DNSSEC

Domain Name System Security Extensions

NANOG On The Road, NYC
21 July 2016

DNSSEC Introduction

How much trust do we put in the Internet?

13.5% of all purchases were done over the internet in 2010, according to BCG, and this is projected to rise to 23% by 2016.

[**UK** - http://www.bbc.com/news/business-17405016]

How much of that trust relies on DNS?

If DNS were to become unreliable or untrustworthy, what would the result be?

DNSSEC Introduction

In the simplest terms:

DNSSEC provides digital signatures that allow validating clients to prove that DNS data was not modified in transit

DNSSEC Introduction

Sources of DNS data generate signatures for data that they are authoritative for

Recursive servers check the signatures for correctness and signal to their clients the results of those checks

- If data is provably good, the AD (Authenticated Data) bit may be set in response headers

- If queried data is unable to be validated, yet is signaled to be signed, SERVFAIL responses are generated

Background Knowledge

Before delving into DNSSEC

DNS resolution mechanics

The Delegation Chain

Some Cryptography Fundamentals

Digital Signatures

DNS Resolution

Resolution is the process of obtaining ***answers*** from the DNS database in response to queries

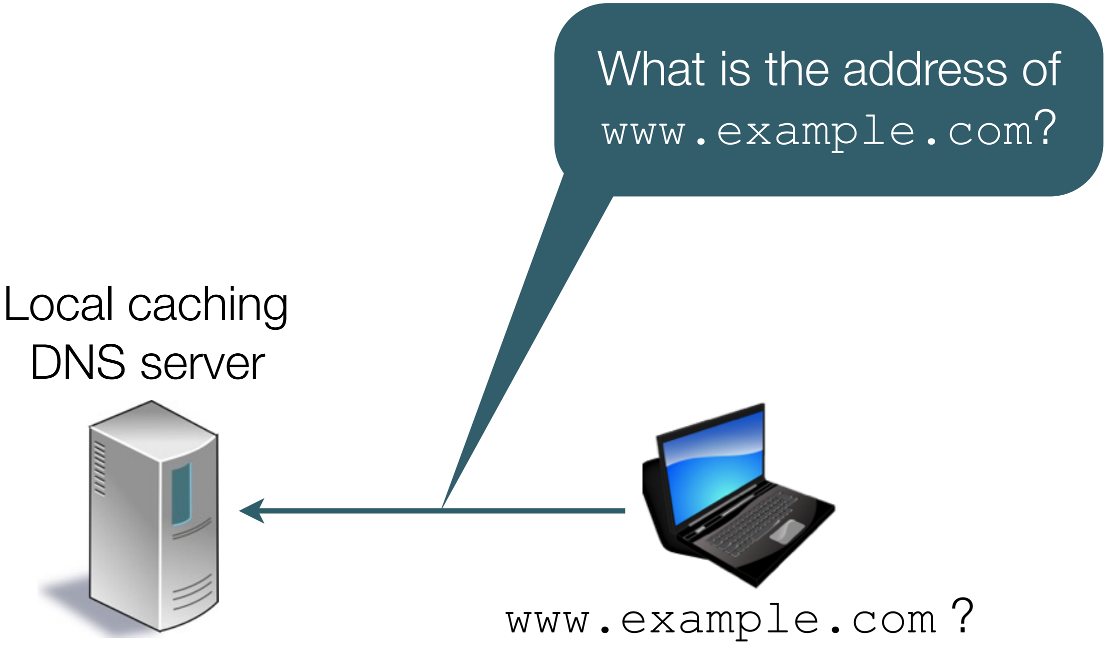
- Answers
  - are provided by **authoritative** servers
  - are cached by both **recursive** servers and **clients**

DNS Resolution

Resolution is the process of obtaining answers from the DNS database in response to ***queries***

- Queries
  - originate within applications
  - are handled on clients by **stub** resolvers
  - are sent to and processed by **recursive** servers

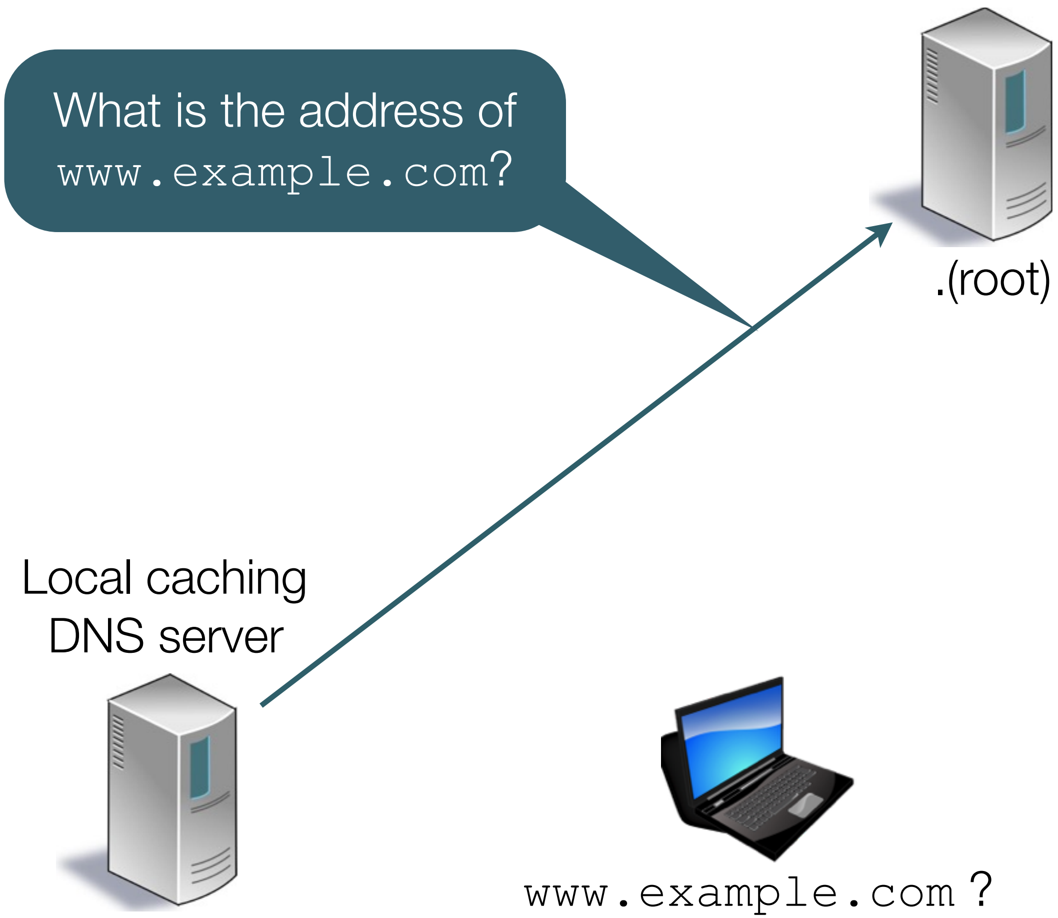
DNS Resolution



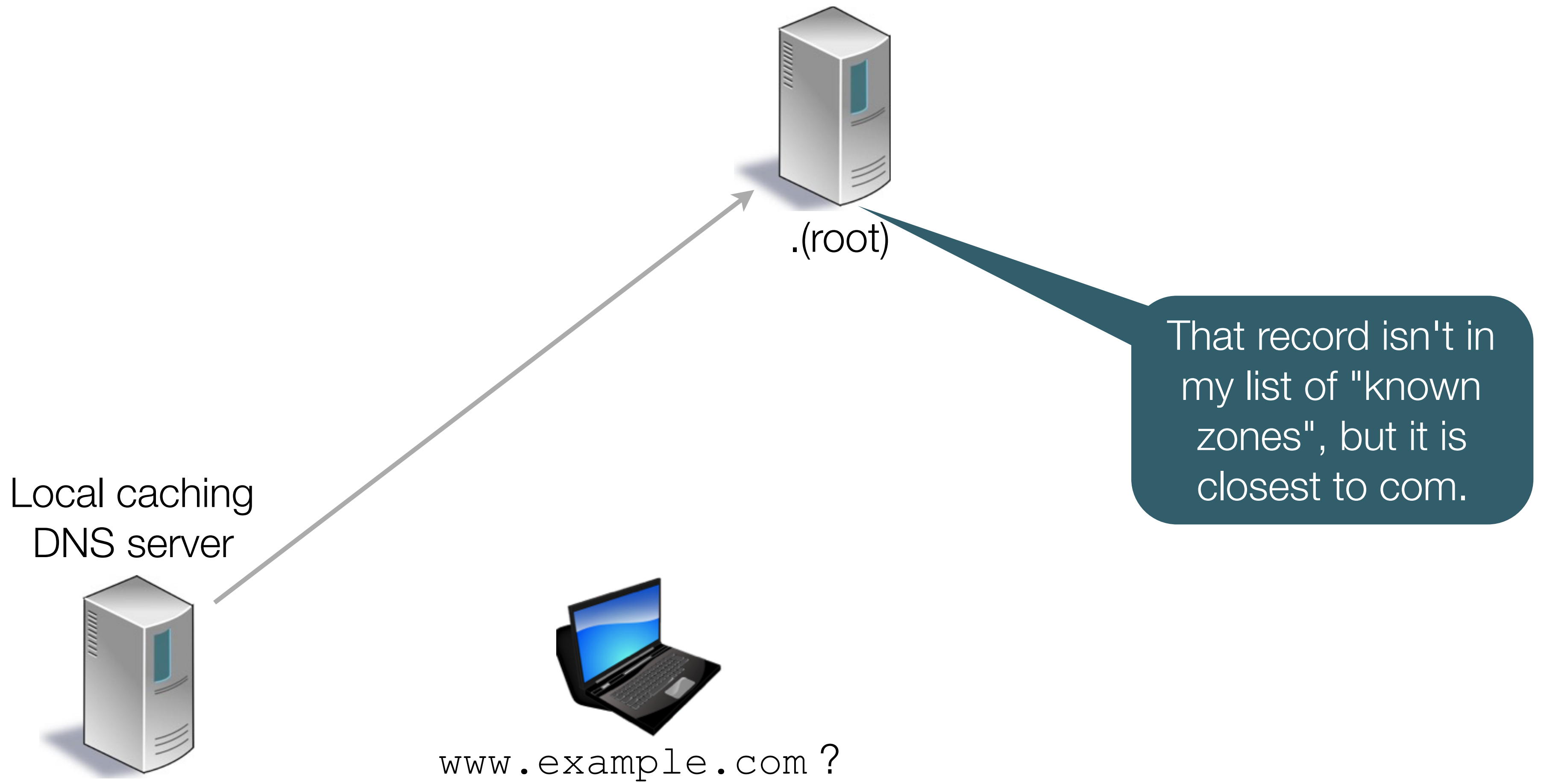
DNS Resolution

At this point, the local server knows nothing except the addresses of the root servers from "root hints"

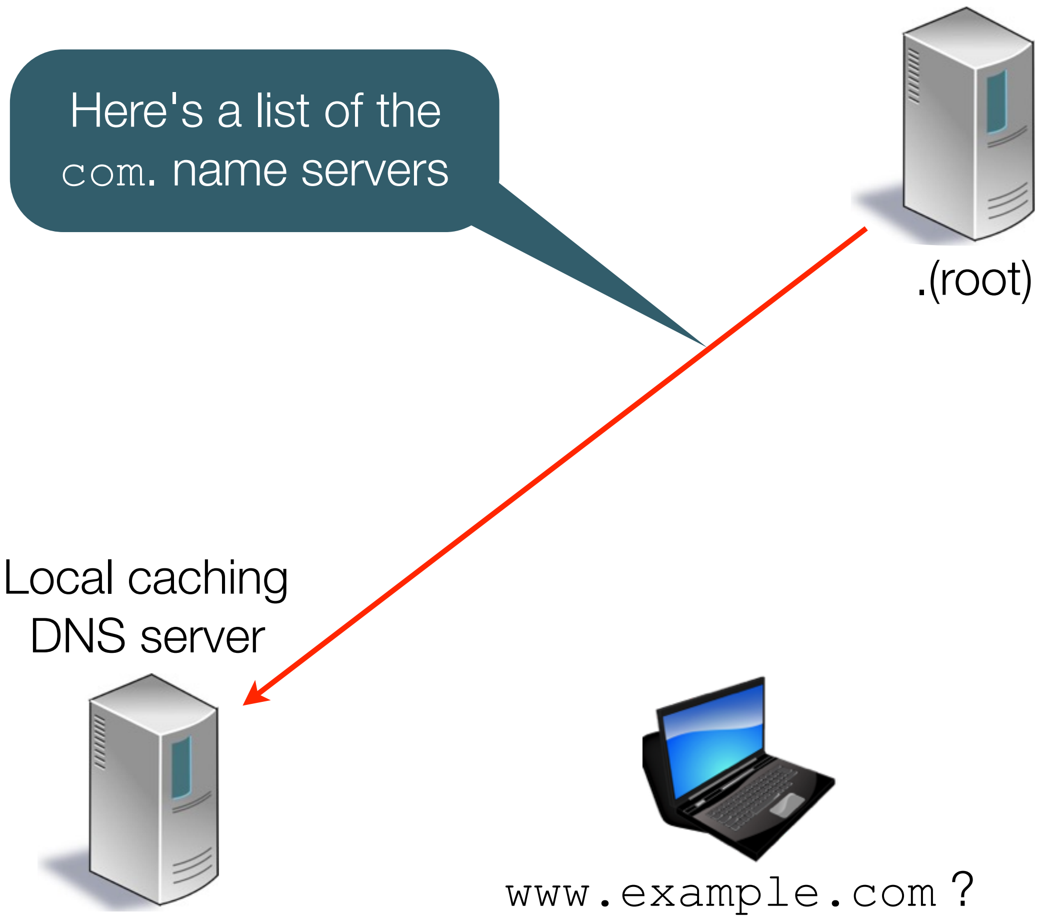
DNS Resolution



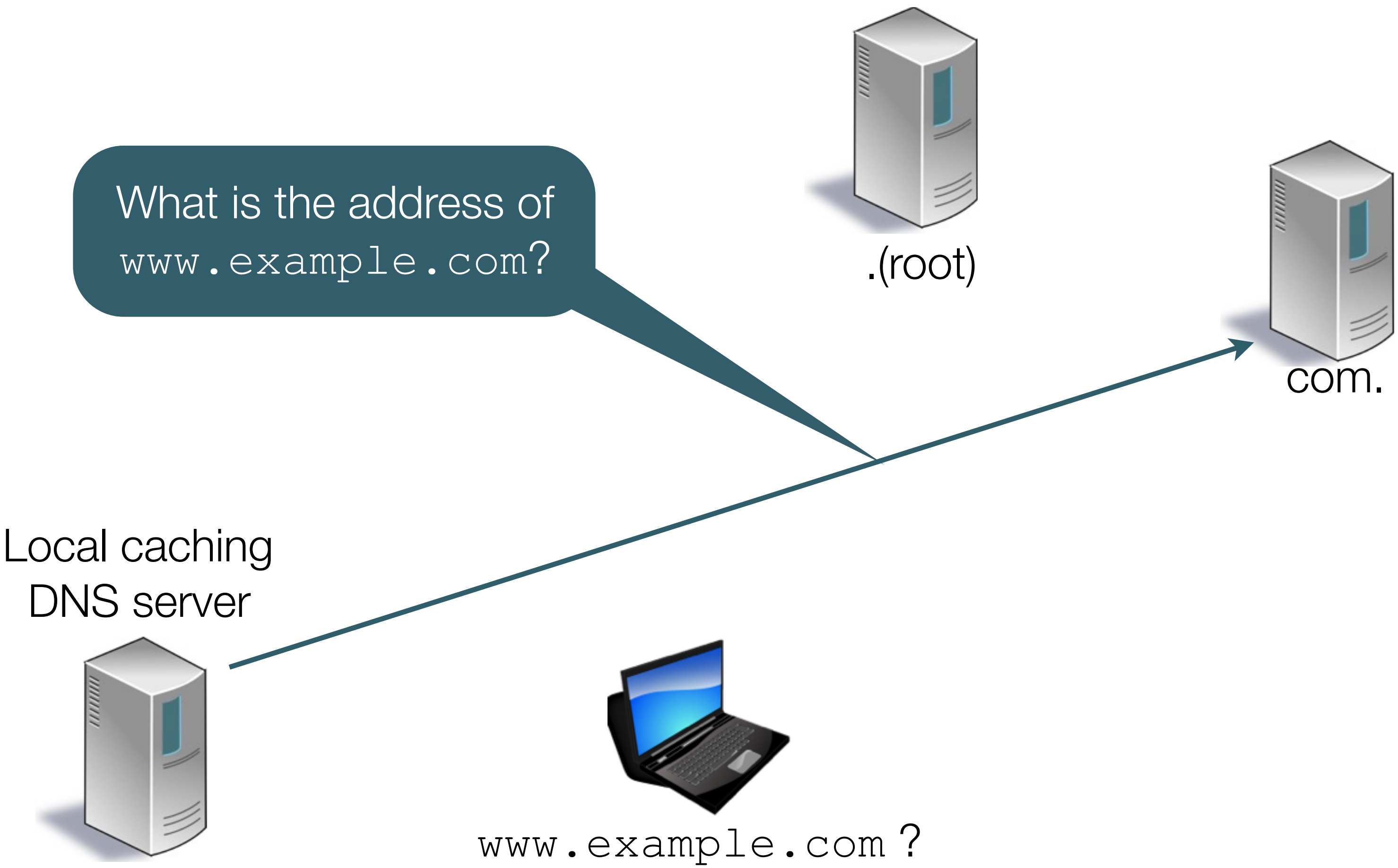
DNS Resolution



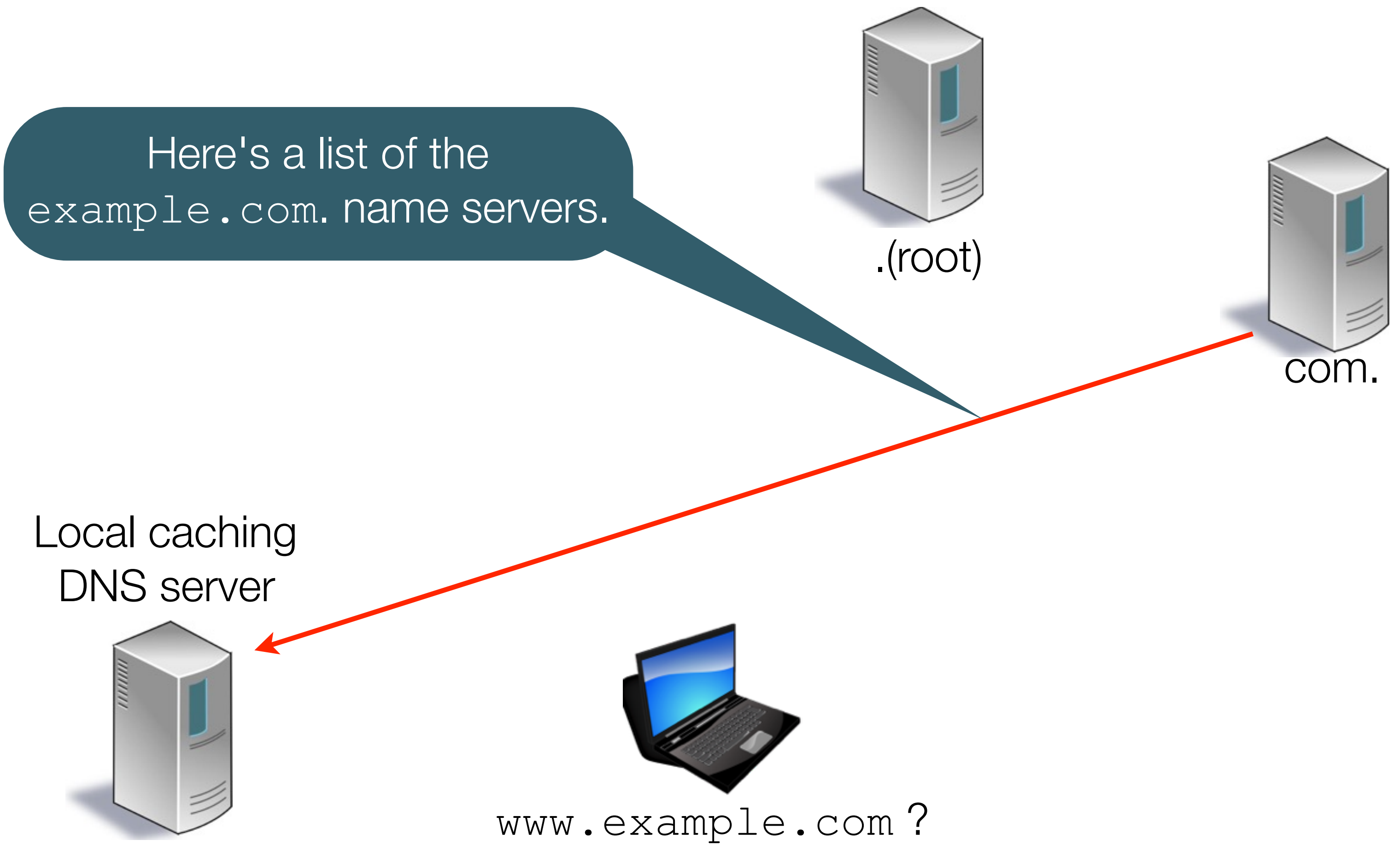
DNS Resolution



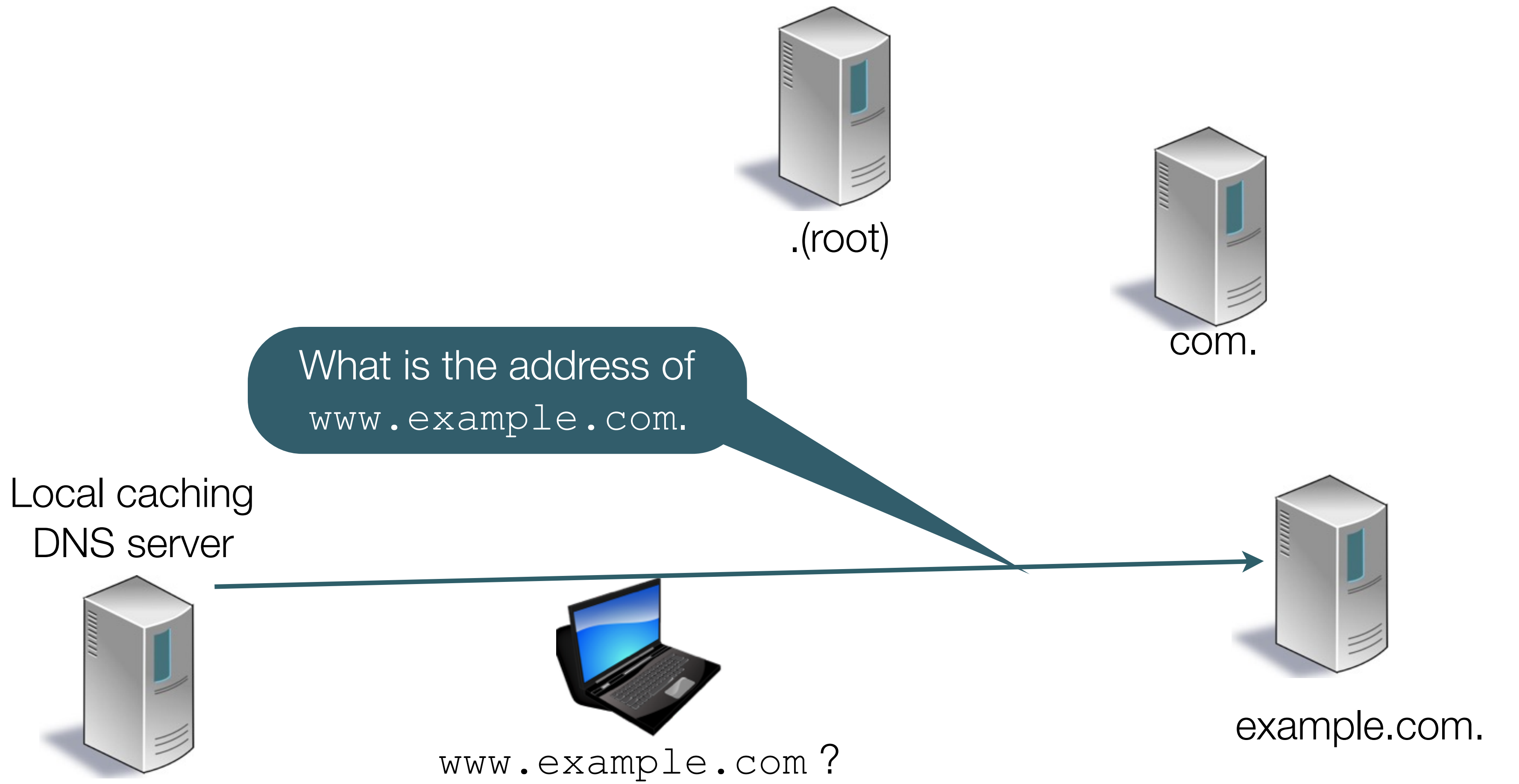
DNS Resolution



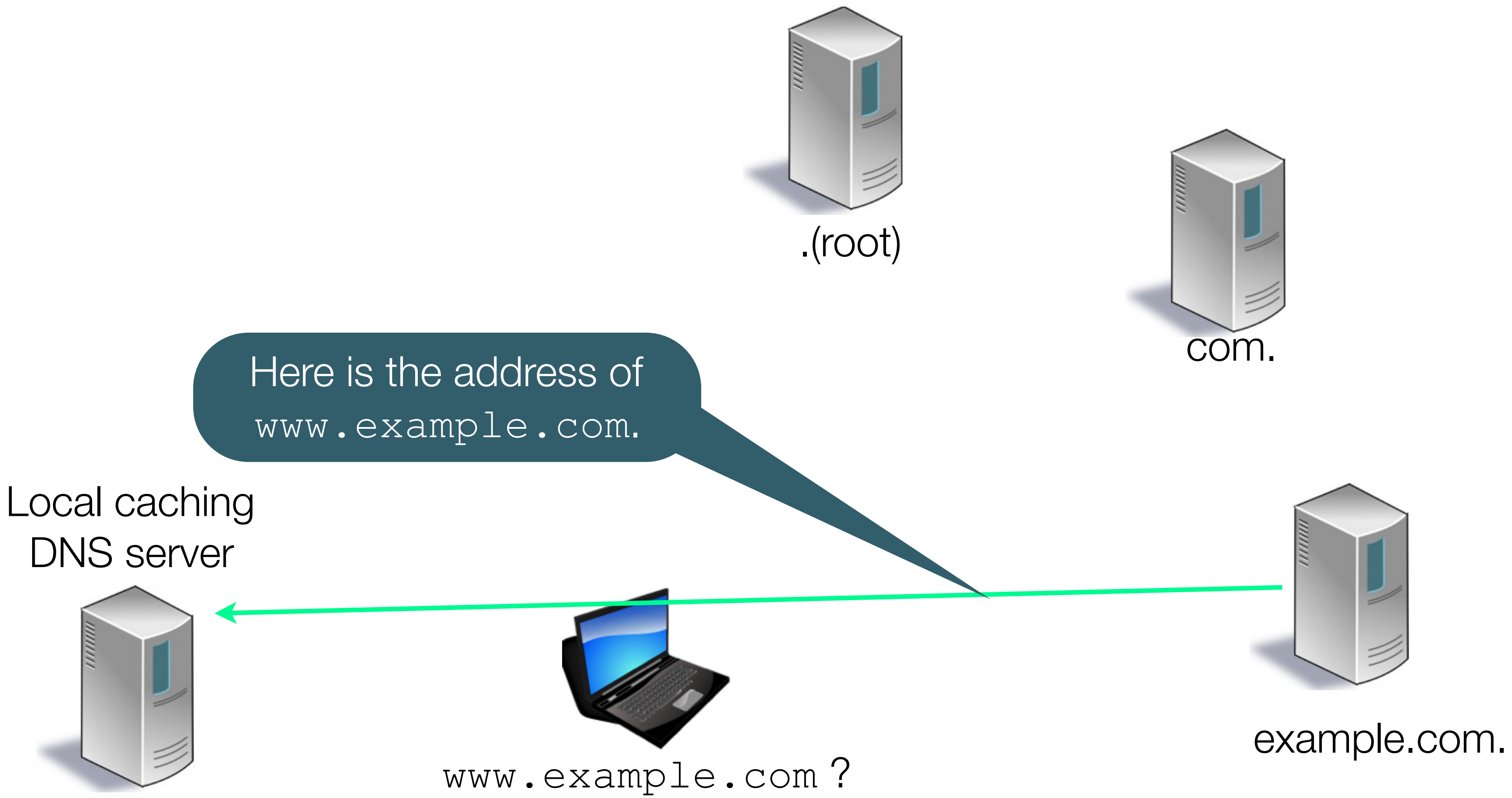
DNS Resolution



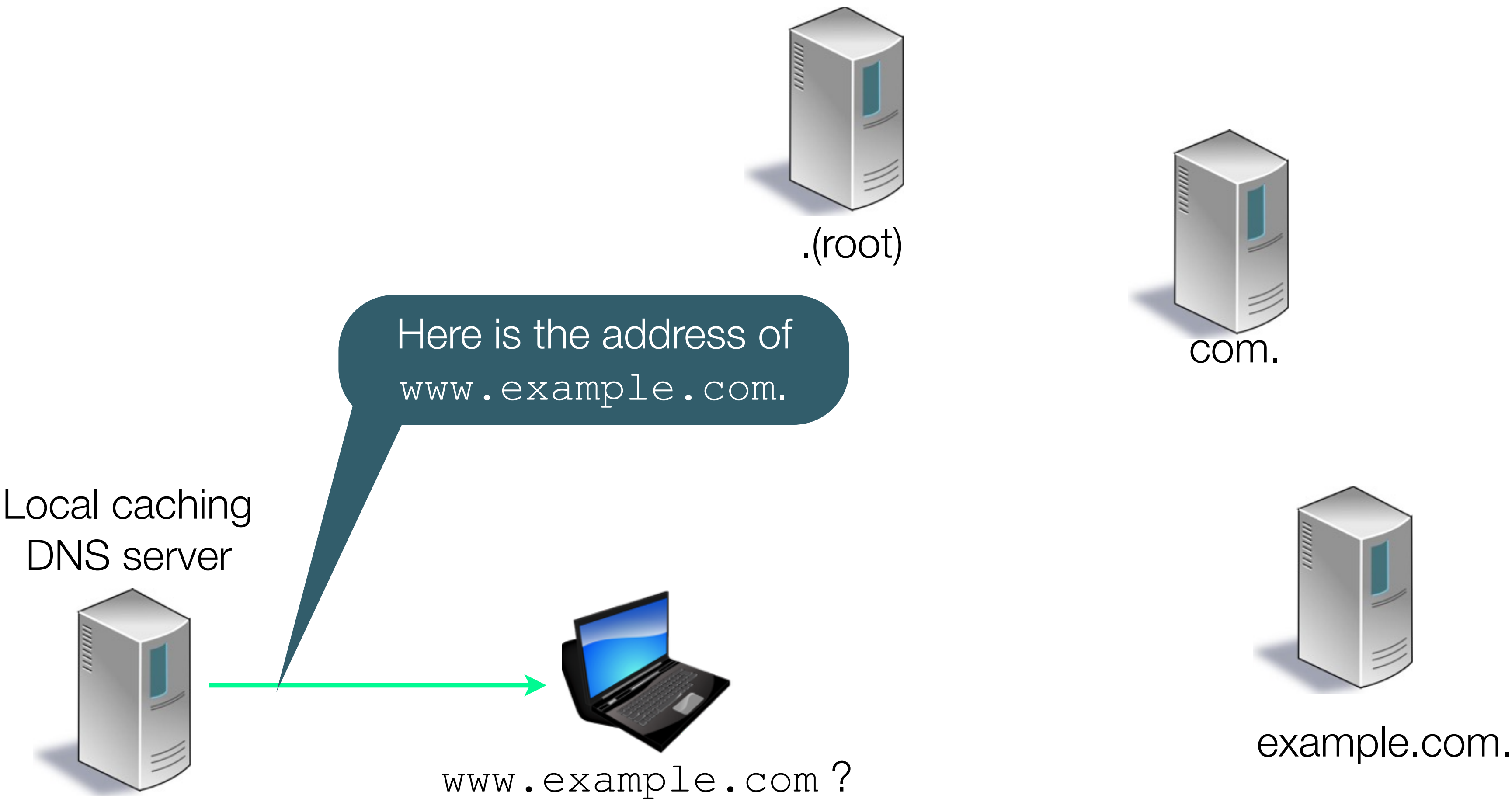
DNS Resolution



DNS Resolution



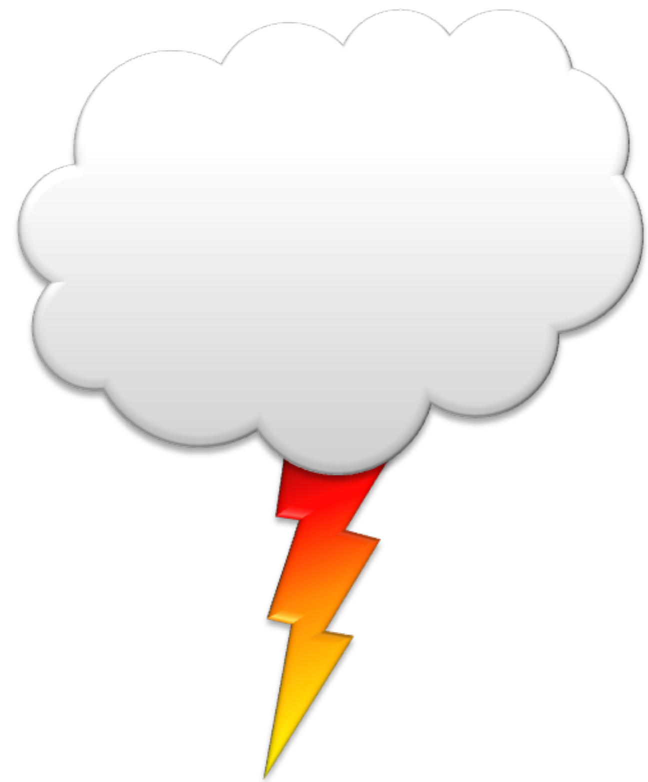
DNS Resolution



DNS Data Flow Vulnerabilities

Cache Poisoning

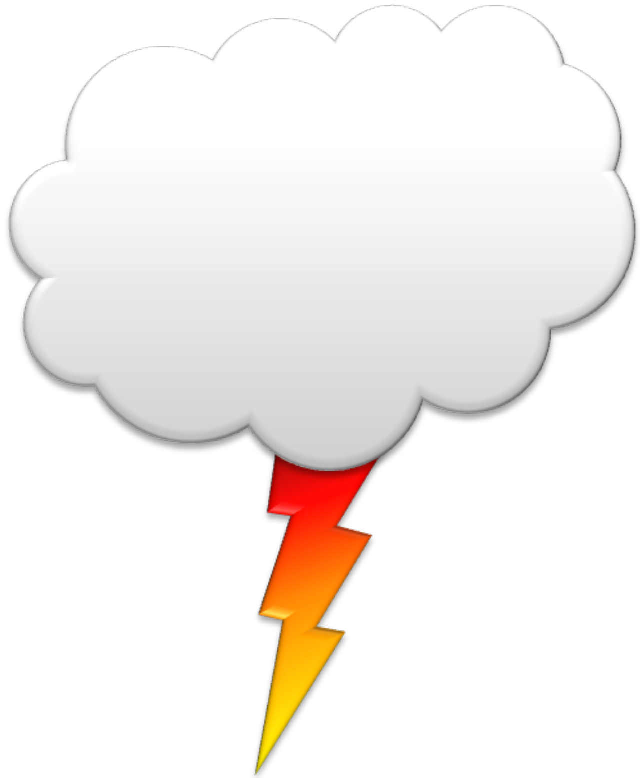
- What if someone were able to insert data into a server's cache
- That information would be returned to clients instead of "real" data



DNS Data Flow Vulnerabilities

Servers can send irrelevant information in the Additional Section

By definition, the additional section should contain answers to questions that have yet to be asked

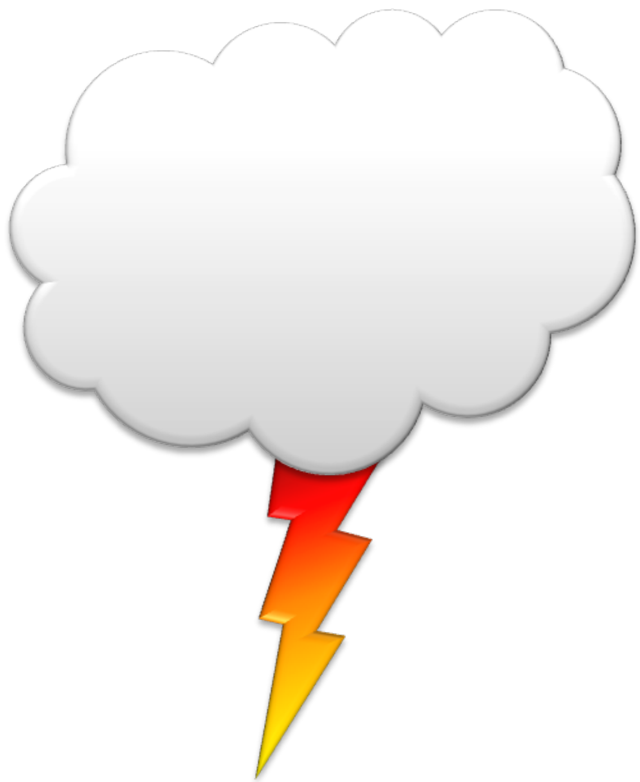


DNS Data Flow Vulnerabilities

	Header
www.isc.org. A ?	Question
www.isc.org. IN A 204.152.184.88	Answer
	Authority
www.bank.com. IN A 204.152.184.88	Additional

DNS Data Flow Vulnerabilities

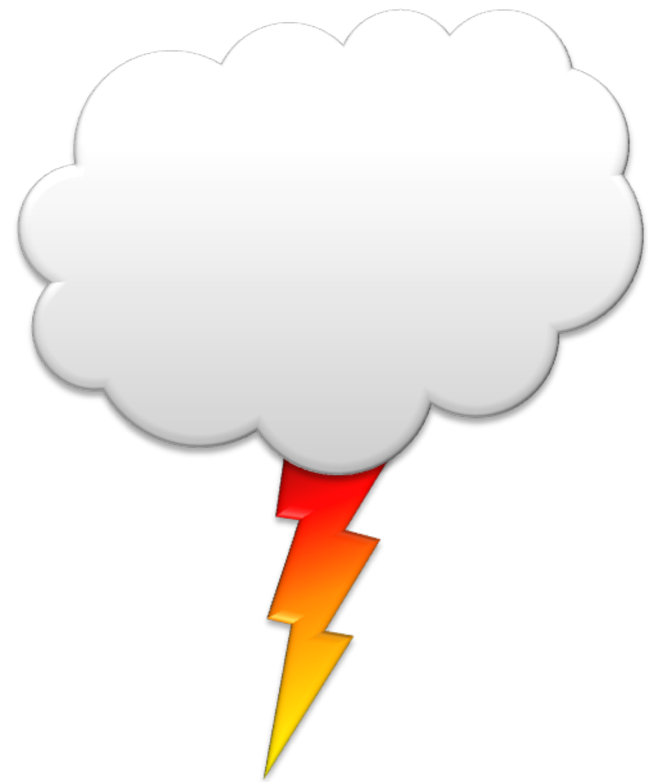
- Cache Poisoning
  - DNS uses UDP by default
  - Sender can fabricate anything in the packet
    - including source address



DNS Data Flow Vulnerabilities

If I know a question that is about to be asked

I can flood responses containing my data, but a legitimate source



Background Knowledge

Before delving into DNSSEC

- DNS resolution mechanics
  - The Delegation Chain
- **Some Cryptography Fundamentals**
  - **Digital Signatures**

Cryptographic Fundamentals

Cryptography has four purposes:

Confidentiality	Keeping data secret
Integrity	Is it "as sent"?
Authenticity	Did it come from the right place?
Non-Repudiation	Don’t tell me you didn’t say that.

Cryptographic Fundamentals

DNSSEC uses cryptography for two purposes:

Confidentiality	Keeping data secret
Integrity	**Is it "as sent"?**
Authenticity	**Did it come from the right place?**
Non-Repudiation	Don’t tell me you didn’t say that.

Cryptography for DNS admins

To provide Authenticity and Integrity, we use:

- Asymmetric Cryptography
  - Digital Signatures

Asymmetric Cryptography

Keypairs – Public and Private Key Portions

Data encrypted with one piece of a key can be decrypted or checked for integrity with the other

It is unlikely that a person holding the public key will be able to reverse engineer the private key

Asymmetric Cryptography

Data that can be decrypted is guaranteed to have been unaltered since encryption

Integrity

Since the data was decrypted with a public portion of a known key pair, the private portion must have been the one to encrypt the data

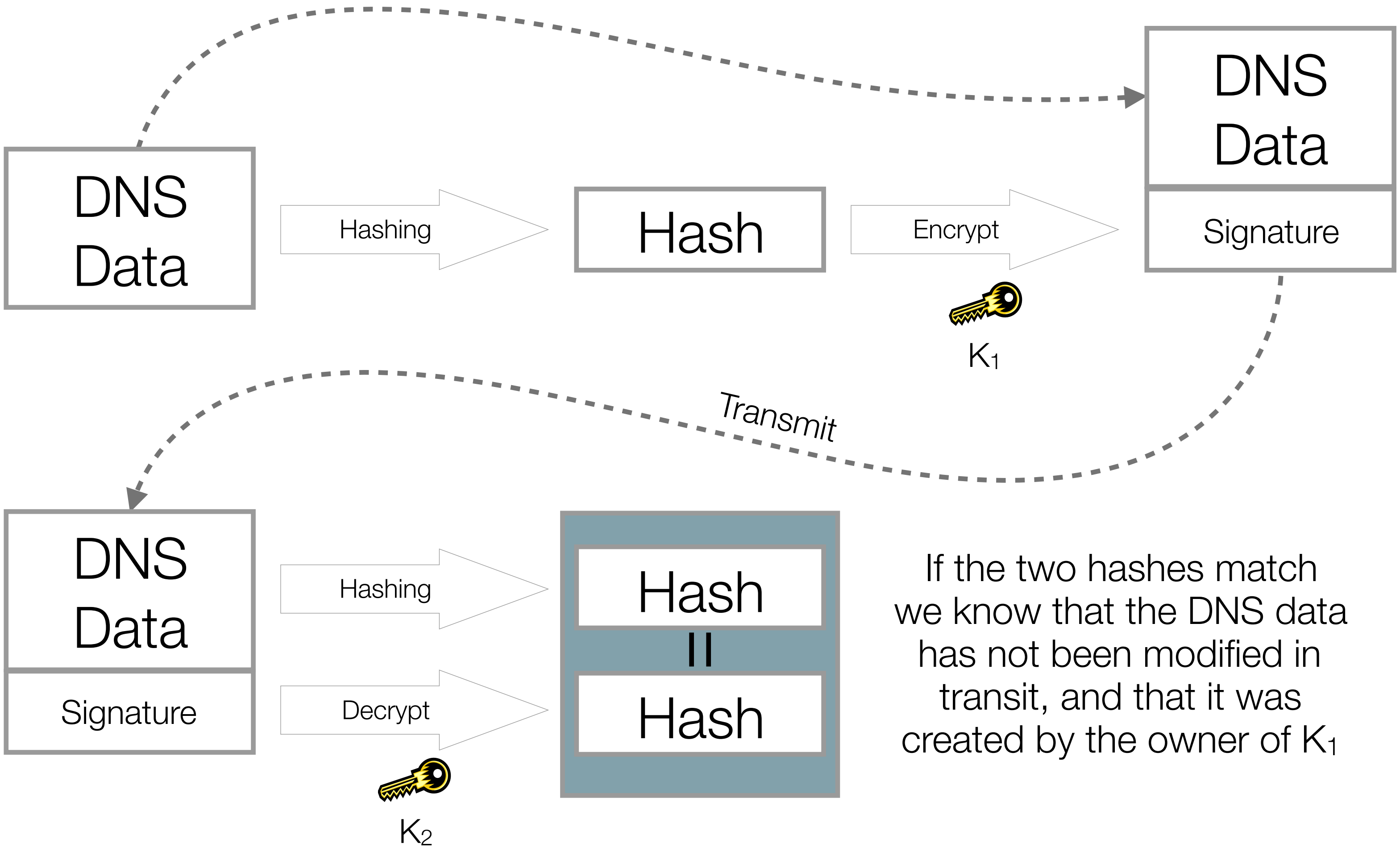
Authenticity

Digital Signatures

Since we don't care about encrypting the entire content of the message...

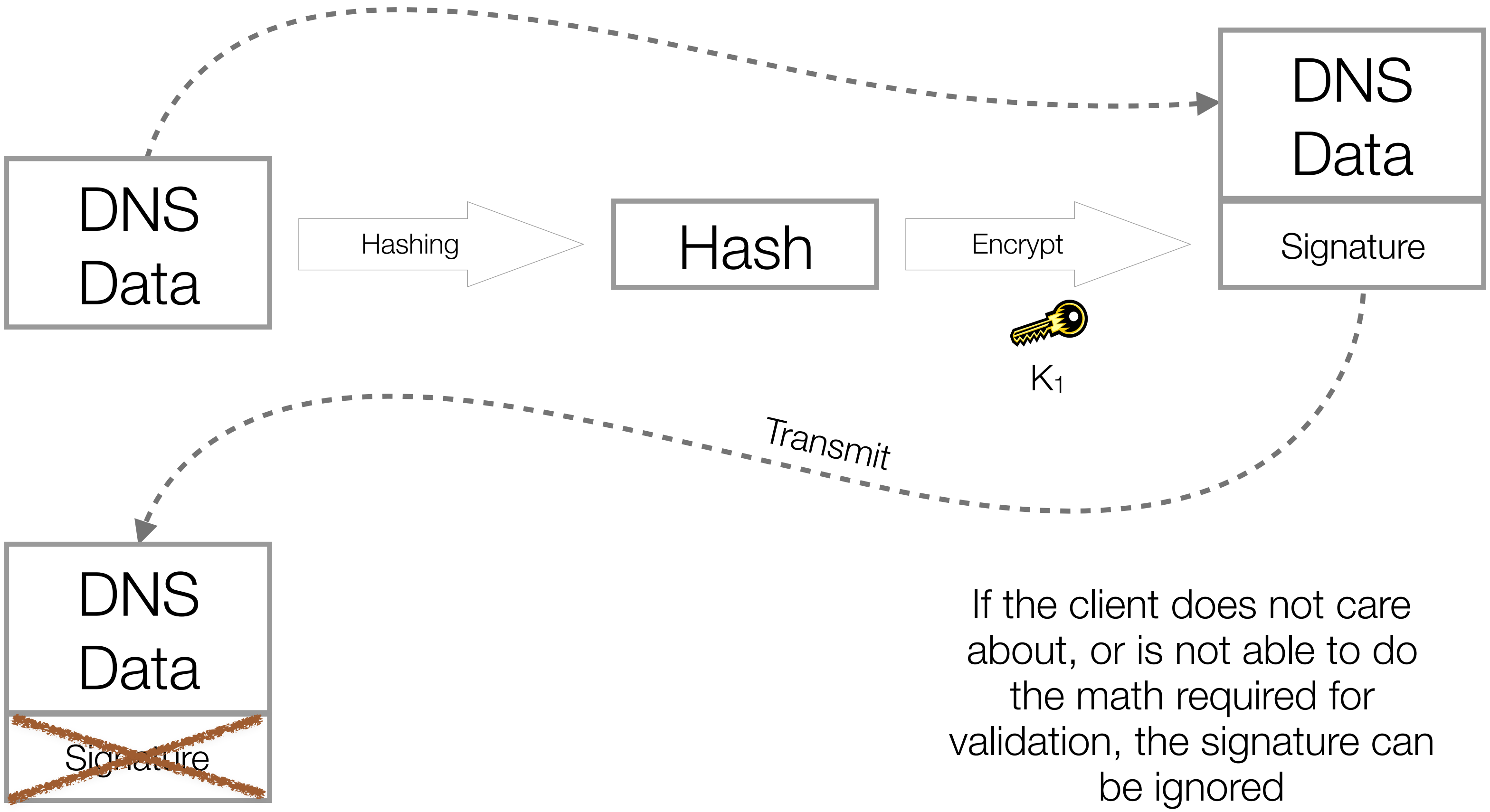
- Create a hash of the data to be sent, encrypt the hash with our private key and transmit it with the message
- Anyone holding public key can authenticate and confirm integrity of the message
  - Anyone without the public key can still see the data

Digital Signatures in DNSSEC



If the two hashes match we know that the DNS data has not been modified in transit, and that it was created by the owner of K_1

Digital Signatures for those that don't care



If the client does not care about, or is not able to do the math required for validation, the signature can be ignored

Deploying DNSSEC Zone

Administrative Decisions

Administrative Decisions about DNSSEC

There are decisions that need to be made prior to deployment:

What algorithm will be used?

What bit-length for keying material?

NSEC or NSEC3 for proof of non-existence?

Two keys per zone? Yes, a Key-Signing Key (**KSK**) & a Zone-Signing Key (**ZSK**).

What Algorithm Should Be Used?

Choice of algorithm depends on a number of criteria:

- Interoperability with "legacy" systems
  - Requires use of RSASHA1 algorithm
- Legality issues
  - GOST vs. RSA
- Wide spread ability to validate chosen algorithm

ALG#	Name	Mnemonic
1	RSA/MD5	Deprecated
3	DSA/SHA1	DSA
5	**RSA/SHA-1**	**RSASHA1**
6	DSA-NSEC3-SHA1	NSEC3DSA
7	RSASHA1-NSEC3-SHA1	NSEC3RSASHA1
8	**RSA/SHA-256**	**RSASHA256**
10	RSA/SHA-512	RSASHA512
12	GOST R 34.10-2001	ECCGOST
13	ECDSA Curve P-256 w/ SHA-256	ECDSAP256SHA256
14	ECDSA Curve P-384 with SHA-384	ECDSAP384SHA384

Key Bit Length

The choice of bit-length for keying material is based on the algorithm being used and the purpose of the key

- Algorithm requirements
  - RSA keys must be between 512 and 2048 bits
  - DSA keys must be between 512 and 1024 bits and an exact multiple of 64
- NIST recommends 1024 bit ZSK and 2048 bit KSK

NSEC vs. NSEC3 denial of existence

The NSEC method of proof-of-nonexistence allows "zone walking", as it proves negative responses by enumerating positive responses

NSEC3 disallows "zone walking", but it requires additional processing on both authoritative servers providing negative responses and on recursive servers doing validation

- If you disallow zone transfers, you will want to deploy NSEC3

DS Resource Records - Talking to our Parent…

To create chains of trust "in-protocol," the Key Signing Key of a zone is hashed and that hash is placed into the parent

This record is known as the Delegation Signing (DS) record

The DS record in the parent creates a secure linkage that an external attacker would have to overcome to forge keying material in the child

Deploying DNSSEC Zones

Technical Decisions

Preparing for DNSSEC Deployment

There are a number of methods of deploying DNSSEC into existing zones:

- Manual zone signing (In 2016, DDT - Don’t Do That!)
- Automatic zone signing of dynamic zones
- Automatic in-line signing "on-box"
- Automatic in-line signing "bump-in-the-wire"

Automatic Zone Signing of Dynamic Zones

BIND 9.7 and newer provide automation of zone signing of dynamic zones

- Keying material contains timing "meta-data" that can allow automation of key rollover

- Making a zone dynamic is significantly easier in recent versions of BIND

Dynamic zones are not always appropriate or allowed

Automatic In-Line Signing

BIND 9.9 introduced In-Line signing

- Signing of zones without knowledge of / changes to existing processes and procedures

On-Box in-line signing DNSSEC signs zones in memory on the same system on which they are mastered

Bump In The Wire signing provides signing on an intermediate system

- Use this where existing infrastructure can't be modified

Deploying DNSSEC Zones

Abbreviated Technical Steps

```
DNSSEC Trust tree:
www.dnslab.org. (A)
|---dnslab.org. (DNSKEY keytag: 7308 alg
    |---dnslab.org. (DNSKEY keytag: 9247
    |---dnslab.org. (DS keytag: 9247 dig
        |---org. (DNSKEY keytag: 24209 a
            |---org. (DNSKEY keytag: 979
            |---org. (DNSKEY keytag: 213
            |---org. (DS keytag: 21366 d
            |   |---. (DNSKEY keytag: 33
            |       |---. (DNSKEY keytag
            |---org. (DS keytag: 21366 d
                |---. (DNSKEY keytag: 33
                    |---. (DNSKEY keytag
;; Chase successful
```

DNSSEC Signing - The Short List

Generate keys for zone

Insert public portions of keys Into zone

Sign zone with appropriate keys

Publish signed zone

DS in the parent zone

Validate!

Insert Public Keying Material into Zone

If using in-line signing, inserting keying material into the zone is automatic

```
zone "dnslab.org" {
        type master;
        file "master/dnslab.org";
        inline-signing yes;
        auto-dnssec maintain;
};
```

In-line signing keeps a separate copy of the zone in memory and adds records to that zone, not modifying the zone on disk

Signing a Zone

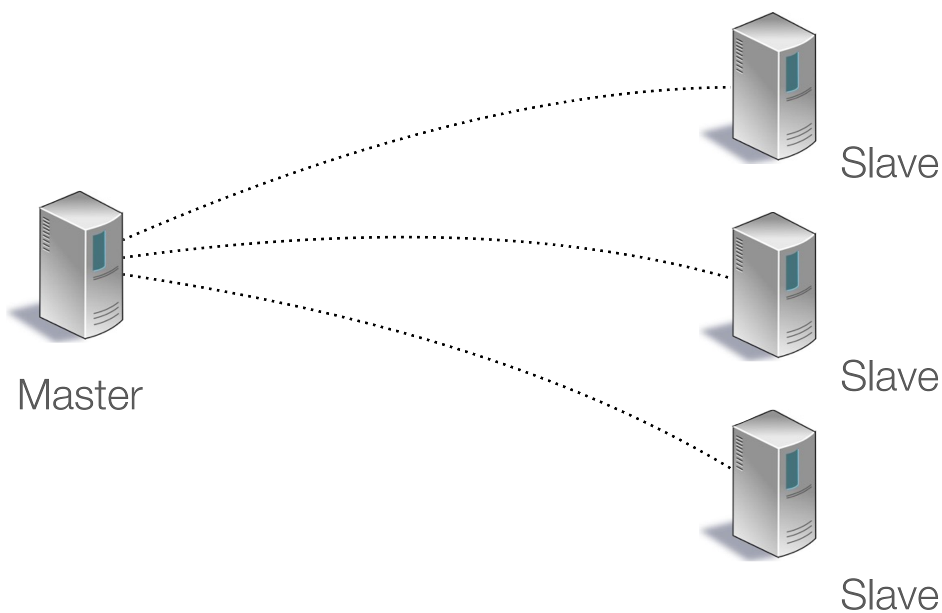
```
dnssec-keygen -K /etc/namedb/keys -a rsasha256 -b 1024 $ZONE

dnssec-keygen -K /etc/namedb/keys -a rsasha256 -b 2048 -f ksk $ZONE

rndc signing -nsec3param 1 0 10 $SALT $ZONE
rndc sign $ZONE
```

"Bump In The Wire" In-Line Signing

If there is a reason that your provisioning infrastructure can't be touched, consider “bump in the wire” in-line signing…



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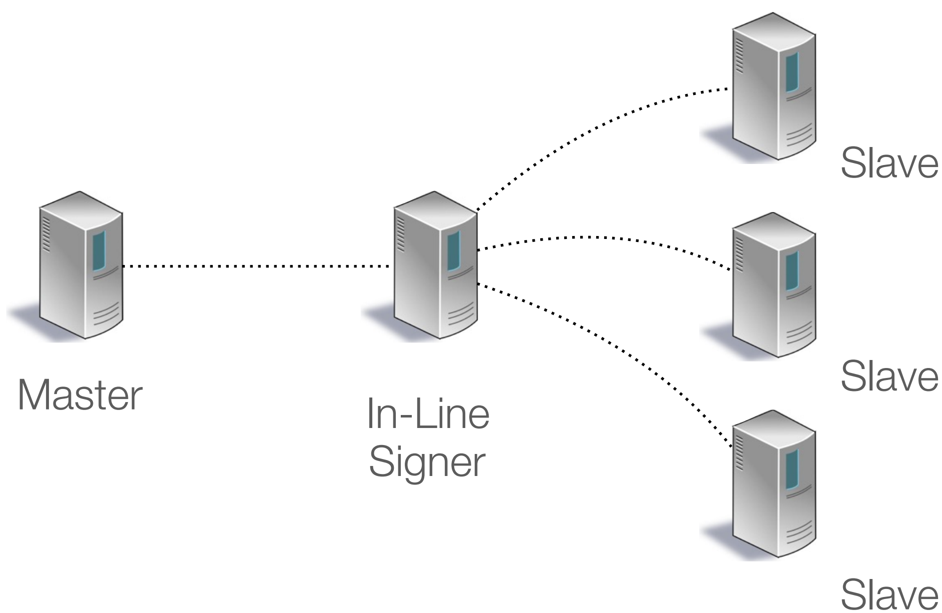

"Bump In The Wire" In-Line Signing

```
zone "dnslab.org" {
        type slave;
            masters { true-master; };
            also-notify { list-of-slaves; };
        file "slave/dnslab.org";
        inline-signing yes;
        auto-dnssec maintain;
};
```

The master must be modified to only send notifies and allow zone transfers from the signing server

The slave servers must be modified to accept notifies and perform zone transfers from the signing server

"Bump In The Wire" In-Line Signing

In-line signing, automatically inserts keying material into the zone

```
dnssec-keygen -K ./keys -a rsasha512 -b 1024 dnslab.org
dnssec-keygen -K ./keys -a rsasha512 -b 2048 -f ksk dnslab.org
rndc signing -nsec3param 1 0 10 bad5a170
rndc retransfer dnslab.org
rndc sign dnslab.org
```

Enabling DNSSEC Validation

```
DNSSEC Trust tree:
www.dnslab.org. (A)
|---dnslab.org. (DNSKEY keytag: 7308 alg
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        |---org. (DNSKEY keytag: 24209 a
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            |---org. (DS keytag: 21366 d
                |---. (DNSKEY keytag: 33
                    |---. (DNSKEY keytag
;; Chase successful
```

Validating DNSSEC

Authoritative Servers (master/slave) never do validation nor provide signaling of validation to clients

- If a DNS response has the AA (authoritative answer) bit set, it will never have the AD (authenticated data) bit set

It is the job of the recursive (validating) server to do the work required to prove data is unmodified

Validating DNSSEC

To validate DNSSEC, a recursive server must be able to track back to a trust anchor

Even if there is no trust anchor in place, a server may return signature data to the client in case the client can do validation itself

- DNSSEC data (RRSIGS) are returned if the DO bit is set in the EDNS0 header
- The AD bit is returned if validation to a trust anchor succeeded

Validating DNSSEC

BIND uses trust anchors from "trusted-keys" statements:

```
trusted-keys {
        "."  257 3 8 "AwEAA[...]ihz0=";
};
```

But what happens if the key changes? RFC-5011!

```
managed-keys {
  "." initial-key 257 3 8 "AwE[..]ihz0=";
};
```

Validating DNSSEC

RFC-5011 covers the problem of validating servers having to be reconfigured when trust-anchor material changes

- If a trust anchor KSK RRSET adds a new key and that key remains published in the zone for 30 days, that key may be considered as a trust anchor for the zone

- If the REVOKE bit is then set in the old KSK, the new KSK should be employed as the new trust-anchor for the zone

The Root KSK will be rolled! Use managed-keys!

```
options {
     dnssec-enable yes;
     dnssec-validation yes;
};
managed-keys {
     "." initial-key [.....];
};
```

DS Resource Records

To create chains of trust "in-protocol," the Key Signing Key of a zone is hashed and that hash is placed into the parent

This record is known as the Delegation Signing (DS) record

The DS record in the parent creates a secure linkage that an external attacker would have to overcome to forge keying material in the child

DS Resource Records

The DS record contains:

- The key tag of the key in the child
- The algorithm number of the key
- The hashing algorithm number used to create the DS

1	**SHA-1**	**2**	**SHA-256**
3	GOST R 34.11-94	4	SHA-384

- The hash of the key

DS Records

TTL

Label

Class

```
dnslab.org.     86400 IN DS 9247 8 2 (
                F788167DCF705C97D0CB1FD61F7B8EA807E61D8077FA
                2F50660B871FF9D8DE24 )
```

DS Records

Key Tag

Type

Key Alg#

```
dnslab.org.        86400 IN DS 9247 8 2 (
                   F788167DCF705C97D0CB1FD61F7B8EA807E61D8077FA
                   2F50660B871FF9D8DE24 )
```

DS Records

Hash Alg

```
dnslab.org.       86400 IN DS 9247 8 2 (
                  F788167DCF705C97D0CB1FD61F7B8EA807E61D8077FA
                  2F50660B871FF9D8DE24 )
```

Hash

DS Records

```
dnslab.org.     86394 IN DS 9247 8 2 (
                F788167DCF705C97D0CB1FD61F7B8EA807E61D8077FA
                2F50660B871FF9D8DE24 )
dnslab.org.     86394 IN RRSIG DS 7 2 86400 (
                20140318154949 20140225144949 24209 org.
                VWhUKxm+ig+yA/gV5kpEKB/Tb91R7b8dZTjpBtt4ZJFN
                AI7OVFT6wlEL9TlZGYsOX8bYB5VQhK6ZOMATIodIS/gG
                hQKGtC8sJG3I4ktuU/nMnyK/0FBCLnUpcGfk+A0E2ECj
                GLOLu6N/0cst9UH01+1oh30hMoMQVfpL9UOse+c= )
```

DS record lives in the parent and is signed with parent ZSK

DS Records

Parent:

```
dnslab.org.         86400 IN DS 9247 8 2 (
                    F788167DCF705C97D0CB1FD61F7B8EA807E61D8077FA
                    2F50660B871FF9D8DE24 )
```

Child:

```
dnslab.org.         3600 IN DNSKEY 257 3 8 (
                    AwEAAaHaqpWsLOXTNKdaYa9kQcK/HTaYYsT05rKzPHsY
                    [...]
                    BFlYBHoDZ6HHf5RmSYWUSXr3YYCpf9DwYnqT6Rc=
                    ) ; KSK; alg = RSASHA256; key id = 9247
```

DNSSEC in the real world

```
DNSSEC Trust tree:
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|---dnslab.org. (DNSKEY keytag: 7308 alg
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                |---. (DNSKEY keytag: 33
                    |---. (DNSKEY keytag
;; Chase successful
```

DNSSEC in the real world

Sandia National Labs & Verisign provide a web page that performs DNSSEC chain testing

http://www.dnsviz.net

DNSSEC in the real world - what about the clients?

run your own validating resolver… NLNetLab's dnssec-trigger

do validation in the browser… cz.nic's DNSSEC Validator for Chrome

More Real-World… Key Rollover Schedule

There is not "one answer" as to how often you should roll your keys.

- NIST recommends:
  - KSK should be rolled once a year
  - ZSK should be rolled every 3 months

NIST
National Institute of Standards and Technology
U.S. Department of Commerce