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Distributed Denial-of-Service Open Threat Signaling (DOTS) Signal Channel Specification

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Abstract

This document specifies the DOTS signal channel, a protocol for signaling the need for protection against Distributed Denial-of-Service (DDoS) attacks to a server capable of enabling network traffic mitigation on behalf of the requesting client.

A companion document defines the DOTS data channel, a separate reliable communication layer for DOTS management and configuration purposes.

Editorial Note (To be removed by RFC Editor)

Please update these statements with the RFC number to be assigned to this document:

- "This version of this YANG module is part of RFC XXXX;"
- "RFC XXXX: Distributed Denial-of-Service Open Threat Signaling (DOTS) Signal Channel Specification";
- "| [RFCXXXX] |"
- reference: RFC XXXX

Please update TBD statements with the port number to be assigned to DOTS Signal Channel Protocol.

Also, please update the "revision" date of the YANG module.

Status of This Memo

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1. Introduction

A distributed denial-of-service (DDoS) attack is an attempt to make machines or network resources unavailable to their intended users. In most cases, sufficient scale can be achieved by compromising enough end-hosts and using those infected hosts to perpetrate and amplify the attack. The victim in this attack can be an application server, a host, a router, a firewall, or an entire network.

Network applications have finite resources like CPU cycles, the number of processes or threads they can create and use, the maximum number of simultaneous connections it can handle, the limited resources of the control plane, etc. When processing network traffic, such applications are supposed to use these resources to offer the intended task in the most efficient manner. However, a DDoS attacker may be able to prevent an application from performing its intended task by making the application exhaust its finite resources.

TCP DDoS SYN-flood, for example, is a memory-exhausting attack while ACK-flood is a CPU-exhausting attack [RFC4987]. Attacks on the link are carried out by sending enough traffic so that the link becomes congested, thereby likely causing packet loss for legitimate traffic. Stateful firewalls can also be attacked by sending traffic that causes the firewall to maintain an excessive number of states that may jeopardize the firewall's operation overall, besides likely

performance impacts. The firewall then runs out of memory, and can no longer instantiate the states required to process legitimate flows. Other possible DDoS attacks are discussed in [RFC4732].

In many cases, it may not be possible for network administrators to determine the cause(s) of an attack. They may instead just realize that certain resources seem to be under attack. This document defines a lightweight protocol that allows a DOTS client to request mitigation from one or more DOTS servers for protection against detected, suspected, or anticipated attacks. This protocol enables cooperation between DOTS agents to permit a highly-automated network defense that is robust, reliable, and secure.

An example of a network diagram that illustrates a deployment of DOTS agents is shown in Figure 1. In this example, a DOTS server is operating on the access network. A DOTS client is located on the LAN (Local Area Network), while a DOTS gateway is embedded in the CPE (Customer Premises Equipment).

```
   Network
   Resource        CPE router         Access network     __________
 +-----------+   +--------------+    +-------------+    /          \
 |           |___|              |____|             |___ | Internet |
 |DOTS client|   | DOTS gateway |    | DOTS server |    |          |
 |           |   |              |    |             |    |          |
 +-----------+   +--------------+    +-------------+    \__________/
```

Figure 1: Sample DOTS Deployment (1)

DOTS servers can also be reachable over the Internet, as depicted in Figure 2.

```
   Network                                          DDoS mitigation
   Resource          CPE router      __________       service
 +-----------+   +-------------+    /          \    +-------------+
 |           |___|             |____|          |___ |             |
 |DOTS client|   |DOTS gateway |    | Internet |    | DOTS server |
 |           |   |             |    |          |    |             |
 +-----------+   +-------------+    \__________/    +-------------+
```

Figure 2: Sample DOTS Deployment (2)

In typical deployments, the DOTS client belongs to a different administrative domain than the DOTS server. For example, the DOTS client is embedded in a firewall protecting services owned and operated by a domain, while the DOTS server is owned and operated by a different domain providing DDoS mitigation services. The latter might or might not provide connectivity services to the network hosting the DOTS client.

The DOTS server may (not) be co-located with the DOTS mitigator. In typical deployments, the DOTS server belongs to the same administrative domain as the mitigator. The DOTS client can communicate directly with a DOTS server or indirectly via a DOTS gateway.

The document adheres to the DOTS architecture [I-D.ietf-dots-architecture]. The requirements for DOTS signal channel protocol are documented in [I-D.ietf-dots-requirements]. This document satisfies all the use cases discussed in [I-D.ietf-dots-use-cases].

This document focuses on the DOTS signal channel. This is a companion document of the DOTS data channel specification [I-D.ietf-dots-data-channel] that defines a configuration and a bulk data exchange mechanism supporting the DOTS signal channel.

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 [RFC2119].

(D)TLS is used for statements that apply to both Transport Layer Security [RFC5246] and Datagram Transport Layer Security [RFC6347]. Specific terms are used for any statement that applies to either

protocol alone.

The reader should be familiar with the terms defined in [I-D.ietf-dots-requirements].

The meaning of the symbols in YANG tree diagrams is defined in [RFC8340].

3. Design Overview

The DOTS signal channel is built on top of the Constrained Application Protocol (CoAP) [RFC7252], a lightweight protocol originally designed for constrained devices and networks. The many features of CoAP (expectation of packet loss, support for asynchronous non-confirmable messaging, congestion control, small message overhead limiting the need for fragmentation, use of minimal resources, and support for (D)TLS) makes it a good candidate to build the DOTS signaling mechanism from.

The DOTS signal channel is layered on existing standards (Figure 3).

```
+---------------------+
| DOTS Signal Channel |
+---------------------+
|         CoAP        |
+----------+----------+
|   TLS    |   DTLS   |
+----------+----------+
|   TCP    |   UDP    |
+----------+----------+
|          IP         |
+---------------------+
```

Figure 3: Abstract Layering of DOTS Signal Channel over CoAP over (D)TLS

By default, a DOTS signal channel MUST run over port number TBD as defined in Section 9.1, for both UDP and TCP, unless the DOTS server has a mutual agreement with its DOTS clients to use a different port number. DOTS clients may alternatively support means to dynamically discover the ports used by their DOTS servers. In order to use a distinct port number (as opposed to TBD), DOTS clients and servers should support a configurable parameter to supply the port number to use. The rationale for not using the default port number 5684 ((D)TLS CoAP) is to allow for differentiated behaviors in environments where both a DOTS gateway and an IoT gateway (e.g., Figure 3 of [RFC7452]) are present.

The signal channel uses the "coaps" URI scheme defined in Section 6 of [RFC7252] and "coaps+tcp" URI scheme defined in Section 8.2 of

[RFC8323] to identify DOTS server resources accessible using CoAP over UDP secured with DTLS and CoAP over TCP secured with TLS.

The signal channel is initiated by the DOTS client (Section 4.4). Once the signal channel is established, the DOTS agents periodically send heartbeats to keep the channel active (Section 4.7). At any time, the DOTS client may send a mitigation request message to a DOTS server over the active channel. While mitigation is active because of the higher likelihood of packet loss during a DDoS attack, the DOTS server periodically sends status messages to the client, including basic mitigation feedback details. Mitigation remains active until the DOTS client explicitly terminates mitigation, or the mitigation lifetime expires.

DOTS signaling can happen with DTLS [RFC6347] over UDP and TLS [RFC5246] over TCP. Likewise, DOTS requests may be sent using IPv4 or IPv6 transfer capabilities. A Happy Eyeballs procedure for DOTS signal channel is specified in Section 4.3.

Messages exchanged between DOTS agents are serialized using Concise Binary Object Representation (CBOR) [RFC7049], CBOR is a binary encoding scheme designed for small code and message size. CBOR-encoded payloads are used to carry signal channel-specific payload messages which convey request parameters and response information such as errors. In order to allow the use of the same data models, [RFC7951] specifies the JSON encoding of YANG-modeled data. A

similar effort for CBOR is defined in [I-D.ietf-core-yang-cbor].

From that standpoint, this document specifies a YANG module for representing mitigation scopes and DOTS signal channel session configuration data (Section 5). Representing these data as CBOR data is assumed to follow the rules in [I-D.ietf-core-yang-cbor] or those in [RFC7951] combined with JSON/CBOR conversion rules in [RFC7049]. All parameters in the payload of the DOTS signal channel are mapped to CBOR types as specified in Section 6.

In order to prevent fragmentation, DOTS agents must follow the recommendations documented in Section 4.6 of [RFC7252]. Refer to Section 7.3 for more details.

DOTS agents MUST support GET, PUT, and DELETE CoAP methods. The payload included in CoAP responses with 2.xx and 3.xx Response Codes MUST be of content type "application/cbor" (Section 5.5.1 of [RFC7252]). CoAP responses with 4.xx and 5.xx error Response Codes MUST include a diagnostic payload (Section 5.5.2 of [RFC7252]). The Diagnostic Payload may contain additional information to aid troubleshooting.

In deployments where multiple DOTS clients are enabled in a network (owned and operated by the same entity), the DOTS server may detect conflicting mitigation requests from these clients. This document does not aim to specify a comprehensive list of conditions under which a DOTS server will characterize two mitigation requests from distinct DOTS clients as conflicting, nor recommend a DOTS server behavior for processing conflicting mitigation requests. Those considerations are implementation- and deployment-specific. Nevertheless, the document specifies the mechanisms to notify DOTS clients when conflicts occur, including the conflict cause (Section 4.4).

In deployments where one or more translators (e.g., Traditional NAT [RFC3022], CGN [RFC6888], NAT64 [RFC6146], NPTv6 [RFC6296]) are enabled between the client's network and the DOTS server, DOTS signal channel messages forwarded to a DOTS server must not include internal IP addresses/prefixes and/or port numbers; external addresses/ prefixes and/or port numbers as assigned by the translator must be used instead. This document does not make any recommendation about possible translator discovery mechanisms. The following are some (non-exhaustive) deployment examples that may be considered:

- o Port Control Protocol (PCP) [RFC6887] or Session Traversal Utilities for NAT (STUN) [RFC5389] may be used to retrieve the external addresses/prefixes and/or port numbers. Information retrieved by means of PCP or STUN will be used to feed the DOTS signal channel messages that will be sent to a DOTS server.

- o A DOTS gateway may be co-located with the translator. The DOTS gateway will need to update the DOTS messages, based upon the local translator's binding table.

4. DOTS Signal Channel: Messages & Behaviors

4.1. DOTS Server(s) Discovery

This document assumes that DOTS clients are provisioned with the reachability information of their DOTS server(s) using a variety of means (e.g., local configuration, or dynamic means such as DHCP). The description of such means is out of scope of this document.

Likewise, it is out of scope of this document to specify the behavior of a DOTS client when it sends requests (e.g., contact all servers, select one server among the list) when multiple DOTS servers are provisioned.

4.2. CoAP URIs

The DOTS server MUST support the use of the path-prefix of "/.well-known/" as defined in [RFC5785] and the registered name of "dots". Each DOTS operation is indicated by a path-suffix that indicates the intended operation. The operation path (Table 1) is appended to the path-prefix to form the URI used with a CoAP request to perform the desired DOTS operation.

Operation	Operation Path	Details
Mitigation	/v1/mitigate	Section 4.4
Session configuration	/v1/config	Section 4.5

Table 1: Operations and their Corresponding URIs

4.3. Happy Eyeballs for DOTS Signal Channel

[I-D.ietf-dots-requirements] mentions that DOTS agents will have to support both connectionless and connection-oriented protocols. As such, the DOTS signal channel is designed to operate with DTLS over UDP and TLS over TCP. Further, a DOTS client may acquire a list of IPv4 and IPv6 addresses (Section 4.1), each of which can be used to contact the DOTS server using UDP and TCP. The following specifies the procedure to follow to select the address family and the transport protocol for sending DOTS signal channel messages.

Such procedure is needed to avoid experiencing long connection delays. For example, if an IPv4 path to reach a DOTS server is found, but the DOTS server's IPv6 path is not working, a dual-stack DOTS client may experience a significant connection delay compared to an IPv4-only DOTS client. The other problem is that if a middlebox between the DOTS client and DOTS server is configured to block UDP traffic, the DOTS client will fail to establish a DTLS session with the DOTS server and, as a consequence, will have to fall back to TLS over TCP, thereby incurring significant connection delays.

To overcome these connection setup problems, the DOTS client attempts to connect to its DOTS server(s) using both IPv6 and IPv4, and tries both DTLS over UDP and TLS over TCP in a manner similar to the Happy Eyeballs mechanism [RFC8305]. These connection attempts are performed by the DOTS client when it initializes. The results of the Happy Eyeballs procedure are used by the DOTS client for sending its subsequent messages to the DOTS server.

The order of preference of the DOTS signal channel address family and transport protocol (most preferred first) is: UDP over IPv6, UDP over IPv4, TCP over IPv6, and finally TCP over IPv4. This order adheres to the address preference order specified in [RFC6724] and the DOTS signal channel preference which privileges the use of UDP over TCP (to avoid TCP's head of line blocking).

In reference to Figure 4, the DOTS client sends two TCP SYNs and two DTLS ClientHello messages at the same time over IPv6 and IPv4. In this example, it is assumed that the IPv6 path is broken and UDP traffic is dropped by a middlebox but has little impact to the DOTS client because there is no long delay before using IPv4 and TCP. The DOTS client repeats the mechanism to discover whether DOTS signal channel messages with DTLS over UDP becomes available from the DOTS server, so the DOTS client can migrate the DOTS signal channel from TCP to UDP. Such probing SHOULD NOT be done more frequently than every 24 hours and MUST NOT be done more frequently than every 5 minutes.

```
+-----------+                                          +-----------+
|DOTS client|                                          |DOTS server|
+-----------+                                          +-----------+
      |                                                      |
      |--DTLS ClientHello, IPv6 ---->X                       |
      |--TCP SYN, IPv6-------------->X                       |
      |--DTLS ClientHello, IPv4 ---->X                       |
      |--TCP SYN, IPv4---------------------------------------->|
      |--DTLS ClientHello, IPv6 ---->X                       |
      |--TCP SYN, IPv6-------------->X                       |
      |<-TCP SYNACK------------------------------------------|
      |--DTLS ClientHello, IPv4 ---->X                       |
      |--TCP ACK---------------------------------------------->|
      |<------------Establish TLS Session-------------------->|
      |----------------DOTS signal--------------------------->|
      |                                                      |
```

Figure 4: DOTS Happy Eyeballs

4.4. DOTS Mitigation Methods

The following methods are used by a DOTS client to request, withdraw, or retrieve the status of mitigation requests:

PUT: DOTS clients use the PUT method to request mitigation from a DOTS server (Section 4.4.1). During active mitigation, DOTS clients may use PUT requests to carry mitigation efficacy updates to the DOTS server (Section 4.4.3).

GET: DOTS clients may use the GET method to subscribe to DOTS server status messages, or to retrieve the list of its mitigations maintained by a DOTS server (Section 4.4.2).

DELETE: DOTS clients use the DELETE method to withdraw a request for mitigation from a DOTS server (Section 4.4.4).

Mitigation request and response messages are marked as Non-confirmable messages (Section 2.2 of [RFC7252]).

DOTS agents SHOULD follow the data transmission guidelines discussed in Section 3.1.3 of [RFC8085] and control transmission behavior by not sending more than one UDP datagram per RTT to the peer DOTS agent on average.

Requests marked by the DOTS client as Non-confirmable messages are sent at regular intervals until a response is received from the DOTS server. If the DOTS client cannot maintain an RTT estimate, it SHOULD NOT send more than one Non-confirmable request every 3 seconds, and SHOULD use an even less aggressive rate whenever possible (case 2 in Section 3.1.3 of [RFC8085]).

4.4.1. Request Mitigation

When a DOTS client requires mitigation for some reason, the DOTS client uses the CoAP PUT method to send a mitigation request to its DOTS server(s) (Figure 5, illustrated in JSON diagnostic notation).

If this DOTS client is entitled to solicit the DOTS service, the DOTS server can enable mitigation on behalf of the DOTS client by communicating the DOTS client's request to a mitigator and relaying the feedback of the thus-selected mitigator to the requesting DOTS client.

```
Header: PUT (Code=0.03)
Uri-Host: "host"
Uri-Path: ".well-known"
Uri-Path: "dots"
Uri-Path: "version"
Uri-Path: "mitigate"
Uri-Path: "cuid=dz6pHjaADkaFTbjr0JGBpw"
Uri-Path: "mid=123"
Content-Type: "application/cbor"
{
  "ietf-dots-signal-channel:mitigation-scope": {
    "scope": [
      {
        "target-prefix": [
           "string"
         ],
        "target-port-range": [
           {
             "lower-port": integer,
             "upper-port": integer
           }
         ],
         "target-protocol": [
           integer
         ],
         "target-fqdn": [
           "string"
         ],
         "target-uri": [
           "string"
         ],
         "alias-name": [
           "string"
```

```
            ],
           "lifetime": ~~integer~~ integer,
           "trigger-mitigation": boolean
         }
       ]
     }
   }
```

Figure 5: PUT to Convey DOTS Mitigation Requests

The Uri-Path option carries a major and minor version nomenclature to manage versioning; DOTS signal channel in this specification uses 'v1' major version.

The order of the Uri-Path options is important as it defines the CoAP resource. In particular, 'mid' MUST follow 'cuid'.

The additional Uri-Path parameters to those defined in Section 4.2 are as follows:

cuid: Stands for Client Unique Identifier. A globally unique identifier that is meant to prevent collisions among DOTS clients, especially those from the same domain. It MUST be generated by DOTS clients.

Implementations SHOULD use the output of a cryptographic hash algorithm whose input is the DER-encoded ASN.1 representation of the Subject Public Key Info (SPKI) of the DOTS client X.509 certificate [RFC5280], the DOTS client raw public key [RFC7250], or the "PSK identity" used by the DOTS client in the TLS ClientKeyExchange message to set 'cuid'. In this version of the specification, the cryptographic hash algorithm used is SHA-256 [RFC6234]. The output of the cryptographic hash algorithm is truncated to 16 bytes; truncation is done by stripping off the final 16 bytes. The truncated output is base64url encoded.

The 'cuid' is intended to be stable when communicating with a given DOTS server, i.e., the 'cuid' used by a DOTS client SHOULD NOT change over time. Distinct 'cuid' values MAY be used per DOTS server.

DOTS servers MUST return 4.09 (Conflict) error code to a DOTS peer to notify that the 'cuid' is already in-use by another DOTS client. Upon receipt of that error code, a new 'cuid' MUST be generated by the DOTS peer.

Client-domain DOTS gateways MUST handle 'cuid' collision directly and it is RECOMMENDED that 'cuid' collision is handled directly by server-domain DOTS gateways.

DOTS gateways MAY rewrite the 'cuid' used by peer DOTS clients. Triggers for such rewriting are out of scope.

This is a mandatory Uri-Path.

mid: Identifier for the mitigation request represented with an integer. This identifier MUST be unique for each mitigation request bound to the DOTS client, i.e., the 'mid' parameter value in the mitigation request needs to be unique relative to the 'mid' parameter values of active mitigation requests conveyed from the DOTS client to the DOTS server. In order to handle out-of-order delivery of mitigation requests, 'mid' values MUST increase monotonically.

This identifier MUST be generated by the DOTS client.

This is a mandatory Uri-Path parameter.

'cuid' and 'mid' MUST NOT appear in the PUT request message body.

The parameters in the CBOR body of the PUT request are described below:

target-prefix: A list of prefixes identifying resources under attack. Prefixes are represented using Classless Inter-Domain Routing (CIDR) notation [RFC4632].
As a reminder, the prefix length must be less than or equal to 32

(resp. 128) for IPv4 (resp. IPv6).

The prefix list MUST NOT include broadcast, loopback, or multicast addresses. These addresses are considered as invalid values. In addition, the DOTS server MUST validate that target prefixes are within the scope of the DOTS client's domain. Other validation checks may be supported by DOTS servers.

This is an optional attribute.

target-port-range: A list of port numbers bound to resources under attack.

A port range is defined by two bounds, a lower port number (lower-port) and an upper port number (upper-port). When only 'lower-port' is present, it represents a single port number.

For TCP, UDP, Stream Control Transmission Protocol (SCTP) [RFC4960], or Datagram Congestion Control Protocol (DCCP) [RFC4340], a range of ports can be, for example, 0-1023, 1024-65535, or 1024-49151.

This is an optional attribute.

target-protocol: A list of protocols involved in an attack. Values are taken from the IANA protocol registry [proto_numbers].

The value '0' has a special meaning for 'all protocols'.

This is an optional attribute.

target-fqdn: A list of Fully Qualified Domain Names (FQDNs) identifying resources under attack. An FQDN is the full name of a resource, rather than just its hostname. For example, "venera" is a hostname, and "venera.isi.edu" is an FQDN [RFC1983].

How a name is passed to an underlying name resolution library is implementation- and deployment-specific. Nevertheless, once the name is resolved into one or multiple IP addresses, DOTS servers MUST apply the same validation checks as those for 'target-prefix'.

This is an optional attribute.

target-uri: A list of Uniform Resource Identifiers (URIs) [RFC3986] identifying resources under attack.

The same validation checks used for 'target-fqdn' MUST be followed by DOTS servers to validate a target URI.

This is an optional attribute.

alias-name: A list of aliases of resources for which the mitigation is requested. Aliases can be created using the DOTS data channel (Section 6.1 of [I-D.ietf-dots-data-channel]), direct configuration, or other means.

An alias is used in subsequent signal channel exchanges to refer more efficiently to the resources under attack.

This is an optional attribute.

lifetime: Lifetime of the mitigation request in seconds. The RECOMMENDED lifetime of a mitigation request is 3600 seconds -- this value was chosen to be long enough so that refreshing is not typically a burden on the DOTS client, while expiring the request where the client has unexpectedly quit in a timely manner. DOTS clients MUST include this parameter in their mitigation requests. Upon the expiry of this lifetime, and if the request is not refreshed, the mitigation request is removed. The request can be refreshed by sending the same request again.

A lifetime of '0' in a mitigation request is an invalid value.

A lifetime of negative one (-1) indicates indefinite lifetime for the mitigation request. The DOTS server MAY refuse indefinite lifetime, for policy reasons; the granted lifetime value is

returned in the response. DOTS clients MUST be prepared to not be granted mitigations with indefinite lifetimes.

The DOTS server MUST always indicate the actual lifetime in the response and the remaining lifetime in status messages sent to the DOTS client.

This is a mandatory attribute.

trigger-mitigation: If the parameter value is set to 'false', DDoS mitigation will not be triggered for the mitigation request unless the DOTS signal channel session is lost. Automated mitigation on loss of signal is discussed in Section 3.3.3 of [I-D.ietf-dots-architecture].

If the DOTS client ceases to respond to heartbeat messages, the DOTS server can detect that the DOTS session is lost.

The default value of the parameter is 'true' (that is, the mitigation starts immediately). If 'trigger-mitigation' is not present in a request, this is equivalent to receiving a request with 'trigger-mitigation' set to 'true.

This is an optional attribute.

In deployments where server-domain DOTS gateways are enabled, identity information about the origin source client domain SHOULD be supplied to the DOTS server. That information is meant to assist the DOTS server to enforce some policies such as correlating DOTS clients that belong to the same DOTS domain, limiting the number of DOTS requests, and identifying the mitigation scope. These policies can be enforced per-client, per-client domain, or both. Also, the identity information may be used for auditing and debugging purposes.

Figure 6 shows an example of a request relayed by a server-domain DOTS gateway.

```
  Header: PUT (Code=0.03)
  Uri-Host: "host"
  Uri-Path: ".well-known"
  Uri-Path: "dots"
  Uri-Path: "v1"
  Uri-Path: "mitigate"
  Uri-Path: "cdid=7eeaf349529eb55ed50113"
  Uri-Path: "cuid=dz6pHjaADkaFTbjr0JGBpw"
  Uri-Path: "mid=123"
  Content-Type: "application/cbor"
  {
    "ietf-dots-signal-channel:mitigation-scope": {
      "scope": [
        {
          "target-prefix": [
             "string"
           ],
          "target-port-range": [
             {
               "lower-port": integer,
               "upper-port": integer
             }
           ],
           "target-protocol": [
             integer
           ],
           "target-fqdn": [
             "string"
           ],
           "target-uri": [
             "string"
           ],
           "alias-name": [
             "string"
           ],
          "lifetime": integer
        }
      ]
    }
  }
```

Figure 6: PUT to Convey DOTS Mitigation Request as relayed by a Server-Domain DOTS Gateway

A server-domain DOTS gateway SHOULD add the following Uri-Path parameter:

cdid: Stands for Client Domain IDentifier. The 'cdid' is conveyed by a server-domain DOTS gateway to propagate the source domain identity from the gateway's client-facing-side to the gateway's server-facing-side, and from the gateway's server-facing-side to the DOTS server. 'cdid' may be used by the final DOTS server for policy enforcement purposes (e.g., enforce a quota on filtering rules). These policies are deployment-specific.

Server-domain DOTS gateways SHOULD support a configuration option to instruct whether 'cdid' parameter is to be inserted.

In order to accommodate deployments that require enforcing per-client policies, per-client domain policies, or a combination thereof, server-domain DOTS gateways MUST supply the SPKI hash of the DOTS client X.509 certificate, the DOTS client raw public key, or the hash of the "PSK identity" in the 'cdid', following the same rules for generating the hash conveyed in 'cuid', which is then used by the ultimate DOTS server to determine the corresponding client's domain. The 'cdid' generated by a server-domain gateway is likely to be the same as the 'cuid' except if the DOTS message was relayed by a DOTS gateway or was generated from a rogue DOTS client.

If a DOTS client is provisioned, for example, with distinct certificates as a function of the peer server-domain DOTS gateway, distinct 'cdid' values may be supplied by a server-domain DOTS gateway. The ultimate DOTS server MUST treat those 'cdid' values as equivalent.

The 'cdid' attribute MUST NOT be generated and included by DOTS clients.

DOTS servers MUST ignore 'cdid' attributes that are directly supplied by source DOTS clients or client-domain DOTS gateways. This implies that first server-domain DOTS gateways MUST strip 'cdid' attributes supplied by DOTS clients. DOTS servers SHOULD support a configuration parameter to identify DOTS gateways that are trusted to supply 'cdid' attributes.

Only single-valued 'cdid' are defined in this document.

This is an optional Uri-Path. When present, 'cdid' MUST be positioned before 'cuid'.

A DOTS gateway may add the following CoAP option:

hop-limit: This option (see Section 9.4) is used to detect and prevent infinite loops. This option is typically inserted by a DOTS gateway. Only one single instance of the option is allowed in a message.

The length of the hop-limit option is 1 byte.

The value of the hop-limit option is encoded as an unsigned integer (see Section 3.2 of [RFC7252]).

Each intermediate DOTS agent involved in the handling of a DOTS message MUST decrement the hop-limit option value by 1 prior to forwarding upstream if this parameter exists. DOTS messages MUST NOT be forwarded if the hop-limit option is set to '0' after decrement. Messages that cannot be forwarded because of exhausted hop-limit SHOULD be logged with a 5.06 (Hop Limit Reached) error message sent back to the DOTS peer. It is RECOMMENDED that DOTS clients and gateways support means to alert administrators about loop errors so that appropriate actions are undertaken.

To ease debugging and troubleshooting, the DOTS gateway which detects a loop SHOULD include its information (e.g., server name, alias, IP address) in the diagnostic payload under the conditions detailed in Section 5.5.2 of [RFC7252]. Each intermediate DOTS

gateway involved in relaying a 5.06 (Hop Limit Reached) error message SHOULD prepend its own information in the diagnostic payload with a space character used as separator. Only one information per DOTS gateway MUST appear in the diagnostic payload. The ultimate DOTS gateway MAY remove the diagnostic payload before forwarding the 5.06 (Hop Limit Reached) error message to a DOTS client domain.

The initial hop-limit value SHOULD be configurable. If no initial value is explicitly provided, the default initial hop-limit value of 16 MUST be used.

Because forwarding errors may occur if inadequate hop-limit values are used, DOTS agents at the boundaries of an administrative domain MAY be instructed to rewrite the value of hop-limit carried in received messages (that is, ignore the value of hop-limit received in a message).

This is an optional CoAP option.

Because of the complexity to handle partial failure cases, this specification does not allow for including multiple mitigation requests in the same PUT request. Concretely, a DOTS client MUST NOT include multiple 'scope' parameters in the same PUT request.

FQDN and URI mitigation scopes may be thought of as a form of scope alias, in which the addresses associated with the domain name or URI represent the full scope of the mitigation.

In the PUT request at least one of the attributes 'target-prefix', 'target-fqdn','target-uri', or 'alias-name' MUST be present.

Attributes and Uri-Path parameters with empty values MUST NOT be present in a request.

The relative order of two mitigation requests from a DOTS client is determined by comparing their respective 'mid' values. If two mitigation requests have overlapping mitigation scopes, the mitigation request with the highest numeric 'mid' value will override the other mitigation request. Two mitigation requests from a DOTS client are overlapping if there is a common IP address, IP prefix, FQDN, URI, or alias-name. To avoid maintaining a long list of overlapping mitigation requests from a DOTS client and avoid error-prone provisioning of mitigation requests from a DOTS client, the overlapped lower numeric 'mid' MUST be automatically deleted and no longer available at the DOTS server.

Figure 7 shows a PUT request example to signal that ports 80, 8080, and 443 used by 2001:db8:6401::1 and 2001:db8:6401::2 servers are under attack (illustrated in JSON diagnostic notation). The presence of 'cdid' indicates that a server-domain DOTS gateway has modified the initial PUT request sent by the DOTS client. Note that 'cdid' MUST NOT appear in the PUT request message body.

```
  Header: PUT (Code=0.03)
  Uri-Host: "www.example.com"
  Uri-Path: ".well-known"
  Uri-Path: "dots"
  Uri-Path: "v1"
  Uri-Path: "mitigate"
  Uri-Path: "cdid=7eeaf349529eb55ed50113"
  Uri-Path: "cuid=dz6pHjaADkaFTbjr0JGBpw"
  Uri-Path: "mid=123"
  Content-Format: "application/cbor"
  {
    "ietf-dots-signal-channel:mitigation-scope": {
      "scope": [
        {
          "target-prefix": [
             "2001:db8:6401::1/128",
             "2001:db8:6401::2/128"
           ],
          "target-port-range": [
            {
              "lower-port": 80
            },
            {
```

```
                "lower-port": 443
              },
              {
                 "lower-port": 8080
              }
             ],
             "target-protocol": [
               6
             ],
            "lifetime": 3600
          }
        ]
      }
    }
```

Figure 7: PUT for DOTS Mitigation Request

The corresponding CBOR encoding format is shown in Figure 8.

```
A1                                      # map(1)
   01                                   # unsigned(1)
   A1                                   # map(1)
      02                                # unsigned(2)
      81                                # array(1)
         A3                             # map(3)
            06                          # unsigned(6)
            82                          # array(2)
               74                       # text(20)
                  323030313A6462383A363430313A3A312F313238 # "2001:db8:6401::1/128"
               74                       # text(20)
                  323030313A6462383A363430313A3A322F313238 # "2001:db8:6401::2/128"
            07                          # unsigned(7)
            83                          # array(3)
               A1                       # map(1)
                  08                    # unsigned(8)
                  18 50                 # unsigned(80)
               A1                       # map(1)
                  08                    # unsigned(8)
                  19 01BB               # unsigned(443)
               A1                       # map(1)
                  08                    # unsigned(8)
                  19 1F90               # unsigned(8080)
            0A                          # unsigned(10)
            81                          # array(1)
               06                       # unsigned(6)
            0E                          # unsigned(14)
            A1                          # map(1)
               19 0E10                  # unsigned(3600)
```

Figure 8: PUT for DOTS Mitigation Request (CBOR)

In both DOTS signal and data channel sessions, the DOTS client MUST authenticate itself to the DOTS server (Section 8). The DOTS server may use the algorithm presented in Section 7 of [RFC7589] to derive the DOTS client identity or username from the client certificate. The DOTS client identity allows the DOTS server to accept mitigation requests with scopes that the DOTS client is authorized to manage.

The DOTS server couples the DOTS signal and data channel sessions using the DOTS client identity and optionally the 'cdid' parameter value, so the DOTS server can validate whether the aliases conveyed in the mitigation request were indeed created by the same DOTS client using the DOTS data channel session. If the aliases were not created by the DOTS client, the DOTS server MUST return 4.00 (Bad Request) in the response.

The DOTS server couples the DOTS signal channel sessions using the DOTS client identity and optionally the 'cdid' parameter value, and the DOTS server uses 'mid' and 'cuid' Uri-Path parameter values to detect duplicate mitigation requests. If the mitigation request contains the 'alias-name' and other parameters identifying the target resources (such as 'target-prefix', 'target-port-range', 'target-fqdn', or 'target-uri'), the DOTS server appends the parameter values in 'alias-name' with the corresponding parameter values in 'target-prefix', 'target-port-range', 'target-fqdn', or 'target-uri'.

The DOTS server indicates the result of processing the PUT request

using CoAP response codes. CoAP 2.xx codes are success. CoAP 4.xx codes are some sort of invalid requests (client errors). COAP 5.xx codes are returned if the DOTS server has erred or is currently unavailable to provide mitigation in response to the mitigation request from the DOTS client.

Figure 9 shows an example response to a PUT request that is successfully processed by a DOTS server (i.e., CoAP 2.xx response codes). This version of the specification forbids 'cuid' and 'cdid' (if used) to be returned in a response.

```
{
  "ietf-dots-signal-channel:mitigation-scope": {
     "scope": [
        {
          "mid": 12332,
          "lifetime": 3600
        }
      ]
   }
}
```

Figure 9: 2.xx Response Body

If the request is missing a mandatory attribute, does not include 'cuid' or 'mid' Uri-Path options, includes multiple 'scope' parameters, or contains invalid or unknown parameters, the DOTS server MUST reply with 4.00 (Bad Request). DOTS agents can safely ignore Vendor-Specific parameters they don't understand.

A DOTS server that receives a mitigation request with a lifetime set to '0' MUST reply with a 4.00 (Bad Request).

If the DOTS server does not find the 'mid' parameter value conveyed in the PUT request in its configuration data, it MAY accept the mitigation request by sending back a 2.01 (Created) response to the DOTS client; the DOTS server will consequently try to mitigate the attack.

If the DOTS server finds the 'mid' parameter value conveyed in the PUT request in its configuration data bound to that DOTS client, it MAY update the mitigation request, and a 2.04 (Changed) response is returned to indicate a successful update of the mitigation request.

If the request is conflicting with an existing mitigation request from a different DOTS client, the DOTS server may return 2.01 (Created) or 4.09 (Conflict) to the requesting DOTS client. If the DOTS server decides to maintain the new mitigation request, the DOTS server returns 2.01 (Created) to the requesting DOTS client. If the DOTS server decides to reject the new mitigation request, the DOTS server returns 4.09 (Conflict) to the requesting DOTS client. For both 2.01 (Created) and 4.09 (Conflict) responses, the response includes enough information for a DOTS client to recognize the source of the conflict as described below:

conflict-information: Indicates that a mitigation request is conflicting with another mitigation request(s) from other DOTS client(s). This optional attribute has the following structure:

conflict-status: Indicates the status of a conflicting mitigation request. The following values are defined:

1: DOTS server has detected conflicting mitigation requests from different DOTS clients. This mitigation request is currently inactive until the conflicts are resolved. Another mitigation request is active.

2: DOTS server has detected conflicting mitigation requests from different DOTS clients. This mitigation request is currently active.

3: DOTS server has detected conflicting mitigation requests from different DOTS clients. All conflicting mitigation requests are inactive.

conflict-cause: Indicates the cause of the conflict. The following values are defined:

1: Overlapping targets. 'conflict-scope' provides more details about the conflicting target clauses.

2: Conflicts with an existing white list. This code is returned when the DDoS mitigation detects source addresses/ prefixes in the white-listed ACLs are attacking the target.

3: CUID Collision. This code is returned when a DOTS client uses a 'cuid' that is already used by another DOTS client.

This code is an indication that the request has been rejected and a new request with a new 'cuid' is to be re-sent by the DOTS client. Note that 'conflict-status', 'conflict-scope', and 'retry-timer' are not returned in the error response.

conflict-scope: Indicates the conflict scope. It may include a list of IP addresses, a list of prefixes, a list of port numbers, a list of target protocols, a list of FQDNs, a list of URIs, a list of alias-names, or references to conflicting ACLs.

retry-timer: Indicates, in seconds, the time after which the DOTS client may re-issue the same request. The DOTS server returns 'retry-timer' only to DOTS client(s) for which a mitigation request is deactivated. Any retransmission of the same mitigation request before the expiry of this timer is likely to be rejected by the DOTS server for the same reasons.

The retry-timer SHOULD be equal to the lifetime of the active mitigation request resulting in the deactivation of the conflicting mitigation request. The lifetime of the deactivated mitigation request will be updated to (retry-timer + 45 seconds), so the DOTS client can refresh the deactivated mitigation request after retry-timer seconds before expiry of lifetime and check if the conflict is resolved.

As an active attack evolves, DOTS clients can adjust the scope of requested mitigation as necessary, by refining the scope of resources requiring mitigation. This can be achieved, for example, by (1) sending a PUT request with a new 'mid' value that will override the existing one with overlapping mitigation scopes or (2) by re- using the same 'mid' with updated mitigation scopes.

For a mitigation request to continue beyond the initial negotiated lifetime, the DOTS client has to refresh the current mitigation request by sending a new PUT request. This PUT request MUST use the same 'mid' value, and MUST repeat all the other parameters as sent in the original mitigation request apart from a possible change to the lifetime parameter value.

4.4.2. Retrieve Information Related to a Mitigation

A GET request is used by a DOTS client to retrieve information (including status) of DOTS mitigations from a DOTS server.

'cuid' is a mandatory Uri-Path parameter for GET requests.

Uri-Path parameters with empty values MUST NOT be present in a request.

The same considerations for manipulating 'cdid' parameter by server-domain DOTS gateways specified in Section 4.4.1 MUST be followed for GET requests.

If the DOTS server does not find the 'mid' Uri-Path value conveyed in the GET request in its configuration data for the requesting DOTS client, it MUST respond with a 4.04 (Not Found) error response code. Likewise, the same error MUST be returned as a response to a request to retrieve all mitigation records (i.e., 'mid' Uri-Path is not defined) of a given DOTS client if the DOTS server does not find any mitigation record for that DOTS client. As a reminder, a DOTS client is identified by its identity (e.g., client certificate, 'cuid') and optionally the 'cdid'.

The 'c' (content) parameter and its permitted values defined in [I-D.ietf-core-comi] can be used to retrieve non-configuration data

(attack mitigation status), configuration data, or both. The DOTS server may support this optional filtering capability. It can safely ignore it if not supported.

The following examples illustrate how a DOTS client retrieves active mitigation requests from a DOTS server. In particular:

o Figure 10 shows the example of a GET request to retrieve all DOTS mitigation requests signaled by a DOTS client.

o Figure 11 shows the example of a GET request to retrieve a specific DOTS mitigation request signaled by a DOTS client. The configuration data to be reported in the response is formatted in the same order as was processed by the DOTS server in the original mitigation request.

These two examples assume the default of "c=a"; that is, the DOTS client asks for all data to be reported by the DOTS server.

```
Header: GET (Code=0.01)
Uri-Host: "host"
Uri-Path: ".well-known"
Uri-Path: "dots"
Uri-Path: "v1"
Uri-Path: "mitigate"
Uri-Path: "cuid=dz6pHjaADkaFTbjr0JGBpw"
Observe: 0
```

Figure 10: GET to Retrieve all DOTS Mitigation Requests

```
Header: GET (Code=0.01)
Uri-Host: "host"
Uri-Path: ".well-known"
Uri-Path: "dots"
Uri-Path: "v1"
Uri-Path: "mitigate"
Uri-Path: "cuid=dz6pHjaADkaFTbjr0JGBpw"
Uri-Path: "mid=12332"
Observe: 0
```

Figure 11: GET to Retrieve a Specific DOTS Mitigation Request

Figure 12 shows a response example of all active mitigation requests associated with the DOTS client as maintained by the DOTS server. The response indicates the mitigation status of each mitigation request.

```
{
  "ietf-dots-signal-channel:mitigation-scope": {
    "scope": [
      {
        "mid": 12332,
        "mitigation-start": 1507818434,
        "target-prefix": [
             "2001:db8:6401::1/128",
             "2001:db8:6401::2/128"
        ],
        "target-protocol": [
          17
        ],
        "lifetime": 1800,
        "status": 2,
        "bytes-dropped": 134334555,
        "bps-dropped": 43344,
        "pkts-dropped": 333334444,
        "pps-dropped": 432432
      },
      {
        "mid": 12333,
        "mitigation-start": 1507818393,
        "target-prefix": [
             "2001:db8:6401::1/128",
             "2001:db8:6401::2/128"
        ],
        "target-protocol": [
          6
        ],
```

```
        "lifetime": 1800,
        "status": 3,
        "bytes-dropped": 0,
        "bps-dropped": 0,
        "pkts-dropped": 0,
        "pps-dropped": 0
      }
    ]
  }
}
```

Figure 12: Response Body to a Get Request

The mitigation status parameters are described below:

mitigation-start: Mitigation start time is expressed in seconds relative to 1970-01-01T00:00Z in UTC time (Section 2.4.1 of

[RFC7049]). The CBOR encoding is modified so that the leading tag 1 (epoch-based date/time) MUST be omitted.

This is a mandatory ~~attribute.~~ **attribute for mitigation requests that are immediately activated.**

lifetime: The remaining lifetime of the mitigation request, in seconds.

This is a mandatory attribute.

status: Status of attack mitigation. The various possible values of 'status' parameter are explained in Table 2.

This is a mandatory attribute.

bytes-dropped: The total dropped byte count for the mitigation request since the attack mitigation is triggered. The count wraps around when it reaches the maximum value of unsigned integer64.

This is an optional attribute.

bps-dropped: The average number of dropped bytes per second for the mitigation request since the attack mitigation is triggered. This SHOULD be a five-minute average.

This is an optional attribute.

pkts-dropped: The total number of dropped packet count for the mitigation request since the attack mitigation is triggered. The count wraps around when it reaches the maximum value of unsigned integer64.

This is an optional attribute.

pps-dropped: The average number of dropped packets per second for the mitigation request since the attack mitigation is triggered. This SHOULD be a five-minute average.

This is an optional attribute.

Parameter Value	Description
1	Attack mitigation is in progress (e.g., changing the network path to redirect the inbound traffic to a DOTS mitigator).
2	Attack is successfully mitigated (e.g., traffic is redirected to a DDoS mitigator and attack traffic is dropped).
3	Attack has stopped and the DOTS client can withdraw the mitigation request.
4	Attack has exceeded the mitigation provider capability.

```
|         5 | DOTS client has withdrawn the mitigation request and  |
|           | the mitigation is active but terminating.             |
+-----------+-------------------------------------------------------+
|         6 | Attack mitigation is now terminated.                  |
+-----------+-------------------------------------------------------+
|         7 | Attack mitigation is withdrawn.                       |
+-----------+-------------------------------------------------------+
|         8 | When the DDoS signal channel session is lost, DDoS    |
|           | mitigation will be triggered for the mitigation       |
|           | request.                                              |
+-----------+-------------------------------------------------------+
```

Table 2: Values of 'status' Parameter

The Observe Option defined in [RFC7641] extends the CoAP core protocol with a mechanism for a CoAP client to "observe" a resource on a CoAP server: The client retrieves a representation of the resource and requests this representation be updated by the server as long as the client is interested in the resource. A DOTS client conveys the Observe Option set to '0' in the GET request to receive unsolicited notifications of attack mitigation status from the DOTS server.

Unidirectional notifications within the bidirectional signal channel allows unsolicited message delivery, enabling asynchronous notifications between the agents. Due to the higher likelihood of packet loss during a DDoS attack, the DOTS server periodically sends attack mitigation status to the DOTS client and also notifies the DOTS client whenever the status of the attack mitigation changes. If the DOTS server cannot maintain an RTT estimate, it SHOULD NOT send more than one unsolicited notification every 3 seconds, and SHOULD use an even less aggressive rate whenever possible (case 2 in Section 3.1.3 of [RFC8085]).

When conflicting requests are detected, the DOTS server enforces the corresponding policy (e.g., accept all requests, reject all requests, accept only one request but reject all the others, ...). It is assumed that this policy is supplied by the DOTS server administrator or it is a default behavior of the DOTS server implementation. Then, the DOTS server sends notification message(s) to the DOTS client(s) at the origin of the conflict (refer to the conflict parameters defined in Section 4.4.1). A conflict notification message includes information about the conflict cause, scope, and the status of the mitigation request(s). For example,

- o A notification message with 'status' code set to '7 (Attack mitigation is withdrawn)' and 'conflict-status' set to '1' is sent to a DOTS client to indicate that an active mitigation request is deactivated because a conflict is detected.

- o A notification message with 'status' code set to '1 (Attack mitigation is in progress)' and 'conflict-status' set to '2' is sent to a DOTS client to indicate that this mitigation request is in progress, but a conflict is detected.

Upon receipt of a conflict notification message indicating that a mitigation request is deactivated because of a conflict, a DOTS client MUST NOT resend the same mitigation request before the expiry of 'retry-timer'. It is also recommended that DOTS clients support means to alert administrators about mitigation conflicts.

A DOTS client that is no longer interested in receiving notifications from the DOTS server can simply "forget" the observation. When the DOTS server sends the next notification, the DOTS client will not recognize the token in the message and thus will return a Reset message. This causes the DOTS server to remove the associated entry. Alternatively, the DOTS client can explicitly deregister itself by issuing a GET request that has the Token field set to the token of the observation to be cancelled and includes an Observe Option with the value set to '1' (deregister).

Figure 13 shows an example of a DOTS client requesting a DOTS server to send notifications related to a given mitigation request.

```
    +-----------+                        +-----------+
    |DOTS client|                        |DOTS server|
    +-----------+                        +-----------+
```

```
              |                                   |
              |  GET /<mid>                       |
              |  Token: 0x4a                      | Registration
              |  Observe: 0                       |
              +---------------------------------->|
              |                                   |
              |  2.05 Content                     |
              |  Token: 0x4a                      | Notification of
              |  Observe: 12                      | the current state
              |  status: "mitigation in progress" |
              |                                   |
              |<----------------------------------+
              |  2.05 Content                     |
              |  Token: 0x4a                      | Notification upon
              |  Observe: 44                      | a state change
              |  status: "mitigation complete"    |
              |                                   |
              |<----------------------------------+
              |  2.05 Content                     |
              |  Token: 0x4a                      | Notification upon
              |  Observe: 60                      | a state change
              |  status: "attack stopped"         |
              |<----------------------------------+
              |                                   |
```

Figure 13: Notifications of Attack Mitigation Status

4.4.2.1. DOTS Clients Polling for Mitigation Status

The DOTS client can send the GET request at frequent intervals without the Observe Option to retrieve the configuration data of the mitigation request and non-configuration data (i.e., the attack status). The frequency of polling the DOTS server to get the mitigation status SHOULD follow the transmission guidelines in Section 3.1.3 of [RFC8085].

If the DOTS server has been able to mitigate the attack and the attack has stopped, the DOTS server indicates as such in the status. In such case, the DOTS client recalls the mitigation request by issuing a DELETE request for this mitigation request (Section 4.4.4).

A DOTS client SHOULD react to the status of the attack as per the information sent by the DOTS server rather than acknowledging by itself, using its own means, that the attack has been mitigated. This ensures that the DOTS client does not recall a mitigation request prematurely because it is possible that the DOTS client does not sense the DDoS attack on its resources, but the DOTS server could be actively mitigating the attack because the attack is not completely averted.

4.4.3. Efficacy Update from DOTS Clients

While DDoS mitigation is in progress, due to the likelihood of packet loss, a DOTS client MAY periodically transmit DOTS mitigation efficacy updates to the relevant DOTS server. A PUT request is used to convey the mitigation efficacy update to the DOTS server.

The PUT request used for efficacy update MUST include all the parameters used in the PUT request to carry the DOTS mitigation request (Section 4.4.1) unchanged apart from the 'lifetime' parameter value. If this is not the case, the DOTS server MUST reject the request with a 4.00 (Bad Request).

The If-Match Option (Section 5.10.8.1 of [RFC7252]) with an empty value is used to make the PUT request conditional on the current existence of the mitigation request. If UDP is used as transport, CoAP requests may arrive out-of-order. For example, the DOTS client may send a PUT request to convey an efficacy update to the DOTS server followed by a DELETE request to withdraw the mitigation request, but the DELETE request arrives at the DOTS server before the PUT request. To handle out-of-order delivery of requests, if an If-Match Option is present in the PUT request and the 'mid' in the request matches a mitigation request from that DOTS client, the request is processed by the DOTS server. If no match is found, the PUT request is silently ignored by the DOTS server.

An example of an efficacy update message, which includes an If-Match

Option with an empty value, is depicted in Figure 14.

```
Header: PUT (Code=0.03)
Uri-Host: "host"
Uri-Path: ".well-known"
Uri-Path: "dots"
Uri-Path: "v1"
Uri-Path: "mitigate"
Uri-Path: "cuid=dz6pHjaADkaFTbjr0JGBpw"
Uri-Path: "mid=123"
Content-Format: "application/cbor"
If-Match:
{
 "ietf-dots-signal-channel:mitigation-scope": {
   "scope": [
     {
       "target-prefix": [
          "string"
        ],
       "target-port-range": [
          {
            "lower-port": integer,
            "upper-port": integer
          }
        ],
        "target-protocol": [
          integer
        ],
        "target-fqdn": [
          "string"
        ],
        "target-uri": [
          "string"
        ],
        "alias-name": [
          "string"
        ],
       "lifetime": integer,
       "attack-status": integer
     }
   ]
 }
}
```

Figure 14: Efficacy Update

The 'attack-status' parameter is a mandatory attribute when performing an efficacy update. The various possible values contained in the 'attack-status' parameter are described in Table 3.

Parameter value	Description
1	The DOTS client determines that it is still under attack.
2	The DOTS client determines that the attack is successfully mitigated (e.g., attack traffic is not seen).

Table 3: Values of 'attack-status' Parameter

The DOTS server indicates the result of processing a PUT request using CoAP response codes. The response code 2.04 (Changed) is returned if the DOTS server has accepted the mitigation efficacy update. The error response code 5.03 (Service Unavailable) is returned if the DOTS server has erred or is incapable of performing the mitigation.

4.4.4. Withdraw a Mitigation

DELETE requests are used to withdraw DOTS mitigation requests from DOTS servers (Figure 15).

'cuid' and 'mid' are mandatory Uri-Path parameters for DELETE

requests.

The same considerations for manipulating 'cdid' parameter by DOTS gateways, as specified in Section 4.4.1, MUST be followed for DELETE requests. Uri-Path parameters with empty values MUST NOT be present in a request.

```
Header: DELETE (Code=0.04)
Uri-Host: "host"
Uri-Path: ".well-known"
Uri-Path: "dots"
Uri-Path: "v1"
Uri-Path: "mitigate"
Uri-Path: "cuid=dz6pHjaADkaFTbjr0JGBpw"
Uri-Path: "mid=123"
```

Figure 15: Withdraw a DOTS Mitigation

If the DELETE request does not include 'cuid' and 'mid' parameters, the DOTS server MUST reply with a 4.00 (Bad Request).

Once the request is validated, the DOTS server immediately acknowledges a DOTS client's request to withdraw the DOTS signal using 2.02 (Deleted) response code with no response payload. A 2.02 (Deleted) Response Code is returned even if the 'mid' parameter value conveyed in the DELETE request does not exist in its configuration data before the request.

If the DOTS server finds the 'mid' parameter value conveyed in the DELETE request in its configuration data for the DOTS client, then to protect against route or DNS flapping caused by a DOTS client rapidly removing a mitigation, and to dampen the effect of oscillating attacks, the DOTS server MAY allow mitigation to continue for a limited period after acknowledging a DOTS client's withdrawal of a mitigation request. During this period, the DOTS server status messages SHOULD indicate that mitigation is active but terminating (Section 4.4.2).

The initial active-but-terminating period SHOULD be sufficiently long to absorb latency incurred by route propagation. The active-but-terminating period SHOULD be set by default to 120 seconds. If the client requests mitigation again before the initial active-but-terminating period elapses, the DOTS server MAY exponentially increase the active-but-terminating period up to a maximum of 300 seconds (5 minutes).

Once the active-but-terminating period elapses, the DOTS server MUST treat the mitigation as terminated, as the DOTS client is no longer responsible for the mitigation. For example, if there is a financial relationship between the DOTS client and server domains, the DOTS client stops incurring cost at this point.

If a mitigation is triggered due to a signal channel loss, the DOTS server relies upon normal triggers to stop that mitigation (typically, receipt of a valid DELETE request, expiry of the mitigation lifetime, or local traffic observation). In particular, the DOTS server MUST NOT consider the signal channel recovery as a trigger to stop the mitigation.

4.5. DOTS Signal Channel Session Configuration

A DOTS client can negotiate, configure, and retrieve the DOTS signal channel session behavior with its DOTS peers. The DOTS signal channel can be used, for example, to configure the following:

a. Heartbeat interval (heartbeat-interval): DOTS agents regularly send heartbeats (CoAP Ping/Pong) to each other after mutual authentication is successfully completed in order to keep the DOTS signal channel open. Heartbeat messages are exchanged between DOTS agents every 'heartbeat-interval' seconds to detect the current status of the DOTS signal channel session.

b. Missing heartbeats allowed (missing-hb-allowed): This variable indicates the maximum number of consecutive heartbeat messages for which a DOTS agent did not receive a response before concluding that the session is disconnected or defunct.

c. Acceptable signal loss ratio: Maximum retransmissions, retransmission timeout value, and other message transmission parameters for the DOTS signal channel.

The same or distinct configuration sets may be used during times when a mitigation is active ('mitigating-config') and when no mitigation is active ('idle-config'). This is particularly useful for DOTS servers that might want to reduce heartbeat frequency or cease heartbeat exchanges when an active DOTS client has not requested mitigation. If distinct configurations are used, DOTS agents MUST follow the appropriate configuration set as a function of the mitigation activity (e.g., if no mitigation request is active, 'idle-config'-related values must be followed). Additionally, DOTS agents MUST automatically switch to the other configuration upon a change in the mitigation activity (e.g., if an attack mitigation is launched after a peacetime, the DOTS agent switches from 'idle-config' to 'mitigating-config'-related values).

Requests and responses are deemed reliable by marking them as Confirmable (CON) messages. DOTS signal channel session configuration requests and responses are marked as Confirmable messages. As explained in Section 2.1 of [RFC7252], a Confirmable message is retransmitted using a default timeout and exponential back-off between retransmissions, until the DOTS server sends an Acknowledgement message (ACK) with the same Message ID conveyed from the DOTS client.

Message transmission parameters are defined in Section 4.8 of [RFC7252]. The DOTS server can either piggyback the response in the acknowledgement message or, if the DOTS server cannot respond immediately to a request carried in a Confirmable message, it simply responds with an Empty Acknowledgement message so that the DOTS client can stop retransmitting the request. Empty Acknowledgement message is explained in Section 2.2 of [RFC7252]. When the response is ready, the server sends it in a new Confirmable message which in turn needs to be acknowledged by the DOTS client (see Sections 5.2.1 and 5.2.2 of [RFC7252]). Requests and responses exchanged between DOTS agents during peacetime are marked as Confirmable messages.

Implementation Note: A DOTS client that receives a response in a CON message may want to clean up the message state right after sending the ACK. If that ACK is lost and the DOTS server retransmits the CON, the DOTS client may no longer have any state that would help it correlate this response: from the DOTS client's standpoint, the retransmission message is unexpected. The DOTS client will send a Reset message so it does not receive any more retransmissions. This behavior is normal and not an indication of an error (see Section 5.3.2 of [RFC7252] for more details).

4.5.1. Discover Configuration Parameters

A GET request is used to obtain acceptable (e.g., minimum and maximum values) and current configuration parameters on the DOTS server for DOTS signal channel session configuration. This procedure occurs between a DOTS client and its immediate peer DOTS server. As such, this GET request MUST NOT be relayed by an on-path DOTS gateway.

Figure 16 shows how to obtain acceptable configuration parameters for the DOTS server.

```
Header: GET (Code=0.01)
Uri-Host: "host"
Uri-Path: ".well-known"
Uri-Path: "dots"
Uri-Path: "v1"
Uri-Path: "config"
```

Figure 16: GET to Retrieve Configuration

The DOTS server in the 2.05 (Content) response conveys the current, minimum, and maximum attribute values acceptable by the DOTS server (Figure 17).

```
Content-Format: "application/cbor"
{
  "ietf-dots-signal-channel:signal-config": {
    "mitigating-config": {
```

```
          "heartbeat-interval": {
            "max-value": integer,
            "min-value": integer,
            "current-value": integer
          },
          "missing-hb-allowed": {
            "max-value": integer,
            "min-value": integer,
            "current-value": integer
          },
          "max-retransmit": {
            "max-value": integer,
            "min-value": integer,
            "current-value": integer
          },
          "ack-timeout": {
            "max-value-decimal": number,
            "min-value-decimal": number,
            "current-value-decimal": number
          },
          "ack-random-factor": {
            "max-value-decimal": number,
            "min-value-decimal": number,
            "current-value-decimal": number
          }
        },
        "idle-config": {
          "heartbeat-interval": {
            "max-value": integer,
            "min-value": integer,
            "current-value": integer
          },
          "missing-hb-allowed": {
            "max-value": integer,
            "min-value": integer,
            "current-value": integer
          },
          "max-retransmit": {
            "max-value": integer,
            "min-value": integer,
            "current-value": integer
          },
          "ack-timeout": {
            "max-value-decimal": number,
            "min-value-decimal": number,
            "current-value-decimal": number
          },
          "ack-random-factor": {
            "max-value-decimal": number,
            "min-value-decimal": number,
            "current-value-decimal": number
          }
        },
        "trigger-mitigation": boolean
        }
      }
    }
```

Figure 17: GET Configuration Response Body

The parameters in Figure 17 are described below:

mitigating-config: Set of configuration parameters to use when a mitigation is active. The following parameters may be included:

heartbeat-interval: Time interval in seconds between two consecutive heartbeat messages.

'0' is used to disable the heartbeat mechanism.

This is an optional attribute.

missing-hb-allowed: Maximum number of consecutive heartbeat messages for which the DOTS agent did not receive a response before concluding that the session is disconnected.

This is an optional attribute.

max-retransmit: Maximum number of retransmissions for a message (referred to as MAX_RETRANSMIT parameter in CoAP).

This is an optional attribute.

ack-timeout: Timeout value in seconds used to calculate the initial retransmission timeout value (referred to as ACK_TIMEOUT parameter in CoAP).

This is an optional attribute.

ack-random-factor: Random factor used to influence the timing of retransmissions (referred to as ACK_RANDOM_FACTOR parameter in CoAP).

This is an optional attribute.

idle-config: Set of configuration parameters to use when no mitigation is active. This attribute has the same structure as 'mitigating-config'.

~~trigger-mitigation: If the parameter value is set to 'false', then DDoS mitigation is triggered only when the DOTS signal channel session is lost. Automated mitigation on loss of signal is discussed in Section 3.3.3 of [I-D.ietf-dots-architecture].~~

~~If the DOTS client ceases to respond to heartbeat messages, the DOTS server can detect that the DOTS session is lost.~~

~~The default value of the parameter is 'true'.~~

~~This is an optional attribute.~~

Figure 18 shows an example of acceptable and current configuration parameters on a DOTS server for DOTS signal channel session configuration. The same acceptable configuration is used during attack and peace times.

Content-Format: "application/cbor"

```
{
  "ietf-dots-signal-channel:signal-config": {
    "mitigating-config": {
      "heartbeat-interval": {
        "max-value": 240,
        "min-value": 15,
        "current-value": 30
      },
      "missing-hb-allowed": {
        "max-value": 9,
        "min-value": 3,
        "current-value": 5
      },
      "max-retransmit": {
        "max-value": 15,
        "min-value": 2,
        "current-value": 3
      },
      "ack-timeout": {
        "max-value-decimal": 30.0,
        "min-value-decimal": 1.0,
        "current-value-decimal": 2.0
      },
      "ack-random-factor": {
        "max-value-decimal": 4.0,
        "min-value-decimal": 1.1,
        "current-value-decimal": 1.5
      }
    },
    "idle-config": {
      "heartbeat-interval": {
        "max-value": 240,
        "min-value": 15,
        "current-value": 30
      },
      "missing-hb-allowed": {
        "max-value": 9,
```

```
            "min-value": 3,
            "current-value": 5
          },
          "max-retransmit": {
            "max-value": 15,
            "min-value": 2,
            "current-value": 3
          },
          "ack-timeout": {
            "max-value-decimal": 30.0,
            "min-value-decimal": 1.0,
            "current-value-decimal": 2.0
          },
          "ack-random-factor": {
            "max-value-decimal": 4.0,
            "min-value-decimal": 1.1,
            "current-value-decimal": 1.5
          }
        },
        "trigger-mitigation": true
        }
      }
    }
```

Figure 18: Example of a Configuration Response Body

4.5.2. Convey DOTS Signal Channel Session Configuration

A PUT request is used to convey the configuration parameters for the signal channel (e.g., heartbeat interval, maximum retransmissions). Message transmission parameters for CoAP are defined in Section 4.8 of [RFC7252]. The RECOMMENDED values of transmission parameter values are ack-timeout (2 seconds), max-retransmit (3), ack-random-factor (1.5). In addition to those parameters, the RECOMMENDED specific DOTS transmission parameter values are 'heartbeat-interval' (30 seconds) and 'missing-hb-allowed' (5).

> Note: heartbeat-interval should be tweaked to also assist DOTS messages for NAT traversal (SIG-010 of [I-D.ietf-dots-requirements]). According to [RFC8085], keepalive messages must not be sent more frequently than once every 15 seconds and should use longer intervals when possible. Furthermore, [RFC4787] recommends NATs to use a state timeout of 2 minutes or longer, but experience shows that sending packets every 15 to 30 seconds is necessary to prevent the majority of middleboxes from losing state for UDP flows. From that standpoint, this specification recommends a minimum heartbeat-interval of 15 seconds and a maximum heartbeat-interval of 240 seconds. The recommended value of 30 seconds is selected to anticipate the expiry of NAT state.
>
> A heartbeat-interval of 30 seconds may be considered as too chatty in some deployments. For such deployments, DOTS agents may negotiate longer heartbeat-interval values to prevent any network overload with too frequent keepalives.
>
> Different heartbeat intervals can be defined for 'mitigating-config' and 'idle-config' to reduce being too chatty during idle times. If there is an on-path translator between the DOTS client (standalone or part of a DOTS gateway) and the DOTS server, the 'mitigating-config' heartbeat-interval has to be smaller than the translator session timeout. It is recommended that the 'idle-config' heartbeat-interval is also smaller than the translator session timeout to prevent translator transversal issues, or set to '0'. Means to discover the lifetime assigned by a translator are out of scope.

When a confirmable "CoAP Ping" is sent, and if there is no response, the "CoAP Ping" is retransmitted max-retransmit number of times by the CoAP layer using an initial timeout set to a random duration between ack-timeout and (ack-timeout*ack-random-factor) and exponential back-off between retransmissions. By choosing the recommended transmission parameters, the "CoAP Ping" will timeout after 45 seconds. If the DOTS agent does not receive any response from the peer DOTS agent for 'missing-hb-allowed' number of consecutive "CoAP Ping" confirmable messages, it concludes that the DOTS signal channel session is disconnected. A DOTS client MUST NOT

transmit a "CoAP Ping" while waiting for the previous "CoAP Ping" response from the same DOTS server.

If the DOTS agent wishes to change the default values of message transmission parameters, it should follow the guidance given in Section 4.8.1 of [RFC7252]. The DOTS agents MUST use the negotiated values for message transmission parameters and default values for non-negotiated message transmission parameters.

The signal channel session configuration is applicable to a single DOTS signal channel session between DOTS agents, so the 'cuid' Uri-Path MUST NOT be used.

```
  Header: PUT (Code=0.03)
  Uri-Host: "host"
  Uri-Path: ".well-known"
  Uri-Path: "dots"
  Uri-Path: "v1"
  Uri-Path: "config"
  Uri-Path: "sid=123"
  Content-Format: "application/cbor"
  {
    "ietf-dots-signal-channel:signal-config": {
      "mitigating-config": {
        "heartbeat-interval": {
          "current-value": integer
        },
        "missing-hb-allowed": {
          "current-value": integer
        },
        "max-retransmit": {
          "current-value": integer
        },
        "ack-timeout": {
          "current-value-decimal": number

        },
        "ack-random-factor": {
          "current-value-decimal": number
        }
      },
      "idle-config": {
        "heartbeat-interval": {
          "current-value": integer
        },
        "missing-hb-allowed": {
          "current-value": integer
        },
        "max-retransmit": {
          "current-value": integer
        },
        "ack-timeout": {
          "current-value-decimal": number
        },
        "ack-random-factor": {
          "current-value-decimal": number
        }
      },
      "trigger-mitigation": boolean
      }
    }
  }
```

Figure 19: PUT to Convey the DOTS Signal Channel Session Configuration Data

The additional Uri-Path parameter to those defined in Table 1 is as follows:

sid: Session Identifier is an identifier for the DOTS signal channel session configuration data represented as an integer. This identifier MUST be generated by DOTS clients. 'sid' values MUST increase monotonically.

This is a mandatory attribute.

The meaning of the parameters in the CBOR body is defined in

Section 4.5.1.

At least one of the attributes 'heartbeat-interval', 'missing-hb-allowed', 'max-retransmit', 'ack-timeout', ~~'ack-random-factor',~~ and ~~'trigger-mitigation'~~ **'ack-random-factor'** MUST be present in the PUT request. Note that 'heartbeat-interval', 'missing-hb-allowed', 'max-retransmit', ~~'ack-timeout',~~ **'ack-timeout',** and ~~'ack-random-factor',~~ **'ack-random-factor',** if present, do not need to be provided for both 'mitigating-config', and 'idle-config' in a PUT request.

The PUT request with a higher numeric 'sid' value overrides the DOTS signal channel session configuration data installed by a PUT request with a lower numeric 'sid' value. To avoid maintaining a long list of 'sid' requests from a DOTS client, the lower numeric 'sid' MUST be automatically deleted and no longer available at the DOTS server.

Figure 20 shows a PUT request example to convey the configuration parameters for the DOTS signal channel. In this example, the heartbeat mechanism is disabled when no mitigation is active, while the heartbeat interval is set to '91' when a mitigation is active.

```
Header: PUT (Code=0.03)
Uri-Host: "www.example.com"
Uri-Path: ".well-known"
Uri-Path: "dots"
Uri-Path: "v1"
Uri-Path: "config"
Uri-Path: "sid=123"
Content-Format: "application/cbor"
{
  "ietf-dots-signal-channel:signal-config": {
    "mitigating-config": {
      "heartbeat-interval": {
        "current-value": 91
      },
      "missing-hb-allowed": {
        "current-value": 3
      },
      "max-retransmit": {
        "current-value": 3
      },
      "ack-timeout": {
        "current-value-decimal": 2.0
      },
      "ack-random-factor": {
        "current-value-decimal": 1.5
      }
    },
    "idle-config": {
      "heartbeat-interval": {
        "current-value": 0
      },
      "max-retransmit": {
        "current-value": 3
      },
      "ack-timeout": {
        "current-value-decimal": 2.0
      },
      "ack-random-factor": {
        "current-value-decimal": 1.5
      }
    },
    "trigger-mitigation": false
    }
  }
}
```

Figure 20: PUT to Convey the Configuration Parameters

The DOTS server indicates the result of processing the PUT request using CoAP response codes:

o If the request is missing a mandatory attribute, does not include a 'sid' Uri-Path, or contains one or more invalid or unknown parameters, 4.00 (Bad Request) MUST be returned in the response.

- o If the DOTS server does not find the 'sid' parameter value conveyed in the PUT request in its configuration data and if the DOTS server has accepted the configuration parameters, then a response code 2.01 (Created) is returned in the response.

- o If the DOTS server finds the 'sid' parameter value conveyed in the PUT request in its configuration data and if the DOTS server has accepted the updated configuration parameters, 2.04 (Changed) MUST be returned in the response.

- o If any of the 'heartbeat-interval', 'missing-hb-allowed', 'max-retransmit', 'target-protocol', 'ack-timeout', and 'ack-random-factor' attribute values are not acceptable to the DOTS server, 4.22 (Unprocessable Entity) MUST be returned in the response. Upon receipt of this error code, the DOTS client SHOULD request the maximum and minimum attribute values acceptable to the DOTS server (Section 4.5.1).

  The DOTS client may re-try and send the PUT request with updated attribute values acceptable to the DOTS server.

A DOTS client may issue a GET message with 'sid' Uri-Path parameter to retrieve the negotiated configuration. The response does not need to include 'sid' in its message body.

4.5.3. Configuration Freshness and Notifications

Max-Age Option (Section 5.10.5 of [RFC7252]) SHOULD be returned by a DOTS server to associate a validity time with a configuration it sends. This feature allows the update of the configuration data if a change occurs at the DOTS server side. For example, the new configuration may instruct a DOTS client to cease heartbeats or reduce heartbeat frequency.

It is NOT RECOMMENDED to return a Max-Age Option set to 0.

Returning a Max-Age Option set to 2**32-1 is equivalent to associating an infinite lifetime with the configuration.

If a non-zero value of Max-Age Option is received by a DOTS client, it MUST issue a GET request to refresh the configuration parameters for the signal channel before the expiry of the value enclosed in the Max-Age option. When a DDoS attack is active, refresh requests MUST NOT be sent by DOTS clients and the DOTS server MUST NOT terminate the (D)TLS session after the expiry of the value returned in Max-Age Option.

If Max-Age Option is not returned in a response, the DOTS client initiates GET requests to refresh the configuration parameters each 60 seconds (Section 5.10.5 of [RFC7252]). To prevent such overload, it is RECOMMENDED that DOTS servers return a Max-Age Option in GET responses. Considerations related to which value to use and how such value is set, are implementation- and deployment-specific.

If an Observe Option set to 0 is included in the configuration request, the DOTS server sends notifications of any configuration change (Section 4.2 of [RFC7641]).

If a DOTS server detects that a misbehaving DOTS client does not contact the DOTS server after the expiry of Max-Age, in order to retrieve the signal channel configuration data, it MAY terminate the (D)TLS session. A (D)TLS session is terminated by the receipt of an authenticated message that closes the connection (e.g., a fatal alert (Section 7.2 of [RFC5246])).

4.5.4. Delete DOTS Signal Channel Session Configuration

A DELETE request is used to delete the installed DOTS signal channel session configuration data (Figure 21).

```
Header: DELETE (Code=0.04)
Uri-Host: "host"
Uri-Path: ".well-known"
Uri-Path: "dots"
Uri-Path: "v1"
Uri-Path: "config"
Uri-Path: "sid=123"
```

Figure 21: DELETE Configuration

The DOTS server resets the DOTS signal channel session configuration back to the default values and acknowledges a DOTS client's request to remove the DOTS signal channel session configuration using 2.02 (Deleted) response code.

Upon bootsrapping or reboot, a DOTS client MAY send a DELETE request to set the configuration parameters to default values. Such a request does not include any 'sid'.

4.6. Redirected Signaling

Redirected DOTS signaling is discussed in detail in Section 3.2.2 of [I-D.ietf-dots-architecture].

If a DOTS server wants to redirect a DOTS client to an alternative DOTS server for a signal session, then the response code 3.00 (alternate server) will be returned in the response to the DOTS client.

The DOTS server can return the error response code 3.00 in response to a request from the DOTS client or convey the error response code 3.00 in a unidirectional notification response from the DOTS server.

The DOTS server in the error response conveys the alternate DOTS server's FQDN, and the alternate DOTS server's IP address(es) and time to live values in the CBOR body (Figure 22).

```
{
  "ietf-dots-signal-channel:redirected-signal": {
    "alt-server": "string",
    "alt-server-record": [
       "string"
     ],
     "alt-server-ttl": integer
}
```

Figure 22: Redirected Server Error Response Body

The parameters are described below:

alt-server: FQDN of an alternate DOTS server.

This is a mandatory attribute.

alt-server-record: A list of IP addresses of an alternate DOTS server.

This is an optional attribute.

alt-server-ttl: Time to live (TTL) of the alternate DOTS server, represented as an integer number of seconds. That is, the time interval that the alternate DOTS server may be cached for use by a DOTS client.

A value of negative one (-1) indicates indefinite TTL. This value means that the alternate DOTS server is to be used until the alternate DOTS server redirects the traffic with another 3.00 response.

If no 'alt-server-ttl' is returned in a redirect response, this is equivalent to returning a 'alt-server-ttl' parameter set to '-1'.

A 'alt-server-ttl' parameter set to '0' may be returned for redirecting mitigation requests. Such value means that the redirection applies only for the mitigation request in progress. Returning short 'alt-server-ttl' may adversely impact DOTS clients on slow links. Returning short values should be avoided under such conditions.

If the alternate DOTS server TTL has expired, the DOTS client MUST use the DOTS server(s), that was provisioned using means discussed in Section 4.1. This fall back mechanism is triggered immediately upon expiry of the TTL, except when a DDoS attack is active.

Requests issued by misbehaving DOTS clients which do not honor the TTL or react to explicit re-direct messages can be rejected by DOTS servers.

This is an optional attribute.

Figure 23 shows a 3.00 response example to convey the DOTS alternate server 'alt-server.example', its IP addresses 2001:db8:6401::1 and 2001:db8:6401::2, and 'alt-server-ttl' value 3600.

```
{
  "ietf-dots-signal-channel:redirected-signal": {
    "alt-server": "alt-server.example",
    "alt-server-record": [
       "2001:db8:6401::1",
       "2001:db8:6401::2"
     ],
    "alt-server-ttl": 3600
}
```

Figure 23: Example of Redirected Server Error Response Body

When the DOTS client receives 3.00 response, it considers the current request as failed, but SHOULD try re-sending the request to the alternate DOTS server. During a DDoS attack, the DNS server may be the target of another DDoS attack, alternate DOTS server's IP addresses conveyed in the 3.00 response help the DOTS client skip DNS lookup of the alternate DOTS server. The DOTS client can then try to establish a UDP or a TCP session with the alternate DOTS server. The DOTS client SHOULD implement a DNS64 function to handle the scenario where an IPv6-only DOTS client communicates with an IPv4-only alternate DOTS server.

If the DOTS client has been redirected to a DOTS server to which it has already communicated with within the last five (5) minutes, it MUST ignore the redirection and try to contact other DOTS servers listed in the local configuration or discovered using dynamic means such as DHCP or SRV procedures. It is RECOMMENDED that DOTS clients support means to alert administrators about redirect loops.

4.7. Heartbeat Mechanism

To provide an indication of signal health and distinguish an 'idle' signal channel from a 'disconnected' or 'defunct' session, the DOTS agent sends a heartbeat over the signal channel to maintain its half of the channel. The DOTS agent similarly expects a heartbeat from its peer DOTS agent, and may consider a session terminated in the prolonged absence of a peer agent heartbeat.

While the communication between the DOTS agents is quiescent, the DOTS client will probe the DOTS server to ensure it has maintained cryptographic state and vice versa. Such probes can also keep firewalls and/or stateful translators bindings alive. This probing reduces the frequency of establishing a new handshake when a DOTS signal needs to be conveyed to the DOTS server.

DOTS servers MAY trigger their heartbeat requests immediately after receiving heartbeat probes from peer DOTS clients. As a reminder, it is the responsibility of DOTS clients to ensure that on-path translators/firewalls are maintaining a binding so that the same external IP address and/or port number is retained for the DOTS session.

In case of a massive DDoS attack that saturates the incoming link(s) to the DOTS client, all traffic from the DOTS server to the DOTS client will likely be dropped, although the DOTS server receives heartbeat requests in addition to DOTS messages sent by the DOTS client. In this scenario, the DOTS agents MUST behave differently to handle message transmission and DOTS session liveliness during link saturation:

- o The DOTS client MUST NOT consider the DOTS session terminated even after a maximum 'missing-hb-allowed' threshold is reached. The DOTS client SHOULD keep on using the current DOTS session to send heartbeat requests over it, so that the DOTS server knows the DOTS client has not disconnected the DOTS session.

After the maximum 'missing-hb-allowed' threshold is reached, the DOTS client SHOULD try to resume the (D)TLS session. The DOTS client SHOULD send mitigation requests over the current DOTS session, and in parallel, for example, try to resume the (D)TLS session or use 0-RTT mode in DTLS 1.3 to piggyback the mitigation request in the ClientHello message.

As soon as the link is no longer saturated, if traffic from the DOTS server reaches the DOTS client over the current DOTS session, the DOTS client can stop (D)TLS session resumption or if (D)TLS session resumption is successful then disconnect the current DOTS session.

o If the DOTS server does not receive any traffic from the peer DOTS client, then the DOTS server sends heartbeat requests to the DOTS client and after maximum 'missing-hb-allowed' threshold is reached, the DOTS server concludes the session is disconnected.

In DOTS over UDP, heartbeat messages MUST be exchanged between the DOTS agents using the "CoAP Ping" mechanism defined in Section 4.2 of [RFC7252]. Concretely, the DOTS agent sends an Empty Confirmable message and the peer DOTS agent will respond by sending a Reset message.

In DOTS over TCP, heartbeat messages MUST be exchanged between the DOTS agents using the Ping and Pong messages specified in Section 4.4 of [RFC8323]. That is, the DOTS agent sends a Ping message and the peer DOTS agent would respond by sending a single Pong message.

5. DOTS Signal Channel YANG Module

This document defines a YANG [RFC7950] module for mitigation scope and DOTS signal channel session configuration data.

This YANG module defines the DOTS client interaction with the DOTS server as seen by the DOTS client. A DOTS server is allowed to update the non-configurable 'ro' entities in the responses. This YANG module is not intended to be used for DOTS server management purposes. Such module is out of the scope of this document.

5.1. Tree Structure

This document defines the YANG module "ietf-dots-signal-channel" (Section 5.2), which has the following tree structure. A DOTS signal message can either be a mitigation or a configuration message.

```
module: ietf-dots-signal-channel
    +--rw dots-signal
       +--rw (message-type)?
          +--:(mitigation-scope)
          |  +--rw scope* [cuid mid]
          |     +--rw cdid?                   string
          |     +--rw cuid                    string
          |     +--rw mid                     uint32
          |     +--rw target-prefix*          inet:ip-prefix
          |     +--rw target-port-range* [lower-port upper-port]
          |     |  +--rw lower-port    inet:port-number
          |     |  +--rw upper-port    inet:port-number
          |     +--rw target-protocol*        uint8
          |     +--rw target-fqdn*            inet:domain-name
          |     +--rw target-uri*             inet:uri
          |     +--rw alias-name*             string
          |     +--rw lifetime?               int32
          |     +--rw trigger-mitigation?     boolean
          |     +--ro mitigation-start?       uint64
          |     +--ro status?                 enumeration
          |     +--ro conflict-information
          |     |  +--ro conflict-status?   enumeration
          |     |  +--ro conflict-cause?    enumeration
          |     |  +--ro retry-timer?       uint32
          |     |  +--ro conflict-scope
          |     |     +--ro target-prefix*       inet:ip-prefix
          |     |     +--ro target-port-range* [lower-port upper-port]
          |     |     |  +--ro lower-port    inet:port-number
          |     |     |  +--ro upper-port    inet:port-number
          |     |     +--ro target-protocol*     uint8
          |     |     +--ro target-fqdn*         inet:domain-name
```

```
|     |     +--ro target-uri*          inet:uri
|     |     +--ro alias-name*          string
|     |     +--ro acl-list* [acl-name]
|     |        +--ro acl-name
|     |        |       -> /ietf-acl:acls/acl/name
|     |        +--ro acl-type?
|     |                -> /ietf-acl:acls/acl/type
|     +--ro bytes-dropped?          yang:zero-based-counter64
|     +--ro bps-dropped?            yang:zero-based-counter64
|     +--ro pkts-dropped?           yang:zero-based-counter64
|     +--ro pps-dropped?            yang:zero-based-counter64
|     +--rw attack-status?          enumeration
+--:(signal-config)
|  +--rw sid                   uint32
|  +--rw mitigating-config
|  |  +--rw heartbeat-interval
|  |  |  +--ro max-value?       uint16
|  |  |  +--ro min-value?       uint16
|  |  |  +--rw current-value?   uint16
|  |  +--rw missing-hb-allowed
|  |  |  +--ro max-value?       uint16
|  |  |  +--ro min-value?       uint16
|  |  |  +--rw current-value?   uint16
|  |  +--rw max-retransmit
|  |  |  +--ro max-value?       uint16
|  |  |  +--ro min-value?       uint16
|  |  |  +--rw current-value?   uint16
|  |  +--rw ack-timeout
|  |  |  +--ro max-value-decimal?       decimal64
|  |  |  +--ro min-value-decimal?       decimal64
|  |  |  +--rw current-value-decimal?   decimal64
|  |  +--rw ack-random-factor
|  |     +--ro max-value-decimal?       decimal64
|  |     +--ro min-value-decimal?       decimal64
|  |     +--rw current-value-decimal?   decimal64
|  +--rw idle-config
|  +     +--rw heartbeat-interval
|     |  +  +--ro max-value?       uint16
|     |  +  +--ro min-value?       uint16
|     |  +  +--rw current-value?   uint16
|  +     +--rw missing-hb-allowed
|     |  +  +--ro max-value?       uint16
|     |  +  +--ro min-value?       uint16
|     |  +  +--rw current-value?   uint16
|  +     +--rw max-retransmit
|     |  +  +--ro max-value?       uint16
|     |  +  +--ro min-value?       uint16
|     |  +  +--rw current-value?   uint16
|  +     +--rw ack-timeout
|     |  +  +--ro max-value-decimal?       decimal64
|     |  +  +--ro min-value-decimal?       decimal64
|     |  +  +--rw current-value-decimal?   decimal64
|  +     +--rw ack-random-factor
|  +        +--ro max-value-decimal?       decimal64
|  +        +--ro min-value-decimal?       decimal64
|  +        +--rw current-value-decimal?   decimal64
+  +--rw trigger-mitigation?   boolean
+--:(redirected-signal)
   +--ro alt-server            string
   +--ro alt-server-record*    inet:ip-address
   +--ro alt-server-ttl?       int32
```

5.2. YANG Module

<CODE BEGINS> file ~~"ietf-dots-signal-channel@2018-05-29.yang"~~ **"ietf-dots-signal-channel@2018-07-24.yang"**

```
module ietf-dots-signal-channel {
  yang-version 1.1;
  namespace "urn:ietf:params:xml:ns:yang:ietf-dots-signal-channel";
  prefix signal;

  import ietf-inet-types {
    prefix inet;
  }
  import ietf-yang-types {
    prefix yang;
  }
```

```
  import ietf-access-control-list {
    prefix ietf-acl;
  }

  organization
    "IETF DDoS Open Threat Signaling (DOTS) Working Group";
  contact
    "WG Web:   <https://datatracker.ietf.org/wg/dots/>
     WG List:  <mailto:dots@ietf.org>

     Editor:  Konda, Tirumaleswar Reddy
              <mailto:TirumaleswarReddy_Konda@McAfee.com>

     Editor:  Mohamed Boucadair
              <mailto:mohamed.boucadair@orange.com>

     Author:  Prashanth Patil
              <mailto:praspati@cisco.com>

     Author:  Andrew Mortensen
              <mailto:amortensen@arbor.net>

     Author:  Nik Teague
              <mailto:nteague@verisign.com>";
  description
    "This module contains YANG definition for the signaling
     messages exchanged between a DOTS client and a DOTS server.

     Copyright (c) 2018 IETF Trust and the persons identified as
     authors of the code.  All rights reserved.

     Redistribution and use in source and binary forms, with or
     without modification, is permitted pursuant to, and subject
     to the license terms contained in, the Simplified BSD License
     set forth in Section 4.c of the IETF Trust's Legal Provisions
     Relating to IETF Documents
     (http://trustee.ietf.org/license-info).

     This version of this YANG module is part of RFC XXXX; see
     the RFC itself for full legal notices.";

  revision 2018-05-29 2018-07-24 {
    description
      "Initial revision.";
    reference
      "RFC XXXX: Distributed Denial-of-Service Open Threat
                 Signaling (DOTS) Signal Channel Specification";
  }

 /*
  * Groupings
  */

  grouping target {
    description
      "Specifies the targets of the mitigation request.";
    leaf-list target-prefix {
      type inet:ip-prefix;
      description
        "IPv4 or IPv6 prefix identifying the target.";
    }
    list target-port-range {
      key "lower-port upper-port";
      description
        "Port range. When only lower-port is
         present, it represents a single port number.";
      leaf lower-port {
        type inet:port-number;
        mandatory true;
        description
          "Lower port number of the port range.";
      }
      leaf upper-port {
        type inet:port-number;
        must ". >= ../lower-port" {
          error-message
            "The upper port number must be greater than
```

```
              or equal to lower port number.";
        }
        description
          "Upper port number of the port range.";
      }
    }
    leaf-list target-protocol {
      type uint8;
      description
        "Identifies the target protocol number.

         The value '0' means 'all protocols'.

         Values are taken from the IANA protocol registry:
         https://www.iana.org/assignments/protocol-numbers/
         protocol-numbers.xhtml

         For example, 6 for TCP or 17 for UDP.";
    }
    leaf-list target-fqdn {
      type inet:domain-name;
      description
        "FQDN identifying the target.";
    }
    leaf-list target-uri {
      type inet:uri;
      description
        "URI identifying the target.";
    }
  }

  grouping mitigation-scope {
    description
      "Specifies the scope of the mitigation request.";
    list scope {
      key "cuid mid";
      description
        "The scope of the request.";
      leaf cdid {
        type string;
        description
          "The cdid should be included by a server-domain
           DOTS gateway to propagate the client domain
           identification information from the
           gateway's client-facing-side to the gateway's
           server-facing-side, and from the gateway's
           server-facing-side to the DOTS server.

           It may be used by the final DOTS server
           for policy enforcement purposes.";
      }
      leaf cuid {
        type string;
        description
          "A unique identifier that is randomly
           generated by a DOTS client to prevent
           request collisions.  It is expected that the
           cuid will remain consistent throughout the
           lifetime of the DOTS client.";

      }
      leaf mid {
        type uint32;
        description
          "Mitigation request identifier.

           This identifier must be unique for each mitigation
           request bound to the DOTS client.";
      }
      uses target;
      leaf-list alias-name {
        type string;
        description
          "An alias name that points to a resource.";
      }
      leaf lifetime {
        type int32;
```

```
          units "seconds";
          default "3600";
          description
            "Indicates the lifetime of the mitigation request.

             A lifetime of '0' in a mitigation request is an
             invalid value.

             A lifetime of negative one (-1) indicates indefinite
             lifetime for the mitigation request.";
        }
        leaf trigger-mitigation {
          type boolean;
          default "true";
          description
            "If set to 'false', DDoS mitigation will not be
             triggered unless the DOTS signal channel
             session is lost.";
        }
        leaf mitigation-start {
          type uint64;
          config false;
          description
            "Mitigation start time is represented in seconds
             relative to 1970-01-01T00:00:00Z in UTC time.";
        }
        leaf status {
          type enumeration {
            enum "attack-mitigation-in-progress" {
              value 1;
              description
                "Attack mitigation is in progress (e.g., changing
                 the network path to re-route the inbound traffic
                 to DOTS mitigator).";
            }
            enum "attack-successfully-mitigated" {
              value 2;
              description
                "Attack is successfully mitigated (e.g., traffic
                 is redirected to a DDoS mitigator and attack
                 traffic is dropped or blackholed).";
            }
            enum "attack-stopped" {
              value 3;
              description
                "Attack has stopped and the DOTS client can
                 withdraw the mitigation request.";
            }
            enum "attack-exceeded-capability" {
              value 4;
              description
                "Attack has exceeded the mitigation provider
                 capability.";
            }
            enum "dots-client-withdrawn-mitigation" {
              value 5;
              description
                "DOTS client has withdrawn the mitigation
                 request and the mitigation is active but
                 terminating.";
            }
            enum "attack-mitigation-terminated" {
              value 6;
              description
                "Attack mitigation is now terminated.";
            }
            enum "attack-mitigation-withdrawn" {
              value 7;
              description
                "Attack mitigation is withdrawn.";
            }
            enum "attack-mitigation-signal-loss" {
              value 8;
              description
                "When the DDoS signal channel session is
                 lost, DDoS mitigation will be triggered
                 for the mitigation request.";
```

```
        }
      }
      config false;
      description
        "Indicates the status of a mitigation request.
         It must be included in responses only.";
    }
    container conflict-information {
      config false;
      description
        "Indicates that a conflict is detected.
         Must only be used for responses.";
      leaf conflict-status {
        type enumeration {
          enum "request-inactive-other-active" {
            value 1;
            description
              "DOTS Server has detected conflicting mitigation
               requests from different DOTS clients.
               This mitigation request is currently inactive
               until the conflicts are resolved. Another
               mitigation request is active.";
          }
          enum "request-active" {
            value 2;
            description
              "DOTS Server has detected conflicting mitigation
               requests from different DOTS clients.
               This mitigation request is currently active.";
          }
          enum "all-requests-inactive" {
            value 3;
            description
              "DOTS Server has detected conflicting mitigation
               requests from different DOTS clients.  All
               conflicting mitigation requests are inactive.";
          }
        }
        description
          "Indicates the conflict status.";
      }
      leaf conflict-cause {
        type enumeration {
          enum "overlapping-targets" {
            value 1;
            description
              "Overlapping targets. conflict-scope provides
               more details about the exact conflict.";
          }
          enum "conflict-with-whitelist" {
            value 2;
            description
              "Conflicts with an existing white list.

               This code is returned when the DDoS mitigation
               detects that some of the source addresses/prefixes
               listed in the white list ACLs are actually
               attacking the target.";
          }
          enum "cuid-collision" {
            value 3;
            description
              "Conflicts with the cuid used by another
               DOTS client.";
          }
        }
        description
          "Indicates the cause of the conflict.";
      }
      leaf retry-timer {
        type uint32;
        units "seconds";
        description
          "The DOTS client must not re-send the
           same request that has a conflict before the expiry of
           this timer.";
      }
```

```
          container conflict-scope {
            description
              "Provides more information about the conflict scope.";
            uses target {
              when "../conflict-cause = 'overlapping-targets'";
            }
            leaf-list alias-name {
              when "../../conflict-cause = 'overlapping-targets'";
              type string;
              description
                "Conflicting alias-name.";
            }
            list acl-list {
              when "../../conflict-cause = 'conflict-with-whitelist'";
              key "acl-name";
              description
                "List of conflicting ACLs as defined in the DOTS data
                 channel.  These ACLs are uniquely defined by
                 cuid and acl-name.";
              leaf acl-name {
                type leafref {
                  path "/ietf-acl:acls/ietf-acl:acl/" +
                       "ietf-acl:name";
                }
                description
                  "Reference to the conflicting ACL name bound to
                   a DOTS client.";
              }
              leaf acl-type {
                type leafref {
                  path "/ietf-acl:acls/ietf-acl:acl/" +
                       "ietf-acl:type";
                }
                description
                  "Reference to the conflicting ACL type bound to
                   a DOTS client.";
              }
            }
          }
        }
        leaf bytes-dropped {
          type yang:zero-based-counter64;
          units "bytes";
          config false;
          description
            "The total dropped byte count for the mitigation
             request since the attack mitigation is triggered.
             The count wraps around when it reaches the maximum value
             of counter64 for dropped bytes.";
        }
        leaf bps-dropped {
          type yang:zero-based-counter64;
          config false;
          description
            "The average number of dropped bits per second for
             the mitigation request since the attack
             mitigation is triggered.  This should be a
             five-minute average.";
        }
        leaf pkts-dropped {
          type yang:zero-based-counter64;
          config false;
          description
            "The total number of dropped packet count for the
             mitigation request since the attack mitigation is
             triggered.  The count wraps around when it reaches
             the maximum value of counter64 for dropped packets.";
        }
        leaf pps-dropped {
          type yang:zero-based-counter64;
          config false;
          description
            "The average number of dropped packets per second
             for the mitigation request since the attack
             mitigation is triggered.  This should be a
             five-minute average.";
        }
```

```
      leaf attack-status {
        type enumeration {
          enum "under-attack" {
            value 1;
            description
              "The DOTS client determines that it is still under
               attack.";
          }
          enum "attack-successfully-mitigated" {
            value 2;
            description
              "The DOTS client determines that the attack is
               successfully mitigated.";
          }
        }
        description
          "Indicates the status of an attack as seen by the
           DOTS client.";
      }
    }
  }

  grouping config-parameters {
    description
      "Subset of DOTS signal channel session configuration.";
    container heartbeat-interval {
      description
        "DOTS agents regularly send heartbeats to each other
         after mutual authentication is successfully
         completed in order to keep the DOTS signal channel
         open.";
      leaf max-value {
        type uint16;
        units "seconds";
        config false;
        description
          "Maximum acceptable heartbeat-interval value.";
      }
      leaf min-value {
        type uint16;
        units "seconds";
        config false;
        description
          "Minimum acceptable heartbeat-interval value.";
      }
      leaf current-value {
        type uint16;
        units "seconds";
        default "30";
        description
          "Current heartbeat-interval value.

           '0' means that heartbeat mechanism is deactivated.";
      }
    }
    container missing-hb-allowed {
      description
        "Maximum number of missing heartbeats allowed.";
      leaf max-value {
        type uint16;
        config false;
        description
          "Maximum acceptable missing-hb-allowed value.";
      }
      leaf min-value {
        type uint16;
        config false;
        description
          "Minimum acceptable missing-hb-allowed value.";
      }
      leaf current-value {
        type uint16;
        default "5";
        description
          "Current missing-hb-allowed value.";
      }
    }
```

```
        container max-retransmit {
          description
            "Maximum number of retransmissions of a Confirmable
             message.";
          leaf max-value {
            type uint16;
            config false;
            description
              "Maximum acceptable max-retransmit value.";
          }
          leaf min-value {
            type uint16;
            config false;
            description
              "Minimum acceptable max-retransmit value.";
          }
          leaf current-value {
            type uint16;
            default "3";
            description
              "Current max-retransmit value.";
          }
        }
        container ack-timeout {
          description
            "Initial retransmission timeout value.";
          leaf max-value-decimal {
            type decimal64 {
              fraction-digits 2;
            }
            units "seconds";
            config false;
            description
              "Maximum ack-timeout value.";
          }
          leaf min-value-decimal {
            type decimal64 {
              fraction-digits 2;
            }
            units "seconds";
            config false;
            description
              "Minimum ack-timeout value.";
          }
          leaf current-value-decimal {
            type decimal64 {
              fraction-digits 2;
            }
            units "seconds";
            default "2";
            description
              "Current ack-timeout value.";
          }
        }
        container ack-random-factor {
          description
            "Random factor used to influence the timing of
             retransmissions.";
          leaf max-value-decimal {
            type decimal64 {
              fraction-digits 2;
            }
            config false;
            description
              "Maximum acceptable ack-random-factor value.";
          }
          leaf min-value-decimal {
            type decimal64 {
              fraction-digits 2;
            }
            config false;
            description
              "Minimum acceptable ack-random-factor value.";
          }
          leaf current-value-decimal {
            type decimal64 {
              fraction-digits 2;
```

```
            }
            default "1.5";
            description
              "Current ack-random-factor value.";
          }
        }
      }

      grouping signal-config {
        description
          "DOTS signal channel session configuration.";
        leaf sid {
          type uint32;
          mandatory true;
          description
            "An identifier for the DOTS signal channel
             session configuration data.";
        }
        container mitigating-config {
          description
            "Configuration parameters to use when a mitigation
             is active.";
          uses config-parameters;
        }
        container idle-config {
          description
            "Configuration parameters to use when no mitigation
             is active.";
          uses config-parameters;
        }
        leaf trigger-mitigation {
          type boolean;
          default "true";
          description
            "If false, then mitigation is triggered
             only when the DOTS server channel session is lost.";
        }

      }

      grouping redirected-signal {
        description
          "Grouping for the redirected signaling.";
        leaf alt-server {
          type string;
          config false;
          mandatory true;
          description
            "FQDN of an alternate server.";
        }
        leaf-list alt-server-record {
          type inet:ip-address;
          config false;
          description
            "List of records for the alternate server.";
        }
        leaf alt-server-ttl {
          type int32;
          config false;
          description
            "TTL associated with alt-server records.

             A value of negative one (-1) indicates indefinite
             TTL. This value means that the alternate
             DOTS server is to be used until the alternate DOTS
             server redirects the traffic with another
             3.00 response.";
        }
      }

     /*
      * Main Container for DOTS Signal Channel
      */

      container dots-signal {
        description
          "Main container for DOTS signal message.
```

```
         A DOTS signal message can be a mitigation, a configuration,
         or a redirected signal message.";
      choice message-type {
        description
          "Can be a mitigation, a configuration, or a redirect
           message.";
        case mitigation-scope {
          description
            "Mitigation scope of a mitigation message.";
          uses mitigation-scope;
        }
        case signal-config {
          description
            "Configuration message.";
          uses signal-config;
        }
        case redirected-signal {
          description
            "Redirected signaling.";
          uses redirected-signal;
        }
      }
    }
  }
  <CODE ENDS>
```

6. Mapping Parameters to CBOR

All parameters in the payload of the DOTS signal channel MUST be mapped to CBOR types as shown in Table 4 and are assigned an integer key to save space. The recipient of the payload MAY reject the information if it is not suitably mapped.

Parameter Name	YANG Type	CBOR Key	CBOR Major Type & Information	JSON Type
ietf-dots-signal-channel:mitigation-scope	container	1	5 map	Object
scope	list	2	4 array	Array
cdid	string	3	3 text string	String
cuid	string	4	3 text string	String
mid	uint32	5	0 unsigned	Number
target-prefix	leaf-list	6	4 array	Array
	inet: ip-prefix		3 text string	String
target-port-range	list	7	4 array	Array
lower-port	inet: port-number	8	0 unsigned	Number
upper-port	inet: port-number	9	0 unsigned	Number
target-protocol	leaf-list	10	4 array	Array
	uint8		0 unsigned	Number
target-fqdn	leaf-list	11	4 array	Array
	inet: domain-name		3 text string	String
target-uri	leaf-list	12	4 array	Array
	inet:uri		3 text string	String
alias-name	leaf-list	13	4 array	Array
	string		3 text string	String
lifetime	int32	14	0 unsigned	Number
			1 negative	Number
mitigation-start	uint64	15	0 unsigned	String
status	enumeration	16	0 unsigned	String
conflict-information	container	17	5 map	Object
conflict-status	enumeration	18	0 unsigned	String
conflict-cause	enumeration	19	0 unsigned	String
retry-timer	uint32	20	0 unsigned	Number
conflict-scope	container	21	5 map	Object
acl-list	list	22	4 array	Array
acl-name	leafref	23	3 text string	String
acl-type	leafref	24	3 text string	String
bytes-dropped	yang:zero-based-counter64	25	0 unsigned	String

bps-dropped	yang:zero-based-counter64	26	0 unsigned	String
pkts-dropped	yang:zero-based-counter64	27	0 unsigned	String
pps-dropped	yang:zero-based-counter64	28	0 unsigned	String
attack-status	enumeration	29	0 unsigned	String
ietf-dots-signal-channel:signal-config	container	30	5 map	Object
sid	uint32	31	0 unsigned	Number
mitigating-config	container	32	5 map	Object
heartbeat-interval	container	33	5 map	Object
max-value	uint16	34	0 unsigned	Number
min-value	uint16	35	0 unsigned	Number
current-value	uint16	36	0 unsigned	Number
missing-hb-allowed	container	37	5 map	Object
max-retransmit	container	38	5 map	Object
ack-timeout	container	39	5 map	Object
ack-random-factor	container	40	5 map	Object
max-value-decimal	decimal64	41	6 tag 4 [-2, integer]	String
min-value-decimal	decimal64	42	6 tag 4 [-2, integer]	String
current-value-decimal	decimal64	43	6 tag 4 [-2, integer]	String
idle-config	container	44	5 map	Object
trigger-mitigation	boolean	45	7 bits 20	False
			7 bits 21	True
ietf-dots-signal-channel:redirected-signal	container	46	5 map	Object
alt-server	string	47	3 text string	String
alt-server-record	leaf-list	48	4 array	Array
	inet:ip-address		3 text string	String
alt-server-ttl	int32	49	0 unsigned	Number
			1 negative	Number

Table 4: CBOR Mappings Used in DOTS Signal Channel Messages

7. (D)TLS Protocol Profile and Performance Considerations

7.1. (D)TLS Protocol Profile

This section defines the (D)TLS protocol profile of DOTS signal channel over (D)TLS and DOTS data channel over TLS.

There are known attacks on (D)TLS, such as man-in-the-middle and protocol downgrade attacks. These are general attacks on (D)TLS and, as such, they are not specific to DOTS over (D)TLS; refer to the (D)TLS RFCs for discussion of these security issues. DOTS agents MUST adhere to the (D)TLS implementation recommendations and security considerations of [RFC7525] except with respect to (D)TLS version. Since DOTS signal channel encryption relies upon (D)TLS is virtually a green-field deployment, DOTS agents MUST implement only (D)TLS 1.2 or later.

When a DOTS client is configured with a domain name of the DOTS server, and connects to its configured DOTS server, the server may present it with a PKIX certificate. In order to ensure proper authentication, a DOTS client MUST verify the entire certification path per [RFC5280]. The DOTS client additionally uses [RFC6125] validation techniques to compare the domain name with the certificate provided.

A key challenge to deploying DOTS is the provisioning of DOTS clients, including the distribution of keying material to DOTS clients to enable the required mutual authentication of DOTS agents. EST defines a method of certificate enrollment by which domains operating DOTS servers may provide DOTS clients with all the necessary cryptographic keying material, including a private key and a certificate to authenticate themselves. One deployment option is DOTS clients behave as EST clients for certificate enrollment from an EST server provisioned by the mitigation provider. This document

does not specify which EST mechanism the DOTS client uses to achieve initial enrollment.

The Server Name Indication (SNI) extension [RFC6066] defines a mechanism for a client to tell a (D)TLS server the name of the server it wants to contact. This is a useful extension for hosting environments where multiple virtual servers are reachable over a single IP address. The DOTS client may or may not know if it is interacting with a DOTS server in a virtual server hosting environment, so the DOTS client SHOULD include the DOTS server FQDN in the SNI extension.

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

- o DTLS record replay detection (Section 3.3 of [RFC6347]) to protect against replay attacks.

- o (D)TLS session resumption without server-side state [RFC5077] to resume session and convey the DOTS signal.

- o Raw public keys [RFC7250] or PSK handshake [RFC4279] which reduces the size of the ServerHello, and can be used by DOTS agents that cannot obtain certificates.

Implementations compliant with this profile SHOULD implement all of the following items to reduce the delay required to deliver a DOTS signal channel message:

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

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

- o TCP Fast Open [RFC7413] can reduce the number of round-trips to convey DOTS signal channel message.

7.2. (D)TLS 1.3 Considerations

TLS 1.3 [I-D.ietf-tls-tls13] provides critical latency improvements for connection establishment over TLS 1.2. The DTLS 1.3 protocol [I-D.ietf-tls-dtls13] is based upon the TLS 1.3 protocol and provides equivalent security guarantees. (D)TLS 1.3 provides two basic handshake modes the DOTS signal channel can take advantage of:

- o A full handshake mode in which a DOTS client can send a DOTS mitigation request message after one round trip and the DOTS server immediately responds with a DOTS mitigation response. This assumes no packet loss is experienced.

- o 0-RTT mode in which the DOTS client can authenticate itself and send DOTS mitigation request messages in the first message, thus reducing handshake latency. 0-RTT only works if the DOTS client has previously communicated with that DOTS server, which is very likely with the DOTS signal channel.

  The DOTS client has to establish a (D)TLS session with the DOTS server during peacetime and share a PSK.

  During a DDoS attack, the DOTS client can use the (D)TLS session to convey the DOTS mitigation request message and, if there is no response from the server after multiple retries, the DOTS client can resume the (D)TLS session in 0-RTT mode using PSK.

  Section 8 of [I-D.ietf-tls-tls13] discusses some mechanisms to implement to limit the impact of replay attacks on 0-RTT data. If TLS1.3 is used, DOTS servers must implement one of these mechanisms.

  A simplified TLS 1.3 handshake with 0-RTT DOTS mitigation request message exchange is shown in Figure 24.

```
    DOTS Client                                       DOTS Server
```

```
        ClientHello
        (Finished)
        (0-RTT DOTS signal message)
        (end_of_early_data)        -------->
                                                   ServerHello
                                             {EncryptedExtensions}
                                             {ServerConfiguration}
                                                     {Certificate}
                                               {CertificateVerify}
                                                         {Finished}
                                   <--------   [DOTS signal message]
        {Finished}                 -------->

        [DOTS signal message]      <------->   [DOTS signal message]
```

Figure 24: TLS 1.3 handshake with 0-RTT

7.3. MTU and Fragmentation

To avoid DOTS signal message fragmentation and the subsequent decreased probability of message delivery, DOTS agents MUST ensure that the DTLS record MUST fit within a single datagram. If the path MTU is not known to the DOTS server, an IP MTU of 1280 bytes SHOULD be assumed. If UDP is used to convey the DOTS signal messages then the DOTS client must consider the amount of record expansion expected by the DTLS processing when calculating the size of CoAP message that fits within the path MTU. Path MTU MUST be greater than or equal to [CoAP message size + DTLS overhead of 13 octets + authentication overhead of the negotiated DTLS cipher suite + block padding] (Section 4.1.1.1 of [RFC6347]). If the request size exceeds the path MTU then the DOTS client MUST split the DOTS signal into separate messages, for example the list of addresses in the 'target-prefix' parameter could be split into multiple lists and each list conveyed in a new PUT request.

Implementation Note: DOTS choice of message size parameters works well with IPv6 and with most of today's IPv4 paths. However, with IPv4, it is harder to safely make sure that there is no IP fragmentation. If IPv4 path MTU is unknown, implementations may want to limit themselves to more conservative IPv4 datagram sizes such as 576 bytes, as per [RFC0791]. IP packets whose size does not exceed 576 bytes should never need to be fragmented: therefore, sending a maximum of 500 bytes of DOTS signal over a UDP datagram will generally avoid IP fragmentation.

8. Mutual Authentication of DOTS Agents & Authorization of DOTS Clients

(D)TLS based upon client certificate can be used for mutual authentication between DOTS agents. If a DOTS gateway is involved, DOTS clients and DOTS gateways MUST perform mutual authentication; only authorized DOTS clients are allowed to send DOTS signals to a DOTS gateway. The DOTS gateway and the DOTS server MUST perform mutual authentication; a DOTS server only allows DOTS signal channel messages from an authorized DOTS gateway, thereby creating a two-link chain of transitive authentication between the DOTS client and the DOTS server.

The DOTS server SHOULD support certificate-based client authentication. The DOTS client SHOULD respond to the DOTS server's TLS certificate request message with the PKIX certificate held by the DOTS client. DOTS client certificate validation MUST be performed as per [RFC5280] and the DOTS client certificate MUST conform to the [RFC5280] certificate profile. If a DOTS client does not support TLS client certificate authentication, it MUST support pre-shared key based or raw public key based client authentication.

```
 +-------------------------------------------------+
 |       example.com domain         +---------+  |
 |                                  | AAA     |  |
 | +---------------+                | Server  |  |
 | | Application   |                +------+--+  |
 | | server        +<-----------------+    ^     |
 | | (DOTS client) |                  |    |     |
 | +---------------+                  |    |     |
 |                                    V    V     |    example.net domain
 |                            +-----+----+--+  |     +---------------+
 | +--------------+           |             |  |     |               |
```

```
 | |   Guest      +<-----x----->+    DOTS     +<------>+    DOTS       |
 | | (DOTS client)|             |    gateway  |  |     |    server     |
 | +--------------+             |             |  |     |               |
 |                              +----+--------+  |     +---------------+
 |                                   ^           |
 |                                   |           |
 | +----------------+                |           |
 | | DDoS detector  |                |           |
 | | (DOTS client)  +<---------------+           |
 | +----------------+                            |
 +-----------------------------------------------+
```

Figure 25: Example of Authentication and Authorization of DOTS Agents

In the example depicted in Figure 25, the DOTS gateway and DOTS clients within the 'example.com' domain mutually authenticate. After the DOTS gateway validates the identity of a DOTS client, it communicates with the AAA server in the 'example.com' domain to determine if the DOTS client is authorized to request DDoS mitigation. If the DOTS client is not authorized, a 4.01 (Unauthorized) is returned in the response to the DOTS client. In this example, the DOTS gateway only allows the application server and DDoS attack detector to request DDoS mitigation, but does not permit the user of type 'guest' to request DDoS mitigation.

Also, DOTS gateways and servers located in different domains MUST perform mutual authentication (e.g., using certificates). A DOTS server will only allow a DOTS gateway with a certificate for a particular domain to request mitigation for that domain. In reference to Figure 25, the DOTS server only allows the DOTS gateway to request mitigation for 'example.com' domain and not for other domains.

9. IANA Considerations

This specification registers a service port (Section 9.1), a URI suffix in the Well-Known URIs registry (Section 9.2), a CoAP response code (Section 9.3), a YANG module (Section 9.6). It also creates a registry for mappings to CBOR (Section 9.5).

9.1. DOTS Signal Channel UDP and TCP Port Number

IANA is requested to assign the port number TBD to the DOTS signal channel protocol for both UDP and TCP from the "Service Name and Transport Protocol Port Number Registry" available at https://www.iana.org/assignments/service-names-port-numbers/service-names-port-numbers.xhtml.

The assignment of port number 4646 is strongly suggested, as 4646 is the ASCII decimal value for ".." (DOTS).

9.2. Well-Known 'dots' URI

This document requests IANA to register the 'dots' well-known URI in the Well-Known URIs registry (https://www.iana.org/assignments/well-known-uris/well-known-uris.xhtml) as defined by [RFC5785]:

URI suffix	Change controller	Specification document(s)	Related information
dots	IETF	[RFCXXXX]	None

Table 5: 'dots' well-known URI

9.3. CoAP Response Code

IANA is requested to add the following entries to the "CoAP Response Codes" sub-registry available at https://www.iana.org/assignments/core-parameters/core-parameters.xhtml#response-codes:

Code	Description	Reference
3.00	Alternate Server	[RFCXXXX]
5.06	Hop Limit Reached	[RFCXXXX]

```
                      +------+-----------------+-----------+
```

Table 6: CoAP Response Codes

9.4. CoAP Option Number

IANA is requested to add the following entry to the "CoAP Option Numbers" sub-registry available at https://www.iana.org/assignments/core-parameters/core-parameters.xhtml#option-numbers:

Number	Name	Reference
2	Hop-Limit	[RFCXXXX]

Table 7: CoAP Option Number

9.5. DOTS Signal Channel CBOR Mappings Registry

The document requests IANA to create a new registry, entitled "DOTS Signal Channel CBOR Mappings Registry". The structure of this registry is provided in Section 9.5.1.

The registry is initially populated with the values in Section 9.5.2.

Values from that registry MUST be assigned via Expert Review [RFC8126].

9.5.1. Registration Template

Parameter name:
Parameter name as used in the DOTS signal channel.

CBOR Key Value:
Key value for the parameter. The key value MUST be an integer in the 1-65535 range. The key values in the 32768-65535 range are assigned to Vendor-Specific parameters.

CBOR Major Type:
CBOR Major type and optional tag for the claim.

Change Controller:
For Standards Track RFCs, list the "IESG". For others, give the name of the responsible party. Other details (e.g., postal address, email address, home page URI) may also be included.

Specification Document(s):
Reference to the document or documents that specify the parameter, preferably including URIs that can be used to retrieve copies of the documents. An indication of the relevant sections may also be included but is not required.

9.5.2. Initial Registry Content

Parameter Name	CBOR Key Value	CBOR Major Type	Change Controller	Specification Document(s)
ietf-dots-signal-chan nel:mitigation-scope	1	5	IESG	[RFCXXXX]
scope	2	4	IESG	[RFCXXXX]
cdid	3	3	IESG	[RFCXXXX]
cuid	4	3	IESG	[RFCXXXX]
mid	5	0	IESG	[RFCXXXX]
target-prefix	6	4	IESG	[RFCXXXX]
target-port-range	7	4	IESG	[RFCXXXX]
lower-port	8	0	IESG	[RFCXXXX]
upper-port	9	0	IESG	[RFCXXXX]
target-protocol	10	4	IESG	[RFCXXXX]
target-fqdn	11	4	IESG	[RFCXXXX]
target-uri	12	4	IESG	[RFCXXXX]
alias-name	13	4	IESG	[RFCXXXX]
lifetime	14	0/1	IESG	[RFCXXXX]
mitigation-start	15	0	IESG	[RFCXXXX]
status	16	0	IESG	[RFCXXXX]

conflict-information	17	5	IESG	[RFCXXXX]
conflict-status	18	0	IESG	[RFCXXXX]
conflict-cause	19	0	IESG	[RFCXXXX]
retry-timer	20	0	IESG	[RFCXXXX]
conflict-scope	21	5	IESG	[RFCXXXX]
acl-list	22	4	IESG	[RFCXXXX]
acl-name	23	3	IESG	[RFCXXXX]
acl-type	24	3	IESG	[RFCXXXX]
bytes-dropped	25	0	IESG	[RFCXXXX]
bps-dropped	26	0	IESG	[RFCXXXX]
pkts-dropped	27	0	IESG	[RFCXXXX]
pps-dropped	28	0	IESG	[RFCXXXX]
attack-status	29	0	IESG	[RFCXXXX]
ietf-dots-signal-channel:signal-config	30	5	IESG	[RFCXXXX]
sid	31	0	IESG	[RFCXXXX]
mitigating-config	32	5	IESG	[RFCXXXX]
heartbeat-interval	33	5	IESG	[RFCXXXX]
min-value	34	0	IESG	[RFCXXXX]
max-value	35	0	IESG	[RFCXXXX]
current-value	36	0	IESG	[RFCXXXX]
missing-hb-allowed	37	5	IESG	[RFCXXXX]
max-retransmit	38	5	IESG	[RFCXXXX]
ack-timeout	39	5	IESG	[RFCXXXX]
ack-random-factor	40	5	IESG	[RFCXXXX]
min-value-decimal	41	6tag4	IESG	[RFCXXXX]
max-value-decimal	42	6tag4	IESG	[RFCXXXX]
current-value-decimal	43	6tag4	IESG	[RFCXXXX]
idle-config	44	5	IESG	[RFCXXXX]
trigger-mitigation	45	7	IESG	[RFCXXXX]
ietf-dots-signal-channel:redirected-signal	46	5	IESG	[RFCXXXX]
alt-server	47	3	IESG	[RFCXXXX]
alt-server-record	48	4	IESG	[RFCXXXX]
alt-server-ttl	49	0/1	IESG	[RFCXXXX]

Table 8: Initial DOTS Signal Channel CBOR Mappings Registry

9.6. DOTS Signal Channel YANG Module

This document requests IANA to register the following URI in the "IETF XML Registry" [RFC3688]:

```
URI: urn:ietf:params:xml:ns:yang:ietf-dots-signal-channel
Registrant Contact: The IESG.
XML: N/A; the requested URI is an XML namespace.
```

This document requests IANA to register the following YANG module in the "YANG Module Names" registry [RFC7950].

```
name: ietf-signal
namespace: urn:ietf:params:xml:ns:yang:ietf-dots-signal-channel
prefix: signal
reference: RFC XXXX
```

10. Security Considerations

Authenticated encryption MUST be used for data confidentiality and message integrity. The interaction between the DOTS agents requires Datagram Transport Layer Security (DTLS) and Transport Layer Security (TLS) with a cipher suite offering confidentiality protection and the guidance given in [RFC7525] MUST be followed to avoid attacks on (D)TLS. The (D)TLS protocol profile for DOTS signal channel is specified in Section 7.

A single DOTS signal channel between DOTS agents can be used to exchange multiple DOTS signal messages. To reduce DOTS client and DOTS server workload, DOTS clients SHOULD re-use the (D)TLS session.

If TCP is used between DOTS agents, an attacker may be able to inject RST packets, bogus application segments, etc., regardless of whether TLS authentication is used. Because the application data is TLS protected, this will not result in the application receiving bogus data, but it will constitute a DoS on the connection. This attack can be countered by using TCP-AO [RFC5925]. If TCP-AO is used, then

any bogus packets injected by an attacker will be rejected by the TCP-AO integrity check and therefore will never reach the TLS layer.

Rate-limiting DOTS requests, including those with new 'cuid' values, from the same DOTS client defends against DoS attacks that would result in varying the 'cuid' to exhaust DOTS server resources. Rate-limit policies SHOULD be enforced on DOTS gateways (if deployed) and DOTS servers.

In order to prevent leaking internal information outside a client-domain, DOTS gateways located in the client-domain SHOULD NOT reveal the identification information that pertains to internal DOTS clients (e.g., source IP address, client's hostname) unless explicitly configured to do so.

DOTS servers MUST verify that requesting DOTS clients are entitled to trigger actions on a given IP prefix. That is, only actions on IP resources that belong to the DOTS client' domain MUST be authorized by a DOTS server. The exact mechanism for the DOTS servers to validate that the target prefixes are within the scope of the DOTS client's domain is deployment-specific.

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