DNS For Network Defense

Using DNS to protect and observe

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WP8-T1

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What we will cover today

- Protect
  - DNS Manipulation for good
    - Blackholing & Response Policy Zones
  - Useful Zones and Resecoure Records (RRs)
    - Localhost, RFC 1918, etc.
    - RRs: TLSA, SSHFP, IPSECKEY, CAA, CERT
- Observe:
  - Query logging
  - Passive DNS monitoring
- Examples will use BIND 9 nameserver

Blacklisting SPAM

- Has been in use for a very long time (MAPS, Spamhaus, …)
- MTA queries special SPAM Blacklist nameserver
  - I.e. SPAM BL is operated apart from normal zones and nameservers
- Nameservers serve zones with FQDNs of known spamming hosts
  - Answer is NXDOMAIN = Host is OK
  - Answer is 127.0.X:Y = Host is spamming,
  - X.Y tells which blacklist the host/domain/ip-address is on
    - Have to look this up for a given blacklist provider (e.g. Spamhaus)
- Usefulness has dimished over time, but is still SOP for most MTAs

BlackHoling DNS (BHDNS)

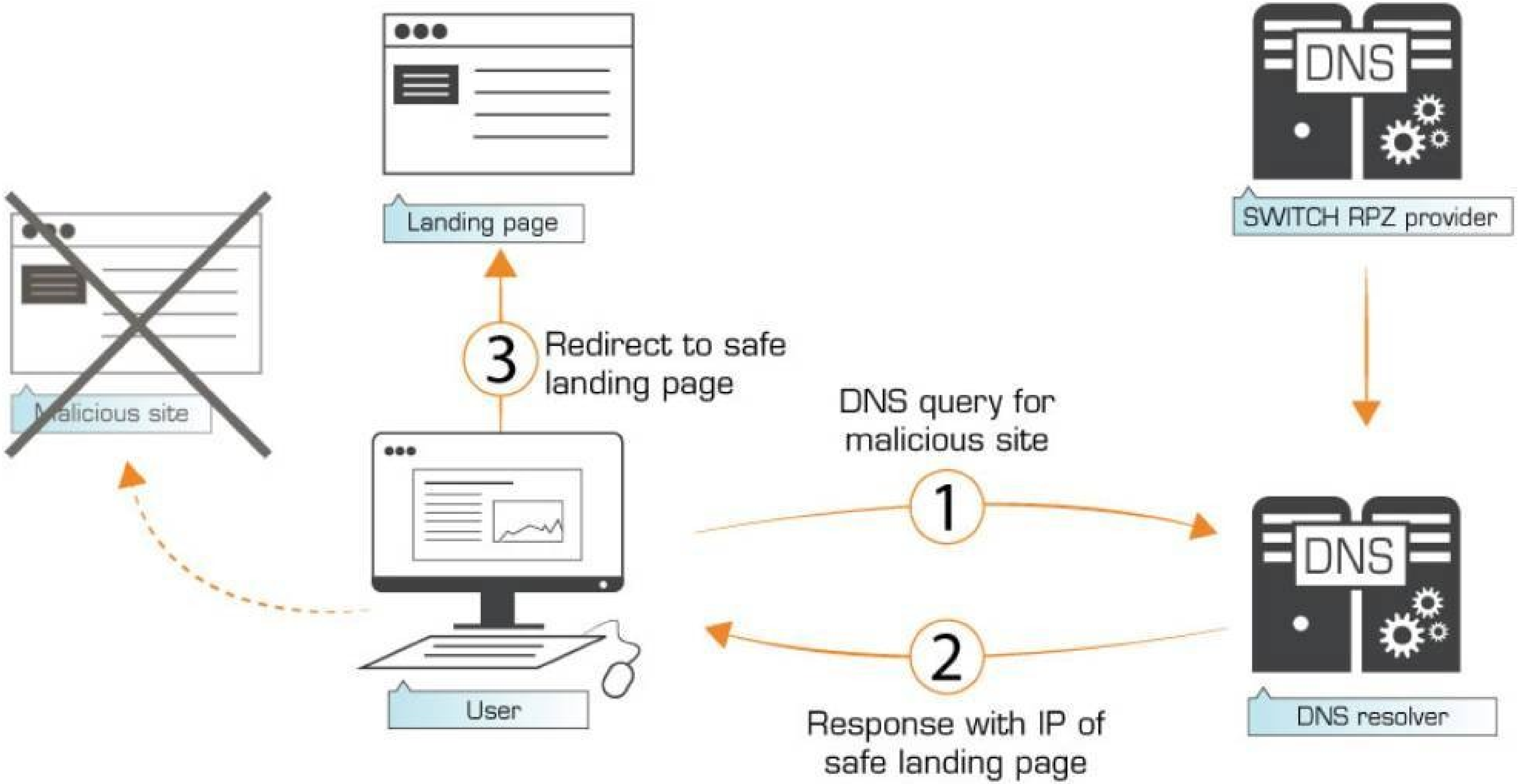
- Other names: Sinkhole DNS, DNS Firewall
  - List of blackholed names: *DNS Blacklist (DNSBL)* or *Realtime Blacklist (RBL)*
- Nameserver answers queries for “known bad” names “differently”
  - With NXDOMAIN or 127.0.0.1 for example
- What exactly is meant by “bad”?
  - Malicious Stuff: Drive-by URLs, C&C servers, landing pages, black market, etc.
  - Others: SPAM, porn, shopping, betting, VPN, proxies, “critics” etc.
- Advantages for network administrators
  - Not limited to browsers (like WoT)
  - No client configuration, etc. (they likely use your nameserver anyway)
  - Names and IP-addresses from your network do not leak to the internet

How to operate a Blacklist

1. Policy should be maintained separately from the rest of the DNS
   - No fiddling with the original zone data
   - Entries would be spread all over the DNS
2. Automation
   - There will be 1000s of entries

- **Response Policy Zones (RPZ)**
  - RPZ zone files are syntactically normal zone files
  - But are treated differently by the nameserver
  - Can be maintained locally or obtained from provider
    - Zone transfer (`AXFR, IXFR`) or file transfer (`wget, ftp,` …)
  - Supported by BIND, Knot DNS, PowerDNS, Unbound, …

RPZ Schema



Source: https://www.switch.ch/dns-firewall/

How RPZs operate (1)

a) Tell the nameserver to use response policies

```
options {
…
  response-policy {
    zone "rpz.local";
    zone "rpz.slave";
    zone "rpz.test" policy passthru;
  };
…
```

Override actions from zone file (i.e. for tests)

How RPZs operate (2)

b) Create zone files

No periods after
Relative owner names

```
$ORIGIN rpz.example.net.
…
nxdomain.example.com            CNAME   .  ; NXDOMAIN
nodata.example.com              CNAME   *. ; NODATA
bad.example.com                 A       10.0.0.1
                                AAAA    2001:db8::1
*.azone.example.com             CNAME   garden.example.net.
ok.azone.example.com            CNAME   rpz-passthru.
24.0.2.0.192.rpz-ip             CNAME   .
32.1.2.0.192.rpz-ip             CNAME   rpz-passthru.
ns.example.com.rpz-nsdname      CNAME   .
32.zz.db8.2001.rpz-nsip         CNAME   .
25.128.2.0.192.rpz-ip           A       172.16.0.1
25.128.2.0.192.rpz-ip           MX      10 mx1.example.com
25.128.2.0.192.rpz-ip           TXT     "Your are infected."
```

5th octet
is subnet
mask

RPZ Zone file rules

TRIGGER → ACTION

TRIGGER

RRSet Owner Name in zone file

1. **QNAME**: Match on domain name queried in requests and responses
2. **Client IP Address**: Match on querying Client IP Address if owner ends in **`.rpz-client-ip`**
3. **Response IP Address**: Match on IP addresses in the DNS response if owner ends in **`.rpz-ip`**
4. **NSDNAME**: Match nameserver names (NS records) if owner ends in **`.rpz-nsdname`**
5. **NSIP**: match on name server IP addresses(A/AAAA) if owner ends in **`.rpz-nsip`**

ACTION

RRSET Target in zone file

1. **NXDOMAIN**: Return NXDOMAIN for targets ending in “**`CNAME .`**”
2. **NODATA**: Return NODATA for targets ending in “**`CNAME *.`**”
3. **PASSTHRU**: Let response pass unaltered if target ends with **`CNAME rpz-passthru.`**
4. **DROP**: Drop query if targets ends with **`CNAME rpz-drop.`**
5. **TCP-Only**: Respond with if target ends with **`CNAME rpz-tcp-only.`**
6. **Local Data**: Respond with other data from zone file (arbitrary RR types)

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RPZ: Sources

- Where Do we get lists of “bad names”?
  - Abuse.ch URLhaus
  - **SWITCH DNS Firewall**
  - SURBL securityZONES
  - FarsightSecurity NOD
  - **More examples in the references**
- Caveat emptor!
  - Quality varies
  - Availability varies
  - Price varies

However

- With great power comes great responsibility
- BHDNS and RPZ are great tools for censorship too
- Check with your legal advice (liability anybody?)
  - Are you allowed to block at all?
  - What has to be done to block in a legally conforming way?
- And check with your users and bosses too
  - A policy will have to be drafted, discussed, etc.
- Much more additional work
  - Configuring RPZs in a nameserver is trivial
  - Using them in a responsible and acceptable way is hard

Useful Zones to serve

- Why?
  - Would be forwarded to root nameservers
  - Information leak (internal names, IP-addresses)
  - Unnecessary traffic/burden on the root NS
- `localhost, .example, .example.net, .example.org`
  - May sometimes be seen on the net
  - Usually misconfigurations (samples copied literally)
  - `.local` will break Bonjour!
- RFC 1918 et al.
  - `10.in-addr.arpa, (16-31).172.in-addr.arpa, 168.192.in-addr.arpa`
  - Also for IPv6 and other networks, see RFC 6890 & RFC 8190

Web Proxy Auto-Discovery Protocol (WPAD) Entries

- Browsers search for hosts named **`wpad`** in their domains to retrieve a URL for proxy auto-configuration
- For `host.sub.dom.tld` it would look for
  - `wpad.sub.dom.tld`
  - `wpad.dom.tld`
  - `wpad.tld`
- The URL tried will be: **`http://wpad … /wpad.dat`**
- **`wpad.dat`** is a JavaScript file doing proxy auto configuration (e.g. **`proxy.pac`**)
- If the host/URL does not serve a file, the next host on the list will be tried
- Information gotten from DHCP (WPAD option) takes precedence
  - But only within IPv4
- Better turn off “detect proxy setting automatically” (aka WPAD) (**`network.proxy.enable_wpad_over_dhcp: false`**)

Useful Entries:

- `use-application-dns.net.`
  - "Canary domain" queried by Firefox (and maybe other Mozilla products)
  - Use case: turn off DNS over HTTPS (DoH), if
    - Negative result (NXDOMAIN, SERVFAIL)
    - or empty answer (no A or AAAA RR)
  - Just put an empty zone file into your nameserver
- Google Chrom* captive portal detection domains
  - Chrom* browsers make DNS queries to three random (8-15 characters) domains
  - If at least two of them resolve to the same IP-address, a DNS captive portal is assumed
  - In turn, chrome does no try to interpret single words as hostnames
  - The same goes for requests to `http://clients3.google.com/generate_204`

Useful RR Types

- SSHFP – SSH Host Key Fingerprints
- TLSA – Binding of a X.509 Certificate to a service
- CAA – Certification Authority Authorization – Who may issue certificates for a domain
- More RRs, very little use so far
  - IPSECKEY – IPSEC Public Key
  - OPENPGPKEY – Bind PGP Keys to an e-mail address

SSHFP RRs

- Puts SSH Host Fingerprints into DNS
  - So you don’t have to distribute files from /etc/ssh/host_key* to /etc/ssh/known_hosts or ~/.ssh/known_hosts
- Example:

```
alice.example.edu. IN      A         10.1.2.3
alice.example.edu. IN SSHFP  4   2   AAAAC3NzaC1lZDI1NTE5AAI…
alice.example.edu. IN SSHFP  1   1   AAAAB3NzaC1yc2EAAAADAQAB…
```

Hostname

Public Key Algorithm

Fingerprint Type

Fingerprint

SSHFP Example

- Generation with `ssh-keygen (from /etc/ssh/host_key_<pub key algorithm>.pub)`

```
ssh-keygen -r alice.example.edu

alice.example.edu IN SSHFP 1 1 cd169ea783f92777390f9f61830fe8d6ee52398f
alice.example.edu IN SSHFP 1 2 dd4f605d871df00b52ca112a216eed55717b6315c4b023ad86668d96f58cc0e5
alice.example.edu IN SSHFP 2 1 2206541d5e37ccbab4729b2dac8d648bb029f97e
alice.example.edu IN SSHFP 2 2 b0a015927594417e5f4ad576cf282148d33e5b578a4fb3e9bd56d541e94a8bbf
alice.example.edu IN SSHFP 3 1 3611fec195ef2e31281490b93e2d697d1f3ecc61
alice.example.edu IN SSHFP 3 2 e4ff16f41711a56349c8a60099e10e9a19fdfd67b8276c33de568815cc05009d
alice.example.edu IN SSHFP 4 1 a4eb77ccca51d06c4d3660c6919c7090bde4a3ab
alice.example.edu IN SSHFP 4 2 83bb62496bb293f2b628891a28bd3db5da3c135880bce31df74066db7a904d90
```

- SSH invocation to verify:

```
ssh -o VerifyHostKeyDNS=ask alice.example.edu
```

- In `~/.ssh/config`

```
Host              alice.example.edu
VerifyHostKeyDNS ask
```

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TLSA RR

- Binds a X.509 certificate to a server (protocol, port) and FQDN
- Prevents stolen X.509 keys to be used on other names or IP addresses
- Part of **DANE** = **D**NS-Based **A**uthentication of **N**amed **E**ntities
- Without DNSSEC, TLSA verification will always fail
- Example/Format:

```
> dig +multi tlsa _443._tcp.bob.dom.example.edu
  …
_443._tcp.bob.dom.example.edu. 10 IN TLSA 3 1 1 ( E3C9F … 74D2 )
```

Port

Protocol

Hostname

Certificate usage

Selector

Matching type

Certificate Association Data

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TLSA RR Fields

- Certificate Usage: Certificate data presented by the service must match
  - 0: against a public CA certificate (“CA restraint”)
  - 1: End Entity (EE) match validated by public CA (“Service certificate restraint”)
  - 2: against a private CA certificate (“Trust anchor assertion”)
  - 3: against only the certificate without any CAs (“Domain issued certificate”)
- Selector - which part of the servers TLS certificate will be matched against the certificate association data
  - 0: Certficate Association Data field is based on the full certificate data
  - 1: Certficate Association Data field is based on the public key only
- Matching Type: how the certificate association data is presented
  - 0: Certificate Association Data field contains the full certificate
  - 1: Certficate Association Data field contains a SHA-256 hash
  - 2: Certficate Association Data field contains a SHA-512 hash

CAA RRs

- Problem it solves: What Certification Authority (CA) may issue certificates for a given domain “say example.net”
- For use by CAs when issuing certificates
- May be set for any level within the DNS
- Records are evaluated from left to right, first match

```
    example.org       IN CAA 0 issue "pki.dfn.de"
sub.example.org       IN CAA 0 issue "example-pki.org"
```

CAA RR Structure

```
<domain> IN CAA <Flag> <Tag> <Value>
```

- Flag:
  - Currently 0 or 1 (*issuer critical*)
  - If set to 1, the tag/value pair must be understood (and followed) or no certificates may be issued
- Tag:
  - **`issue`**: CA under “value” is allowed to issue certificates for the domain
  - **`issuewild`**: CA under “value” is allowed to issue wildcard (*) certificates for the domain
  - **`iodef`**: value is an URL to report certificate misuse

DNS Query logging

- Log DNS queries at central (caching) nameservers
  - Look for queries to “bad” domains
  - Take action (i.e. clean host)
- Easy to enable
  - Just type **`rndc querylog`** to turn on in BIND9
  - Logs to Syslog (usually ends up in `/var/log/messages`)
- **Check with your lawyers & privacy officers first!**
- Tells
  - Who made the query (the IP address)
  - When the query was made (the timestamp)
  - What the query was asking for (i.e. RR type and domain)
- Does not tell what the answer was

DNS Query logging: Nameserver Config

- Two parts in BIND9

```
# cat /etc/named.conf
...
options {
    querylog yes;
}
```

```
# cat /etc/named.conf
...
logging {
    channel querylog {
        file "/var/log/querylog";
        print-time yes;
        print-category yes;
        print-severity yes;
        severity debug 3;
    };
};
```

- Performance impact can be huge
  - Use seperate server for caching resolver, log there

Passive DNS (PDNS) Monitoring

- Invented 2004 by Florian Weimer (then at RUS-CERT)
- Sensor monitors incoming DNS responses (and sometimes queries)
- Logs data in a "standard" format
  - Timestamped (for the history)
  - De-duplicated (resolvers sent several queries in parallel)
- Example of a “standard” format: ***dnstap*** (binary)
  - Also the name of a PDNS monitoring tool
- Data from many sensors can be combined in a shared database
- Little impact on privacy when logging only responses to caching resolvers
  - But personally identifiable information when combined with internal data
- **Again: Check with your lawyers & privacy officers first!**

Importance of PDNS Monitoring

- Historical DNS data is the point (e.g. past DNS responses)
- Think threat hunting, i.e. you have a C&C server hostname
- But firewalls, NAT, VPN, NetFlows log IP-addresses, not FQDNs
- Lookup of name in PDNS DB gives closes the gap
  - Timestamps also give further hints
  - Frequency of address changes might hint at Fast-Flux DNS networks
- Hints for other names for a given IP (multiple SPAM domains)
- Looking responses that are typos of your domain
  - e.g. `dfm-cert` instead `dfn-cert`
  - Needs PDNS DB that supports Soundex or fuzzy matching
- Detecting cache poisoning by querying external PDNS DBs

PDNS Sensors

- Primitive sensor: **`tshark -i <if> "udp and src port 53"`**
  - Pair with PacketQ für SQL queries against `.pcap` files
- Use your recursive/caching Nameservers as sensors
  - Format & Tool: **`dnstap`**
  - Supported by: BIND, CoreDNS, Dnsdist, Knot, NSD, PowerDNS, Unbound, …
- NIDS (Snort, Suricata, OSSEC, etc.)
  - Have to write rules for that
  - Bro: `https://github.com/JustinAzoff/bro-pdns`
- Firewalls can act as Sensors (Palo Alto, Cisco, Watchguard, etc.)
- Option for Outsourced DNS services (OpenDNS, etc.)
- Sensors on endpoints (Red Canary, etc.)

PDNS (public) Databases

- Companies:
  - Farsight Security's Passive DNS database (PNSDB): https://scout.dnsdb.info/
  - VirusTotal (aka Google): https://blog.virustotal.com/2013/04/virustotal-passive-dns-replication.html
  - SecurityTrails: https://securitytrails.com/dns-trails
- CERTs:
  - CIRCL Passive DNS: https://www.circl.lu/services/passive-dns/
  - CERT-EE: ?
  - BFK: Down, see https://www.bfk.de/bfk_dnslogger_en.html
    - Non public service may be still active: https://portal.bfk.de/

What have you learned?

- How to use DNS Response policy zones to blackhole traffic to/from malicious hosts/domains
- Utilize DNS to distribute and verify public key information
- Monitor DNS traffic for malicious activity

What has been left out?

- All this would not be secure if the integrity of the DNS itself can't be ascertained
- How do we do that? → DNSSEC, see you in the next module

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Thank you

Any questions?

Next module: ***DNSSEC***, 7th of December 2020

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References:

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- Vixie et al.: DNS Response Policy Zones (RPZ), `https://tools.ietf.org/html/draft-ietf-dnsop-dns-rpz-00`
- Building DNS Firewalls with Response Policy Zones (RPZ) `https://kb.isc.org/docs/aa-00525`
- Windows DNS Server Sinkhole Domains Tool, `https://www.sans.org/blog/windows-dns-server-sinkhole-domains-tool/`
- DANE Testsites: `https://www.huque.com/dane/testsite/`
- Hash-slinger - Generate and verify various DNS records such as SSHFP, TLSA and OPENPGPKEY: `https://github.com/letoams/hash-slinger`

Response Policy Zone Providers (Examples)

- Abuse.ch URLhaus `https://abuse.ch/blog/using-urlhaus-as-response-policy-zone-rpz/`
- CleanBrowsing `https://cleanbrowsing.org/filters`
- Deteque: `https://www.deteque.com/dns-firewall/`
- FarsightSecurity NOD: `https://www.farsightsecurity.com/Services/NOD/`
- RiskAnalytics Malwaredomains: `https://www.malwaredomains.com/`
- Malwaredomainlist: `https://www.malwaredomainlist.com/mdl.php`
- SpamHaus: `https://www.spamhaus.com/product/dns-firewall/`
- SURBL securityZONES: `http://www.surbl.org/df`
- **SWITCH DNS Firewall `https://swit.ch/dnsfirewall`**
- ThreatStop: `https://www.threatstop.com/solutions/threatstop-dns-firewall-overview`

References:

- SANS InfoSec Handlers Diary Blog: “Internet Choke Points: Concentration of Authoritative Name Servers”, https://isc.sans.edu/forums/diary/Internet+Choke+Points+Concentration+of+Authoritative+Name+Servers/26428/
- APNIC Blog: “Chromium’s impact on root DNS traffic”, https://blog.apnic.net/2020/08/21/chromiums-impact-on-root-dns-traffic/
- Domain Name System Operations Analysis and Research (DNS OARC), also maintains PacketQ, https://www.dns-oarc.net/
- Marchal et al.: “DNSSM: A Large Scale Passive DNS Security Monitoring Framework”, https://orbilu.uni.lu/bitstream/10993/13059/1/noms12 _cameraready.pdf
- Passive DNS monitoring with dnsmasq, rsyslog and Splunk, https://darthmdh.blogspot.com/2015/08/passive-dns-monitoring-with-dnsmasq.html
- Query multiple PDNS databases: Passive::DNS Client: https://github.com/tresni/passivedns-client
- dnstap: https://dnstap.info/

Requests For Comments (RFCs):

- RFC 4025, Richardson: A Method for Storing IPsec Keying Material in DNS, `https://tools.ietf.org/html/rfc4025`
- RFC 4255, “Using DNS to Securely Publish Secure Shell (SSH) Key Fingerprints”, `https://tools.ietf.org/html/rfc4255`
- RFC 6594, “Use of the SHA-256 Algorithm with RSA, Digital Signature Algorithm (DSA), and Elliptic Curve DSA (ECDSA) in SSHFP Resource Records”, `https://tools.ietf.org/html/rfc6594`
- RFC 6844, “DNS Certification Authority Authorization (CAA) Resource Record”, `https://tools.ietf.org/html/rfc6844`
- RFC 7479, “Using Ed25519 in SSHFP Resource Records”, `https://tools.ietf.org/html/rfc7479`
- RFC 8709, “Ed25519 and Ed448 Public Key Algorithms for the Secure Shell (SSH) Protocol”, `https://tools.ietf.org/html/rfc8709`