client gets to see

Security Status of Data

- Secure
  - Resolver can build chain of signed DNSKEY and DS RRs from trusted anchor to RRset
- Insecure
  - Resolver knows it has no chain of signed DNSKEY and DS RRs from any trusted starting point to RRset
- Bogus
  - Resolver thinks it can build a chain of trust but it is unable to do so
  - May indicate attack or configuration error or data corruption
- Indeterminate
  - Resolver cannot determine whether the RRset should be signed

Update the zone file in BIND

Exercise B

Using Dig to find Information

Exercise C

DNSSEC: New Resource Records in DNS

Section 5

RRs and RRSets

- **Resource Record:**

name	TTL	class	type	rdata
www.ripe.net.	7200	IN	A	192.168.10.3

- **RRset: RRs with same name, class and type:**

www.ripe.net.	7200	IN	A	192.168.10.3
www.ripe.net.	7200	IN	A	10.0.0.3
www.ripe.net.	7200	IN	A	172.25.215.2

- **RRSets are signed, not the individual RRs**

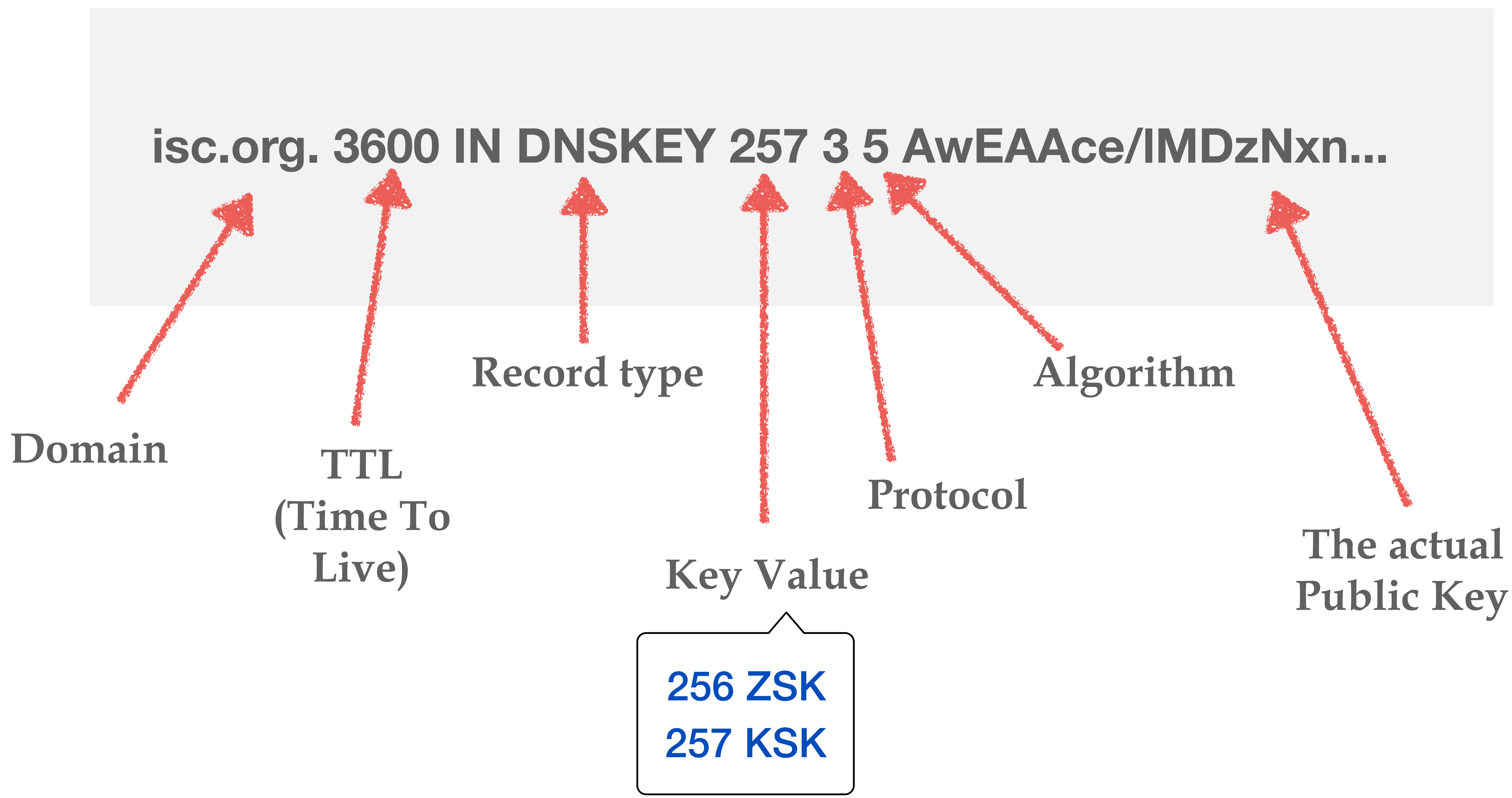
New Resource Records

- Three Public key crypto related RRs
  - **RRSIG** Signature over RRset using private key
  - **DNSKEY** Public key, needed for verifying an RRSIG
  - **DS** Delegation Signer; 'Pointer' for building chains of authentication

- One RR for internal consistency
  - **NSEC** shows which name is the next one in the zone and which types exist for the name queried
  - authenticated non-existence of data

DNSKEY Record

- Contains Zone’s public key(s)



DNSKEY Record (cont.)

OWNER — TYPE — FLAGS — PROTOCOL — ALGORITHM

```
MYZONE.   600  DNSKEY  256  3  5  (
          AwEAAdevJXb4NxFnDFT0Jg9d/jRhJwzM/YTu
          PJqpvjRl14WabhabS6vioBX8Vz6XvnCzhlAx
          ...) ; key id = 5538
```

KEY ID: 5538

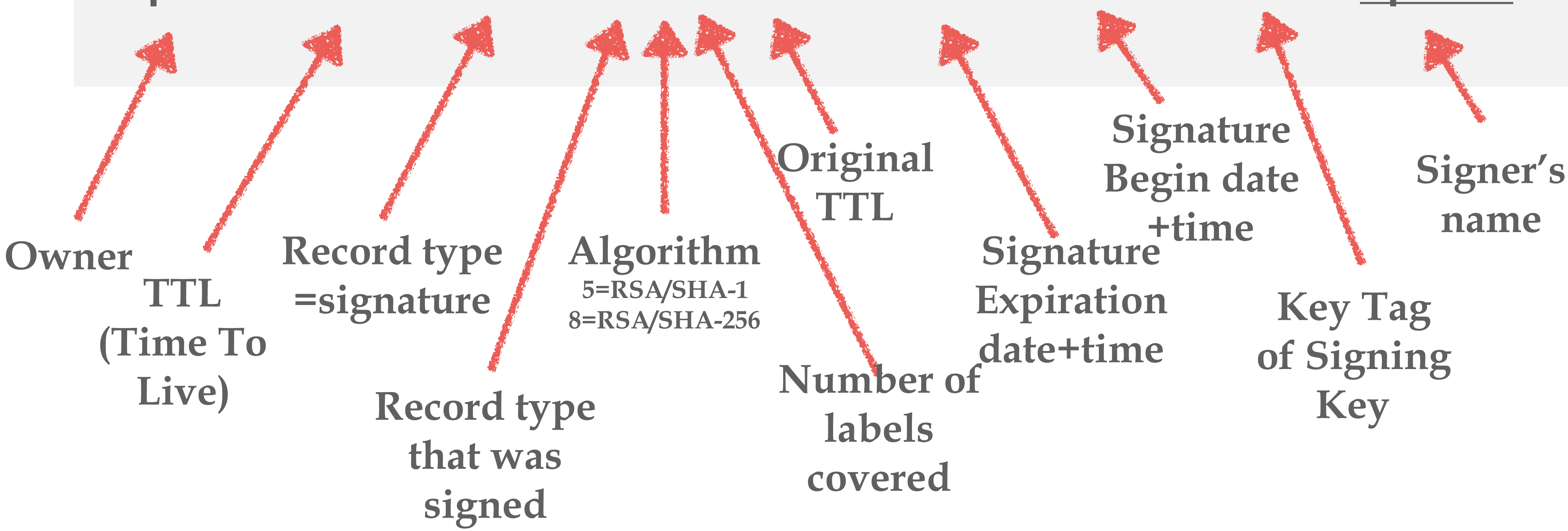
PUBLIC KEY (BASE64)

- FLAGS determines the usage of the key (more on this...)
- PROTOCOL is always 3 (DNSSEC(
- ALGORITHM can be:
  - 0 – reserved
  - 1 – RSA/MD5 (deprecated)
  - 2 – Diffie/Hellman
  - 3 – DSA/SHA-1 (optional)
  - 4 – reserved
  - 5 – RSA/SHA-1 (mandatory in validator)
  - 8 – RSA/SHA-256

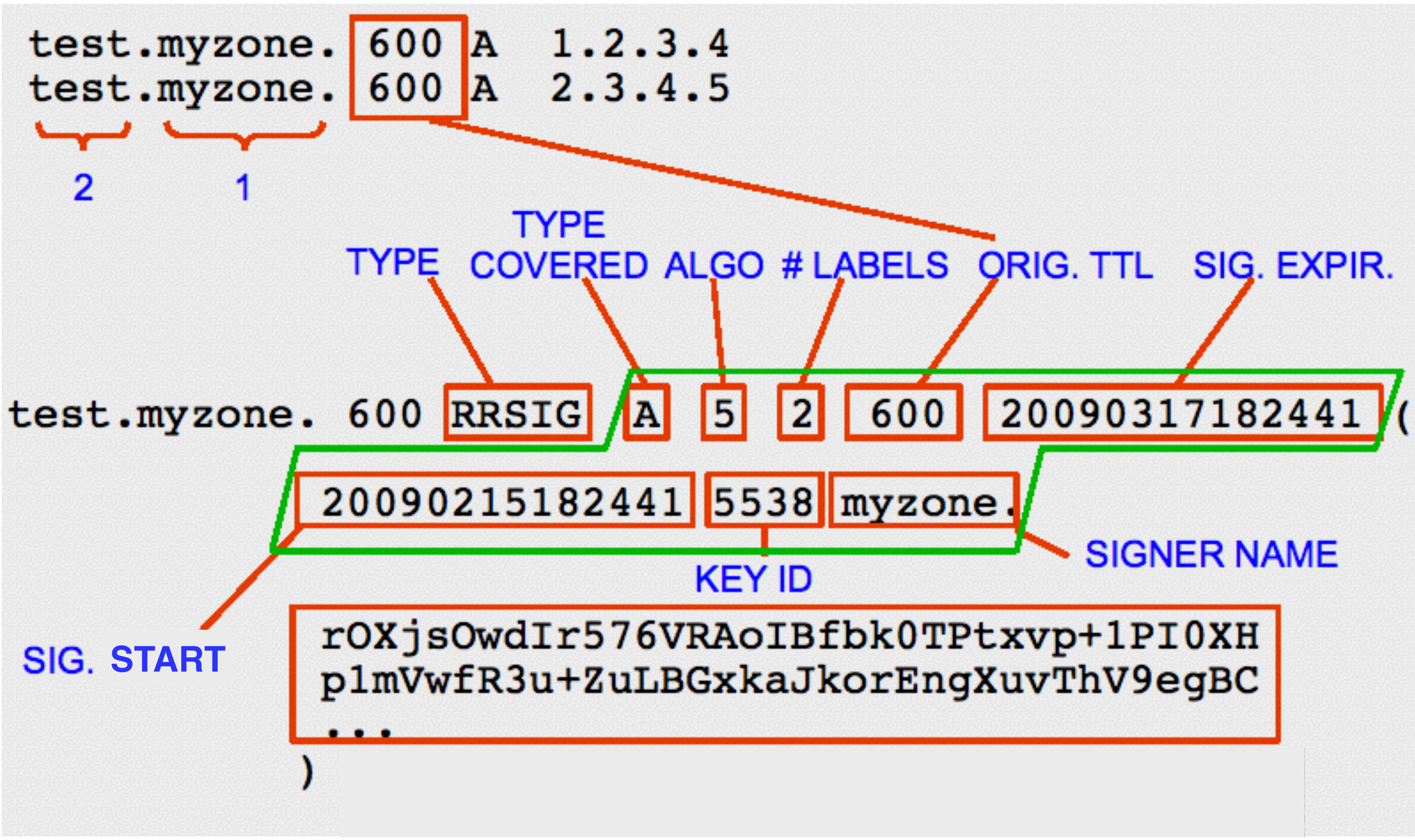
RRSIG

- Resource Record SIGnature
- Digital signature of a set of records

ripe.net. 3600 IN RRSIG A 5 2 3600 20140201 20140101 65306 ripe.net



RRSIG (cont.)



RR set

RRSIG

Delegation Signer Record

- **The child's DNSKEY is hashed**
- **The hash of the key is signed by the parent's DNSKEY**
  - and included in the parent's zone file
- **Repeat for grandchild**
- **Chain of trust**

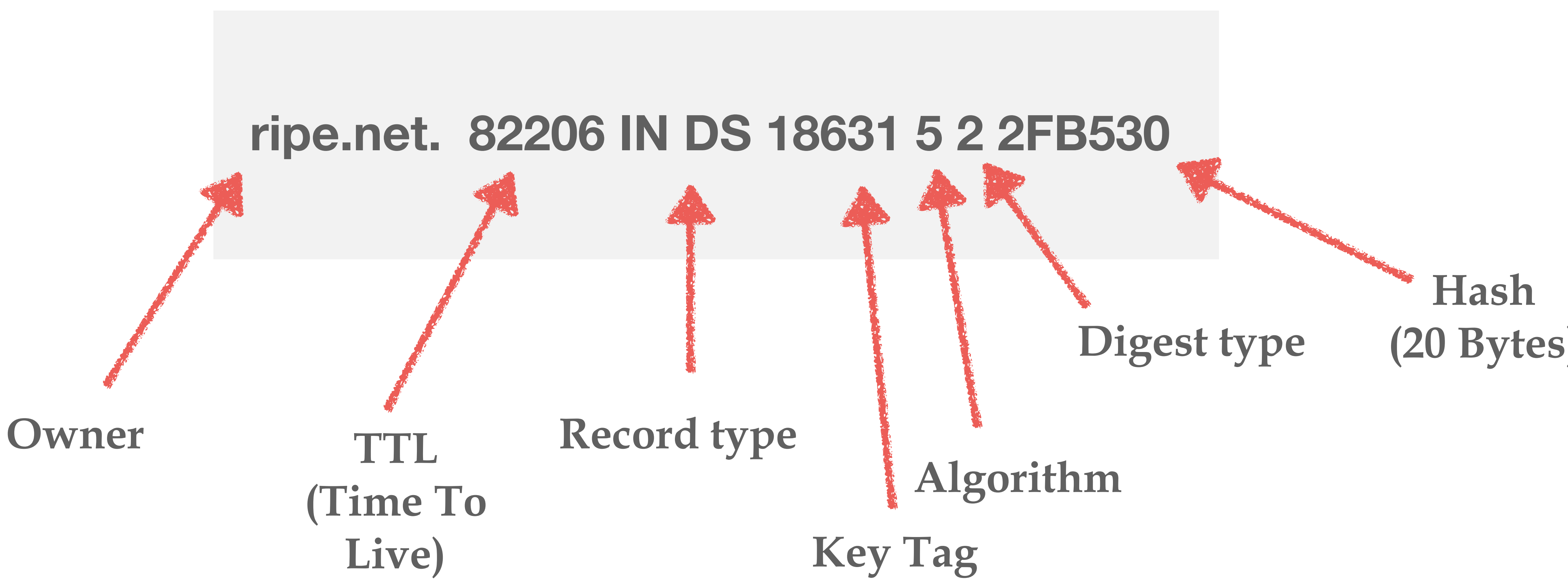
Delegation Signer (DS)

- **Delegation Signer (DS) RR shows that:**
  - child's zone is digitally signed
  - hashed key is used for the child's zone

- **Parent is authoritative for the DS of the child's zone**
  - DS should be in the parent's , not the child's zone

DS

- Delegation Signer
- Contains hash of the (KSK) DNSKEY
- To be published in the parent zone of DNS chain



NSEC Record

- “Next SECure” record
- Authenticates non-existence of data
- Side Effect: allows discovery of zone contents

NSEC Example 1

ZONE FILE

ant.ripe.net NSEC baby.ripe.net A AAAA NSEC RRSIG
baby.ripe.net NSEC cat.ripe.net A NSEC RRSIG
cat.ripe.net NSEC dodo.ripe.net A AAAA NSEC RRSIG
dodo. ripe.net NSEC mouse.ripe net A NSEC RRSIG
mouse.ripe.net NSEC ripe.net A AAAA NSEC RRSIG
ripe.net NSEC www.ripe.net A AAAA MX NSEC RRSIG
www.ripe.net NSEC ant.ripe.net A AAA NSEC RRSIG

Q: A for fruit.ripe.net ?

Doesn't exist! There is nothing between **dodo** and **mouse** !

A: **dodo.ripe.net** NSEC mouse.ripe net A NSEC RRSIG

RRSIG over NSEC

NSEC Example 2

ZONE FILE

ant.ripe.net	NSEC	baby.ripe.net	A AAAA NSEC RRSIG
baby.ripe.net	NSEC	cat.ripe.net	A NSEC RRSIG
cat.ripe.net	NSEC	dodo.ripe.net	A AAAA NSEC RRSIG
dodo. ripe.net	NSEC	mouse.ripe net	A NSEC RRSIG
mouse.ripe.net	NSEC	ripe.net	A AAAA NSEC RRSIG
ripe.net	NSEC	www.ripe.net	A AAAA MX NSEC RRSIG
www.ripe.net	NSEC	ant.ripe.net	A AAA NSEC RRSIG

Q: **AAAA** for baby.ripe.net ?

Doesn't exist! Its not in the list in the NSEC record

A: **baby.ripe.net** NSEC cat.ripe.net A NSEC RRSIG

RRSIG over NSEC

NSEC Record

- **Points to the next domain name in the zone**
  - also lists what are all the existing RRs for “owner”
  - NSEC record for last name “wraps around” to first name in zone
- **Used for authenticated denial-of-existence of data**
  - authenticated non-existence of TYPEs and labels

Existing Resource Record types for www.ripe.net

next owner in zone file

“owner”

www.ripe.net. 3600 IN NSEC ant.ripe.net. A RRSIG NSEC

Problem: NSEC Walk

- NSEC records allow for zone “re-construction”
- Causes privacy issues
- It’s a deployment barrier

Solution: NSEC3 Record

- Same as NSEC
- But hashes all names to avoid zone discovery
- Hashed names are ordered

DRVR6JA3E4VO5UIPOFAO5OEEVV2U4T1K.dnssec-course.net. 3600 IN

NSEC3 1 0 10 03F92714 GJPS66MS4J1N6TIIJ4CL58TS9GQ2KRJ0 A RRSIG

NSEC3 Example

ZONE FILE

ant.ripe.net	NSEC	baby.ripe.net	A AAAA NSEC RRSIG
baby.ripe.net	NSEC	cat.ripe.net	A NSEC RRSIG
cat.ripe.net	NSEC	dodo.ripe.net	A AAAA NSEC RRSIG
dodo. ripe.net	NSEC	mouse.ripe net	A NSEC RRSIG
mouse.ripe.net	NSEC		A AAAA NSEC RRSIG
ripe.net	NSEC	www.ripe.net	A AAAA MX NSEC RRSIG
www.ripe.net	NSEC	ant.ripe.net	A AAA NSEC RRSIG

ZONE FILE

df67wer9x1	NSEC3	8d5g8rt69v	A AAAA NSEC3 RRSIG
8d5g8rt69v	NSEC3	5tyro47f75	A NSEC3 RRSIG
5tyro47f75	NSEC3	h3aq475y76q	A AAAA NSEC3 RRSIG
h3aq475y76q	NSEC3	1z45wt6P3d	A NSEC3 RRSIG
1z45wt6P3d	NSEC3	gf8r8yt64j	A AAAA NSEC3 RRSIG
gf8r8yt64j	NSEC3	9t8y0gur9a	A AAAA MX NSEC3 RRSIG
9t8y0gur9a	NSEC3	df67wer9x1	A AAAA NSEC3 RRSIG

Q: A for fruit.ripe.net ?

Doesn't exist! There is nothing between **h3aq475y76** and **1z45wt6P3q** !

A: **h3aq475y76** NSEC3 1z45wt6P3q net A NSEC3 RRSIG

RRSIG over NSEC

New Resource Records

- Three Public key crypto related RRs
  - **RRSIG** Signature over RRset using private key
  - **DNSKEY** Public key, needed for verifying an RRSIG
  - **DS** Delegation Signer; 'Pointer' for building chains of authentication

- One RR for internal consistency
  - **NSEC** shows which name is the next one in the zone and which types exist for the name queried
  - authenticated non-existence of data

Delegating Signing Authority
Chains of Trust

Section 6

What if There Was No DS ?

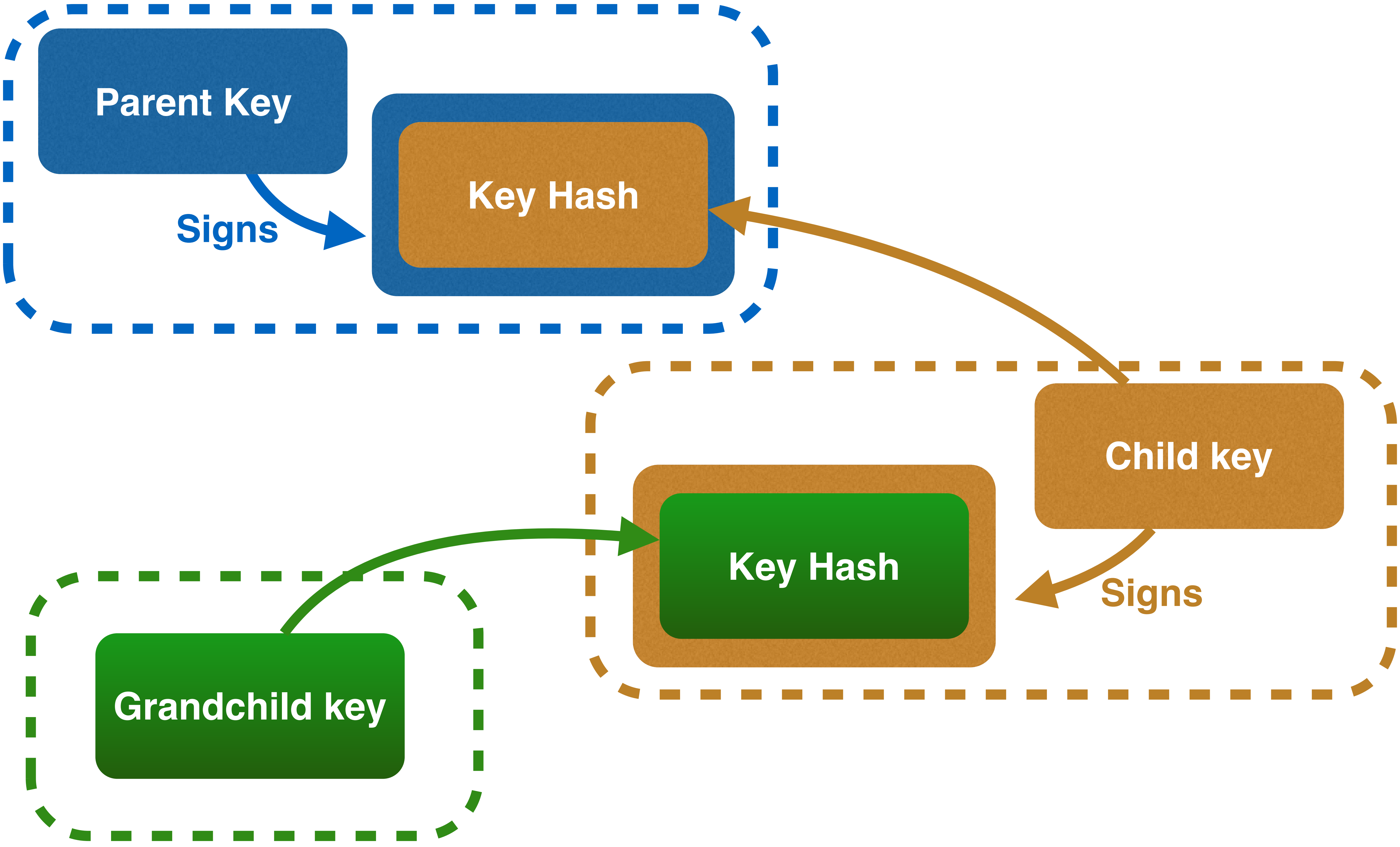
- Without delegating signing authority (DS) the resolver would need to store millions of public keys

- But with DS only one key is needed: the root key

DNS and Keys

- DNS is made of islands of trust, with delegations
- A parent needs to have pointers to child keys
  - in order to sign/verify them
  - DS Records are used for this
- You want to keep interaction between parent and children at a minimum

DNSSEC Made simple



Key Problem

- Interaction with parent administratively expensive
  - Should only be done when needed
  - Bigger keys are better

- Signing zones should be fast
  - Memory restrictions
  - Space and time concerns
  - Smaller keys with short lifetimes are better

Key Functions

- Large keys are more secure
  - Can be used longer ✓
  - Large signatures => large zonefiles ✗
  - Signing and verifying computationally expensive ✗

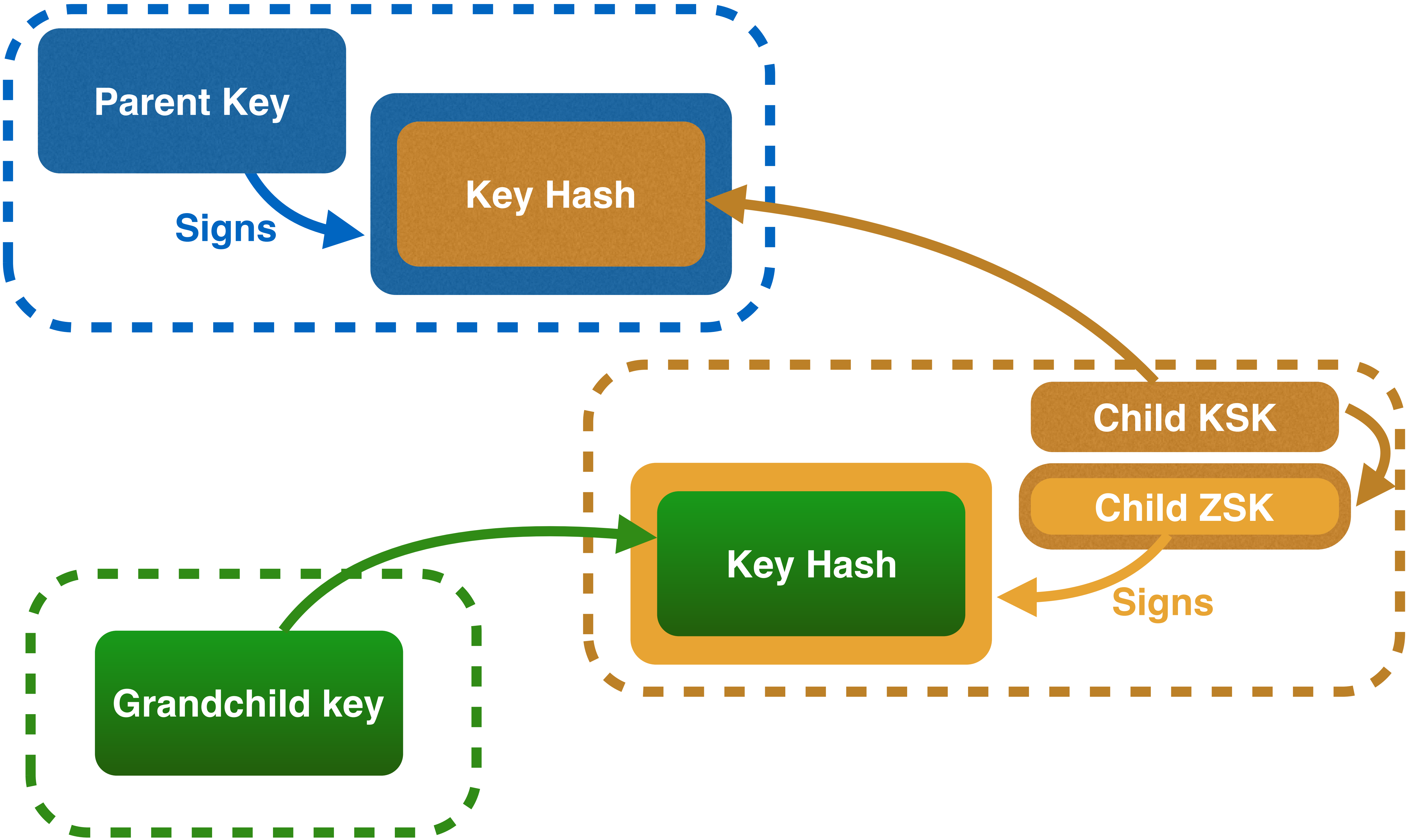
- Small keys are fast
  - Small signatures ✓
  - Signing and verifying less expensive ✓
  - Short lifetime ✗

Key Solution: More Than One Key

- **Key Signing Key (KSK)** only signs DNSKEY RRset
- **Zone Signing Key (ZSK)** signs all RRset-s in zone

- RRsets are signed, not RRs
- DS points to child's KSK
  - Parent's ZSK signs DS
  - Signature transfers trust from parent key to child key

Key split - ZSK and KSK



Zone Signing Key - ZSK

- Used to sign a zone
- Can be lower strength than the KSK
- No need to coordinate with parent zone if you want to change it

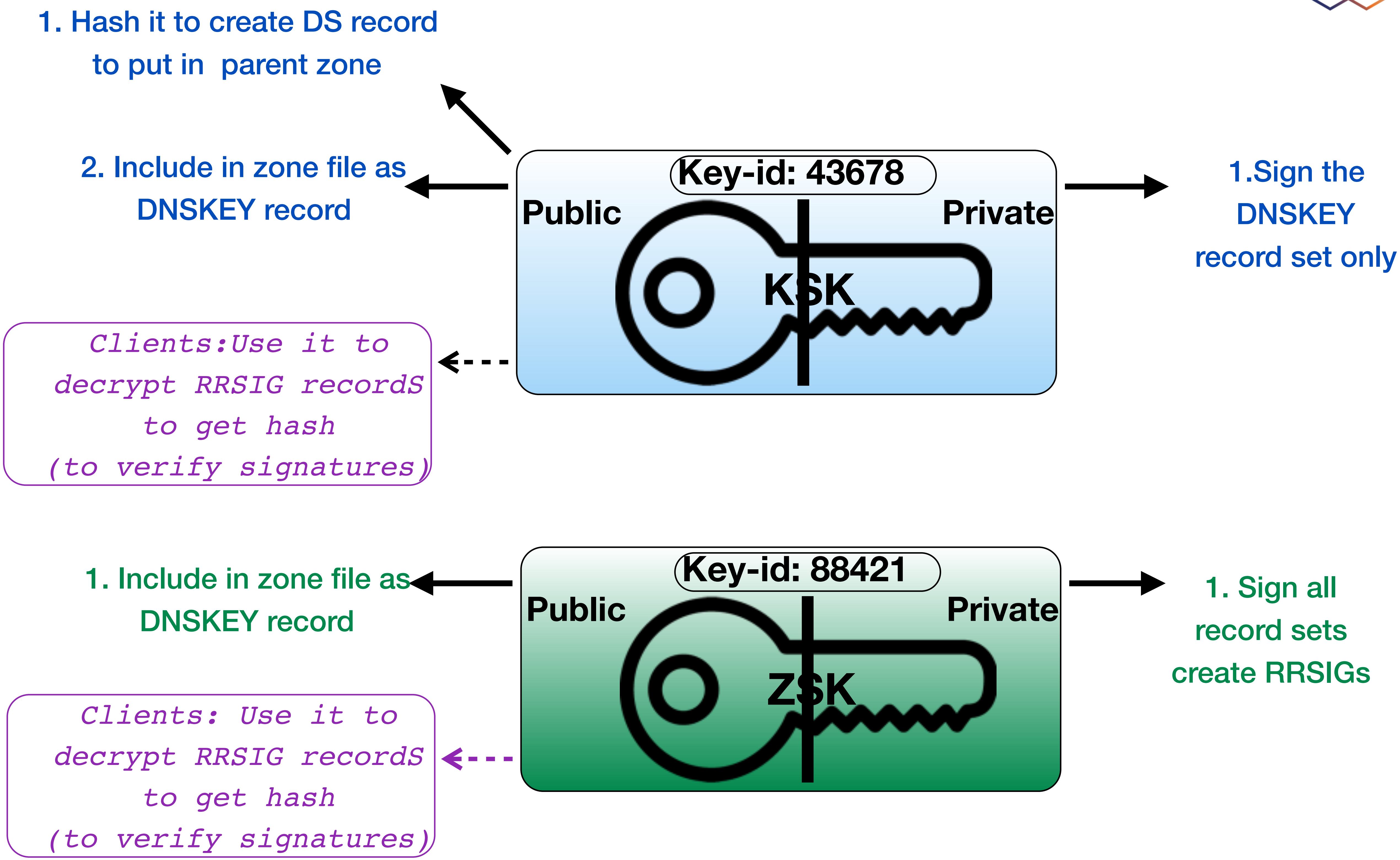
Key Signing Key - KSK

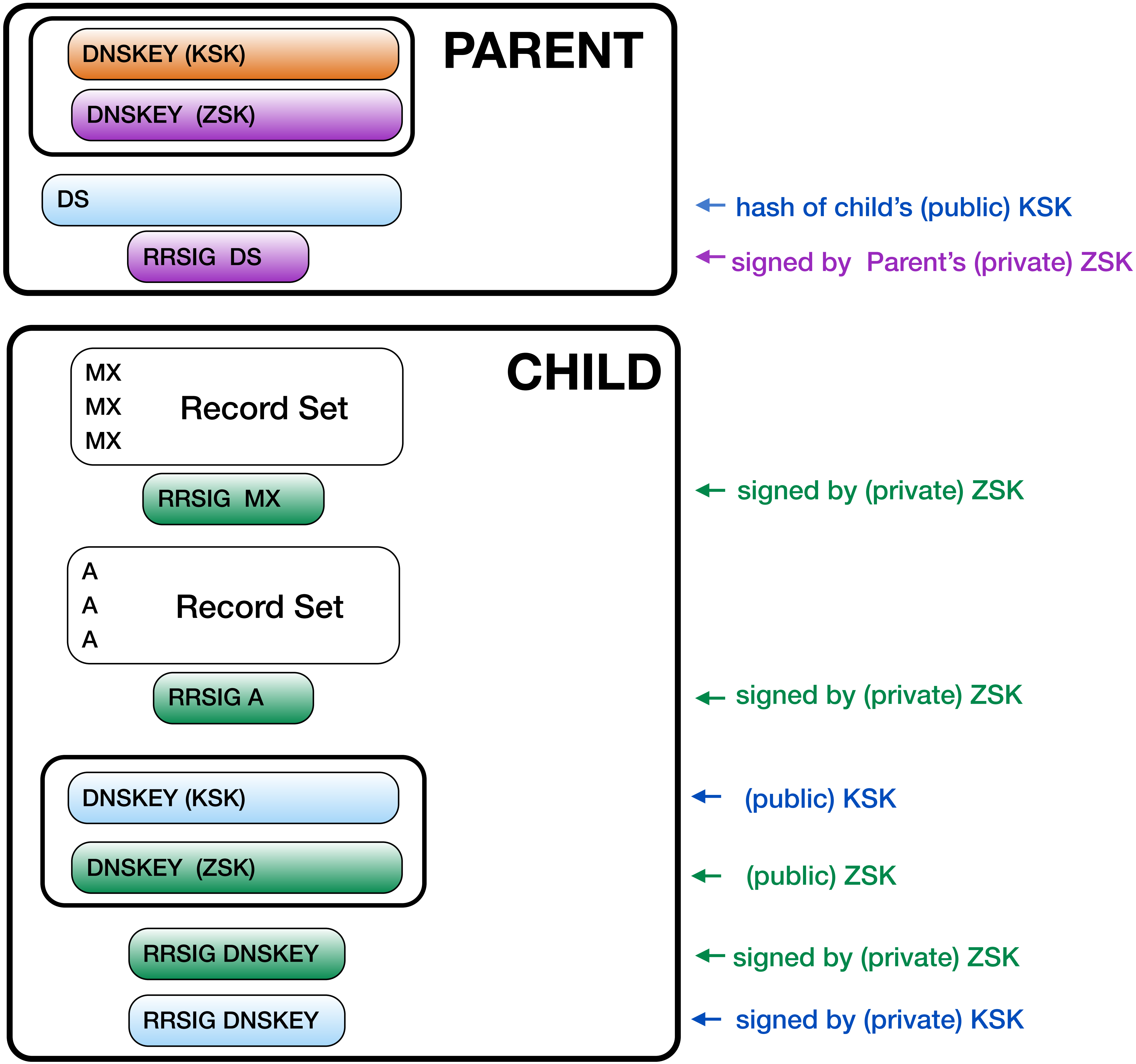
- Only signs the Resource Record Set containing DNSKEYs for a zone
- Used as the trust anchor
- Needs to be specified in the parent zone using DS (Delegation Signature) records

Initial Key Exchange

- **Child needs to:**
    - **Send key signing keyset to parent**
- **Parent needs to:**
    - **Check childs zone**
        - for DNSKEY & RRSIGs
    - **Verify if key can be trusted**
    - **Generate DS RR**

Keys


1. Hash it to create DS record
to put in parent zone
2. Include in zone file as
DNSKEY record
Key-id: 43678
Public
Private
KSK
1.Sign the
DNSKEY
record set only
Clients:Use it to
decrypt RRSIG recordS
to get hash
(to verify signatures)
1. Include in zone file as
DNSKEY record
Key-id: 88421
Public
Private
ZSK
1. Sign all
record sets
create RRSIGs
Clients: Use it to
decrypt RRSIG recordS
to get hash
(to verify signatures)


PARENT
DNSKEY (KSK)
DNSKEY (ZSK)
DS
RRSIG DS
hash of child's (public) KSK
signed by Parent's (private) ZSK
CHILD
MX
MX
MX
Record Set
RRSIG MX
signed by (private) ZSK
A
A
A
Record Set
RRSIG A
signed by (private) ZSK
DNSKEY (KSK)
DNSKEY (ZSK)
(public) KSK
(public) ZSK
RRSIG DNSKEY
signed by (private) ZSK
RRSIG DNSKEY
signed by (private) KSK

Walking the Chain of Trust

Locally Configured

```
Trusted Key . 8907
```

1.Recursive Resolver

(root) .

```
.          DNSKEY (…) 5TQ3s… (8907) ; KSK
           DNSKEY (…) lasE5… (2983) ; ZSK

           RRSIG  DNSKEY (…)  8907 .  69Hw9…

net.       DS   7834 3 1ab15…
           RRSIG  DS (…) . 2983
```

2. KSK = Trusted entry point

3. KSK signed KEY RRset : so ZSK becomes trusted

4. ZSK signed Hash of child's KSK , (DS), so child's KSK becomes trusted

net.

```
net.       DNSKEY (…) q3dEw… (7834) ; KSK
           DNSKEY (…) 5TQ3s… (5612) ; ZSK

           RRSIG  DNSKEY (…)  7834 net.  cMas…

ripe.net.  DS   4252 3 1ab15…
           RRSIG  DS (…) net. 5612
```

5. KSK signed KEY RRset : so ZSK becomes trusted

6. ZSK signed Hash of child's KSK , so child's KSK becomes trusted

ripe.net.

```
ripe.net.      DNSKEY (…) rwx002…  (4252) ; KSK
               DNSKEY (…) sovP42…  (1111) ; ZSK

               RRSIG  DNSKEY (…) 4252 ripe.net.  5t...

www.ripe.net.  A 193.0.0.202
               RRSIG  A  (…)  1111 ripe.net.  a3...
```

7. KSK signed KEY RRset : so ZSK becomes trusted

8. ZSK signs all records so the record becomes trusted

Setting Up a Secure Zone
Step by Step

Section 7

DNSSEC Step-by-Step

1. Generate the key pair

2. Sign and publish the zone(s)

DNSSEC **NOT** active

- -

DNSSEC active

3. Create DS Record on parent

Step 1 : Generate the Key Pair

```
dnssec-keygen -a alg -b bits -f KSK -n type [options] name
```

- algorithm: RSA-SHA1
- Bitsize: depends on key function & paranoia level
- type: zone
- name: zone you want to sign
    - key type: either null or KSK

- ‘-r /dev/urandom’ might be needed

1. Creating the Key Pair

```
$ dnssec-keygen -a RSASHA1 -b 1024 -n zone example.net.

$ kexample.net.+005+20704
```

- **2 files are created:**
  - **Kexample.net.+005+20704.key**
    - contains the public key
    - should go into the zone file
  - **Kexample.net.+005+20704.private**
    - contains the private key

1. Generate Keys

- in /etc/bind/keys/example.com:

Directory where keys are stored

```
# mkdir -p /etc/bind/keys/example.com
# cd /etc/bind/keys/example.com
# dnssec-keygen -a RSASHA256 -b 1024 example.com
Generating key pair...++++++ .............++++++
Kexample.com.+008+17694
# dnssec-keygen -a RSASHA256 -b 2048 -f KSK example.com
Generating key pair.......................+++ .......
Kexample.com.+008+06817
```

ZSK key

KSK key

Algorithm

Number of bits

1. Generate Keys (cont.)

- 4 files in /etc/bind/keys/example.com:
  - Kexample.com.+008+06817.key
  - Kexample.com.+008+06817.private
  - Kexample.com.+008+17694.key
  - Kexample.com.+008+17694.private
- looking inside the key file you can tell if ZSK or KSK

1. Generate Keys

```
# cat Kexample.com.+008+06817.key
; This is a key-signing key, keyid 6817, for example.com.
; Created: 20141120094612 (Thu Nov 20 17:46:12 2014)
; Publish: 20141120094612 (Thu Nov 20 17:46:12 2014)
; Activate: 20141120094612 (Thu Nov 20 17:46:12 2014)
example.com. IN DNSKEY 257 3 8 AwEAAcWDps...lM3NRn/G/R
# cat Kexample.com.+008+17694.key
; This is a zone-signing key, keyid 17694, for example.com.
; Created: 20141120094536 (Thu Nov 20 17:45:36 2014)
; Publish: 20141120094536 (Thu Nov 20 17:45:36 2014)
; Activate: 20141120094536 (Thu Nov 20 17:45:36 2014)
example.com. IN DNSKEY 256 3 8 AwEAAcjGaU...zuu55If5
```

2. Signing by Reconfiguring BIND

- Add extra lines to 'named.conf' file
  - /etc/bind/named.conf

```
options {
     directory "/etc/bind";
     recursion no;
     minimal-responses yes;
};

zone "example.com" IN {
     type master;
     file "db/example.com.db";
     key-directory "keys/example.com";
     inline-signing yes;
     auto-dnssec maintain;
};
```

created a subfolder 'example.com" for that zone's keys

where named should look for the public and private DNSSec key files

BIND keeps unsigned zone and creates signed zone

next slide

2. Reconfigure BIND (cont)

- **auto-dnssec …**
  - off   default. Key management manually
  - allow   allows uploading keys and resigning the zone

    when user runs rndc -sign [zone-name]
  - maintain   same as “allow” +automatically adjusts the keys on schedule (key’s timing metadata)

2. Reload named.conf

```
# rndc reload
server reload successful
```

2 : What Does Signing the Zone Do?

- Sort the Zone
- Insert:
    - **NSEC** records
    - **RRSIG** records (signature over each RRset)
    - **DS** records (optional)
- Generate ‘key-set’ and ‘ds-set’ files

- Remember: Test! (use recursive resolver)

Securing the Zone

- Publish signed zone
- Signed zone is regular zone file format
  - With extra resource records
- Make sure all your DNS servers are DNSSEC capable!

Step 3 : Setting up DNSSEC

- Distribute your public key (DNSKEY)
  - To parent zone (key-set or ds-set can be used)
  - To everyone who wants/needs you as SEP

- Make sure to inform everyone of key rollovers!

```
$ dnssec-dsfromkey kexample.net.+005+20704
```

Verifying with the Recursive Resolver

- To verify the content of a zone:
  - Get the public (key signing) key and check that this key belongs to the zone owner

- Configure the keys you trust as secure entry points in named.conf

```
trusted-keys {
    "example.net." 256 3 1 "AQ...QQ==";
};
```

Configure DNSSEC for the Domain

Exercise D

Flags and Scenarios

Section 8

Flags Intro

- Flags modify or fine-tune DNS queries.
- They have effect on the communications between the “recursive resolver” and the “authoritative server”
- They are used in both the query and the response

Types of flags

- **Command line flags**
- **Internal flags** in question or answer section of dig response
  - **DNS flags** vs **DNSSEC flags**

Flags Intro 2

- DNSSEC happens between “recursive resolver“ and “authoritative server”
- DNS queried by
  - client application or
  - diagnostics tool (dig) running on client
- Diagnostic tool tells recursive resolver which flags to set
- Diagnostic tool shows flags received by“recursive resolver” in response from “authoritative server”

Where Do You See These Flags?

- dig (query) response:

```
$ dig ns .

; <<>> DiG 9.9.4 <<>> ns .
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 53999
;; flags: qr rd ra ad; QUERY: 1, ANSWER: 13, AUTHORITY: 0, ADDITIONAL: 1

;; OPT P        CTION:
; EDNS: version: 0, flags:; udp: 4096
;; QUESTION SECTION:
;.                         IN        NS

;; ANSWER SECTION:
.          183478    IN        NS        f.root-servers.net.
.          183478    IN        NS        m.root-servers.net.
.          183478    IN        NS        c.root-servers.net.

;; Query time: 0 msec
;; SERVER: 193.0.19.101#53(193.0.19.101)
;; WHEN: Mon Oct 31 11:32:56 CET 2016
;; MSG SIZE  rcvd: 239
```

question. what you typed

status NOERROR/SERVFAIL

flags

question. translated to its own “language”

answer

dig

- **DNS diagnostic**
- **Can simulate DNS queries and more**
- **flags:**
    - +dnssec
    - +cdflag
    - +multiline

dig Command Line Flags

+dnssec flag

- Requests DNSSEC records be sent by setting the DNSSEC OK bit (DO flag) the query.

dig Command Line Flags

+cdflag

- Set the CD (checking disabled) bit/flag in the query. This requests the recursive server to not perform DNSSEC validation of responses.

Internal Flags

DNS:

- qr query response (A)
- rd recursion desired (Q) (A)
- ra recursion available (A)
- aa authoritative server (A)

DNSSec:

- ad authenticated data (A)
- cd checking disabled (Q) (A)
- do show me DNSSec data (Q) (A)

DNS Flags Explained: qr

- **Query response: This is a response to a query**
  - only used in responses

DNS Flags Explained: rd

- **Recursion desired: “If you, the recursive resolver” don’t know the answer, then go look it up, if necessary in several steps, from the authoritative servers**
  - In query: an instruction
  - In response; info. I was asked to do recursion in the query

DNS Flags Explained: ra

- **Recursion available: response to “rd” flag**
  - Only in response: Info. “Recursion as instructed in the query”

DNS Flags Explained: aa

- “Authoritative answer” flag
  - The “recursive resolver” didn’t have to do recursively query other authoritative servers, because by chance it was itself authoritative for what was being queried.
  - Only in the response

DNSSEC Flags Explained: ad

- "Authenticated Data" flag
  - "ad" flag tells us that the answer received has passed the validation process We can have confidence in the authenticity and integrity of the answer
- only in response

DNSSEC Flags Explained: cd

- "Checking Disable" flag
  - disables DNSSEC validation in dig
  - appears in both query and response

DNSSEC Flags Explained: do

- “DNSSEC OK” flag
- visualise the RRSIG records with the query
    - appears in both the query and the answer

DNSSEC Statuses

- NOERROR
- SERVFAIL

DNS and DNSSEC Statuses

DNS	DNSSEC
NOERROR	NOERROR
NXDOMAIN	NSEC/NSEC3
SERVFAIL	SERVFAIL

dig

- `dig www.isc.org`
- `dig www.isc.org A`

same answer

- `dig @192.168.1.7 www.isc.org A`

which recursive server to use

- **DNSSec validated answers?**
  - depends whether Server and Recursive Resolver configured for DNSSec

dig Example 1

If DNSSec is **disabled** on resolver:

No DNSSEC validation on recursive resolver

DNSSEC enabled on server

Q

```
$ dig @192.168.1.7 www.isc.org. A +dnssec +multiline
; <<>> DiG 9.10.0-P2 <<>> @192.168.1.7 www.isc.org. A +dnssec +multiline
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 20416
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0
```

A

recursion was desired

recursion was available

dig Example 1

If DNSSec is **disabled** on resolver: (whole answer)

No DNSSEC validation on recursive resolver

DNSSEC enabled on server

```
$ dig @192.168.1.7 www.isc.org. A +dnssec +multiline
; <<>> DiG 9.10.0-P2 <<>> @192.168.1.7 www.isc.org. A +dnssec +multiline
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 20416
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 0

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
;; QUESTION SECTION:
;www.isc.org.      IN  A

;; ANSWER SECTION:
www.isc.org.    60   IN   A 149.20.64.69
```

dig Example 2

If DNSSec enabled on resolver:

DNSSEC validation on recursive resolver

DNSSEC enabled on server

show DNSSec data (RRSIG)

sets the DO flag

```
$ dig @192.168.1.7 www.isc.org. A +dnssec +multiline

; <<>> DiG 9.10.0-P2 <<>> @192.168.1.7 www.isc.org. A +dnssec +multiline
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 32472
;; flags: qr rd ra ad; QUERY: 1, ANSWER: 2, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags: do; udp: 4096
```

Authenticated (DNSSec validated) data

“I am showing you the DNSSec records (RRSIG)”

How would the flags and answers be different without the +dnnsec flag?

dig Example 2

If DNSSec **enabled** on resolver: (whole answer)

```
$ dig @192.168.1.7 www.isc.org. A +dnssec +multiline

; <<>> DiG 9.10.0-P2 <<>> @192.168.1.7 www.isc.org. A +dnssec +multiline
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 32472
;; flags: qr rd ra ad; QUERY: 1, ANSWER: 2, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags: do; udp: 4096
;; QUESTION SECTION:
;www.isc.org.    IN A

;; ANSWER SECTION:
www.isc.org.     4 IN A   149.20.64.69
www.isc.org.     4 IN RRSIG A 5 3 60 (
        20141029233238 20140929233238 4521 isc.org.
        DX5BaGVd4KzU2AIH911Kar/UmdmkARyPhJVLr0oyPZaq
        5zoobGqFI4efvzL0mcpncuUg3BSU5Q48WdBu92xinMdb
        E75zl+adgEBOsFgFQR/zqM3myt/8SngWm4+TQ3XFh9eN
        iqExHZZuZ268Ntlxqgf9OmKRRv8X8YigaPShuyU= )

;; Query time: 3 msec
;; SERVER: 192.168.1.7#53(192.168.1.7)
;; WHEN: Fri Oct 03 16:40:04 CST 2014
;; MSG SIZE  rcvd: 223
```

shows RRSIG record

dig Examples 3 + 4

- Let’s use dig to examine a domain with “broken” DNSSec
- 3: Validation NOT enabled on recursive server
- 4: Validation ENABLED on recursive server

dig Example 3

No DNSSEC validation on recursive server

DNSSEC broken on server

```
$ dig @192.168.1.7 www.dnssec-failed.org. A

; <<>> DiG 9.10.1 <<>> @192.168.1.7 www.dnssec-failed.org. A
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 28878
;; flags: qr rd ra; QUERY: 1, ANSWER: 2, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
;; QUESTION SECTION:
;www.dnssec-failed.org.    IN   A

;; ANSWER SECTION:
www.dnssec-failed.org.   7200   IN   A 68.87.109.242
www.dnssec-failed.org.   7200   IN   A 69.252.193.191

;; Query time: 955 msec
;; SERVER: 192.168.1.7#53(192.168.1.7)
;; WHEN: Fri Oct 17 07:42:50 CST 2014
;; MSG SIZE  rcvd: 82
```

dig Example 4

DNSSEC validation on recursive server

DNSSEC broken on server

```
$ dig @192.168.1.7 www.dnssec-failed.org. A

; <<>> DiG 9.10.1 <<>> @192.168.1.7 www.dnssec-failed.org. A
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: SERVFAIL, id: 46592
;; flags: qr rd ra; QUERY: 1, ANSWER: 0, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
;; QUESTION SECTION:
;www.dnssec-failed.org.    IN  A

;; Query time: 2435 msec
;; SERVER: 192.168.1.7#53(192.168.1.7)
;; WHEN: Fri Oct 17 07:44:56 CST 2014
;; MSG SIZE  rcvd: 50
```

dig Example 5 (Diagnostics)

- All DNSSec validation failures -> “SERVFAIL”
    - how do I know failure because of validation?
    - +cd flag!
    - “checking disabled”

dig Example 5 (Diagnostics)

DNSSEC validation on recursive server

DNSSEC broken on server

CHECKING DISABLED

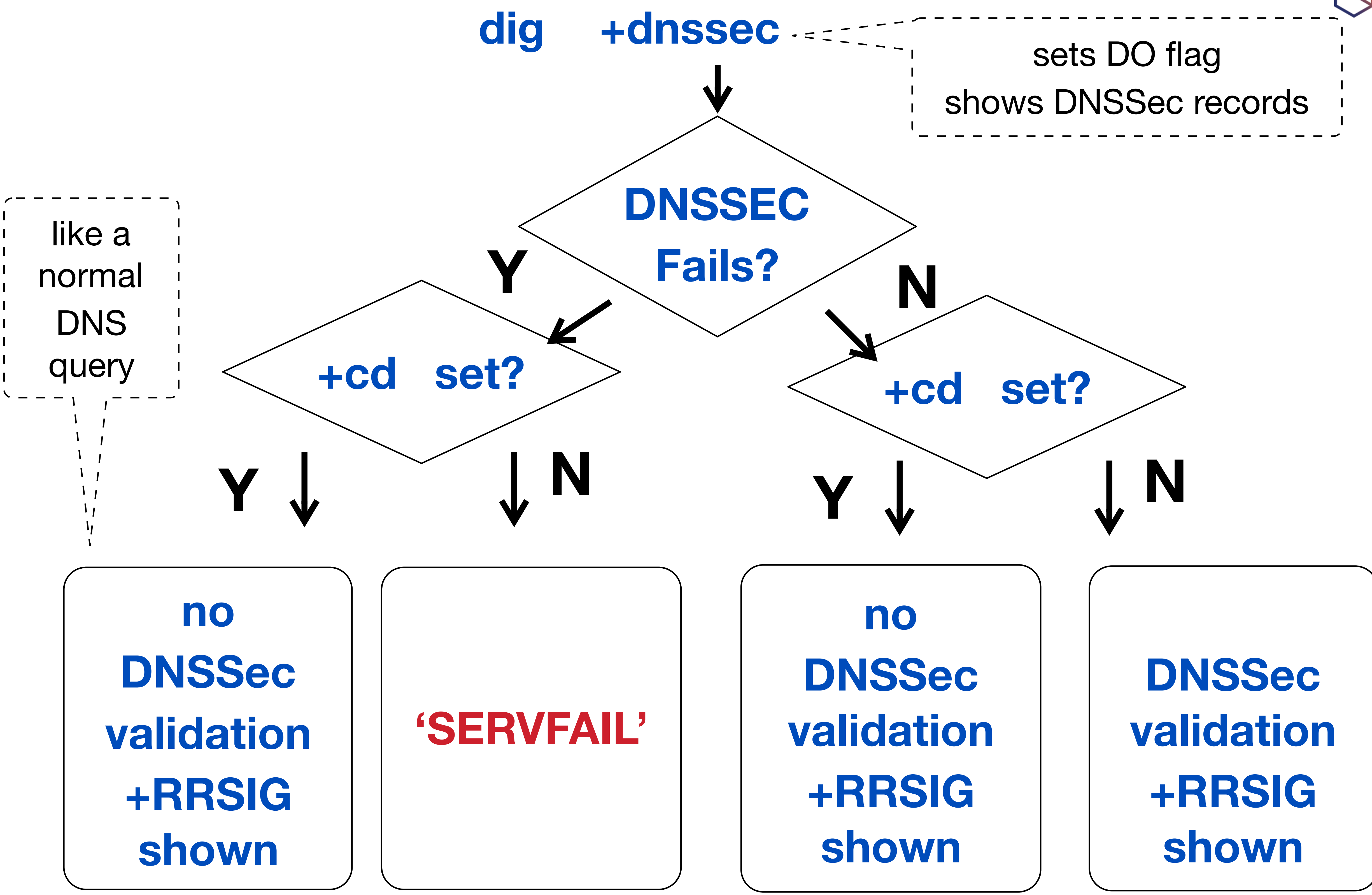
```
$ dig @192.168.1.7 www.isc.org. A +cd

; <<>> DiG 9.10.1 <<>> @192.168.1.7 www.isc.org. A +cd
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 33590
;; flags: qr rd ra cd; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 4096
;; QUESTION SECTION:
;www.isc.org.       IN  A

;; ANSWER SECTION:
www.isc.org.    30  IN  A 149.20.64.69
```

+dnssec


dig +dnssec
sets DO flag
shows DNSSec records
DNSSEC Fails?
Y
N
+cd set?
+cd set?
like a normal DNS query
Y
N
Y
N
no DNSSec validation +RRSIG shown
'SERVFAIL'
no DNSSec validation +RRSIG shown
DNSSec validation +RRSIG shown

Key Rollovers

Section 9

Keys need to be changed

- **Keys become old quickly**
  - New exploits are discovered every day
  - Brute force becomes less and less expensive
- **Your keys could be stolen or compromised**
- **You need to have a plan**

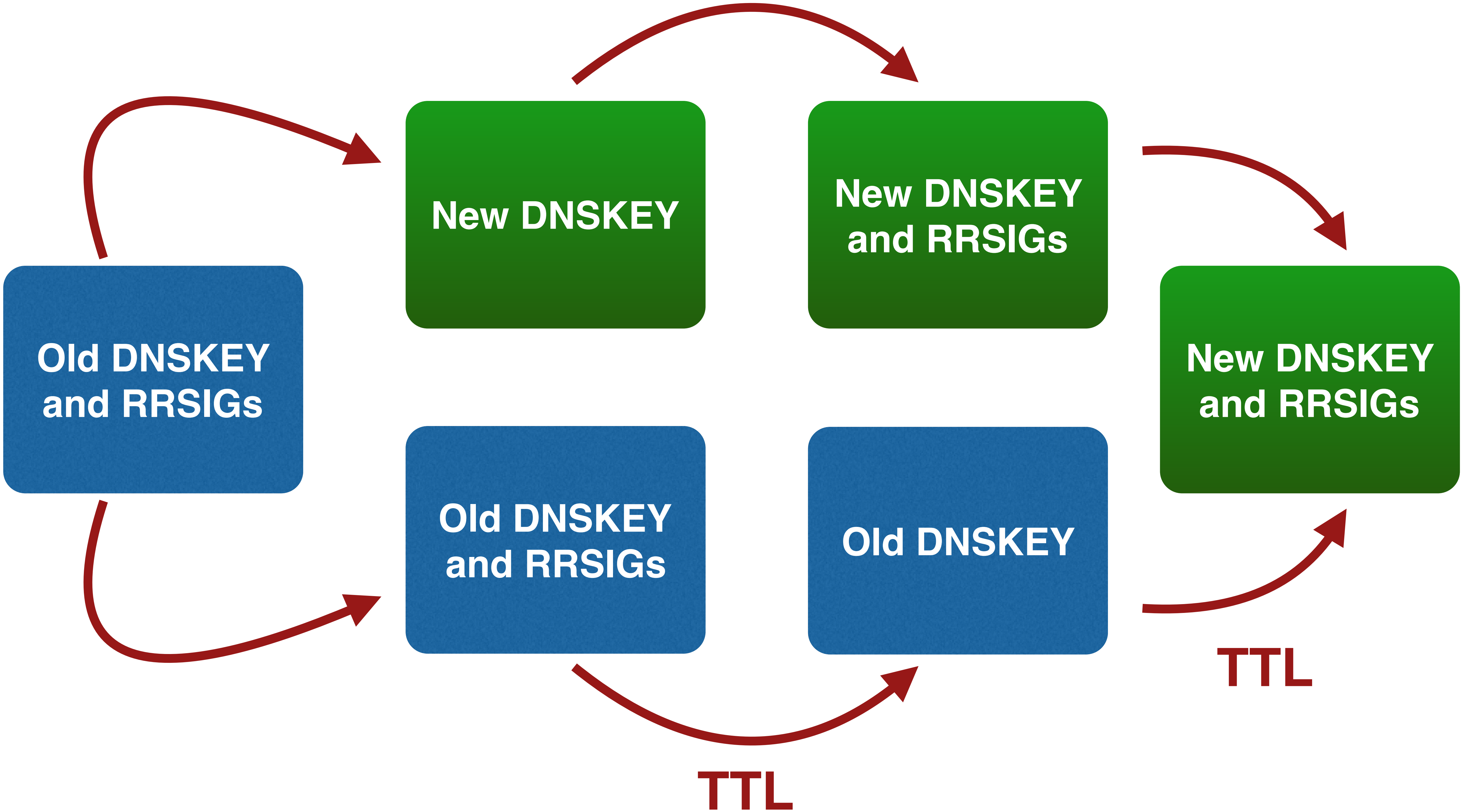
Key rollover methods

- **Pre-publish**
- **Double signature**

- **Both for ZSK and KSK**
  - Rolling a KSK means changing parent DS records

- **Rollover times depend on TTL and method**

Pre-publish method



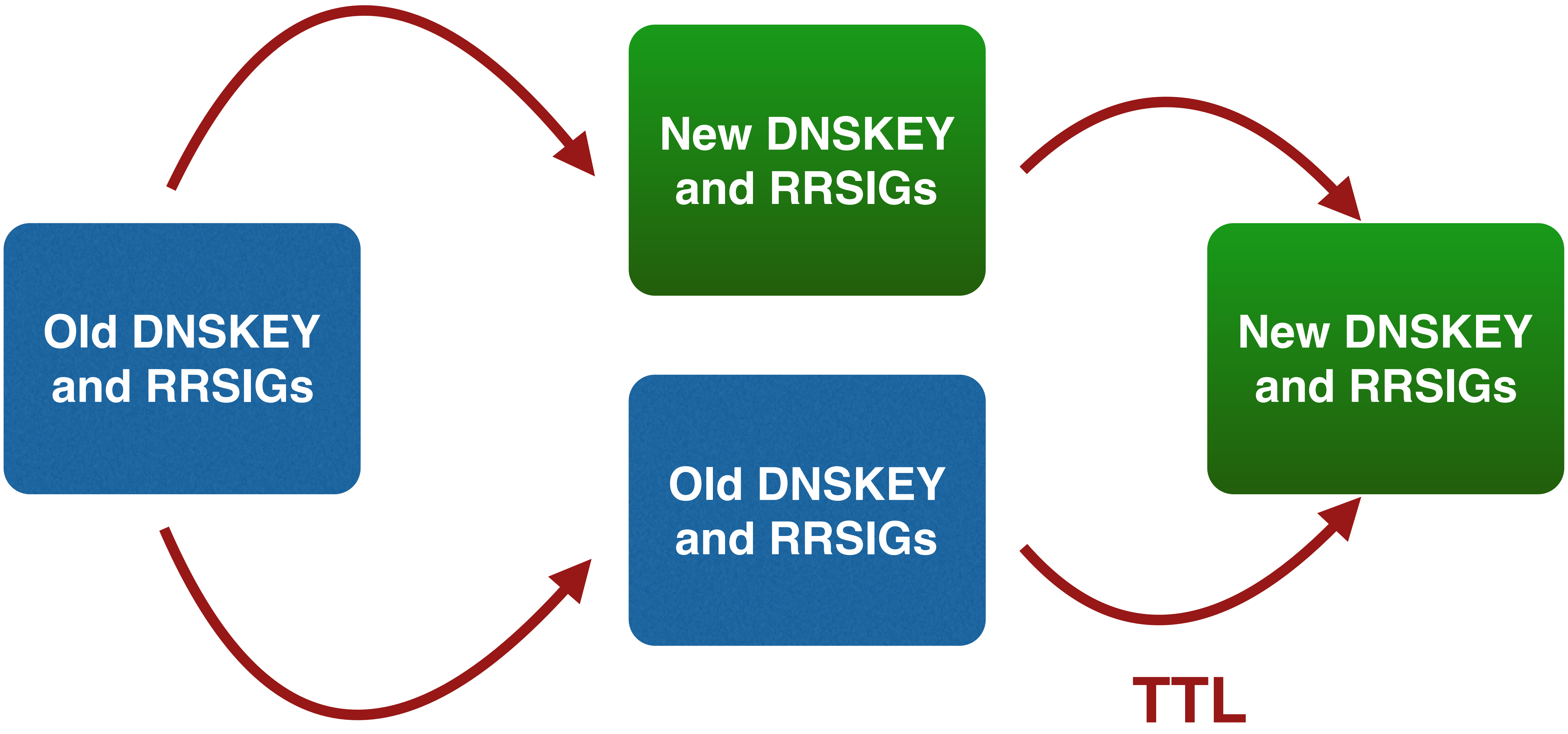
Pre-publishing Method

- **A new DNSKEY record is introduced with new key**
  - Not used for signing, yet

- **After TTL expires, new RRSIGs are created with new DNSKEY**
  - Old DNSKEY remains published

- **After TTL expires again, old DNSKEY is removed**

Double Signature Method



Double signature Method

- A new DNSKEY is introduced, and immediately used to sign the records
- We have two RRSIGs for every record, with signatures from both DNSKEYs
- After TTL expires, old DNSKEY is removed, and records are again signed only once

So do I Have to Remember to Rollover?

- **No, you can automate it**
  - in the configuration
  - including the schedule

- **Just provide ahead of time enough DNSSEC keys for the next few rollovers**

Keys in practice

- **A key has 5 important dates:**
  - Publication
  - Activation
  - Inactivation
  - Revocation
  - Deletion

- **BIND with *auto-dnssec* will automatically manage them for you**

Recommendations

- **Use pre-publishing for ZSK**
  - Especially for large zones
- **Use double signature for KSK**
  - KSK double-signs the DNSKEY, not the zone
- **For KSK rollovers, update DS records**

CDS/CDNSKEY

- Same exact records ad DS and DNSKEY
- Published at child to influence parent
- Not used for initial setup
- Require chain of trust to be already established

Recommendations

- Change your keys regularly
- Set up automatic rotation every 6 months
- You can already prepare for 2-4 years worth of keys

DANE
Distributing secure data

Section 10

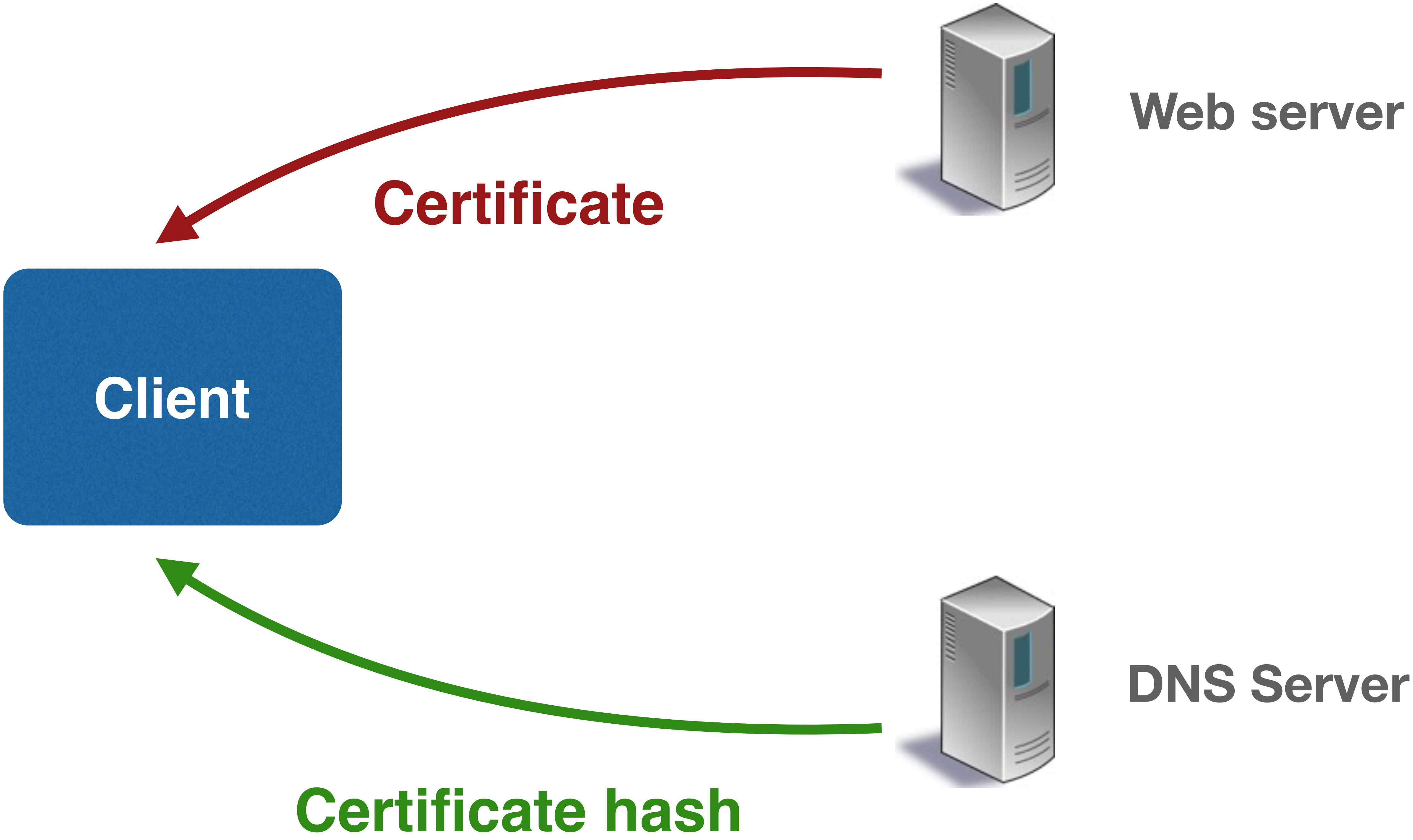
Authenticating

- **With DNSSEC, we can assume the content of the DNS response is authentic**

- **We can use it to distribute authenticated data**
  - Certificate hashes
  - SSH key Fingerprints

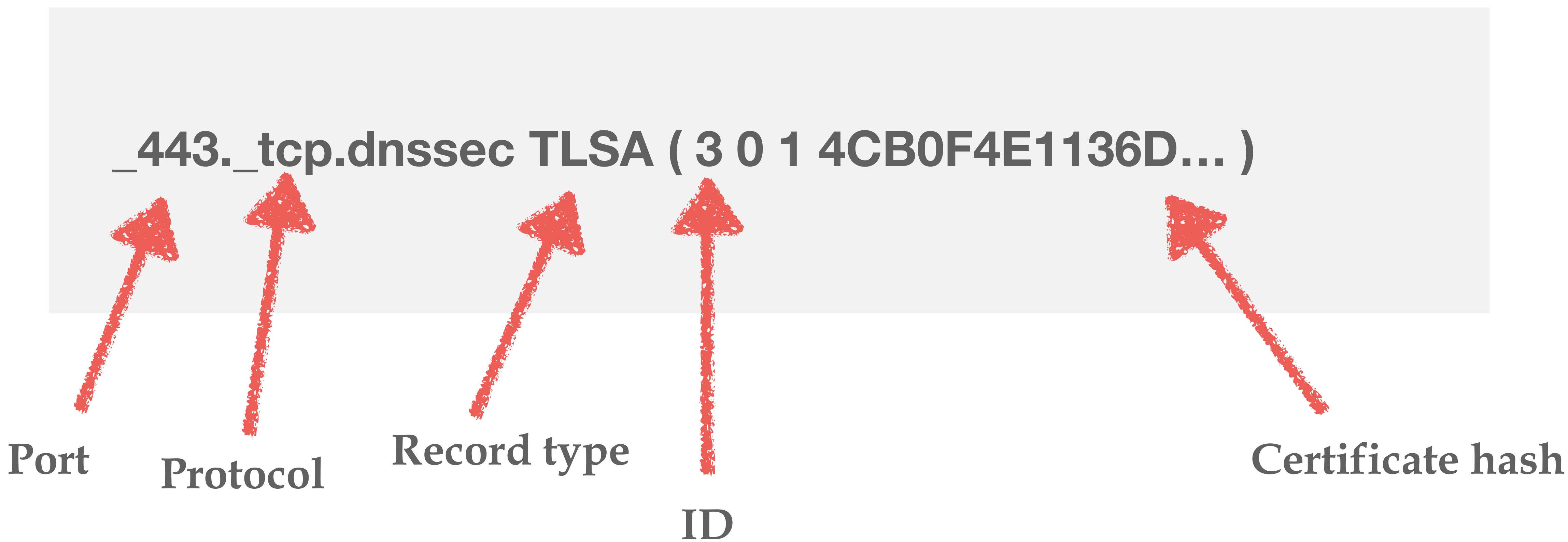
SSH Certificate Clicking Hell

DANE Mechanism: Alternate certificate validation



Certificates

- **TLSA Record**
  - Stands for Transport Layer Security A record
  - You can put a certificate, to be validated by the client
  - Also a self-signed certificate



SSH host fingerprints

- Fingerprints can be stored in DNS records
- SSHFP records
- Validates the SSH keys using DNS

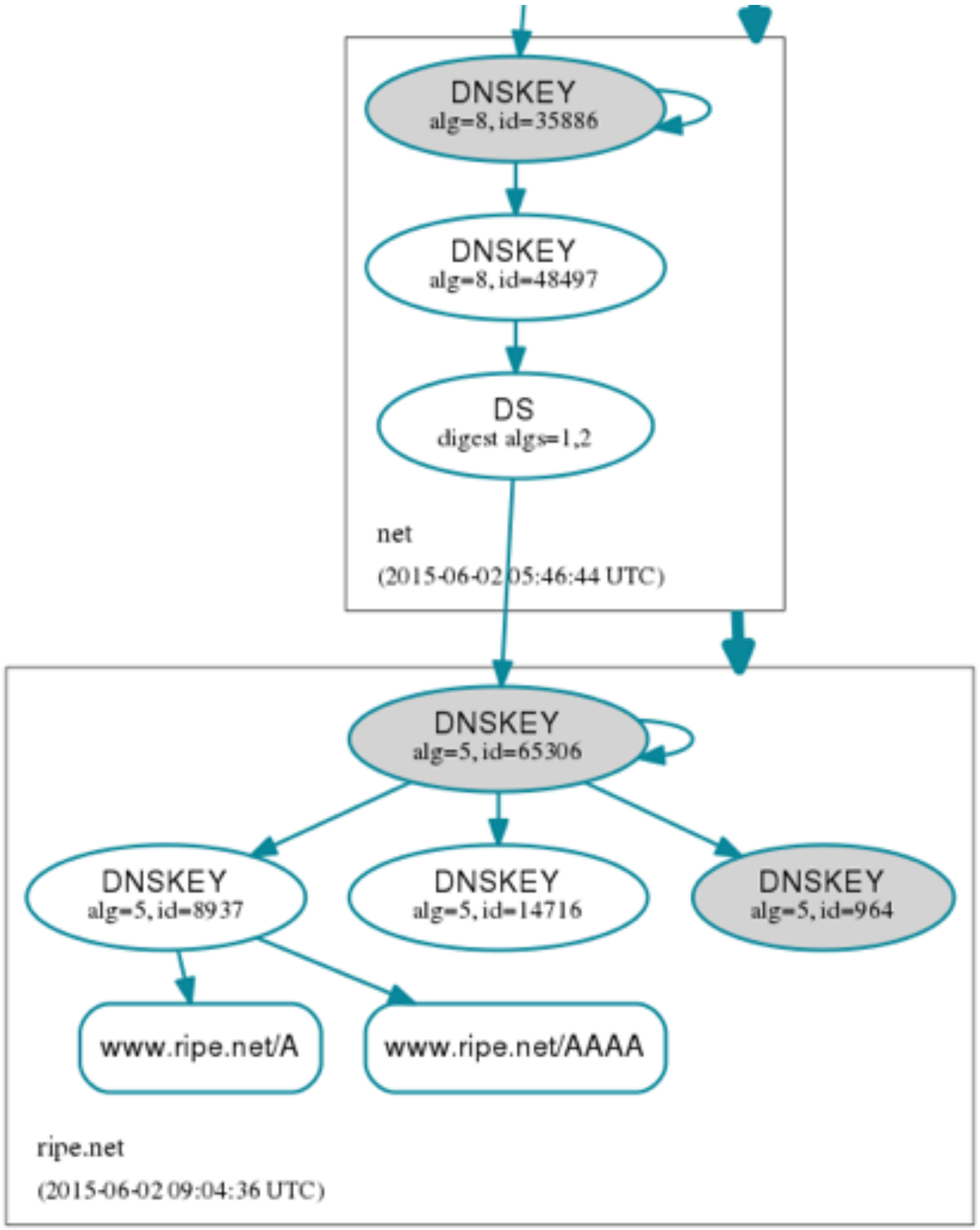
```
hostname IN SSHFP 1 1 372h1173312eqrqr
hostname IN SSHFP 1 2 383h23r73rwdqwe
```

Troubleshooting, Tips and Tricks

Section 11

Troubleshooting basics

- If query returns *servfail*, DNSSEC did not validate
  - A non-existent record will generate NSEC/NSEC3
- Use dig, drill, or dnsviz.net to investigate
  - Also check port 53 TCP



Changing registrar

- **Changing registrar is a quick procedure nowadays**
  - It also involves moving DS records
  - and checking if they're right

- **A bogus DS record breaks DNSSEC**

- **Solution is to remove DS records prior to transfer**
  - Add them back after the transfer

DNSSEC TLSA Validator

- A plugin for browsers to check DNSSEC/TLSA
- Works on every browser (IE, Chrome, Safari, Firefox)
- https://www.dnssec-validator.cz

DNSSEC-Trigger

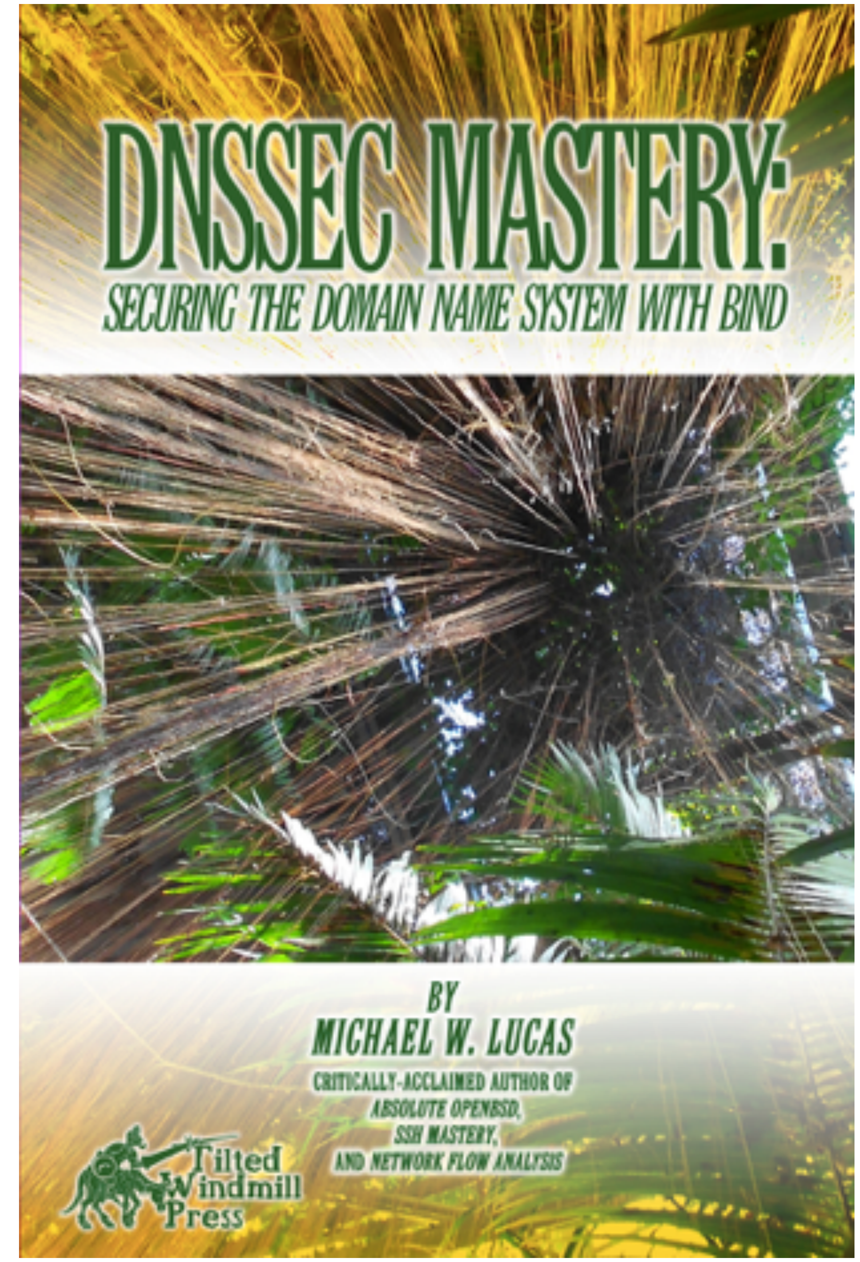
- **Clients rely on resolvers**
  - An attacker can still get into the way between the resolver and the user

- **Use DNSSEC-trigger to run a local resolver with DNSSEC capabilities**

- **http://www.nlnetlabs.nl/projects/dnssec-trigger/**

DNSSEC Mastery

- Published in December 2012
- Walkthrough in configuring DNSSEC on BIND
- Available from https://www.tiltedwindmillpress.com/



BIND ARM

- Bind Administrator Reference Manual
- One-stop resource for every aspect of BIND
- ftp://ftp.isc.org/isc/bind9

Check and Troubleshoot

Exercise E

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