DNS and DNSSEC

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<u>DNS and DNSSEC</u>

This tutorial is being presented at the LISA 2012 Conference held in San Diego, CA, on Dec 11th 2012.

Feedback, critique, suggestions on these slides gladly received at <shuque @ upenn.edu>

Reminder: Please fill out the evaluation forms for this course!

Course blurb from LISA conference brochure:

This tutorial will provide system administrators an understanding of the DNS protocol, including advanced topics such as DNSSEC (DNS Security). It will provide practical information about configuring DNS services using examples from the popular ISC BIND DNS software platform.

Topics include: the DNS protocol and how it works, DNS master zone file format, a look at a variety of server configurations and recommendations, DNSSEC (DNS Security Extensions) and how to deploy it, many examples of DNS query and debugging using the "dig" tool, DNS and IPv6, and more.

Who am I?

- An I.T. Director at the University of Pennsylvania
- Have also been:
  - Programmer (C, Perl, Python, Lisp)
  - UNIX Systems Administrator
  - Network Engineer
- Education: B.S. and M.S. (Computer Science) from Penn
- Also teach a Lab course on Network Protocols at Penn's School of Engineering & Applied Science

Who am I?

- Website: http://www.huque.com/~shuque/
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  - https://plus.google.com/105308234918217701741/posts

Course Topics

1. DNS Tutorial
2. Configuring DNS in BIND
3. Live queries using ‘dig’
   [... break ...]
4. DNSSEC Tutorial
5. Configuring DNSSEC in BIND
6. Application uses of DNSSEC
7. DNSSEC deployment status

DNS Tutorial

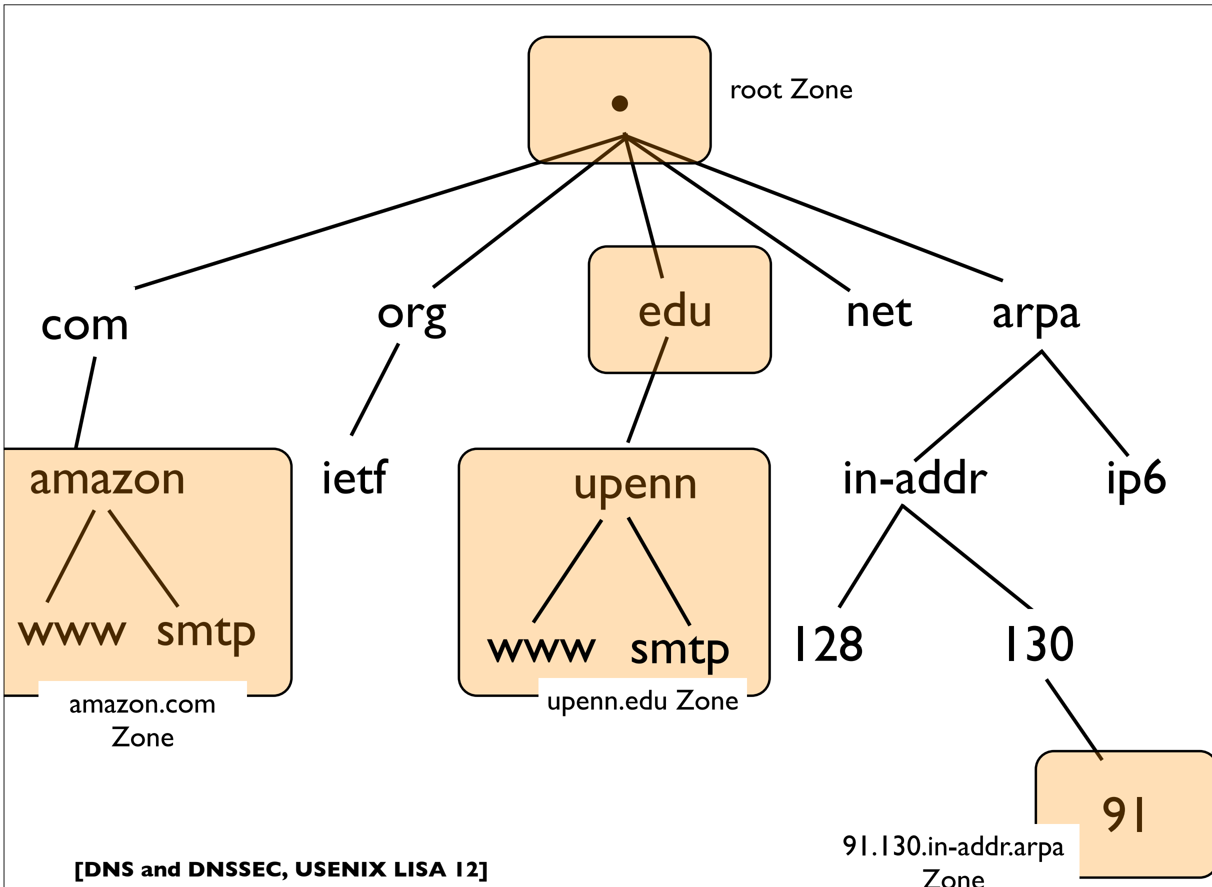
DNS

- Domain Name System
- Base specs in RFC 1034 & 1035 (obs 882 & 883)
- Distributed global database
- Indexed by "domain names" (together with a type and class)
- A domain name is a sequence of labels, eg.
  - www.amazon.com.
- Domain Names are case insensitive, but case preserving
- Transport protocol: UDP and TCP port 53

DNS

- DNS can be represented as a tree of labels
- Sibling nodes must have unique labels
- Domain name at a particular label can be formed by the sequence of labels traversed by walking up the tree from that label to the root
- Zone - autonomously managed subtree
- Delegations: boundaries between zones

[DNS and DNSSEC, USENIX LISA 12]



[DNS and DNSSEC, USENIX LISA 12]

Root and TLDs

- Root of the DNS (“empty label”)
- Next level of names are called Top Level Domains (TLDs)
- Until recently 3 primary classes of TLDs
  - GTLD: Generic Top Level Domains (.com, .net, .edu, .org etc)
  - CCTLD: Country Code TLD (2 letter codes for each country, eg. .us, .fr, .jp, .de, ...)
  - Infrastructure: eg. .arpa etc (uses: reverse DNS e164, etc)
- IDN cctld (Internationalized domain name ccTLD)
- The new gTLDs - the wild west? (newgtlds.icann.org)

[DNS and DNSSEC, USENIX LISA 12]

DNS main components

- Server Side:
  - Authoritative Servers
  - Resolvers (Recursive Resolvers)
- Client Side:
  - Stub resolvers (usually on DNS client machines)

[DNS and DNSSEC, USENIX LISA 12]

Authoritative Server

- A server that directly serves data for a particular zone
- Said to be "authoritative" for that zone
- These servers are the ones specified in NS records

[DNS and DNSSEC, USENIX LISA 12]

Resolver

- Aka "Recursive Resolver", "Cache" etc
- Used by endsystems (stub resolvers) to query ("resolve") arbitrary domain names
- Receives "recursive" queries from these endsystems
- Resolvers query authoritative servers, following DNS delegations until they obtain the answer they need (this process is called "iterative" resolution)
- Resolvers "cache" (remember) query results for the specified "TTL" (also some negative results are cached)

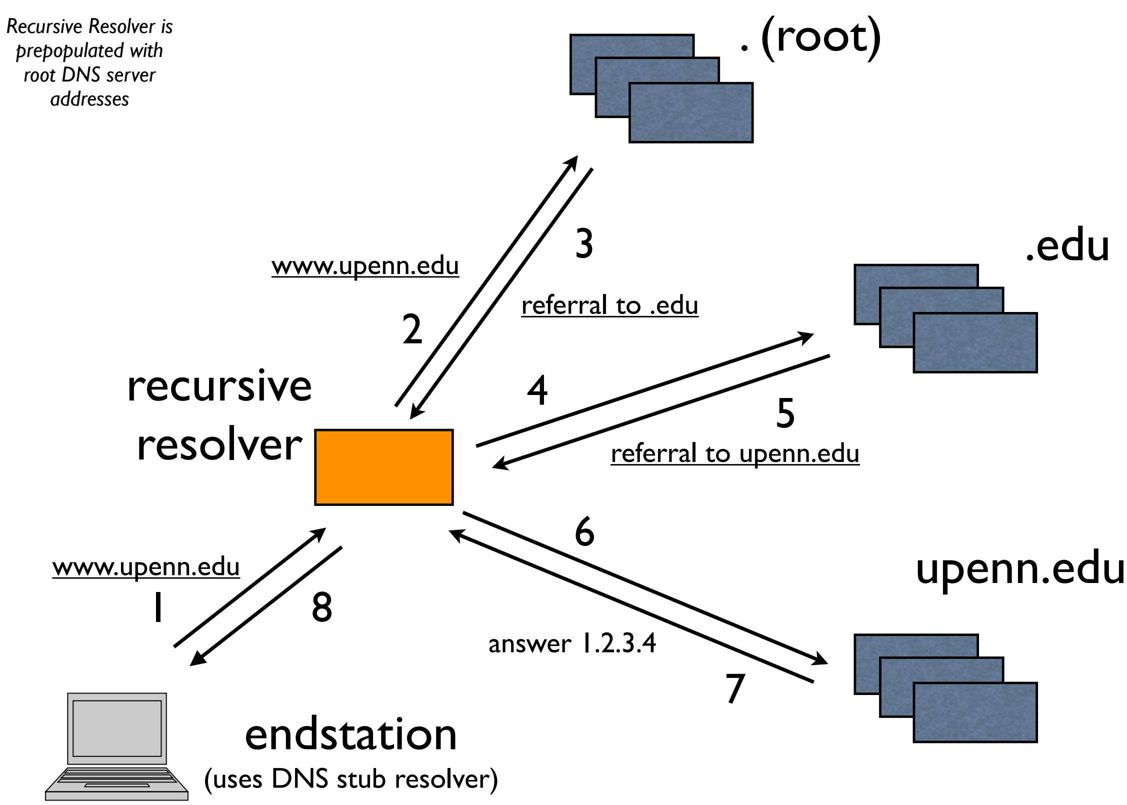
[DNS and DNSSEC, USENIX LISA 12]

Stub Resolver

- The DNS client software component that resides on most endsystems
- Commonly implemented by the Operating System as a set of library routines
- Has a configured set of addresses of the Recursive Resolvers that should be used to lookup ("resolve") domain names
  - usually by manual configuration, or dynamically learned via DHCP
- Some stub resolvers also cache results

Stub resolver configuration

```
$ cat /etc/resolv.conf

search          finance.example.com example.com
;;
nameserver      10.12.3.1
nameserver      10.254.23.71
nameserver      10.15.18.9
;;
options timeout:1 attempts:2 rotate
```



[DNS and DNSSEC, USENIX LISA 12]

Parts of a DNS query

- Each DNS query needs a query name, type, and class

- **qname**: a domain name, eg. www.upenn.edu
- **qtype**: A, AAAA, MX, CNAME, PTR, SRV, TXT, NS, SOA, ...
- **qclass**: IN, CH, HS (only "IN" is commonly used)

- Various flags: QR, RD, EDNS Opt, DO etc

[DNS and DNSSEC, USENIX LISA 12]

Life of a typical DNS query

- Type "www.amazon.com" into browser
- Browser calls a name lookup function (eg. getaddrinfo())
- DNS may not be the only name lookup service in use. The lookup function might consult a nameservice switch table to figure out what order of services to consult (eg. /etc/nsswitch.conf -- flat file, LDAP, NIS, DNS etc)
- If/when DNS is used, then call DNS specific calls in stub resolver
  - res_ninit(), res_nquery(), res_nsearch()

[DNS and DNSSEC, USENIX LISA 12]

Life of a typical DNS query

- Stub resolver formulates and makes DNS query:
  - qname www.amazon.com, qtype=A, qclass=IN
  - Note: IPv6 enabled resolvers might try AAAA, then A
- Sends query to DNS servers (resolvers) specified in stub resolver configuration (eg. /etc/resolv.conf) in the order specified until it gets a successful response, failure, or times out
- If a "search" domain list is configured, on lookup failure, the stub retries queries with domain suffixes from this list appended to the original query

[DNS and DNSSEC, USENIX LISA 12]

Life of a typical DNS query

- DNS resolvers will get the answer:
  - from their authoritative zones if they have any relevant ones
  - from their cache if the answer is already there
  - by iterative queries of the DNS tree, as necessary, eg.
    - root servers, amazon.com servers, ...

Resource Records (RR)

- The fundamental unit of data in the DNS database
- A grouping of a {domain name, type, class}, a TTL (time-to-live), and the associated "resource data"
- Has a defined text "presentation format"

```
www.example.com.        86400 IN   A  10.253.12.7
```

name, or owner name	ttl	class	type	rdata

Resource Record Sets

- A set of RRs with the same name, class, and type
- The rdata (resource data) associated with each RR in the set must be distinct
- The TTL of all RRs in the set also must match
- RR sets are treated atomically when returning responses

```
www.ucla.edu.        300   IN   A   169.232.33.224
www.ucla.edu.        300   IN   A   169.232.55.224
www.ucla.edu.        300   IN   A   169.232.56.224
```

[DNS and DNSSEC, USENIX LISA 12]

Resource Record types

Type	Description
SOA	marks **S**tart **O**f a zone of **A**uthority
NS	NameServer record
A	IPv4 Address record
AAAA	IPv6 Address record
CNAME	Canonical name (ie. an alias)
MX	Mail Exchanger record
SRV	Service Location record
PTR	Pointer (most commonly for reverse DNS)
TXT	Text record (free form text with no semantics)
NAPTR	Naming Authority Pointer Record

for full list, see
www.iana.org/assignments/dns-parameters

[DNS and DNSSEC, USENIX LISA 12]

Other special RRtypes

Type	Description
TSIG	Transaction Signature (RFC 2845)
TKEY	Transaction Key (RFC 2930) - estab secret keys
AXFR	Zone Transfer
IXFR	Incremental Zone Transfer (RFC 1995)
OPT	Opt pseudo RR (RFC 2671 - EDNS0)

for full list, see
www.iana.org/assignments/dns-parameters

SOA record

- Defines the start of a new zone; and important parameters for the zone
- Always appears at the apex of the zone
- Serial number should be incremented on zone content updates

```
google.com.     86400 IN SOA ns1.google.com. (
                            dns-admin.google.com.
                            2012042000 ; serial number
                            7200       ; refresh (2 hours)
                            1800       ; retry (30 minutes)
                            1209600    ; expire (2 weeks)
                            300        ; minimum (5 minutes)
                            )
```

NS record

- Name Server record: owner is the zone name
- Delegates a DNS subtree from parent (ie. create new zone)
- Lists the authoritative servers for the zone
- Appears in both parent and child zones
- rdata contains hostname of the DNS server

```
upenn.edu.    86400 IN NS noc3.dccs.upenn.edu.
upenn.edu.    86400 IN NS noc2.dccs.upenn.edu.
upenn.edu.    86400 IN NS dns2.udel.edu.
upenn.edu.    86400 IN NS dns1.udel.edu.
upenn.edu.    86400 IN NS sns-pb.isc.org.
```

[DNS and DNSSEC, USENIX LISA 12]

A record

- IPv4 Address Record
- rdata contains an IPv4 address

```
www.example.com.   86400   IN  A  192.0.43.10
```

[DNS and DNSSEC, USENIX LISA 12]

AAAA record

- IPv6 Address Record
- rdata contains an IPv6 address
- Note: there was another record called A6, which didn't catch on, and which has now been declared historic (RFC 6563)

```
www.example.com.  86400  IN  AAAA  2001:500:88:200::10
```


CNAME record

- An "alias", ie. maps one name to another (regardless of type)
- Put another way, "this is another name for this name"
- rdata contains the mapped domain name ("canonical name")
- CNAME records have special rules

```
www.example.com.  86400  IN CNAME  worf.example.com.
```

CNAME special rules

```
[from RFC 1034, Section 3.6.2]
```

<u>>>> CNAME and no other data rule:</u>
A CNAME RR identifies its owner name as an alias, and specifies the corresponding canonical name in the RDATA section of the RR. **If a CNAME RR is present at a node, no other data should be present; this ensures that the data for a canonical name and its aliases cannot be different.** This rule also insures that a cached CNAME can be used without checking with an authoritative server for other RR types.

[Note: there is now an exception to this because of DNSSEC metadata records, which are allowed to appear with CNAMEs]

<u>>>> CNAME special action processing:</u>
CNAME RRs cause special action in DNS software. **When a name server fails to find a desired RR in the resource set associated with the domain name, it checks to see if the resource set consists of a CNAME record with a matching class. If so, the name server includes the CNAME record in the response and restarts the query at the domain name specified in the data field of the CNAME record.** The one exception to this rule is that queries which match the CNAME type are not restarted.

CNAME special rules

Illustration of special action processing of CNAMEs:

```
$ dig www.sas.upenn.edu A

;; QUESTION SECTION:
;www.sas.upenn.edu.    IN A

;; ANSWER SECTION:
www.sas.upenn.edu.     300   IN   CNAME  virgo.sas.upenn.edu.
virgo.sas.upenn.edu.   900   IN   A      128.91.55.21
```

PTR record

- Pointer record
- The most common use is to map IP addresses back to domain names (reverse DNS mappings)
- IPv4 uses in-addr.arpa, and IPv6 uses ip6.arpa subtrees

IPv4 PTR records

- Uses "**in-addr.arpa**" subtree
- The LHS of the PTR record ("owner name") is constructed by the following method:
  - Reverse all octets in the IPv4 address
  - Make each octet a DNS label
  - Append "in-addr.arpa." to the domain name

IPv4 PTR example

```
host1.example.com.   IN   A    192.0.2.17

192.0.2.17                         (orig IPv4 address)

17.2.0.192                         (reverse octets)

17.2.0.192.in-addr.arpa.           (append in-addr.arpa.)
```

<u>Resulting PTR record:</u>

```
17.2.0.192.in-addr.arpa. IN PTR host1.example.com.
```

[DNS and DNSSEC, USENIX LISA 12]

IPv6 addresses

- 128-bits (four times as large)
- 8 fields of 16 bits each (4 hex digits) separated by colons (:)
- [Hex digits are: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f]
- 2^{128} possible addresses (an incomprehensibly large number)

2001:0db8:3902:00c2:0000:0000:0000:fe04

(2^{128} = 340,282,366,920,938,463, 463,374,607,431,768,211,456)

[DNS and DNSSEC, USENIX LISA 12]

IPv6 addresses

- Zero suppression & compression for more compact format
  - Suppress (omit) leading zeros in each field
  - Replace consecutive fields of all zeros with a double colon (::) - only one sequence of zero fields can be compressed this way

```
2001:0db8:3902:00c2:0000:0000:0000:fe04
```

```
2001:db8:3902:c2::fe04
```


IPv6 PTR records

- Uses "**ip6.arpa**" subtree
- The LHS of the PTR record ("owner name") is constructed by the following method:
  - Expand all the zeros in the IPv6 address
  - Reverse all the hex digits
  - Make each hex digit a DNS label
  - Append "ip6.arpa." to the domain name (note: the older "ip6.int" was formally deprecated in 2005, RFC 4159)

IPv6 PTR example

```
host1.example.com. IN AAAA 2001:db8:3902:7b2::fe04

2001:db8:3902:7b2::fe04                       (orig IPv6 address)

2001:0db8:3902:07b2:0000:0000:0000:fe04       (expand zeros)

20010db8390207b2000000000000fe04              (delete colons)

40ef000000000002b7020938bd01002               (reverse digits)

4.0.e.f.0.0.0.0.0.0.0.0.0.0.0.0.2.b.7.0.2.0.9.3.8.b.d.
0.1.0.0.2                                     (make DNS labels)

4.0.e.f.0.0.0.0.0.0.0.0.0.0.0.0.2.b.7.0.2.0.9.3.8.b.d.
0.1.0.0.2.ip6.arpa.                           (append ip6.arpa.)

4.0.e.f.0.0.0.0.0.0.0.0.0.0.0.0.2.b.7.0.2.0.9.3.8.b.d.
0.1.0.0.2.ip6.arpa. IN PTR host1.example.com.
```


MX record

- Mail Exchanger: defines the host receiving mail
- rdata consists of a preference field and the hostname of the mail receiver
- Lower preference = higher priority

```
example.com.    86400 IN MX  10 mail1.example.com.
example.com.    86400 IN MX  20 mail2.example.com.
```

preference   mailserver name

SRV record

- Service Location record (RFC 2782)
- Allows designation of server(s) providing service for a particular application and transport at a domain name
- Owner name has special form: _service._transport.<domain>
- rdata contains priority, weight, port and server hostname
- Some applications using SRV records include: LDAP, Kerberos, XMPP, SIP, Windows Active Directory, ...

SRV record

service name transport priority weight port server name

```
_ldap._tcp.example.com  600 IN SRV 1 0 389 ldap1.example.com
_ldap._tcp.example.com  600 IN SRV 2 1 389 ldap2.example.com
_ldap._tcp.example.com  600 IN SRV 2 2 389 ldap3.example.com
_ldap._tcp.example.com  600 IN SRV 2 1 289 ldap4.example.com
```

- Priority defines the order in which to query servers (lower number = higher priority)
- Weight defines the proportion in which to send queries to servers at the same priority level (load distribution)

TXT record

- free form descriptive text strings, with no defined semantics
- Although some applications have defined their own meanings (eg. DKIM, SPF, ...)
- rdata: one or more character strings

```
blah.example.com.   300  IN  TXT   "Hello World" "Goodbye"
```


NAPTR record

- Naming Authority Pointer Record (RFC 3403 - DDDS)
- Very complex record, and induces additional complex processing on resolver (lookup and rewrite)
- Uses: URL resolver discovery service, E164, SIP, ...

```
*.freenum       IN      NAPTR   (100 10 "u" "E2U+sip"
        "!^\\+*([^\\*]*)!sip:\\1@sip.magpi.org!" .)
```

Wildcards

- RRs with owner names starting with the label "*" (asterisk)
- When the wildcard is *matched*, the DNS server returns a response with:
  - query name returned as owner name
  - rest of RR content taken from the wildcard record

```
mail.example.com.     300  IN  A    10.1.1.1
www.example.com.      300  IN  A    10.1.1.2
*.example.com.        300  IN  A    10.1.1.7

Here, query for blah.example.com returns:
blah.example.com.     300  IN  A    10.1.1.7
```


ANY query type

- A pseudo record type used in DNS queries only
- Used to match any record type for the queried domain name
- Server will return all records of all types for that domain name that it possesses (note: caches may return incomplete data; to obtain all data for the name, you need to issue ANY query to authoritative servers)
- For debugging and troubleshooting purposes only; *do not use in production code*

Master Zone file format

- RFC 1035, Section 5 for details
- Entries in the master zone file are DNS resource records in their textual "presentation format"

[DNS and DNSSEC, USENIX LISA 12]

Zone file example

```
Zone: example.com

@           3600 IN SOA master.example.com. hostmaster.example.com. (
                                1001514808 ; serial
                                10800      ; refresh (3 hours)
                                3600       ; retry (1 hour)
                                604800     ; expire (1 week)
                                3600       ; minimum (1 hour)
                                )
                86400   IN      NS      ns1.example.com.
                86400   IN      NS      ns2.example.com.
                86400   IN      MX      10 mail1.example.com.
                86400   IN      MX      20 mail2.example.com.
ns1             86400   IN      A       10.1.1.1
ns2             86400   IN      A       10.1.1.2
www               900   IN      A       10.1.2.2
mail1            3600   IN      A       10.3.3.3
mail2            3600   IN      A       10.3.3.4
```

[TCOM 504, Spring 2012]

Master Zone file format

```
@           Denotes current origin; defaulting to zone name
            Appended to any domain name not ending in a period.
()          Parens used to group data that crosses a line boundary
;           Starts a comment
$ORIGIN     Resets the origin for subsequent relative names

RRs beginning with whitespace implicitly inherit last owner name.
TTL and Class fields are optional (default to last explicitly stated)

Extensions usable in BIND master files:
$TTL        Define TTL parameter for subsequent records
$GENERATE   Programmatically generate records, eg.
            eg. $GENERATE 10-90 client-$ A 10.4.4.$
                $GENERATE 0-62 blah-${0,3,x}  A 192.168.154.${+64,0,d}
```

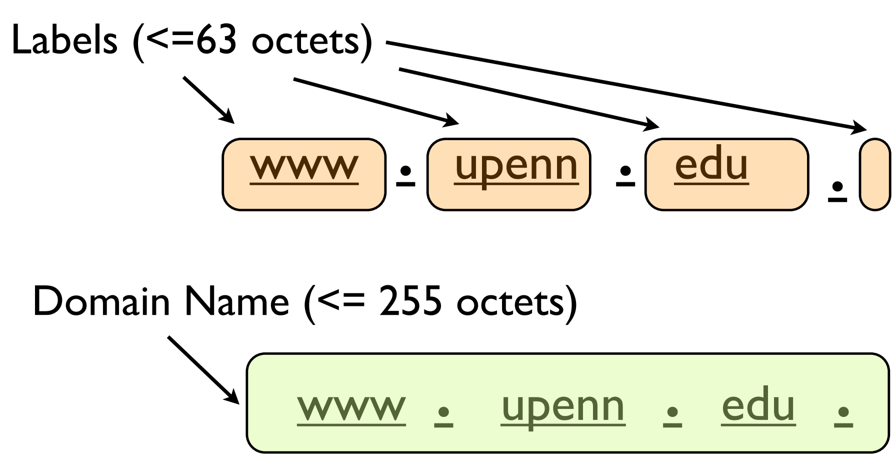

Size restrictions

- Label: 63 octets max
- Domain Name: 255 octets max
- TTL: positive signed 32-bit integer
- Entire DNS message: 512 bytes (UDP) - plain DNS
- Messages larger than 512 bytes requires:
  - Use of TCP (often truncated UDP response followed by TCP retry)
  - EDNS0 - a DNS extension mechanism allowing negotiation of larger UDP message buffers

Textual vs wire format

- The human readable "textual representation" or "presentation format" of a domain name is different from the the domain name as it actually appears in DNS protocol messages ("on the wire" or "wire format")
- Text format: labels written in ASCII delimited by periods
- Wire format: label bytes one after the other, always ending with the empty label. each label is composed of a label length followed by the label bytes

[DNS and DNSSEC, USENIX LISA 12]



Wire format of this domain name:

```
(hex) 037777770575706656e6e0365647500

4 Component labels:
www      0x 03 77 77 77
upenn    0x 05 75 70 65 6e 6e
edu      0x 03 65 64 75
.        0x 00
```

label length in 1st octet (lower 6-bits)

[DNS and DNSSEC, USENIX LISA 12]

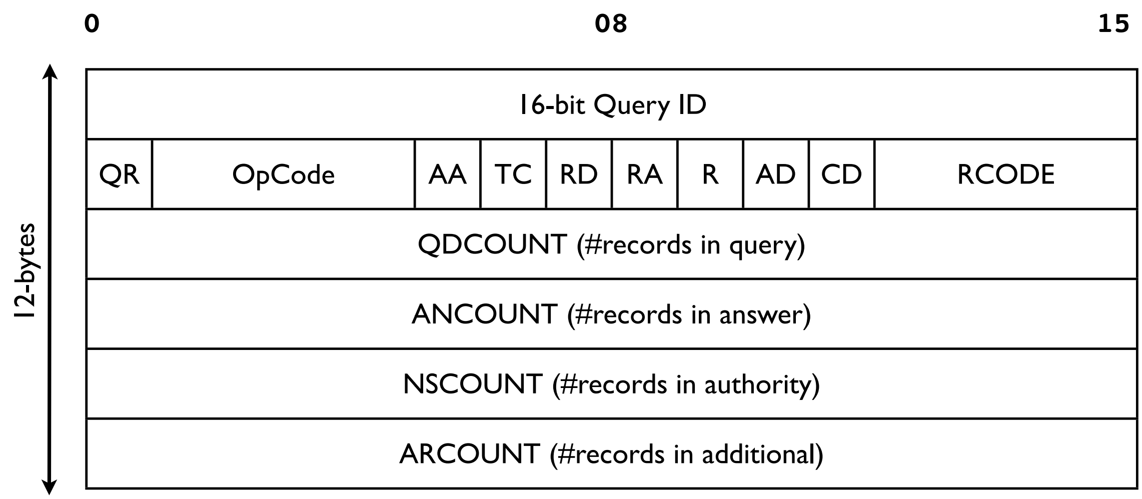
IDNs and punycode

- IDN: Internationalized Domain Name
- Uses an ASCII encoding called "Punycode" to represent non-english characters in domain names
- See RFC 3492: Punycode: A Bootstring encoding of Unicode for Internationalized Domain Names in Applications (IDNA)
  - **`xn--80ao21a.`** (A Kazakh TLD)

DNS Packet Format

DNS Header (12 bytes)
Question Section
Answer Section
Authority Section
Additional Section

DNS Header



[DNS and DNSSEC, USENIX LISA 12]

DNS Header

QR: set to 1 in DNS response messages

<u>OpCode</u>:

```
  0    Standard Query
  1    Inverse Query (deprecated)
  2    Status request (undefined and unused?)
  4    Notify
  5    Update
  3,6-15   Undefined
```

AA = Authoritative answer (ie. not from cache)
TC = message was truncated (exceeded 512 byte UDP limit)
RD = Recursion desired
RA = Recursion available
R = Reserved/Unused
AD = Authenticated Data (DNSSEC)
CD = Checking Disabled (DNSSEC)

[DNS and DNSSEC, USENIX LISA 12]

DNS Response Codes

Common Response codes:

```
  0    NOERROR   No Error
  1    FORMERR   Format Error
  2    SERVFAIL  Server Failure
  3    NXDOMAIN  Not existent domain name
  4    NOTIMPL   Function not implemented
  5    REFUSED   Query Refused, usually by policy
```

Used by DNS Dynamic Update (RFC 2136):

```
  6    YXDomain  Name Exists when it should not
  7    YXRRSet   RR Set Exists when it should not
  8    NXRRSet   RR Set that should exist does not
  9    NotAuth   Server not authoritative for zone
  10   NotZone   Name not contained in zone
  11-15 Unassigned
```


Extended RCodes

Extended RCODES do not appear in the DNS header (since there isn't enough space there). They instead appear in the OPT pseudo RR, which has a special format designed to accommodate them.

Extended RCodes used by EDNS0, TSIG, TKEY, etc:

```
  16   BADVERS   Bad OPT version
  16   BADSIG    TSIG Signature Failure
  17   BADKEY    Key not recognized
  18   BADTIME   Signature out of time window
  19   BADMODE   Bad TKEY Mode
  20   BADNAME   Duplicate Key Name
  21   BADALG    Algorithm not supported
  22   BADTRUNK  Bad Truncation
```

DNS RR common format

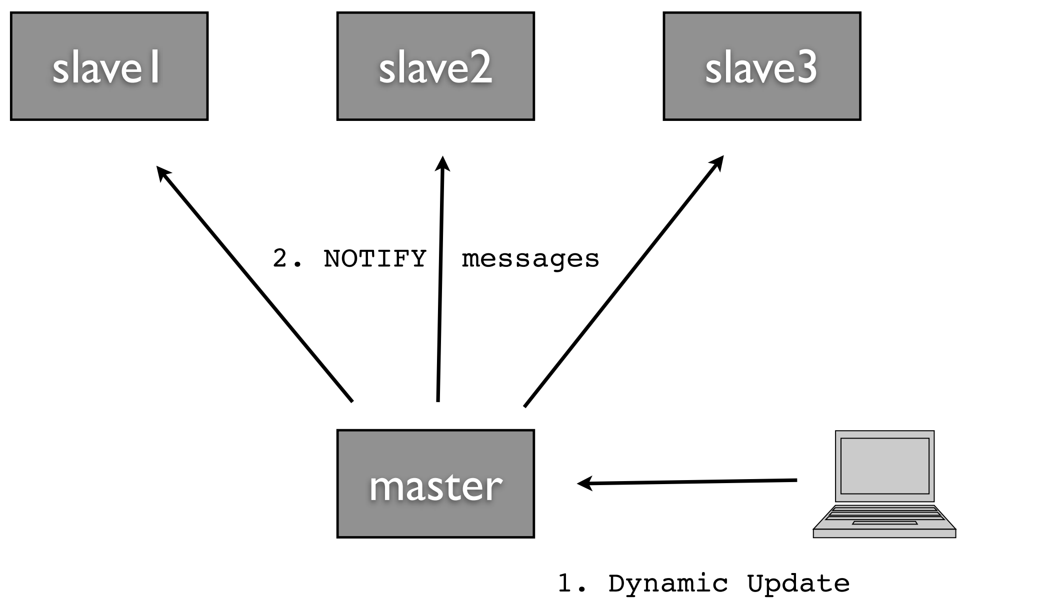
0 — 08 — 15
NAME (variable length, upto 255 octets)
TYPE (16 bits)
CLASS (16 bits)
TTL (32 bits)
RDLENGTH (16 bits)
RDATA (variable length)

[DNS and DNSSEC, USENIX LISA 12]

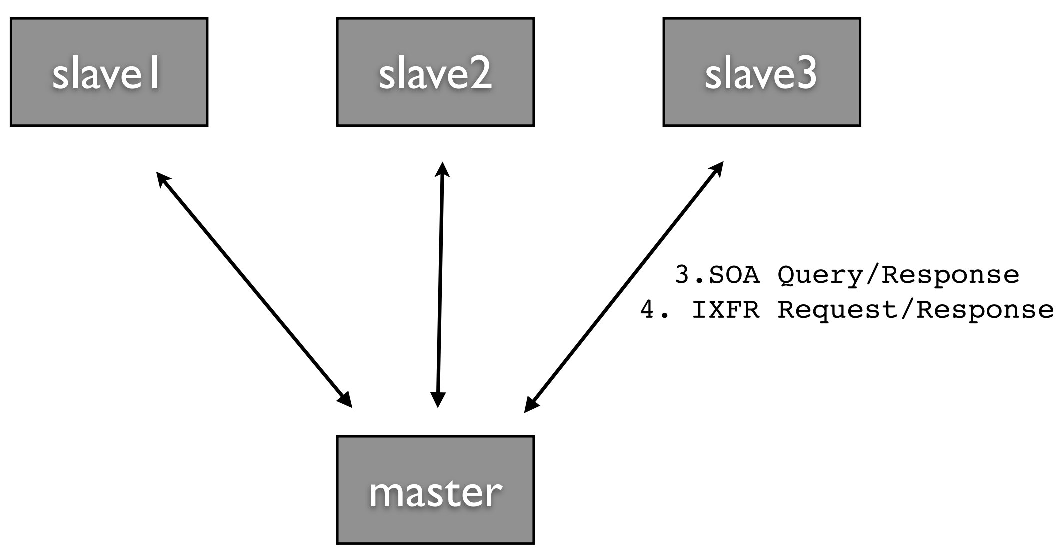
Zone Data Synchronization

- Authoritative server operators can synchronize zone data on their servers in a number of ways
- However, DNS provides a way to do this using the DNS protocol itself: **Zone Transfers**, and it's widely used
- Full zone transfers: **AXFR**: slaves send period transfer requests to masters (SOA refresh interval)
- Incremental zone transfers: **IXFR**, usually in combination with the NOTIFY mechanism (see RFC 1995 and 1996)
    - Commonly used in conjunction with Dynamic Update
- A good idea to authenticate zone transfers with TSIG

[DNS and DNSSEC, USENIX LISA 12]



[DNS and DNSSEC, USENIX LISA 12]



[DNS and DNSSEC, USENIX LISA 12]

Zone Delegation

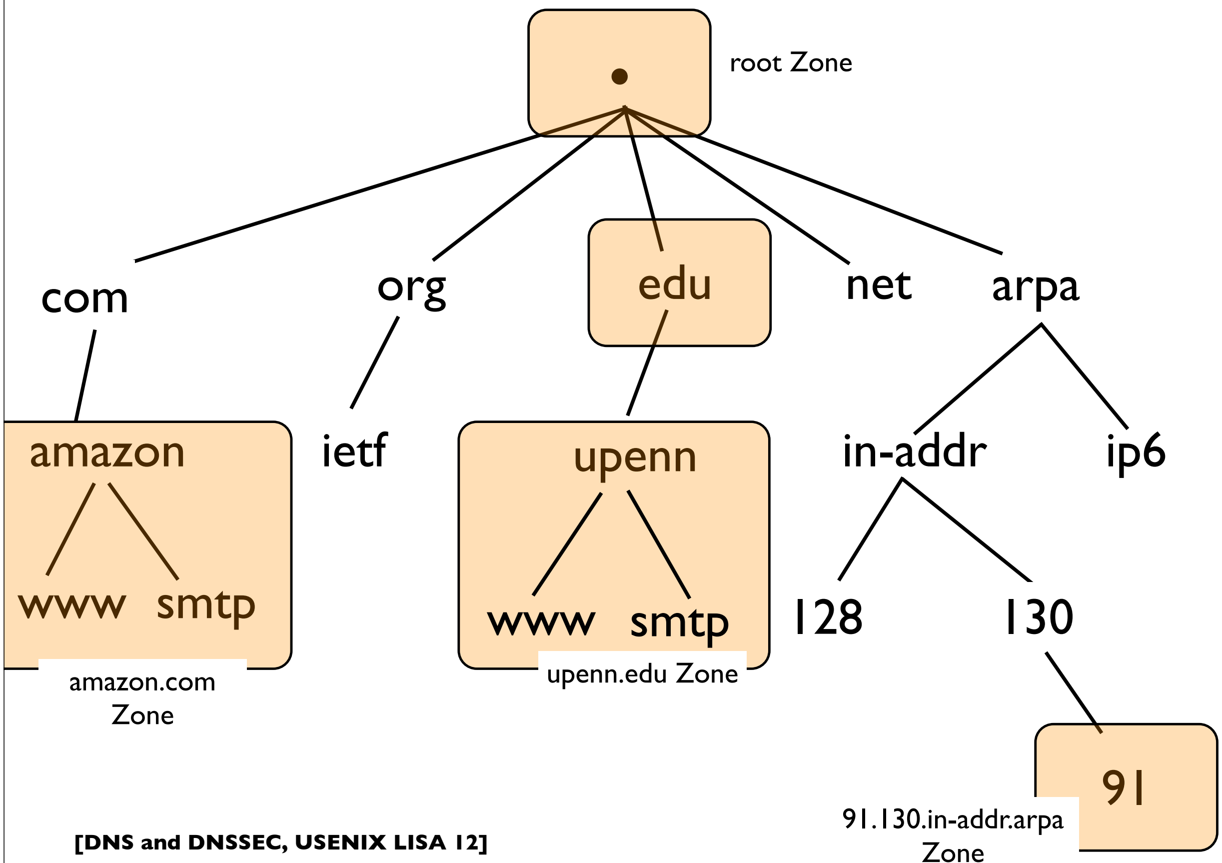
- Decentralized administration of DNS subtrees
- Delegations cause new zones to be created, that are (typically) served by different servers, run by different people
- Boundaries between zones (sometimes called zone cuts)
- An NS record set is needed in both the parent and child zones; these indicate the delegation, and the set of new nameservers involved in serving the child zone
- "Glue records" may be needed in the parent zone in order to find the addresses of the servers

Zone Delegation

<u>Example of delegation of google.com in .com zone:</u>

```
;; NS Record Set for google
google.com.     172800  IN NS  ns2.google.com.
google.com.     172800  IN NS  ns1.google.com.
google.com.     172800  IN NS  ns3.google.com.
google.com.     172800  IN NS  ns4.google.com.

;; Glue records for google nameservers
ns2.google.com.    172800 IN  A   216.239.34.10
ns1.google.com.    172800 IN  A   216.239.32.10
ns3.google.com.    172800 IN  A   216.239.36.10
ns4.google.com.    172800 IN  A   216.239.38.10
```

The glue records in the .COM zone are needed because the google DNS servers are inside the child google.com zone, otherwise they couldn't be found.



Configuring BIND

Simple zone file

```
Zone: example.com
$TTL 6h
@ IN SOA master.example.com. hostmaster.example.com.(
                     1001       ; Serial
                     10800      ; Refresh (3h)
                     3600       ; Retry (1h)
                     604800     ; Expire (1w)
                     3600 )     ; Min/ncache (1h)
;
             IN NS  ns1.example.com.
             IN NS  ns2.example.com.
             IN MX  10 mail.example.com.
;
ns1          IN A   192.168.1.1
ns2          IN A   192.168.2.2
www          IN A   192.168.4.4
mail         IN A   192.168.5.1
smtp         IN CNAME mail.example.com.
```


Recursive Resolver

```
# named.conf Recursive resolver example

acl trusted {
        192.0.2.0/24;            # my clients IPv4 address block
        2001:db8:f470::/48;      # my clients IPv6 address block
}

options {
        max-cache-size 1024M;
        listen-on-v6 { any; };
        allow-query-cache {
                trusted;
        };
        allow-recursion {
                trusted;
        };
};

zone "." {
        type hint;
        file "named.root";
};
```

who's allowed to use the recursive resolver. (note: some people run open servers)

root nameserver addresses. latest version at www.internic.net/domain/named.root

Authoritative Server

The master (primary master) authoritative server should define an access control list to limit the servers (usually only its slave servers) which can perform zone transfers of the DNS database. Note however, that this is a policy decision. Some folks allow anyone to transfer the contents of their zone.

```
# List of authorized secondary/slave servers
acl transferlist {
        192.0.2.2/32;
        192.0.2.3/32;
        2001:db8:f470:1234:2/128;
        2001:db8:f470:1234:3/128;
}

options {
        [...]
        allow-transfer {
                transferlist;
        };
       [...]
};
```

[DNS and DNSSEC, USENIX LISA 12]

Authoritative Server

Authoritative Servers, need **zone definitions** for the zones they are serving. They should also disable recursion if not also providing recursive resolver service to endusers.

```
options {
        [ ... various options ...];
        recursion no;                    <----- if authoritative only
};

zone "example.com" {
        type master;                     <----- on master server
        file "zone.example.com";
};


zone "example.com" {
        type slave;                      <----- on slave server
        file "zone.example.com";
        masters { 10.2.2.2; };
};
```

[DNS and DNSSEC, USENIX LISA 12]

Reverse zones

```
# Reverse zone for 10.74.213.0/24
zone "213.74.10.in-addr.arpa" {
        type master;
        file "zone.213.74.10.in-addr.arpa";
};
```

(Delegation on non-octet boundaries is a bit trickier. Need zones per address or the trick described in RFC 2317)

```
# Reverse zone for 2001:db8:c472::/48
zone "2.7.4.c.8.b.d.0.1.0.0.2.ip6.arpa" {
        type master;
        file "zone.2.7.4.c.8.b.d.0.1.0.0.2.ip6.arpa";
};
```


zone xfr with TSIG

Authenticating Zone Transfers with TSIG:

On primary master server:

Generate TSIG key with (example):

```
   $ dnssec-keygen -a HMAC-MD5 -b 128 -n HOST slave1.example.com.
```

File: zonetransfer.key:

```
key "slave1.example.com." {
        algorithm "hmac-md5";
        secret "xjlsjdlfdfhfhdfldfljdflsjdljsdlfjdlkf=";
};
```

secret key taken from K* files produced by dnssec-keygen

File: named.conf:

```
include "/usr/local/bind/zonetransfer.key"

options {
        [...]
        allow-transfer { key slave1.example.com.; };
        [...]
};
```

can also be used within individual zone stanzas

zone xfr with TSIG

Authenticating Zone Transfers with TSIG (continued):

On secondary (slave) server (use same key as configured on master):

```
File: named.conf:
include "/usr/local/bind/zonetransfer.key"

zone "example.com" {
        type slave;
        masters { 10.12.7.26 key slave1.example.com.;  };
        [...]
};
```

It is also possible to sign and authenticate all transactions with a master server (not just AXFR/IXFR) with a "server" statement:

```
server 10.12.7.26 {
        keys { slave1.example.com.; };
};
```


rndc

rndc: Name Server Control Utility

```
  reload
  reload zone [class [view]]
  refresh zone [class [view]]
  retransfer zone [class [view]]
  freeze
  freeze zone [class [view]]
  thaw
  thaw zone [class [view]]
  sync [-clean]
  sync [-clean] zone [class [view]]
  notify zone [class [view]]
  reconfig
  stats
  dumpdb [-all|-cache|-zones] [view ...]
  stop
  halt
  flush
  flush [view]
  flushname name [view]
  flushtree name [view]
  status
```

More examples

[Placeholder: Show fuller examples online]

Additional details

- The BIND ARM (Administrator's Reference Manual)
- http://www.isc.org/software/bind/documentation
- For latest BIND version (9.9):
  - http://ftp.isc.org/isc/bind9/cur/9.9/doc/arm/Bv9ARM.html
- Essential reading for the BIND DNS operator

Live DNS queries with dig

In this section, we'll look at some live DNS queries with the "**dig**" tool, widely available on most UNIX/Linux platforms.

```
Common invocations:
dig <qname>
dig <qname> <qtype>
dig @server <qname> <qtype>
dig -x <ipaddress>
dig +trace <qname> <qtype>
```

DNSSEC Tutorial

[DNS and DNSSEC, USENIX LISA 12]

DNSSEC at a glance

- "DNS Security Extensions"
- A system to verify the authenticity of DNS "data" using public key signatures
  - Specs: RFC 4033, 4034, 4035, 5155 (and more)
- Helps detect DNS spoofing, misdirection, cache poisoning ..
- Recall the "Kaminsky attack"
- Additional benefits:
  - Ability to store and use cryptographic keying material in the DNS, eg. SSHFP, IPSECKEY, CERT, DKIM, TLSA, etc ..

[DNS and DNSSEC, USENIX LISA 12]

DNSSEC at a glance

- Each zone has a public and private key pair
- The zone owner uses the private key to sign the zone data, producing digital signatures for each resource record set
- Public key is used by others (DNS resolvers) to validate the signatures (proof of authenticity)
- Public key is published in the zone itself so that resolvers can find it
- Zone public keys are organized in a chain of trust following the normal DNS delegation path
- DNS resolvers authenticate DNS signatures from root to leaf zone containing name. Failed validations result in SERVFAIL responses

[DNS and DNSSEC, USENIX LISA 12]

DNSSEC Records

DNSKEY	Contains zone public key
RRSIG	Contains DNSSEC signature
NSEC	Points to next name in zone (used for authenticated denial of existence)
DS	Delegation Signer (certifies public key for subordinate zone)
NSEC3	Enhanced version of NSEC (provides zone enumeration protection and opt-out)
NSEC3PARAM	NSEC3 parameters

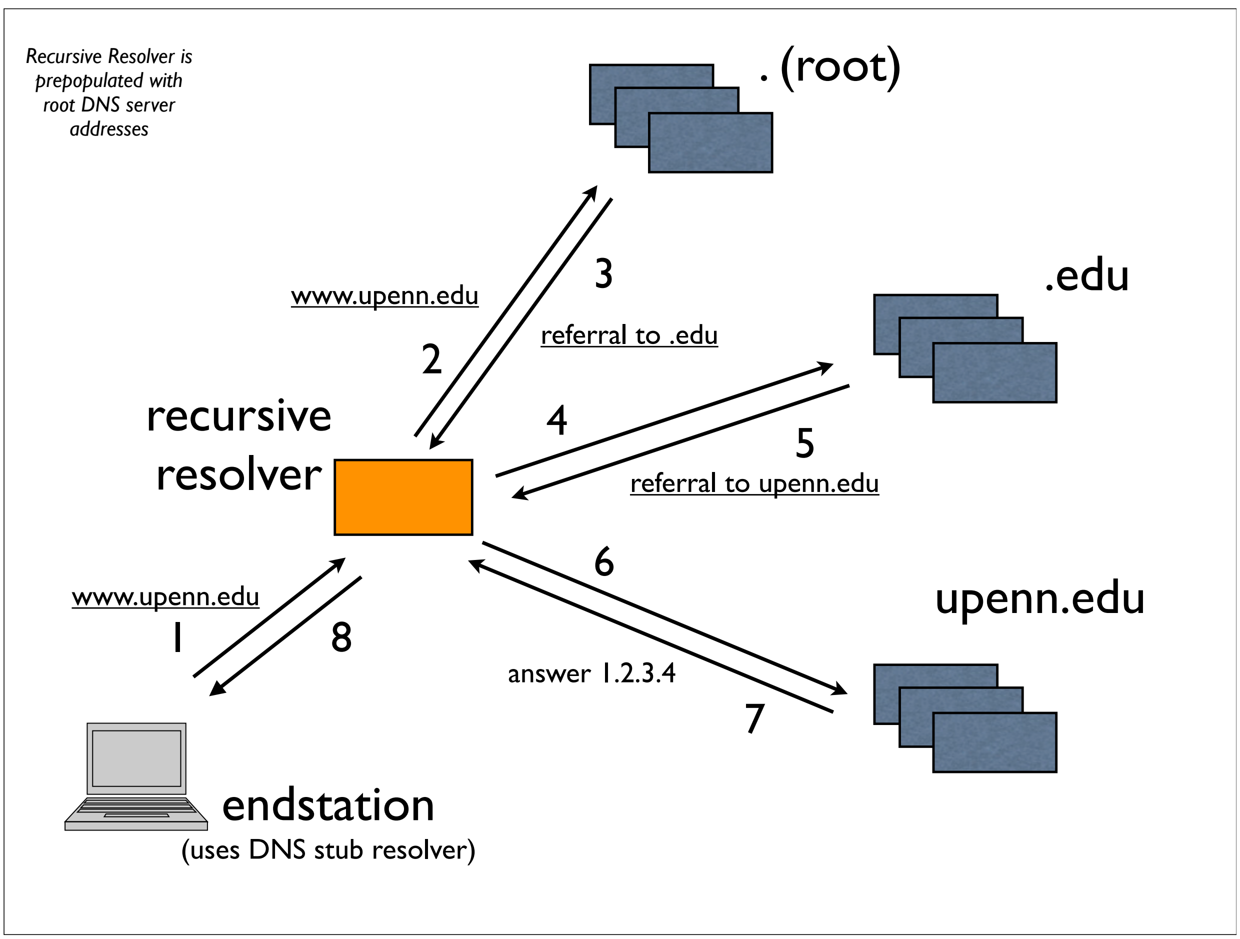
[DNS and DNSSEC, USENIX LISA 12]

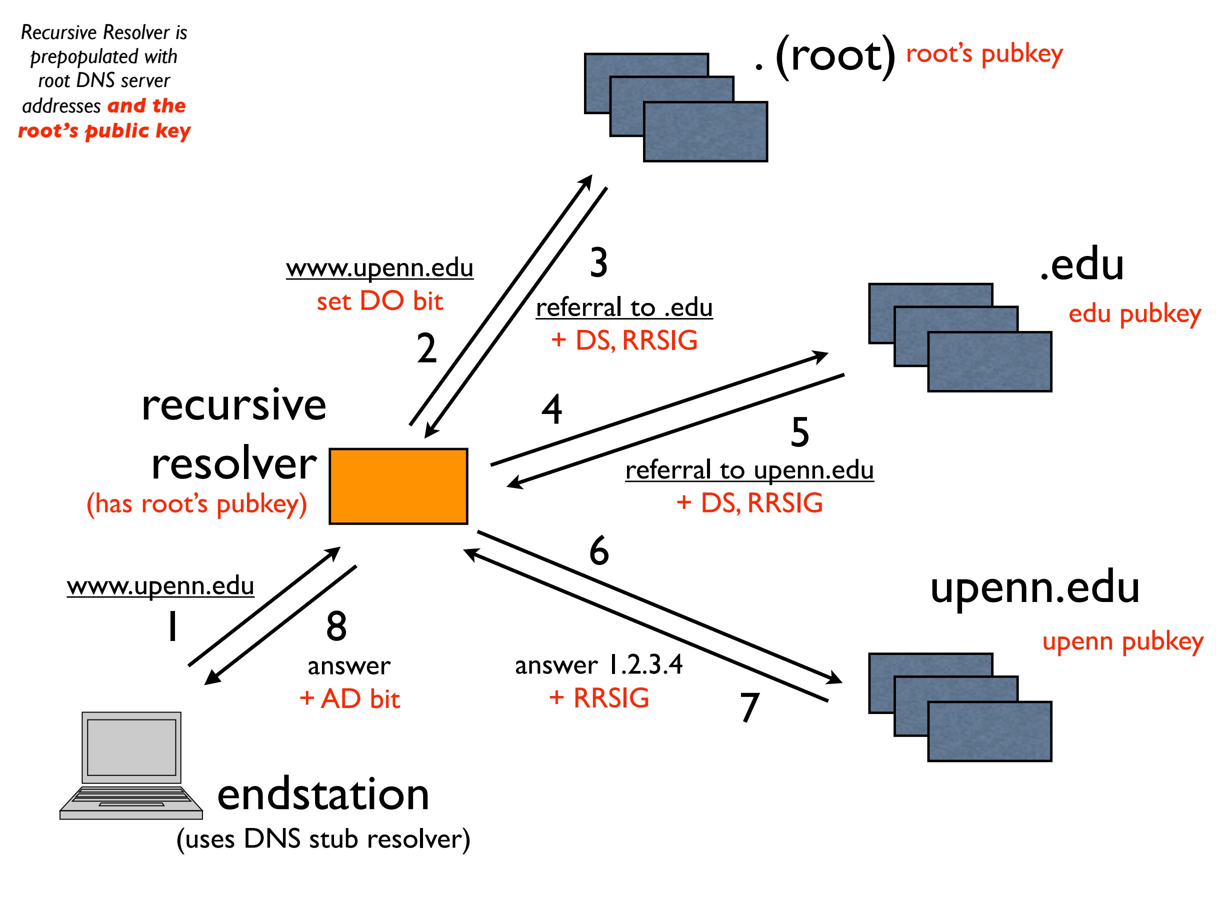
Signed zone additions

- One or more DNSKEY at the zone apex
- One or more NSEC for every DNS name
- One or more RRSIG for every RR set
- One or more DS records for every secure delegation

- Exceptions: non-authoritative data like delegation NS records and glue have no signatures (RRSIG)

[DNS and DNSSEC, USENIX LISA 12]





Multiple DNSKEYs

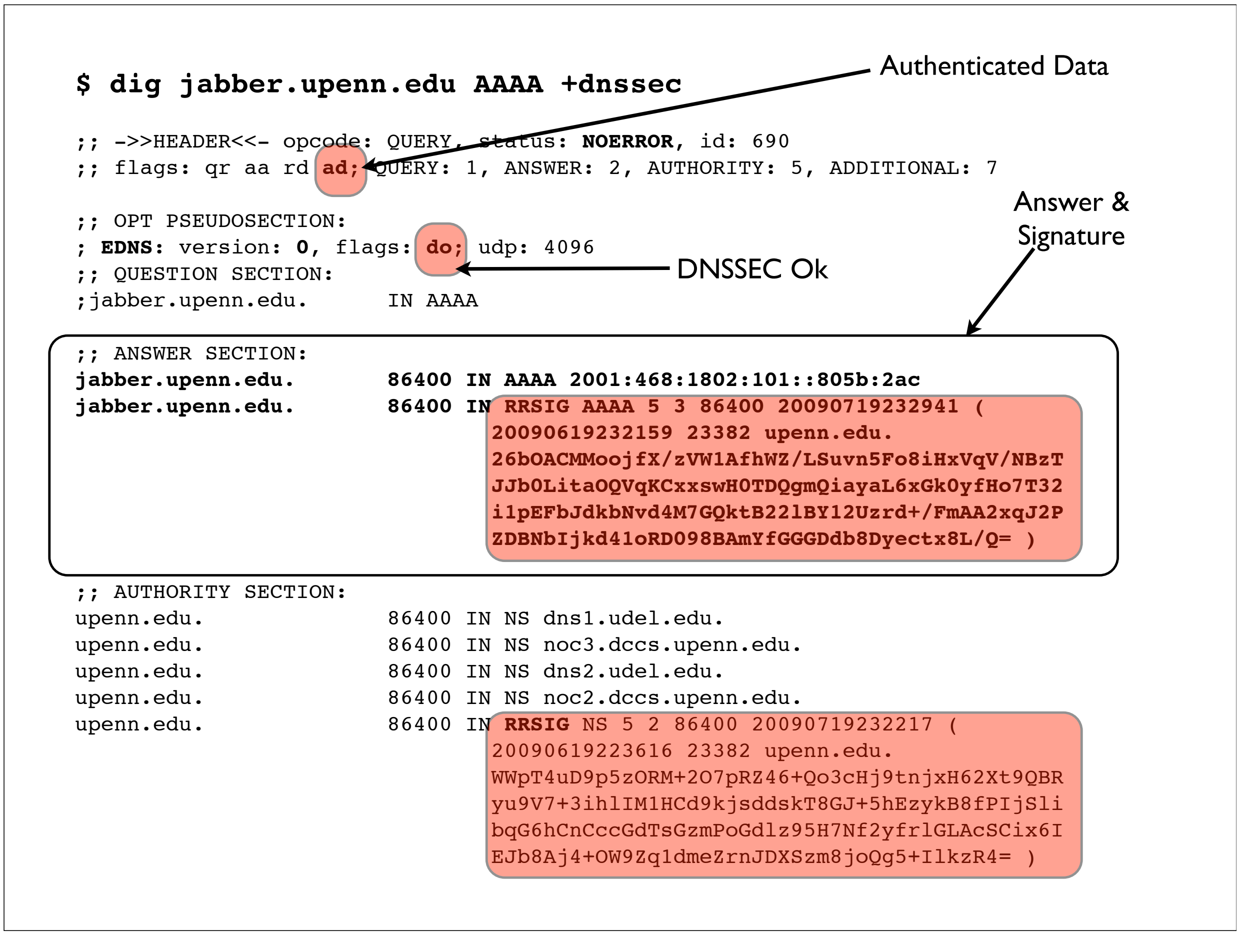
- Typically, a 2-level hierarchy of DNSKEYs is employed
- KSK: Key Signing Key
  - Signs other keys (can be larger, ie. stronger, and kept offline; used as the trust anchor and certified by the parent zone in the DS)
- ZSK: Zone Signing Key
  - Signs all data in the zone (can be lower strength and impose less computational overhead; can be changed without co-ordination with parent zone)

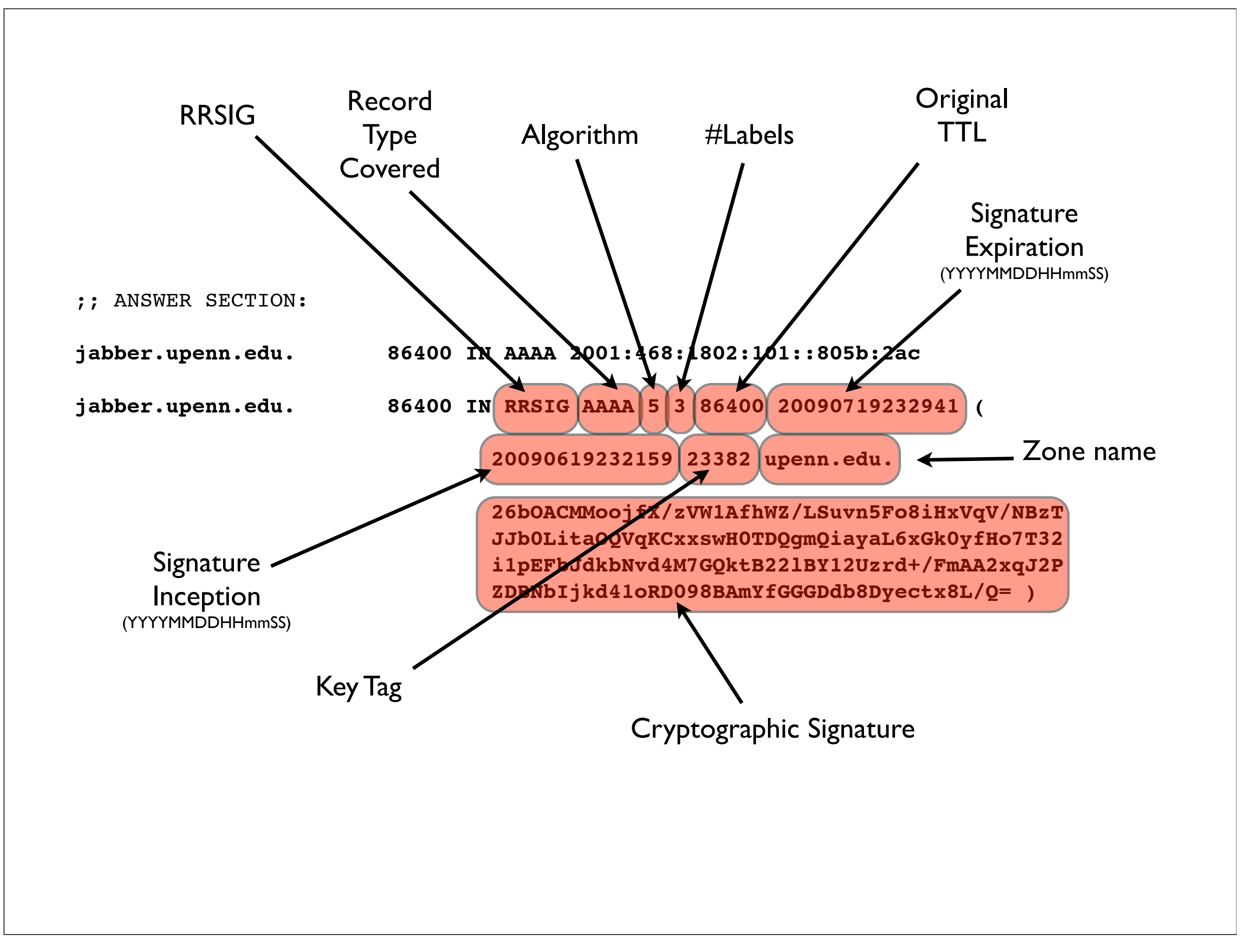
[DNS and DNSSEC, USENIX LISA 12]

Protection of signing keys

- Keep offline? Problems with dynamic signing
- Keep only KSK offline? But need to bring them online for key rollovers (even only ZSK rollovers)
- If keeping online, lock down housing server rigorously, as you might do a critical authentication server, like a KDC
- Physically secured machine room & racks
- Tamper resistant HSM (Hardware Security Module)


```
$ dig jabber.upenn.edu AAAA

;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 337

;; QUESTION SECTION:
;jabber.upenn.edu.              IN      AAAA

;; ANSWER SECTION:
jabber.upenn.edu.       86400   IN      AAAA  2001:468:1802:101::805b:2ac

;; AUTHORITY SECTION:
upenn.edu.              86400   IN      NS      dns2.udel.edu.
upenn.edu.              86400   IN      NS      noc2.dccs.upenn.edu.
upenn.edu.              86400   IN      NS      noc3.dccs.upenn.edu.
upenn.edu.              86400   IN      NS      dns1.udel.edu.

;; ADDITIONAL SECTION:
noc2.dccs.upenn.edu.    86400   IN      A       128.91.254.1
noc2.dccs.upenn.edu.    86400   IN      AAAA    2001:468:1802:102::805b:fe01
noc3.dccs.upenn.edu.    86400   IN      A       128.91.251.158
dns1.udel.edu.          86400   IN      A       128.175.13.16
dns2.udel.edu.          86400   IN      A       128.175.13.17
```


$ dig jabber.upenn.edu AAAA +dnssec
Authenticated Data
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 690
;; flags: qr aa rd ad; QUERY: 1, ANSWER: 2, AUTHORITY: 5, ADDITIONAL: 7
;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags: do; udp: 4096
DNSSEC Ok
;; QUESTION SECTION:
;jabber.upenn.edu. IN AAAA
Answer & Signature
;; ANSWER SECTION:
jabber.upenn.edu. 86400 IN AAAA 2001:468:1802:101::805b:2ac
jabber.upenn.edu. 86400 IN RRSIG AAAA 5 3 86400 20090719232941 (
20090619232159 23382 upenn.edu.
26bOACMMoojfX/zVW1AfhWZ/LSuvn5Fo8iHxVqV/NBzT
JJbOLitaOQVqKCxxswHOTDQgmQiayaL6xGk0yfHo7T32
i1pEFbJdkbNvd4M7GQktB22lBY12Uzrd+/FmAA2xqJ2P
ZDBNbIjkd41oRD098BAmYfGGGDdb8Dyectx8L/Q=)
;; AUTHORITY SECTION:
upenn.edu. 86400 IN NS dns1.udel.edu.
upenn.edu. 86400 IN NS noc3.dccs.upenn.edu.
upenn.edu. 86400 IN NS dns2.udel.edu.
upenn.edu. 86400 IN NS noc2.dccs.upenn.edu.
upenn.edu. 86400 IN RRSIG NS 5 2 86400 20090719232217 (
20090619223616 23382 upenn.edu.
WWpT4uD9p5zORM+2O7pRZ46+Qo3cHj9tnjxH62Xt9QBR
yu9V7+3ihlIM1HCd9kjsddskT8GJ+5hEzykB8fPIjSli
bqG6hCnCccGdTsGzmPoGdlz95H7Nf2yfrlGLAcSCix6I
EJb8Aj4+OW9Zq1dmeZrnJDXSzm8joQg5+IlkzR4=)


RRSIG
Record Type Covered
Algorithm
#Labels
Original TTL
Signature Expiration
(YYYYMMDDHHmmSS)
;; ANSWER SECTION:
jabber.upenn.edu. 86400 IN AAAA 2001:468:1802:101::805b:2ac
jabber.upenn.edu. 86400 IN RRSIG AAAA 5 3 86400 20090719232941 (
20090619232159 23382 upenn.edu.
Zone name
26bOACMMoojfX/zVW1AfhWZ/LSuvn5Fo8iHxVqV/NBzT
JJbOLitaOQVqKCxxswHOTDQgmQiayaL6xGk0yfHo7T32
i1pEFbJdkbNvd4M7GQktB22lBY12Uzrd+/FmAA2xqJ2P
ZDBNbIjkd41oRD098BAmYfGGGDdb8Dyectx8L/Q=)
Signature Inception
(YYYYMMDDHHmmSS)
Key Tag
Cryptographic Signature

flags proto algorithm

```
$ dig upenn.edu DNSKEY

;; ANSWER SECTION:
upenn.edu.              7200 IN DNSKEY 256 3 5 (
                        AwEAAcDt107stSjvoBA/YVPr+2gvB3v33tXr7ROZ/Jqm
                        WtNLraxQPzgXM1AhwjtdEqwCAnk01V7+Fw7K94sh6jpI
                        5bFofS7MGtd0VvNyq52bgRnusgbm1ME2Lx9+o3fy9ppv
                        7C6bahGrV3aiq9wNVPj/ccJn5AnZCOsi3grVsj6izCYH
                        ) ; key id = 46752
upenn.edu.              7200 IN DNSKEY 256 3 5 (
                        AwEAAfAHsS33kJEImVk09yFJY5hXumAo+JVVJMJpJUaj
                        l/rh0fFkdikS2oatVvxHHHqKN9Kg3DoKQss/CzCZa4zn
                        KlqYGvSl7RefKR3QLyPBGQN2aOUWxshDgOWLmOtqNpmP
                        +6Drfn8LJVTOjuwmU80laQcdA/AoOGVPE3zP16G/F+qp
                        ) ; key id = 43248
upenn.edu.              7200 IN DNSKEY 257 3 5 (
                        AwEAAek95gyBF2nurdIE2Q63VVcMlazOlQEnz0N4Ce89
                        SB4Juw2eEBerLmEanuGJbrs0oGx3SKCMyhOYL9q1ZrmC
                        NCf6PnACwv88NtrYOjHAOmOlLAvKAQv8MTBbEwTWBBw5
                        K8jUwzcaGyDjo3U+Hai+ow8Tiev0By+hrcT4DegsbEB8
                        MEQIgEUO/Kw9wbJLEdpvVXtuV2l78G75FUwmrA8jzEka
                        M7bKg/HSTIMupbwfs4IHYgbG/PkqOZYL3uxm9gncVjbh
                        4YYd4OG6koVoWteWTS8JdYq4gr9b9AEjhwAzbe7bd7pX
                        +qD70CCbh0jSOVhPvhRpCHIYZAJIwEAWs711HHM=
                        ) ; key id = 29242
```

encoded public key

Negative answers

- "Authenticated Denial of Existence"
- NSEC or NSEC3 records (and their signatures)
- Chain together DNS records in a zone; can think of them and their signatures as spanning the gaps between names in the zone
- Canonical ordering of names in signed zones needed (RFC 4034, Section 6.1)
- Needed because of the pre-computed signature model of DNSSEC (computational concerns & signing key security)

[DNS and DNSSEC, USENIX LISA 12]

NSEC3 differences

- NSEC3 instead of NSEC records
- Owner name is a cryptographic hash of the name (flattened) rather than the actual name - provides zone enumeration defense
- Some names may not have an NSEC3 (the "opt-out" feature)
- Additional apex record: NSEC3PARAM
- Increased CPU usage implications
- See RFC 5155 (Hashed Authenticated Denial of Existence) for details

[DNS and DNSSEC, USENIX LISA 12]

NSEC record

- "Next Secure" record
- Describes interval between consecutive names in a zone
- Type-bitmap defines RRtypes available at owner
- Side Effect: allows enumeration of zone contents

```
a.example.com. 300 IN NSEC  d.example.com. A MX RRSIG NSEC
```

Owner Name — SOA min TTL — Next Owner Name — Type Bitmap (List of Types defined at Owner Name)

[DNS and DNSSEC, USENIX LISA 12]

An authenticated negative answer (nxdomain)

*.upenn.edu would have been between upenn.edu and _kerberos.upenn.edu

```
$ dig +dnssec +multi bozo.upenn.edu A

;; ->>HEADER<<- opcode: QUERY, status: NXDOMAIN, id: 7708

;; ;; AUTHORITY SECTION:

[SOA and RRSIG(SOA) records omitted for brevity]

upenn.edu.          3600 IN   NSEC _kerberos.upenn.edu. NS SOA MX RRSIG NSEC DNSKEY TYPE65534
upenn.edu.          3600 IN   RRSIG NSEC 5 2 3600 (
                    20120508051318 20120408042226 50475 upenn.edu.
                    ZzTYjeHECy5xLo+wrXq1VwmtNI3Wz7cpNLBdg+3xM9ph
                    H9jOndAViCKwsDa4uLBYBcKss9qbbYjVtMp5w0lmVpwm
                    cwxYheAyEN+w2VPBhLZ9qjfib8Q6Lfi3r3lC8EDJciL0
                    1LSQwP2gyFx7V6VG08z11W6fuB6A/6/3/55xwW0= )
cagrid.bmif.upenn.edu.  3600 IN   NSEC BRYNMAWR-GW.upenn.edu. CNAME RRSIG NSEC
cagrid.bmif.upenn.edu.  3600 IN   RRSIG NSEC 5 4 3600 (
                    20120507190845 20120407181400 50475 upenn.edu.
                    yn4Au0Q4EViYu0LonWlWviTUn6kLYfyMMERajl2Jdaob
                    CYLfwnWMrXYPh6IZu03dYSkIRg7WEoyEGckk5J5Gudok
                    ikdFEEuuBjV4cdUCMp67lvUjCGVclFWnKhb5ni/FmieH
                    q7yFeztBt/IsKxtbcFSX0Isjt5mtNqt5is+UNpY= )
```

bozo.upenn.edu would have been between cagrid.bmif.upenn.edu & brynmawr-gw.upenn.edu

An authenticated negative answer (nodata)

NOERROR (nodata) responses can be authenticated with one signed NSEC record, which just reports all available RRTYPEs at that name

```
$ dig +dnssec upenn.edu A

;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 44529

;; AUTHORITY SECTION:

[SOA and RRSIG(SOA) records omitted for brevity]

upenn.edu.          3600 IN   NSEC _kerberos.upenn.edu. NS SOA MX RRSIG NSEC DNSKEY TYPE65534
upenn.edu.          3600 IN   RRSIG NSEC 5 2 3600 (
                    20120508051318 20120408042226 50475 upenn.edu.
                    ZzTYjeHECy5xLo+wrXq1VwmtNI3Wz7cpNLBdg+3xM9ph
                    H9jOndAViCKwsDa4uLBYBcKss9qbbYjVtMp5w0lmVpwm
                    cwxYheAyEN+w2VPBhLZ9qjfib8Q6Lfi3r3lC8EDJciL0
                    1LSQwP2gyFx7V6VG08z11W6fuB6A/6/3/55xwW0= )
```

NSEC3 record

- New version of NSEC that provides defense against zone enumeration (see RFC 5155 for details)
- Hashed owner names (base 32 with extended hex alphabet)
- Optional "opt-out" feature
- rdata: nsec3 parameters (hash alg, flags, iterations), hashed next owner name, type bitmap

hashed owner name

SOA min TTL

```
N3O3HKFAKV0FDU4OMHFEHT0FROFG6RQL.example.com. 3600 IN
NSEC3 1 0 5 9EBA4228 Q9T0VRM5S6EEF2N72RPCC5ENOF4IGV3O A
MX RRSIG
```

nsec3 params
hashalg, flags, iterations, salt

next hashed owner

[DNS and DNSSEC, USENIX LISA 12]

NSEC3PARAM record

- NSEC3PARAM record at zone apex also holds the parameters
- Hash algorithm, Flags, #Iterations, Salt
- This is used by secondary nameservers for the zone

```
lsu.edu.     0   IN NSEC3PARAM 1 0 10 6F772A6B
```

Zone Name

alg#

flags

iters

Salt

[DNS and DNSSEC, USENIX LISA 12]

An authenticated negative answer (NSEC3)

```
(Example taken from RFC 5155 Appendix B. Consult for details)
Question: a.c.x.w.example.        IN A

;; AUTHORITY SECTION:
0p9mhaveqvm6t7vbl5lop2u3t2rp3tom.example. NSEC3 1 1 12 aabbccdd (
                        2t7b4g4vsa5smi47k61mv5bv1a22bojr MX DNSKEY NS
                        SOA NSEC3PARAM RRSIG )
0p9mhaveqvm6t7vbl5lop2u3t2rp3tom.example. RRSIG NSEC3 7 2 3600 (
                        20150420235959 20051021000000 40430 example.
                        OSgWSm26B+cS+dDL8b5QrWr/dEWhtCsKlwKL
                        IBHYH6blRxK9rC0bMJPwQ4mLIuw85H2EY762
                        BOCXJZMnpuwhpA== )

b4um86eghhds6nea196smvmlo4ors995.example. NSEC3 1 1 12 aabbccdd (
                        gjeqe526plbf1g8mklp59enfd789njgi MX RRSIG )
b4um86eghhds6nea196smvmlo4ors995.example. RRSIG NSEC3 7 2 3600 (
                        20150420235959 20051021000000 40430 example.
                        ZkPG3M32lmoHM6pa3D6gZFGB/rhL//Bs3Omh
                        5u4m/CUiwtblEVOaAKKZd7S959OeiX43aLX3
                        pOv0TSTyiTxIZg== )

35mthgpgcu1qg68fab165klnsnk3dpvl.example. NSEC3 1 1 12 aabbccdd (
                        b4um86eghhds6nea196smvmlo4ors995 NS DS RRSIG )
35mthgpgcu1qg68fab165klnsnk3dpvl.example. RRSIG NSEC3 7 2 3600 (
                        20150420235959 20051021000000 40430 example.
                        g6jPUUpduAJKRljUsN8gB4UagAX0NxY9shwQ
                        Aynzo8EUWH+z6hEIBlUTPGj15eZll6VhQqgZ
                        XtAIR3chwgW+SA== )
```

covers "next closer name" (points to the first NSEC3 record)

matches closest encloser (points to the second NSEC3 record)

covers wildcard at closest encloser (points to the third NSEC3 record)

An authenticated negative answer (NSEC3)

NOERROR (nodata) responses can be authenticated with one signed NSEC record, which just reports all available RRTYPEs at that name (for qtype != DS)

In the example below blah.huque.com exists (TXT) but not for the MX record type.

```
$ dig +dnssec blah.huque.com. MX

;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 65366

;; AUTHORITY SECTION:

[SOA and RRSIG(SOA) omitted for brevity]

Q9T0VRM5S6EEF2N72RPCC5ENOF4IGV3O.huque.com. 3284 IN RRSIG NSEC3 8 3 3600 (
                    20121114122449 20121015121429 14703 huque.com.
                    lSu/WBJb3rBsU8ObV4bChPIMWcK93ac1B4b0Pq14m+Zo
                    XOkgu+PAqWLbM8FFeWwnT74XOWMXe+jvNMLSQ/nWfEjE
                    s+l51Wsm4XJma0Pl+SoSHdIq1vJ9KfeEiWD8xLbpKH/N
                    3qwjnf4p4Fcma8LB6va4niZiJulMGNFzgRmtFDE= )

Q9T0VRM5S6EEF2N72RPCC5ENOF4IGV3O.huque.com. 3284 IN NSEC3 1 0 5 9EBA4228 (
                    1M2GGNB8TPSI4SPF73V8RJS95FLHBNCO  TXT RRSIG )
```

Hash of blah.huque.com. (points to the owner name Q9T0VRM5S6EEF2N72RPCC5ENOF4IGV3O)

Next hashed name (points to 1M2GGNB8TPSI4SPF73V8RJS95FLHBNCO)

Type bitmap (points to TXT RRSIG)

Secure Delegations

- Indicated by DS (Delegation Signer) record
- Appears in the delegating (ie. parent) zone
- Contains a hash of the public key of the child zone's
- Validating resolvers use the presence of the DS record *and* its corresponding signature (RRSIG) to securely authenticate the delegation

[DNS and DNSSEC, USENIX LISA 12]

DS contains hash (digest) of the public key of delegated domain. 2 DS records are shown here because 2 different hashing algorithms were used

hash algorithm

dnskey algorithm

keytag

```
magpi.net.      3587 IN     DS 15462 5 2 (
                            9EFD691150378921179A5408F04E6EA93CBA2488B221
                            96493142E47D1AD24C3A )
magpi.net.      3587 IN     DS 15462 5 1 (
                            C020FB9E09EE30568F250E2086D52E62F2B4FA17 )
magpi.net.      3587 IN     RRSIG DS 5 5 3600 20090812170009 (
                            20090713170009 64263 dlv.isc.org.
                            M+09bX9XP79yfDhWDUNuDEg9KOEHV2eV33/dEYnutVpD
                            iZYGqJ6BWLhWZYE8Y8megYozfa5UJv/AVcdIZ51JCPI4
                            k/jlRDj60kRaWRlfCBgqOR2WPL+F20vhg3wS57bIjmRW
                            To0r/HpXemnJVdXLbrzWD5WdpYGFy1UVX+15N4o= )
```

Signature of DS record set

hash algorithms
1 - SHA-1
2 - SHA256

DNSSEC Lookaside Validation (DLV)

- A mechanism to securely locate DNSSEC trust anchors "off path"
- Intended as an early deployment aid until top-down deployment of DNSSEC is completed
- DLV Registry operated by Internet Systems Consortium (https://www.isc.org/solutions/dlv)
- If you can't find a DS record for example.com, look for a DLV record for example.com.<dlv-domain>

```
magpi.net.dlv.isc.org.  IN DLV 15463 5 2
           (9EFD691150378921179A5408F04E6EA93CBA
            2488B22196493142E47D1AD24C3A )
```


Configuring DNSSEC in BIND

General advice

- Use the latest possible version of BIND (current is v9.9)
- Many more features that make DNSSEC configuration much much easier, and almost automated ...

Validating Resolver

In named.conf (this will use BIND's built-in keys for the root and the ISC DLV registry, and will automatically rollover keys as they are detected:

```
options {
        [...]
        dnssec-enable yes;
        dnssec-validation auto;
        dnssec-lookaside auto;
        [...]
};
```

Validating Resolver

Manually configured keys (if needed):

```
# manually configured static key
trusted-keys {
    . 257 3 8 “AwE...jlsdjfld=”;
};

# managed keys (with automated rollover)
managed-keys {
     “.” initial-key 257 3 8 “Awlsdjflkdjfl”;
};
```


Signing zones

Generating Keys:

```
  dnssec-keygen <zone>
  dnssec-keygen -f KSK <zone>
  dnssec-keygen -3 <zone>          # NSEC3 zone
```

Creates K<zone>+mmm+nnnn.key and K<zone>+mmm+nnnn.private files

Signing Zone:

```
  dnssec-signzone -o zone -S <zonefile>
```

-S: smart signing

Authoritative Server

```
options {
        [...]
        dnssec-enable yes;
        [...]
};
```


Dynamic Update + DNSSEC

```
The easiest way, in my opinion.

* Configure dynamic zones (ie. zones updated only
  with the Dynamic Update protocol, eg. with the
  nsupdate program)
* Make DNSSEC keys available to named
* When dynamic updates are made, named will
  automatically sign the records and generate or
  re-generate related DNSSEC metadata

* Latest BIND versions include special options to
  make this really easy.
```

Live example of signing a zone with DNSSEC
(Time permitting!)

Signing a zone

```
Steps for reference.


# Create zone for “example.com” and configure named
[...]

# Generate KSK and ZSK (in this example RSASHA256 2048/1024bit)
dnssec-keygen -a RSASHA256 -b 2048 -n ZONE -f KSK example.com
dnssec-keygen -a RSASHA256 -b 1024 -n ZONE example.com

# Sign zone (will generate “zonefile.signed”)
dnssec-signzone -o example.com -S zonefile

# Reconfigure named.conf to serve “zonefile.signed”
[...]
```

Signing a zone (dynamic)

```
# Generate KSK and ZSK as before, but don't use dnssec-signzone
[...]

# Setup named.conf with the "auto-dnssec" option for the zone
zone "example.com" {
     type master;
     update-policy local;                    # allow-update for expl key
     auto-dnssec allow;                      # also see "maintain"
     file "zones/example.com/zonefile";
     key-directory "zones/example.com";
};

# Tell named to sign the zone
  rndc sign example.com

# From now, use dynamic update (eg. via nsupdate) to update
# zone contents.
```


Signing a zone (dynamic)

```
# Example of using dynamic update to add an ldap.example.com
# A RR to the zone .. This will cause named to automatically
# compute and add RRSIGs and NSEC/NSEC3s as needed, and install
# then in the zone.

$ nsupdate -l
ttl 86400
zone example.com.
update add ldap.example.com. A 10.4.4.4
send
^D
$
```

Other methods

Newest versions of BIND have some other ways that might make it easier to deploy DNSSEC in some environments where it's not easy to modify the master server ...

* **Inline Signing** (BIND 9.9)

This feature greatly simplifies the deployment of DNSSEC by allowing completely automatic, fully transparent signing of zones. Using the new 'inline-signing' option in a master server allows named to switch on DNSSEC in a zone without modifying the original zone file in any way. Using it in a slave server allows a zone to be signed even if it's served from a master database that doesn't support DNSSEC.

Some example configurations may be found at
https://kb.isc.org/article/AA-00626/0/Inline-Signing-in-ISC-BIND-9.9.0-Examples.html

Key Rollover

Key Rollover

- Conventional wisdom is that DNSSEC keys should be changed ("rolled over") at regular intervals. However, not everyone agrees, including some noted security experts
- If you choose strong enough keys, there is no cryptographic reason to routinely roll them
- There are good operational reasons to change keys *after specific events*, eg. turnover of a staff member who had access to the private keys, or a system compromise of the server
- Some argue routine key rollover instills practice & confidence that you'll be able to do it properly when you really need to. However, do we do this for other applications (Kerberos, PKI/CAs, SSL)?

Key Rollover

- RFC 4641: DNSSEC Operational Practices
  - Covers general practices, procedures, recommendations
  - Update: http://tools.ietf.org/html/draft-ietf-dnsop-rfc4641bis-11
- Most commonly used:
  - KSK rollover: double signature policy
  - ZSK rollover: pre-publish policy

KSK: Double signature

- Generate new KSK; publish (public part) in zone
- Sign DNSKEY RRset with both keys
- Publish additional DS record in parent for new key
- Wait until DS is propagated and TTL of the old DS record
- Remove the old KSK and re-sign DNSKEY RRset with only new key

[DNS and DNSSEC, USENIX LISA 12]

ZSK: Pre-publish

- Generate new ZSK, and publish the DNSKEY in the zone, but do not yet sign zone data with it
- Wait zone propagation time + TTL of the DNSKEY RRset
- Use new ZSK for signing zone records instead of old ZSK, but leave the old ZSK published in the zone
- Wait zone propagation time + largest TTL of all records in the zone
- Remove old key & re-sign DNSKEY RRset

[DNS and DNSSEC, USENIX LISA 12]

Other DNSSEC caveats

[DNS and DNSSEC, USENIX LISA 12]

General DNSSEC Caveats

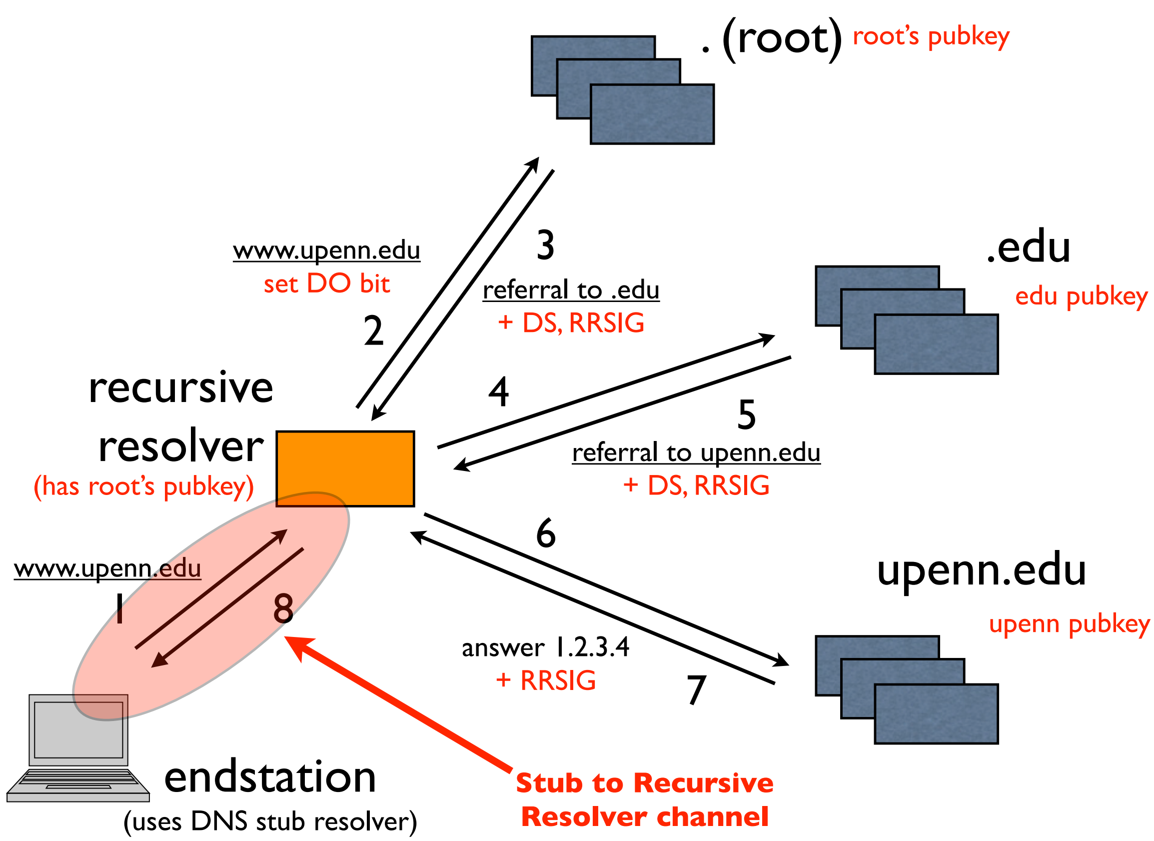
- Zone size increases significantly when signed
- Memory and CPU usage increase
- DNSSEC answers are larger
- Server side & query side impacts
- Interference by firewalls, proxies, and other middlebox, eg. botching EDNS0, large packets, DNSSEC meta data , not passing all UDP fragments, etc
- Fallback to TCP increases
- Many modern resolvers already ask for DNSSEC by default (ie. set the DNSSEC-OK bit in their queries)

[DNS and DNSSEC, USENIX LISA 12]

Securing the last hop

- How do we protect the stub resolver?
- Employ a channel security mechanism between stub and the upstream recursive resolver:
  - TSIG, SIG(0), IPSEC, etc
- Have the stub validate DNSSEC responses? Set CD bit and authenticate signatures directly?
- Give up, and run a full service DNS Resolver on clients?

[DNS and DNSSEC, USENIX LISA 12]



Channel Security

- For stub channel security, simple symmetric key TSIG won't work
- Can't distribute same TSIG key to many clients, because that allows any of them to forge answers to all others
- Need per client keys and thus a key management infrastructure
- GSS-TSIG has a chicken-egg problem, because DNS is often used to locate Kerberos servers
- SIG(0) may be better - distribute single public key to clients
- Microsoft supposedly has an implementation of IPsec (GSS authenticated) to protect client to recursive resolver path
- DNSCurve?

Application use of DNSSEC

Application use of DNSSEC

- One of the more exciting prospects for DNSSEC
- DNSSEC allows applications to securely obtain (authenticate) cryptographic keying material stored in the DNS
- A variety of existing and proposed record types have been designed to store crypto material:
  - SSHFP, IPSECKEY, CERT
  - DKIM _domainkey TXT record (p=... public key data)
  - TLSA (upcoming, see IETF DANE working group)

Application use of DNSSEC

- Securely obtaining other assertions from the DNS
  - DKIM/ADSP
  - Route Origination Authorizations (controversial - see RPKI, the standardized mechanism to do this, which will allow BGP path validation also)

SSHFP record

- SSH Host Key Fingerprint (RFC 4255)
- Allows you to validate SSH host keys using DNS (securely using DNSSEC)

algorithm number

fingerprint type (1= SHA-1)

```
grodd.magpi.net. 86400 IN SSHFP (1 1
      F60AE0994C0B02545D444F7996088E9EA7359CBA)
```

fingerprint

[DNS and DNSSEC, USENIX LISA 12]

IPSECKEY record

- RFC 4025: method for storing IPSEC keying material in DNS
- rdata format: precedence, gateway-type, algorithm, gateway address, public key (base64 encoded)

```
38.2.0.192.in-addr.arpa. 7200 IN  IPSECKEY ( 10 1 2
     192.0.2.38
     AQNRU3mG7TVTO2BkR47usntb102uFJtugbo6BSGvgqt4AQ== )
```

[DNS and DNSSEC, USENIX LISA 12]

Public CA model problems

- Applications need to trust a large number of global certificate authorities, and this trust appears to be unfounded
- No namespace constraints! **Any** of them can issue certificates for **any** entity on the Internet, whether you have a business relationship with them or not
- Least common denominator security: our collective security is equivalent to weakest one
- Furthermore, many of them issue subordinate CA certificates to their customers, again with no naming constraints
- Most are incapable of issuing certs with any but the most basic capabilities (eg. alternate name forms or other extensions)

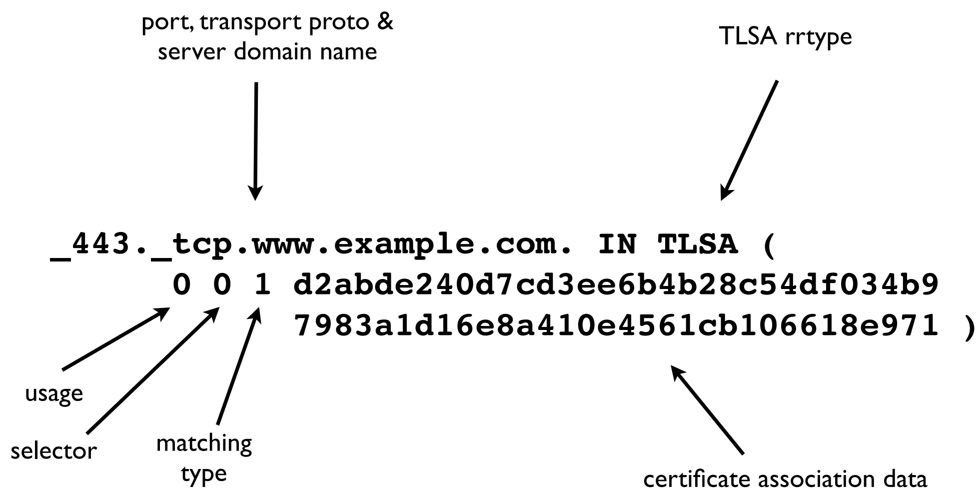
[DNS and DNSSEC, USENIX LISA 12]

DANE/TLSA record

- RFC 6698: The DNS-Based Authentication of Named Entities (DANE) Protocol for Transport Layer Security (TLS)
  - http://tools.ietf.org/html/rfc6698
- Use DNSSEC for better & more secure ways to authenticate SSL/TLS certificates:
  - by specifying authorized public CAs, allowable end entity certs, authorizing new non-public CAs, or even directly authenticating certs without involving CAs!
- New record type: **TLSA**

[DNS and DNSSEC, USENIX LISA 12]

TLSA record example



[DNS and DNSSEC, USENIX LISA 12]

TLSA rdata parameters

```
Usage field:
    0   CA Constraint
    1   Service Certificate Constraint
    2   Trust Anchor Assertion
    3   Domain Issued Certificate

Selector field:
    0   Match full certificate
    1   Match only SubjectPublicKeyInfo

Matching type field:
    0   Exact match on selected content
    1   SHA-256 hash of selected content
    2   SHA-512 hash of selected content

Certificate Association Data: raw cert data in hex
```

[DNS and DNSSEC, USENIX LISA 12]

TLSA record example

Usage type 1: Service certificate constraint; match an end-entity certificate

```
_443._tcp.www.example.com. IN TLSA (
      1 1 2 92003ba34942dc74152e2f2c408d29ec
            a5a520e7f2e06bb944f4dca346baf63c
            1b177615d466f6c4b71c216a50292bd5
            8c9ebdd2f74e38fe51ffd48c43326cbc )
```


TLSA record example

(my own website; full cert assoc, no CA required)

```
$ dig +dnssec +multi _443._tcp.www.huque.com. TLSA


;; ANSWER SECTION:
_443._tcp.www.huque.com. 874 IN TLSA 3 0 1 (
            8CB0FC6C527506A053F4F14C8464BEBBD6DEDE2738D1
            1468DD953D7D6A3021F1 )

_443._tcp.www.huque.com. 874 IN RRSIG TLSA 8 5 900 (
            20121117202722 20121018192722 14703 huque.com.
            OJ4b/O7J+Fh3KVDGG8nH9X5dRSXgl3j7/S/PbB1RczcY
            fYxdu5C9xZSALCz0MgVFW6Kcne74ou5R/Wd+CDKm7mYY
            Ga28MrtE1boNLuOTa6kOpFcNjW+UYnMFQuc6S8zhU1G7
            LHOn3TbM3rJSOwHOu6J4NgtiowZS2VlkwPez3D8= )
```

TLSA tools?

- TLSA record generation:
  - swede, hash-slinger, ...
- TLSA validators:
  - Browser enhancements in progress by some
  - Other software?

DNSSEC Deployment Status

Deployment status

- DNSSEC Root signed (July 2010)
- Many TLDs signed: 102 of 313 (32%) as of Oct 2012:
  - GTLD: edu gov com net org biz info arpa
  - ccTLD: many, including a number of IDNs
  - See http://stats.research.icann.org/dns/tld_report/
  - Also http://www.huque.com/app/dnsstat/category/tld/
- Reverse trees: in-addr.arpa ip6.arpa
- Note: not all TLD registrars support DNSSEC yet (ie. ability to install a DS record in the TLD)

Deployment status

- Note: not all TLD registrars support DNSSEC yet (ie. ability to install a DS record in the TLD)
- ICANN maintains a list at:
  - http://www.icann.org/en/news/in-focus/dnssec/deployment

Validator status

- Measuring the extent of deployment of DNSSEC validating resolvers is more difficult, but there have been some attempts:
  - http://validator-search.verisignlabs.com/
  - http://www.potaroo.net/ispcol/2012-10/counting-dnssec.html
- Heard at ICANN'45 (Oct 2012): US gov now requiring DNSSEC validation in all systems operated in that space

SecSpider

- DNSSEC zone monitoring project
- http://secspider.cs.ucla.edu/
- Over 37,000 signed zones as of mid April 2012
- Crawling and user submissions
- Distributed polling
- Also a DLV registry

DNSSEC Tools

Some useful tools

- Checking correct operation/deployment:
  - DNSviz: http://dnsviz.net/
  - http://dnssec-debugger.verisignlabs.com/
  - http://dnscheck.iis.se/
- DNSSEC Validation testing
  - http://dnssectest.sidn.nl/
  - http://test.dnssec-or-not.com/
- DNSSEC Trigger
  - http://nlnetlabs.nl/projects/dnssec-trigger/

Some useful tools

- 3rd party tools that some folks use to deploy/manage DNSSEC with BIND (mostly everything can be done in BIND itself these days):
  - OpenDNSSEC
  - zkt
  - http://www.dnssec-tools.org/
- Microsoft DNSSEC deployment guide
  - http://www.microsoft.com/en-us/download/details.aspx?id=15204

Thank you!

twitter
@shuque

Shumon Huque
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Reminder: Please fill out the evaluation forms for this course!

Internet Society's "ION" Conference is being held on Tuesday afternoon (Dec 11th).

Topics: DNSSEC, IPv6, Secure Routing
Registration: free

http://www.internetsociety.org/deploy360/ion/sandiego2012/