Domain Name System Security

T-110.4100 Tietokoneverkot
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Bengt Sahlin
<Bengt.Sahlin@tml.hut.fi>

Objectives

- Provide DNS basics, essential for understanding DNS security
- Understand threats against DNS
- Provide examples of vulnerabilities and attacks
- Understand mechanisms in DNSSEC
- Understand effects of using DNSSEC
- Understand what can be done to improve security of DNS

Humans and Addresses

- Numeric addresses are used in the Internet
  - example: 10.0.0.1 (IPv4), fe80::a0a1:46ff:fe06:61ee (IPv6)
- Humans are better at remembering names than numbers
- In the Internet, names have been used from the start on

History

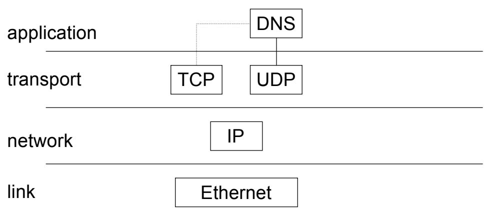
- In the beginning … there was the file **hosts**
  - mapping between "hostname" and address
- Internet grew, one file was not a scalable solution
- A more scalable and automated procedure was needed

The Solution...

- DNS (Domain Name System)
- Main tasks
  - mapping between names and IP addresses, and vice versa
  - controlling e-mail delivery
- But today DNS is used to store a lot of other data also
  - for example DNS SRV record
    - specifying the location of services

Basic Internet Infrastructure

- DNS is a fundamental component of the Internet infrastructure



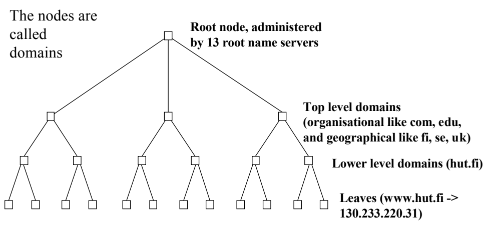
Basic Characteristics (1/2)

- DNS is a database
- The three basic characteristics of the database:
  - 1) global
    - All the names need to be unique
  - 2) distributed
    - no node has complete information
    - an organisation can administer its own DNS information

Basic Characteristics (2/2)

- 3) Hierarchical
  - the data is arranged in a tree structure with a single root node
  - the structure is similar to the Unix file system structure

DNS Structure



DNS Concepts (1/3)

- The servers are called name servers
  - name server “roles”
    - master (primary)
      - the name server where the data is administered
      - is the ultimate authority for the data (authoritative)
    - slave (secondary)
      - is authoritative for a zone
      - gets the data from the master through a zone transfer
    - cache
      - a name server can store data DNS data (that it is not authoritative for) for a while

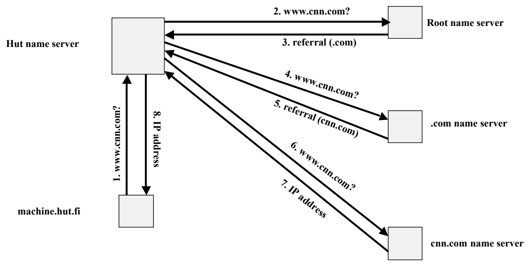
DNS Concepts (2/3)

- The client is called a resolver
  - can do name queries
  - Typically implemented with library functions that applications use
  - nslookup (looking at DNS data), dig (for serious debugging)
- Name resolution
  - the process of acquiring some data, possible by performing several name queries
- The name servers need to know (“are booted up with”) the names and addresses of the root name servers (file root.cache)

DNS Concepts (3/3)

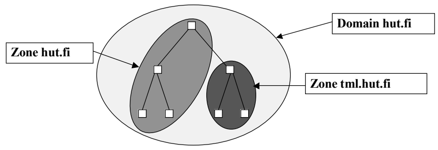
- Delegation
  - the authority for some sub-domain is given to another name server

Name resolution example



Zone vs. Domain

- Zone: a contiguous part of the DNS tree for which a name server has complete information



Resource Records

- The data in the DNS database is stored in entities called resource records
- The most common resource records:
  - A (name to address mapping)
  - PTR (address to name mapping
  - MX (Mail Exchanger record)
  - NS: name server record
  - CNAME: name alias
  - SOA: Start of authority

Master Zone File Example

```
verkot.example.  IN   SOA   ns.verkot.example.
   dnsadmin.verkot.example. (
                 6 28800 7200 604800 86400 )
                 IN   NS    ns.verkot.example.
                 IN   MX    10 mail.verkot.example
$ORIGIN verkot.example.
localhost        IN   A     127.0.0.1
ns               IN   A     10.10.10.1
mail             IN   A     10.10.10.2
www              IN   A     10.10.10.3
                 IN   TXT   "Our web server"
ftp              IN   CNAME mail
```

Serial, refresh, retry, expiry, minimum TTL

Error, dot missing

DNS Today

- DNS has served its purpose well
- Internet is evolving, and new requirements have been issued
  - Support for IPv6
  - DNS security extensions
    - Vulnerabilities in DNS used in many attacks (like DNS spoofing)
    - security needed
  - DNS dynamic update
  - International DNS
  - Other new requirements

DNS Threats (1/2)

- Threats to the protocol
  - Packet Interception
    - Eavesdropping, man-in-the-middle attacks, DNS spoofing
  - ID guessing and Query Prediction
    - Predict resolver behavior and send a bogus response
    - Could be a blind attack
  - Name-based attacks
    - For example cache poisoning (using packet interception attacks)

DNS Threats (2/2)

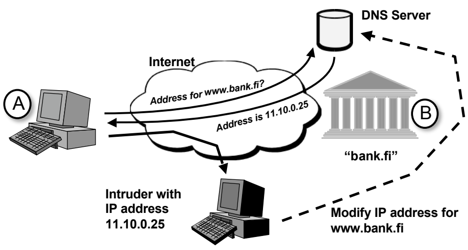
- DOS attacks
- Issues with authenticating non-existence of a DNS name
- Wildcard handling issues

- DNSSEC weaknesses
- DNS Software vulnerabilities

DNS Vulnerabilities

- Crackers often start planning attacks by collecting DNS information
  - many organizations try to make this harder by prohibiting zone transfers and by using split DNS
- Crackers try to use DNS vulnerabilities
  - Both for direct attacks against DNS or for mounting further attacks

Manipulating DNS



DNS Spoofing

- Three ways to manipulate DNS
  - answer to queries with a false reply before the actual name server answers
  - cache poisoning: send false data to a recursive name server with a long TTL
    - the data is cached for a long time
  - compromise the DNS server
    - Using DNS software vulnerabilities

DOS Attacks using Name Servers

- Send a large number of DNS queries (using UDP) to a name server or several name servers (DDOS), using a spoofed IP address
  - responses will be sent to the spoofed IP address
    - the spoofed IP address is the victim
  - hard to trace because of the spoofed IP address
- the responses can be significantly larger than the queries
- DOS possibly both on victim machine and name server

BIND Vulnerabilities (1/3)

- Use the BIND vulnerabilities to compromise the DNS server machine
- often BIND is run as superuser!!!!
- Examples of vulnerabilities
  - BIND Dynamic Update DoS (July 2009)
    - BIND denial of service (server crash) caused by receipt of a specific remote dynamic update message.
    - Fix: upgrade
  - CERT VU#800113 DNS Cache Poisoning Issue (Aug 2008)
    - Fix: DNSSEC, Query Port Randomization for BIND 9 (upgrade)

BIND vulnerabilities (2/3)

- BIND 8: cryptographically weak DNS query IDs (Aug 2007)
  - Consequence: remote attacker could predict DNS query IDs and respond with arbitrary answers, thus poisoning DNS caches.
  - Fix: Upgrade or Patch
  - Note that BIND 8.x.x is End of Life as of August 2007
- BIND 9: allow-query-cache/allow-recursion default acls not set (July 2007)
  - Consequence: The default access control lists (acls) are not being correctly set. If not set anyone can make recursive queries and/or query the cache contents.
  - Fix: configure BIND correctly
- BIND 9: cryptographically weak query ids (July 2007)
  - Consequence: DNS query id generation is vulnerable to cryptographic analysis which provides a 1 in 8 chance of guessing the next query id for 50% of the query ids. This can be used to perform cache poisoning by an attacker
  - Fix: upgrade

BIND vulnerabilities (3/3)

- "BIND: Remote Execution of Code“ (Nov 2002)
  - Versions affected: BIND 4.9.5 to 4.9.10, 8.1, 8.2 to 8.2.6, 8.3.0 to 8.3.3
  - SIG RR code bug
  - Consequence: possibility to execute arbitrary code
  - Fix: upgrade
- Up-to-date information on BIND vulnerabilities
  - https://www.isc.org/advisories/bind

Attack on the DNS InfraStructure

- Distributed DOS attack against the DNS root servers 6 February 2007
  - six of the 13 root servers were affected, two badly
    - the two servers affected badly did not use anycast
  - Anycast
    - spread the load on several servers in different locations
  - Also measures to block the packets part of the DDOS
    - the packets had a larger size than 512 bytes
  - If the root servers do not function, eventually name resolution will not work
    - in this case, fast reaction and a new technology (anycast) lead to limited impact on the actual Internet users

DNS Security (1/3)

- Main documents
  - DNS security extensions
    - New RFCs approved 2005
      - DNS Security Introduction and Requirements, RFC 4033
      - Resource Records for DNS Security Extensions, RFC 4034
      - Protocol Modifications for the DNS Security Extensions, RFC 4035
    - new RFC in 2006
      - Minimally Covering NSEC Records and DNSSEC On-line Signing, RFC 4470
  - Protection of queries and responses
    - Secret Key Transaction Authentication for DNS (TSIG), RFC 2845
    - DNS Request and Transaction Signatures (SIG(0)s), RFC 2931
  - Secure Dynamic Update
    - Secure Domain Name System (DNS) Dynamic Update, RFC 3007
  - Storing Certificates in the Domain Name System (CERT RR), RFC 4398

DNS Security (2/3)

- Security services:
  - Data origin authentication and integrity
    - including ability to prove non-existence of DNS data
  - Transaction and request authentication and integrity
  - Means for public key distribution

DNS Security (3/3)

- DNS security does not offer:
  - confidentiality
  - access control
    - but often the DNS server implementations do
  - protection against attacks on the name server node itself
  - protection against denial of service attacks
  - protection against misconfiguration

DNSSEC Security Extensions (1/9)

- Signature record (RRSIG)
  - a record containing a signature for a DNS RR
  - contains the following information
    - type of record signed
    - algorithm number
    - Labels Field
    - Original TTL
    - signature expiration and inception
    - Key tag
    - signer name
    - Signature
  - replaces SIG record

DNSSEC Security Extensions (2/9)

- Example

```
host.example.com. 86400 IN RRSIG A 5 3 86400 20030322173103 (
                  20030220173103 2642 example.com.
                  oJB1W6WNGv+ldvQ3WDG0MQkg5IEhjRip8WTr
                  PYGv07h108dUKGMeDPKijVCHX3DDKdfb+v6o
                  B9wfuh3DTJXUAfI/M0zmO/zz8bW0Rznl8O3t
                  GNazPwQKkRN20XPXV6nwwfoXmJQbsLNrLfkG
                  J5D6fwFm8nN+6pBzeDQfsS3Ap3o= )
```


DNSSEC Security Extensions (3/9)

- DNSKEY record
  - Stores public keys that are intended for use in DNSSEC
  - contains the following fields
    - flags (indicating a zone key, public key used for TKEY)
    - the protocol (DNS, value 3)
    - the algorithm (RSA, DSA, private)
    - the public key
  - replaces KEY record

DNSSEC Security Extensions (4/9)

- Example

```
example.com. 86400 IN DNSKEY 256 3 5 ( AQPSKmynfzW4kyBv015MUG2DeIQ3
                  Cbl+BBZH4b/0PY1kxkmvHjcZc8no
                  kfzj31GajIQKY+5CptLr3buXA10h
                  WqTkF7H6RfoRqXQeogmMHfpftf6z
                  Mv1LyBUgia7za6ZEzOJBOztyvhjL
                  742iU/TpPSEDhm2SNKLijfUppn1U
                  aNvv4w==  )
```


DNSSEC Security Extensions (5/9)

- Delegation Signer record (DS)
  - Indicates which key(s) the child zone uses to sign its records.
  - Contains the following fields
    - Key tag
    - Algorithm
    - Digest type
    - Digest

DNSSEC Security Extensions (6/9)

- Example

```
dskey.example.com. 86400 IN DNSKEY 256 3 5 (
AQOeiiR0GOMYkDshWoSKz9Xz fwJr1AYtsmx3TGkJaNXVbfi/
2pHm822aJ5iI9BMzNXxeYCmZDRD99WYwYqUSdjMmmAphXdvxegXd/
M5+X7OrzKBaMbCVdFLUUh6DhweJBjEVv5f2wwjM9Xzc
nOf+EPbtG9DMBmADjFDc2w/rljwvFw== ) ; key id = 60485

dskey.example.com. 86400 IN DS 60485 5 1 (
2BB183AF5F22588179A53B0A 98631FAD1A292118 )
```

DNSSEC Security Extensions (7/9)

- NSEC record
  - data origin authentication of a non-existent name or record type
  - implies a canonical ordering of records
  - NSEC records are created automatically when doing the signing process
  - replaces NXT records

DNSSEC Security Extensions (8/9)

- Example:

```
ns      86400 IN   A     10.10.10.1
ns      86400 IN   NSEC  www.example.com. (A NSEC)
www     86400 IN   A     10.10.10.3
```

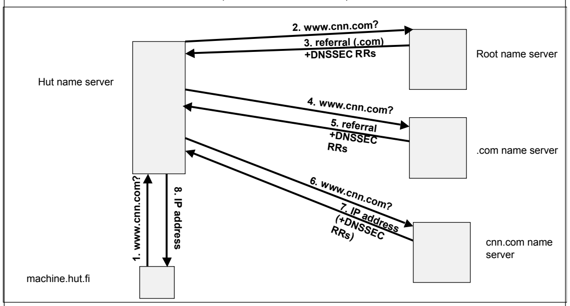

DNSSEC Security Extensions (9/9)

- CERT record
  - can contain different kinds of certificates (SPKI, PKIX X.509, PGP)
  - recommended to be stored under a domain named related to the subject of the certificate

Secure Name Resolution

- The resolver is statically configured with some keys (*key signing key*) it trusts
- the process involves verifying a chain of keys and signatures
  - a record retrieved will include a signature
  - the resolver needs to retrieve the corresponding *zone signing key* to be able to verify the signature
  - Verifications starts from the highest level RR and continues through a chain of verifications, until the zone signing key for the DNS data is verified
  - After that, the DNS data can be verified

Secure Name Resolution (Scenario)



Original Master Zone File

```
verkot.example.       IN       SOA      ns.verkot.example.
dnsadmin.verkot.example. (
                               6 28800 7200 604800 86400 )
                               IN       NS       ns.verkot.example.
                               IN       MX       10 mail.verkot.example.
$ORIGIN verkot.example.
localhost             IN       A        127.0.0.1
ns                             IN       A        10.10.10.1
mail                           IN       A        10.10.10.2
www                            IN       A        10.10.10.3
                               IN       TXT      "Our web server"
ftp                            IN       CNAME    mail
verkot.example. IN DNSKEY 256 3 5
AQOoIPWnXoZXUI26cJmIWDNps+hes9uKt71+QzFiTc3FB3xIUPd+nyjB
hArIe1HqcKW4+hE8DtDl//zeVa90LEid2PvdP8Zy++tFZ7Zyhg1lKgIc
TD8qA7DaqHa9Rwhtl9U=
```

Zone File after Signing (1/4)

```
; File written on Wed Sep 28 16:17:16 2005
; dnssec_signzone version 9.3.1
verkot.example.          86400     IN SOA     ns.verkot.example. dnsadmin.verkot.example.
                         (6        ; serial 28800     ; refresh (8 hours) 7200      ; retry (2 hours)
                         604800    ; expire (1 week) 86400      ; minimum (1 day))

86400          RRSIG          SOA 5 2 86400 20051028121716 (
20050928121716 23576 verkot.example.
VZ92OWwT7rK5Nj9yksqdsWJ3GaNGp8tNAL7Bs2Vb8uB1+XN+EPHP4uwlDK43JyzlV0Vj0FHt7hmj9bgws
u6A3Mp332D7k+DRFmhfgHMRdXeMxSGrP+IB89f2BknCyoXQ )
86400          NS             ns.verkot.example.
86400          RRSIG          NS 5 2 86400 20051028121716 (20050928121716 23576 verkot.example.

hXX6fGWcTI+q1NFWJznffkCYPg86wQyW7nwHcdKg0YF2FX57w12A1P9zUlxT8SJ5kJyAEAjBvaxbzKy3q
q3NiNq24vaaU0gjJFt7z+4ZgvVBjcGPq3owrlVX+IjlTCue )
86400          MX             10 mail.verkot.example.
86400          RRSIG          MX 5 2 86400 20051028121716 (20050928121716 23576 verkot.example.

RqOyunvHTO1Rbuc/HNMe35kXNddlHGrtMubjra7CdO5mDrOJlQicdy7YSuyFfeUdZrF0+px8gv0x0daZabP
73zMNW2nKIRtuwDhoNlZLK+op3ycurZ38BR2s79JqfHyD )
86400          NSEC           ftp.verkot.example. NS SOA MX RRSIG NSEC DNSKEY
86400          RRSIG          NSEC 5 2 86400 20051028121716 (20050928121716 23576 verkot.example.

Yi2YRyNpRCUujfWUt0TaG4zyHb1CTVr3BRXDU0JWvG9ECD6AYvpYpMrPUj4pN+qKa4v4MaXNaSKC4
XWsv8Hk/OJIf/BrgCK9OlrPMnPokSd/NSJYEGeTJoI38TZOQYBf )
86400          DNSKEY         256 3 5
(AQOoIPWnXoZXUI26cJmIWDNps+hes9uKt71+OzFiTc3FB3xIUPd+nyjBhArle1HqcKW4+hE8DtDl//zeVa9
0LEid2PvdP8Zy++tFZ7Zyhg1lKglcTD8qA7DaqHa9RwhtI9U=) ; key id = 23576
```


Zone File after Signing (2/4)

```
86400          RRSIG          DNSKEY 5 2 86400 20051028121716 (20050928121716 23576 verkot.example.

EYhRu2WPmgjo8O1JeIgTGgVJvLpExihk8ZDMENyBp5PI+/ioyFFnDeBbi7JtflMGtzHL5oi7yhTVebH5SXZxsxu/Xg6wVD9G6
nQIx/19XNgP5RqMOjA9+z5I8mIye386 )
ftp.verkot.example.      86400     IN CNAME mail.verkot.example.
                         86400     RRSIG     CNAME 5 3 86400 20051028121716 (20050928121716 23576
verkot.example.

JIVlLtqKls8Km78rAIInGb7uwLF6SQxl7WjXHem6LJ/R2nemrPfpYml0YNXdeVGOTv3n+mRZK4Z/yTySfIxckTqk666X8WYIs
RMhwsvdljWHjlj2u4eArbYcdCLeO33s )
                         86400     NSEC      localhost.verkot.example. CNAME RRSIG NSEC
                         86400     RRSIG     NSEC 5 3 86400 20051028121716 (20050928121716 23576
verkot.example.

J3DgodgZgvbnnvZBWzgdJ2qrWjHg19d88Mwj6LiRP+Z8n7xFa9km8Dh/YT+MUWv10nd5b9qOzVYMqmPzxJ7EVd0LgTp09
V3lgz7Ki7pZcfIzNhnLHc+03racm5ImHf12 )
localhost.verkot.example. 86400    IN A      127.0.0.1
                         86400     RRSIG     A 5 3 86400 20051028121716 (20050928121716 23576
verkot.example.

Uq0P6qTaT2sxSbXqZwqyKNEBUXNS49zUPAJxdcdwukcO3FyQYb6ld269Q7XAhVPVgxXCYOupcU47vWrPhb9C+/ymRh
EYFKi/zXt+pNVQyedVKtLtTSqoLzcjsC7kbVXw )
                         86400     NSEC      mail.verkot.example. A RRSIG NSEC
                         86400     RRSIG     NSEC 5 3 86400 20051028121716 (20050928121716 23576
verkot.example.

M2I0NaBE00lbE3k97kOBhItlp4dnVCZUrTQSZFr/hBAiZ1hSz4CnX3NLAZdr3d55bNqGa75xPm+1Dg4igfQ/TZRK4p/IOplgCZz
ggVIWbcTQkndifyHa8tF3mskekSii/ )
```


Zone File after Signing (3/4)

```
mail.verkot.example.     86400     IN A      10.10.10.2
                         86400     RRSIG     A 5 3 86400 20051028121716 (20050928121716 23576
verkot.example.

Nhk09EIqZAT/KOkfLtkf9S4IwI8dlxZHsDQFPuqRUP/riA8HAl1CzcBVZrZ19S8MNiJ6o22yFQp/0rzMfBnJD/0f0hL
o2kaz7Zcsapk+mXd7vsf9Fpi2HrRrdMFWP6nt )
                         86400     NSEC      ns.verkot.example. A RRSIG NSEC
                         86400     RRSIG     NSEC 5 3 86400 20051028121716 (20050928121716
23576 verkot.example.

SxxQMF2soXT3gHrVV9TNEsA6zPXEifGynZ7eFi4/vGm12tkKzA3BTpkImRrLHTrxWuFHpvpUQHxvCxaO8ad3
oP6NCHesI1ICENkuUsFW3MMo7uXNZa3t3VxwOIjtVsw+ )
ns.verkot.example.       86400     IN A      10.10.10.1
                         86400     RRSIG     A 5 3 86400 20051028121716 (
                         20050928121716 23576 verkot.example.

dQIY/CTSUMbPKKxv1DcN1osbAuEpjt5SWmgZgLYx3kpVAk4aSuCGdOWCylRoQdRs/MRx62K6dHhyDy7qtA
yMM//NHwGUbnkrDoSurXsmDS2ud6JCfNyTCWJl+qK5MUKH )
                         86400     NSEC      www.verkot.example. A RRSIG NSEC
                         86400     RRSIG     NSEC 5 3 86400 20051028121716 ( 20050928121716
23576 verkot.example.

Ik+ovY4k2CFyX3vEo66N0HUHNgLmv7h2a7T08E/4FocQgKXhAv8LU4tG+437IEYxwfKo9/j2w5E9cjb+oikTqWq
i3jPTD/Zi74wvVa1SHQR4Is6AMwE7DBdM1od3tSrY )
```


Zone File after Signing (4/4)

```
www.verkot.example.      86400     IN A      10.10.10.3
                         86400     RRSIG     A 5 3 86400 20051028121716 ( 20050928121716
23576 verkot.example.

bsxBpAxE7xw9uzV30kTjif7E6IMHHOsn17EZyDp+01dFR3zNv2Zcu6bvy+crnihJNzgzASeXYvnUq4JaJk0U0q
GTDJSlEiDfti/XzflYH3sqDFjw1Yw+ykp4x+gwXOk6 )
              86400     TXT       "Our web server"
              86400     RRSIG     TXT 5 3 86400 20051028121716 (        20050928121716 23576
verkot.example.

Spxg5JIy7vMK8co6hgFng1rlSRZENhxkD27jGPxOtH7wjd7wuuktvI2sNgkBo2dtNuAPVdh256jRe9Eo8xd3cP2
MG//NzLjhL05coelgKEpThHQ6orT2WE0FbN/FNxLW )
              86400     NSEC      verkot.example. A TXT RRSIG NSEC
              86400     RRSIG     NSEC 5 3 86400 20051028121716 (20050928121716 23576
verkot.example.

mgO9FIagQqRCmsGbKnBizkxHxUizPv79gcIAl1eaoSAAFwciTWQpJ4hqrcE9MgS67K0qK/aouoLiNct966GlvK
uk41HEIXaDDoCBQ2YJ+zA9              n9CGqRiO4NRY++eKN5AA )
```


Implications of the Security Extensions (1/2)

- the record number in the database grows roughly by a factor of three (NSEC, RRSIG records needed)
  - New records have a large size, so the actual database grows even more.
- NSEC records make it possible to list the complete contents of the zone (effectively do a zone transfer)
  - Some ideas
    - Minimally Covering NSEC Records and DNSSEC On-line Signing, RFC 4470
    - DNSSEC Hashed Authenticated Denial of Existence, RFC 5155

Implications of the Security Extensions (2/2)

- DNS UDP packets are limited to the size of 512 (RFC 1035)
  - answer packets including required signature records might exceed the limit
  - IPv6 support also increases DNS message sizes
  - Extension mechanism for DNS (EDNS) provides a solution
  - EDNS must be supported in DNSSEC

Transaction and Request Authentication and Integrity

- Secret Key Transaction Authentication for DNS (TSIG)
  - symmetric encryption
  - covers a complete DNS message with a Message Authentication Code (MAC)
  - signature calculation and verification relatively simple and inexpensive
- DNS Request and transaction signatures (SIG (0))
  - public key encryption, sign the message
  - offers scalability

DNS Dynamic Updates (1/2)

- Authorized clients or servers can dynamically update the zone data
  - zones can not be created or deleted
- example

```
prereq nxrrset www.example.com A
prereq nxrrset www.example.com CNAME
update add www.example.com 3600 CNAME test.example.com
```


DNS Dynamic Updates (2/2)

- Example of use
  - mechanism to automate network configuration even further
    - a DHCP server can update the DNS after it has granted a client a lease for an IP address
  - Can be protected with transaction protection methods
    - Secret Key Transaction Authentication for DNS (TSIG), RFC 2845
    - DNS Request and Transaction Signatures (SIG(0)s), RFC 2931

TKEY RR

- TKEY record
  - can be used for establishing a shared secret between the server and the resolver
    - negotiate a shared secret using Diffie-Hellman
      - Authentication using public keys (SIG (0)) or a previously established shared secret
    - The resolver or server generates the key and encrypts it with the server or resolver public key
  - meta-RR, not present in any master zone files or caches

DNSSEC Issues (1/2)

- DNSSEC is complex
- Significant increase of response packets
- Signature validation increases work load and thus increases response time
- Hierarchical trust model
- Key rollover at the root and TLD name servers
  - for example .com contains millions of RRs
- Strict time synchronization needed

DNSSEC Issues (2/2)

- TSIG
  - Keys need to be online
  - Fine grained authorization not possible
- Many workshops have been held to progress DNSSEC
  - Number of open issues decreasing
- Not much real deployment yet
  - Some secure islands exist
  - TSIG more common

Internationalized DNS (IDN)

- DNS originally designed to work with ASCII as the character set
- Internationalized DNS aims to provide support for other character sets.
  - An encoding from other character sets to ASCII is needed

Security Problems in Internationalized DNS (IDN)

- Phishing concerns known related to IDN
  - Idea: use a different characters set where a name looks the same, but translates to an entirely different domain name
    - Example: http://www.pàypal.com instead of www.paypal.com
- No technical solution has been found to the problems

DNS as a PKI? (1/3)

- Public keys of an entity can be stored under its domain name
  - not intended for personal keys
- DNS can be used to store certificates (CERT record)
  - can include personal keys

DNS as a PKI? (2/3)

- the public key or certificate will be bound to a domain name
  - search for a public key or a certificate must be performed on basis of the domain name
  - a convenient naming convention needs to be used
  - an efficient search algorithm is required

DNS as a PKI? (3/3)

- research on DNS as a certificate repository can be found from the Tessa project at Helsinki University of Technology
  - http://www.tml.tkk.fi/Research/TeSSA/

Conclusions: how to handle DNS Security (1/4)

- Basic security first!
  - Run latest version of the name server
  - Firewall protection
  - Don't run any other services on the machine
  - Run as non-root
  - Run in a sandbox: chroot environment ("jail")
  - Eliminate single points of failure
    - Redundancy, run at least two name servers
    - Put name servers in separate sub-networks and behind separate routers

Conclusions: how to handle DNS Security (2/4)

- Basic security (cont.)
  - Consider non-recursive behavior and restricting queries
    - To mitigate against cache poisoning
  - Use random message Ids
  - Hide version number
  - Prevent unauthorized zone transfer
    - TSIG can be used to authenticate zone transfers
  - Restrict DNS dynamic updates
    - TSIG can be used to authenticate dynamic updates

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Conclusions: how to handle DNS Security (3/4)

- Split DNS (internal/external)
  - Useful when using private addresses in the internal network
    - Enhances overall security of the network, as only some nodes can connect to the external network directly
    - Firewalls between external and internal network
    - External DNS servers in the DMZ
    - Internal DNS servers in the internal network

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Conclusions: how to handle DNS Security (4/4)

- Additional security measures
  - Secret Key Transaction Authentication for DNS (TSIG)
    - Can be used to ensure authentication and integrity for queries, responses, zone transfers, dynamic updates
    - The communication parties need a shared secret
    - Good performance
  - DNS Security Extensions (DNSSEC)
    - Public-key methods
    - Provides scalability but bad performance
- Security is a process
  - Monitor CERT and similar organizations, monitor relevant mailing lists

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Some interesting books and links

- Cricket Liu, Paul Albitz, DNS & BIND
  - **the** DNS book
- http://www.ietf.org/html.charters/dnsext-charter.html
- www.dns.net/dnsrd
- www.menandmice.com

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