DNS/DNSSEC

23 January 2015

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DNS Security - Background

- The original DNS protocol wasn't designed with security in mind
  - It has very few built-in security mechanism
- As the Internet grew wilder, IETF realized this would be a problem
  - For example DNS spoofing was to easy
- DNSSEC and TSIG were develop to help address this problem
- Some security problems:
  - Using reverse DNS to impersonate hosts
  - Software bugs (buffer overflows, bad pointer handling)
  - Bad crypto (predictable sequences, forgeable signatures)
  - Cache poisoning (putting inappropriate data into the cache)

https://wiki.tools.isoc.org/DNSSEC_History_Project

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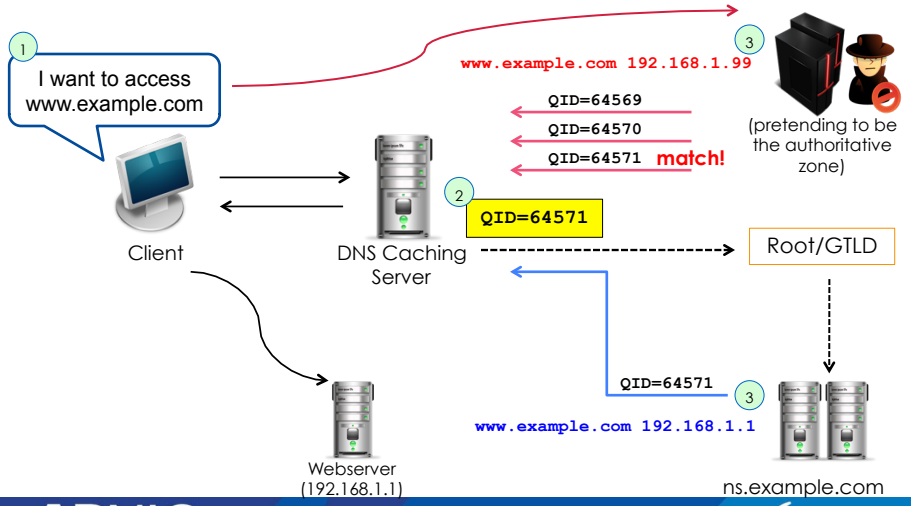
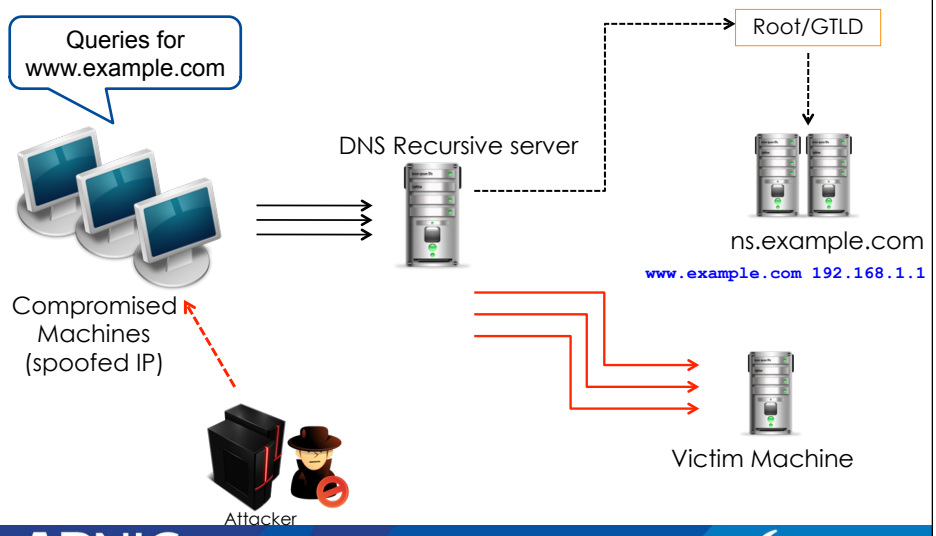
DNS Cache Poisoning



DNS Amplification

- A type of reflection attack combined with amplification
  - Source of attack is reflected off another machine
  - Traffic received is bigger (amplified) than the traffic sent by the attacker
- UDP packet's source address is spoofed

DNS Amplification



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Open Resolvers

- DNS servers that answer recursive queries from any host on the Internet
- http://openresolverproject.org/
- Check if you're running open resolvers
  - http://dns.measurement-factory.com/cgi-bin/openresolvercheck.pl
- More statistics at
  - http://dns.measurement-factory.com/surveys/openresolvers/ASN-reports/latest.html

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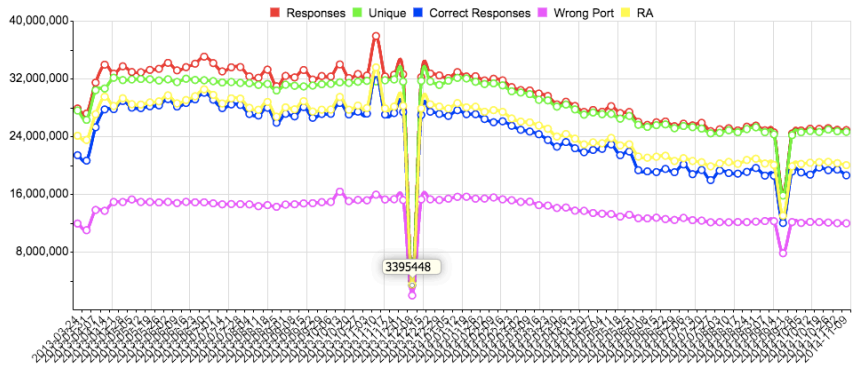
Open Resolvers

As of 19 Nov 2014:
22,796,823 servers responded to udp/53 probe
17,939,673 returned OK



Reference: http://openresolverproject.org/

Response Rate Limiting (RRL)

- Protects against DNS amplification attack
- Implemented in CZ-NIC Knot (v1.2-RC3), NLNetLabs NSD (v3.2.15), and ISC BIND 9 (v9.9.4) release

```
rate-limit {
            responses-per-second 5;
            log-only yes;
    };
```

- If using older versions, a patch is available from
  - http://ss.vix.su/~vjs/rrlrpz.html
  - `patch -p0 -l`

DNS Changer

- “Criminals have learned that if they can control a user’s DNS servers, they can control what sites the user connects to the Internet.”
- How: infect computers with a malicious software (malware)
- This malware changes the user’s DNS settings with that of the attacker’s DNS servers
- Points the DNS configuration to DNS resolvers in specific address blocks and use it for their criminal enterprise
- For more: see the NANOG presentation by Merike

Top DNS Changer Infections

- By country (as of 11 June 2012):
  - USA - 69517
  - IT – 26494
  - IN – 21302
  - GB – 19589
  - DE – 18427
- By ASNs
  - AS9829 (India) – 15568
  - AS3269 – 13406
  - AS7922 – 11964
  - AS3320 – 9250
  - AS7132 – 6743
- More info at http://dcwg.org/

Securing the Nameserver

- Run the most recent version of the DNS software
  - Apply the latest patches
- Hide version
- Restrict queries
  - `Allow-query { acl_match_list; };`
- Prevent unauthorized zone transfers
  - `Allow-transfer { acl_match_list; };`
- Run BIND with the least privilege (use `chroot`)
- Randomize source ports
  - don't use `query-source` option
- Secure the box
- Use TSIG and DNSSEC

Sender Policy Framework (SPF)

- Using DNS for email validation
- Checks the sender IP address
- Defined in RFC 4408 with updates in RFC 6652

```
apnic.net.          3600    IN      TXT     "v=spf1 mx
a:clove.apnic.net a:asmtp.apnic.net ip4:203.119.93.0/24
ip4:203.119.101.0/24 ip4:203.89.255.141/32
ip4:203.190.232.30/32 ip4:122.248.232.184/32
include:_spf.google.com -all"
```

DANE

- DNS-Based Authentication of Named Entities
- RFC 6698 (proposed standard)
- “secure method to associate the certificate that is obtained from the TLS server with a domain name using DNS”
- Adds a TLSA resource record

DNS RPZ

- Resource Policy Zone
- Developed for ISC Bind. Built in from version 9.8
- Turns a recursive DNS server into a “DNS firewall”
- “reputation-based” zones
- Like creating a reputation server for recursive DNS servers
  - Function is similar to DNSBL for email SMTP servers
- Blocks DNS resolution to malicious hosts

Questions

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Transaction Signature (TSIG)

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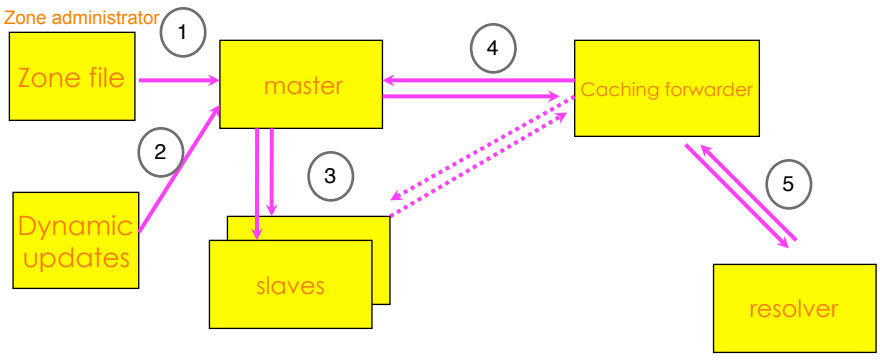
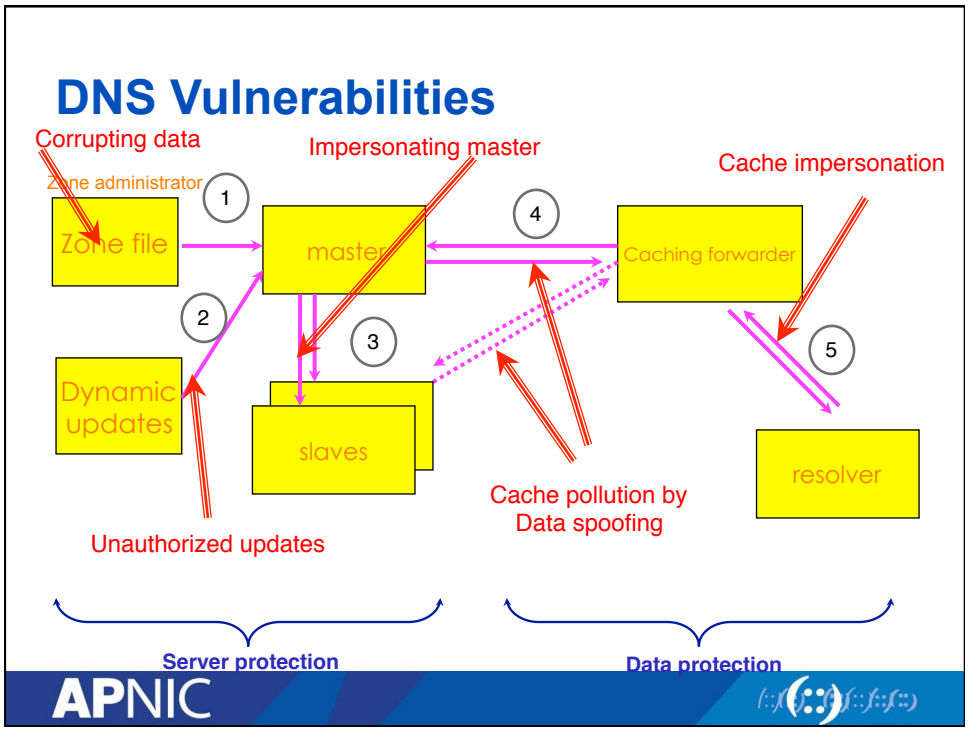
DNS Protocol Vulnerability

- DNS data can be spoofed and corrupted between master server and resolver or forwarder
- The DNS protocol does not allow you to check the validity of DNS data
  - Exploited by bugs in resolver implementation (predictable transaction ID)
  - Polluted caching forwarders can cause harm for quite some time (TTL)
  - Corrupted DNS data might end up in caches and stay there for a long time
- How does a slave (secondary) know it is talking to the proper master (primary)?

DNS: Data Flow




DNS Vulnerabilities
Corrupting data
Impersonating master
Cache impersonation
Zone administrator
Zone file
master
Caching forwarder
resolver
Dynamic updates
slaves
1
2
3
4
5
Unauthorized updates
Cache pollution by Data spoofing
Server protection
Data protection
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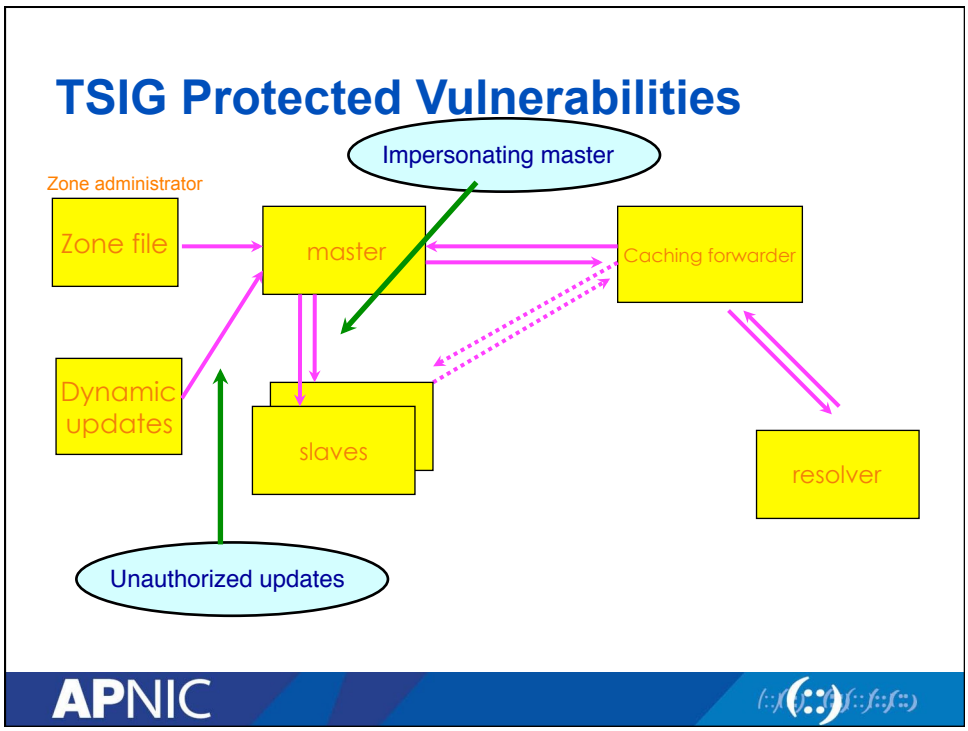
TSIG Protected Vulnerabilities
Impersonating master
Zone administrator
Zone file
master
Caching forwarder
resolver
Dynamic updates
slaves
Unauthorized updates
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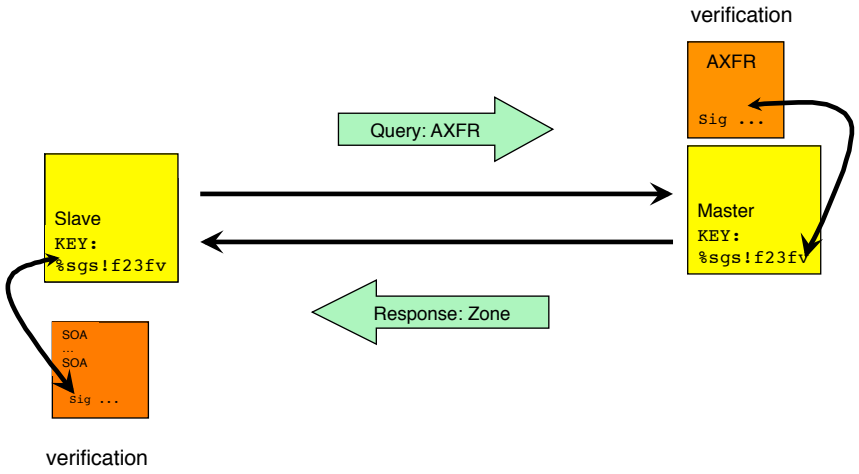
What is TSIG - Transaction Signature?

- A mechanism for protecting a message from a primary to secondary and vice versa
- A keyed-hash is applied (like a digital signature) so recipient can verify the message
  - DNS question or answer
  - & the timestamp
- Based on a shared secret - both sender and receiver are configured with it
  - TSIG/TKEY uses DH, HMAC-MD5, HMAC-SHA1, HMAC-SHA224, HMAC-SHA512 among others

What is TSIG - Transaction Signature?

- TSIG (RFC 2845)
  - authorizing dynamic updates & zone transfers
  - authentication of caching forwarders
- Used in server configuration, not in zone file

TSIG example



TSIG steps

1. Generate secret
2. Communicate secret
3. Configure servers
4. Test

TSIG - Names and Secrets

- TSIG name
  - A name is given to the key, the name is what is transmitted in the message (so receiver knows what key the sender used)
- TSIG secret value
  - A value determined during key generation
  - Usually seen in Base64 encoding

TSIG – Generating a Secret

- dnssec-keygen
  - Simple tool to generate keys
  - Used here to generate TSIG keys

```
> dnssec-keygen -a <algorithm> -b <bits> -n host
  <name of the key>
```

TSIG – Generating a Secret

- Example

```
> dnssec-keygen -a HMAC-MD5 -b 128 -n HOST ns1-
  ns2.pcx.net

This will generate the key
> Kns1-ns2.pcx.net.+157+15921

>ls
Kns1-ns2.pcx.net.+157+15921.key
Kns1-ns2.pcx.net.+157+15921.private
```


TSIG – Generating a Secret

- TSIG should never be put in zone files
  - might be confusing because it looks like RR:

```
ns1-ns2.pcx.net. IN KEY 128 3 157 nEfRX9…bbPn7lyQtE=
```

TSIG – Configuring Servers

- Configuring the key
  - in named.conf file, same syntax as for rndc
  - `key { algorithm ...; secret ...;}`
- Making use of the key
  - in named.conf file
  - `server x { key ...; }`
  - where 'x' is an IP number of the other server

Configuration Example – named.conf

Primary server 10.33.40.46

```
key ns1-ns2.pcx. net {
        algorithm hmac-md5;
        secret "APlaceToBe";
};
server 10.33.50.35 {
        keys {ns1-ns2.pcx.net;};
};
zone "my.zone.test." {
        type master;
        file “db.myzone”;
        allow-transfer {
        key ns1-ns2.pcx.net ;};
};
```

Secondary server 10.33.50.35

```
key ns1-ns2.pcx.net {
        algorithm hmac-md5;
        secret "APlaceToBe";
};
server 10.33.40.46 {
  keys {ns1-ns2.pcx.net;};
};
zone "my.zone.test." {
        type slave;
        file “myzone.backup”;
        masters {10.33.40.46;};
};
```

You can save this in a file and refer to it in the named.conf using ‘include’ statement:

```
include “/var/named/master/tsig-key-ns1-ns2”;
```

TSIG Testing : dig

- You can use dig to check TSIG configuration
  - `dig @<server> <zone> AXFR -k <TSIG keyfile>`

```
$ dig @127.0.0.1 example.net AXFR \
    -k Kns1-ns2.pcx.net.+157+15921.key
```

- Wrong key will give “Transfer failed” and on the server the security-category will log this.

TSIG Testing - TIME!

- TSIG is time sensitive - to stop replays
  - Message protection expires in 5 minutes
  - Make sure time is synchronized
  - For testing, set the time
  - In operations, (secure) NTP is needed

TSIG steps

1. Generate secret
   - `dnssec-keygen -a <algorithm> -b <bits> -n host <name of the key>`
2. Communicate secret
   - `scp <keyfile> <user>@<remote-server>:<path>`
3. Configure servers
   - `key { algorithm ...; secret ...;}`
   - `server x { key ...; }`
4. Test
   - `dig @<server> <zone> AXFR -k <TSIG keyfile>`

Questions

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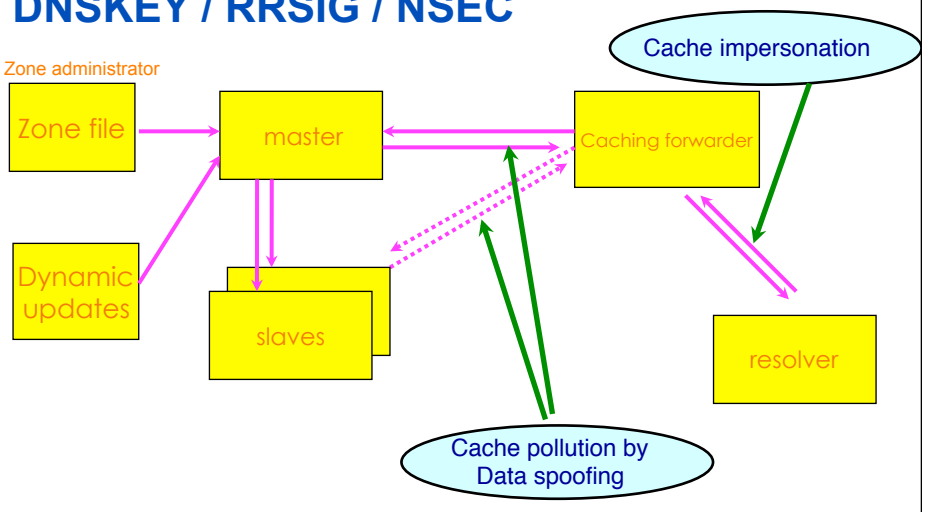
Vulnerabilities protected by DNSKEY / RRSIG / NSEC



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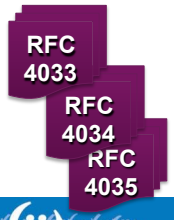
DNS Security Extensions (DNSSEC)

- Protects the integrity of data in the DNS by establishing a chain of trust
- Uses public key cryptography – each link in the chain has a public/private key pair
- A form of digitally signing the data to attest its validity
- Standard is defined in RFC4033, RFC4034, and RFC4035
- Guarantees
  - Authenticity
  - Integrity
  - Non-existence of a domain



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DNSSEC History

- **1990**: Steven Bellovin discovers a major flaw in the DNS
- **1995**: Bellovin publishes his research; DNSSEC (as it became later known) becomes a topic within IETF
- **1997**: RFC 2065 (adding security extensions) was published
- **1998**: Dan Kaminsky discovers some security flaw
- **1999**: RFC 2535, the DNSSEC protocol, is published; BIND 9 developed to be DNSSEC-capable
- **2001**: key handling in RFC2535 is causing operational problems
- **2005**: Three new RFCs published to update RFC2535
  - RFC 4033 (DNS Security Introduction and Requirements)
  - RFC 4034 (Resource Records for DNS Security Extensions)
  - RFC 4035 (Protocol Modifications)

https://wiki.tools.isoc.org/DNSSEC_History_Project

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DNSSEC History

- **2005**: In October, Sweden (.SE) becomes the first ccTLD to deploy DNSSEC
- **2008**: new DNSSEC record created to address privacy concerns (RFC 5155)
- **2010**
  - In July 15, the root zone was signed
  - In July 29, .edu was signed
  - In December 9, .net was signed
- **2011**: In March 31, `.com` was signed

https://wiki.tools.isoc.org/DNSSEC_History_Project

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DNSSEC Resource Records

- 3 Public key crypto related RRs
  - **RRSIG** = Signature over RRset made using private key
  - **DNSKEY** = Public key, needed for verifying a RRSIG
  - **DS** = Delegation Signer; 'Pointer' for building chains of authentication
- One RR for internal consistency
  - **NSEC** = Next Secure; indicates which name is the next one in the zone and which typecodes are available for the current name
    - authenticated non-existence of data

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DNSSEC Resource Records

- DNSKEY, RRSIG, and NSEC records provide mechanisms to establish authenticity and integrity of data
- DS record provides a mechanism to delegate trust to public keys of third parties

DNSSEC RRs

- Data authenticity and integrity by signing the Resource Records Sets with private key
- Public DNSKEY is used to verify the RRSIG
- Children sign their zones with their private key
  - Authenticity of that key established by signature/checksum by the parent (DS)
- Ideal case: one public DNSKEY distributed

RR's and RRsets

- Resource Record:

Name	TTL	class	type	rdata
www.example.net.	7200	IN	A	192.168.1.1

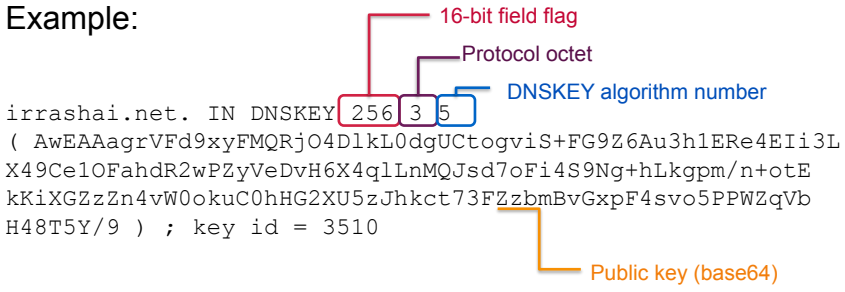
- RRset: RRs with same name, class and type:

www.example.net.	7200	IN	A	192.168.1.1
			A	10.0.0.3
			A	172.10.1.1

- RRsets are signed, not the individual RRs

DNSKEY

- Contains the zone's public key
- Uses public key cryptography to sign and authenticate DNS resource record sets (RRsets).
- Example:



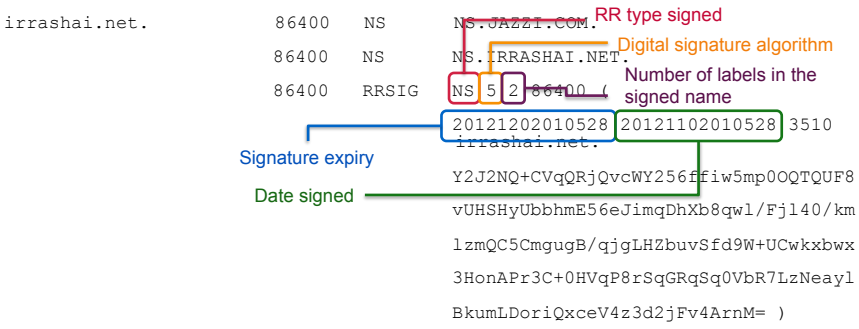
DNSKEY

- Also contains some timing metadata – as a comment in the key file

```
; This is a key-signing key, keyid 19996, for myzone.net.
; Created: 20121102020008 (Fri Nov  2 12:00:08 2012)
; Publish: 20121102020008 (Fri Nov  2 12:00:08 2012)
; Activate: 20121102020008 (Fri Nov  2 12:00:08 2012)
```


RRSIG

- The private part of the key-pair is used to sign the resource record set (RRset) per zone
- The digital signature per RRset is saved in an RRSIG record



NSEC / NSEC3

- Next Secure
- Forms a chain of authoritative owner names in the zone
- Lists two separate things:
  - Next owner name (canonical ordering)
  - Set of RR types present at the NSEC RR's owner name
- Also proves the non-existence of a domain

```
irrashai.net.  NSEC    blog.irrashai.net. A NS SOA MX
                  RRSIG NSEC DNSKEY
```


NSEC / NSEC3

- "The last NSEC wraps around from the last name in the ordered zone to the first"
- Each NSEC record also has a corresponding RRSIG

NSEC RDATA

- Points to the next domain name in the zone
  - also lists what are all the existing RRs for “name”
  - 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

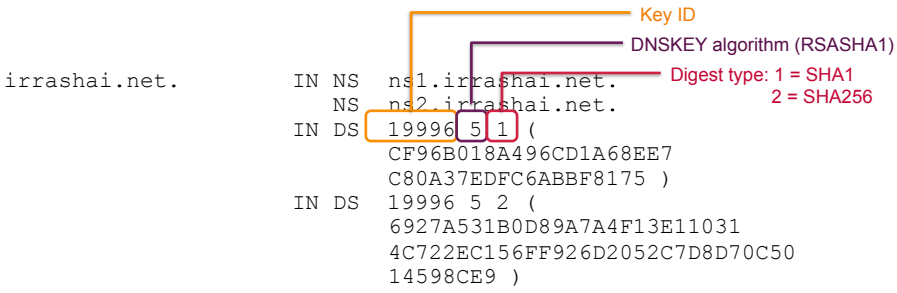
NSEC Record example

```
$ORIGIN example.net.
@ SOA       …
      NS     NS.example.net.
      DNSKEY …
      NSEC    mailbox.example.net. SOA NS NSEC DNSKEY       RRSIG

mailbox      A      192.168.10.2
                    NSEC  www.example.net.  A NSEC RRSIG
 WWW         A      192.168.10.3
                    TXT    Public webserver
                    NSEC  example.net. A NSEC RRSIG TXT
```

Delegation Signer (DS)

- Establishes the chain of trust from parent to child zones
- Found in the parent's zone file
- In this example, irrashai.net has been delegated from .net. This is how it looks like in .net zone file




```
irrashai.net.          IN NS  ns1.irrashai.net.
                       NS     ns2.irrashai.net.
                       IN DS  19996 5 1 (
                              CF96B018A496CD1A68EE7
                              C80A37EDFC6ABBF8175 )
                       IN DS  19996 5 2 (
                              6927A531B0D89A7A4F13E11031
                              4C722EC156FF926D2052C7D8D70C50
                              14598CE9 )
```


Delegation Signer (DS)

- Delegation Signer (DS) RR indicates that:
  - delegated zone is digitally signed
  - indicated key is used for the delegated zone
- Parent is authorative for the DS of the childs zone
  - Not for the NS record delegating the childs zone!
  - DS **should not** be in the childs zone

Types of Keys

- Zone Signing Key (ZSK)
  - Sign the RRsets within the zone
  - Public key of ZSK is defined by a DNSKEY RR
- Key Signing Key (KSK)
  - Signed the keys which includes ZSK and KSK and may also be used outside the zone
- Trusted anchor in a security aware server
- Part of the chain of trust by a parent name server
- Using a single key or both keys is an operational choice (RFC allows both methods)

Creation of keys

- Zones are digitally signed using the private key
- Can use RSA-SHA-1, DSA-SHA-1 and RSA-MD5 digital signatures
- The public key corresponding to the private key used to sign the zone is published using a DNSKEY RR

Chain of Trust

- DNSSEC is based on trust
- Root is on top of the chain of trust.
  - Root servers were signed on July 15, 2010.

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Implementing DNSSEC

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DNSSEC - Setting up a Secure Zone

- Enable DNSSEC in the configuration file (named.conf)
  - `dnssec-enable yes; dnssec-validation yes;`
- Create key pairs (KSK and ZSK)
  - `dnssec-keygen -a rsasha1 -b 1024 -n zone champika.net`
- Publish your public key
- Signing the zone
- Update the config file
  - Modify the zone statement, replace with the signed zone file
- Test with dig

Updating the DNS Configuration

- Enable DNSSEC in the configuration file (named.conf)

```
options {
        directory "…."
        dnssec-enable yes;
        dnssec-validation yes;
 };
```

- Other options that can be added later
  - `auto-dnssec { off | allow | maintain} ;`
  - These options are used to automate the signing and key rollover

Creating key pairs

- To create ZSK

```
dnssec-keygen -a rsasha1 -b 1024 -n zone
<myzone>
```

- To create KSK

```
dnssec-keygen -a rsasha1 -b 1400 -f KSK -n
zone champika.net
```


Generating Key Pair

- Generate ZSK and KSK

```
dnssec-keygen -a rsasha1 -b 1024 -n zone <myzone>
```

Default values are RSASHA1 for algorithm, 1024 bits for ZSK and 2048 bits for KSK

The command above can be simplified as:

```
dnssec-keygen -f KSK <myzone>
```

This generates four files.

Note: There has to be at least one public/private key pair for each DNSSEC zone

Publishing your public key

- Using $INCLUDE you can call the public key (DNSKEY RR) inside the zone file

```
$INCLUDE /path/Kchampika.net.+005+33633.key ; ZSK
$INCLUDE /path/Kchampika.net.+005+00478.key ; KSK
```

- You can also manually enter the DNSKEY RR in the zone file

Signing the Zone

- Sign the zone using the secret keys:

```
dnssec-signzone –o <zonename> -N INCREMENT -f
<output-file> -k <KSKfile> <zonefile> <ZSKfile>

dnssec-signzone –o champika.net db.champika.net
Kchampika.net.+005+33633
```

- Once you sign the zone a file with a .signed extension will be created
  - `db.champika.net.signed`

Signing the Zone

- Note that only authoritative records are signed
  - NS records for the zone itself are signed
  - NS records for delegations are not signed
  - DS RRs are signed!
  - Glue is not signed
- Difference in the file size
  - db.champika.net vs. db.champika.net.signed

Smart Signing

- Searches the key repository for any keys that will match the zone being signed

```
options {
keys-directory { "path/to/keys"; };
```

- Then the command for smart signing is

```
dnssec-signzone -S db.myzone.net
```

Publishing the Zone

- Reconfigure to load the signed zone. Edit named.conf and point to the signed zone.

```
zone "<myzone>" {
     type master;
     # file "db.myzone.net";
     file "db.myzone.net.signed";
};
```


Pushing the DS record

- The DS record must now be published by the parent zone.
- Contact the parent zone to communicate the KSK to them.

KSK Key Rollover

- Perform scheduled zone maintenance.
- KSK rollover using Double signing
- When you change the KSK keys, the DS record in the parent zone must also be updated.

```
dnssec-signzone -o myzone.net -N increment -f <output- \
file> -k Kmyzone.net.+005+11111 db.myzone.net \
Kmyzone.net.+005+67890
```

- Send the new DS record to the parent, and wait for it to propagate.
- Remove the old key and resign.

KSK Key Rollover

- Using Pre-publication
- In this method, the new key will be published but will not be used for signing yet.

```
dnssec-keygen -K keydir -f ksk -A none <myzone.net>
rndc loadkeys <myzone.net>
```

- Publish both keys, but use only the old one for signing
- Wait for the propagation time and TTL of the DNSKEY RR to expire.

KSK Key Rollover

- Then use dnssec-settime once you are ready to sign the zone. Use the new key for zone signing, leaving the old one published.

```
dnssec-settime -K keydir -A now Kexample.com.+005+12345
rndc loadkeys example.com
```

- Wait for the propagation and TTL in the old zone. Set the old key to no longer sign with the key, but leaves it in the zone.

```
dnssec-settime -K keydir -I now Kexample.com.+005+12345
rndc loadkeys example.com
```

- Now remove the old keys. This completely removes the keys.

```
dnssec-settime -K keydir -D now Kexample.com.+005+12345
rndc loadkeys example.com
```


Automated Signing

- Using RNDC
- Add the option to named.conf

```
auto-dnssec allow;
```

- Then you can use the commands:

```
rndc loadkeys zone
rndc sign zone
```

Testing the server

- Ask a dnssec enabled question from the server and see whether the answer contains dnssec-enabled data
  - Basically the answers are signed

```
dig @localhost www.champika.net +dnssec
+multiline
```


Testing with dig: an example

Registries / Hosting Providers – Sign your Zones

- All the zones you serve can be signed
  - think about key rollover
  - think about key compromise scenarios, and what processes you will follow when you detect them
- Think about how you can detect compromises, and monitor signatures

For ISPs – Validate!

- The most effective step you can take to encourage DNSSEC uptake as an ISP is to validate responses
- DNSSEC-signed zones are fairly new, so expect this to cause some non-zero (but manageable) amount of helpdesk load
- Comcast is an example of a large ISP (in the US) who has taken this step

DNSSEC Validation - Tools

- Use a validating resolver
  - From your ISP
  - From Google Public DNS – 8.8.8.8
  - From DNS-OARC - 149.20.64.20, 149.20.64.21
- DNS/TLSA Validator
  - https://www.dnssec-validator.cz/
- Web tools
  - DNSSEC Failed - http://www.dnssec-failed.org/
  - DNSSEC Debugger (Verisign) - http://dnssec-debugger.verisignlabs.com/
  - DNSSEC or NOT - http://test.dnssec-or-not.com/

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DNSSEC Key Management

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Ways to Deploy DNSSEC

- As part of the DNS software used
  - Manual key management
  - Can be quite complex
  - For static environment
  - Some means of automation using
    - option commands and scripts

DNSSEC tools for BIND, NSD, PowerDNS, etc

- Use with a hardware security module (HSM)
  - Semi-automatic
  - Good for dynamic environment

HSM, OpenDNSSEC

- Using an external appliance
  - 'dnssec-in-a-box'
  - Fully automates key generation, signing and rollover

DNS Appliance

Hardware Security Module

- Cryptographic devices used for storage of the encryption keys
  - Smart cards, PCI cards, USB tokens
- It also speeds up the cryptographic key generation
- Implements PKCS#11 (Cryptographic Token Key Interface)
  - A standard interface or API to cryptographic tokens

DNSSEC Signer Appliance

- Can be a pure signer or packaged with an IPAM or a DNS server
- In pure signer, the hardware appliance interfaces between the master/slave servers
- Examples: Secure64, Xelerance, SolidDNS, etc

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Questions

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Further Readings

- DNS Operational Practices
  - http://tools.ietf.org/html/rfc6781
  - Informational, published December 2012
- A Framework for DNSSEC Policies and DNSSEC Practice Statements
  - http://tools.ietf.org/html/rfc6841
  - Informational, published January 2013

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Thank you!

End of Session

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