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Establishing Local DNS Authority in Validated Split-Horizon Environments

Abstract

When split-horizon DNS is deployed by a network, certain domains can
be resolved authoritatively by the network-provided DNS resolver.
DNS clients that don't always use this resolver might wish to do so
for these domains. This specification defines a mechanism for domain
owners to inform clients about local resolvers that are authorized
to answer authoritatively for certain subdomains.

Discussion Venues

This note is to be removed before publishing as an RFC.

Discussion of this document takes place on the Adaptive DNS
Discovery Working Group mailing list (add@ietf.org), which is
archived at https://mailarchive.ietf.org/arch/browse/add/.

Source for this draft and an issue tracker can be found at https://
github.com/ietf-wg-add/draft-ietf-add-split-horizon-authority.

Status of This Memo

This Internet-Draft is submitted in full conformance with the
provisions of BCP 78 and BCP 79.

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This Internet-Draft will expire on 9 September 2023.

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1. Introduction

To resolve a DNS query, there are three essential behaviors that an implementation can apply: (1) answer from a local database, (2) query the relevant authorities and their parents, or (3) ask a server to query those authorities and return the final answer. Implementations that use these behaviors are called "authoritative nameservers", "full resolvers", and "forwarders" (or "stub resolvers"). However, an implementation can also implement a mixture of these behaviors, depending on a local policy, for each query. We term such an implementation a "hybrid resolver".

Most DNS resolvers are hybrids of some kind. For example, stub resolvers frequently support a local "hosts file" that preempts query forwarding, and most DNS forwarders and full resolvers can also serve responses from a local zone file. Other standardized hybrid resolution behaviors include Local Root [RFC8806], mDNS [RFC6762], and NXDOMAIN synthesis for .onion [RFC7686].

In many network environments, the network offers clients a DNS server (e.g. DHCP OFFER, IPv6 Router Advertisement). Although this server is formally specified as a recursive resolver (e.g. Section 5.1 of [RFC8106]), some networks provide a hybrid resolver instead. If this resolver acts as an authoritative server for some names, we say that the network has "split-horizon DNS", because those names resolve in this way only from inside the network.

Network clients that use pure stub resolution, sending all queries to the network-provided resolver, will always receive the split-horizon results. Conversely, clients that send all queries to a different resolver or implement pure full resolution locally will never receive them. Clients that strictly implement either of these resolution behaviors are out of scope for this specification. Instead, this specification enables hybrid clients to access split-horizon results from a network-provided hybrid resolver, while using a different resolution method for some or all other names.

There are several existing mechanisms for a network to provide clients with "local domain hints", listing domain names that have special treatment in this network (e.g., RDNSS Selection [RFC6731], "Access Network Domain Name" [RFC5986], and "Client FQDN" [RFC4702] [RFC4704] in DHCP, "dnsZones" in Provisioning Domains [RFC8801], and INTERNAL_DNS_DOMAIN [RFC8598] in IKEv2). However, none of the local domain hint mechanisms enable clients to determine whether this special treatment is authorized by the domain owner. Instead, these specifications require clients to make their own determinations about whether to trust and rely on these hints.

This specification describes a protocol between domains, networks, and clients that allows the network to establish its authority over a domain to a client (Section 5). Clients can use this protocol to confirm that a local domain hint was authorized by the domain (Section 6), which might influence its processing of that hint. This process requires cooperation between the local DNS zone and the public zone.

This specification relies on securely identified local DNS servers, and checks each local domain hint against a globally valid parent zone. Use of this specification is therefore limited to servers that support authenticated encryption and split-horizon DNS names that are rooted in the global DNS.

2. Terminology

The key words "**MUST**", "**MUST NOT**", "**REQUIRED**", "**SHALL**", "**SHALL NOT**", "**SHOULD**", "**SHOULD NOT**", "**RECOMMENDED**", "**NOT RECOMMENDED**", "**MAY**", and "**OPTIONAL**" in this document are to be interpreted as described in BCP 14 [RFC2119][RFC8174] when, and only when, they appear in all capitals, as shown here.

This document makes use of the terms defined in [RFC8499], e.g. "Global DNS". The following additional terms are used throughout the document:

Encrypted DNS A DNS protocol that provides an encrypted channel between a DNS client and server (e.g., DoT, DoH, or DoQ).

Split-Horizon DNS The DNS service provided by a resolver that also acts as an authoritative server for some names, providing resolution results that are meaningfully different from those in the Global DNS. (See "Split DNS" in Section 6 of [RFC8499].)

Validated Split-Horizon A split horizon configuration for some name is considered "validated" if the client has confirmed that a parent of that name has authorized this resolver to serve its own responses for that name. Such authorization generally extends to the entire subtree of names below the authorization point.

3. Scope

The protocol in this document is designed to support the ability of a domain owner to create or authorize a split-horizon view of their domain. The protocol does not support split-horizon views created by any other entity. Thus, DNS filtering is not enabled by this protocol.

The protocol is applicable to any type of network offering split-horizon DNS configuration. The endpoint does not need any prior

configuration to confirm that a local domain hint was indeed
authorized by the domain.

All of the special-use domain names registered with IANA
[IANA-SUDN], most notably ".home.arpa", "resolver.arpa.",
"ipv4only.arpa." and ".local", are never unique to a specific DNS
server's authority. All special-use domain names are outside the
scope of this document and MUST NOT be validated using the mechanism
described in this document.

4. Requirements

This solution seeks to fulfill the following requirements:

  *No loss of security: No unauthorized party can impersonate a zone
   unless they could already do so without use of this
   specification.

  *Least privilege: Local resolvers do not hold any secrets that
   could weaken the security of the public zone if compromised.

  *Local zone confidentiality: The specification does not leak local
   network subdomains to anyone outside of the network.

  *Flexibility: The specification can represent and authorize any
   reasonable Split DNS zone structure.

  *DNSSEC Compatibility: The specification supports DNSSEC-based
   object security for local zone contents.

5. Establishing Local DNS Authority

To establish its authority over some DNS zone, a participating
network **MUST** offer one or more encrypted resolvers via DNR
[I-D.ietf-add-dnr], DDR [I-D.ietf-add-ddr], or an equivalent
mechanism (see Section 9).

To establish local authority, the network MUST convey one or more
"Authorization Claims" to the client. An "Authorization Claim" is an
abstract structure comprising:

  *An Authentication Domain Name (ADN) of a local encrypted
   resolver.

  *The DNS name of the authorizing parent zone.

  *A set of subdomains of this parent zone that are claimed by the
   named local resolver (potentially including the entire parent
   zone).

*A ZONEMD Hash Algorithm ([Section 5.3](#) of [[RFC8976](#)]).

*A high-entropy salt, up to 255 octets.

If the local encrypted resolver is identified by name (e.g., DNR), that identifying name MUST be the one used in any corresponding Authorization Claim. Otherwise (e.g., DDR using IP addresses), the resolver MUST present a validatable certificate containing a subjectAltName that matches the Authorization Claim.

To establish its authority, the network MUST provide each Authorization Claim to the parent zone operator. If the contents are approved, the parent zone operator computes a "Verification Token" according to the following procedure:

1. Convert all subdomains into canonical form and sort them in canonical order ([Section 6](#) of [[RFC4034](#)]).

2. Replace the suffix corresponding to the parent zone with a zero byte.

3. Let $X be the concatenation of the resulting pseudo-FQDNs.

4. Let len($SALT) be the number of octets of salt, as a single octet.

5. Let $TOKEN = hash(len($SALT) || $SALT || $X).

The zone operator then publishes a "Verification Record" with the following structure, following the advice of [[I-D.ietf-dnsop-domain-verification-techniques](#)]:

*Type = TXT.

*Owner Name = Concatenation of the ADN, "_splitdns-challenge", and the parent zone name.

*Contents = "token=base64url($TOKEN)" (without padding)

By publishing this record, the parent zone authorizes the local encrypted resolver to serve these subdomains authoritatively.

5.1. Example

Consider the following authorization claim:

*ADN = "resolver17.parent.example"

*Parent = "parent.example"

*Subdomains = "payroll.parent.example",
     "secret.project.parent.example"

    *Hash Algorithm = SHA-384

    *Salt = "example salt bytes (should be random)"

  To approve this claim, the zone operator would publish the following
  record (using [RFC8792] line-wrapping):

  resolver17.parent.example._splitdns-challenge.parent.example. IN TXT \
  "token=6rQ7oOZqdg8qQFRqtxpEhK97mNkgFwzNKTmNOtlxspBscZqUwFZZJDDD- \
  Djetw2MCg"

5.2. Conveying Authorization Claims

  The Authorization Claim is an abstract structure that must be
  encoded in some concrete syntax in order to convey it from the
  network to the client. This section defines some encodings of the
  Authorization Claims.

5.2.1. Using DHCP

  In DHCP, each Authorization Claim is encoded as a DHCP
  Authentication Option [RFC3118], using the Protocol value $TBD1,
  "Split DNS Authentication". The Algorithm field provides the ZONEMD
  Hash Algorithm, represented by its registered Value. The RDM value
  MUST be 0x00. The Authentication Information **MUST** contain the
  following information, concatenated:

   1. The ADN in canonical form.

   2. The parent name in canonical form.

   3. A one-octet "salt length" field.

   4. The salt value.

   5. The $X value defined in Section 5.

5.2.2. Using Provisioning Domains

  When using Provisioning Domains [RFC8801], the Authorization Claims
  are represented by the PvD Additional Information key
  "splitDnsClaims", whose value is a JSON Array. Each entry in the
  array **MUST** be a JSON object with the following structure:

    *"resolver": The ADN as a dot-separated name.

    *"parent": The parent zone name as a dot-separated name.

*"subdomains": An array containing the claimed subdomains, as dot-
 separated names with the parent suffix already removed, in
 canonical order.

*"algorithm": The hash algorithm, identified by its IANA-
 registered Mnemonic.

*"salt": The salt, encoded in base64url.

6. Validating Authority over Local Domain Hints

To validate an Authorization Claim provided by the network,
participating clients **MUST** resolve the Verification Record for that
name. If the resolution produces an RRSet containing the expected
token for this Claim, the client **SHALL** regard the named resolver as
authoritative for the claimed subdomains. Clients **MUST** ignore any
unrecognized keys in the Verification Record.

Each validation of authority applies only to a specific
Authentication Domain Name. If a network offers multiple encrypted
resolvers, each claimed subdomain may be authorized for a distinct
subset of the network-provided resolvers.

A zone is termed a "Validated Split-Horizon zone" after successful
validation using a "tamperproof" DNS resolution method, i.e. a
method that is not subject to interference by the local network
operator. Two possible tamperproof resolution methods are presented
below.

6.1. Using a Pre-configured External Resolver

This method applies only if the client is already configured with a
default resolution strategy that sends queries to a resolver outside
of the network over a secure transport. That resolution strategy is
considered "tamperproof" because any actor who could modify the
response could already modify all of the user's other DNS responses.

To ensure that this assumption holds, clients **MUST NOT** relax the
acceptance rules they would otherwise apply when using this
resolver. For example, if the client would check the AD bit or
validate RRSIGs locally when using this resolver, it must also do so
when resolving TXT records for this purpose. Alternatively, a client
might perform DNSSEC validation for the verification query even if
it has disabled DNSSEC validation for other DNS queries.

6.2. Using DNSSEC

The client resolves the Verification Record using any resolution
method of its choice (e.g. querying one of the network-provided
resolvers, performing iterative resolution locally), and performs

full DNSSEC validation locally [RFC6698]. The result is processed
based on its DNSSEC validation state ([RFC4035], Section 4.3):

   Secure: The response is used for validation.

   Bogus or **Indeterminate**: The response is rejected and validation
   is considered to have failed.

   Insecure: The client **SHOULD** retry the validation process using a
   different method, such as the one in Section 6.1, to ensure
   compatibility with unsigned names.

7. Delegating DNSSEC across Split DNS Boundaries

We wish to enable DNSSEC validation of local DNS names without
requiring the local resolver to hold DNSSEC private keys that are
valid for the parent zone. To support this configuration, parent
zones **MAY** add a "ds=..." key to the Verification Record whose value
is the RDATA of a single DS record, base64url-encoded. This DS
record authorizes a DNSKEY whose Owner Name is "resolver.arpa."

To validate DNSSEC, the client first fetches and validates the
Verification Record. If it is valid and contains a "ds" key, the
client **MAY** send a DNSKEY query for "resolver.arpa." to the local
encrypted resolver. At least one resulting DNSKEY RR **MUST** match the
DS RDATA from the "ds" key in the Verification Record. All local
resolution results for subdomains in this claim **MUST** offer RRSIGs
that chain to one of these approved DNSKEYs.

The "ds" key **MAY** appear multiple times in a single Verification
Record, in order to authorize multiple DNSKEYs for this local
encrypted resolver. If the "ds" key is not present in a valid
Verification Record, the client **MUST** disable DNSSEC validation when
resolving the claimed subdomains via this local encrypted resolver.

```
;; Parent zone
$ORIGIN parent.example.

; Parent zone's public KSK and ZSK
@ IN DNSKEY 257 3 5 ABCD...=
@ IN DNSKEY 256 3 5 DCBA...=

; Verification Record containing DS RDATA for the local
; resolver's KSK.  This is an ordinary public TXT record,
; secured by RRSIGs from the public ZSK.
resolver.example._splitdns-challenge IN TXT "token=abc...,ds=QWE..."

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

;; Local zone, claiming "subdomain.parent.example".

; The local resolver's KSK, validated by the Verification Record.
resolver.arpa. IN DNSKEY 257 3 5 ASDF...=

; Each claimed subdomain has its own ZSK, which is signed by the
; KSK and is used to sign records at that subdomain and below.
subdomain.parent.example.        IN DNSKEY 256 3 5 FDSA...=
subdomain.parent.example.        IN AAAA 2001:db8::17
deeper.subdomain.parent.example. IN AAAA 2001:db8::18
```

                     Figure 1: Example use of "ds=..."

8. Examples of Split-Horizon DNS Configuration

   Two examples are shown below. The first example shows a company with
   an internal-only DNS server that claims the entire zone for that
   company (e.g., *.example.com). In the second example, the internal
   servers resolves only a subdomain of the company's zone (e.g.,
   *.internal.example.com).

8.1. Split-Horizon Entire Zone

   Consider an organization that operates "example.com", and runs a
   different version of its global domain on its internal network.

   First, the host and network both need to support one of the
   discovery mechanisms described in Section 5. Figure 2 shows
   discovery using DNR and PvD.

   Validation is then perfomed using either an external resolver
   (Section 8.1.1) or DNSSEC (Section 8.1.2).

      Steps 1-2: The client determines the network's DNS server
      (dns.example.net) and Provisioning Domain (pvd.example.com) using

DNR [I-D.ietf-add-dnr] and PvD [RFC8801], using one of DNR Router
Solicitation, DHCPv4, or DHCPv6.

Step 3-5: The client connects to dns.example.net using an
encrypted transport as indicated in DNR [I-D.ietf-add-dnr],
authenticating the server to its name using TLS ([RFC8310],
Section 8), and sends it a query for the address of
pvd.example.com.

Steps 6-7: The client connects to the PvD server, validates its
certificate, and retrieves the provisioning domain JSON
information indicated by the associated PvD. The PvD contains:

```
{
  "identifier": "pvd.example.com",
  "expires": "2020-05-23T06:00:00Z",
  "prefixes": ["2001:db8:1::/48", "2001:db8:4::/48"],
  "splitDnsClaims": [{
    "resolver": "dns.example.net",
    "parent": "example.com",
    "subdomains": [""],
    "algorithm": "SHA384",
    "salt": "abc...123"
  }]
}
```

The JSON keys "identifier", "expires", and "prefixes" are defined
in [RFC8801].

```
+---------+          +--------------------+  +------------+ +--------+
| Client  |          | Network's          |  | Network    | | Router |
|         |          | Encrypted Resolver |  | PvD Server | |        |
+---------+          +--------------------+  +------------+ +--------+
    |                         |                   |              |
    | Router Solicitation or  |                   |              |
    | DHCPv4/DHCPv6 (1)        |                   |              |
    |--------------------------------------------------------------->|
    |                         |                   |              |
    |   Response with DNR hostnames &             |              |
    |   PvD FQDN (2)          |                   |              |
    |<-------------------------------------------------------------|
    | ----------------------------\              |              |
    |-| now knows DNR hostnames & |              |              |
    | | PvD FQDN                  |              |              |
    | |--------------------------/               |              |
    |                         |                   |              |
    | TLS connection to dns.example.net (3)       |              |
    |------------------------------------>|        |              |
    | --------------------------\         |        |              |
    |-| validate TLS certificate |        |        |              |
    | |-------------------------/         |        |              |
    |                         |                   |              |
    | resolve pvd.example.com  (4)        |        |              |
    |------------------------------------>|        |              |
    |                         |                   |              |
    |           A or AAAA records (5)     |        |              |
    |<------------------------------------|        |              |
    |                         |                   |              |
    | https://pvd.example.com/.well-known/pvd (6)  |              |
    |--------------------------------------------->|              |
    |                         |                   |              |
    |   200 OK (JSON Additional Information) (7)    |              |
    |<---------------------------------------------|              |
    | ------------------------------\ |           |              |
    |-| {..., "splitDnsClaims": [...] } | |        |              |
    | |------------------------------/ |           |              |
```

               Figure 2: Learning Local Claims of DNS Authority

8.1.1. Verification using an external resolver

   The figure below shows the steps performed to verify the local
   claims of DNS authority using an external resolver.

      Steps 1-2: The client uses an encrypted DNS connection to an
      external resolver (e.g., 1.1.1.1) to issue TXT queries for the
      Verification Records. The TXT lookup returns a token that matches
      the claim.

Step 3: The client has validated that example.com has authorized
dns.example.net to serve example.com. When the client connects
using an encrypted transport as indicated in DNR
[I-D.ietf-add-dnr], it will authenticate the server to its name
using TLS ([RFC8310], Section 8), and send queries to resolve any
names that fall within the claimed zones.

```
+---------+                        +--------------------+  +----------+
| Client  |                        | Network's          |  | External |
|         |                        | Encrypted Resolver |  | Resolver |
+---------+                        +--------------------+  +----------+
     |                                       |             |
     | TLS connection                        |             |
     |------------------------------------------------------->|
     | --------------------------\           |             |
     |-| validate TLS certificate |          |             |
     | |--------------------------|          |             |
     |                                       |             |
     | TXT? dns.example.net.\                 |             |
     |    _splitdns-challenge.example.com  (1)  |          |
     |--------------------------------------------------------->|
     |                                       |             |
     |   TXT "token=ABC..."                (2) |           |
     |<-------------------------------------------------------|
     | ------------------------------\       |             |
     |-| dns.example.net is authorized |     |             |
     | ----------------------\---------|     |             |
     |-| finished validation |               |             |
     | |--------------------|                |             |
     |                                       |             |
     |   use dns.example.net when            |             |
     |   resolving example.com (3)           |             |
     |------------------------------------------>|          |
     |                                       |             |
```

             Figure 3: Verifying claims using an external resolver

8.1.2. Verification using DNSSEC

   The figure below shows the steps performed to verify the local
   claims of DNS authority using DNSSEC.

   Steps 1-2: The DNSSEC-validating client queries the network
   encrypted resolver to issue TXT queries for the Verification
   Records. The TXT lookup will return a signed response containing
   the expected token. The client then performs full DNSSEC
   validation locally.

Step 3: The DNSSEC validation is successful and the token
matches, so this Authorization Claim is validated. When the
client connects using an encrypted transport as indicated in DNR
[I-D.ietf-add-dnr], it will authenticate the server to its name
using TLS ([RFC8310], Section 8), and send queries to resolve any
names that fall within the claimed zones.

```
+---------+                              +-------------------+
| Client  |                              | Network's         |
|         |                              | Encrypted Resolver |
+---------+                              +-------------------+
   |                                                         |
   | DNSSEC OK (DO), TXT? dns.example.net.\                  |
   |   _splitdns-challenge.example.com  (1)                 |
   |------------------------------------------------------->|
   |                                                         |
   | TXT token=DEF..., Signed Answer (RRSIG) (2)            |
   |<-------------------------------------------------------|
   | -------------------------------------\                 |
   |-| DNSKEY+TXT matches RRSIG, use TXT  |                 |
   | |-----------------------------------|                  |
   | -------------------------------\                       |
   |-| dns.example.net is authorized |                      |
   | |------------------------------|                       |
   | ---------------------\                                 |
   |-| finished validation |                                |
   | |--------------------|                                 |
   |                                                         |
   | use encrypted network-designated resolver for example.com (3) |
   |------------------------------------------------------->|
   |                                                         |
```

Figure 4: Verifying claims using DNSSEC

8.2. Internal-only Subdomains

In many split-horizon deployments, all non-public domain names are
placed in a separate child zone (e.g., internal.example.com). In
this configuration, the message flow is similar to Section 8.1,
except that queries for hosts not within the subdomain (e.g.,
www.example.com) are sent to the external resolver rather than the
resolver for internal.example.com.

As in Section 8.1, the internal DNS server will need a certificate
signed by a CA trusted by the client.

9. Validation with IKEv2

When the VPN tunnel is IPsec, the encrypted DNS resolver hosted by
the VPN service provider can be securely discovered by the endpoint
using the ENCDNS_IP*_* IKEv2 Configuration Payload Attribute Types
defined in [I-D.ietf-ipsecme-add-ike].

Other VPN tunnel types have similar configuration capabilities, not
detailed here.

10. Security Considerations

If an internal zone name (e.g., internal.example.com) is used with
this specification and a public certificate is obtained for
validation, that internal zone name will exist in Certificate
Transparency logs [RFC9162]. In order to not leak the internal
domains to an external resolver, the internal domains can be kept in
a child zone of the local domain hints advertised by the network.
For example, if the PvD "dnsZones" entry is "internal.example.com"
and the network-provided DNS resolver is "ns1.internal.example.com",
the network operator can structure the internal domain names as
"private1.internal.example.com", "private2.internal.example.com",
etc. The network-designated resolver will be used to resolve the
subdomains of the local domain hint "*.internal.example.com".
Further, adversaries that monitor a network such as through passive
monitoring or active probing of protocols, such as DHCP will only
learn the local domain hints but not learn the labels below
internal.example.com. However, security by obscurity may not
maintain or increase the security of the internal domain names, as
they may be leaked in various other ways (e.g., browser reload).

The Authentication Domain Names of authorized local encrypted
resolvers are revealed in the Owner Names of Verification Records.
This makes it easier for domain owners to understand which resolvers
they are currently authorizing to implement Split DNS, but it could
create a confidentiality problem if the local encrypted resolver's
name is inside a secret subdomain. To avoid leakage, local resolvers
should be given a name that does not reveal any sensitive
information (perhaps in addition to the more sensitive name).

11. IANA Considerations

11.1. DHCP Split DNS Authentication Algorithm

IANA is requested to add the following entry to the "Protocol Name
Space Values" registry on the "Dynamic Host Configuration Protocol
(DHCP) Authentication Option Name Spaces" page:

   *Value: $TBD1

*Description: Split DNS

   *Reference: (This Document)

11.2. Provisioning Domains Split DNS Additional Information

   IANA is requested to add the following entry to the "Additional
   Information PvD Keys" registry on the "Provisioning Domains (PvDs)"
   page:

   *JSON key: "splitDnsClaims"

   *Description: "Verifiable locally served domains"

   *Type: Array of Objects

   *Example:

```
 [{
   "resolver": "dns.example.net",
   "parent": "example.com",
   "subdomains": ["sub"],
   "algorithm": "SHA384",
   "salt": "abc...123"
 }]
```

   *Reference: (This document)

11.3. DNS Underscore Name

   IANA is requested to add the following entry to the "Underscored and
   Globally Scoped DNS Node Names" registry on the "Domain Name System
   (DNS) Parameters" page:

   *RR Type: TXT

   *_NODE NAME: _splitdns-challenge

   *Reference: (This document)

12. Acknowledgements

   Thanks to Mohamed Boucadair, Jim Reid, Tommy Pauly, Paul Vixie,
   Michael Richardson and Vinny Parla for the discussion and comments.

13. References

13.1. Normative References

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