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Chain Query requests in DNS
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Abstract

This document defines an EDNS0 extension that can be used by a security-aware validating Resolver configured as a Forwarder to send a single query, requesting a complete validation path along with the regular query answer. The reduction in queries lowers the latency. This extension requries the use of source IP verified transport such as TCP or UDP with EDNS-COOKIE so it cannot be abused in amplification attacks.

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1. Introduction

Traditionally, a DNS client operates in stub-mode. For each DNS question the DNS client needs to resolve, it sends a single query to an upstream Recursive Resolver to obtain a single DNS answer. When DNSSEC [RFC4033] is deployed on such DNS clients, validation requires that the client obtains all the intermediate information from the DNS root down to the queried-for hostname so it can perform DNSSEC validation on the complete chain of trust.

Currently, applications send out many UDP requests concurrently. This requires more resources on the DNS client with respect to state (cpu, memory, battery) and bandwidth. There is also no guarantee

that the initial set of UDP questions will result in all the records required for DNSSEC validation. More round trips could be required depending on the resulting DNS answers. This especially affects high-latency links.

This document specifies an EDNS0 extension that allows a validating Resolver running as a Forwarder to open a TCP connection to another Resolver and request a DNS chain answer using one DNS query/answer pair. This reduces the number of round trips to two. If combined with long lived TCP or [TCP-KEEPALIVE] there is only one round trip. While the upstream Resolver still needs to perform all the individual queries required for the complete answer, it usually has a much bigger cache and does not experience significant slowdown from last-mile latency.

This EDNS0 extension allows the Forwarder to indicate which part of the DNS hierarchy it already contains in its cache. This reduces the amount of data required to be transferred and reduces the work the upstream Recursive Resolver has to perform.

This EDNS0 extension is only intended to be sent by Forwarders to Recursive Resolvers. It can (and should) be ignored by Authoritative Servers.

1.1. Requirements Notation

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

2. Terminology

The DNS terminology used in this document is that of [DNS-TERMINOLOGY]. Additionally, the following terms are used: [edit: which I hope will end up in the terminology document]

Recursive Resolver: A nameserver that is responsible for resolving domain names for clients by following the domain's delegation chain, starting at the root. Recursive Resolvers frequently use caches to be able to respond to client queries quickly. Described in [RFC1035] chapter 7.

Validating Resolver: A recursive nameserver that also performs DNSSEC [RFC4033] validation. Also known as "security-aware resolver".

3. Overview

When DNSSEC is deployed on a host, it can no longer delegate all DNS work to the upstream Recursive Resolver. Obtaining just the DNS answer itself is not enough to validate that answer using DNSSEC. For DNSSEC validation, the DNS client requires a locally running validating Resolver so it can confirm DNSSEC validation of all intermediary DNS answers. It can configure itself as a Forwarder if it obtains the IP addresses of one or more Recursive Resolvers that are available, or as a stand-alone Recursive Resolver if no functional Recursive Resolvers were obtained. Generating the required queries for validation adds a significant delay in answering the DNS question of the locally running application. The application must wait while the Resolver validates all intermediate answers. Each round-trip adds to the total time waiting on DNS resolution with validation to complete. This makes DNSSEC resolving impractical for devices on networks with a high latency.

This document defines the CHAIN option that allows the Resolver to request all intermediate DNS data it requires to resolve and validate a particular DNS answer in a single round-trip. The Resolver could be part of the application or a Recursive Resolver running on the host.

Servers answering with CHAIN data should ensure that the transport is TCP or source IP address verified UDP. See Section 8. This avoids abuse in DNS amplification attacks.

Applications that support CHAIN internally can perform validation without requiring the host the run a Recursive Resolver. This is particularly useful for virtual servers in a cloud or container based deployment where it is undesirable to run a Recursive Resolver per virtual machine.

The format of this option is described in Section 4.

As described in Section 5.4, a Recursive Resolver could use this EDNS0 option to include additional data required by the Resolver in the Authority Section of the DNS answer packet when using a source IP verified transport. The Answer Section remains unchanged from a traditional DNS answer and contains the answer and related DNSSEC entries.

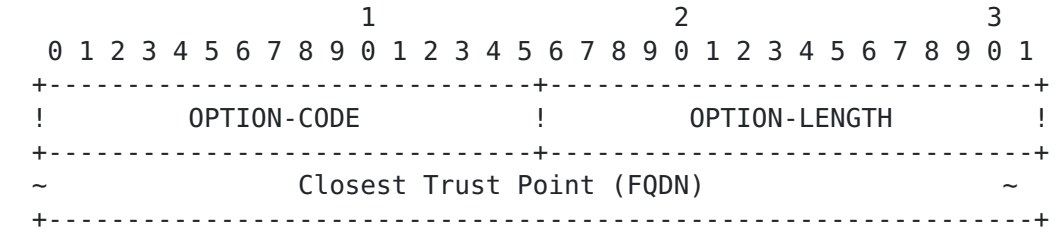
An empty CHAIN EDNS0 option MAY be sent over any transport as a discovery method. A DNS server receiving such an empty CHAIN option SHOULD add an empty CHAIN option in its answer to indicate that it supports CHAIN for source IP address verified transports.

The mechanisms provided by CHAIN raise various security related concerns, related to the additional work, bandwidth, amplification

attacks as well as privacy issues with the cache. These concerns are described in Section 8.

4. Option Format

This draft uses an EDNS0 [RFC6891] option to include client IP information in DNS messages. The option is structured as follows:



- OPTION-CODE, 2 octets, for CHAIN is [TBD1].
- OPTION-LENGTH, 2 octets, contains the length of the payload (everything after Option-length) in octets.
- Closest Trust Point, a variable length FDQN of the requested start point of the chain. This entry is the 'lowest' known entry in the DNS chain known by the recursive server seeking a CHAIN answer for which it has a validated DS and DNSKEY record. The end point of the chain is obtained from the DNS Query Section itself. No DNS name compression is allowed for this value.

5. Protocol Description

5.1. Discovery of Support

A Forwarder may include a zero-length CHAIN option in a regular query over any transport to discover the DNS server capability for CHAIN. Recursive Resolvers that support and are willing to accept CHAIN queries over source IP verified transport respond to a zero-length CHAIN received by including a zero-length CHAIN option in the answer. If not already using a source IP verified transport, the Forwarder MAY then switch to a source IP verified transport and start sending queries with the CHAIN option to request a CHAIN response from the Recursive Resolver. Examples of source IP verification are the 3-way TCP handshake and UDP with [EDNS-COOKIE].

5.2. Generate a Query

In this option value, the Forwarder sets the Closest Trust Point in the chain - furthest from the root - that it already has a DNSSEC validated (secure or not) answer for in its cache. The upstream Recursive Resolver does not need to include any part of the chain from the root down to this option's FQDN. A complete example is described in Section 9.1.

The CHAIN option should generally be sent by system Forwarders and Resolvers within an application that also perform DNSSEC validation.

5.3. Send the Option

When CHAIN is available, the downstream Recursive Resolver can adjust its query strategy based on the desired queries and its cache contents.

A Forwarder can request the CHAIN option with every outgoing DNS query. However, it is RECOMMENDED that Forwarders remember which upstream Recursive Resolvers did not return the option (and additional data) with their response. The Forwarder SHOULD fallback to regular DNS for subsequent queries to those Recursive Resolvers. It MAY switch to another Recursive Resolver that does support the CHAIN option or try again later to see if the server has become less loaded and is now willing to answer with Query Chains.

5.4. Generate a Response

When a query containing a non-zero CHAIN option is received from a Forwarder, the upstream Recursive Resolver supporting CHAIN MAY respond by confirming that it is returning a CHAIN. To do so, it MUST set the CHAIN option to the lowest Trust Point sent as part of the chain, with its corresponding OPTION-LENGTH. It extends the Authority Section in the DNS answer packet with the DNS RRsets required for validating the answer. The DNS RRsets added start with the first chain element below the received Closest Trust Point up to and including the NS and DS RRsets that represent the zone cut (authoritative servers) of the QNAME. The actual DNS answer to the question in the Query Section is placed in the DNS Answer Section identical to the traditional DNS answer. All required DNSSEC related records must be added to their appropriate sections. This includes records required for proof of non-existence of regular and/or wildcard records, such as NSEC or NSEC3 records.

Recursive Resolvers that have not implemented or enabled support for the CHAIN option, or are otherwise unwilling to perform the additional work for a Chain Query due to work load, may safely ignore the option in the incoming queries. Such a server MUST NOT include an CHAIN option when sending DNS answer replies back, thus indicating it is not able or willing to support Chain Queries at this time.

Requests with wrongly formatted options (i.e. bogus FQDN) MUST be rejected and a FORMERR response must be returned to the sender, as described by [RFC6891].

Requests resulting in chains that the receiving resolver is unwilling to serve can be rejected by answering the query as a regular DNS reply but with an empty CHAIN payload. Replying with an empty CHAIN can be used for chains that would be too big or chains that would reveal too much information considered private.

At any time, a Recursive Resolver that has determined that it is running low on resources can refuse CHAIN queries by replying with a regular DNS reply with an empty CHAIN payload.

If a CHAIN answer would be bigger than the Recursive Resolver is willing to serve, it SHOULD send a partial chain starting with the data closest to the top of the chain. The client MAY re-send the query with an updated Closest Trust Point until it has received the full chain. The CHAIN response will contain the lowest Closest Trust Point that was included in the CHAIN answer.

If the DNS request results in an CNAME or DNAME for the Answer Section, the Recursive Resolver MUST return these records in the Answer Section similar to regular DNS processing. The CNAME or DNAME target MAY be placed in the Additional Section only if all supporting records for DNSSEC validation of the CNAME or DNAME target are also added to the Authority Section.

The response from a Recursive Resolver to a Resolver MUST NOT contain the CHAIN option if none was present in the Resolver's original request.

A DNS query that contains the CHAIN option MUST also have the DNSSEC OK bit set. If this bit is not set, the CHAIN option received MUST be ignored.

6. Protocol Considerations

6.1. DNSSEC Considerations

The presence or absence of an OPT resource record containing an CHAIN option in a DNS query does not change the usage of those resource records and mechanisms used to provide data origin authentication and data integrity to the DNS, as described in [RFC4033], [RFC4034] and [RFC4035].

6.2. NS record Considerations

CHAIN responses MUST include the NS RRset from the child zone including the RRSIG records required for validation.

When a DNSSEC chain is supplied via CHAIN, the Forwarder is no longer required to use the NS RRset, as it can construct the validation path via the DNSKEY and DS RRsets without using the NS RRset. However, the Forwarder might be forced to switch from Forwarder mode to Recursive Resolver mode due to a network topology change. In Recursive Resolver mode, the NS RRsets are needed to find and query Authoritative Servers directly. It is RECOMMENDED that the DNS Forwarder populate its cache with this information to avoid requiring future queries to obtain any missing NS records. Therefore, CHAIN responses MUST include the NS RRset from the child zone, including the RRSIG records required for validation.

6.3. TCP Session Management

It is RECOMMENDED that TCP sessions not immediately be closed after the DNS answer to the first query is received. It is recommended to use [TCP-KEEPALIVE].

Both DNS clients and servers are subject to resource constraints which will limit the extent to which Chain Queries can be executed. Effective limits for the number of active sessions that can be maintained on individual clients and servers should be established, either as configuration options or by interrogation of process limits imposed by the operating system.

In the event that there is greater demand for Chain Queries than can be accommodated, DNS servers may stop advertising the CHAIN option in successive DNS messages. This allows, for example, clients with other candidate servers to query to establish new sessions with different servers in expectation that those servers might still allow Chain Queries.

6.4. Negative Trust Anchors

If a CHAIN answer would intersect with a Negative Trust Anchor [RFC7646], a partian CHAIN up to the node above the Negative Trust Anchor should be returned.

6.5. Non-Clean Paths

Many paths between DNS clients and Recursive Resolvers suffer from poor hygiene, limiting the free flow of DNS messages that include particular EDNS0 options, or messages that exceed a particular size. A fallback strategy similar to that described in [RFC6891] section 6.2.2 SHOULD be employed to avoid persistent interference due to non-clean paths.

6.6. Anycast Considerations

Recursive Resolvers of various types are commonly deployed using anycast [RFC4786].

Successive DNS transactions between a client and server using UDP transport may involve responses generated by different anycast nodes, and the use of anycast in the implementation of a DNS server is effectively undetectable by the client. The CHAIN option SHOULD NOT be included in responses using UDP transport from servers provisioned using anycast unless all anycast server nodes are capable of processing the CHAIN option.

Changes in network topology between clients and anycast servers may cause disruption to TCP sessions making use of CHAIN more often than with TCP sessions that omit it, since the TCP sessions are expected to be longer-lived. Anycast servers MAY make use of TCP multipath [RFC6824] to anchor the server side of the TCP connection to an unambiguously-unicast address in order to avoid disruption due to topology changes.

7. Implementation Status

This section records the status of known implementations of the protocol defined by this specification at the time of posting of this Internet-Draft, and is based on a proposal described in [RFC6982]. The description of implementations in this section is intended to assist the IETF in its decision processes in progressing drafts to RFCs. Please note that the listing of any individual implementation here does not imply endorsement by the IETF. Furthermore, no effort has been spent to verify the information presented here that was supplied by IETF contributors. This is not intended as, and must not be construed to be, a catalog of available implementations or their

features. Readers are advised to note that other implementations may exist.

According to [RFC6982], "this will allow reviewers and working groups to assign due consideration to documents that have the benefit of running code, which may serve as evidence of valuable experimentation and feedback that have made the implemented protocols more mature. It is up to the individual working groups to use this information as they see fit".

[While there is some interest, no work has started yet]

8. Security Considerations

8.1. Amplification Attacks

Chain Queries can potentially send very large DNS answers. Attackers could abuse this using spoofed source IP addresses to inflict large Distributed Denial of Service attacks using query-chains as an amplification vector in their attack. While TCP is not vulnerable for this type of abuse, the UDP protocol is vulnerable to this.

A Recursive Resolver MUST NOT return CHAIN answers to clients over UDP without source IP address verification. An example of UDP based source IP address verification is [EDNS-COOKIE]. A Recursive Resolver refusing a CHAIN option MUST respond with a zero-length CHAIN option to indicate support for CHAIN queries when a proper transport is used. It MUST NOT send an RCODE of REFUSED.

9. Examples

9.1. Simple Query for example.com

- A web browser on a client machine asks the Forwarder running on localhost to resolve the A record of "www.example.com." by sending a regular DNS UDP query on port 53 to 127.0.0.1.

- The Forwarder on the client machine checks its cache, and notices it already has a DNSSEC validated entry of "com." in its cache. This includes the DNSKEY RRset with its RRSIG records. In other words, according to its cache, ".com" is DNSSEC validated as "secure" and can be used to continue a DNSSEC validated chain.

- The Forwarder on the client opens a TCP connection to its upstream Recursive Resolver on port 53. It adds the CHAIN option as follows:

  * Option-code, set to [TBD1]

    * Option-length, set to 0x00 0x04

    * Closest Trust Point set to "com."

- The upstream Recursive Resolver receives a DNS query over TCP with the CHAIN Closest Trust Point set to "com.". After accepting the query it starts constructing a DNS reply packet.

- The upstream Recursive Resolver performs all the regular work to ensure it has all the answers to the query for the A record of "www.example.com.". It does so without using the CHAIN option - unless it is also configured as a Forwarder. The answer to the original DNS question could be the actual A record, the DNSSEC proof of non-existence, or an insecure NXDOMAIN response.

- The upstream Recursive Resolver adds the CHAIN option to the DNS response as follows:

    * Option-code, set to [TBD1]

    * Option-length, set to 0x00 0x00

    * The Closest Trust Point is ommited (zero length)

- The upstream Recursive Resolver constructs the DNS Authority Section and fills it with:

    * The DS RRset for "example.com." and its corresponding RRSIGs (made by the "com." DNSKEY(s))

    * The DNSKEY RRset for "example.com." and its corresponding RRSIGs (made by the "example.com" DNSKEY(s))

    * The authoritative NS RRset for "example.com." and its corresponding RRSIGs (from the child zone)

    If the answer does not exist, and the zone uses DNSSEC, it also adds the proof of non-existence, such as NSEC or NSEC3 records, to the Authority Section.

- The upstream Recursive Resolver constructs the DNS Answer Section and fills it with:

    * The A record of "www.example.com." and its corresponding RRSIGs

If the answer does not exist (NODATA or NXDOMAIN), the Answer Section remains empty. For the NXDOMAIN case, the RCode of the DNS answer packet is set to NXDOMAIN. Otherwise it remains NOERROR.

- The upstream Recursive Resolver returns the DNS answer over the existing TCP connection. When all data is sent, it SHOULD keep the TCP connection open to allow for additional incoming DNS queries - provided it has enough resources to do so.

- The Forwarder receives the DNS answer. It processes the Authority Section and the Answer Section and places the information in its local cache. It ensures that no data is accepted into the cache without having proper DNSSEC validation. It MAY do so by looping over the entries in the Authority and Answer Sections. When an entry is validated for its cache, it is removed from the processing list. If an entry cannot be validated it is left in the process list. When the end of the list is reached, the list is processed again until either all entries are placed in the cache, or the remaining items cannot be placed in the cache due to lack of validation. Those entries are then discarded.

- If the cache contains a valid answer to the application's query, this answer is returned to the application via a regular DNS answer packet. This packet MUST NOT contain an CHAIN option. If no valid answer can be returned, normal error processing is done. For example, an NXDOMAIN or an empty Answer Section could be returned depending on the error condition.

9.2. Out-of-path Query for example.com

A Recursive Resolver receives a query for the A record for example.com. It includes the CHAIN option with the following parameters:

- Option-code, set to [TBD1]

- Option-length, set to 0x00 0x0D

- The Closest Trust Point set to 'unrelated.ca.'

As there is no chain that leads from "unrelated.ca." to "example.com", the Resolving Nameserver answers with an empty CHAIN specified using:

- Option-code, set to [TBD1]

- Option-length, set to 0x00 0x00

- The Closest Trust Point is omitted (zero length)

Note that the regular answer is still present just as it would be for a query that did not specify the CHAIN option.

9.3. Non-existent data

A Recursive Resolver receives a query for the A record for "ipv6.toronto.redhat.ca". It includes the CHAIN option with the following parameters:

- Option-code, set to [TBD1]
- Option-length, set to 0x00 0x03
- The Closest Trust Point set to 'ca.'

Using regular UDP queries towards Authoritative Nameservers, it locates the NS RRset for "toronto.redhat.ca.". When querying for the A record it receives a reply with RCODE "NoError" and an empty Answer Section. The Authority Section contains NSEC3 and RRSIG records proving there is no A RRtype for the QNAME "ipv6.toronto.redhat.ca".

The Recursive Resolver constructs a DNS reply with the following CHAIN option parameters:

- Option-code, set to [TBD1]
- Option-length, set to 0x00 0x00
- The Closest Trust Point is ommited (zero length)

The RCODE is set to "NoError". The Authority Section is filled in with:

- The DS RRset for "redhat.ca." plus RRSIGs
- The DNSKEY RRset for "redhat.ca." plus RRSIGs
- The NS RRset for "redhat.ca." plus RRSIGs (eg ns[01].redhat.ca)
- The A RRset for "ns0.redhat.ca." and "ns1.redhat.ca." plus RRSIGs
- The DS RRset for "toronto.redhat.ca." plus RRSIGs
- The NS RRset for "toronto.redhat.ca." plus RRSIGs (eg ns[01].toronto.redhat.ca)

- The DNSKEY RRset for "toronto.redhat.ca." plus RRSIGs
- The A RRset and/or AAAA RRset for "ns0.toronto.redhat.ca." and "ns1.toronto.redhat.ca." plus RRSIGs
- The NSEC record for "ipv6.toronto.redhat.ca." (proves what RRTYPEs do exist, does not include A)
- The NSEC record for "toronto.redhat.ca." (proves no wildcard exists)

The Answer Section is empty. The RCode is set to NOERROR.

10. IANA Considerations

10.1. EDNS0 option code for CHAIN

IANA has assigned option code [TBD1] in the "DNS EDNS0 Option Codes (OPT)" registry to CHAIN.

11. Acknowledgements

Andrew Sullivan pointed out that we do not need any new data formats to support DNS chains. Olafur Gudmundsson ensured the RRsets are returned in the proper Sections. Thanks to Tim Wicinski for his thorough review.

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