ADD
Internet-Draft
Intended status: Standards Track
Expires: October 4, 2020

M. Boucadair
Orange
T. Reddy
McAfee
D. Wing
Citrix
N. Cook
Open-Xchange
April 2, 2020

# DNS-over-HTTPS and DNS-over-TLS Server Discovery and Deployment Considerations for Home Networks
## draft-btw-add-home-05

Abstract

This document discusses DoT/DoH deployment considerations for home networks. It particularly sketches the required steps to use DoT/DoH capabilities provided by local networks.

One of the goals of this document is to assess to what extent existing tools can be used to provide a DoT/DoH service. As an outcome, new DHCP and Router Advertisement Options are specified in order to convey a DNS Authentication Domain Name.

Table of Contents

## 1. Introduction

Internet Service Providers (ISPs) traditionally provide DNS resolvers to their customers. Typically, ISPs deploy the following mechanisms to advertise a list of DNS Recursive DNS server(s) to their customers:

- Protocol Configuration Options in cellular networks [TS.24008].
- DHCP [RFC2132] (Domain Name Server Option) or DHCPv6 [RFC8415][RFC3646] (OPTION_DNS_SERVERS).
- 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, [I-D.ietf-dnsop-terminology-ter]). 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.

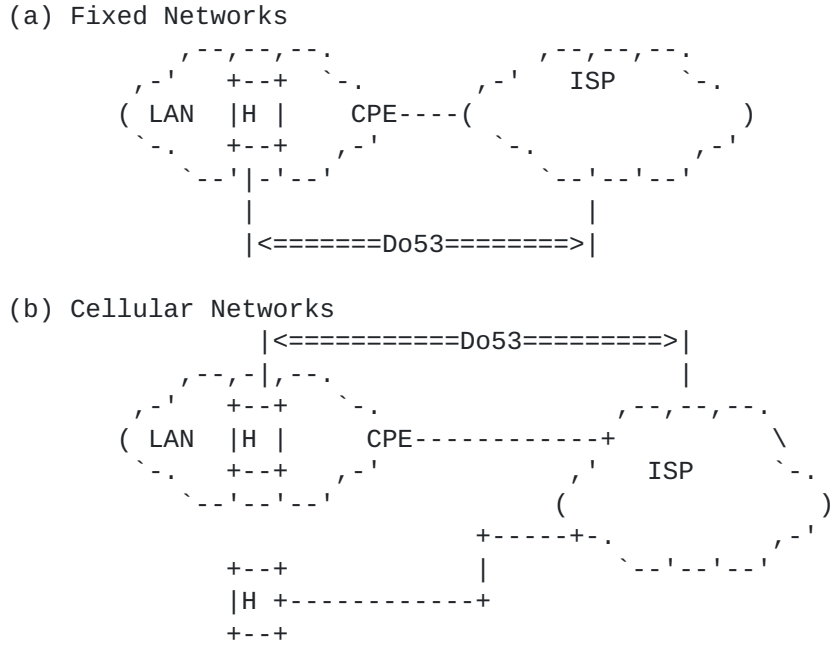



Figure 1: Sample Legacy Deployments

ISPs use DNS to provide additional services such as (but not limited to) malware filtering, parental control, or VoD (Video on Demand) optimization. DNS is also a central component for mastering the quality of experience for current latency-sensitive services, but also emerging ones (such as those services that pertain to the Ultra Reliability and Low Latency Communications (uRLLC) or Enhanced Mobile Broadband (eMBB).

> For example, the latency targets set in the context of 5G are 1ms (uRLLC) and 4ms (eMBB). An ISP will be able to address such demanding latency requirements assuming the corresponding services rely upon resources (network, compute, storage) that are located as close to the user as possible (e.g., by means of Edge Computing techniques and resources). Such latency requirements are likely to be addressed by means of optimized designs (DNS, in particular), too.

Relying upon local DNS resolvers will therefore contribute to meet the aforementioned service requirements. The use of external resolvers is likely to induce an extra service delay which exceeds by far the service target.

This document focuses on the support of DNS-over-HTTPS (DoH) [RFC8484] or DNS-over-TLS (DoT) [RFC7858] in local networks. In particular, the document describes how a local DoH/DoT server can be discovered and used by connected hosts. This document specifies options that allow DNS clients to discover local DoT/DoH servers. Section 4 describes DHCP, DHCPv6, and RA options to convey the Authentication Domain Name (ADN, defined in [RFC8310]).

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 the same mechanisms listed above. 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.

Both managed and unmanaged CPEs are discussed in the document (Section 3). Also, considerations related to hosting a DNS forwarder in the CPE are described (Section 7).

Hosts and/or CPEs 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.

## 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] and [I-D.ietf-dnsop-terminology-ter].

Do53 refers to unencrypted DNS.

'DoH/DoT' refers to DNS-over-HTTPS and/or DNS-over-TLS.

## 3. Sample Deployment Scenarios

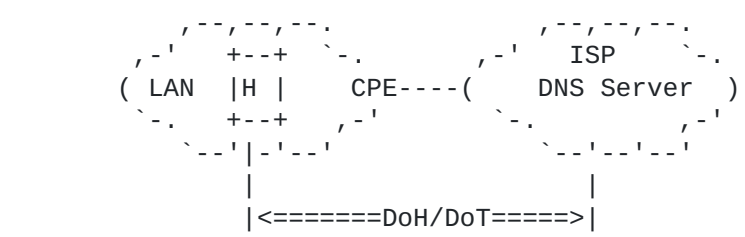
### 3.1. Managed CPEs

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 authentication domain name information (ADN) to managed CPEs if DoH/DoT is supported by a local network similar to what is depicted in Figure 2.

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 by using a dedicated field in the discovery message: Encrypted DNS Type (Section 4).

(a) Fixed Networks




(b) Cellular Networks

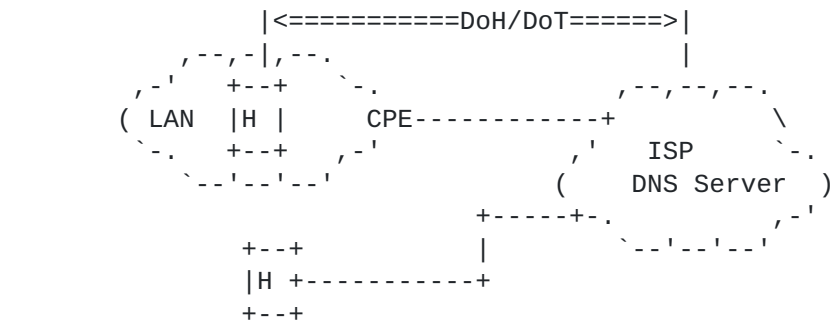



Figure 2: DoH/DoT in the WAN

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

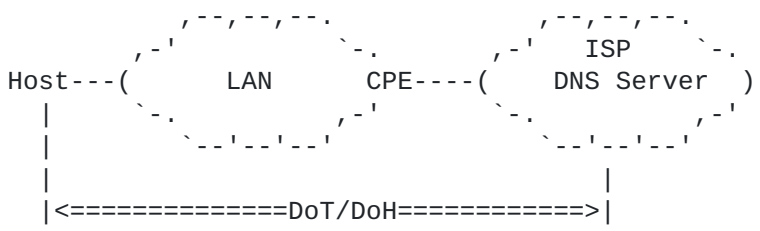



Figure 3: Direct DoH/DoT Sessions

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., [I-D.ietf-v6ops-rfc7084-bis]) or for supporting advanced services within the home (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:

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

An ISP that offers DoH/DoT to its customers may enable DoH/DoT in both legs as shown in Figure 4. Additional considerations related to this deployment are discussed in Section 7.

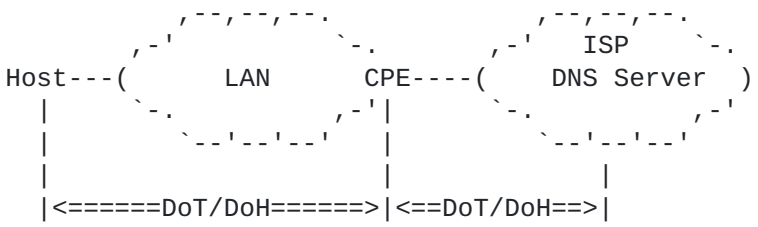



Figure 4: Proxied DoH/DoT Sessions

## 3.2. 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.

Customers may also decide to deploy internal home 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. DoH/DoT sessions can be established by a host with the DoH/DoT servers of the ISP (see Figure 5).

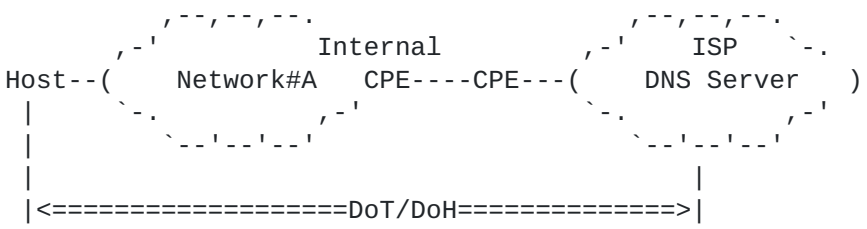



Figure 5: Direct DoH/DoT Sessions with the ISP DNS Resolver (Internal CPE)

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

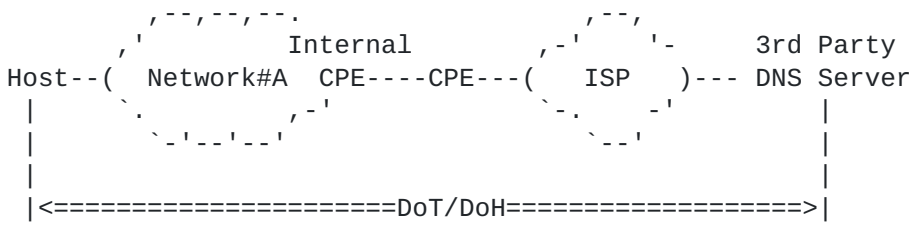



Figure 6: Direct DoH/DoT Sessions with a Third Party DNS Resolver

Section 7.2 discusses considerations related to hosting a forwarder in the Internal CPE.

## 4. DNS Reference Identifier Option

This section describes how a DNS client can discover the ADN of local DoH/DoT server(s) using DHCP (Sections 4.1 and 4.2) and Neighbor Discovery protocol (Section 4.3).

As reported in Section 1.7.2 of [RFC6125]:

> "few 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".

In order to allow for PKIX-based authentication between a DNS client and a DoH/DoT server while accommodating the current best practices for issuing certificates, this document allows for configuring an authentication domain name to be presented as a reference identifier for DNS authentication purposes.

The DNS client establishes a DoH/DoT session with the discovered DNS IP address(es) (Section 6) and uses the mechanism discussed in Section 8 of [RFC8310] to authenticate the DNS server certificate using the authentication domain name conveyed in the DNS Reference Identifier.

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

## 4.1. DHCPv6 DNS Reference Identifier Option

The DHCPv6 DNS Reference Identifier option is used to configure an authentication domain name of the DoH/DoT server. The format of this option is shown in Figure 7.

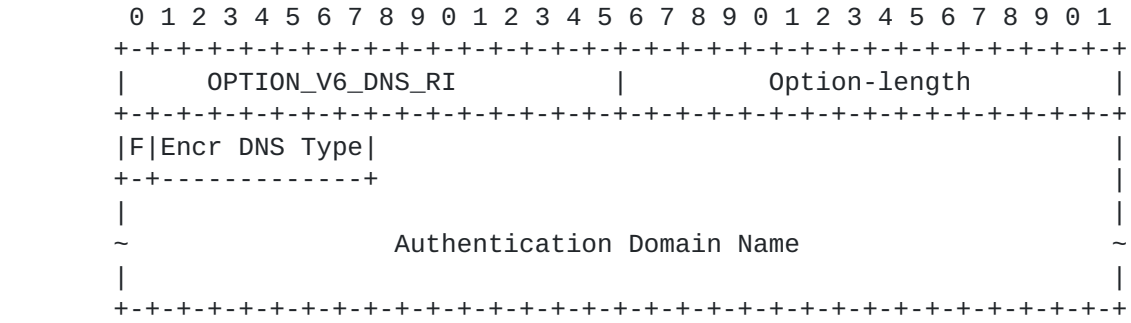



Figure 7: DHCPv6 DNS Reference Identifier Option

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

- Option-code: OPTION_V6_DNS_RI (TBA1, see Section 9.1)
- Option-length: Length of the enclosed data in octets.
- F bit: Forwarder bit. If set, it instructs the DNS client to retrieve the forwarder identifier from the resolver identified by the Authentication Domain Name (Section 7).
- Encr DNS Type (Encrypted DNS Type): Indicates the type of the encrypted DNS server conveyed in this attribute. The following values are defined:

  0: Any encrypted DNS
  1: DoT
  2: DoH
  See Section 9.5 for future assignment considerations.
- Authentication Domain Name: A fully qualified domain name of the DoH/DoT server. This field is formatted as specified in Section 10 of [RFC8415].

An example of the Authentication Domain Name encoding is shown in Figure 8. This example conveys the FQDN "doh1.example.com.".

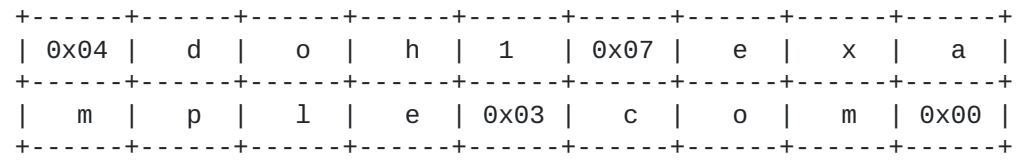



Figure 8: An example of the authentication-domain-name Encoding

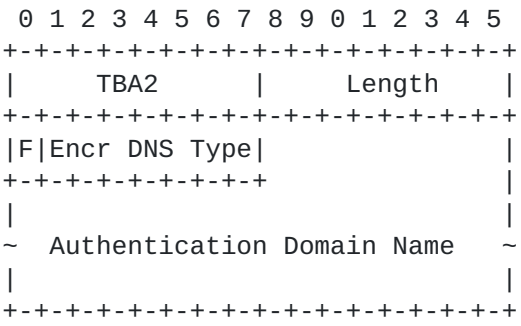
Multiple instances of OPTION_V6_DNS_RI may be returned to a DHCPv6 client; each pointing to a distinct encrypted DNS server type.

To discover an encrypted DNS server, the DHCPv6 client including OPTION_V6_DNS_RI 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 sets the Encrypted DNS Type field to the requested encrypted DNS server.

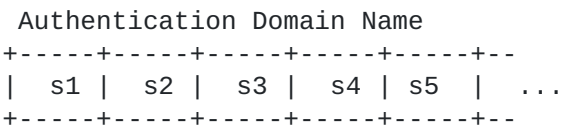
If the DHCPv6 client requested any encrypted DNS server, the DHCP client MUST be prepared to receive multiple DHCP OPTION_V6_DNS_RI options; each option is to be treated as a separate encrypted DNS server.

## 4.2. DHCP DNS Reference Identifier Option

The DHCP DNS Reference Identifier option is used to configure an authentication domain name of the DoH/DoT server. The format of this option is illustrated in Figure 9.




with:




The values s1, s2, s3, etc. represent the domain name labels in the domain name encoding.

Figure 9: DHCP DNS Reference Identifier Option

The fields of the option shown in Figure 9 are as follows:

- Code: OPTION_V4_DNS_RI (TBA2, see Section 9.2).
- Length: Length of the enclosed data in octets.
- F bit: Forwarder bit. If set, it instructs the DNS client to retrieve the forwarder identifier from the resolver identified by the Authentication Domain Name (Section 7).
- Encr DNS Type (Encrypted DNS Type): Indicates the type of the encrypted DNS server conveyed in this attribute. The following values are defined:

  0: Any encrypted DNS
  1: DoT
  2: DoH
  See Section 9.5 for future assignment considerations.
- Authentication Domain Name: The domain name of the DoH/DoT server. This field is formatted as specified in Section 10 of [RFC8415].

OPTION_V4_DNS_RI is a concatenation-requiring option. As such, the mechanism specified in [RFC3396] MUST be used if OPTION_V4_DNS_RI exceeds the maximum DHCP option size of 255 octets.

To discover an encrypted DNS server, the DHCP client requests the Encrypted DNS Reference Identifier by including OPTION_V4_DNS_RI in a

Parameter Request List option [RFC2132]. The DHCP client sets the Encrypted DNS Type field to the requested encrypted DNS server.

If the DHCP client requested any encrypted DNS server, the DHCP client MUST be prepared to receive multiple DHCP OPTION_V4_DNS_RI options; each option is to be treated as a separate encrypted DNS server.

## 4.3. RA DNS Reference Identifier Option

The IPv6 Router Advertisement (RA) DNS Reference Identifier option is used to configure an authentication domain name of the DoH/DoT server. The format of this option is illustrated in Figure 10.

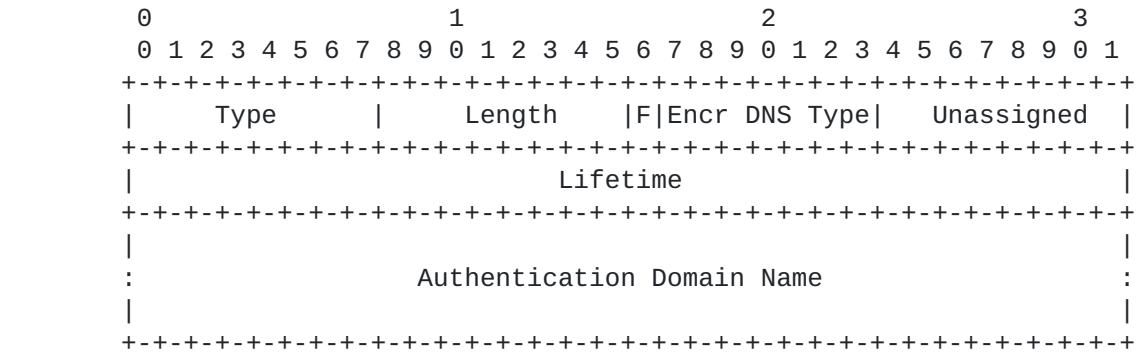



Figure 10: RA DNS Reference Identifier Option

The fields of the option shown in Figure 10 are as follows:

- Type: 8-bit identifier of the DNS Reference Identifier Option as assigned by IANA (TBA3, see Section 9.3).
- Length: 8-bit unsigned integer. The length of the option (including the Type and Length fields) is in units of 8 octets.
- F bit: Forwarder bit. If set, it instructs the DNS client to retrieve the forwarder identifier from the resolver identified by the Authentication Domain Name (Section 7).
- Encr DNS Type (Encrypted DNS Type): Indicates the type of the encrypted DNS server conveyed in this attribute. The following values are defined:

  0: Any encrypted DNS
  1: DoT
  2: DoH
  See Section 9.5 for future assignment considerations.
- Unassigned: This field is unused. It MUST be initialized to zero by the sender and MUST be ignored by the receiver.

- Lifetime: 32-bit unsigned integer. The maximum time in seconds (relative to the time the packet is received) over which the authentication domain name MAY be used as a DNS Reference Identifier.

  The value of Lifetime SHOULD by default be at least 3 * 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 the DNS Reference Identifier MUST no longer be used.
- Authentication Domain Name: The domain name of the DoH/DoT server. This field is formatted as specified in Section 10 of [RFC8415].

  This field MUST be padded with zeros so that its size is a multiple of 8 octets.

## 5. DoH URI Templates

DoH servers may support more than one URI Template [RFC8484]. The following sub-sections discuss some candidate solutions for a DoH client to retrieve the list of supported templates by a DoH server. Also, if the resolver hosts several DoH services (e.g., no-filtering, blocking adult content, blocking malware), these services can be discovered as templates.

How a DoH client makes use of the configured DoH services is out of scope of this document.

- DISCUSSION: More feedback is needed to assess whether URI RA/DHCP options have to be specified.

### 5.1. Define a Dedicated DHCP/RA Option

This solution assumes that DHCP servers and access routers maintain an updated list of the templates used by DoH resolvers.

The following observations can be made:

- In order to avoid that stale DoH information is supplied to connected devices, each time the URI templates are updated at a DoH resolver (e.g., add a new DoH service, withdraw a DoH service), DHCP servers (or access routers for the RA case) have to be updated accordingly to reflect the DNS service change.

- This dependency may be affordable if the ISP providing the connectivity service is also the one operating the DoH resolver.

- Nevertheless, if the DNS service is provided by a distinct entity than the ISP, an out-of-band mechanism is required to synchronize the list of DoH services that are active on a DoH resolver vs. the list maintained locally by the ISP.

- Also, it is not clear how enclosed URI templates will be validated by DHCP clients given that future specifications may allow for other variables in the URI.

- Including a large list of templates may cause the size of an RA to exceed the link MTU. In such case, multiple RAs must be used.

RA/DHCP has the following advantages:

- Notify clients whenever there is a change in the DoH service configuration.

- The DoH client can immediately use available DoH services.

- It is convenient if very few (stable) URIs are in use.

- It allows for customized configuration within the home network. For example, a child host can be provided by the CPE with a DoH server that supports parental filtering, while other hosts can be provisioned with a DoH server that does not enable such capabilities.

### 5.2. Retrieve the List Directly from the DoH Server

Upon discovery of a DoH resolver (Section 4), the DoH client contacts that DoH resolver to retrieve the list of supported DoH services (e.g., use of a well-known URI). That information is cached by the DoH client for a given period (e.g., 24h). DoH clients re-iterates that request regularly (e.g., 24h) to retrieve an updated list of supported DoH services. Note that a "push" mode can be considered using the mechanism defined in [I-D.ietf-dnssd-push].

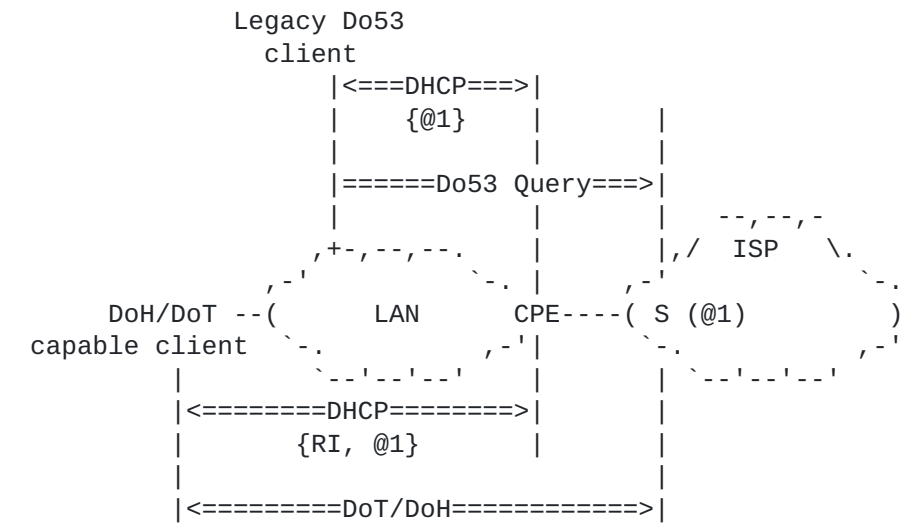
This approach allows to avoid adherence of DoH servers with DHCP servers (or access routers) for (de)activating new DoH services.

## 6. Locating DoH/DoT Servers

A CPE or a host relies upon discovery mechanisms (such as PCO, DHCP, or RA) to retrieve DoH/DoT servers' reachability information. In the various scenarios sketched in Section 3, Do53, DoH, and DoT may

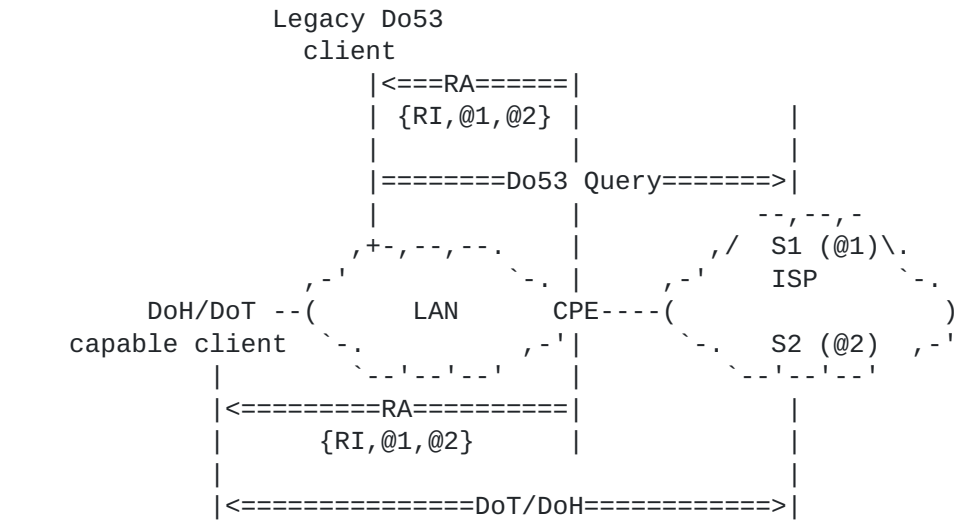
terminate on the same IP address (or distinct IP addresses as depicted in Figure 12). Terminating Do53/DoH/DoT on the same or distinct IP addresses is deployment-specific.

From an IP reachability standpoint, DoH/DoT servers SHOULD be located by their address literals rather than their names. This avoids adding a dependency on another server to resolve the DoH/DoT name. Concretely, if Do53/DoH/DoT terminate on same IP addresses, existing discovery mechanisms [RFC2132][RFC3646][RFC8106] can be leveraged to learn the IP addresses of DoT/DoH servers while an authentication domain name is supplied by one of the options discussed in Section 4. An example is depicted in Figure 11.




Legend:
* S: DNS server
* {@1}: IP address of S; returned in a DHCP Domain Name Server option
* RI: DNS Reference Identifier

Figure 11: Locating DoH/DoT/Do53 (Same DNS Server)




Legend:
* S1: Do53 server
* S2: DoH/DoT server
* @1: IP address of S1
* @1: IP address of S2
* RI: DNS Reference Identifier

Figure 12: Locating DoH/DoT/Do53 (Distinct Servers)

The following sub-sections discusses the conditions under which discovered DoT/DoH server can be used.

## 6.1. DoT/DoH Auto-Upgrade

Additional considerations are discussed below for the use of DoH and DoT servers provided by local networks:

- If the DNS server's IP address discovered by using DHCP/RA is pre-configured in the OS or Browser as a verified resolver (e.g., part of an auto-upgrade program such as [Auto-upgrade]), the DNS client auto-upgrades to use the pre-configured DoH/DoT server tied to the discovered DNS server IP address. In such a case the DNS client will perform additional checks out of band, such as confirming that the Do53 IP address and the DoH server are owned and operated by the same organisation.

- Similarly, if the ADN conveyed in DHCP/RA (Section 4) is pre-configured in the OS or browser as a verified resolver, the DNS client auto-upgrades to establish a DoH/DoT session with the ADN.

In such case, the DNS client matches the domain name in the DNS Reference Identifier DHCP/RA option with the 'DNS-ID' identifier type within subjectAltName entry in the server certificate conveyed in the TLS handshake.

Such an auto-upgrade mechanism would be compatible with the Redirection method of Section 7.1.2, for managed CPEs hosting a DoT/DoH forwarder.

## 6.2. Other Deployment Options

Some deployment options to securely configure hosts are discussed below. These options are provided for the sake of completeness.

- If Device Provisioning Protocol (DPP) [DPP] is used, the configurator can securely configure devices in the home network with the local DoT/DoH server using DPP. If the DoT/DoH servers use raw public keys [RFC7250], the Subject Public Key Info (SPKI) pin set [RFC7250] of raw public keys may be encoded in a QR code. The configurator (e.g., mobile device) can scan the QR code and provision SPKI pin set in OS/Browser. The configurator can in-turn securely configure devices (e.g., thermostat) in the home network with the SPKI pin set using DPP.

- If a CPE is co-located with security services within the home network, the CPE can use WPA-PSK but with unique pre-shared keys for different endpoints to deal with security issues. In such networks, [I-D.reddy-dprive-bootstrap-dns-server] may be used to securely bootstrap endpoint devices with the authentication domain name and DNS server certificate of the local network's DoH/DoT server.

  The OS would not know if the WPA pre-shared-key is the same for all clients or a unique pre-shared key is assigned to the host. Hence, the user has to indicate to the system that a unique pre-shared key is assigned to trigger the bootstrapping procedure.

  If the device joins a home network using a single shared password among all the attached devices, a compromised device can host a fake access point, and the device cannot be securely bootstrapped with the home network's DoH/DoT server.

# 7. Hosting DoH/DoT Forwarder in the CPE

### 7.1. Managed CPEs

The following mechanisms can be used to host a DoH/DoT forwarder in a managed CPE (Section 3.1).

#### 7.1.1. ACME

The ISP can assign a unique FQDN (e.g., cpe1.example.com) and a domain-validated public certificate to the DoH/DoT 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.

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.

If the CPE announces itself as a DNS forwarder, the F-bit MUST NOT be set.

#### 7.1.2. Redirection

##### 7.1.2.1. Server-Driven Redirection

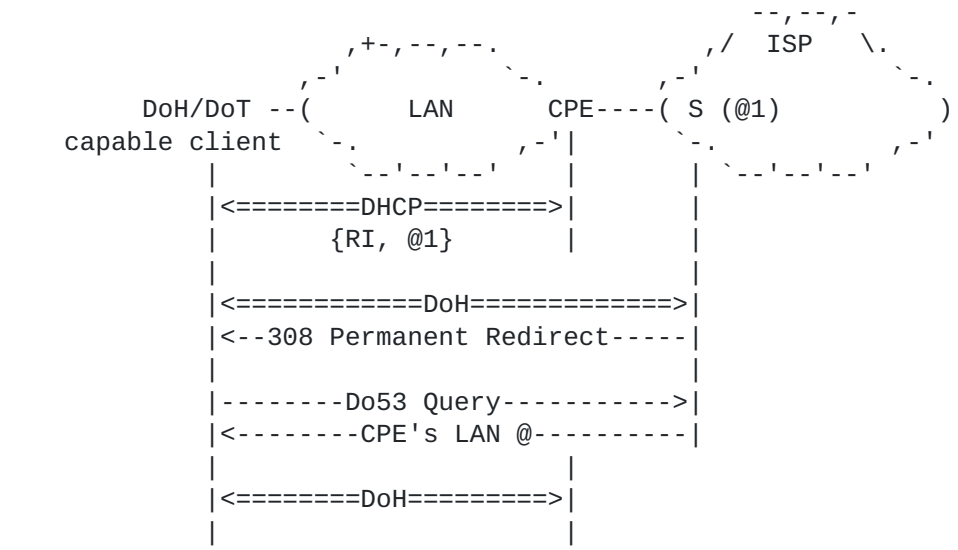
The mechanism specified in this section is specific to DoH.

An ISP-managed CPE can be configured with the ISP's DoH resolver IP addresses and ADN, which it will communicate to internal hosts using DHCP/RA (Section 4). Upon joining the network, a DoH client follows the procedure specified in Section 6.1 to upgrade to DoH.

Once the DoH session is established, the ISP DoH server uses HTTP redirection (Section 6.4.4 in [RFC7231] and [RFC7538]) to redirect the DNS client to the DoH forwarder hosted on the CPE (e.g., cpe1-internal.example.net). The DNS client either uses Do53 to resolve the domain name in the redirected URI and eventually establishes DoH session with the DoH forwarder in the CPE reachable on the LAN interface. A simplified example is illustrated in Figure 13.

PKIX authentication [RFC6125] based upon the domain name in the redirected URI will detect rogue DNS servers.

A DNS client that successfully connects to a redirected DoH server may choose to locally cache the server host IP addresses in order to not have to repeat the Do53 query.




Legend:
* S: DoH/DoT server
* @1: IP address of S

Figure 13: A Simplified Example of Server-Driven Redirection

Notes:

* As an optimization, the redirect response can be modified to include a list of IPv4/IPv6 addresses in addition to the CPE's name.

  [RFC7838] allows an origin's resource to be authoritatively available at a separate network location, nevertheless it requires the alternative service to present a certificate for the origin's host name. This is not acceptable for the case discussed in this section.

* Clients not caching the redirect information may experience an extra delay for each request.

### 7.1.2.2. Client-Initiated Redirection

This section assumes that the procedure discussed in Section 7.1.2.1 is disabled.

An ISP-managed CPE can be configured with the ISP's DoH/DoT resolver IP addresses and ADN, which it will communicate to internal hosts using DHCP/RA (Section 4). In addition, the CPE sets the F-bit to inform the client that a forwarder is available locally.

Upon joining the LAN, a DoH/DoT client follows the procedure specified in Section 6.1 to upgrade to DoH/DoT.

Once the DoH/DoT session is established, and given that F-bit is set, the DoH/DoT client uses SRV resource record lookup for discovering the DoH/DoT forwarder available in the local network to redirect the DNS client to the DoH/DoT forwarder hosted on the CPE (e.g., cpe1-internal.example.net). A simplified example is illustrated in Figure 14.

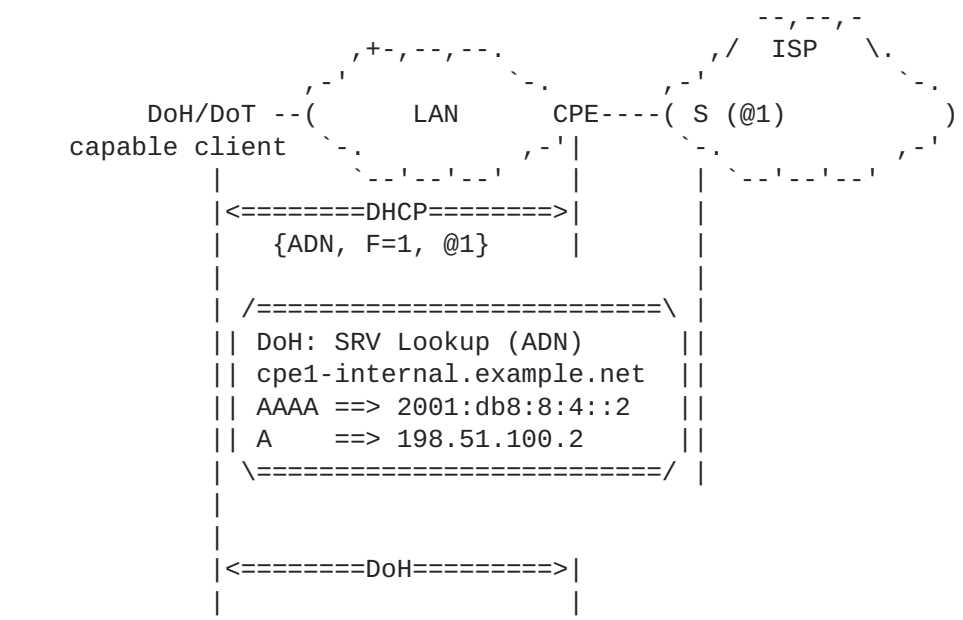
```
_domain-s._tcp.example.net  SRV 0 0 853 cpe1-internal.example.net
cpe1-internal.example.net  AAAA 2001:db8:8:4::2
cpe1-internal.example.net  A 198.51.100.2
```

Figure 14: DoT Redirect Example

The <Service> portion of the DNS service instance name MUST be "_domain-s._tcp" (Section 6 of [RFC7858]) or "_doh._tcp" (Section 9.4).

The SRV record can only convey a sub-domain of the parent domain otherwise the SRV record MUST be rejected by the DoH/DoT client.

A DNS client that successfully connects to a redirected DoH/DoT server may choose to locally cache the server IP addresses in order to avoid repeating the SRV lookup.




Legend:

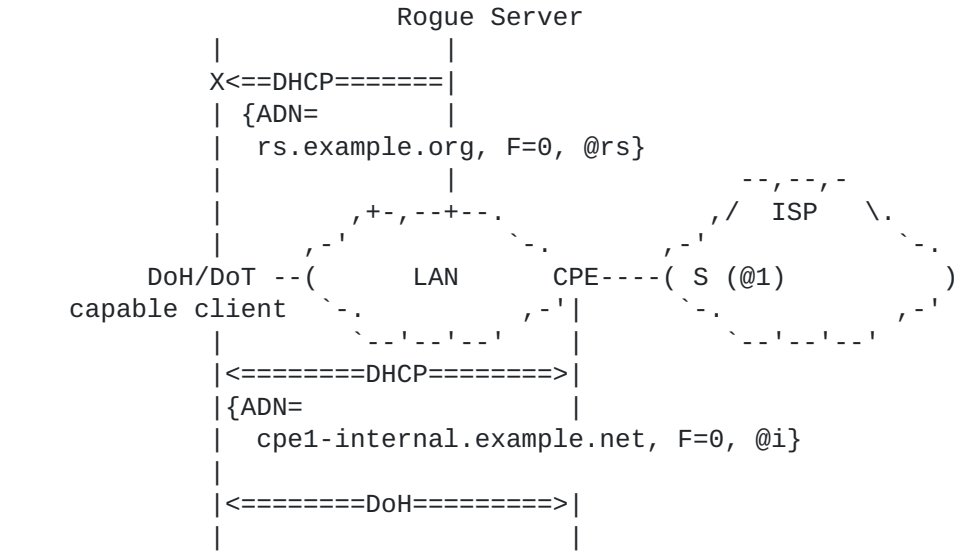
* S: DoH/DoT server
* @1: IP address of S
* F: Forwarding bit

Figure 15: A Simplified Example of Client-Initiated Redirection

### 7.1.3. Auto-Upgrade based on Domains and their Sub-domains

If the ADN conveyed in DHCP/RA (Section 4) is pre-configured in popular OSes or browsers as a verified resolver and the auto-upgrade (Section 6.1) is allowed for both the pre-configured ADN and its sub-domains, the redirection mechanisms discussed in Section 7.1.2 can be avoided. Concretely, the CPE can communicate the ADN of the local DoH forwarder (Section 7.1.1) to internal hosts using DHCP/RA (Section 4).

Let's suppose that "example.net" is pre-configured as a verified resolved in the browser or OS. If the DoH/DoT client discovers a local forwarder "cpe1-internal.example.net", the DoH/DoT client will auto-upgrade because the pre-configured ADN would match subjectAltName value "cpe1-internal.example.net" of type dNSName. As shown in Figure 16, the auto-upgrade to a rogue server advertising "rs.example.org" will fail.




Legend:

* S: DoH/DoT server
* @1: IP address of S
* @i: internal IP address of the CPE
* @rs: IP address of a rogue server

Figure 16: A Simplified Example of Auto-upgrade based on Sub-domains

## 7.2. Unmanaged CPEs

The approach specified in Section 7.1 does not apply for hosting a DNS forwarder in an unmanaged CPE.

The unmanaged CPE administrator (referred to as administrator) can host a DoH/DoT forwarder on the unmanaged CPE. This assumes the following:

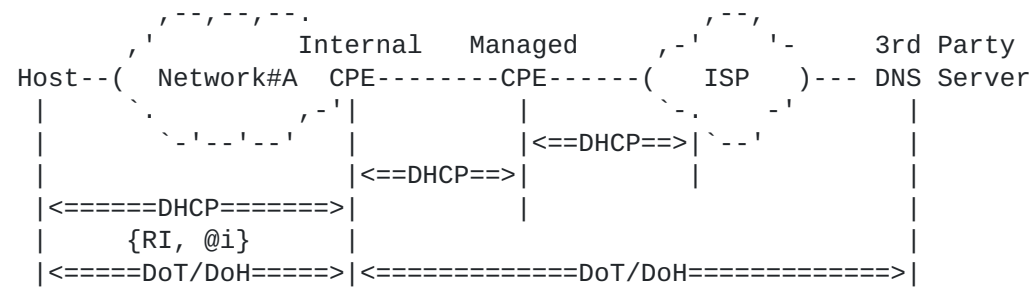
- The DoH/DoT server certificate is managed by the entity in-charge of hosting the DoT/DoH forwarder.

  Alternatively, a security service provider can assign a unique FQDN to the CPE. The DoH/DoT forwarder will act like a private DoT/DoH server only be accessible from within the home network.

- The DoH/DoT forwarder will either be configured to use the ISP's or a 3rd party DoH/DoT server.

- The unmanaged CPE will advertise the DoH/DoT forwarder ADN using DHCP/RA to internal hosts.

Figure 17 illustrates an example of an unmanaged CPE hosting a forwarder which connects to a 3rd party DoH/DoT 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 17: Example of an Internal CPE Hosting a Forwarder

## 8. Security Considerations

An attacker can get a domain name, domain-validated public certificate from a CA, host a DoT/DoH server and claim the best DNS privacy preservation policy. Also, an attacker within the home network can use the public IP address, get an 'IP address'-validated public certificate from a CA, host a DoT/DoH server and claim the best DNS privacy preservation policy.

Because DHCP/RA messages are not encrypted or protected against modification in any way, their content can be spoofed or modified by compromised devices within the home network. An attacker can spoof the DHCP/RA response to provide the attacker's DoT/DoH server. Note that such an attacker can launch other attacks as discussed in Section 22 of [RFC8415]. Furthermore, if the browser or the OS is pre-configured with a list of DNS servers and some of which perform malware filtering while others do not, an attacker can prevent contacting the preferred filtering DNS servers causing a downgrade attack to a non-filtering DNS server, which the attacker can leverage to deliver malware.

The use of DoH/DoT also depends on the user's policies. For example, the user may indicate his/her consent to use (or not) the locally-discovered DoH/DoT server or request to review human-readable privacy policy information of a selected DNS server and to assess whether that DNS server performs DNS-based content filtering (e.g.,

[I-D.reddy-dprive-dprive-privacy-policy]). The DNS client is assumed to adhere to these policies. This document does not make any assumption about the structure of such policies nor mandates specific requirements. Such policies and their handling is out of scope.

DoH/DoT servers discovered using insecure discovery mechanisms like DHCP/RA are used by a DNS client if the insecurely discovered DoH/DoT server is pre-configured in the OS or the browser. Section 6.1 identifies a set of deployment options under which DHCP/RA RI options can be used.

If the insecurely discovered DoH/DoT server is not pre-configured in the OS or browser, the client may validate the signatory (e.g., cryptographically attested by the ISP). However, as discussed above, the use of policies to select servers is out of scope of this document.

DoT/DoH sessions with rogue servers spoofing 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] based upon the authentication domain name in the Reference Identifier 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).

The resolution of redirected domain using Do53 (Section 7.1.2.1) is a minimal leakage (see Section 6.3 of [RFC8310]). To protect against DNS-vectored attacks, DNSSEC can be used to ensure the validity of the received DNS records received. Impersonation of a DoH/DoT forwarder is prevented by validating the certificate presented by the DoH/DoT forwarder.

TCP connections received outside the home network MUST be discarded by the DoH/DoT forwarder in the CPE. This behavior adheres to REQ#8 in [RFC6092]; it MUST apply for both IPv4 and IPv6.

## 9. IANA Considerations

### 9.1. DHCPv6 Option

IANA is requested to assign the following new DHCPv6 Option Code in the registry maintained in: https://www.iana.org/assignments/dhcpv6-parameters/dhcpv6-parameters.xhtml#dhcpv6-parameters-2.

| Value | Description | Client ORO | Singleton Option | Reference |
|---|---|---|---|---|
| TBA1 | OPTION_V6_DNS_RI | Yes | Yes | [ThisDocument] |

## 9.2. DHCP Option

IANA is requested to assign the following new DHCP Option Code in the registry maintained in: https://www.iana.org/assignments/bootp-dhcp-parameters/bootp-dhcp-parameters.xhtml#options.

| Tag | Name | Data Length | Meaning | Reference |
|---|---|---|---|---|
| TBA2 | OPTION_V4_DNS_RI | N | DoT/DoH server authentication domain name | [ThisDocument] |

## 9.3. RA 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 http://www.iana.org/assignments/icmpv6-parameters/icmpv6-parameters.xhtml#icmpv6-parameters-5.

| Type | Description | Reference |
|---|---|---|
| TBA3 | DNS Reference Identifier Option | [ThisDocument] |

## 9.4. Service Name

IANA is requested to allocate the following service name from the registry available at: https://www.iana.org/assignments/service-names-port-numbers/service-names-port-numbers.xhtml.

| | |
|---|---|
| Service Name: | doh |
| Port Number: | N/A |
| Transport Protocol(s): | TCP |
| Description: | DNS-over-HTTPS |
| Assignee: | IESG <iesg@ietf.org> |
| Contact: | IETF Chair <chair@ietf.org> |
| Reference: | [ThisDocument] |

### 9.5. Encrypted DNS Types

This document requests IANA to create a new registry called "Encrypted DNS Types". The initial values of the registery is as follows:

| Value | Description | Reference |
|---|---|---|
| 0 | Any | RFC XXXX |
| 1 | DNS-over-TLS (DoT) | RFC XXXX |
| 2 | DNS-over-HTTPs (DoH) | RFC XXXX |

New values are assigned on a First Come, First Served (FCFS) basis (Section 4.4 of [RFC8126]).

## 10. Acknowledgements

Many thanks to Christian Jacquenet for the review.

Thanks to Tommy Jensen, Stephen Farrell, Martin Thomson, Vittorio Bertola, and Iain Sharp for the comments.

Thanks to Mark Nottingham for the feedback on HTTP redirection.

## 11. References

### 11.1. 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/info/rfc2119>.

[RFC2132] Alexander, S. and R. Droms, "DHCP Options and BOOTP Vendor Extensions", RFC 2132, DOI 10.17487/RFC2132, March 1997, <https://www.rfc-editor.org/info/rfc2132>.

[RFC3396] Lemon, T. and S. Cheshire, "Encoding Long Options in the Dynamic Host Configuration Protocol (DHCPv4)", RFC 3396, DOI 10.17487/RFC3396, November 2002, <https://www.rfc-editor.org/info/rfc3396>.

[RFC4861] Narten, T., Nordmark, E., Simpson, W., and H. Soliman, "Neighbor Discovery for IP version 6 (IPv6)", RFC 4861, DOI 10.17487/RFC4861, September 2007, <https://www.rfc-editor.org/info/rfc4861>.

[RFC7538] Reschke, J., "The Hypertext Transfer Protocol Status Code 308 (Permanent Redirect)", RFC 7538, DOI 10.17487/RFC7538, April 2015, <https://www.rfc-editor.org/info/rfc7538>.

[RFC7858] Hu, Z., Zhu, L., Heidemann, J., Mankin, A., Wessels, D., and P. Hoffman, "Specification for DNS over Transport Layer Security (TLS)", RFC 7858, DOI 10.17487/RFC7858, May 2016, <https://www.rfc-editor.org/info/rfc7858>.

[RFC8106] Jeong, J., Park, S., Beloeil, L., and S. Madanapalli, "IPv6 Router Advertisement Options for DNS Configuration", RFC 8106, DOI 10.17487/RFC8106, March 2017, <https://www.rfc-editor.org/info/rfc8106>.

[RFC8126] Cotton, M., Leiba, B., and T. Narten, "Guidelines for Writing an IANA Considerations Section in RFCs", BCP 26, RFC 8126, DOI 10.17487/RFC8126, June 2017, <https://www.rfc-editor.org/info/rfc8126>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/info/rfc8174>.

[RFC8310] Dickinson, S., Gillmor, D., and T. Reddy, "Usage Profiles for DNS over TLS and DNS over DTLS", RFC 8310, DOI 10.17487/RFC8310, March 2018, <https://www.rfc-editor.org/info/rfc8310>.

[RFC8415] Mrugalski, T., Siodelski, M., Volz, B., Yourtchenko, A., Richardson, M., Jiang, S., Lemon, T., and T. Winters, "Dynamic Host Configuration Protocol for IPv6 (DHCPv6)", RFC 8415, DOI 10.17487/RFC8415, November 2018, <https://www.rfc-editor.org/info/rfc8415>.

[RFC8484] Hoffman, P. and P. McManus, "DNS Queries over HTTPS (DoH)", RFC 8484, DOI 10.17487/RFC8484, October 2018, <https://www.rfc-editor.org/info/rfc8484>.

### 11.2. Informative References

[Auto-upgrade]
The Unicode Consortium, "DoH providers: criteria, process for Chrome", <docs.google.com/document/d/128i2YTV2C7T6Gr3I-81zlQ-_Lprnsp24qzy_20Z1Psw/edit>.

[DPP] The Wi-Fi Alliance, "Device Provisioning Protocol Specification", <https://www.wi-fi.org/file/device-provisioning-protocol-specification>.

[I-D.ietf-dnsop-terminology-ter]
Hoffman, P., "Terminology for DNS Transports and Location", draft-ietf-dnsop-terminology-ter-01 (work in progress), February 2020.

[I-D.ietf-dnssd-push]
Pusateri, T. and S. Cheshire, "DNS Push Notifications", draft-ietf-dnssd-push-25 (work in progress), October 2019.

[I-D.ietf-v6ops-rfc7084-bis]
Palet, J., "Basic Requirements for IPv6 Customer Edge Routers", draft-ietf-v6ops-rfc7084-bis-04 (work in progress), June 2017.

[I-D.reddy-dprive-bootstrap-dns-server]
Reddy.K, T., Wing, D., Richardson, M., and M. Boucadair, "A Bootstrapping Procedure to Discover and Authenticate DNS-over-TLS and DNS-over-HTTPS Servers", draft-reddy-dprive-bootstrap-dns-server-08 (work in progress), March 2020.

[I-D.reddy-dprive-dprive-privacy-policy]
Reddy.K, T., Wing, D., Richardson, M., and M. Boucadair, "DNS Server Privacy Statement and Filtering Policy with Assertion Token", draft-reddy-dprive-dprive-privacy-policy-03 (work in progress), March 2020.

[RFC3646] Droms, R., Ed., "DNS Configuration options for Dynamic Host Configuration Protocol for IPv6 (DHCPv6)", RFC 3646, DOI 10.17487/RFC3646, December 2003, <https://www.rfc-editor.org/info/rfc3646>.

[RFC6092] Woodyatt, J., Ed., "Recommended Simple Security Capabilities in Customer Premises Equipment (CPE) for Providing Residential IPv6 Internet Service", RFC 6092, DOI 10.17487/RFC6092, January 2011, <https://www.rfc-editor.org/info/rfc6092>.

[RFC6125] Saint-Andre, P. and J. Hodges, "Representation and Verification of Domain-Based Application Service Identity within Internet Public Key Infrastructure Using X.509 (PKIX) Certificates in the Context of Transport Layer Security (TLS)", RFC 6125, DOI 10.17487/RFC6125, March 2011, <https://www.rfc-editor.org/info/rfc6125>.

[RFC6731] Savolainen, T., Kato, J., and T. Lemon, "Improved Recursive DNS Server Selection for Multi-Interfaced Nodes", RFC 6731, DOI 10.17487/RFC6731, December 2012, <https://www.rfc-editor.org/info/rfc6731>.

[RFC7231] Fielding, R., Ed. and J. Reschke, Ed., "Hypertext Transfer Protocol (HTTP/1.1): Semantics and Content", RFC 7231, DOI 10.17487/RFC7231, June 2014, <https://www.rfc-editor.org/info/rfc7231>.

[RFC7250] Wouters, P., Ed., Tschofenig, H., Ed., Gilmore, J., Weiler, S., and T. Kivinen, "Using Raw Public Keys in Transport Layer Security (TLS) and Datagram Transport Layer Security (DTLS)", RFC 7250, DOI 10.17487/RFC7250, June 2014, <https://www.rfc-editor.org/info/rfc7250>.

[RFC7838] Nottingham, M., McManus, P., and J. Reschke, "HTTP Alternative Services", RFC 7838, DOI 10.17487/RFC7838, April 2016, <https://www.rfc-editor.org/info/rfc7838>.

[RFC7969] Lemon, T. and T. Mrugalski, "Customizing DHCP Configuration on the Basis of Network Topology", RFC 7969, DOI 10.17487/RFC7969, October 2016, <https://www.rfc-editor.org/info/rfc7969>.

[RFC8499] Hoffman, P., Sullivan, A., and K. Fujiwara, "DNS Terminology", BCP 219, RFC 8499, DOI 10.17487/RFC8499, January 2019, <https://www.rfc-editor.org/info/rfc8499>.

[RFC8520] Lear, E., Droms, R., and D. Romascanu, "Manufacturer Usage Description Specification", RFC 8520, DOI 10.17487/RFC8520, March 2019, <https://www.rfc-editor.org/info/rfc8520>.

[RFC8555] Barnes, R., Hoffman-Andrews, J., McCarney, D., and J. Kasten, "Automatic Certificate Management Environment (ACME)", RFC 8555, DOI 10.17487/RFC8555, March 2019, <https://www.rfc-editor.org/info/rfc8555>.

[TR-069] The Broadband Forum, "CPE WAN Management Protocol", December 2018, <https://www.broadband-forum.org/technical/download/TR-069.pdf>.

[TS.24008] 3GPP, "Mobile radio interface Layer 3 specification; Core network protocols; Stage 3 (Release 16)", December 2019, <http://www.3gpp.org/DynaReport/24008.htm>.

## Authors' Addresses

Mohamed Boucadair
Orange
Rennes 35000
France

Email: mohamed.boucadair@orange.com

Tirumaleswar Reddy
McAfee, Inc.
Embassy Golf Link Business Park
Bangalore, Karnataka 560071
India

Email: TirumaleswarReddy_Konda@McAfee.com

Dan Wing
Citrix Systems, Inc.
USA

Email: dwing-ietf@fuggles.com

Neil Cook
Open-Xchange
UK

Email: neil.cook@noware.co.uk