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Usage and (D)TLS Profiles for DNS-over-(D)TLS
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Abstract

   This document discusses Usage Profiles, based on one or more
   authentication mechanisms, which can be used for DNS over Transport
   Layer Security (TLS) or Datagram TLS (DTLS). These profiles can
   increase the privacy of DNS transactions compared to using only clear
   text DNS. This document also specifies new authentication mechanisms
   - it describes several ways a DNS client can use an authentication
   domain name to authenticate a (D)TLS connection to a DNS server.
   Additionally, it defines (D)TLS protocol profiles for DNS clients and
   servers implementing DNS-over-(D)TLS. This document updates RFC
   7858.

Status of This Memo

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1. Introduction

   DNS Privacy issues are discussed in [RFC7626]. The specific issues
   described there that are most relevant to this document are

   o Passive attacks which eavesdrop on clear text DNS transactions on
      the wire (Section 2.4) and

   o Active attacks which redirect clients to rogue servers to monitor
      DNS traffic (Section 2.5.3).

   Mitigating against these attacks increases the privacy of DNS
   transactions, however many of the other issues raised in [RFC7626]
   still apply.

   Two documents that provide ways to increase DNS privacy between DNS
   clients and DNS servers are:

   o Specification for DNS over Transport Layer Security (TLS)
      [RFC7858], referred to here as simply 'DNS-over-TLS'

   o DNS over Datagram Transport Layer Security (DTLS) [RFC8094],
      referred to here simply as 'DNS-over-DTLS'. Note that this
      document has the Category of Experimental.

   Both documents are limited in scope to communications between stub
   clients and recursive resolvers and the same scope is applied to this
   document (see Section 2 and Section 3). The proposals here might be
   adapted or extended in future to be used for recursive clients and
   authoritative servers, but this application was out of scope for the
   Working Group charter at the time this document was finished.

   This document specifies two Usage Profiles (Strict and Opportunistic)
   for DTLS [RFC6347] and TLS [RFC5246] which provide improved levels of
   mitigation against the attacks described above compared to using only
   clear text DNS.

Section 5 presents a generalized discussion of Usage Profiles by
separating the Usage Profile, which is based purely on the security
properties it offers the user, from the specific mechanism(s) that
are used for DNS server authentication. The Profiles described are:

o A Strict Profile that requires an encrypted connection and
   successful authentication of the DNS server which mitigates both
   passive eavesdropping and client re-direction (at the expense of
   providing no DNS service if this is not available).

o An Opportunistic Profile that will attempt, but does not require,
   encryption and successful authentication; it therefore provides
   limited or no mitigation against such attacks but offers maximum
   chance of DNS service.

The above Usage Profiles attempt authentication of the server using
at least one authentication mechanism. Section 6.4 discusses how to
combine authentication mechanisms to determine the overall
authentication result. Depending on that overall authentication
result (and whether encryption is available) the Usage Profile will
determine if the connection should proceed, fallback or fail.

One authentication mechanism is already described in [RFC7858]. That
document specifies a Subject Public Key Info (SPKI) based
authentication mechanism for DNS-over-TLS in the context of a
specific case of a Strict Usage Profile using that single
authentication mechanism. Therefore the "Out-of-band Key-pinned
Privacy Profile" described in [RFC7858] would qualify as a "Strict
Usage Profile" that used SPKI pinning for authentication.

This document extends the use of SPKI pinset based authentication so
that it is considered a general authentication mechanism that can be
used with either DNS-over-(D)TLS Usage Profile. That is, the SPKI
pinset mechanism described in [RFC7858] MAY be used with DNS-
over-(D)TLS.

This document also describes a number of additional authentication
mechanisms all of which specify how a DNS client should authenticate
a DNS server based on an 'authentication domain name'. In
particular, the following is described:

o How a DNS client can obtain the combination of an authentication
   domain name and IP address for a DNS server. See Section 7.

o What are the acceptable credentials a DNS server can present to
   prove its identity for (D)TLS authentication based on a given
   authentication domain name. See Section 8.

o How a DNS client can verify that any given credential matches the
   authentication domain name obtained for a DNS server. See
   Section 8.

In Section 9 this document defines a (D)TLS protocol profile for use
with DNS. This profile defines the configuration options and
protocol extensions required of both parties to optimize connection
establishment and session resumption for transporting DNS, and to
support all currently specified authentication mechanisms.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
"SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
document are to be interpreted as described in [RFC2119].

Several terms are used specifically in the context of this draft:

o DNS client: a DNS stub resolver or forwarder. In the case of a
   forwarder, the term "DNS client" is used to discuss the side that
   sends queries.

o DNS server: a DNS recursive resolver or forwarder. In the case of
   a forwarder, the term "DNS server" is used to discuss the side
   that responds to queries. For emphasis, in this document the term
   does not apply to authoritative servers.

o Privacy-enabling DNS server: A DNS server that implements DNS-
   over-TLS [RFC7858] and may optionally implement DNS-over-DTLS
   [RFC8094]. The server should also offer at least one of the
   credentials described in Section 8 and implement the (D)TLS
   profile described in Section 9.

o (D)TLS: For brevity this term is used for statements that apply to
   both Transport Layer Security [RFC5246] and Datagram Transport
   Layer Security [RFC6347]. Specific terms will be used for any
   statement that applies to either protocol alone.

o DNS-over-(D)TLS: For brevity this term is used for statements that
   apply to both DNS-over-TLS [RFC7858] and DNS-over-DTLS [RFC8094].
   Specific terms will be used for any statement that applies to
   either protocol alone.

o Authentication domain name: A domain name that can be used to
   authenticate a privacy-enabling DNS server. Sources of
   authentication domain names are discussed in Section 7.

o SPKI Pinsets: [RFC7858] describes the use of cryptographic digests
   to "pin" public key information in a manner similar to HTTP Public
   Key Pinning [RFC7469] (HPKP). An SPKI pinset is a collection of
   these pins that constrains a DNS server.

o Authentication information: Information a DNS client may use as
   the basis of an authentication mechanism. In this context that
   can be either a:

   * a SPKI pinset or

   * an authentication domain name

o Reference Identifier: a Reference Identifier as described in
   [RFC6125], constructed by the DNS client when performing TLS
   authentication of a DNS server.

o Credential: Information available for a DNS server which proves
   its identity for authentication purposes. Credentials discussed
   here include:

   * PKIX certificate

   * DNSSEC validated chain to a TLSA record

   but may also include SPKI pinsets.

3. Scope

This document is limited to describing

o Usage Profiles based on general authentication mechanisms

o The details of domain name based authentication of DNS servers by
   DNS clients (as defined in the terminology section)

o The (D)TLS profiles needed to support authentication in DNS-
   over-(D)TLS.

As such, the following things are out of scope:

o Authentication of authoritative servers by recursive resolvers.

o Authentication of DNS clients by DNS servers.

o The details of how to perform SPKI-pinset-based authentication.
   This is defined in [RFC7858].

o Any server identifier other than domain names, including IP
   addresses, organizational names, country of origin, etc.

4. Discussion

One way to mitigate against passive attackers eavesdropping on clear
text DNS transactions is to encrypt the query (and response). Such
encryption typically provides integrity protection as a side-effect,
which means on-path attackers cannot simply inject bogus DNS
responses. To also mitigate against active attackers pretending to
be the server, the client must authenticate the (D)TLS connection to
the server.

This document discusses Usage Profiles, which provide differing
levels of attack mitigation to DNS clients, based on the requirements
for authentication and encryption, regardless of the context (for
example, which network the client is connected to). A Usage Profile
is a distinct concept to a usage policy or usage model, which might
dictate which Profile should be used in a particular context
(enterprise vs coffee shop), with a particular set of DNS Servers or
with reference to other external factors. A description of the
variety of usage policies is out of scope of this document, but may
be the subject of future work.

The term 'privacy-enabling DNS server' is used throughout this
document. This is a DNS server that:

o MUST implement DNS-over-TLS [RFC7858].

o MAY implement DNS-over-DTLS [RFC8094].

o SHOULD offer at least one of the credentials described in
   Section 8.

o Implements the (D)TLS profile described in Section 9.

5. Usage Profiles

A DNS client has a choice of Usage Profiles available to increase the
privacy of DNS transactions. This choice is briefly discussed in
both [RFC7858] and [RFC8094]. These Usage Profiles are:

o Strict profile: the DNS client requires both an encrypted and
   authenticated connection to a privacy-enabling DNS Server. A hard
   failure occurs if this is not available. This requires the client
   to securely obtain authentication information it can use to
   authenticate the server. This profile mitigates against both
   passive and active attacks providing the client with the best

available privacy for DNS. This Profile is discussed in detail in
Section 6.6.

o Opportunistic Privacy: the DNS client uses Opportunistic Security
   as described in [RFC7435]

      "... the use of cleartext as the baseline communication
      security policy, with encryption and authentication negotiated
      and applied to the communication when available."

   As described in [RFC7435] it might result in

   * an encrypted and authenticated connection

   * an encrypted connection

   * a clear text connection

   depending on the fallback logic of the client, the available
   authentication information and the capabilities of the DNS Server.
   In all these cases the DNS client is willing to continue with a
   connection to the DNS Server and perform resolution of queries.
   The use of Opportunistic Privacy is intended to support
   incremental deployment of increased privacy with a view to
   widespread adoption of the Strict profile. It should be employed
   when the DNS client might otherwise settle for cleartext; it
   provides the maximum protection available depending on the
   combination of factors described above. If all the configured DNS
   Servers are DNS Privacy servers then it provides protection
   against passive attacks but not active ones.

Both profiles can include an initial meta query (performed using an
Opportunistic lookup) to obtain the IP address for the privacy-
enabling DNS server to which the DNS client will subsequently
connect. The rationale for permitting this for the Strict profile is
that requiring such meta queries to also be performed using the
Strict profile would introduce significant deployment obstacles.
However, it should be noted that in this scenario an active attack is
possible on the meta query. Such an attack could result in a Strict
profile client connecting to a server it cannot authenticate and so
not obtaining DNS service, or an Opportunistic Privacy client
connecting to a server controlled by the attacker. DNSSEC validation
can detect the attack on the meta query and results in the client not
obtaining DNS service (for both Usage profiles) because it will not
proceed to connect to the server in question (see Section 7.2)

To compare the two Usage profiles the table below shows a successful
Strict profile along side the 3 possible outcomes of an Opportunistic

profile. In the best case scenario for the Opportunistic profile (an
authenticated and encrypted connection) it is equivalent to the
Strict profile. In the worst case scenario it is equivalent to clear
text. Clients using the Opportunistic profile SHOULD try for the
best case but MAY fallback to the intermediate case and eventually
the worst case scenario in order to obtain a response. One reason to
fallback without trying every available privacy-enabling DNS server
is if latency is more important than attack mitigation, see
Appendix A. The Opportunistic profile therefore provides varying
protection depending on what kind of connection is actually used
including no attack mitigation at all.

Note that there is no requirement in Opportunistic Security to notify
the user what type of connection is actually used, the 'detection'
described below is only possible if such connection information is
available. However, if it is available and the user is informed that
an unencrypted connection was used to connect to a server then the
user should assume (detect) that the connection is subject to both
active and passive attack since the DNS queries are sent in clear
text. This might be particularly useful if a new connection to a
certain server is unencrypted when all previous connections were
encrypted. Similarly if the user is informed that an encrypted but
unauthenticated connection was used then the user can detect that the
connection may be subject to active attack. In other words for the
cases where no protection is provided against an attacker (N) it is
possible to detect that an attack might be happening (D). This is
discussed in Section 6.5.

```
+---------------+------------+-----------------+-----------------+
| Usage Profile | Connection | Passive Attacker | Active Attacker |
+---------------+------------+-----------------+-----------------+
|     Strict    |    A, E    |        P        |        P        |
| Opportunistic |    A, E    |        P        |        P        |
| Opportunistic |     E      |        P        |       N, D      |
| Opportunistic |            |                 |       N, D      |
+---------------+------------+-----------------+-----------------+
```

P == Protection; N == No protection; D == Detection is possible; A ==
        Authenticated connection; E == Encrypted connection

   Table 1: Attack protection by Usage Profile and type of attacker

The Strict profile provides the best attack mitigation and therefore
SHOULD always be implemented in DNS clients that implement
Opportunistic Privacy.

A DNS client that implements DNS-over-(D)TLS SHOULD NOT be configured
by default to use only clear text.

The choice between the two profiles depends on a number of factors including which is more important to the particular client:

o DNS service at the cost of no attack mitigation (Opportunistic) or

o best available attack mitigation at the potential cost of no DNS service (Strict).

Additionally the two profiles require varying levels of configuration (or a trusted relationship with a provider) and DNS server capabilities, therefore DNS clients will need to carefully select which profile to use based on their communication needs.

A DNS server that implements DNS-over-(D)TLS SHOULD provide at least one credential so that those DNS clients that wish to do so are able to use the Strict profile (see Section 2).

5.1. DNS Resolution

A DNS client SHOULD select a particular Usage Profile when resolving a query. A DNS client MUST NOT fallback from Strict Privacy to Opportunistic Privacy during the resolution of a given query as this could invalidate the protection offered against attackers. It is anticipated that DNS clients will use a particular Usage Profile for all queries to all configured servers until an operational issue or policy update dictates a change in the profile used.

6. Authentication in DNS-over(D)TLS

This section describes authentication mechanisms and how they can be used in either Strict or Opportunistic Privacy for DNS-over-(D)TLS.

6.1. DNS-over-(D)TLS Startup Configuration Problems

Many (D)TLS clients use PKIX authentication [RFC6125] based on an authentication domain name for the server they are contacting. These clients typically first look up the server's network address in the DNS before making this connection. Such a DNS client therefore has a bootstrap problem, as it will typically only know the IP address of its DNS server.

In this case, before connecting to a DNS server, a DNS client needs to learn the authentication domain name it should associate with the IP address of a DNS server for authentication purposes. Sources of authentication domain names are discussed in Section 7.

One advantage of this domain name based approach is that it encourages association of stable, human recognizable identifiers with secure DNS service providers.

6.2. Credential Verification

The use of SPKI pinset verification is discussed in [RFC7858].

In terms of domain name based verification, once an authentication domain name is known for a DNS server a choice of authentication mechanisms can be used for credential verification. Section 8 discusses these mechanisms in detail, namely PKIX certificate based authentication and DANE.

Note that the use of DANE adds requirements on the ability of the client to get validated DNSSEC results. This is discussed in more detail in Section 8.2.

6.3. Summary of Authentication Mechanisms

This section provides an overview of the various authentication mechanisms. The table below indicates how the DNS client obtains information to use for authentication for each option; either statically via direct configuration or dynamically. Of course, the Opportunistic Usage Profile does not require authentication and so a client using that profile may choose to connect to a privacy-enabling DNS server on the basis of just an IP address.

```
+---+-----------+------------+-----------------------------------+
| # | Static    | Dynamically| Short name: Description            |
|   | Config    | Obtained   |                                   |
+---+-----------+------------+-----------------------------------+
| 1 | SPKI + IP |            | SPKI: SPKI pinset(s) and IP       |
|   |           |            | address obtained out of band      |
|   |           |            | [RFC7858]                         |
|   |           |            |                                   |
| 2 | ADN + IP  |            | ADN: ADN and IP address obtained  |
|   |           |            | out of band (see Section 7.1)     |
|   |           |            |                                   |
| 3 | ADN       | IP         | ADN only: Opportunistic lookups to|
|   |           |            | a NP DNS server for A/AAAA (see   |
|   |           |            | Section 7.2)                      |
|   |           |            |                                   |
| 4 |           | ADN + IP   | DHCP: DHCP configuration only (see|
|   |           |            | Section 7.3.1)                    |
|   |           |            |                                   |
| 5 | [ADN + IP]| [ADN + IP] | DANE: DNSSEC chain obtained via   |
|   |           | TLSA record| Opportunistic lookups to NP DNS   |
|   |           |            | server (see Section 8.2.1)        |
|   |           |            |                                   |
| 6 | [ADN + IP]| [ADN + IP] | TLS extension: DNSSEC chain       |
|   |           | TLSA record| provided by PE DNS server in TLS  |
|   |           |            | DNSSEC chain extension (see       |
|   |           |            | Section 8.2.2)                    |
+---+-----------+------------+-----------------------------------+
```

SPKI == SPKI pinset(s), IP == IP Address, ADN == Authentication
Domain Name, NP == Network provided, PE == Privacy-enabling, [ ] ==
Data may be obtained either statically or dynamically

Table 2: Overview of Authentication Mechanisms

The following summary attempts to present some key attributes of each
of the mechanisms (using the 'Short name' from Table 2), indicating
attractive attributes with a '+' and undesirable attributes with a
'-'.

1. SPKI

        + Minimal leakage (Note that the ADN is always leaked in the
        Server Name Indication (SNI) field in the Client Hello in TLS
        when communicating with a privacy-enabling DNS server)

        - Overhead of on-going key management required

2. ADN

       + Minimal leakage

       + One-off direct configuration only

   3. ADN only

       + Minimal one-off direct configuration, only a human
       recognizable domain name needed

       - A/AAAA meta queries leaked to network provided DNS server
       that may be subject to active attack (attack can be mitigated
       by DNSSEC validation).

   4. DHCP

       + No static config

       - Requires a non-standard or future DHCP option in order to
       provide the ADN

       - Requires secure and trustworthy connection to DHCP server if
       used with a Strict Usage profile

   5. DANE

       The ADN and/or IP may be obtained statically or dynamically
       and the relevant attributes of that method apply

       + DANE options (e.g., matching on entire certificate)

       - Requires a DNSSEC validating stub implementation (deployment
       of which is limited at the time of writing)

       - DNSSEC chain meta queries leaked to network provided DNS
       server that may be subject to active attack

   6. TLS extension

       The ADN and/or IP may be obtained statically or dynamically
       and the relevant attributes of that method apply

       + Reduced latency compared with 'DANE'

       + No network provided DNS server required if ADN and IP
       statically configured

       + DANE options (e.g., matching on entire certificate)

        - Requires a DNSSEC validating stub implementation

6.4. Combining Authentication Mechanisms

   This draft does not make explicit recommendations about how an SPKI
   pinset based authentication mechanism should be combined with a
   domain based mechanism from an operator perspective. However it can
   be envisaged that a DNS server operator may wish to make both an SPKI
   pinset and an authentication domain name available to allow clients
   to choose which mechanism to use. Therefore, the following is
   guidance on how clients ought to behave if they choose to configure
   both, as is possible in HPKP [RFC7469].

   A DNS client that is configured with both an authentication domain
   name and a SPKI pinset for a DNS server SHOULD match on both a valid
   credential for the authentication domain name and a valid SPKI pinset
   (if both are available) when connecting to that DNS server. In this
   case the client SHOULD treat the SPKI pin as specified in Section 2.6
   of [RFC7469] with regard to user defined trust anchors. The overall
   authentication result SHOULD only be considered successful if both
   authentication mechanisms are successful.

6.5. Authentication in Opportunistic Privacy

   An Opportunistic Security [RFC7435] profile is described in [RFC7858]
   which MAY be used for DNS-over-(D)TLS.

   DNS clients issuing queries under an opportunistic profile and which
   know authentication information for a given privacy-enabling DNS
   server SHOULD try to authenticate the server using the mechanisms
   described here. This is useful for detecting (but not preventing)
   active attack, since the fact that authentication information is
   available indicates that the server in question is a privacy-enabling
   DNS server to which it should be possible to establish an
   authenticated and encrypted connection. In this case, whilst a
   client cannot know the reason for an authentication failure, from a
   security standpoint the client should consider an active attack in
   progress and proceed under that assumption. For example, a client
   that implements a nameserver selection algorithm that preferentially
   uses nameservers which successfully authenticated (see Section 5)
   might not continue to use the failing server if there were
   alternative servers available.

   Attempting authentication is also useful for debugging or diagnostic
   purposes if there are means to report the result. This information
   can provide a basis for a DNS client to switch to (preferred) Strict
   Privacy where it is viable e.g, where all the configured servers
   support DNS-over-(D)TLS and successfully authenticate.

6.6. Authentication in Strict Privacy

   To authenticate a privacy-enabling DNS server, a DNS client needs to
   know authentication information for each server it is willing to
   contact. This is necessary to protect against active attacks which
   attempt to re-direct clients to rogue DNS servers.

   A DNS client requiring Strict Privacy MUST either use one of the
   sources listed in Section 7 to obtain an authentication domain name
   for the server it contacts, or use an SPKI pinset as described in
   [RFC7858].

   A DNS client requiring Strict Privacy MUST only attempt to connect to
   DNS servers for which at least one piece of authentication
   information is known. The client MUST use the available verification
   mechanisms described in Section 8 to authenticate the server, and
   MUST abort connections to a server when no verification mechanism
   succeeds.

   With Strict Privacy, the DNS client MUST NOT commence sending DNS
   queries until at least one of the privacy-enabling DNS servers
   becomes available.

   A privacy-enabling DNS server may be temporarily unavailable when
   configuring a network. For example, for clients on networks that
   require registration through web-based login (a.k.a. "captive
   portals"), such registration may rely on DNS interception and
   spoofing. Techniques such as those used by DNSSEC-trigger
   [dnssec-trigger] MAY be used during network configuration, with the
   intent to transition to the designated privacy-enabling DNS servers
   after captive portal registration. If using a Strict Usage profile
   the system MUST alert by some means that the DNS is not private
   during such bootstrap.

6.7. Implementation guidance

   Section 9 describes the (D)TLS profile for DNS-over(D)TLS.
   Additional considerations relating to general implementation
   guidelines are discussed in both Section 11 and in Appendix A.

7. Sources of Authentication Domain Names

7.1. Full direct configuration

   DNS clients may be directly and securely provisioned with the
   authentication domain name of each privacy-enabling DNS server. For
   example, using a client specific configuration file or API.

In this case, direct configuration for a DNS client would consist of both an IP address and an authentication domain name for each DNS server.

7.2. Direct configuration of ADN only

A DNS client may be configured directly and securely with only the authentication domain name of each of its privacy-enabling DNS servers. For example, using a client specific configuration file or API.

A DNS client might learn of a default recursive DNS resolver from an untrusted source (such as DHCP's DNS server option [RFC3646]). It can then use Opportunistic DNS connections to an untrusted recursive DNS resolver to establish the IP address of the intended privacy-enabling DNS resolver by doing a lookup of A/AAAA records. Such records SHOULD be DNSSEC validated when using a Strict Usage profile and MUST be validated when using Opportunistic Privacy. Private DNS resolution can now be done by the DNS client against the pre-configured privacy-enabling DNS resolver, using the IP address gathered from the untrusted DNS resolver.

A DNS client so configured that successfully connects to a privacy-enabling DNS server MAY choose to locally cache the server host IP addresses in order to not have to repeat the opportunistic lookup.

7.3. Dynamic discovery of ADN

This section discusses the general case of a DNS client discovering both the authentication domain name and IP address dynamically. This is not possible at the time of writing by any standard means. However since, for example, a future DHCP extension could (in principle) provide this mechanism the required security properties of such mechanisms are outlined here.

When using a Strict profile the dynamic discovery technique used as a source of authentication domain names MUST be considered secure and trustworthy. This requirement does not apply when using an Opportunistic profile given the security expectation of that profile.

7.3.1. DHCP

In the typical case today, a DHCP server [RFC2131] [RFC3315] provides a list of IP addresses for DNS resolvers (see Section 3.8 of [RFC2132]), but does not provide an authentication domain name for the DNS resolver, thus preventing the use of most of the authentication methods described here (all those that are based on a mechanism with ADN in Table 2).

This document does not specify or request any DHCP extension to provide authentication domain names. However, if one is developed in future work the issues outlined in Section 8 of [RFC7227] should be taken into account as should the Security Considerations in Section 23 of [RFC3315]).

This document does not attempt to describe secured and trusted relationships to DHCP servers, which is a purely DHCP issue (still open, at the time of writing.) Whilst some implementation work is in progress to secure IPv6 connections for DHCP, IPv4 connections have received little to no implementation attention in this area.

8. Authentication Domain Name based Credential Verification

8.1. PKIX Certificate Based Authentication

When a DNS client configured with an authentication domain name connects to its configured DNS server over (D)TLS, the server may present it with a PKIX certificate. In order to ensure proper authentication, DNS clients MUST verify the entire certification path per [RFC5280]. The DNS client additionally uses [RFC6125] validation techniques to compare the domain name to the certificate provided.

A DNS client constructs one Reference Identifier for the server based on the authentication domain name: A DNS-ID which is simply the authentication domain name itself.

If the Reference Identifier is found in the PKIX certificate's subjectAltName extension as described in section 6 of [RFC6125], the DNS client should accept the certificate for the server.

A compliant DNS client MUST only inspect the certificate's subjectAltName extension for the Reference Identifier. In particular, it MUST NOT inspect the Subject field itself.

8.2. DANE

DANE [RFC6698] provides mechanisms to anchor certificate and raw public key trust with DNSSEC. However this requires the DNS client to have an authentication domain name for the DNS Privacy Server which must be obtained via a trusted source.

This section assumes a solid understanding of both DANE [RFC6698] and DANE Operations [RFC7671]. A few pertinent issues covered in these documents are outlined here as useful pointers, but familiarity with both these documents in their entirety is expected.

It is noted that [RFC6698] says

"Clients that validate the DNSSEC signatures themselves MUST use
standard DNSSEC validation procedures. Clients that rely on
another entity to perform the DNSSEC signature validation MUST use
a secure mechanism between themselves and the validator."

It is noted that [RFC7671] covers the following topics:

o Section 4.1: Opportunistic Security and PKIX Usages and
   Section 14: Security Considerations, which both discuss the use of
   Trust Anchor and End Entity based schemes (PKIX-TA(0) and PKIX-
   EE(1) respectively) for Opportunistic Security.

o Section 5: Certificate-Usage-Specific DANE Updates and Guidelines.
   Specifically Section 5.1 which outlines the combination of
   Certificate Usage DANE-EE(3) and Selector Usage SPKI(1) with Raw
   Public Keys [RFC7250]. Section 5.1 also discusses the security
   implications of this mode, for example, it discusses key lifetimes
   and specifies that validity period enforcement is based solely on
   the TLSA RRset properties for this case.

o Section 13: Operational Considerations, which discusses TLSA TTLs
   and signature validity periods.

The specific DANE record for a DNS Privacy Server would take the
form:

   _853._tcp.[authentication-domain-name] for TLS

   _853._udp.[authentication-domain-name] for DTLS

8.2.1. Direct DNS Lookup

The DNS client MAY choose to perform the DNS lookups to retrieve the
required DANE records itself. The DNS queries for such DANE records
MAY use Opportunistic encryption or be in the clear to avoid trust
recursion. The records MUST be validated using DNSSEC as described
above in [RFC6698].

8.2.2. TLS DNSSEC Chain extension

The DNS client MAY offer the TLS extension described in
[I-D.ietf-tls-dnssec-chain-extension]. If the DNS server supports
this extension, it can provide the full chain to the client in the
handshake.

If the DNS client offers the TLS DNSSEC Chain extension, it MUST be
capable of validating the full DNSSEC authentication chain down to
the leaf. If the supplied DNSSEC chain does not validate, the client

MUST ignore the DNSSEC chain and validate only via other supplied
credentials.

9. (D)TLS Protocol Profile

This section defines the (D)TLS protocol profile of DNS-over-(D)TLS.

Clients and servers MUST adhere to the (D)TLS implementation
recommendations and security considerations of [RFC7525] except with
respect to (D)TLS version.

Since encryption of DNS using (D)TLS is a green-field deployment DNS
clients and servers MUST implement only (D)TLS 1.2 or later. For
example, implementing TLS 1.3 [I-D.ietf-tls-tls13] is also an option.

Implementations MUST NOT offer or provide TLS compression, since
compression can leak significant amounts of information, especially
to a network observer capable of forcing the user to do an arbitrary
DNS lookup in the style of the CRIME attacks [CRIME].

Implementations compliant with this profile MUST implement all of the
following items:

o TLS session resumption without server-side state [RFC5077] which
   eliminates the need for the server to retain cryptographic state
   for longer than necessary (This statement updates [RFC7858]).

o Raw public keys [RFC7250] which reduce the size of the
   ServerHello, and can be used by servers that cannot obtain
   certificates (e.g., DNS servers on private networks). A client
   MUST only indicate support for raw public keys if it has an SPKI
   pinset pre-configured (for interoperability reasons).

Implementations compliant with this profile SHOULD implement all of
the following items:

o TLS False Start [RFC7918] which reduces round-trips by allowing
   the TLS second flight of messages (ChangeCipherSpec) to also
   contain the (encrypted) DNS query.

o Cached Information Extension [RFC7924] which avoids transmitting
   the server's certificate and certificate chain if the client has
   cached that information from a previous TLS handshake.

Guidance specific to TLS is provided in [RFC7858] and that specific
to DTLS it is provided in [RFC8094].

10. IANA Considerations

   This memo includes no request to IANA.

11. Security Considerations

   Security considerations discussed in [RFC7525], [RFC8094] and
   [RFC7858] apply to this document.

   DNS Clients SHOULD implement support for the mechanisms described in
   Section 8.2 and offering a configuration option which limits
   authentication to using only those mechanisms (i.e., with no fallback
   to pure PKIX based authentication) such that authenticating solely
   via the PKIX infrastructure can be avoided.

11.1. Counter-measures to DNS Traffic Analysis

   This section makes suggestions for measures that can reduce the
   ability of attackers to infer information pertaining to encrypted
   client queries by other means (e.g., via an analysis of encrypted
   traffic size, or via monitoring of resolver to authoritative
   traffic).

   DNS-over-(D)TLS clients and servers SHOULD implement the following
   relevant DNS extensions

   o EDNS(0) padding [RFC7830], which allows encrypted queries and
      responses to hide their size making analysis of encrypted traffic
      harder.

   Guidance on padding policies for EDNS(0) is provided in
   [I-D.ietf-dprive-padding-policy]

   DNS-over-(D)TLS clients SHOULD implement the following relevant DNS
   extensions

   o Privacy Election using Client Subnet in DNS Queries [RFC7871]. If
      a DNS client does not include an EDNS0 Client Subnet Option with a
      SOURCE PREFIX-LENGTH set to 0 in a query, the DNS server may
      potentially leak client address information to the upstream
      authoritative DNS servers. A DNS client ought to be able to
      inform the DNS Resolver that it does not want any address
      information leaked, and the DNS Resolver should honor that
      request.

12. Acknowledgments

Thanks to the authors of both [RFC8094] and [RFC7858] for laying the ground work that this draft builds on and for reviewing the contents. The authors would also like to thank John Dickinson, Shumon Huque, Melinda Shore, Gowri Visweswaran, Ray Bellis, Stephane Bortzmeyer, Jinmei Tatuya, Paul Hoffman, Christian Huitema and John Levine for review and discussion of the ideas presented here.

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Appendix A. Server capability probing and caching by DNS clients

   This section presents a non-normative discussion of how DNS clients
   might probe for and cache capabilities of privacy-enabling DNS
   servers.

   Deployment of both DNS-over-TLS and DNS-over-DTLS will be gradual.
   Not all servers will support one or both of these protocols and the
   well-known port might be blocked by some middleboxes. Clients will
   be expected to keep track of servers that support DNS-over-TLS and/or
   DNS-over-DTLS, and those that have been previously authenticated.

   If no server capability information is available then (unless
   otherwise specified by the configuration of the DNS client) DNS
   clients that implement both TLS and DTLS should try to authenticate
   using both protocols before failing or falling back to a
   unauthenticated or clear text connections. DNS clients using an
   Opportunistic Usage profile should try all available servers
   (possibly in parallel) in order to obtain an authenticated and
   encrypted connection before falling back. (RATIONALE: This approach
   can increase latency while discovering server capabilities but
   maximizes the chance of sending the query over an authenticated and
   encrypted connection.)

Appendix B. Changes between revisions

   [Note to RFC Editor: please remove this section prior to
   publication.]

B.1. -11 version

   Section 5: Re-ordered and re-worded the text in section on
   Opportunistic profile to make the protection offered by Opportunistic
   clearer.

   Section 5: Provide a more detailed analysis of attacks on the meta
   queries

   Section 7.2: Re-introduce a requirement to DNSSEC validate the meta-
   queries making it as SHOULD for Strict and a MUST for Opportunistic.

B.2. -10 version

   Clarified the specific attacks the Usage profiles mitigate against.

   Revised wording in the draft relating 'security/privacy guarantees'
   and generally improved consistency of wording throughout the
   document.

   Corrected and added a number of references:

   o   RFC7924 is now Normative

   o   RFC7918 and RFC8094 are now Normative (and therefore Downrefs)

   o   draft-ietf-tls-tls13, draft-ietf-dprive-padding-policy, RFC3315
       and RFC7227 added

   Terminology: Update definition of Privacy-enabling DNS server and
   moved normative definition to section 4.

   Section 5 and 6.3: Included discussion of the additional attacks
   possible when using meta-queries to bootstrap the DNS service

   Section 5: Added sentence on why Opportunistic Profile may fallback
   for latency reasons.

   Section 5.1: Added discussion of when clients might change Usage
   Profiles.

   Section 6.4: Added caveat on use of combined authentication re
   RFC7469.

   Section 6.5: Added more detail on how authentication results might be
   used in Opportunistic. Opportunistic clients now SHOULD try for the
   best case.

Section 7.3: Re-worked this section and the discussion of DHCP.

Section 9: Removed unnecessary text, added condition on use of
RFC7250 (Raw public keys).

Section 11.: More detail on padding policies.

Numerous editorial corrections.

B.3. -09 version

Remove the SRV record to simplify the draft.

Add suggestion that clients offer option to avoid using only PKIX
authentication.

Clarify that the MUST on implementing TLS session resumption updates
RFC7858.

Update page header to be '(D)TLS Authentication for TLS'.

B.4. -08 version

Removed hard failure as an option for Opportunistic Usage profile.

Added a new section comparing the Authentication Mechanisms

B.5. -07 version

Re-work of the Abstract and Introduction to better describe the
contents in this version.

Terminology: New definition of 'authentication information'.

Scope: Changes to the Scope section.

Moved discussion of combining authentication mechanism earlier.

Changes to the section headings and groupings to make the
presentation more logical.

B.6. -06 version

Introduction: Re-word discussion of Working group charter.

Introduction: Re-word first and third bullet point about 'obtaining'
a domain name and IP address.

Introduction: Update reference to DNS-over-TLS draft.

Terminology: Change forwarder/proxy to just forwarder

Terminology: Add definition of 'Authentication domain name' and use this throughout

Section 4.2: Remove parenthesis in the table.

Section 4.2: Change the text after the table as agreed with Paul Hoffman.

Section 4.3.1: Change title and remove brackets around last statement.

Section 11: Split second paragraph.

B.7. -05 version

Add more details on detecting passive attacks to section 4.2

Changed X.509 to PKIX throughout

Change comment about future I-D on usage policies.

B.8. -04 version

Introduction: Add comment that DNS-over-DTLS draft is Experiments

Update 2 I-D references to RFCs.

B.9. -03 version

Section 9: Update DANE section with better references to RFC7671 and RFC7250

B.10. -02 version

Introduction: Added paragraph on the background and scope of the document.

Introduction and Discussion: Added more information on what a Usage profiles is (and is not) the the two presented here.

Introduction: Added paragraph to make a comparison with the Strict profile in RFC7858 clearer.

   Section 4.2: Re-worked the description of Opportunistic and the
   table.

   Section 8.3: Clarified statement about use of DHCP in Opportunistic
   profile

   Title abbreviated.

B.11. -01 version

   Section 4.2: Make clear that the Strict Privacy Profile can include
   meta queries performed using Opportunistic Privacy.

   Section 4.2, Table 1: Update to clarify that Opportunistic Privacy
   does not guarantee protection against passive attack.

   Section 4.2: Add sentence discussing client/provider trusted
   relationships.

   Section 5: Add more discussion of detection of active attacks when
   using Opportunistic Privacy.

   Section 8.2: Clarify description and example.

B.12. draft-ietf-dprive-dtls-and-tls-profiles-00

   Re-submission of draft-dgr-dprive-dtls-and-tls-profiles with name
   change to draft-ietf-dprive-dtls-and-tls-profiles. Also minor nits
   fixed.

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