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Discovery of Encrypted DNS Resolvers: Deployment Considerations  
draft-boucadair-add-deployment-considerations-00

#### Abstract

The document discusses some deployment considerations of the various options to discover encrypted DNS servers (e.g., DNS-over-HTTPS, DNS-over-TLS, DNS-over-QUIC).

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## 1. Introduction

[I-D.ietf-add-dnr] specifies how a local encrypted DNS server can be discovered by connected hosts by means of DHCP [RFC2132], DHCPv6 [RFC8415], and IPv6 Router Advertisement (RA) [RFC4861] options. These options are designed to convey the following information: the DNS Authentication Domain Name (ADN), a list of IP addresses, and a set of service parameters.

This document discusses deployment considerations for the discovery of encrypted DNS servers such as DNS-over-HTTPS (DoH) [RFC8484], DNS-over-TLS (DoT) [RFC7858], or DNS-over-QUIC (DoQ) [I-D.ietf-dprive-dnsquic] in local networks.

Sample target deployment scenarios are discussed in Section 3; both managed and unmanaged Customer Premises Equipment (CPEs) are covered.

It is out of the scope of this document to provide an exhaustive inventory of deployments where Encrypted DNS options can be used.

Considerations related to hosting a DNS forwarder in a local network are described in Section 4.

## 2. Terminology

This document makes use of the terms defined in [RFC8499]. The following additional terms are used:

Do53: refers to unencrypted DNS.

Encrypted DNS: refers to a scheme where DNS exchanges are transported over an encrypted channel. Examples of encrypted DNS are DNS-over-TLS (DoT) [RFC7858], DNS-over-HTTPS (DoH) [RFC8484], or DNS-over-QUIC (DoQ) [I-D.ietf-dprive-dnsquic].

Encrypted DNS options: refers to the options defined in [I-D.ietf-add-dnr].

Managed CPE: refers to a CPE that is managed by an Internet Service Provider (ISP).

Unmanaged CPE: refers to a CPE that is not managed by an ISP.

DHCP: refers to both DHCPv4 and DHCPv6.

## 3. Sample Target Deployment Scenarios

ISPs traditionally provide DNS resolvers to their customers. To that aim, ISPs deploy the following mechanisms to advertise a list of DNS Recursive DNS server(s) to their customers:

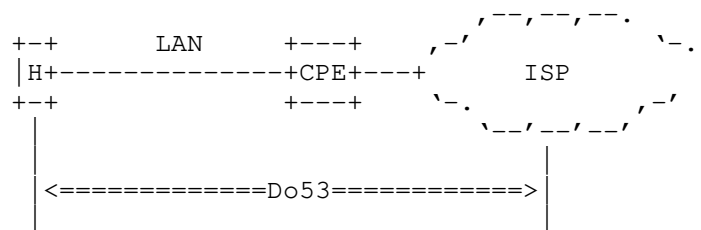
- o Protocol Configuration Options in cellular networks [TS.24008].
- o DHCPv4 [RFC2132] (Domain Name Server Option) or DHCPv6 [RFC8415][RFC3646] (OPTION\_DNS\_SERVERS).
- o IPv6 Router Advertisement [RFC4861][RFC8106] (Type 25 (Recursive DNS Server Option)).

The communication between a customer's device (possibly via Customer Premises Equipment (CPE)) and an ISP-supplied DNS resolver takes place by using cleartext DNS messages (Do53). Some examples are depicted in Figure 1. In the case of cellular networks, the cellular network will provide connectivity directly to a host (e.g., smartphone, tablet) or via a CPE. Do53 mechanisms used within the

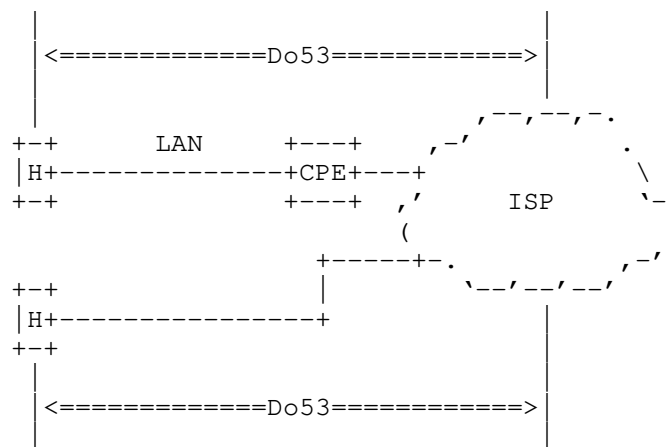
Local Area Network (LAN) are similar in both fixed and cellular CPE-based broadband service offerings.

Some ISPs rely upon external resolvers (e.g., outsourced service or public resolvers); these ISPs provide their customers with the IP addresses of these resolvers. These addresses are typically configured on CPEs using dedicated management tools. Likewise, users can modify the default DNS configuration of their CPEs (e.g., supplied by their ISP) to configure their favorite DNS servers. This document permits such deployments.

(a) Fixed Networks



(b) Cellular Networks



Legend:

\* H: refers to a host.

Figure 1: Sample Legacy Deployments

### 3.1. Managed CPEs

This section focuses on CPEs that are managed by ISPs.

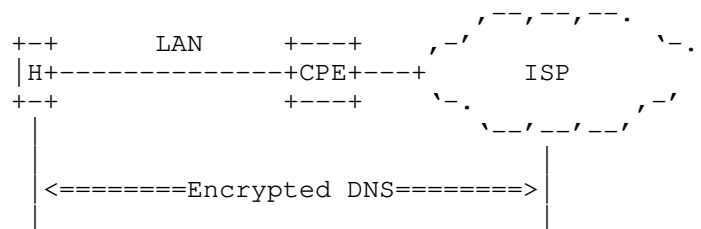
#### 3.1.1. Direct DNS

ISPs have developed an expertise in managing service-specific configuration information (e.g., CPE WAN Management Protocol [TR-069]). For example, these tools may be used to provision the DNS server's ADN to managed CPEs if an encrypted DNS is supported by a local network similar to what is depicted in Figure 2.

For example, DoH-capable (or DoT) clients establish the DoH (or DoT) session with the discovered DoH (or DoT) server.

The DNS client discovers whether the DNS server in the local network supports DoH/DoT/DoQ by using the service parameters (ALPN).

(a) Fixed Networks



(b) Cellular Networks

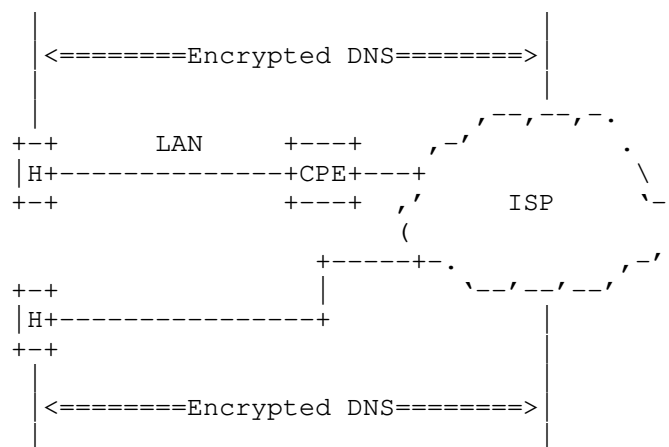


Figure 2: Encrypted DNS in the WAN

Figure 2 shows the scenario where the CPE relays the list of encrypted DNS servers it learns for the network by using mechanisms like DHCP or a specific Router Advertisement message. In such context, direct encrypted DNS sessions will be established between a host serviced by a CPE and an ISP-supplied encrypted DNS server (see the example depicted in Figure 3 for a DoH/DoT-capable host).

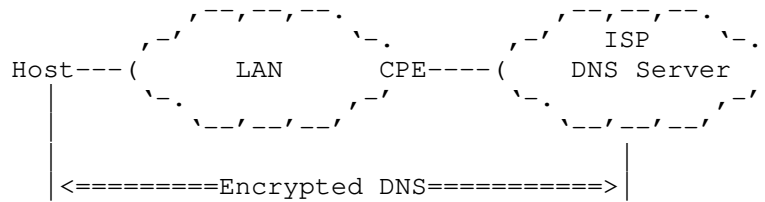


Figure 3: Direct Encrypted DNS Sessions

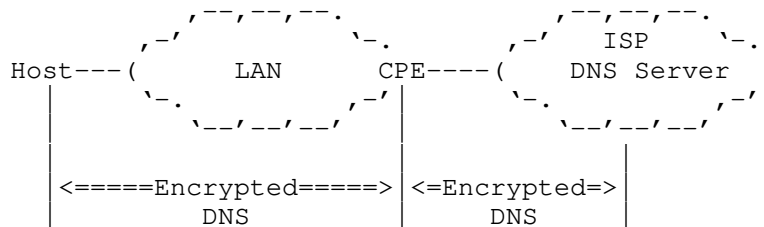
### 3.1.2. Proxied DNS

Figure 4 shows a deployment where the CPE embeds a caching DNS forwarder. The CPE advertises itself as the default DNS server to the hosts it serves. The CPE relies upon DHCP or RA to advertise itself to internal hosts as the default DoT/DoH/Do53 server. When receiving a DNS request it cannot handle locally, the CPE forwards the request to an upstream DoH/DoT/Do53 resolver. Such deployment is required for IPv4 service continuity purposes (e.g., Section 5.4.1 of [I-D.ietf-v6ops-rfc7084-bis]) or for supporting advanced services within a local network (e.g., malware filtering, parental control, Manufacturer Usage Description (MUD) [RFC8520] to only allow intended communications to and from an IoT device). When the CPE behaves as a DNS forwarder, DNS communications can be decomposed into two legs:

- o The leg between an internal host and the CPE.
- o The leg between the CPE and an upstream DNS resolver.

An ISP that offers encrypted DNS to its customers may enable encrypted DNS in one or both legs as shown in Figure 4. Additional considerations related to this deployment are discussed in Section 4.

(a)



(b)

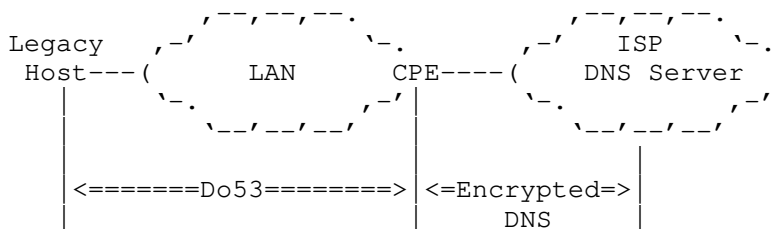


Figure 4: Proxied Encrypted DNS Sessions

### 3.2. Unmanaged CPEs

#### 3.2.1. ISP-facing Unmanaged CPEs

Customers may decide to deploy unmanaged CPEs (assuming the CPE is compliant with the network access technical specification that is usually published by ISPs). Upon attachment to the network, an unmanaged CPE receives from the network its service configuration (including the DNS information) by means of, e.g., DHCP. That DNS information is shared within the LAN following the same mechanisms as those discussed in Section 3.1. A host can thus establish DoH/DoT session with a DoH/DoT server similar to what is depicted in Figure 3 or Figure 4.

#### 3.2.2. Internal Unmanaged CPEs

Customers may also decide to deploy internal routers (called hereafter, Internal CPEs) for a variety of reasons that are not detailed here. Absent any explicit configuration on the internal CPE to override the DNS configuration it receives from the ISP-supplied CPE, an Internal CPE relays the DNS information it receives via DHCP/RA from the ISP-supplied CPE to connected hosts. Encrypted DNS sessions can be established by a host with the DNS servers of the ISP (see Figure 5).

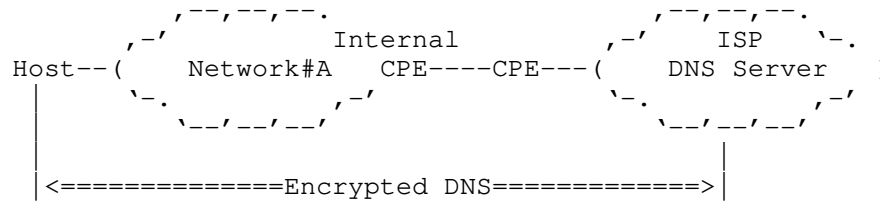


Figure 5: Direct Encrypted DNS Sessions with the ISP DNS Resolver (Internal CPE)

Similar to managed CPEs, a user may modify the default DNS configuration of an unmanaged CPE to use his/her favorite DNS servers instead. Encrypted DNS sessions can be established directly between a host and a 3rd Party DNS server (see Figure 6).

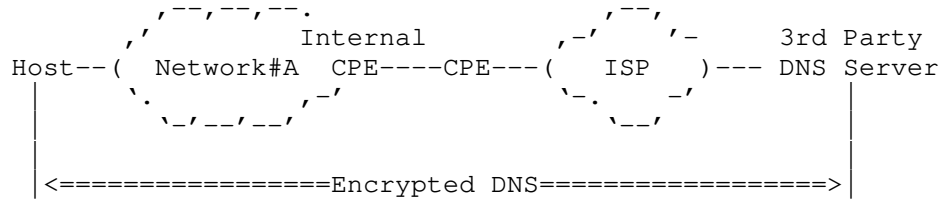


Figure 6: Direct Encrypted DNS Sessions with a Third Party DNS Resolver

Section 4.2 discusses considerations related to hosting a forwarder in the Internal CPE.

#### 4. Hosting Encrypted DNS Forwarder in Local Networks

This section discusses some deployment considerations to host an encrypted DNS forwarder within a local network.

##### 4.1. Managed CPEs

The section discusses mechanisms that can be used to host an encrypted DNS forwarder in a managed CPE (Section 3.1).

##### 4.1.1. DNS Forwarders

The managed CPE should support a configuration parameter to instruct the CPE whether it has to relay the encrypted DNS server received from the ISP's network or has to announce itself as a forwarder within the local network. The default behavior of the CPE is to supply the encrypted DNS server received from the ISP's network.



#### 4.1.2. ACME

The ISP can assign a unique FQDN (e.g., "cpel.example.com") and a domain-validated public certificate to the encrypted DNS forwarder hosted on the CPE. Automatic Certificate Management Environment (ACME) [RFC8555] can be used by the ISP to automate certificate management functions such as domain validation procedure, certificate issuance and certificate revocation.

#### 4.2. Unmanaged CPEs

The approach specified in Section 4.1 does not apply for hosting a DNS forwarder in an unmanaged CPE.

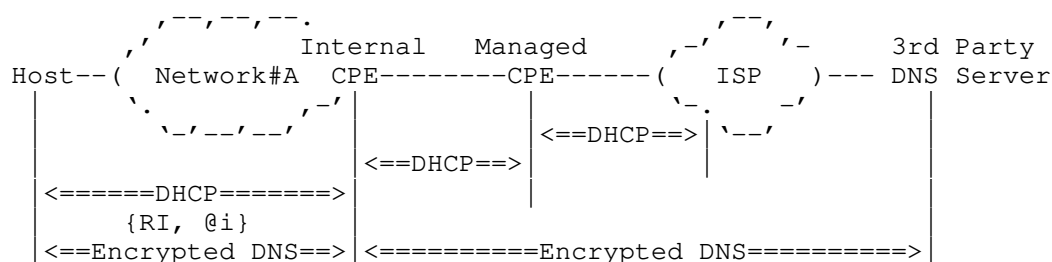
The unmanaged CPE administrator can host an encrypted DNS forwarder on the unmanaged CPE. This assumes the following:

- o The encrypted DNS server certificate is managed by the entity in-charge of hosting the encrypted DNS forwarder.

Alternatively, a security service provider can assign a unique FQDN to the CPE. The encrypted DNS forwarder will act like a private encrypted DNS server only be accessible from within the local network.

- o The encrypted DNS forwarder will either be configured to use the ISP's or a 3rd party encrypted DNS server.
- o The unmanaged CPE will advertise the encrypted DNS forwarder ADN using DHCP/RA to internal hosts.

Figure 7 illustrates an example of an unmanaged CPE hosting a forwarder which connects to a 3rd party encrypted DNS server. In this example, the DNS information received from the managed CPE (and therefore from the ISP) is ignored by the Internal CPE hosting the forwarder.



Legend:

\* @i: IP address of the DNS forwarder hosted in the Internal CPE.

Figure 7: Example of an Internal CPE Hosting a Forwarder

## 5. Legacy CPEs

Hosts serviced by legacy CPEs that can't be upgraded to support the options defined in Sections 4, 5, and 6 of [I-D.ietf-add-dnr] won't be able to learn the encrypted DNS server hosted by the ISP, in particular. If the ADN is not discovered using DHCP/RA, such hosts will have to fallback to use discovery using the resolver IP address as defined in Section 4 of [I-D.ietf-add-ddr] to discover the designated resolvers.

The guidance in Sections 4.1 and 4.2 of [I-D.ietf-add-ddr] related to the designated resolver verification has to be followed in such case.

## 6. Security Considerations

DNR-related security considerations are discussed in Section 7 of [I-D.ietf-add-dnr].

## 7. IANA Considerations

This document does not require any IANA action.

## 8. Acknowledgements

This text was initially part of [I-D.ietf-add-dnr].

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Discovery of Designated Resolvers  
draft-ietf-add-ddr-06

Abstract

This document defines Discovery of Designated Resolvers (DDR), a mechanism for DNS clients to use DNS records to discover a resolver's encrypted DNS configuration. This mechanism can be used to move from unencrypted DNS to encrypted DNS when only the IP address of a resolver is known. This mechanism is designed to be limited to cases where unencrypted resolvers and their designated resolvers are operated by the same entity or cooperating entities. It can also be used to discover support for encrypted DNS protocols when the name of an encrypted resolver is known.

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](mailto: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-ddr>.

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## 1. Introduction

When DNS clients wish to use encrypted DNS protocols such as DNS-over-TLS (DoT) [RFC7858] or DNS-over-HTTPS (DoH) [RFC8484], they require additional information beyond the IP address of the DNS server, such as the resolver's hostname, non-standard ports, or URL paths. However, common configuration mechanisms only provide the resolver's IP address during configuration. Such mechanisms include network provisioning protocols like DHCP [RFC2132] and IPv6 Router Advertisement (RA) options [RFC8106], as well as manual configuration.

This document defines two mechanisms for clients to discover designated resolvers using DNS server Service Binding (SVCB, [I-D.ietf-dnsop-svcb-https]) records:

1. When only an IP address of an Unencrypted Resolver is known, the client queries a special use domain name (SUDN) [RFC6761] to discover DNS SVCB records associated with one or more Encrypted Resolvers the Unencrypted Resolver has designated for use when support for DNS encryption is requested (Section 4).
2. When the hostname of an Encrypted Resolver is known, the client requests details by sending a query for a DNS SVCB record. This can be used to discover alternate encrypted DNS protocols supported by a known server, or to provide details if a resolver name is provisioned by a network (Section 5).

Both of these approaches allow clients to confirm that a discovered Encrypted Resolver is designated by the originally provisioned resolver. "Designated" in this context means that the resolvers are operated by the same entity or cooperating entities; for example, the resolvers are accessible on the same IP address, or there is a certificate that claims ownership over the IP address for the original designating resolver.

### 1.1. Specification of Requirements

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.

## 2. Terminology

This document defines the following terms:



DDR: Discovery of Designated Resolvers. Refers to the mechanisms defined in this document.

Designated Resolver: A resolver, presumably an Encrypted Resolver, designated by another resolver for use in its own place. This designation can be verified with TLS certificates.

Encrypted Resolver: A DNS resolver using any encrypted DNS transport. This includes current mechanisms such as DoH and DoT as well as future mechanisms.

Unencrypted Resolver: A DNS resolver using TCP or UDP port 53.

### 3. DNS Service Binding Records

DNS resolvers can advertise one or more Designated Resolvers that may offer support over encrypted channels and are controlled by the same entity.

When a client discovers Designated Resolvers, it learns information such as the supported protocols and ports. This information is provided in ServiceMode Service Binding (SVCB) records for DNS Servers, although AliasMode SVCB records can be used to direct clients to the needed ServiceMode SVCB record per [I-D.ietf-dnsop-svcb-https]. The formatting of these records, including the DNS-unique parameters such as "dohpath", are defined by [I-D.ietf-add-svcb-dns].

The following is an example of an SVCB record describing a DoH server discovered by querying for `_dns.example.net`:

```
_dns.example.net. 7200 IN SVCB 1 example.net. (  
    alpn=h2 dohpath=/dns-query{?dns} )
```

The following is an example of an SVCB record describing a DoT server discovered by querying for `_dns.example.net`:

```
_dns.example.net 7200 IN SVCB 1 dot.example.net (  
    alpn=dot port=8530 )
```

If multiple Designated Resolvers are available, using one or more encrypted DNS protocols, the resolver deployment can indicate a preference using the priority fields in each SVCB record [I-D.ietf-dnsop-svcb-https].

If the client encounters a mandatory parameter in an SVCB record it does not understand, it MUST NOT use that record to discover a Designated Resolver. The client can still use others records in the

same response if the client can understand all of their mandatory parameters. This allows future encrypted deployments to simultaneously support protocols even if a given client is not aware of all those protocols. For example, if the Unencrypted Resolver returns three SVCB records, one for DoH, one for DoT, and one for a yet-to-exist protocol, a client which only supports DoH and DoT should be able to use those records while safely ignoring the third record.

To avoid name lookup deadlock, Designated Resolvers SHOULD follow the guidance in Section 10 of [RFC8484] regarding the avoidance of DNS-based references that block the completion of the TLS handshake.

This document focuses on discovering DoH and DoT Designated Resolvers. Other protocols can also use the format defined by [I-D.ietf-add-svcb-dns]. However, if any protocol does not involve some form of certificate validation, new validation mechanisms will need to be defined to support validating designation as defined in Section 4.2.

#### 4. Discovery Using Resolver IP Addresses

When a DNS client is configured with an Unencrypted Resolver IP address, it SHOULD query the resolver for SVCB records for "dns://resolver.arpa" before making other queries. Specifically, the client issues a query for \_dns.resolver.arpa with the SVCB resource record type (64) [I-D.ietf-dnsop-svcb-https].

Because this query is for an SUDN, which no entity can claim ownership over, the ServiceMode SVCB response MUST NOT use the "." value for the TargetName. Instead, the domain name used for DoT or used to construct the DoH template MUST be provided.

The following is an example of an SVCB record describing a DoH server discovered by querying for \_dns.resolver.arpa:

```
_dns.resolver.arpa 7200 IN SVCB 1 doh.example.net (  
    alpn=h2 dohpath=/dns-query{?dns} )
```

The following is an example of an SVCB record describing a DoT server discovered by querying for \_dns.resolver.arpa:

```
_dns.resolver.arpa 7200 IN SVCB 1 dot.example.net (  
    alpn=dot port=8530 )
```

If the recursive resolver that receives this query has one or more Designated Resolvers, it will return the corresponding SVCB records. When responding to these special queries for "dns://resolver.arpa",

the recursive resolver SHOULD include the A and AAAA records for the name of the Designated Resolver in the Additional Answers section. This will allow the DNS client to make queries over an encrypted connection without waiting to resolve the Encrypted Resolver name per [I-D.ietf-dnsop-svcb-https]. If no A/AAAA records or SVCB IP address hints are included, clients will be forced to delay use of the Encrypted Resolver until an additional DNS lookup for the A and AAAA records can be made to the Unencrypted Resolver (or some other resolver the DNS client has been configured to use).

If the recursive resolver that receives this query has no Designated Resolvers, it SHOULD return NODATA for queries to the "resolver.arpa" SUDN.

#### 4.1. Use of Designated Resolvers

When a client discovers Designated Resolvers from an Unencrypted Resolver IP address, it can choose to use these Designated Resolvers either automatically, or based on some other policy, heuristic, or user choice.

This document defines two preferred methods to automatically use Designated Resolvers:

- \* Verified Discovery Section 4.2, for when a TLS certificate can be used to validate the resolver's identity.
- \* Opportunistic Discovery Section 4.3, for when a resolver is accessed using a non-public IP address.

A client MAY additionally use a discovered Designated Resolver without either of these methods, based on implementation-specific policy or user input. Details of such policy are out of scope of this document. Clients SHOULD NOT automatically use a Designated Resolver without some sort of validation, such as the two methods defined in this document or a future mechanism.

A client MUST NOT use a Designated Resolver designated by one Unencrypted Resolver in place of another Unencrypted Resolver. As these are known only by IP address, this means each unique IP address used for unencrypted DNS requires its own designation discovery. This ensures queries are being sent to a party designated by the resolver originally being used.

Generally, clients also SHOULD NOT reuse the Designated Resolver discovered from an Unencrypted Resolver over one network connection in place of the same Unencrypted Resolver on another network connection. Instead, clients SHOULD repeat the discovery process on the other network connection.

However, if a given Unencrypted Resolver designates a Designated Resolver that uses a public IP address and can be verified using the mechanism described in Section 4.2, it MAY be used on different network connections so long as the subsequent connections over other networks can also be successfully verified using the mechanism described in Section 4.2. This is a tradeoff between performance (by having no delay in establishing an encrypted DNS connection on the new network) and functionality (if the Unencrypted Resolver intends to designate different Designated Resolvers based on the network from which clients connect).

#### 4.2. Verified Discovery

Verified Discovery is a mechanism that allows automatic use of a Designated Resolver that supports DNS encryption that performs a TLS handshake.

In order to be considered a verified Designated Resolver, the TLS certificate presented by the Designated Resolver MUST contain the IP address of the designating Unencrypted Resolver in a subjectAltName extension. If the certificate can be validated, the client SHOULD use the discovered Designated Resolver for any cases in which it would have otherwise used the Unencrypted Resolver. If the Designated Resolver has a different IP address than the Unencrypted Resolver and the TLS certificate does not cover the Unencrypted Resolver address, the client MUST NOT automatically use the discovered Designated Resolver. Additionally, the client SHOULD suppress any further queries for Designated Resolvers using this Unencrypted Resolver for the length of time indicated by the SVCB record's Time to Live (TTL).

If the Designated Resolver and the Unencrypted Resolver share an IP address, clients MAY choose to opportunistically use the Designated Resolver even without this certificate check (Section 4.3).

If resolving the name of a Designated Resolver from an SVCB record yields an IP address that was not presented in the Additional Answers section or ipv4hint or ipv6hint fields of the original SVCB query, the connection made to that IP address MUST pass the same TLS certificate checks before being allowed to replace a previously known and validated IP address for the same Designated Resolver name.

#### 4.3. Opportunistic Discovery

There are situations where Verified Discovery of encrypted DNS configuration over unencrypted DNS is not possible. This includes Unencrypted Resolvers on non-public IP addresses such as those defined in [RFC1918] whose identity cannot be confirmed using TLS certificates.

Opportunistic Privacy is defined for DoT in Section 4.1 of [RFC7858] as a mode in which clients do not validate the name of the resolver presented in the certificate. A client MAY use information from the SVCB record for "dns://resolver.arpa" with this "opportunistic" approach (not validating the names presented in the SubjectAlternativeName field of the certificate) as long as the IP address of the Encrypted Resolver does not differ from the IP address of the Unencrypted Resolver. Clients SHOULD use this mode only for resolvers using non-public IP addresses. This approach can be used for any encrypted DNS protocol that uses TLS.

#### 5. Discovery Using Resolver Names

A DNS client that already knows the name of an Encrypted Resolver can use DDR to discover details about all supported encrypted DNS protocols. This situation can arise if a client has been configured to use a given Encrypted Resolver, or if a network provisioning protocol (such as DHCP or IPv6 Router Advertisements) provides a name for an Encrypted Resolver alongside the resolver IP address.

For these cases, the client simply sends a DNS SVCB query using the known name of the resolver. This query can be issued to the named Encrypted Resolver itself or to any other resolver. Unlike the case of bootstrapping from an Unencrypted Resolver (Section 4), these records SHOULD be available in the public DNS.

For example, if the client already knows about a DoT server resolver.example.com, it can issue an SVCB query for \_dns.resolver.example.com to discover if there are other encrypted DNS protocols available. In the following example, the SVCB answers indicate that resolver.example.com supports both DoH and DoT, and that the DoH server indicates a higher priority than the DoT server.

```
_dns.resolver.example.com. 7200 IN SVCB 1 resolver.example.com. (
  alpn=h2 dohpath=/dns-query{?dns} )
_dns.resolver.example.com. 7200 IN SVCB 1 resolver.example.com. (
  alpn=dot )
```

Clients MUST validate that for any Encrypted Resolver discovered using a known resolver name, the TLS certificate of the resolver contains the known name in a subjectAltName extension. In the example above, this means that both servers need to have certificates that cover the name resolver.example.com. Often, the various supported encrypted DNS protocols will be specified such that the SVCB TargetName matches the known name, as is true in the example above. However, even when the TargetName is different (for example, if the DoH server had a TargetName of doh.example.com), the clients still check for the original known resolver name in the certificate.

Note that this resolver validation is not related to the DNS resolver that provided the SVCB answer.

As another example, being able to discover a Designated Resolver for a known Encrypted Resolver is useful when a client has a DoT configuration for foo.resolver.example.com but is on a network that blocks DoT traffic. The client can still send a query to any other accessible resolver (either the local network resolver or an accessible DoH server) to discover if there is a designated DoH server for foo.resolver.example.com.

## 6. Deployment Considerations

Resolver deployments that support DDR are advised to consider the following points.

### 6.1. Caching Forwarders

A DNS forwarder SHOULD NOT forward queries for "resolver.arpa" upstream. This prevents a client from receiving an SVCB record that will fail to authenticate because the forwarder's IP address is not in the upstream resolver's Designated Resolver's TLS certificate SAN field. A DNS forwarder which already acts as a completely blind forwarder MAY choose to forward these queries when the operator expects that this does not apply, either because the operator knows the upstream resolver does have the forwarder's IP address in its TLS certificate's SAN field or that the operator expects clients of the unencrypted resolver to use the SVCB information opportunistically.

Operators who choose to forward queries for "resolver.arpa" upstream should note that client behavior is never guaranteed and use of DDR by a resolver does not communicate a requirement for clients to use the SVCB record when it cannot be verified.

## 6.2. Certificate Management

Resolver owners that support Verified Discovery will need to list valid referring IP addresses in their TLS certificates. This may pose challenges for resolvers with a large number of referring IP addresses.

## 6.3. Server Name Handling

Clients MUST NOT use "resolver.arpa" as the server name either in the TLS Server Name Indication (SNI) ([RFC8446]) for DoT or DoH connections, or in the URI host for DoH requests.

When performing discovery using resolver IP addresses, clients MUST use the IP address as the URI host for DoH requests.

Note that since IP addresses are not supported by default in the TLS SNI, resolvers that support discovery using IP addresses will need to be configured to present the appropriate TLS certificate when no SNI is present for both DoT and DoH.

## 6.4. Handling non-DDR queries for resolver.arpa

DNS resolvers that support DDR by responding to queries for `_dns.resolver.arpa` SHOULD treat `resolver.arpa` as a locally served zone per [RFC6303]. In practice, this means that resolvers SHOULD respond to queries of any type other than SVCB for `_dns.resolver.arpa` with NODATA and queries of any type for any domain name under `resolver.arpa` with NODATA.

## 6.5. Interaction with Network-Designated Resolvers

Discovery of network-designated resolvers (DNR, [I-D.ietf-add-dnr]) allows a network to provide designation of resolvers directly through DHCP [RFC2132] [RFC8415] and IPv6 Router Advertisement (RA) [RFC4861] options. When such indications are present, clients can suppress queries for "resolver.arpa" to the unencrypted DNS server indicated by the network over DHCP or RAs, and the DNR indications SHOULD take precedence over those discovered using "resolver.arpa" for the same resolver if there is a conflict.

The designated resolver information in DNR might not contain a full set of SvcParams needed to connect to an encrypted resolver. In such a case, the client can use an SVCB query using a resolver name, as described in Section 5, to the authentication-domain-name (ADN).

## 7. Security Considerations

Since clients can receive DNS SVCB answers over unencrypted DNS, on-path attackers can prevent successful discovery by dropping SVCB packets. Clients should be aware that it might not be possible to distinguish between resolvers that do not have any Designated Resolver and such an active attack. To limit the impact of discovery queries being dropped either maliciously or unintentionally, clients can re-send their SVCB queries periodically.

DoH resolvers that allow discovery using DNS SVCB answers over unencrypted DNS MUST NOT provide differentiated behavior based on the HTTP path alone, since an attacker could modify the "dohpath" parameter.

While the IP address of the Unencrypted Resolver is often provisioned over insecure mechanisms, it can also be provisioned securely, such as via manual configuration, a VPN, or on a network with protections like RA guard [RFC6105]. An attacker might try to direct Encrypted DNS traffic to itself by causing the client to think that a discovered Designated Resolver uses a different IP address from the Unencrypted Resolver. Such a Designated Resolver might have a valid certificate, but be operated by an attacker that is trying to observe or modify user queries without the knowledge of the client or network.

If the IP address of a Designated Resolver differs from that of an Unencrypted Resolver, clients applying Verified Discovery (Section 4.2) MUST validate that the IP address of the Unencrypted Resolver is covered by the SubjectAlternativeName of the Designated Resolver's TLS certificate.

Clients using Opportunistic Discovery (Section 4.3) MUST be limited to cases where the Unencrypted Resolver and Designated Resolver have the same IP address.

The constraints on the use of Designated Resolvers specified here apply specifically to the automatic discovery mechanisms defined in this document, which are referred to as Verified Discovery and Opportunistic Discovery. Clients MAY use some other mechanism to verify and use Designated Resolvers discovered using the DNS SVCB record. However, use of such an alternate mechanism needs to take into account the attack scenarios detailed here.

## 8. IANA Considerations



### 8.1. Special Use Domain Name "resolver.arpa"

This document calls for the addition of "resolver.arpa" to the Special-Use Domain Names (SUDN) registry established by [RFC6761]. This will allow resolvers to respond to queries directed at themselves rather than a specific domain name. While this document uses "resolver.arpa" to return SVCB records indicating designated encrypted capability, the name is generic enough to allow future reuse for other purposes where the resolver wishes to provide information about itself to the client.

The "resolver.arpa" SUDN is similar to "ipv4only.arpa" in that the querying client is not interested in an answer from the authoritative "arpa" name servers. The intent of the SUDN is to allow clients to communicate with the Unencrypted Resolver much like "ipv4only.arpa" allows for client-to-middlebox communication. For more context, see the rationale behind "ipv4only.arpa" in [RFC8880].

IANA is requested to add an entry in "Transport-Independent Locally-Served DNS Zones" registry for 'resolver.arpa.' with the description "DNS Resolver Special-Use Domain", listing this document as the reference.

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## Appendix A. Rationale for using SVCB records

This mechanism uses SVCB/HTTPS resource records [I-D.ietf-dnsop-svcb-https] to communicate that a given domain designates a particular Designated Resolver for clients to use in place of an Unencrypted Resolver (using a SUDN) or another Encrypted Resolver (using its domain name).

There are various other proposals for how to provide similar functionality. There are several reasons that this mechanism has chosen SVCB records:

- \* Discovering encrypted resolver using DNS records keeps client logic for DNS self-contained and allows a DNS resolver operator to define which resolver names and IP addresses are related to one another.
- \* Using DNS records also does not rely on bootstrapping with higher-level application operations (such as [I-D.schinazi-httpbis-doh-preference-hints]).
- \* SVCB records are extensible and allow definition of parameter keys. This makes them a superior mechanism for extensibility as compared to approaches such as overloading TXT records. The same keys can be used for discovering Designated Resolvers of different transport types as well as those advertised by Unencrypted Resolvers or another Encrypted Resolver.
- \* Clients and servers that are interested in privacy of names will already need to support SVCB records in order to use Encrypted TLS Client Hello [I-D.ietf-tls-esni]. Without encrypting names in TLS, the value of encrypting DNS is reduced, so pairing the solutions provides the largest benefit.
- \* Clients that support SVCB will generally send out three queries when accessing web content on a dual-stack network: A, AAAA, and HTTPS queries. Discovering a Designated Resolver as part of one of these queries, without having to add yet another query, minimizes the total number of queries clients send. While [RFC5507] recommends adding new RRTypes for new functionality, SVCB provides an extension mechanism that simplifies client behavior.

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DHCP and Router Advertisement Options for the Discovery of Network-  
designated Resolvers (DNR)  
draft-ietf-add-dnr-07

## Abstract

The document specifies new DHCP and IPv6 Router Advertisement options to discover encrypted DNS servers (e.g., DNS-over-HTTPS, DNS-over-TLS, DNS-over-QUIC). Particularly, it allows to learn an authentication domain name together with a list of IP addresses and a set of service parameters to reach such encrypted DNS servers.

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## 1. Introduction

This document focuses on the support of encrypted DNS such as DNS-over-HTTPS (DoH) [RFC8484], DNS-over-TLS (DoT) [RFC7858], or DNS-over-QUIC (DoQ) [I-D.ietf-dprive-dnsquic] in local networks.

In particular, the document specifies how a local encrypted DNS server can be discovered by connected hosts by means of DHCPv4 [RFC2132], DHCPv6 [RFC8415], and IPv6 Router Advertisement (RA) [RFC4861] options. These options are designed to convey the following information: the DNS Authentication Domain Name (ADN), a list of IP addresses, and a set of service parameters. This procedure is called Discovery of Network-designated Resolvers (DNR).

The options defined in this document can be deployed in a variety of deployments (e.g., local networks with Customer Premises Equipment (CPEs) that may or may not be managed by an Internet Service Provider (ISP), local networks with or without DNS forwarders). It is out of the scope of this document to provide an inventory of such deployments.

## 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]. The following additional terms are used:

Do53: refers to unencrypted DNS.

DNR: refers to the Discovery of Network-designated Resolvers procedure.

Encrypted DNS: refers to a scheme where DNS exchanges are transported over an encrypted channel. Examples of encrypted DNS are DoT, DoH, or DoQ.

Encrypted DNS options: refers to the options defined in Sections 4, 5, and 6.

DHCP: refers to both DHCPv4 and DHCPv6.

## 3. Overview

This document describes how a DNS client can discover local encrypted DNS servers using DHCP (Sections 4 and 5) and Neighbor Discovery protocol (Section 6): Encrypted DNS options.



These options configure an authentication domain name, a list of IPv6 addresses, and a set of service parameters of the encrypted DNS server. More information about the design of these options is provided in the following subsections.

### 3.1. Configuration Data for Encrypted DNS

In order to allow for PKIX-based authentication between a DNS client and an encrypted DNS server, the Encrypted DNS options are designed to include an authentication domain name. This ADN is presented as a reference identifier for DNS authentication purposes. This design accommodates the current best practices for issuing certificates as per Section 1.7.2 of [RFC6125]:

Some certification authorities issue server certificates based on IP addresses, but preliminary evidence indicates that such certificates are a very small percentage (less than 1%) of issued certificates.

To avoid adding a dependency on another server to resolve the ADN, the Encrypted DNS options return the IP address(es) to locate the encrypted DNS server. These encrypted DNS servers may be hosted on the same or distinct IP addresses. Such a decision is deployment specific.

In order to optimize the size of discovery messages when all DNS servers terminate on the same IP address, early versions of this document considered relying upon the discovery mechanisms specified in [RFC2132][RFC3646][RFC8106] to retrieve a list of IP addresses to reach their DNS servers. Nevertheless, this approach requires a client that supports more than one encrypted DNS protocol (e.g., DoH and DoT) to probe that list of IP addresses. To avoid such a probing, the options defined in Sections 4, 5, and 6 associate an IP address with an encrypted DNS protocol. No probing is required in such a design.

A list of IP addresses to reach an encrypted DNS server may be returned in an Encrypted DNS option to accommodate current deployments relying upon primary and backup servers. Whether one or more IP addresses are returned in an Encrypted DNS option is deployment specific. For example, a router embedding a recursive server or a forwarder has to include one single IP address pointing to one of its LAN-facing interfaces. This IP address can be a private IPv4 address, a link-local address, a Unique Local IPv6 unicast Address (ULA), or a Global Unicast Address (GUA).

If more than one IP address are to be returned in an Encrypted DNS option, these addresses are ordered in the preference for use by the client.

Because distinct encrypted DNS protocols may be provisioned by a network (e.g., DoT, DoH, and DoQ) and that some of these protocols may make use of customized port numbers instead of default ones, the Encrypted DNS options are designed to return a set of service parameters. These parameters are encoded following the same rules for encoding SvcParams in Section 2.1 of [I-D.ietf-dnsop-svcb-https]. This encoding approach may increase the size of the options but it has the merit to rely upon an existing IANA registry and, thus, to accommodate new encrypted DNS protocols and service parameters that may be defined in the future. At least the following service parameters are RECOMMENDED to be supported by a DNR implementation:

alpn: Used to indicate the set of supported protocols (Section 7.1 of [I-D.ietf-dnsop-svcb-https]).

port: Used to indicate the target port number for the encrypted DNS connection (Section 7.2 of [I-D.ietf-dnsop-svcb-https]).

ech: Used to enable Encrypted ClientHello (ECH) (Section 7.3 of [I-D.ietf-dnsop-svcb-https]).

dohpath: Used to supply a relative DoH URI Template (Section 5.1 of [I-D.ietf-add-svcb-dns]).

A single option is used to convey both the ADN and IP addresses because otherwise means to correlate an IP address with an ADN will be required if, for example, more than one ADN is supported by the network.

The DHCP options defined in Sections 4 and 5 follow the option ordering guidelines in Section 17 of [RFC7227]. Likewise, the RA option (Section 6) adheres to the recommendations in Section 9 of [RFC4861].

ServiceMode (Section 2.4.3 of [I-D.ietf-dnsop-svcb-https]) SHOULD be used because the Encrypted DNS options are self-contained and do not require any additional DNS queries. The reader may refer to [RFC7969] for an overview of advanced capabilities that are supported by DHCP servers to populate configuration data (e.g., issue DNS queries).

In contexts where putting additional complexity on requesting hosts is acceptable, returning an ADN only can be considered. The supplied ADN will be processed by a host following the procedure in Section 5 of [I-D.ietf-add-ddr]. Note that this mode may be subject to active attacks, which can be mitigated by DNSSEC.

Other mechanisms may be considered in other contexts (e.g., secure discovery) for the provisioning of encrypted DNS servers. It is RECOMMENDED that at least the following DNR information is made available to a requesting host:

- \* A service priority whenever the discovery mechanism does not rely on implicit ordering if multiple instances of the encrypted DNS are used.
- \* An authentication domain name.
- \* A list of IP addresses to locate the encrypted DNS server.
- \* A set of service parameters.

### 3.2. Handling Configuration Data Conflicts

If the encrypted DNS is discovered by a host using both RA and DHCP, the rules discussed in Section 5.3.1 of [RFC8106] MUST be followed.

DHCP/RA options to discover encrypted DNS servers (including, DoH URI Templates) takes precedence over Discovery of Designated Resolvers (DDR) [I-D.ietf-add-ddr] since DDR uses Do53 to an external DNS resolver, which is susceptible to both internal and external attacks whereas DHCP/RA is typically protected using the mechanisms discussed in Section 7.1.

### 3.3. Connection Establishment

If the local DNS client supports one of the discovered Encrypted DNS protocols identified by Application Layer Protocol Negotiation (ALPN) protocol identifiers, the DNS client establishes an encrypted DNS session following the order of the discovered servers. The client follows the mechanism discussed in Section 8 of [RFC8310] to authenticate the DNS server certificate using the authentication domain name conveyed in the Encrypted DNS options. ALPN-related considerations can be found in Section 6.1 of [I-D.ietf-dnsop-svcb-https].

### 3.4. Multihoming Considerations

Devices may be connected to multiple networks; each providing their own DNS configuration using the discovery mechanisms specified in this document. Nevertheless, it is out of the scope of this specification to discuss DNS selection of multi-interface devices. The reader may refer to [RFC6731] for a discussion of issues and an example of DNS server selection for multi-interfaced devices.

## 4. DHCPv6 Encrypted DNS Option

### 4.1. Option Format

The format of the DHCPv6 Encrypted DNS option is shown in Figure 1.

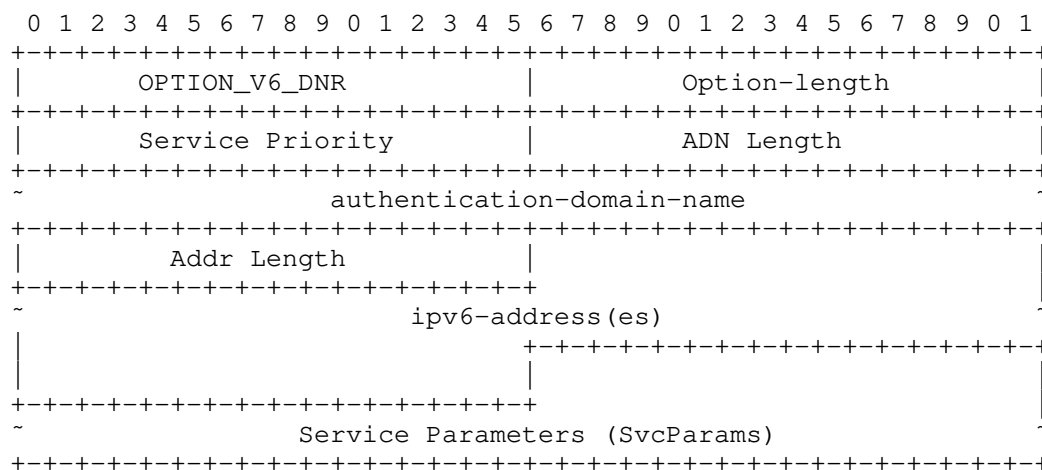


Figure 1: DHCPv6 Encrypted DNS Option

The fields of the option shown in Figure 1 are as follows:

Option-code: OPTION\_V6\_DNR (TBA1, see Section 8.1)

Option-length: Length of the enclosed data in octets. The option length is ('ADN Length' + 4) when only an ADN is included in the option.

Service Priority: The priority of this OPTION\_V6\_DNR instance compared to other instances. This field is encoded following the rules specified in Section 2.4.1 of [I-D.ietf-dnsop-svcb-https].

ADN Length: Length of the authentication-domain-name field in



If no port service parameter is included, this indicates that default port numbers should be used. As a reminder, the default port number is 853 for DoT, 443 for DoH, and 853 for DoQ.

The length of this field is ('Option-length' - 6 - 'ADN Length' - 'Addr Length').

#### 4.2. DHCPv6 Client Behavior

To discover an encrypted DNS server, the DHCPv6 client MUST include OPTION\_V6\_DNR in an Option Request Option (ORO), as in Sections 18.2.1, 18.2.2, 18.2.4, 18.2.5, 18.2.6, and 21.7 of [RFC8415].

The DHCPv6 client MUST be prepared to receive multiple instances of the OPTION\_V6\_DNR option; each option is to be treated as a separate encrypted DNS server. These instances SHOULD be processed following their service priority (i.e., smaller service priority indicates a higher preference).

The DHCPv6 client MUST silently discard multicast and host loopback addresses conveyed in OPTION\_V6\_DNR.

### 5. DHCPv4 Encrypted DNS Option

#### 5.1. Option Format

The format of the DHCPv4 Encrypted DNS option is illustrated in Figure 4.

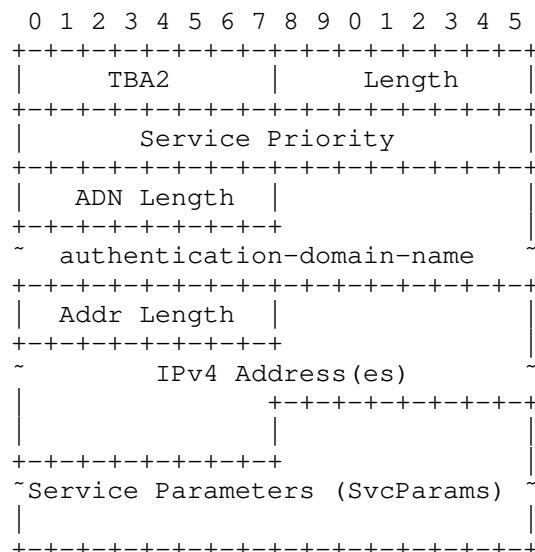


Figure 4: DHCPv4 Encrypted DNS Option

The fields of the option shown in Figure 4 are as follows:

Code: OPTION\_V4\_DNR (TBA2, see Section 8.2).

Length: Indicates the length of the enclosed data in octets. The option length is ('ADN Length' + 3) when only an ADN is included in the option.

Service Priority: The priority of this OPTION\_V4\_DNR instance compared to other instances. This field is encoded following the rules specified in Section 2.4.1 of [I-D.ietf-dnsop-svcb-https].

ADN Length: Indicates the length of the authentication-domain-name in octets.

authentication-domain-name (variable length): Includes the authentication domain name of the encrypted DNS server. This field is formatted as specified in Section 10 of [RFC8415]. The format of this field is shown in Figure 5. The values s1, s2, s3, etc. represent the domain name labels in the domain name encoding.

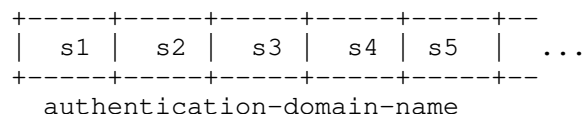


Figure 5: Format of the Authentication Domain Name Field

**Addr Length:** Indicates the length of included IPv4 addresses in octets. It MUST be a multiple of 4 for ServiceMode.

**IPv4 Address(es) (variable length):** Indicates one or more IPv4 addresses to reach the encrypted DNS server. Both private and public IPv4 addresses can be included in this field. The format of this field is shown in Figure 6. This format assumes that an IPv4 address is encoded as a1.a2.a3.a4.

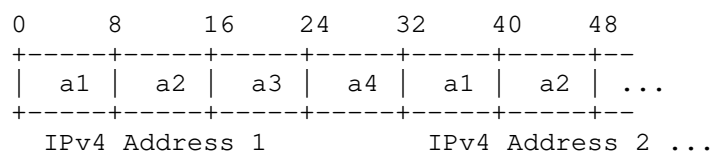


Figure 6: Format of the IPv4 Addresses Field

**Service Parameters (SvcParams) (variable length):** Specifies a set of service parameters that are encoded following the rules in Section 2.1 of [I-D.ietf-dnsop-svcb-https]. Service parameters may include, for example, a list of ALPN protocol identifiers or alternate port numbers. The service parameters MUST NOT include "ipv4hint" or "ipv6hint" SvcParams as they are superseded by the included IP addresses.

If no port service parameter is included, this indicates that default port numbers should be used.

The length of this field is ('Option-length' - 4 - 'ADN Length' - 'Addr Length').

OPTION\_V4\_DNR is a concatenation-requiring option. As such, the mechanism specified in [RFC3396] MUST be used if OPTION\_V4\_DNR exceeds the maximum DHCPv4 option size of 255 octets.

## 5.2. DHCPv4 Client Behavior

To discover an encrypted DNS server, the DHCPv4 client requests the Encrypted DNS server by including OPTION\_V4\_DNR in a Parameter Request List option [RFC2132].

The DHCPv4 client MUST be prepared to receive multiple instances of the OPTION\_V4\_DNR option; each option is to be treated as a separate encrypted DNS server. These instances SHOULD be processed following their service priority (i.e., smaller service priority indicates a higher preference).



The DHCPv4 client MUST silently discard multicast and host loopback addresses conveyed in OPTION\_V4\_DNR.

## 6. IPv6 RA Encrypted DNS Option

### 6.1. Option Format

This section defines a new Neighbor Discovery option [RFC4861]: IPv6 RA Encrypted DNS option. This option is useful in contexts similar to those discussed in Section 1.1 of [RFC8106].

The format of the IPv6 RA Encrypted DNS option is illustrated in Figure 7.

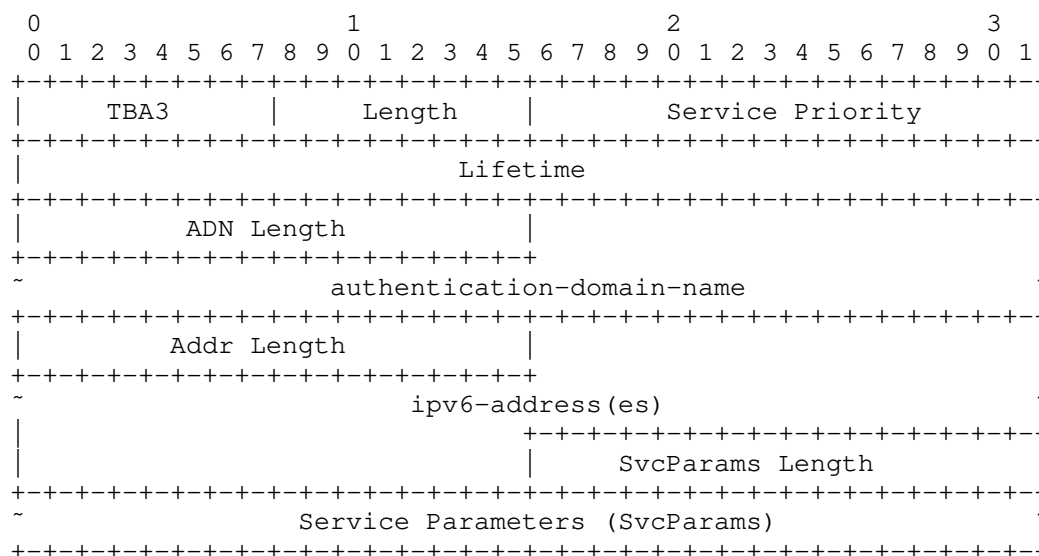


Figure 7: RA Encrypted DNS Option

The fields of the option shown in Figure 7 are as follows:

**Type:** 8-bit identifier of the Encrypted DNS option as assigned by IANA (TBA3, see Section 8.3).

**Length:** 8-bit unsigned integer. The length of the option (including the Type and Length fields) is in units of 8 octets.

**Service Priority:** The priority of this Encrypted DNS option instance compared to other instances. This field is encoded following the rules specified in Section 2.4.1 of [I-D.ietf-dnsop-svcb-https].

**Lifetime:** 32-bit unsigned integer. The maximum time in seconds (relative to the time the packet is received) over which the discovered Authentication Domain Name is valid.

The value of Lifetime SHOULD by default be at least  $3 * \text{MaxRtrAdvInterval}$ , where MaxRtrAdvInterval is the maximum RA interval as defined in [RFC4861].

A value of all one bits (0xffffffff) represents infinity.

A value of zero means that this Authentication Domain Name MUST no longer be used.

**ADN Length:** 16-bit unsigned integer. This field indicates the length of the authentication-domain-name field in octets.

**authentication-domain-name (variable length):** The domain name of the encrypted DNS server. This field is formatted as specified in Section 10 of [RFC8415].

**Addr Length:** 16-bit unsigned integer. This field indicates the length of enclosed IPv6 addresses in octets. It MUST be a multiple of 16 for ServiceMode.

**ipv6-address(es) (variable length):** One or more IPv6 addresses of the encrypted DNS server. An address can be link-local, ULA, or GUA.

All of the addresses share the same Lifetime value. Similar to [RFC8106], if it is desirable to have different Lifetime values per IP address, multiple Encrypted DNS options may be used.

The format of this field is shown in Figure 3.

**SvcParams Length:** 16-bit unsigned integer. This field indicates the length of the Service Parameters field in octets.

**Service Paramters (SvcParams) (variable length):** Specifies a set of service parameters that are encoded following the rules in Section 2.1 of [I-D.ietf-dnsop-svcb-https]. Service parameters may include, for example, a list of ALPN protocol identifiers or alternate port numbers. The service parameters MUST NOT include "ipv4hint" or "ipv6hint" SvcParams as they are superseded by the included IP addresses.

If no port service parameter is included, this indicates that default port numbers should be used.

The option MUST be padded with zeros so that the full enclosed data is a multiple of 8 octets (Section 4.6 of [RFC4861]).

## 6.2. IPv6 Host Behavior

The procedure for DNS configuration is the same as it is with any other Neighbor Discovery option [RFC4861]. In addition, the host follows the procedure described in Section 5.3.1 of [RFC8106] with the formatting requirements in Section 6.1 substituted for the length validation.

The host MUST be prepared to receive multiple Encrypted DNS options in RAs. These instances SHOULD be processed following their service priority (i.e., smaller service priority indicates a higher preference).

The host MUST silently discard multicast and host loopback addresses conveyed in the Encrypted DNS options.

## 7. Security Considerations

### 7.1. Spoofing Attacks

DHCP/RA messages are not encrypted or protected against modification within the LAN. Unless mitigated (described below), the content of DHCP and RA messages can be spoofed or modified by active attackers, such as compromised devices within the local network. An active attacker (Section 3.3 of [RFC3552]) can spoof the DHCP/RA response to provide the attacker's Encrypted DNS server. Note that such an attacker can launch other attacks as discussed in Section 22 of [RFC8415]. The attacker can get a domain name with a domain-validated public certificate from a CA and host an Encrypted DNS server.

Attacks of spoofed or modified DHCP responses and RA messages by attackers within the local network may be mitigated by making use of the following mechanisms:

- \* DHCPv6-Shield described in [RFC7610], the router (e.g., a border router, a CPE) discards DHCP response messages received from any local endpoint.
- \* RA-Guard described in [RFC7113], the router discards RAs messages received from any local endpoint.
- \* Source Address Validation Improvement (SAVI) solution for DHCP described in [RFC7513], the router filters packets with forged source IP addresses.

The above mechanisms would ensure that the endpoint receives the correct configuration information of the encrypted DNS servers selected by the DHCP server (or RA sender), but cannot provide any information about the DHCP server or the entity hosting the DHCP server (or RA sender) .

Encrypted DNS sessions with rogue servers that spoof the IP address of a DNS server will fail because the DNS client will fail to authenticate that rogue server based upon PKIX authentication [RFC6125], particularly the authentication domain name in the Encrypted DNS Option. DNS clients that ignore authentication failures and accept spoofed certificates will be subject to attacks (e.g., redirect to malicious servers, intercept sensitive data).

Encrypted DNS connections received from outside the local network MUST be discarded by the encrypted DNS forwarder in the CPE. This behavior adheres to REQ#8 in [RFC6092]; it MUST apply for both IPv4 and IPv6.

## 7.2. Deletion Attacks

If the DHCP responses or RAs are dropped by the attacker, the client can fallback to use a preconfigured encrypted DNS server. However, the use of policies to select servers is out of the scope of this document.

Note that deletion attack is not specific to DHCP/RA.

## 7.3. Passive Attacks

A passive attacker (Section 3.2 of [RFC3552]) can identify a host is using DHCP/RA to discover an encrypted DNS server and can infer that host is capable of using DoH/DoT/DoQ to encrypt DNS messages. However, a passive attacker cannot spoof or modify DHCP/RA messages.

## 7.4. Wireless Security - Authentication Attacks

Wireless LAN (WLAN) as frequently deployed in local networks (e.g., home networks) is vulnerable to various attacks (e.g., [Evil-Twin], [Krack], [Dragonblood]). Because of these attacks, only cryptographically authenticated communications are trusted on WLANs. This means that an information (e.g., NTP server, DNS server, default domain) provided by such networks via DHCP, DHCPv6, or RA are untrusted because DHCP and RA messages are not authenticated.

If the pre-shared key is the same for all clients that connect to the same WLAN, the shared key will be available to all nodes, including attackers. As such, it is possible to mount an active on-path attack. Man-in-the-middle attacks are possible within local networks because such WLAN authentication lacks peer entity authentication.

This leads to the need for provisioning unique credentials for different clients. Endpoints can be provisioned with unique credentials (username and password, typically) provided by the local network administrator to mutually authenticate to the local WLAN Access Point (e.g., 802.1x Wireless User Authentication on OpenWRT [dot1x], EAP-pwd [RFC8146]). Not all endpoint devices (e.g., IoT devices) support 802.1x supplicant and need an alternate mechanism to connect to the local network. To address this limitation, unique pre-shared keys can be created for each such device and WPA-PSK is used (e.g., [PSK]).

## 8. IANA Considerations

### 8.1. DHCPv6 Option

IANA is requested to assign the following new DHCPv6 Option Code in the registry maintained in [DHCPV6].

Value	Description	Client ORO	Singleton Option	Reference
TBA1	OPTION_V6_DNR	Yes	No	[ThisDocument]

Table 1

### 8.2. DHCPv4 Option

IANA is requested to assign the following new DHCP Option Code in the registry maintained in [BOOTP].

Tag	Name	Data Length	Meaning	Reference
TBA2	OPTION_V4_DNR	N	Encrypted DNS Server	[ThisDocument]

### 8.3. Neighbor Discovery Option

IANA is requested to assign the following new IPv6 Neighbor Discovery Option type in the "IPv6 Neighbor Discovery Option Formats" sub-registry under the "Internet Control Message Protocol version 6 (ICMPv6) Parameters" registry maintained in [ND].

Type	Description	Reference
TBA3	DNS Encrypted DNS Option	[ThisDocument]

Table 2

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The use of DHCP to retrieve an authentication domain name was discussed in Section 7.3.1 of [RFC8310] and [I-D.pusateri-dhc-dns-driu].

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Establishing Local DNS Authority in Split-Horizon Environments  
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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 describes how clients can confirm the local resolver's authority over these domains.

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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 [RFC6106]), 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 with either pure resolution behavior 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 (Section 4). 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 specification relies on securely identified local DNS servers and globally valid NS records. Use of this specification is therefore limited to servers that support authenticated encryption and split-horizon DNS names that are properly 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]. The term "Global DNS" is defined in [RFC8499].

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

The term 'Validated Split-Horizon' is also defined.

### 2.1. Validated Split-Horizon

A split horizon configuration for some name is considered "validated" if the network client has confirmed that a parent of that name has authorized the local network 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 allows the domain owner to create a split-horizon DNS. Other entities which do not own the domain are detected by the client. Thus, DNS filtering is not enabled by this protocol.

## 4. Local Domain Hint Mechanisms

There are various mechanisms by which a network client might learn "local domain hints", which indicate a special treatment for particular domain names upon joining a network. This section provides a review of some common and standardized mechanisms for receiving domain hints.

### 4.1. DHCP Options

There are several DHCP options that convey local domain hints of different kinds. The most directly relevant is "RDNSS Selection" [RFC6731], which provides "a list of domains ... about which the RDNSS has special knowledge", along with a "High", "Medium", or "Low" preference for each name. The specification notes the difficulty of relying on these hints without validation:

Trustworthiness of an interface and configuration information received over the interface is implementation and/or node deployment dependent, and the details of determining that trust are beyond the scope of this specification.

Other local domain hints in DHCP include the "Domain Name" [RFC2132], "Access Network Domain Name" [RFC5986], "Client FQDN" [RFC4702][RFC4704], and "Name Service Search" [RFC2937] options. This specification may help clients to interpret these hints. For example, a rogue DHCP server could use the "Client FQDN" option to assign a client the name "www.example.com" in order to prevent the client from reaching the true "www.example.com". A client could use this specification to check the network's authority over this name, and adjust its behavior to avoid this attack if authority is not established.

The Domain Search option [RFC3397] [RFC3646], which offers clients a way to expand short names into Fully Qualified Domain Names, is not a "local domain hint" by this definition, because it does not modify the processing of any specific domain. (The specification notes that this option can be a "fruitful avenue of attack for a rogue DHCP server", and provides a number of cautions against accepting it unconditionally.)

#### 4.2. Host Configuration

A host can be configured with DNS information when it joins a network, including when it brings up VPN (which is also considered joining a(n additional) network, detailed in Section 8). Existing implementations determine the host has joined a certain network via SSID, IP subnet assigned, DNS server IP address or name, and other similar mechanisms. For example, one existing implementation determines the host has joined an internal network because the DHCP-assigned IP address belongs to the company's IP address (as assigned by the regional IP addressing authority) and the DHCP-advertised DNS IP address is one used by IT at that network. Other mechanisms exist in other products but are not interesting to this specification; rather what is interesting is this step to determine "we have joined the internal corporate network" occurred and the DNS server is configured as authoritative for certain DNS zones (e.g., \*.example.com).

Because a rogue network can simulate all or most of the above characteristics this specification details how to validate these claims in Section 6.



#### 4.3. Provisioning Domains dnsZones

Provisioning Domains (PvDs) are defined in [RFC7556] as sets of network configuration information that clients can use to access networks, including rules for DNS resolution and proxy configuration. The PvD Key "dnsZones" is defined in [RFC8801] as a list of "DNS zones searchable and accessible" in this provisioning domain. Attempting to resolve these names via another resolver might fail or return results that are not correct for this network.

#### 4.4. Split DNS Configuration for IKEv2

In IKEv2 VPNs, the INTERNAL\_DNS\_DOMAIN configuration attribute can be used to indicate that a domain is "internal" to the VPN [RFC8598]. To prevent abuse, the specification notes various possible restrictions on the use of this attribute:

"If a client is configured by local policy to only accept a limited set of INTERNAL\_DNS\_DOMAIN values, the client MUST ignore any other INTERNAL\_DNS\_DOMAIN values."

"IKE clients MAY want to require whitelisted domains for Top-Level Domains (TLDs) and Second-Level Domains (SLDs) to further prevent malicious DNS redirections for well-known domains."

Within these guidelines, a client could adopt a local policy of accepting INTERNAL\_DNS\_DOMAIN values only when it can validate the local DNS server's authority over those names as described in this specification.

### 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] or an equivalent mechanism (see Section 8). At least one of these resolvers' Authentication Domain Names (ADNs) MUST appear in an NS record for that zone. This arrangement establishes this resolver's authority over the zone.

### 6. Validating Authority over Local Domain Hints

To validate the network's authority over a domain name, participating clients MUST resolve the NS record for that name. If the resolution result is NODATA, the client MUST remove the last label and repeat the query until a response other than NODATA is received.

Once the NS record has been resolved, the client MUST check if each local encrypted resolver's Authentication Domain Name appears in the NS record. The client SHALL regard each such resolver as authoritative for the zone of this NS record.

Each validation of authority applies only to the specific resolvers whose names appear in the NS RSet. If a network offers multiple encrypted resolvers, each DNS entry 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" NS 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 Pre-configured Public Resolver

The client sends the NS query to a pre-configured resolver that is external to the network, over a secure transport. Clients SHOULD apply whatever acceptance rules they would otherwise apply when using this resolver (e.g. checking the AD bit, validating RRSIGs).

#### 6.2. Using DNSSEC

The client resolves the NS 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 (Section 4.3 of [RFC4035]):

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. Examples of Split-Horizon DNS Configuration

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

### 7.1. Split-Horizon Entire Zone

Consider an organization that operates "example.com", and runs a different version of its global domain on its internal network. Today, on the Internet it publishes two NS records, "ns1.example.com" and "ns2.example.com".

The host and network first need mutual support one of the mechanisms described in learning (Section 4). Shown in Figure 1 is learning using DNR and PvD.

Validation is then performed using either Public DNS (Section 7.1.1) or DNSSEC (Section 7.1.2).

steps 1-2: The client determines the network's DNS server (ns1.example.com) 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 the DNR-learned DNS server (ns1.example.com), validates its certificate, and queries for 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"],
  "dnsZones": ["example.com"]
}
```

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

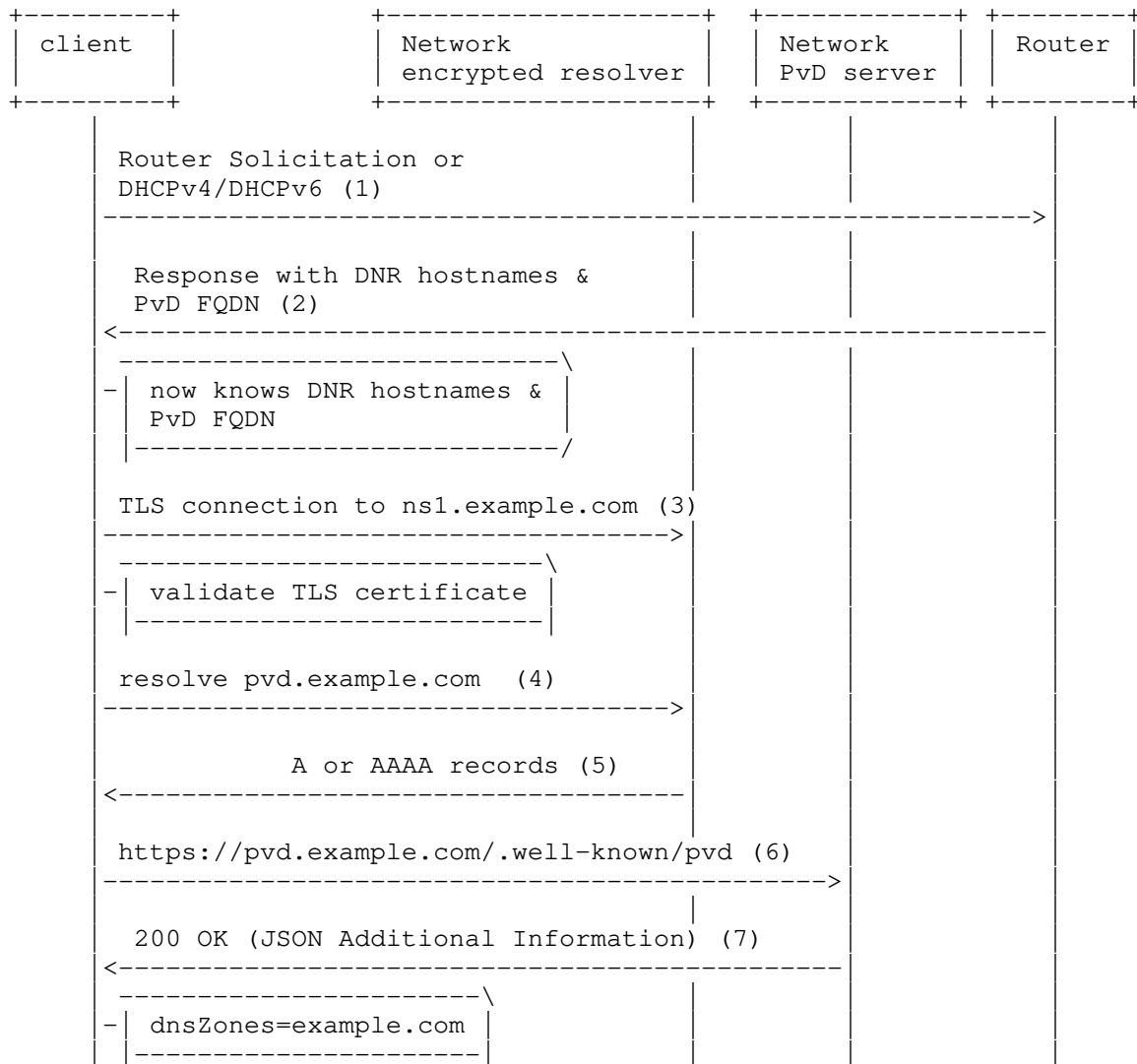


Figure 1: Learning Local Claims of DNS Authority

#### 7.1.1. Verification using Public Resolver

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

Steps 1-2: The client uses an encrypted DNS connection to a public

resolver (e.g., 1.1.1.1) to issue NS queries for the domains in dnsZones. The NS lookup for "example.com" will return "ns1.example.com" and "ns2.example.com".

Step 3: As the network-provided nameservers are the same as the names retrieved from the public resolver and the network-designated resolver's certificate includes at least one of the names retrieved from the public resolver, the client has finished validation that the nameservers signaled in [I-D.ietf-add-dnr] and [RFC8801] are owned and managed by the same entity that published the NS records on the Internet. The endpoint will then use that information from [I-D.ietf-add-dnr] and [RFC8801] to resolve names within dnsZones.

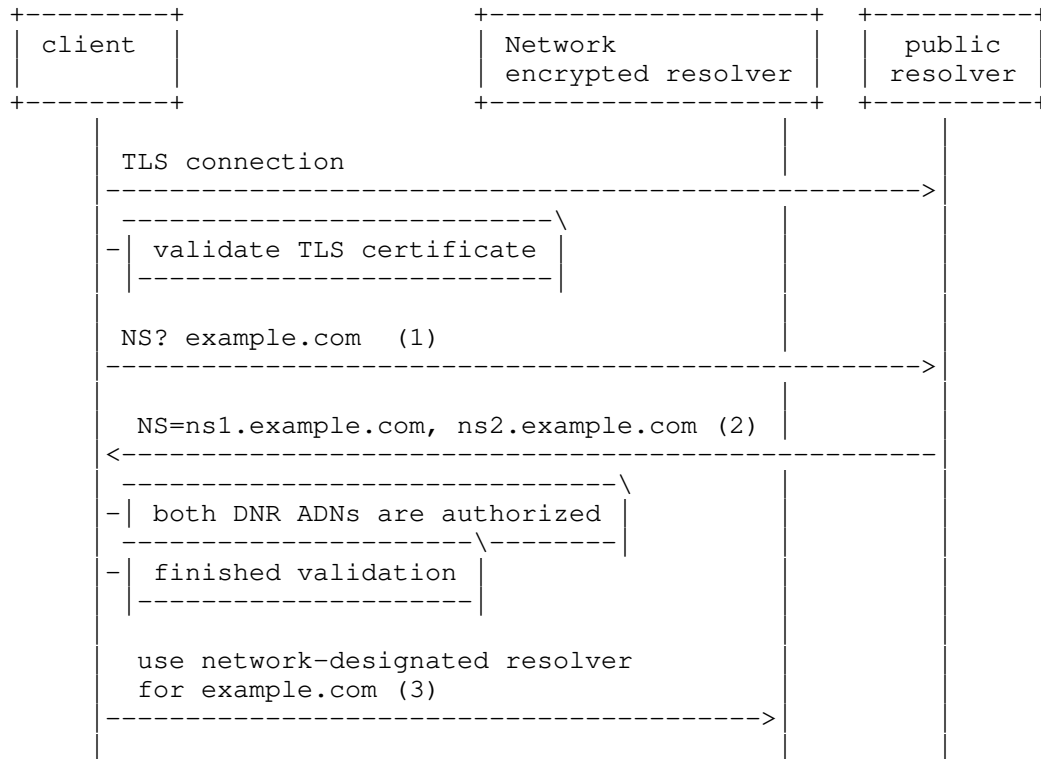


Figure 2: Verifying Claims using Public Resolver

#### 7.1.2. 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 NS queries for the domains in dnsZones. The NS lookup for "example.com" will return a signed response containing "ns1.example.com" and "ns2.example.com". The client then performs full DNSSEC validation locally.

Step 3: As the DNSSEC validation is successful and the network-provided nameservers are the same as the names in the DNSSEC response, and the network-designated resolver's certificate includes at least one of the names returned in the DNSSEC response, the client has finished validation that the nameservers signaled in [I-D.ietf-add-dnr] and [RFC8801] are owned and managed by the same entity that published the NS records on the Internet. The endpoint will then use that information from [I-D.ietf-add-dnr] and [RFC8801] to resolve names within dnsZones.

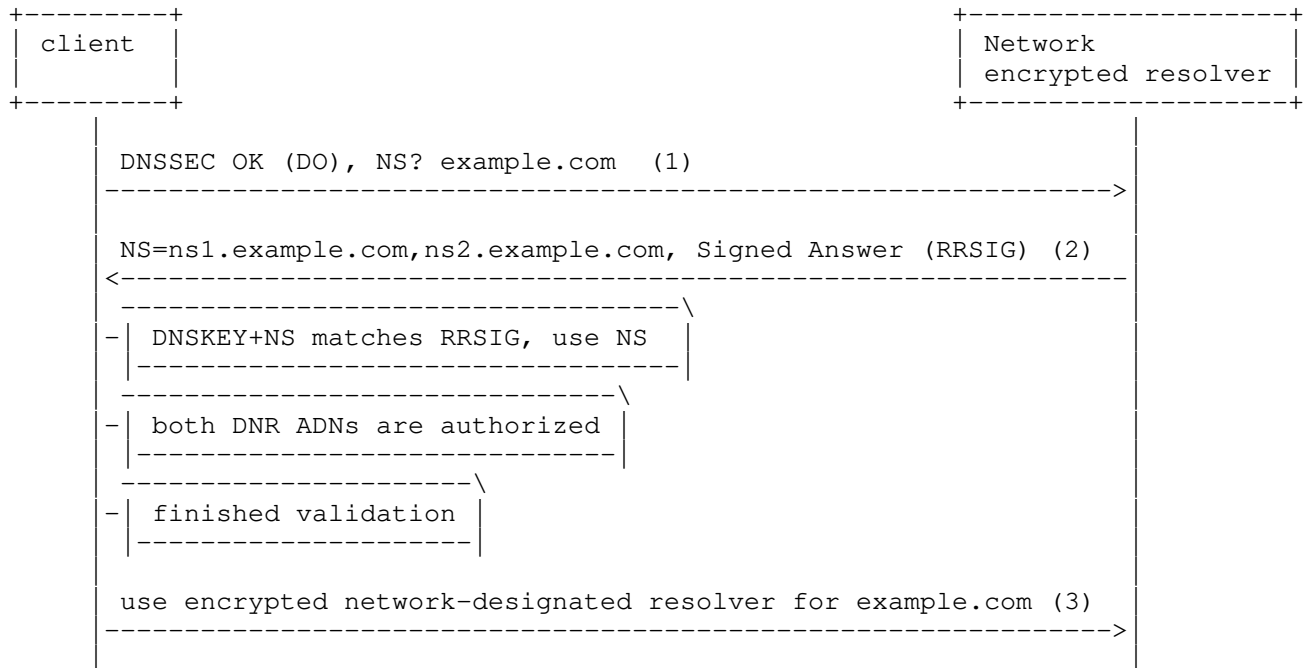


Figure 3: Verifying Claims using DNSSEC

## 7.2. Split-Horizon Only Subdomain of Zone

A subdomain can also be used for all internal DNS names (e.g., the zone `internal.example.com` exists only on the internal DNS server). For successful validation described in this document the internal DNS server will need a certificate signed by a CA trusted by the client.

For such a name `internal.example.com` the message flow is similar to Section 7.1 the difference is that queries for hosts not within the subdomain (`www.example.com`) are sent to the public resolver rather than resolver for `internal.example.com`.

## 8. 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.

## 9. Security Considerations

This specification does not alter DNSSEC validation behaviour. To ensure compatibility with validating clients, network operators **MUST** ensure that names under the split-horizon are correctly signed or place them in an unsigned zone.

If an internal zone name (e.g., `internal.example.com`) is used with in conjunction with this specification and a public certificate is obtained for validation, that internal zone name will exist in Certificate Transparency [RFC9162] logs. It should be noted, however, that this specification does not leak individual host names (e.g., `www.internal.example.com`) into the Certificate Transparency logs or to public DNS resolvers.

## 10. IANA Considerations

This document has no IANA actions.

## 11. Acknowledgements

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Analysis of DNS Forwarder Scenario Relative to DDR and DNR  
draft-stark-add-dns-forwarder-analysis-00

## Abstract

This draft analyzes the behaviors that residential end users and home network owners (e.g., parents of young children) might experience when operating systems and clients support [I-D.ietf-add-ddr] and/or [I-D.ietf-add-dnr] for discovery of encrypted DNS services and the CE router of the home network offers itself as the Do53 resolver. This use case is explicitly mentioned in [I-D.ietf-add-requirements] Section 3.2 and has several requirements related to it. This draft has two goals: determine if the analysis it provides is accurate and, if it is accurate, determine if the behavior is acceptable to the WG or if there should be changes to either of the discovery mechanisms.

## Discussion Venues

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

Discussion of this document takes place on the 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/bhstark2/dns-forwarder-analysis>.

## 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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## 1. Introduction

This draft analyzes the behaviors that residential end users and home network owners (e.g., parents of young children) might experience when operating systems and clients support [I-D.ietf-add-ddr] and/or [I-D.ietf-add-dnr] for discovery of encrypted DNS services and the CE router of the home network offers itself as the Do53 resolver. This use case is explicitly mentioned in [I-D.ietf-add-requirements] Section 3.2 and has several requirements related to it.

This draft has two goals:

- \* determine if the analysis it provides is accurate
- \* if it is accurate, determine if the behavior is acceptable to the WG or if there should be changes to either of the discovery mechanisms.

Becoming a WG draft is not a goal of this draft. There is and will be no request for adoption by any WG.

While DNS forwarders / proxies may exist in environments other than home networks (e.g., hotspots, small businesses), this draft does not attempt to examine those usages. This draft is focused on home networks.

## 2. Conventions and Definitions

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.

## 3. Background

Having a DNS forwarder in the CE router that is advertised to the LAN using DHCP and RDNS options is a common deployment model for many ISPs and is also the default in many retail consumer routers (e.g., Netgear).

[I-D.ietf-add-requirements] contains the following text related to this use case:

"Many networks offer a Do53 resolver on an address that is not globally meaningful, e.g. [RFC1918], link-local or unique local addresses. To support the discovery of encrypted DNS in these environments, a means is needed for the discovery process to work from a locally-addressed Do53 resolver to an encrypted DNS resolver that is accessible either at the same (local) address, or at a different global address. Both options need to be supported."

"R4.1 If the local network resolver is a forwarder that does not offer encrypted DNS service, an upstream encrypted resolver SHOULD be retrievable via queries sent to that forwarder."

"R4.2 Achieving requirement 4.1 SHOULD NOT require any changes to DNS forwarders hosted on non-upgradable legacy network devices."

In the context of a home network, there are several reasons why this deployment model is used. Some reasons are:

- \* Provide local name resolution
- \* Captive portal (Note that [RFC8952] defines an architecture that does not rely on "breaking" DNS; however, there exist many legacy devices with captive portals that do rely on "breaking" DNS.)
- \* Provide filtering (aka parental controls) and DNS-based vulnerability assessment in the CE router. Note that [I-D.ietf-add-requirements] describes this sort of filtering and monitoring behavior as an attack; nonetheless, this functionality is popular with many people -- especially parents.
- \* Caching responses to improve DNS performance

#### 4. Scenario Analysis

The following sections will analyze what behavior a user is expected to see when certain conditions exist. In all cases, it's assumed the CE router is advertising itself as the Do53 server (using DHCP and/or RA). The clients and OSs that are of interest in these scenarios are using whatever Do53 server is advertised to them by DHCP/RA. There may be clients and devices that use other Do53 servers; those are out of scope of this analysis. Analyzing the behavior of clients that do not support either DoH or DoT, or do not support any mechanism to discover encrypted servers are also out of scope.

Assumptions common to all scenarios are:

- \* Common OSs support both DNR and DDR
- \* Some applications (e.g., browsers) support DDR
- \* No Certificate Authority will sign a certificate with a private IP address in a SAN

##### 4.1. Scenario 1: No changes to CE router

Assumptions:

- \* The CE router (including its DNS forwarder and DHCP/RA capabilities) are not updated.

Expected behaviors:

- \* There will be no DHCP or RA advertisement of encrypted servers.

- \* The DNS forwarder will forward DDR queries (dns://resolver.arpa) to the DNS recursive resolver the CE router is configured to use.
- \* If that recursive resolver has the appropriate SVCB record, it will provide that in the response that is returned.
- \* The querying OS/app will determine that the IP address of its Unencrypted Resolver (the CE router) and the IP address of the Unencrypted Resolver in the supplied certificate do not match and will not do "authenticated discovery".
- \* The querying OS/app will determine that the IP address of its Unencrypted Resolver (the CE router) does not match the IP address of the Encrypted Resolver and will not do "opportunistic discovery".
- \* The OS/app will not discover a local Encrypted Resolver.

The end result is that no Encrypted Resolver will be used by an OS or app that uses DDR or DNR to discover an Encrypted Resolver, unless the OS or app subsequently uses some non-standard mechanism to select an Encrypted Resolver. Note that this suggests that the DDR and DNR proposals in their current form do not satisfy the requirement "R4.2 Achieving requirement 4.1 SHOULD NOT require any changes to DNS forwarders hosted on non-upgradable legacy network devices."

Also note that non-upgraded legacy routers will not satisfy the [I-D.ietf-add-ddr] requirement that a "DNS forwarder SHOULD NOT forward queries for "resolver.arpa" upstream." If the CE router were updated to not forward queries for "resolver.arpa" upstream, the end result would not change. Since this scenario provides the same end result, it isn't broken out separately.

#### 4.2. Scenario 2: CE router updated to provide DNR in DHCP/RA

##### Assumptions:

- \* The CE router is updated to provide Encrypted Resolver info in DHCP/RA
- \* The CE router gets its Encrypted Resolver info from DHCP; getting that was part of the update
- \* The upstream ISP has updated its core network resolver to support encryption, and announces this resolver in DHCP

##### Expected behaviors:



- \* OSs will use the Encrypted Resolver
- \* Applications that try "resolver.arpa" will not do their own upgrade, because that will fail

Additional results:

- \* Local name resolution is broken?
- \* Legacy captive portal is now broken?
- \* Filtering in the CE router (parental controls and other security mechanisms enabled by the home network owner) is now broken
- \* Any filtering deployed in the core network resolver continues to operate
- \* No local caching

#### 4.3. Scenario 3: CE router updated to support opportunistic encryption to its DNS forwarder

Assumptions:

- \* The CE router supports encrypted connectivity to its DNS forwarder
- \* The CE router is updated to provide Encrypted Resolver info in DHCP/RA
- \* The CE router is updated to reply to "dns://resolver.arpa"; SVCB record points to the CE router with a self-signed certificate

Note that the effort to do these upgrades is considered to be rather large.

Expected behaviors:

- \* Some OSs and applications accept DDR Opportunistic Discovery, resulting in use of the CE router's Encrypted Resolver.
- \* Some OSs and applications do not.
- \* Across a range of households, and even within a single household, there is inconsistent behavior.

## 5. Conclusions

Since Scenario 3 is considered a large effort and the resulting behavior is unpredictable, it is unlikely to be pursued.

Since Scenario 2 will break some of the functionality that a significant number of home network owners have purposefully enabled (e.g., router-based DNS-based parental controls), will break existing captive portal implementations used to simplify setup of broadband connections, and may break local name resolution (?) it is unlikely to be pursued.

This leaves Scenario 1 (do nothing in routers that provide DNS forwarder).

## 6. Questions for the WG

Are these the results we want to achieve with Encrypted Resolver discovery mechanisms?

## 7. Security Considerations

Breaking the security mechanisms that many users currently have enabled in their home network routers (e.g., DNS filtering) will worsen the security of those users. While these mechanisms are not perfect, and can easily be bypassed by client applications that run DoH, this does not make them completely useless.

## 8. IANA Considerations

This document has no IANA actions.

## 9. References

### 9.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/rfc/rfc2119>>.

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