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IP Flow Information Export (IPFIX) Information Elements Extension for TCP Connection Tracking
draft-fu-dots-ipfix-tcp-tracking-00

Abstract

This document proposes several new TCP connection related Information Elements (IEs) for the IP Flow Information Export (IPFIX) protocol. The new Information Elements can be used to export certain characteristics regarding a TCP connection. Through massive gathering of such characteristics, it can help build an image of the TCP traffics passing through a network. The image will facilitate the detection of anomaly TCP traffic, especially attacks targeting at TCP.

Status of this Memo

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1. Introduction

Due to its complex stateful operations, TCP [RFC0793] is especially vulnerable to attacks. The SYN Flood attack is an example, it involves with massive malicious clients attempting to set up connections with a server, but never completing the three-way handshake process, leaving the server-side of the connections in waiting states, eventually exhausting the server resources and no new connection can be created.

Attack aiming at TCP can be low and slow in traffic pattern. Sometimes it may not take down the server, but just impair the provided service. Even though a victim server is still operating, its performance can be significantly degraded. Without the insight of what is going on with the TCP traffics, this kind of situation can be very hard to detect and analyze.

For a network device, such as a router, to detect anomaly TCP traffics, it has to understand the semantics of TCP operations, more specifically, it has to be able to track TCP connection states. If a router has implemented such ability, it can export characteristics information regarding the TCP connections. By this way, offline analysis can be performed over the gathered information, which will facilitate the detection of anomaly TCP traffics, such as attacks.

The IP Flow Information Export (IPFIX) protocol [RFC7011], already defines a generic mechanism for flow information export. This document introduces several new Information Elements of IPFIX, that can be used to export TCP connection characteristics. The proposed Information Elements are listed in Figure 1 below.

Field Name	IANA IPFIX ID
tcpHandshakeSyn2SynAckTime	TBD
tcpHandshakeSynAck2AckTime	TBD
tcpHandshakeSyn2AckRttTime	TBD
tcpConnectionTrackingBits	TBD
tcpPacketIntervalAverage	TBD
tcpPacketIntervalVariance	TBD
tcpOutOfOrderDeltaCount	TBD

Figure 1: Information Element Table

The Information Elements defined in Figure 1 are supposed to be

incorporated into the IANA IPFIX Information Elements registry [IPFIX-IANA]. Their definitions can be found at Section 6.

2. Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC-2119 [RFC2119]

2.1. Terminology

IPFIX-specific terminology (Information Element, Template, Template Record, Options Template Record, Template Set, Collector, Exporter, Data Record, etc.) used in this document is defined in Section 2 of [RFC7011]. As in [RFC7011], these IPFIX-specific terms have the first letter of a word capitalized.

This document also makes use of the same terminology and definitions as Section 2 of [RFC5470].

o Victim

The target that suffers from DDoS attack.

3. Connection Sampling and new IEs

3.1. Use Cases for New IEs

In this section, several use cases are discussed to identify the requirements where new IEs are desirable for the network attacks detection.

3.1.1. Response Time Calculation

For other DDoS attacks such as Http slowloris, there will be too many connections that should be kept in the victim (server), which lead to excessive resource consumption. As a result, the response time between client and server will increase greatly. Challenge Collapasar(CC) attack can also exhaust the resources of the server and generate the similar results. Thus, the following IEs are proposed as a symptom of these kinds of attacks:

tcpHandshakeSyn2SynAckTime: it denotes the time difference between the time point that the Metering Process detects the SYN packet from client to server and the time point that the observer views the SYN-ACK packet from server to client.

tcpHandshakeSynAck2AckTime: it denotes the time difference between the time point that the Metering Process detects the SYN-ACK packet from server to client and the time point that the observer views the ACK packet from client to server.

tcpHandshakeSyn2AckRttTime: it denotes The sum of tcpHandshakeSyn2SynAckTime and tcpHandshakeSynAck2AckTime. It is the Round Trip Time (RTT) between client and server.

3.1.2. Symptoms of Exceptions

In http slowloris attack the client may send packets to victim periodically which can cause the performance lost on the server. The characteristic of the attack is that there are too many connections on the victim. However, the traffic volume for these connections is small. In order to detect this attack, the first step is to get the packets that are belonging to the same connection. The second step is to find the periodicity. Thus the two indices tcpPacketIntervalAverage and tcpPacketIntervalVariance are needed. The index tcpPacketIntervalAverage denotes the average time difference between two successive packets and the index tcpPacketIntervalVariance denotes the variance of multiple time difference. Large tcpPacketIntervalAverage and small tcpPacketIntervalVariance can be a symptom of slow packet attack, since the attacker sends packets in large intervals just as to keep the connection open, and the intervals tend to differ very little in time.

To degrade the performance of the victim, the malicious clients may send too many out-of-order packets, which will consume too much memory on the server. Although out-of-order packets are permit in the TCP protocol, it is possible to be leveraged to cause DDoS attack. So the index tcpOutOfOrderDeltaCount is helpful to detect this kind of exception. For observer, it maintains one counter for each TCP connection. The initial sequence number of the client is saved in the counter. The counter increases by the sequence number of the packets it sees from client to server. If the observer sees a packet with lower sequence number than the current counter value, then the packet will be considered as an out-of-order packet.

In IPFIX, the index tcpControlBits is used to record the corresponding status bits in TCP header of the packets[IPFIX-IANA]. In order to detect the application attacks which can cause the protocol exception such as the wrong use of the TCP status bits before and after the TCP connection establishment, another index called tcpConnectionTrackingBits is needed. For example, when the observer sees the SYN packet from client to server, it sets 15th bit of tcpConnectionTrackingBits to 1; when it sees the SYN-ACK packet

from server to client, it sets 14th bit to 1, and so on. If one endpoint sends the packet with wrong bits during the establishment of the connection, then the observer will identify the exception by the value of tcpConnectionTrackingBits.

4. Application of the New IEs for Attack Detection

This section presents a number of examples to help for the easy understanding of the application of these new IEs for attack detection.

4.1. Detect Slowloris Attack

The template for detecting resource exhausting application attack such as http slowloris attack should contain a subnet of IEs shown in Table 4.

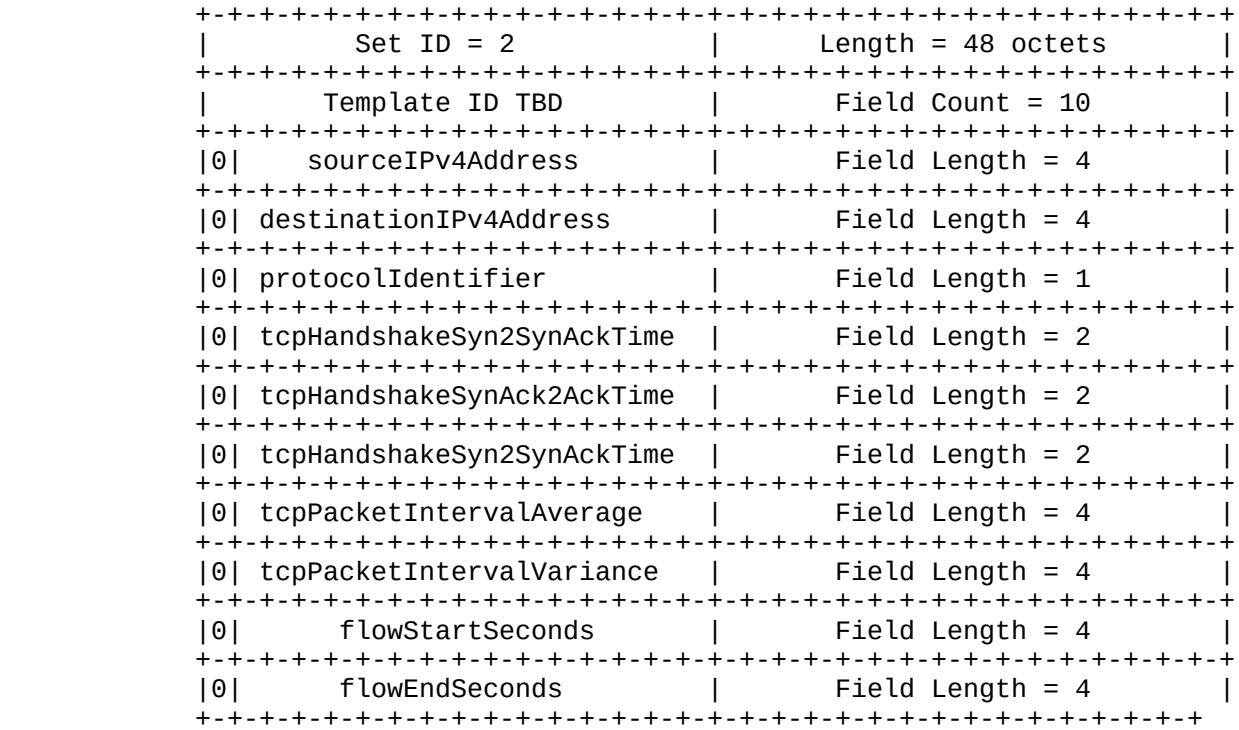


Figure 2: Template example for detecting slowloris attack

An example of the actual record is shown below in a readable form as below:

{sourceIPv4Address = 192.168.0.101, destinationIPv4Address = 192.168.0.201, protocolIdentifier = 6, tcpHandshakeSyn2SynAckTime = 200, tcpHandshakeSynAck2AckTime = 10, tcpHandshakeSyn2AckRttTime = 210, tcpPacketIntervalAverage = 500, tcpPacketIntervalVariance = 1000, flowStartSeconds = 100, flowEndSeconds = 200}

4.2. Detect Out-of-order Packets Attack

The template for detecting out-of-order packets attack should contain IEs shown in Table 5.

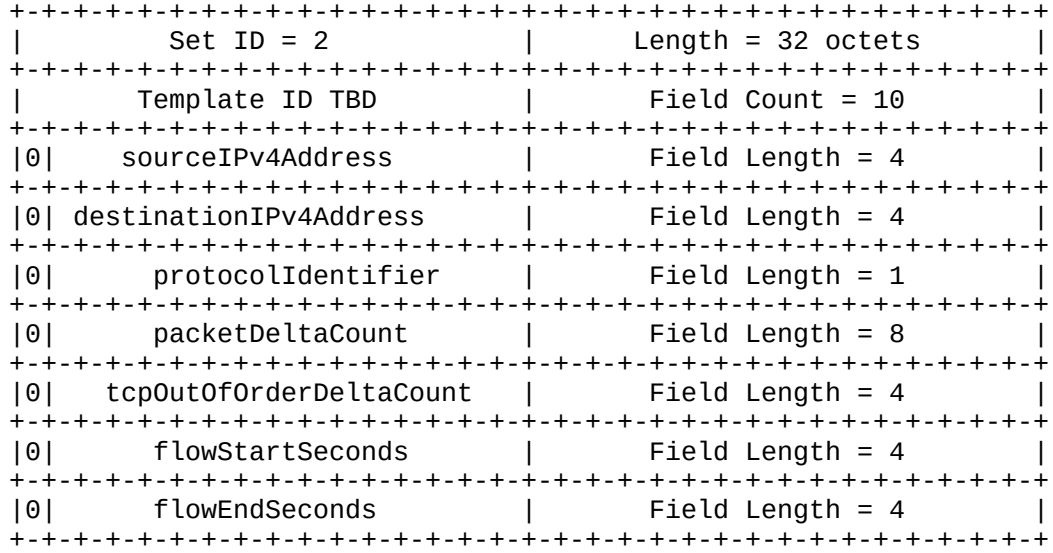


Figure 3: Template example for detecting out-of-order attack

An example of the actual record is shown below in a readable form as below:

{sourceIPv4Address = 192.168.0.101, destinationIPv4Address = 192.168.0.201, protocolIdentifier = 6, packetDeltaCount =3000, tcpOutOfOrderDeltaCount = 2000, flowStartSeconds = 100, flowEndSeconds = 200}

5. Security Considerations

No additional security considerations are introduced in this document. The same security considerations as for the IPFIX protocol [RFC7011] apply.

6. IANA Considerations

The following information elements are requested from IANA IPFIX registry. Upon acceptation, the 'TBD' values of the ElementIds should be replaced by IANA for assigned numbers.

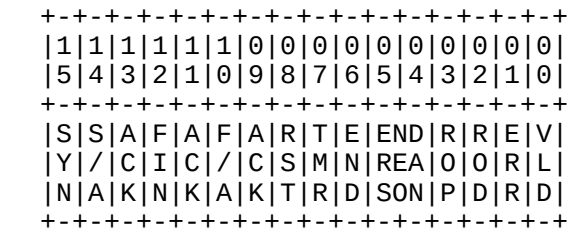
Name: tcpHandshakeSyn2SynAckTime
Description:
The time difference between a SYN and its corresponding SYN-ACK when the Metering Process observes a new TCP connection is going to be set up.
Abstract Data Type: dateTimeMicroseconds
ElementId: TBD
Status: current
Units: microseconds

Name: tcpHandshakeSynAck2AckTime
Description:
The time difference between a SYN-ACK and its corresponding ACK when the Metering Process observes a new TCP connection is going to be set up.
Abstract Data Type: dateTimeMicroseconds
ElementId: TBD
Status: current
Units: microseconds

Name: tcpHandshakeSyn2AckRttTime
Description:
The time difference between a SYN and its corresponding ACK sent from the same endpoint when the Metering Process observes a new TCP connection is going to be set up.

Conceptually tcpHandshakeSyn2AckRttTime can be thought as the sum of tcpHandshakeSyn2SynAckTime and tcpHandshakeSynAck2AckTime, but practically the values may differ.
Abstract Data Type: dateTimeMicroseconds
ElementId: TBD
Status: current
Units: microseconds

Name: tcpConnectionTrackingBits
Description:
These bits are used by the Metering Process to track a TCP connection. A bit is set to 1 if the corresponding condition is met. A value of 0 for a bit indicates the corresponding condition was net met.



Bit 15 (SYN):
Set when there is no TCP connection between the endpoints and the Metering Process detects a SYN as it is used to setup a new TCP connection. The Metering Process starts to track the TCP connection.

Bit 14 (S/A):
Set when bit 15 has been set and the Metering Process detects a SYN-ACK in the flow, which effectively acknowledges the SYN causing bit 15 to be set.

Bit 13 (ACK):
Set when bit 15 and bit 14 have been set and the Metering Process detects an ACK which effectively acknowledges the SYN causing bit 14 to be set. Upon setting this bit, it means handshake of the TCP connection setup has completed.

Bit 12 (FIN):
Set when the Metering Process detects the first FIN for the established and tracked TCP connection. It means the TCP connection is going to be closed.

Bit 11 (ACK):
Set when bit 12 has been set and the Metering Process detects an ACK which effectively acknowledges the FIN causing bit 12 to be set.

Bit 10 (F/A):
Set when bit 12 has been set and the Metering Process detects a FIN that is from the opposite of the endpoint which sent the FIN causing bit 12 to be set.

Bit 09 (ACK):
Set when bit 10 has been set and the Metering Process detects an ACK that is from the same endpoint which sent the FIN causing bit 10 to be set.

Bit 08 (RST):
Set when the Metering Process detects any RST from either party of the tracked TCP connection.

Bit 07 (TMR):
Set when a flow record report is triggered by a periodic reporting timer. It means the TCP connection is still under tracking.

Bit 06 (END):
Set when the Metering Process has stopped tracking the TCP

connection, as the connection has been closed or aborted.
Bit 05 & Bit 04 (END REASON):
00: as default value or the tracked TCP connection is closed.
01: the tracked TCP connection is aborted.
10: the tracked TCP connection is inactive after a period of time.
11: reserved.
Bit 03 (ROP):
Set when the Metering Process detects any SYN or SYNACK, after the both endpoints have sent FIN or an RST has been detected.
Bit 02 (ROD):
Set when the Metering Process detects at least 50 TCP segments being exchanged, after both endpoints have sent FIN or an RST has been detected.
Bit 01 (ERR):
Set when the Metering Process detects any of the following abnormal signaling sequences for the TCP connection: SYN/FIN, SYN/FIN/PSH, SYN/FIN/RST, SYN/FIN/RST/PSH.
Bit 00 (VLD):
Set when the tracked TCP connection is closed normally.

Abstract Data Type: unsigned16
Data Type Semantics: flags
ElementId: TBD
Status: current

Name: tcpPacketIntervalAverage
Description:
The average time interval calculated by the Metering Process between two successive packets in the data flow of a TCP connection.
Abstract Data Type: unsigned32
ElementId: TBD
Status: current

Name: tcpPacketIntervalVariance
Description:
The variance of the time intervals calculated by the Metering Process between two successive packets in the data flow of a TCP connection.
Abstract Data Type: unsigned64
ElementId: TBD
Status: current

Name: tcpOutOfOrderDeltaCount
Description:
The number of out of order packets in the data flow of a TCP connection detected at the Observation Point since the previous report.
Abstract Data Type: unsigned64
Data Type Semantics: deltaCounter
ElementId: TBD
Status: current

7. References

7.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC7011] Claise, B., Trammell, B., and P. Aitken, "Specification of the IP Flow Information Export (IPFIX) Protocol for the Exchange of Flow Information", STD 77, RFC 7011, September 2013.

[RFC5470] Sadasivan, G., Brownlee, N., Claise, B., and J. Quittek, "Architecture for IP Flow Information Export", RFC 5470, March 2009.

[RFC0793] J. Postel, "Transmission Control Protocol", STD 7, RFC 793, September 1981.

7.2. Informative References

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IANA, "IPFIX Information Elements registry", <http://www.iana.org/assignments/ipfix>.

[RFC5474] Duffield, N., Ed., Chiou, D., Claise, B., Greenberg, A., Grossglauser, M., and J. Rexford, "A Framework for Packet Selection and Reporting", RFC 5474, March 2009.

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Distributed-Denial-of-Service Open Threat Signaling (DOTS) Architecture
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Abstract

This document describes an architecture for establishing and maintaining Distributed Denial of Service (DDoS) Open Threat Signaling (DOTS) within and between domains. The document does not specify protocols or protocol extensions, instead focusing on defining architectural relationships, components and concepts used in a DOTS deployment.

Status of This Memo

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

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This Internet-Draft will expire on May 4, 2017.

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1. Context and Motivation

Signaling the need for help defending against an active distributed denial of service (DDoS) attack requires a common understanding of mechanisms and roles among the parties coordinating defensive response. The signaling layer and supplementary messaging is the focus of DDoS Open Threat Signaling (DOTS). DOTS defines a method of coordinating defensive measures among willing peers to mitigate attacks quickly and efficiently, enabling hybrid attack responses coordinated locally at or near the target of an active attack, or anywhere in-path between attack sources and target.

This document describes an architecture used in establishing, maintaining or terminating a DOTS relationship within a domain or between domains.

1.1. Terminology

1.1.1. Key Words

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

1.1.2. Definition of Terms

This document uses the terms defined in [I-D.ietf-dots-requirements].

1.2. Scope

In this architecture, DOTS clients and servers communicate using the DOTS signaling. As a result of signals from a DOTS client, the DOTS server may modify the forwarding path of traffic destined for the attack target(s), for example by diverting traffic to a mitigator or pool of mitigators, where policy may be applied to distinguish and discard attack traffic. Any such policy is deployment-specific.

The DOTS architecture presented here is applicable across network administrative domains - for example, between an enterprise domain and the domain of a third-party attack mitigation service - as well as to a single administrative domain. DOTS is generally assumed to be most effective when aiding coordination of attack response between two or more participating network domains, but single domain scenarios are valuable in their own right, as when aggregating intra-domain DOTS client signals for inter-domain coordinated attack response.

This document does not address any administrative or business agreements that may be established between involved DOTS parties. Those considerations are out of scope. Regardless, this document assumes necessary authentication and authorization mechanism are put in place so that only authorized clients can invoke the DOTS service.

1.3. Assumptions

This document makes the following assumptions:

- All domains in which DOTS is deployed are assumed to offer the required connectivity between DOTS agents and any intermediary network elements, but the architecture imposes no additional limitations on the form of connectivity.

- Congestion and resource exhaustion are intended outcomes of a DDoS attack [RFC4732]. Some operators may utilize non-impacted paths or networks for DOTS, but in general conditions should be assumed to be hostile and that DOTS must be able to function in all circumstances, including when the signaling path is significantly impaired.

- There is no universal DDoS attack scale threshold triggering a coordinated response across administrative domains. A network domain administrator, or service or application owner may arbitrarily set attack scale threshold triggers, or manually send requests for mitigation.

- Mitigation requests may be sent to one or more upstream DOTS servers based on criteria determined by DOTS client administrators. The number of DOTS servers with which a given DOTS client has established signaling sessions is determined by local policy and is deployment-specific.

- The mitigation capacity and/or capability of domains receiving requests for coordinated attack response is opaque to the domains sending the request. The domain receiving the DOTS client signal may or may not have sufficient capacity or capability to filter any or all DDoS attack traffic directed at a target. In either case, the upstream DOTS server may redirect a request to another DOTS server. Redirection may be local to the redirecting DOTS server’s domain, or may involve a third-party domain.

- DOTS client and server signals, as well as messages sent through the data channel, are sent across any transit networks with the same probability of delivery as any other traffic between the DOTS client domain and the DOTS server domain. Any encapsulation required for successful delivery is left untouched by transit

network elements. DOTS server and DOTS client cannot assume any preferential treatment of DOTS signals. Such preferential treatment may be available in some deployments, and the DOTS architecture does not preclude its use when available. However, DOTS itself does not address how that may be done.

- The architecture allows for, but does not assume, the presence of Quality of Service (QoS) policy agreements between DOTS-enabled peer networks or local QoS prioritization aimed at ensuring delivery of DOTS messages between DOTS agents. QoS is an operational consideration only, not a functional part of the DOTS architecture.

- The signal channel and the data channel may be loosely coupled, and need not terminate on the same DOTS server.

2. Architecture

The basic high-level DOTS architecture is illustrated in Figure 1:

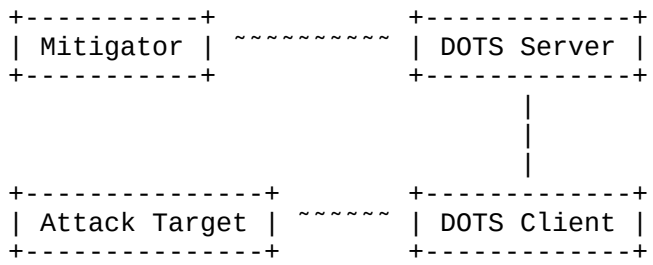

Figure 1: Basic DOTS Architecture

A simple example instantiation of the DOTS architecture could be an enterprise as the attack target for a volumetric DDoS attack, and an upstream DDoS mitigation service as the Mitigator. The enterprise (attack target) is connected to the Internet via a link that is getting saturated, and the enterprise suspects it is under DDoS attack. The enterprise has a DOTS client, which obtains information about the DDoS attack, and signals the DOTS server for help in mitigating the attack. The DOTS server in turn invokes one or more mitigators, which are tasked with mitigating the actual DDoS attack, and hence aim to suppress the attack traffic while allowing valid traffic to reach the attack target.

The scope of the DOTS specifications is the interfaces between the DOTS client and DOTS server. The interfaces to the attack target and the mitigator are out of scope of DOTS. Similarly, the operation of both the attack target and the mitigator are out of scope of DOTS.

Thus, DOTS neither specifies how an attack target decides it is under DDoS attack, nor does DOTS specify how a mitigator may actually mitigate such an attack. A DOTS client's request for mitigation is advisory in nature, and may not lead to any mitigation at all, depending on the DOTS server domain's capacity and willingness to mitigate on behalf of the DOTS client's domain.

As illustrated in Figure 2, there are two interfaces between the DOTS server and the DOTS client:

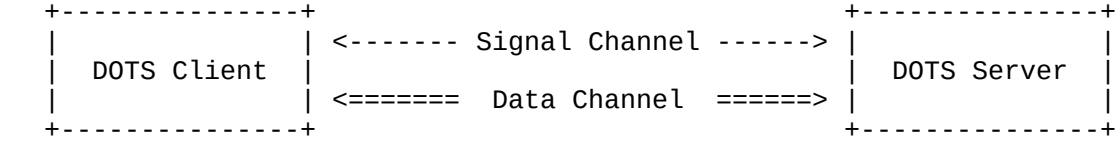

Figure 2: DOTS Interfaces

The DOTS client may be provided with a list of DOTS servers, each associated with one or more IP addresses. These addresses may or may not be of the same address family. The DOTS client establishes one or more signaling sessions by connecting to the provided DOTS server addresses.

[[EDITOR'S NOTE: We request feedback from the working group about the mechanism of server discovery.]]

The primary purpose of the signal channel is for a DOTS client to ask a DOTS server for help in mitigating an attack, and for the DOTS server to inform the DOTS client about the status of such mitigation. The DOTS client does this by sending a client signal, which contains information about the attack target or targets. The client signal may also include telemetry information about the attack, if the DOTS client has such information available. The DOTS server in turn sends a server signal to inform the DOTS client of whether it will honor the mitigation request. Assuming it will, the DOTS server initiates attack mitigation (by means outside of DOTS), and periodically informs the DOTS client about the status of the mitigation. Similarly, the DOTS client periodically informs the DOTS server about the client's status, which at a minimum provides client (attack target) health information, but it may also include telemetry information about the attack as it is now seen by the client. At some point, the DOTS client may decide to terminate the server-side attack mitigation, which it indicates to the DOTS server over the signal channel. A mitigation may also be terminated if a DOTS client-specified mitigation time limit is exceeded; additional considerations around mitigation time limits may be found below. Note that the signal channel may need to operate over a link that is

experiencing a DDoS attack and hence is subject to severe packet loss and high latency.

While DOTS is able to request mitigation with just the signal channel, the addition of the DOTS data channel provides for additional and more efficient capabilities; both channels are required in the DOTS architecture. The primary purpose of the data channel is to support DOTS related configuration and policy information exchange between the DOTS client and the DOTS server. Examples of such information include, but are not limited to:

- Creating identifiers, such as names or aliases, for resources for which mitigation may be requested. Such identifiers may then be used in subsequent signal channel exchanges to refer more efficiently to the resources under attack, as seen in Figure 3 below, using JSON to serialize the data:

```
{
    "https1": [
        "192.0.2.1:443",
        "198.51.100.2:443",
    ],
    "proxies": [
        "203.0.113.3:3128",
        "[2001:DB8:AC10::1]:3128"
    ],
    "api_urls": "https://apiserver.example.com/api/v1",
}
```

Figure 3: Protected resource identifiers

- Black-list management, which enables a DOTS client to inform the DOTS server about sources to suppress.

- White-list management, which enables a DOTS client to inform the DOTS server about sources from which traffic should always be accepted.

- Filter management, which enables a DOTS client to install or remove traffic filters dropping or rate-limiting unwanted traffic.

- DOTS client provisioning.

Note that while it is possible to exchange the above information before, during or after a DDoS attack, DOTS requires reliable delivery of the this information and does not provide any special means for ensuring timely delivery of it during an attack. In

practice, this means that DOTS deployments SHOULD NOT rely on such information being exchanged during a DDoS attack.

2.1. DOTS Operations

The scope of DOTS is focused on the signaling and data exchange between the DOTS client and DOTS server. DOTS does not prescribe any specific deployment models, however DOTS is designed with some specific requirements around the different DOTS agents and their relationships.

First of all, a DOTS agent belongs to an domain, and that domain has an identity which can be authenticated and authorized. DOTS agents communicate with each other over a mutually authenticated signal channel and data channel. However, before they can do so, a service relationship needs to be established between them. The details and means by which this is done is outside the scope of DOTS, however an example would be for an enterprise A (DOTS client) to sign up for DDoS service from provider B (DOTS server). This would establish a (service) relationship between the two that enables enterprise A's DOTS client to establish a signal channel with provider B's DOTS server. A and B will authenticate each other, and B can verify that A is authorized for its service.

From an operational and design point of view, DOTS assumes that the above relationship is established prior to a request for DDoS attack mitigation. In particular, it is assumed that bi-directional communication is possible at this time between the DOTS client and DOTS server. Furthermore, it is assumed that additional service provisioning, configuration and information exchange can be performed by use of the data channel, if operationally required. It is not until this point that the mitigation service is available for use.

Once the mutually authenticated signal channel has been established, it will remain in place. This is done to increase the likelihood that the DOTS client can signal the DOTS server for help when the attack target is being flooded, and similarly raise the probability that DOTS server signals reach the client regardless of inbound link congestion. This does not necessarily imply that the attack target and the DOTS client have to be co-located in the same administrative domain, but it is expected to be a common scenario.

DDoS mitigation service with the help of an upstream mitigator will often involve some form of traffic redirection whereby traffic destined for the attack target is diverted towards the mitigator, e.g. by use of BGP [RFC4271] or DNS [RFC1034]. The mitigator in turn inspects and scrubs the traffic, and forwards the resulting (hopefully non-attack) traffic to the attack target. Thus, when a

DOTS server receives an attack mitigation request from a DOTS client, it can be viewed as a way of causing traffic redirection for the attack target indicated.

DOTS relies on mutual authentication and the pre-established service relationship between the DOTS client's domain and the DOTS server's domain to provide basic authorization. The DOTS server SHOULD enforce additional authorization mechanisms to restrict the mitigation scope a DOTS client can request, but such authorization mechanisms are deployment-specific.

Although co-location of DOTS server and mitigator within the same domain is expected to be a common deployment model, it is assumed that operators may require alternative models. Nothing in this document precludes such alternatives.

2.2. Components

2.2.1. DOTS Client

A DOTS client is a DOTS agent from which requests for help coordinating attack response originate. The requests may be in response to an active, ongoing attack against a target in the DOTS client's domain, but no active attack is required for a DOTS client to request help. Local operators may wish to have upstream mitigators in the network path for an indefinite period, and are restricted only by business relationships when it comes to duration and scope of requested mitigation.

The DOTS client requests attack response coordination from a DOTS server over the signal channel, including in the request the DOTS client's desired mitigation scoping, as described in [I-D.ietf-dots-requirements]. The actual mitigation scope and countermeasures used in response to the attack are up to the DOTS server and Mitigator operators, as the DOTS client may have a narrow perspective on the ongoing attack. As such, the DOTS client's request for mitigation should be considered advisory: guarantees of DOTS server availability or mitigation capacity constitute service level agreements and are out of scope for this document.

The DOTS client adjusts mitigation scope and provides available attack details at the direction of its local operator. Such direction may involve manual or automated adjustments in response to feedback from the DOTS server.

To provide a metric of signal health and distinguish an idle signaling session from a disconnected or defunct session, the DOTS client sends a heartbeat over the signal channel to maintain its half

of the signaling session. The DOTS client similarly expects a heartbeat from the DOTS server, and MAY consider a signaling session terminated in the extended absence of a DOTS server heartbeat.

2.2.2. DOTS Server

A DOTS server is a DOTS agent capable of receiving, processing and possibly acting on requests for help coordinating attack response from one or more DOTS clients. The DOTS server authenticates and authorizes DOTS clients as described in Signaling Sessions below, and maintains signaling session state, tracking requests for mitigation, reporting on the status of active mitigations, and terminating signaling sessions in the extended absence of a client heartbeat or when a session times out.

Assuming the preconditions discussed below exist, a DOTS client maintaining an active signaling session with a DOTS server may reasonably expect some level of mitigation in response to a request for coordinated attack response.

The DOTS server enforces authorization of DOTS clients' signals for mitigation. The mechanism of enforcement is not in scope for this document, but is expected to restrict requested mitigation scope to addresses, prefixes, and/or services owned by the DOTS client's administrative domain, such that a DOTS client from one domain is not able to influence the network path to another domain. A DOTS server MUST reject requests for mitigation of resources not owned by the requesting DOTS client's administrative domain. A DOTS server MAY also refuse a DOTS client's mitigation request for arbitrary reasons, within any limits imposed by business or service level agreements between client and server domains. If a DOTS server refuses a DOTS client's request for mitigation, the DOTS server SHOULD include the refusal reason in the server signal sent to the client.

A DOTS server is in regular contact with one or more mitigators. If a DOTS server accepts a DOTS client's request for help, the DOTS server forwards a translated form of that request to the mitigator or mitigators responsible for scrubbing attack traffic. Note that the form of the translated request passed from the DOTS server to the mitigator is not in scope: it may be as simple as an alert to mitigator operators, or highly automated using vendor or open application programming interfaces supported by the mitigator. The DOTS server MUST report the actual scope of any mitigation enabled on behalf of a client.

The DOTS server SHOULD retrieve available metrics for any mitigations activated on behalf of a DOTS client, and SHOULD include them in

server signals sent to the DOTS client originating the request for mitigation.

To provide a metric of signal health and distinguish an idle signaling session from a disconnected or defunct session, the DOTS server sends a heartbeat over the signal channel to maintain its half of the signaling session. The DOTS server similarly expects a heartbeat from the DOTS client, and MAY consider a signaling session terminated in the extended absence of a DOTS client heartbeat.

2.2.3. DOTS Gateway

Traditional client to server relationships may be expanded by chaining DOTS sessions. This chaining is enabled through "logical concatenation" [RFC7092] of a DOTS server and a DOTS client, resulting in an application analogous to the SIP logical entity of a Back-to-Back User Agent (B2BUA) [RFC3261]. The term DOTS gateway will be used here and the following text will describe some interactions in relation to this application.

A DOTS gateway may be deployed client-side, server-side or both. The gateway may terminate multiple discrete client connections and may aggregate these into a single or multiple DOTS signaling sessions.

The DOTS gateway will appear as a server to its downstream agents and as a client to its upstream agents, a functional concatenation of the DOTS client and server roles, as depicted in Figure 4:

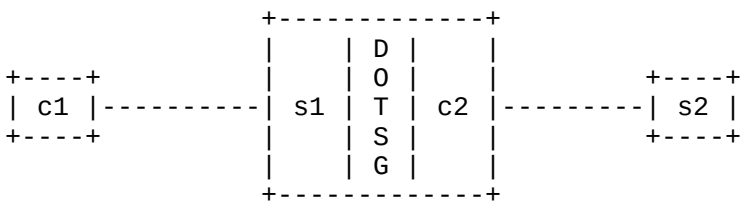

Figure 4: DOTS gateway

The DOTS gateway performs full stack DOTS session termination and reorigination between its client and server side. The details of how this is achieved are implementation specific. The DOTS protocol does not include any special features related to DOTS gateways, and hence from a DOTS perspective, whenever a DOTS gateway is present, the DOTS session simply terminates/originates there.

2.3. DOTS Agent Relationships

So far, we have only considered a relatively simple scenario of a single DOTS client associated with a single DOTS server, however DOTS supports more advanced relationships.

A DOTS server may be associated with one or more DOTS clients, and those DOTS clients may belong to different domains. An example scenario is a mitigation provider serving multiple attack targets (Figure 5):

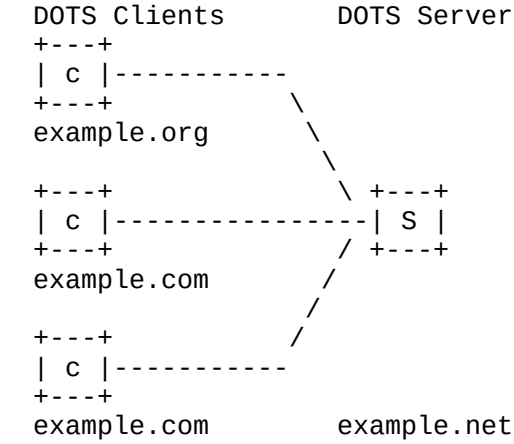

Figure 5: DOTS server with multiple clients

A DOTS client may be associated with one or more DOTS servers, and those DOTS servers may belong to different domains. This may be to ensure high availability or co-ordinate mitigation with more than one directly connected ISP. An example scenario is for an enterprise to have DDoS mitigation service from multiple providers, as shown in Figure 6 below. Operational considerations relating to co-ordinating multiple provider responses are beyond the scope of DOTS.

[[EDITOR'S NOTE: we request working group feedback and discussion of operational considerations relating to coordinating multiple provider responses to a mitigation request.]]

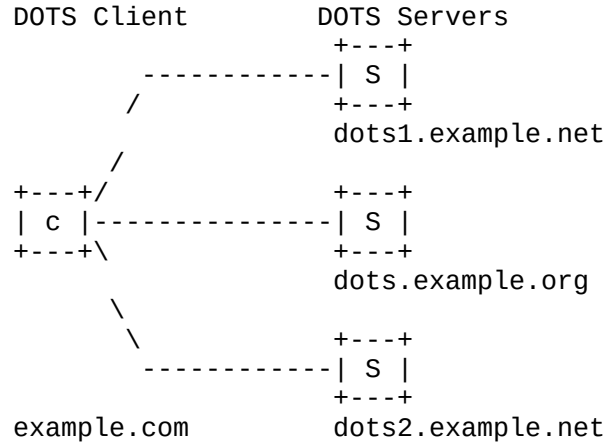

Figure 6: Multi-Homed DOTS Client

2.3.1. Gatewayed signaling

As discussed above in Section 2.2.3, a DOTS gateway is a logical function chaining signaling sessions through concatenation of a DOTS server and DOTS client.

An example scenario, as shown in Figure 7 and Figure 8 below, is for an enterprise to have deployed multiple DOTS capable devices which are able to signal intra-domain using TCP [RFC0793] on un-congested links to a DOTS gateway which may then transform these to a UDP [RFC0768] transport inter-domain where connection oriented transports may degrade; this applies to the signal channel only, as the data channel requires a connection-oriented transport. The relationship between the gateway and its upstream agents is opaque to the initial clients.

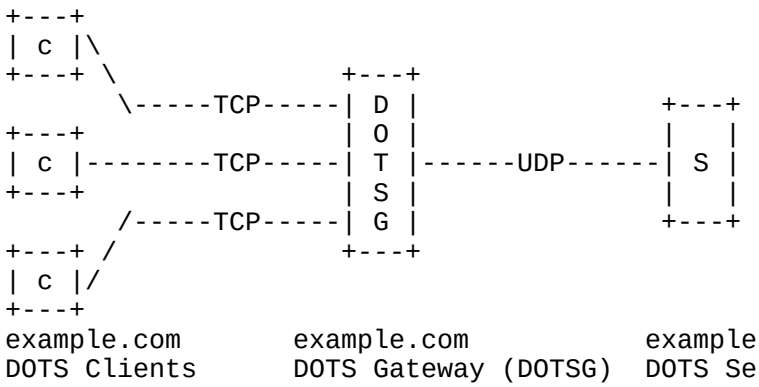

Figure 7: Client-Side Gateway with Aggregation

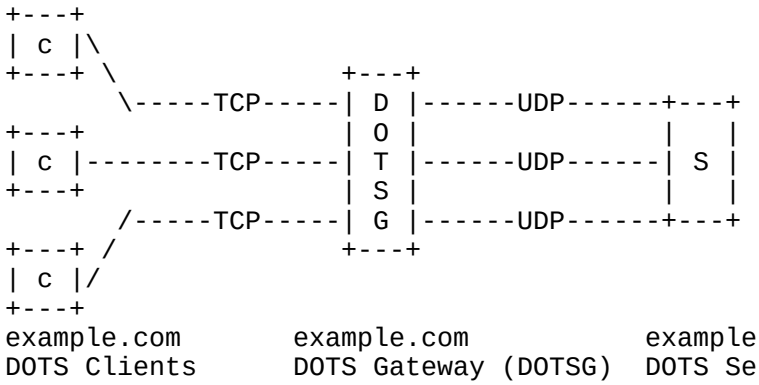

Figure 8: Client-Side Gateway without Aggregation

This may similarly be deployed in the inverse scenario where the gateway resides in the server-side domain and may be used to terminate and/or aggregate multiple clients to single transport as shown in figures Figure 9 and Figure 10 below.

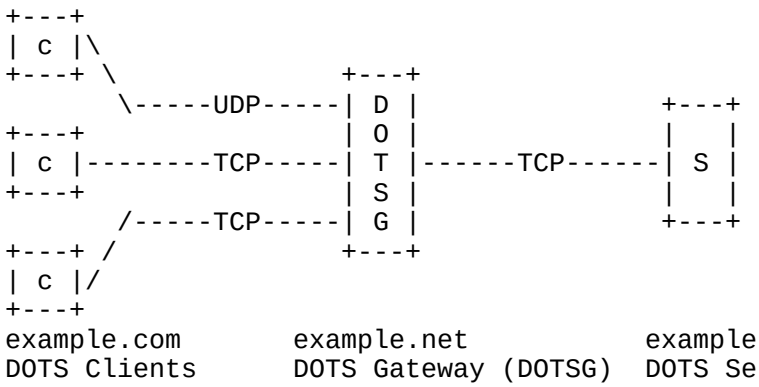

Figure 9: Server-Side Gateway with Aggregation

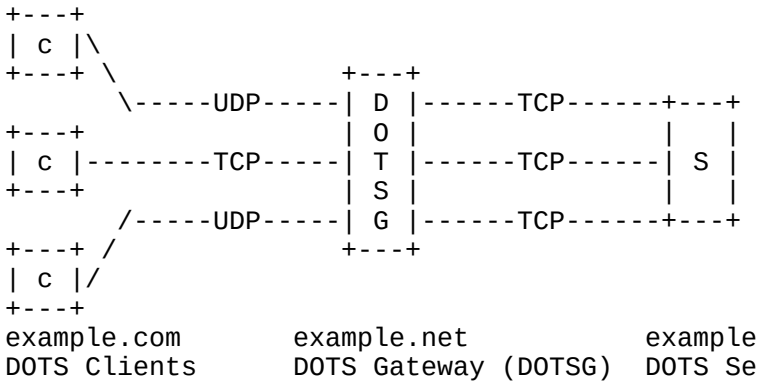

Figure 10: Server-Side Gateway without Aggregation

3. Concepts

3.1. Signaling Sessions

In order for DOTS to be effective as a vehicle for DDoS mitigation requests, one or more DOTS clients must establish ongoing communication with one or more DOTS servers. While the preconditions for enabling DOTS in or among network domains may also involve business relationships, service level agreements, or other formal or informal understandings between network operators, such considerations are out of scope for this document.

An established communication layer between DOTS agents is a Signaling Session. At its most basic, for a DOTS signaling session to exist both signal channel and data channel must be functioning between DOTS agents. That is, under nominal network conditions, signals actively

sent from a DOTS client are received by the specific DOTS server intended by the client, and vice versa.

3.1.1. Preconditions

Prior to establishing a signaling session between agents, the owners of the networks, domains, services or applications involved are assumed to have agreed upon the terms of the relationship involved. Such agreements are out of scope for this document, but must be in place for a functional DOTS architecture.

It is assumed that as part of any DOTS service agreement, the DOTS client is provided with all data and metadata required to establish communication with the DOTS server. Such data and metadata would include any cryptographic information necessary to meet the message confidentiality, integrity and authenticity requirement in [I-D.ietf-dots-requirements], and might also include the pool of DOTS server addresses and ports the DOTS client should use for signal and data channel messaging.

3.1.2. Establishing the Signaling Session

With the required business or service agreements in place, the DOTS client initiates a signal session by contacting the DOTS server over the signal channel and the data channel. To allow for DOTS service flexibility, neither the order of contact nor the time interval between channel creations is specified. A DOTS client MAY establish signal channel first, and then data channel, or vice versa.

The methods by which a DOTS client receives the address and associated service details of the DOTS server are not prescribed by this document. For example, a DOTS client may be directly configured to use a specific DOTS server address and port, and directly provided with any data necessary to satisfy the Peer Mutual Authentication requirement in [I-D.ietf-dots-requirements], such as symmetric or asymmetric keys, usernames and passwords, etc. All configuration and authentication information in this scenario is provided out-of-band by the domain operating the DOTS server.

At the other extreme, the architecture in this document allows for a form of DOTS client auto-provisioning. For example, the domain operating the DOTS server or servers might provide the client domain only with symmetric or asymmetric keys to authenticate the provisioned DOTS clients. Only the keys would then be directly configured on DOTS clients, but the remaining configuration required to provision the DOTS clients could be learned through mechanisms similar to DNS SRV [RFC2782] or DNS Service Discovery [RFC6763].

The DOTS client SHOULD successfully authenticate and exchange messages with the DOTS server over both signal and data channel as soon as possible to confirm that both channels are operational.

As described in [I-D.ietf-dots-requirements], the DOTS client can configure preferred values for acceptable signal loss, mitigation lifetime, and heartbeat intervals when establishing the signaling session. A signaling session is not active until DOTS agents have agreed on the values for these signaling session parameters, a process defined by the protocol.

Once the DOTS client begins receiving DOTS server signals, the signaling session is active. At any time during the signaling session, the DOTS client MAY use the data channel to adjust initial configuration, manage black- and white-listed prefixes or addresses, leverage vendor-specific extensions, and so on. Note that unlike the signal channel, there is no requirement that the data channel remain operational in attack conditions (See Data Channel Requirements, [I-D.ietf-dots-requirements]).

3.1.3. Maintaining the Signaling Session

DOTS clients and servers periodically send heartbeats to each other over the signal channel, per Operational Requirements discussed in [I-D.ietf-dots-requirements]. DOTS agent operators SHOULD configure the heartbeat interval such that the frequency does not lead to accidental denials of service due to the overwhelming number of heartbeats a DOTS agent must field.

Either DOTS agent may consider a signaling session terminated in the extended absence of a heartbeat from its peer agent. The period of that absence will be established in the protocol definition.

3.2. Modes of Signaling

This section examines the modes of signaling between agents in a DOTS architecture.

3.2.1. Direct Signaling

A signaling session may take the form of direct signaling between the DOTS clients and servers, as shown in Figure 11 below:

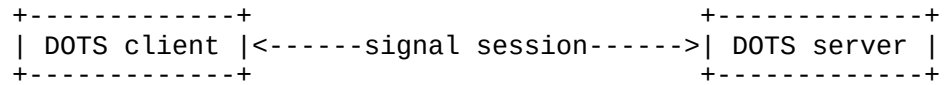

Figure 11: Direct Signaling

In a direct signaling session, DOTS client and server are communicating directly. A direct signaling session MAY exist inter- or intra-domain. The signaling session is abstracted from the underlying networks or network elements the signals traverse: in a direct signaling session, the DOTS client and server are logically peer DOTS agents.

3.2.2. Redirected Signaling

In certain circumstances, a DOTS server may want to redirect a DOTS client to an alternative DOTS server for a signaling session. Such circumstances include but are not limited to:

- Maximum number of signaling sessions with clients has been reached;
- Mitigation capacity exhaustion in the Mitigator with which the specific DOTS server is communicating;
- Mitigator outage or other downtime, such as scheduled maintenance;
- Scheduled DOTS server maintenance;
- Scheduled modifications to the network path between DOTS server and DOTS client.

A basic redirected signaling session resembles the following, as shown in Figure 12:

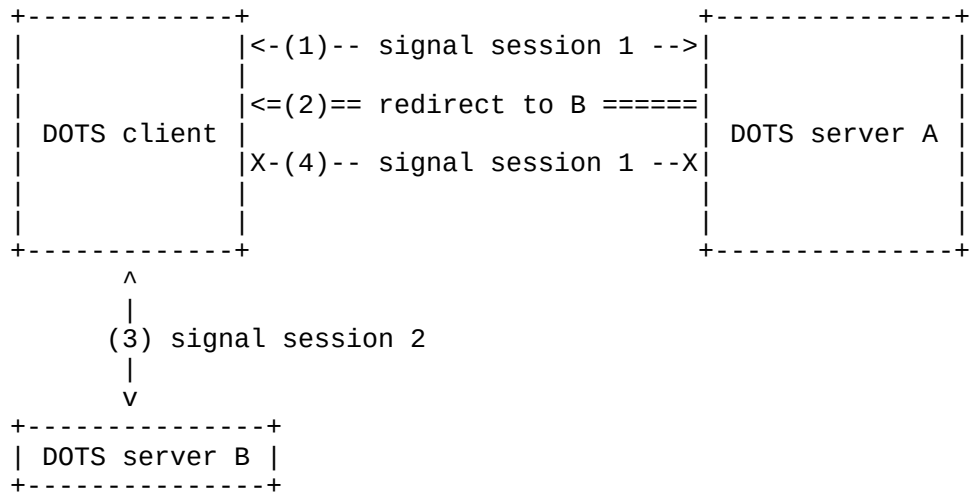

Figure 12: Redirected Signaling

1. Previously established signaling session 1 exists between a DOTS client and DOTS server with address A.

2. DOTS server A sends a server signal redirecting the client to DOTS server B.

3. If the DOTS client does not already have a separate signaling session with the redirection target, the DOTS client initiates and establishes a signaling session with DOTS server B as described above.

4. Having redirected the DOTS client, DOTS server A ceases sending server signals. The DOTS client likewise stops sending client signals to DOTS server A. Signal session 1 is terminated.

[[EDITOR'S NOTE: we request working group feedback and discussion of the need for redirected signaling.]]

3.2.3. Recursive Signaling

DOTS is centered around improving the speed and efficiency of coordinated response to DDoS attacks. One scenario not yet discussed involves coordination among federated domains operating DOTS servers and mitigators.

In the course of normal DOTS operations, a DOTS client communicates the need for mitigation to a DOTS server, and that server initiates mitigation on a mitigator with which the server has an established service relationship. The operator of the mitigator may in turn monitor mitigation performance and capacity, as the attack being mitigated may grow in severity beyond the mitigating domain's capabilities.

The operator of the mitigator has limited options in the event a DOTS client-requested mitigation is being overwhelmed by the severity of the attack. Out-of-scope business or service level agreements may permit the mitigating domain to drop the mitigation and let attack traffic flow unchecked to the target, but this is only encourages attack escalation. In the case where the mitigating domain is the upstream service provider for the attack target, this may mean the mitigating domain and its other services and users continue to suffer the incidental effects of the attack.

A recursive signaling model as shown in Figure 13 below offers an alternative. In a variation of the primary use case "Successful Automatic or Operator-Assisted CPE or PE Mitigators Request Upstream DDoS Mitigation Services" described in [I-D.ietf-dots-use-cases], an domain operating a DOTS server and mitigation also operates a DOTS

client. This DOTS client has an established signaling session with a DOTS server belonging to a separate administrative domain.

With these preconditions in place, the operator of the mitigator being overwhelmed or otherwise performing inadequately may request mitigation for the attack target from this separate DOTS-aware domain. Such a request recurses the originating mitigation request to the secondary DOTS server, in the hope of building a cumulative mitigation against the attack:

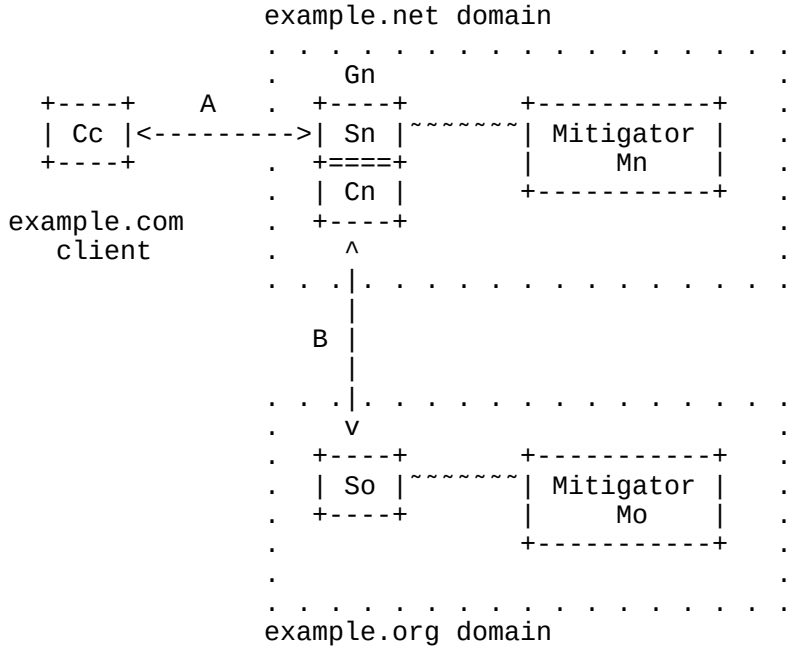

Figure 13: Recursive Signaling

In Figure 13 above, client Cc signals a request for mitigation across inter-domain signaling session A to the DOTS server Sn belonging to the example.net domain. DOTS server Sn enables mitigation on mitigator Mn. DOTS server Sn is half of DOTS gateway Gn, being deployed logically back-to-back with DOTS client Cn, which has pre-existing inter-domain signaling session B with the DOTS server So belonging to the example.org domain. At any point, DOTS server Sn MAY recurse an on-going mitigation request through DOTS client Cn to DOTS server So, in the expectation that mitigator Mo will be activated to aid in the defense of the attack target.

Recursive signaling is opaque to the DOTS client. To maximize mitigation visibility to the DOTS client, however, the recursing

domain SHOULD provide recursed mitigation feedback in signals reporting on mitigation status to the DOTS client. For example, the recursing domain's mitigator should incorporate into mitigation status messages available metrics such as dropped packet or byte counts from the recursed mitigation.

DOTS clients involved in recursive signaling MUST be able to withdraw requests for mitigation without warning or justification, per [I-D.ietf-dots-requirements].

Operators recursing mitigation requests MAY maintain the recursed mitigation for a brief, protocol-defined period in the event the DOTS client originating the mitigation withdraws its request for help, as per the discussion of managing mitigation toggling in the operational requirements ([I-D.ietf-dots-requirements]). Service or business agreements between recursing domains are not in scope for this document.

[[EDITOR'S NOTE: Recursive signaling raises questions about operational and data privacy, as well as what level of visibility a client has into the recursed mitigation. We ask the working group for feedback and additional discussion of these issues to help settle the way forward.]]

3.2.4. Anycast Signaling

The DOTS architecture does not assume the availability of anycast within a DOTS deployment, but neither does the architecture exclude it. Domains operating DOTS servers MAY deploy DOTS servers with an anycast Service Address as described in BCP 126 [RFC4786]. In such a deployment, DOTS clients connecting to the DOTS Service Address may be communicating with distinct DOTS servers, depending on the network configuration at the time the DOTS clients connect. Among other benefits, anycasted signaling potentially offers the following:

- Simplified DOTS client configuration, including service discovery through the methods described in [RFC7094]. In this scenario, the "instance discovery" message would be a DOTS client initiating a signaling session to the DOTS server anycast Service Address, to which the DOTS server would reply with a redirection to the DOTS server unicast address the client should use for DOTS.

- Region- or customer-specific deployments, in which the DOTS Service Addresses route to distinct DOTS servers depending on the client region or the customer network in which a DOTS client resides.

- Operational resiliency, spreading DOTS signaling traffic across the DOTS server domain's networks, and thereby also reducing the potential attack surface, as described in BCP 126 [RFC4786].

3.2.4.1. Anycast Signaling Considerations

As long as network configuration remains stable, anycast DOTS signaling is to the individual DOTS client indistinct from direct signaling. However, the operational challenges inherent in anycast signaling are anything but negligible, and DOTS server operators must carefully weigh the risks against the benefits before deploying.

While the DOTS signal channel primarily operates over UDP per [I-D.ietf-dots-requirements], the signal channel also requires mutual authentication between DOTS agents, with associated security state on both ends. The resulting considerations therefore superficially resemble the deployment of anycast DNS over DTLS, as described in [I-D.ietf-dprive-dnsodtls], but the similiarities only go so far.

Network instability is of particular concern with anycast signaling, as DOTS signaling sessions are expected to be long-lived, and potentially operating under congested network conditions caused by a volumetric DDoS attack.

For example, a network configuration altering the route to the DOTS server during active anycast signaling may cause the DOTS client to send messages to a DOTS server other than the one with which it initially established a signaling session. That second DOTS server may not have the security state of the existing session, forcing the DOTS client to initialize a new signaling session. This challenge may in part be mitigated by use of pre-shared keys, as described in [I-D.ietf-tls-tls13], but keying material must be available to all DOTS servers sharing the anycast Service Address in that case.

While the DOTS client will try to establish a new signaling session with the DOTS server now acting as the anycast DOTS Service Address, the link between DOTS client and server may be congested with attack traffic, making signal session establishment difficult. In such a scenario, anycast Service Address instability becomes a sort of signal session flapping, with obvious negative consequences for the DOTS deployment.

Anycast signaling deployments similarly must also take into account active mitigations. Active mitigations initiated through a signaling session may involve diverting traffic to a scrubbing center. If the signaling session flaps due to anycast changes as described above, mitigation may also flap as the DOTS servers sharing the anycast DOTS service address toggles mitigation on detecting signaling session

loss, depending on whether the client has configured mitigation on loss of signal.

[[EDITOR'S NOTE: We request feedback from the working group regarding the complexities inherent in an anycast DOTS deployment. Outside of using anycast for service discovery, significant challenges need to be overcome, particularly when dealing with security and mitigation state, and the resulting operational complexity may outweigh the expected benefits.]]

3.3. Triggering Requests for Mitigation

[I-D.ietf-dots-requirements] places no limitation on the circumstances in which a DOTS client operator may request mitigation, nor does it demand justification for any mitigation request, thereby reserving operational control over DDoS defense for the domain requesting mitigation. This architecture likewise does not prescribe the network conditions and mechanisms triggering a mitigation request from a DOTS client.

However, considering selected possible mitigation triggers from an architectural perspective offers a model for alternative or unanticipated triggers for DOTS deployments. In all cases, what network conditions merit a mitigation request are at the discretion of the DOTS client operator.

The interfaces required to trigger the mitigation request in the following scenarios are implementation-specific.

3.3.1. Manual Mitigation Request

A DOTS client operator may manually prepare a request for mitigation, including scope and duration, and manually instruct the DOTS client to send the mitigation request to the DOTS server. In context, a manual request is a request directly issued by the operator without automated decision-making performed by a device interacting with the DOTS client. Modes of manual mitigation requests include an operator entering a command into a text interface, or directly interacting with a graphical interface to send the request.

An operator might do this, for example, in response to notice of an attack delivered by attack detection equipment or software, and the alerting detector lacks interfaces or is not configured to use available interfaces to translate the alert to a mitigation request automatically.

In a variation of the above scenario, the operator may have preconfigured on the DOTS client mitigation request for various

resources in the operator's domain. When notified of an attack, the DOTS client operator manually instructs the DOTS client to send the preconfigured mitigation request for the resources under attack.

A further variant involves recursive signaling, as described in Section 3.2.3. The DOTS client in this case is the second half of a DOTS gateway (back-to-back DOTS server and client). As in the previous scenario, the scope and duration of the mitigation request are pre-existing, but in this case are derived from the mitigation request received from a downstream DOTS client by the DOTS server. Assuming the preconditions required by Section 3.2.3 are in place, the DOTS gateway operator may at any time manually request mitigation from an upstream DOTS server, sending a mitigation request derived from the downstream DOTS client's request.

The motivations for a DOTS client operator to request mitigation manually are not prescribed by this architecture, but are expected to include some of the following:

- Notice of an attack delivered via e-mail or alternative messaging
- Notice of an attack delivered via phone call
- Notice of an attack delivered through the interface(s) of networking monitoring software deployed in the operator's domain
- Manual monitoring of network behavior through network monitoring software

3.3.2. Automated Conditional Mitigation Request

Unlike manual mitigation requests, which depend entirely on the DOTS client operator's capacity to react with speed and accuracy to every detected or detectable attack, mitigation requests triggered by detected attack conditions reduce the operational burden on the DOTS client operator, and minimize the latency between attack detection and the start of mitigation.

Mitigation requests are triggered in this scenario by operator-specified network conditions. Attack detection is deployment-specific, and not constrained by this architecture. Similarly the specifics of a condition are left to the discretion of the operator, though common conditions meriting mitigation include the following:

- Detected attack exceeding a rate in packets per second (pps).
- Detected attack exceeding a rate in bytes per second (bps).

- Detected resource exhaustion in an attack target.
- Detected resource exhaustion in the local domain's mitigator.
- Number of open connections to an attack target.
- Number of attack sources in a given attack.
- Number of active attacks against targets in the operator's domain.
- Conditional detection developed through arbitrary statistical analysis or deep learning techniques.
- Any combination of the above.

When automated conditional mitigation requests are enabled, violations of any of the above conditions, or any additional operator-defined conditions, will trigger a mitigation request from the DOTS client to the DOTS server. The interfaces between the application detecting the condition violation and the DOTS client are implementation-specific.

3.3.3. Automated Mitigation on Loss of Signal

To maintain a signaling session, the DOTS client and the DOTS server exchange regular but infrequent messages across the signaling channel. In the absence of an attack, the probability of message loss in the signaling channel should be extremely low. Under attack conditions, however, some signal loss may be anticipated as attack traffic congests the link, depending on the attack type.

While [I-D.ietf-dots-requirements] specifies the DOTS protocol be robust when signaling under attack conditions, there are nevertheless scenarios in which the DOTS signal is lost in spite of protocol best efforts. To handle such scenarios, a DOTS client operator may configure the signaling session to trigger mitigation when the DOTS server ceases receiving DOTS client signals (or vice versa) beyond the miss count or period permitted by the protocol.

The impact of mitigating due to loss of signal in either direction must be considered carefully before enabling it. Signal loss is not caused by links congested with attack traffic alone, and as such mitigation requests triggered by signal channel degradation in either direction may incur unnecessary costs, in network performance and operational expense alike.

4. Security Considerations

This section describes identified security considerations for the DOTS architecture.

DOTS is at risk from three primary attack vectors: agent impersonation, traffic injection and signal blocking. These vectors may be exploited individually or in concert by an attacker to confuse, disable, take information from, or otherwise inhibit DOTS agents.

Any attacker with the ability to impersonate a legitimate client or server or, indeed, inject false messages into the stream may potentially trigger/withdraw traffic redirection, trigger/cancel mitigation activities or subvert black/whitelists. From an architectural standpoint, operators SHOULD ensure best current practices for secure communication are observed for data and signal channel confidentiality, integrity and authenticity. Care must be taken to ensure transmission is protected by appropriately secure means, reducing attack surface by exposing only the minimal required services or interfaces. Similarly, received data at rest SHOULD be stored with a satisfactory degree of security.

As many mitigation systems employ diversion to scrub attack traffic, operators of DOTS agents SHOULD ensure signaling sessions are resistant to Man-in-the-Middle (MitM) attacks. An attacker with control of a DOTS client may negatively influence network traffic by requesting and withdrawing requests for mitigation for particular prefixes, leading to route or DNS flapping.

Any attack targeting the availability of DOTS servers may disrupt the ability of the system to receive and process DOTS signals resulting in failure to fulfill a mitigation request. DOTS agents SHOULD be given adequate protections, again in accordance with best current practices for network and host security.

5. Acknowledgments

Thanks to Matt Richardson and Med Boucadair for their comments and suggestions.

6. Change Log

2016-03-18 Initial revision

7. References

7.1. Normative References

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Distributed Denial of Service (DDoS) Open Threat Signaling Requirements
draft-ietf-dots-requirements-04

Abstract

This document defines the requirements for the Distributed Denial of Service (DDoS) Open Threat Signaling (DOTS) protocols coordinating attack response against DDoS attacks.

Status of This Memo

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

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1. Introduction

1.1. Context and Motivation

Distributed Denial of Service (DDoS) attacks continue to plague networks around the globe, from Tier-1 service providers on down to enterprises and small businesses. Attack scale and frequency similarly have continued to increase, in part as a result of software vulnerabilities leading to reflection and amplification attacks. Once-staggering attack traffic volume is now the norm, and the impact of larger-scale attacks attract the attention of international press agencies.

The greater impact of contemporary DDoS attacks has led to increased focus on coordinated attack response. Many institutions and enterprises lack the resources or expertise to operate on-premise

attack mitigation solutions themselves, or simply find themselves constrained by local bandwidth limitations. To address such gaps, security service providers have begun to offer on-demand traffic scrubbing services, which aim to separate the DDoS traffic from legitimate traffic and forward only the latter. Today each such service offers its own interface for subscribers to request attack mitigation, tying subscribers to proprietary implementations while also limiting the subset of network elements capable of participating in the attack response. As a result of incompatibility across services, attack responses may be fragmentary or otherwise incomplete, leaving key players in the attack path unable to assist in the defense.

The lack of a common method to coordinate a real-time response among involved actors and network domains inhibits the speed and effectiveness of DDoS attack mitigation. This document describes the required characteristics of a DOTS protocol enabling requests for DDoS attack mitigation, reducing attack impact and leading to more efficient defensive strategies.

DOTS communicates the need for defensive action in anticipation of or in response to an attack, but does not dictate the form any defensive action takes. DOTS supplements calls for help with pertinent details about the detected attack, allowing entities participating in DOTS to form ad hoc, adaptive alliances against DDoS attacks as described in the DOTS use cases [I-D.ietf-dots-use-cases]. The requirements in this document are derived from those use cases and [I-D.ietf-dots-architecture].

1.2. Terminology

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

This document adopts the following terms:

DDoS: A distributed denial-of-service attack, in which traffic originating from multiple sources are directed at a target on a network. DDoS attacks are intended to cause a negative impact on the availability of servers, services, applications, and/or other functionality of an attack target. Denial-of-service considerations are discussed in detail in [RFC4732].

DDoS attack target: A network connected entity with a finite set of resources, such as network bandwidth, memory or CPU, that is the focus of a DDoS attack. Potential targets include network elements, network links, servers, and services.

DDoS attack telemetry: Collected measurements and behavioral characteristics defining the nature of a DDoS attack.

Countermeasure: An action or set of actions taken to recognize and filter out DDoS attack traffic while passing legitimate traffic to the attack target.

Mitigation: A set of countermeasures enforced against traffic destined for the target or targets of a detected or reported DDoS attack, where countermeasure enforcement is managed by an entity in the network path between attack sources and the attack target. Mitigation methodology is out of scope for this document.

Mitigator: An entity, typically a network element, capable of performing mitigation of a detected or reported DDoS attack. For the purposes of this document, this entity is a black box capable of mitigation, making no assumptions about availability or design of countermeasures, nor about the programmable interface between this entity and other network elements. The mitigator and DOTS server are assumed to belong to the same administrative entity.

DOTS client: A DOTS-aware software module responsible for requesting attack response coordination with other DOTS-aware elements.

DOTS server: A DOTS-aware software module handling and responding to messages from DOTS clients. The DOTS server SHOULD enable mitigation on behalf of the DOTS client, if requested, by communicating the DOTS client’s request to the mitigator and returning selected mitigator feedback to the requesting DOTS client. A DOTS server MAY also be a mitigator.

DOTS agent: Any DOTS-aware software module capable of participating in a DOTS signaling session.

DOTS gateway: A logical DOTS agent resulting from the logical concatenation of a DOTS server and a DOTS client, analogous to a SIP Back-to-Back User Agent (B2BUA) [RFC3261]. DOTS gateways are discussed in detail in [I-D.ietf-dots-architecture].

Signal channel: A bidirectional, mutually authenticated communication channel between DOTS agents characterized by resilience even in conditions leading to severe packet loss, such as a volumetric DDoS attack causing network congestion.

DOTS signal: A concise authenticated status/control message transmitted between DOTS agents, used to indicate client’s need for mitigation, as well as to convey the status of any requested mitigation.

Heartbeat: A message transmitted between DOTS agents over the signal channel, used as a keep-alive and to measure peer health.

Client signal: A message sent from a DOTS client to a DOTS server over the signal channel, indicating the DOTS client's need for mitigation, as well as the scope of any requested mitigation, optionally including additional attack details to supplement server-initiated mitigation.

Server signal: A message sent from a DOTS server to a DOTS client over the signal channel. Note that a server signal is not a response to client signal, but a DOTS server-initiated status message sent to DOTS clients with which the server has established signaling sessions.

Data channel: A secure communication layer between DOTS clients and DOTS servers used for infrequent bulk exchange of data not easily or appropriately communicated through the signal channel under attack conditions.

Filter: A policy matching a network traffic flow or set of flows and rate-limiting or discarding matching traffic.

Blacklist: A filter list of addresses, prefixes and/or other identifiers indicating sources from which traffic should be blocked, regardless of traffic content.

Whitelist: A list of addresses, prefixes and/or other identifiers from indicating sources from which traffic should always be allowed, regardless of contradictory data gleaned in a detected attack.

Multi-homed DOTS client: A DOTS client exchanging messages with multiple DOTS servers, each in a separate administrative domain.

2. Requirements

This section describes the required features and characteristics of the DOTS protocol.

DOTS is an advisory protocol. An active DDoS attack against the entity controlling the DOTS client need not be present before establishing DOTS communication between DOTS agents. Indeed, establishing a relationship with peer DOTS agents during normal network conditions provides the foundation for more rapid attack response against future attacks, as all interactions setting up DOTS, including any business or service level agreements, are already complete.

DOTS must at a minimum make it possible for a DOTS client to request a DOTS server's aid in mounting a coordinated defense against a suspected attack, signaling within or between domains as requested by local operators. DOTS clients should similarly be able to withdraw aid requests. DOTS requires no justification from DOTS clients for requests for help, nor do DOTS clients need to justify withdrawing help requests: the decision is local to the DOTS clients' domain. Regular feedback between DOTS clients and DOTS server supplement the defensive alliance by maintaining a common understanding of DOTS peer health and activity. Bidirectional communication between DOTS clients and DOTS servers is therefore critical.

Yet DOTS must also work with a set of competing operational goals. On the one hand, the protocol must be resilient under extremely hostile network conditions, providing continued contact between DOTS agents even as attack traffic saturates the link. Such resiliency may be developed several ways, but characteristics such as small message size, asynchronous, redundant message delivery and minimal connection overhead (when possible given local network policy) will tend to contribute to the robustness demanded by a viable DOTS protocol. Operators of peer DOTS-enabled domains may enable quality- or class-of-service traffic tagging to increase the probability of successful DOTS signal delivery, but DOTS requires no such policies be in place. The DOTS solution indeed must be viable especially in their absence.

On the other hand, DOTS must include protections ensuring message confidentiality, integrity and authenticity to keep the protocol from becoming another vector for the very attacks it's meant to help fight off. DOTS clients must be able to authenticate DOTS servers, and vice versa, for DOTS to operate safely, meaning the DOTS agents must have a way to negotiate and agree upon the terms of protocol security. Attacks against the transport protocol should not offer a means of attack against the message confidentiality, integrity and authenticity.

The DOTS server and client must also have some common method of defining the scope of any mitigation performed by the mitigator, as well as making adjustments to other commonly configurable features, such as listen ports, exchanging black- and white-lists, and so on.

Finally, DOTS should provide sufficient extensibility to meet local, vendor or future needs in coordinated attack defense, although this consideration is necessarily superseded by the other operational requirements.

2.1. General Requirements

GEN-001 Extensibility: Protocols and data models developed as part of DOTS MUST be extensible in order to keep DOTS adaptable to operational and proprietary DDoS defenses. Future extensions MUST be backward compatible.

GEN-002 Resilience and Robustness: The signaling protocol MUST be designed to maximize the probability of signal delivery even under the severely constrained network conditions imposed by particular attack traffic. The protocol MUST be resilient, that is, continue operating despite message loss and out-of-order or redundant message delivery. In support signaling protocol robustness, DOTS signals SHOULD be conveyed over a transport not susceptible to Head of Line Blocking.

GEN-003 Bidirectionality: To support peer health detection, to maintain an open signal channel, and to increase the probability of signal delivery during attack, the signal channel MUST be bidirectional, with client and server transmitting signals to each other at regular intervals, regardless of any client request for mitigation. Unidirectional messages MUST be supported within the bidirectional signal channel to allow for unsolicited message delivery, enabling asynchronous notifications between agents.

GEN-004 Sub-MTU Message Size: To avoid message fragmentation and the consequently decreased probability of message delivery, signaling protocol message size MUST be kept under signaling Path Maximum Transmission Unit (PMTU), including the byte overhead of any encapsulation, transport headers, and transport- or message-level security.

DOTS agents SHOULD attempt to learn the PMTU through mechanisms such as Path MTU Discovery [RFC1191] or Packetization Layer Path MTU Discovery [RFC4821]. If the PMTU cannot be discovered, DOTS agents SHOULD assume a PMTU of 1280 bytes. If IPv4 support on legacy or otherwise unusual networks is a consideration and PMTU is unknown, DOTS implementations MAY rely on a PMTU of 576 bytes, as discussed in [RFC0791] and [RFC1122].

GEN-005 Bulk Data Exchange: Infrequent bulk data exchange between DOTS agents can also significantly augment attack response coordination, permitting such tasks as population of black- or white-listed source addresses; address or prefix group aliasing; exchange of incident reports; and other hinting or configuration supplementing attack response.

As the resilience requirements for the DOTS signal channel mandate small signal message size, a separate, secure data channel utilizing a reliable transport protocol MUST be used for bulk data exchange.

2.2. Operational Requirements

OP-001 Use of Common Transport Protocols: DOTS MUST operate over common widely deployed and standardized transport protocols. While the User Datagram Protocol (UDP) [RFC0768] SHOULD be used for the signal channel, the Transmission Control Protocol (TCP) [RFC0793] MAY be used if necessary due to network policy or middlebox capabilities or configurations. The data channel MUST use a reliable transport; see Section 2.3 below.

OP-002 Session Health Monitoring: Peer DOTS agents MUST regularly send heartbeats to each other after mutual authentication in order to keep the DOTS session active. A session MUST be considered active until a DOTS agent explicitly ends the session, or either DOTS agent fails to receive heartbeats from the other after a mutually agreed upon timeout period has elapsed.

OP-003 Session Redirection: In order to increase DOTS operational flexibility and scalability, DOTS servers SHOULD be able to redirect DOTS clients to another DOTS server at any time. DOTS clients MUST NOT assume the redirection target DOTS server shares security state with the redirecting DOTS server. DOTS clients MAY attempt abbreviated security negotiation methods supported by the protocol, such as DTLS session resumption, but MUST be prepared to negotiate new security state with the redirection target DOTS server.

Due to the increased likelihood of packet loss caused by link congestion during an attack, it is RECOMMENDED DOTS servers avoid redirecting while mitigation is enabled during an active attack against a target in the DOTS client’s domain.

OP-004 Mitigation Requests and Status: Authorized DOTS clients MUST be able to request scoped mitigation from DOTS servers. DOTS servers MUST send mitigation request status in response to DOTS clients requests for mitigation, and SHOULD accept scoped mitigation requests from authorized DOTS clients. DOTS servers MAY reject authorized requests for mitigation, but MUST include a reason for the rejection in the status message sent to the client.

Due to the higher likelihood of packet loss during a DDoS attack, DOTS servers SHOULD regularly send mitigation status to authorized

DOTS clients which have requested and been granted mitigation, regardless of client requests for mitigation status.

When DOTS client-requested mitigation is active, DOTS server status messages SHOULD include the following mitigation metrics:

* Total number of packets blocked by the mitigation

* Current number of packets per second blocked

* Total number of bytes blocked

* Current number of bytes per second blocked

DOTS clients SHOULD take these metrics into account when determining whether to ask the DOTS server to cease mitigation.

Once a DOTS client requests mitigation, the client MAY withdraw that request at any time, regardless of whether mitigation is currently active. The DOTS server MUST immediately acknowledge a DOTS client's request to stop mitigation.

To protect against route or DNS flapping caused by a client rapidly toggling mitigation, and to dampen the effect of oscillating attacks, DOTS servers MAY continue mitigation for a period of up to five minutes after acknowledging a DOTS client's withdrawal of a mitigation request. During this period, DOTS server status messages SHOULD indicate that mitigation is active but terminating. After the five-minute 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 ceases incurring cost at this point.

OP-005 Mitigation Lifetime: DOTS servers MUST support mitigation lifetimes, and MUST terminate a mitigation when the lifetime elapses. DOTS servers also MUST support renewal of mitigation lifetimes in mitigation requests from DOTS clients, allowing clients to extend mitigation as necessary for the duration of an attack.

DOTS servers MUST treat a mitigation terminated due to lifetime expiration exactly as if the DOTS client originating the mitigation had asked to end the mitigation, including the five-minute termination period, as described above in OP-004.

DOTS clients SHOULD include a mitigation lifetime in all mitigation requests. If a DOTS client does not include a mitigation lifetime in requests for help sent to the DOTS server, the DOTS server will use a reasonable default as defined by the protocol.

DOTS servers SHOULD support indefinite mitigation lifetimes, enabling architectures in which the mitigator is always in the traffic path to the resources for which the DOTS client is requesting protection. DOTS servers MAY refuse mitigations with indefinite lifetimes, for policy reasons. The reasons themselves are out of scope for this document, but MUST be included in the mitigation rejection message from the server, per OP-004.

OP-006 Mitigation Scope: DOTS clients MUST indicate desired mitigation scope. The scope type will vary depending on the resources requiring mitigation. All DOTS agent implementations MUST support the following required scope types:

* IPv4 addresses in dotted quad format

* IPv4 address prefixes in CIDR notation [RFC4632]

* IPv6 addresses [RFC2373]

* IPv6 address prefixes [RFC2373]

* Domain names [RFC1035]

The following mitigation scope types are OPTIONAL:

* Uniform Resource Identifiers [RFC3986]

DOTS agents MUST support mitigation scope aliases, allowing DOTS client and server to refer to collections of protected resources by an opaque identifier created through the data channel, direct configuration, or other means.

If there is additional information available narrowing the scope of any requested attack response, such as targeted port range, protocol, or service, DOTS clients SHOULD include that information in client signals. DOTS clients MAY also include additional attack details. Such supplemental information is OPTIONAL, and DOTS servers MAY ignore it when enabling countermeasures on the mitigator.

As an active attack evolves, clients MUST be able to adjust as necessary the scope of requested mitigation by refining the scope of resources requiring mitigation.

OP-007 Mitigation Efficacy: When a mitigation request by a DOTS client is active, DOTS clients SHOULD transmit a metric of perceived mitigation efficacy to the DOTS server, per "Automatic or Operator-Assisted CPE or PE Mitigators Request Upstream DDoS Mitigation Services" in [I-D.ietf-dots-use-cases]. DOTS servers MAY use the efficacy metric to adjust countermeasures activated on a mitigator on behalf of a DOTS client.

OP-008 Conflict Detection and Notification: Multiple DOTS clients controlled by a single administrative entity may send conflicting mitigation requests for pool of protected resources , as a result of misconfiguration, operator error, or compromised DOTS clients. DOTS servers attempting to honor conflicting requests may flap network route or DNS information, degrading the networks attempting to participate in attack response with the DOTS clients. DOTS servers SHALL detect such conflicting requests, and SHALL notify the DOTS clients in conflict. The notification SHOULD indicate the nature and scope of the conflict, for example, the overlapping prefix range in a conflicting mitigation request.

OP-009: Network Address Translator Traversal: The DOTS protocol MUST operate over networks in which Network Address Translation (NAT) is deployed. As UDP is the recommended transport for the DOTS signal channel, all considerations in "Middlebox Traversal Guidelines" in [RFC5405] apply to DOTS. Regardless of transport, DOTS protocols MUST follow established best common practices (BCPs) for NAT traversal.

2.3. Data Channel Requirements

The data channel is intended to be used for bulk data exchanges between DOTS agents. Unlike the signal channel, which must operate nominally even when confronted with signal degradation due to packet loss, the data channel is not expected to be constructed to deal with attack conditions. As the primary function of the data channel is data exchange, a reliable transport is required in order for DOTS agents to detect data delivery success or failure.

The data channel must be extensible. We anticipate the data channel will be used for such purposes as configuration or resource discovery. For example, a DOTS client may submit to the DOTS server a collection of prefixes it wants to refer to by alias when requesting mitigation, to which the server would respond with a success status and the new prefix group alias, or an error status and

message in the event the DOTS client's data channel request failed. The transactional nature of such data exchanges suggests a separate set of requirements for the data channel, while the potentially sensitive content sent between DOTS agents requires extra precautions to ensure data privacy and authenticity.

DATA-001 Reliable transport: Messages sent over the data channel MUST be delivered reliably, in order sent.

DATA-002 Data privacy and integrity: Transmissions over the data channel are likely to contain operationally or privacy-sensitive information or instructions from the remote DOTS agent. Theft or modification of data channel transmissions could lead to information leaks or malicious transactions on behalf of the sending agent (see Section 4 below). Consequently data sent over the data channel MUST be encrypted and authenticated using current industry best practices. DOTS servers MUST enable means to prevent leaking operationally or privacy-sensitive data. Although administrative entities participating in DOTS may detail what data may be revealed to third-party DOTS agents, such considerations are not in scope for this document.

DATA-003 Resource Configuration: To help meet the general and operational requirements in this document, DOTS server implementations MUST provide an interface to configure resource identifiers, as described in OP-007. DOTS server implementations MAY expose additional configurability. Additional configurability is implementation-specific.

DATA-004 Black- and whitelist management: DOTS servers SHOULD provide methods for DOTS clients to manage black- and white-lists of traffic destined for resources belonging to a client.

For example, a DOTS client should be able to create a black- or whitelist entry; retrieve a list of current entries from either list; update the content of either list; and delete entries as necessary.

How the DOTS server determines client ownership of address space is not in scope.

2.4. Security requirements

DOTS must operate within a particularly strict security context, as an insufficiently protected signal or data channel may be subject to abuse, enabling or supplementing the very attacks DOTS purports to mitigate.

SEC-001 Peer Mutual Authentication: DOTS agents MUST authenticate each other before a DOTS session is considered valid. The method of authentication is not specified, but should follow current industry best practices with respect to any cryptographic mechanisms to authenticate the remote peer.

SEC-002 Message Confidentiality, Integrity and Authenticity: DOTS protocols MUST take steps to protect the confidentiality, integrity and authenticity of messages sent between client and server. While specific transport- and message-level security options are not specified, the protocols MUST follow current industry best practices for encryption and message authentication.

In order for DOTS protocols to remain secure despite advancements in cryptanalysis and traffic analysis, DOTS agents MUST be able to negotiate the terms and mechanisms of protocol security, subject to the interoperability and signal message size requirements above.

While the interfaces between downstream DOTS server and upstream DOTS client within a DOTS gateway are implementation-specific, those interfaces nevertheless MUST provide security equivalent to that of the signaling sessions bridged by gateways in the signaling path. For example, when a DOTS gateway consisting of a DOTS server and DOTS client is running on the same logical device, they must be within the same process security boundary.

SEC-003 Message Replay Protection: In order to prevent a passive attacker from capturing and replaying old messages, DOTS protocols MUST provide a method for replay detection.

2.5. Data Model Requirements

The value of DOTS is in standardizing a mechanism to permit elements, networks or domains under or under threat of DDoS attack to request aid mitigating the effects of any such attack. A well-structured DOTS data model is therefore critical to the development of a successful DOTS protocol.

DM-001: Structure: The data model structure for the DOTS protocol may be described by a single module, or be divided into related collections of hierarchical modules and sub-modules. If the data model structure is split across modules, those distinct modules MUST allow references to describe the overall data model’s structural dependencies.

DM-002: Versioning: To ensure interoperability between DOTS protocol implementations, data models MUST be versioned. The version

number of the initial data model SHALL be 1. Each published change to the initial published DOTS data model SHALL increment the data model version by 1.

How the protocol represents data model versions is not defined in this document.

DM-003: Mitigation Status Representation: The data model MUST provide the ability to represent a request for mitigation and the withdrawal of such a request. The data model MUST also support a representation of currently requested mitigation status, including failures and their causes.

DM-004: Mitigation Scope Representation: The data model MUST support representation of a requested mitigation's scope. As mitigation scope may be represented in several different ways, per OP-006 above, the data model MUST be capable of flexible representation of mitigation scope.

DM-005: Mitigation Lifetime Representation: The data model MUST support representation of a mitigation request's lifetime, including mitigations with no specified end time.

DM-006: Mitigation Efficacy Representation: The data model MUST support representation of a DOTS client's understanding of the efficacy of a mitigation enabled through a mitigation request.

DM-007: Acceptable Signal Loss Representation: The data model MUST be able to represent the DOTS agent's preference for acceptable signal loss when establishing a signaling session, as described in GEN-002.

DM-008: Heartbeat Interval Representation: The data model MUST be able to represent the DOTS agent's preferred heartbeat interval, which the client may include when establishing the signal channel, as described in OP-002.

DM-009: Relationship to Transport: The DOTS data model MUST NOT depend on the specifics of any transport to represent fields in the model.

3. Congestion Control Considerations

3.1. Signal Channel

As part of a protocol expected to operate over links affected by DDoS attack traffic, the DOTS signal channel MUST NOT contribute significantly to link congestion. To meet the operational

requirements above, DOTS signal channel implementations MUST support UDP. However, UDP when deployed naively can be a source of network congestion, as discussed in [RFC5405]. Signal channel implementations using UDP MUST therefore include a congestion control mechanism.

Signal channel implementations using TCP may rely on built-in TCP congestion control support.

3.2. Data Channel

As specified in DATA-001, the data channel requires reliable, in-order message delivery. Data channel implementations using TCP may rely on the TCP implementation’s built-in congestion control mechanisms.

4. Security Considerations

DOTS is at risk from three primary attacks:

- DOTS agent impersonation
- Traffic injection
- Signaling blocking

The DOTS protocol MUST be designed for minimal data transfer to address the blocking risk. Impersonation and traffic injection mitigation can be managed through current secure communications best practices. See Section 2.4 above for a detailed discussion.

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7. Change Log

7.1. 04 revision

2017-03-13

- Establish required and optional mitigation scope types
- Specify message size for DOTS signal channel
- Recast mitigation lifetime as a DOTS server requirement
- Clarify DOTS server’s responsibilities after client request to end mitigation
- Specify security state handling on redirection
- Signal channel should use transport not susceptible to HOL blocking
- Expanded list of DDoS types to include network links

7.2. 03 revision

2016-10-30

- Extended SEC-003 to require secure interfaces within DOTS gateways.
- Changed DATA-003 to Resource Configuration, delegating control of acceptable signal loss, heartbeat intervals, and mitigation lifetime to DOTS client.
- Added data model requirements reflecting client control over the above.

7.3. 02 revision

7.4. 01 revision

2016-03-21

- Reconciled terminology with -00 revision of [I-D.ietf-dots-use-cases].
- Terminology clarification based on working group feedback.
- Moved security-related requirements to separate section.
- Made resilience/robustness primary general requirement to align with charter.
- Clarified support for unidirectional communication within the bidirectional signal channel.
- Added proposed operational requirement to support session redirection.
- Added proposed operational requirement to support conflict notification.
- Added proposed operational requirement to support mitigation lifetime in mitigation requests.
- Added proposed operational requirement to support mitigation efficacy reporting from DOTS clients.
- Added proposed operational requirement to cache lookups of all kinds.
- Added proposed operational requirement regarding NAT traversal.
- Removed redundant mutual authentication requirement from data channel requirements.

7.5. 00 revision

2015-10-15

7.6. Initial revision

2015-09-24 Andrew Mortensen

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Use cases for DDoS Open Threat Signaling
draft-ietf-dots-use-cases-04.txt

Abstract

The DDoS Open Threat Signaling (DOTS) effort is intended to provide a protocol that facilitates interoperability between multivendor solutions/services. This document presents use cases to evaluate the interactions expected between the DOTS components as well as the DOTS exchanges. The purpose of the use cases is to identify the interacting DOTS component, how they collaborate and what are the types of information to be exchanged.

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1. Introduction

Currently, distributed denial-of-service (DDoS) attack mitigation solutions/services are largely based upon siloed, proprietary communications paradigms which result in vendor/service lock-in. As a side-effect, this makes the configuration, provisioning, operation, and activation of these solutions a highly manual and often time-consuming process. Additionally, coordination of multiple DDoS mitigation solutions/services simultaneously engaged in defending the same organization against DDoS attacks is fraught with both technical

and process-related hurdles. This greatly increase operational complexity and often results in suboptimal DDoS attack mitigation efficacy.

The DDoS Open Threat Signaling (DOTS) effort is intended to provide a protocol that facilitates interoperability between multivendor DDoS mitigation solutions/services. As DDoS solutions/services are broadly heterogeneous among different vendors, the primary goal for DOTS is to provide a high level interaction with these DDoS solutions/services such as initiating or terminating DDoS mitigation assistance.

It should be noted that DOTS is not in and of itself intended to perform orchestration functions duplicative of the functionality being developed by the [I2NSF] WG; rather, DOTS is intended to allow devices, services, and applications to request DDoS attack mitigation assistance and receive mitigation status updates from systems of this nature.

The use cases presented in the document are intended to provide examples of communications interactions DOTS-enabled nodes in both inter- and intra-organizational DDoS mitigation scenarios. These use cases are expected to provide inputs for the design of the DOTS protocol(s).

2. Terminology and Acronyms

2.1. Requirements Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

2.2. Acronyms

This document makes use of the same terminology and definitions as [I-D.ietf-dots-requirements], except where noted.

2.3. Terms

Inter-organizational: a DOTS communications relationship between distinct organizations with separate spans of administrative control. Typical inter-organizational DOTS communication relationships would be between a DDoS mitigation service provider and an end-customer organizational which requires DDoS mitigation assistance; between multiple DDoS mitigation service providers coordinating mutual defense of a mutual end-customer; or between DDoS mitigation service providers which are requesting additional DDoS mitigation assistance

in for attacks which exceed their inherent DDoS mitigation capacities and/or capabilities.

Intra-organizational: a DOTS communications relationship between various elements within a single span of administrative control. A typical intra-organizational DOTS communications relationship would be between DOTS clients, DOTS gateways, and DOTS servers within the same organization.

3. Use Cases Scenarios

This section provides a high-level description of scenarios addressed by DOTS. In both sections, the scenarios are provided in order to illustrate the use of DOTS in typical DDoS attack scenarios. They are not definitive, and other use cases are expected to emerge with widespread DOTS deployment.

All scenarios present a coordination between the targeted organization, the DDoS attack telemetry and the mitigator. The coordination and communication between these entity depends, for example on the characteristic or functionality of the equipment, the reliability of the information provided by DDoS attack telemetry, and the business relationship between the DDoS target domain and the mitigator.

More explicitly, in some cases, the DDoS attack telemetry may simply activate a DDoS mitigation, whereas in other cases, it may collaborate by providing some information about an attack. In some cases, the DDoS mitigation may be orchestrated, which includes selecting a specific appliance as well as starting/ending a mitigation.

3.1. Inter-domain Use Cases

3.1.1. Enterprise with an upsteam transit provider DDoS mitigation Service

In this scenario, an enterprise network with self-hosted Internet-facing properties such as Web servers, authoritative DNS servers, and VoIP PBXes has an intelligent DDoS mitigation system (IDMS) deployed to protect those servers and applications from DDoS attacks. In addition to their on-premise DDoS defense capability, they have contracted with their Internet transit provider for DDoS mitigation services which threaten to overwhelm their transit link bandwidth.

The IDMS is configured such that if the incoming Internet traffic volume exceeds 50% of the provisioned upstream Internet transit link

capacity, the IDMS will request DDoS mitigation assistance from the upstream transit provider.

The communication to trigger, manage, and finalize a DDoS mitigation between the enterprise IDMS and the transit provider is performed using DOTS. The enterprise IDMS implements a DOTS client while the transit provider implements a DOTS server.

When the IDMS detects an inbound DDoS attack targeting the enterprise servers and applications, it immediately begins mitigating the attack.

During the course of the attack, the inbound traffic volume exceeds the 50% threshold; the IDMS DOTS client signals the DOTS server on the upstream transit provider network to initiate DDoS mitigation. The DOTS server signals the DOTS client that it can service this request, and mitigation is initiated on the transit provider network.

Over the course of the attack, the DOTS server on the transit provider network periodically signals the DOTS client on the enterprise IDMS in order to provide mitigation status information, statistics related to DDoS attack traffic mitigation, and related information. Once the DDoS attack has ended, the DOTS server signals the enterprise IDMS DOTS client that the attack has subsided.

The enterprise IDMS then requests that DDoS mitigation services on the upstream transit provider network be terminated. The DOTS server on the transit provider network receives this request, communicates with the transit provider orchestration system controlling its DDoS mitigation system to terminate attack mitigation, and once the mitigation has ended, confirms the end of upstream DDoS mitigation service to the enterprise IDMS DOTS client.

3.1.2. Enterprise with on Cloud DDoS mitigation provider

This use case details an enterprise that has a local DDoS detection and classification capability and may or may not have a mitigation capability. The enterprise is contracted with a cloud DDoS mitigation provider who can redirect (offramp) traffic away from the enterprise, provide scrubbing services and return clean traffic back to the enterprise (onramp) on an ad-hoc, on demand basis.

The enterprise may, either by hard coding or on a case by case basis, determine thresholds at which a request for mitigation is triggered indicating to the cloud provider that traffic should be redirected and scrubbed.

The communication to trigger, manage, and finalize a DDoS mitigation between the enterprise and the Cloud provider is performed using DOTS. The enterprise implements a DOTS client while the Cloud Provider implements a DOTS server.

The enterprise detection and classification systems encompass a DOTS client and the cloud provider a DOTS server.

When an attack is detected an automated or manual DOTS mitigation request will be generatd and sent to the cloud provider. The cloud provider will assess the request for validity and if passed a mitigation action may then be initiated. This action will usually involve the offramp of all traffic destined to the target for further scrutiny and filtering by the cloud provider. This should not only result in an alleviation of pressure on the enterprise network but also on its upstream provider and peers.

The cloud provider should signal via DOTS to the enterprise that a mitigation request has been received and acted upon and should also include a basic situational status of the attack. The cloud provider may respond periodically with additional updates on the status to enable the enterprise to make an informed decision on whether to maintain or cancel the mitigation. An alternative approach would be for the DOTS client mitigation request to include a time to live (ttl) for the mitigation which may be extended by the client should the attack still be ongoing as the ttl reaches expiration.

A variation of this use case may be that the enterprise is providing a flow based monitoring and analysis service to customers whose networks may be protected by any one of a number of 3rd party providers. The enterprise in question may integrate with these 3rd party providers using DOTS and signal accordingly when a customer is attacked - the enterprise may then manage the life-cycle of the attack on behalf of the enterprise.

3.2. Intra-domain Use Cases

3.2.1. Homenet DDoS protection by ISP

In this use case home networks or small businesses networks (SOHO), subscribe with their upstream ISP a DDoS mitigation service.

Home networks run with limited bandwidth as well as limited routing resources, while they are expected to provide services reachable from the outside [RFC7368]. This makes such organizations some easy targets to DDoS attacks. In addition, these DDoS attacks might even not be noticed by the upstream ISP.

This scenario is considered as an intra-domain as ISPs have a specific relationship with these customers. The ISP is the connectivity provider, and in some cases, they even provides the CPE with a set of associated services. Moreover, in case of any connectivity issue the customer is likely to call the hotline. In order to improve the QoS of the connectivity as well as to automate the request for DDoS mitigation, ISP is likely to consider a standard mean for CPEs to notify when they are under a suspected DDoS. Such notification may be triggered automatically or manually. As the ISP and the customer share a common interest in mitigating the DDoS attack, this slightly differs from cases where a contract is negotiated with a third party, such as in the inter-domain use cases.

In most cases, CPEs are unlikely to diagnose whether an DDoS attack is ongoing or not and simply rely on the upstream equipment provided by the ISP for detection and potential mitigation.

The DDoS Mitigation service of the ISP may be hard coded or may be configured by the customer manually or automatically while the CPE is being connected to the Internet -- eventually the DHCP server may provide the DDoS Mitigation service via specific DHCP options.

The communication to trigger a DDoS mitigation between the home network and the ISP is performed using DOTS. The home network CPE implements a DOTS client while the ISP implements a DOTS server.

The DOTS Client on the CPE monitors the status of CPE’s resource and link bandwidth usage. If something unusual happens based on preconfigured throughput or some heuristics methods, the DOTS Client sends a DOTS mitigation request to the ISP DOTS Server. Typically, a default configuration with no additional information associated to the DOTS mitigation request is expected. The ISP derives traffic to mitigate from the CPE IP address.

In some cases, the DOTS mitigation request contains options such as some IP addresses or prefixes that belongs to a whitelist or respectively to a blacklist. In this case, the white and black lists are not associated to some analysis performed by the CPE -- as the CPE is clearly not expected to analyze such attacks. Instead these are part of some configuration parameters. For example, in the case of small business, one may indicate specific legitimate IP addresses such as those used for VPNs, or third party services the company is likely to set a session. Similarly, the CPE may provides the IP addresses of the assets to be protected inside the network. Such options may include the IP address as well as a service description. Similarly to the previous blacklist and whitelist, such information are not derived from a traffic analysis performed by the CPE, but instead are more related to configuration parameters.

Upon receiving the DOTS mitigation request, the ISP acknowledges its reception and confirms DDoS mitigation starts or not. Such feed back is mostly to avoid retransmission of the request.

Note that the ISP is connected to multiple CPEs and as such the CPE can potentially perform DDoS attack to the DOTS server. ISP may use relays to absorbs the traffic. In addition, such attack may be triggered by a large scale DDoS attack, which is expected to be detected and mitigated by the upstream architecture.

ISP may activate mitigation for the traffic associated to the CPE sending the alert or instead to the traffic associated to all CPE. Such decisions are not part of DOTS, but instead depend on the policies of the ISP network administrator.

It is unlikely the CPE will follow the status of the mitigation. The ISP is only expected to inform the CPE the mitigation has been stopped.

Upon receipt of such notification the CPE may re-activate the monitoring jobs and thus is likely to provide some further DOTS alert.

3.2.2. DDoS Orchestration

In this use case, one or multiple telemetry systems or monitoring devices like a flow collector monitor a network -- typically an ISP network. Upon detection of a DDoS attack, these telemetry systems alert an orchestrator in charge of coordinating the various DDoS mitigation systems within the domain. The telemetry systems may be configured to provide some necessary or useful pieces of informations, such as a preliminary analysis of the observation to the orchestrator.

The orchestrator analyses the various information it receives from specialized equipements, and elaborates one or multiple DDoS mitigation strategies. In some case, a manual confirmation may also be required to chose a proposed strategy or to start the DDoS mitigation. The DDoS mitigation may consists in multiple steps such as configuring the network, the various hardware or already instantiated DDoS mitigation functions. In some cases, some specific virtual DDoS mitigation functions need to be instantiated and properly chained between each other. Eventually, the coordination of the mitigation may involved external DDoS resources such as a transit provider Section 3.1 or a cloud provider Section 3.1.2.

The communication to trigger a DDoS mitigation between the telemetry and monitoring systems and the orchestrator is performed using DOTS.

The telemetry systems implements a DOTS client while the Orchestrator implements a DOTS server.

The communication between to select a DDoS strategy by a network administrator and the orchestrator is also performed using DOTS. The network administrator via its web interfaces implements a DOTS client while the Orchestrator implements a DOTS server.

The communication between the Orchestrator and the DDoS mitigation systems is performed using DOTS. The Orchestrator implements a DOTS client while the DDoS mitigation systems implement a DOTS server.

The configuration aspects of each DDoS mitigation systems, as well as the instantiations of DDoS mitigation functions or network configuration is not part of DOTS. Similarly the discovery of the available DDoS mitigation functions is not pat of DOTS.

The Telemetry or monitoring systems monitors each various traffic network and each performs their measurement tasks. They are configure so that when an event or some measurements reach a predefined level to report a DOTS mitigation request to the orchestrator. The DOTS mitigation request may be associated with some element such as specific reporting, or analysis.

Upon receipt of the DOTS mitigation request from the telemetry system, the orchestrator responds with an acknowledgement, to avoid retransmission of the request for mitigation. The status of the DDoS mitigation indicates the orchestrator is in an analysing phase. The orchestrator begins collecting various informations from various telemetry systems on the network in order to correlate the measurements and provide an analyse of the event. Eventually, the orchestrator may ask additional informations to the telemetry system that just sent the DOTS request, however, the collection of these information is performed outside DOTS.

The orchestrator may be configured to start a DDoS mitigation upon approval from a network administrator. The analysis from the orchestrator is reported to the network administrator via a web interface. If the network administrator decides to start the mitigation, she order through her web interface a DOTS client to send a request for DDoS mitigation. This request is expected to be associated with a context that identifies the DDoS mitigation selected.

Upon receiving the DOTS request for DDoS mitigation from the network administrator, the orchestrator orchestrates the DDoS mitigation according to the specified strategy. It status first indicates the DDoS mitigation is starting while not effective. In fact the

orchestrator is expected to proceed to a significant number of configurations.

Orchestration of the DDoS mitigation systems works similarly as described in Section 3.1 or Section 3.1.2. The orchestrator indicates with its status the DDoS Mitigation is effective.

When the DDoS mitigation is finished on the DDoS mitigation systems, the orchestrator indicates to the Telemetry systems as well as to the network administrator the DDoS mitigation is finished.

4. Security Considerations

DOTS is at risk from three primary attacks: DOTS agent impersonation, traffic injection, and signaling blocking. The DOTS protocol MUST be designed for minimal data transfer to address the blocking risk.

Impersonation and traffic injection mitigation can be managed through current secure communications best practices. DOTS is not subject to anything new in this area. One consideration could be to minimize the security technologies in use at any one time. The more needed, the greater the risk of failures coming from assumptions on one technology providing protection that it does not in the presence of another technology.

Additional details of DOTS security requirements may be found in [I-D.ietf-dots-requirements].

5. IANA Considerations

No IANA considerations exist for this document at this time.

6. Acknowledgments

TBD

7. References

7.1. Normative References

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March 10, 2017

Distributed Denial-of-Service Open Threat Signaling (DOTS) Data Channel
draft-reddy-dots-data-channel-05

Abstract

The document specifies a Distributed Denial-of-Service Open Threat Signaling (DOTS) data channel used for bulk exchange of data not easily or appropriately communicated through the DOTS signal channel under attack conditions. This is a companion document to the DOTS signal channel specification.

Status of This Memo

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

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at http://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on September 11, 2017.

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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 client, a router, a firewall, or an entire network.

DDoS Open Threat Signaling (DOTS) defines two channels: signal and data channels [I-D.ietf-dots-architecture] (Figure 1). The DOTS signal channel used to convey that a network is under a DDOS attack to an upstream DOTS server so that appropriate mitigation actions are undertaken on the suspect traffic is further elaborated in [I-D.reddy-dots-signal-channel]. The DOTS data channel is used for infrequent bulk data exchange between DOTS agents in the aim to significantly augment attack response coordination.

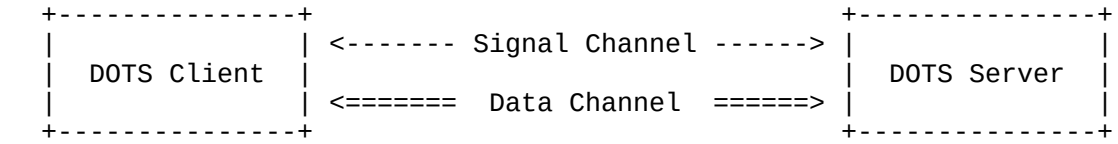

Figure 1: DOTS Channels

Section 2 of [I-D.ietf-dots-architecture] identifies that the DOTS data channel is used to perform the tasks listed below:

- Filter management, which enables a DOTS client to install or remove traffic filters, dropping or rate-limiting unwanted traffic and permitting white-listed traffic. Sample use cases for populating black- or white-list filtering rules are detailed hereafter:

  A. If a network resource (DOTS client) detects a potential DDoS attack from a set of IP addresses, the DOTS client informs its servicing router (DOTS gateway) of all suspect IP addresses that need to be blocked or black-listed for further investigation. The DOTS client could also specify a list of protocols and ports in the black-list rule. That DOTS gateway in-turn propagates the black-listed IP addresses to the DOTS server which will undertake appropriate action so that traffic from these IP addresses to the target network (specified by the DOTS client) is blocked.
  B. An enterprise network has partner sites from which only legitimate traffic arrives and the enterprise network wants to ensure that the traffic from these sites is not penalized

during DDOS attacks. The DOTS client uses DOTS data channel to convey the white-listed IP addresses or prefixes of the partner sites to its DOTS server. The DOTS server uses this information to white-list flows from such IP addresses or prefixes reaching the enterprise network.

- o Creating identifiers, such as names or aliases, for resources for which mitigation may be requested:

  A. The DOTS client may submit to the DOTS server a collection of prefixes it wants to refer to by alias when requesting mitigation, to which the server would respond with a success status and the new prefix group alias, or an error status and message in the event the DOTS client's data channel request failed (see requirement OP-006 in [I-D.ietf-dots-requirements] and Section 2 in [I-D.ietf-dots-architecture]).

2. Notational Conventions and Terminology

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

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

For simplicity, all of the examples in this document use "/restconf" as the discovered RESTCONF API root path. Many protocol header lines and message-body text within examples throughout the document are split into multiple lines for display purposes only. When a line ends with backslash ('\') as the last character, the line is wrapped for display purposes. It is to be considered to be joined to the next line by deleting the backslash, the following line break, and the leading whitespace of the next line.

3. DOTS Data Channel

The DOTS data channel is intended to be used for bulk data exchanges between DOTS agents. Unlike the signal channel, which must operate nominally even when confronted with despite signal degradation due to packet loss, the data channel is not expected to be constructed to deal with attack conditions.

As the primary function of the data channel is data exchange, a reliable transport is required in order for DOTS agents to detect data delivery success or failure. RESTCONF [RFC8040] over TLS [RFC5246] over TCP is used for DOTS data channel (Figure 2). RESTCONF uses HTTP methods to provide CRUD operations on a conceptual datastore containing YANG-defined data, which is compatible with a

server which implements NETCONF datastores. The HTTP POST, PUT, PATCH, and DELETE methods are used to edit data resources represented by DOTS data channel YANG data models. These basic edit operations allow the DOTS data channel running configuration to be altered by a DOTS client. DOTS data channel configuration data and state data can be retrieved with the GET method. HTTP status codes are used to report success or failure for RESTCONF operations. The DOTS client will perform the root resource discovery procedure discussed in Section 3.1 of [RFC8040] to determine the root of the RESTCONF API. After discovering the RESTCONF API root, the DOTS client MUST use this value as the initial part of the path in the request URI, in any subsequent request to the DOTS server. The DOTS server can optionally support retrieval of the YANG modules it supports (Section 3.7 in [RFC8040]), for example, DOTS client can use RESTCONF to retreive the company proprietary YANG model supported by the DOTS server.

Note: This document uses RESTCONF, a protocol based on HTTP [RFC7230], for configuring data defined in YANG version 1 [RFC6020] or YANG version 1.1 [RFC7950], using the datastore concepts defined in the Network Configuration Protocol (NETCONF) [RFC6241]. RESTCONF combines the simplicity of the HTTP protocol with the predictability and automation potential of a schema-driven API. RESTCONF offers a simple subset of NETCONF functionality and provides a simplified interface using REST-like API which addresses the needs of the DOTS data channel and hence an optimal choice.

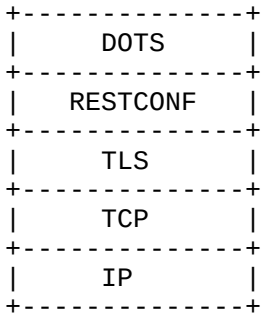

Figure 2: Abstract Layering of DOTS data channel over RESTCONF over TLS

JavaScript Object Notation (JSON) [RFC7159] payload is used to propogate data channel specific payload messages that convey request parameters and response information such as errors. This specification uses the encoding rules defined in [RFC7951] for representing DOTS data channel configuration data defined using YANG (Section 3.1) as JSON text.

A DOTS client registers itself to its DOTS server(s) in order to set up DOTS data channel related configuration data on the DOTS server and receive state data (i.e., non-configuration data) from the DOTS server. A single DOTS data channel between DOTS agents can be used to exchange multiple requests and multiple responses. To reduce DOTS client and DOTS server workload, DOTS client SHOULD re-use the TLS session. While the communication to the DOTS server is quiescent, the DOTS client MAY probe the server to ensure it has maintained cryptographic state. Such probes can also keep alive firewall or NAT bindings. A TLS heartbeat [RFC6520] verifies the DOTS server still has TLS state by returning a TLS message.

3.1. DOTS Data Channel YANG Model

3.1.1. Identifier Model structure

This document defines a YANG [RFC6020] data model for creating identifers, such as names or aliases, for resources for which mitigation may be requested. Such identifiers may then be used in subsequent DOTS signal channel exchanges to refer more efficiently to the resources under attack.

This document defines the YANG module "ietf-dots-data-channel-identifier", which has the following structure:

```
module: ietf-dots-data-channel-identifier
    +--rw identifier
       +--rw alias* [alias-name]
          +--rw alias-name          string
          +--rw ip*                 inet:ip-address
          +--rw prefix*             inet:ip-prefix
          +--rw port-range* [lower-port upper-port]
          |  +--rw lower-port    inet:port-number
          |  +--rw upper-port    inet:port-number
          +--rw traffic-protocol*   uint8
          +--rw FQDN*               inet:domain-name
          +--rw URI*                inet:uri
          +--rw E.164*              string
```

3.1.2. Identifier Model

<CODE BEGINS> file "ietf-dots-data-channel-identifier@2016-11-28.yang"

```
module ietf-dots-data-channel-identifier {
      namespace "urn:ietf:params:xml:ns:yang:ietf-dots-data-channel-identifier";
      prefix "alias";
      import ietf-inet-types {
          prefix "inet";
```

```
 }
organization "Cisco Systems, Inc.";
contact "Tirumaleswar Reddy <tireddy@cisco.com>";

description
  "This module contains YANG definition for
   configuring identifiers for resources using DOTS data channel";

revision 2016-11-28 {
  reference
  "https://tools.ietf.org/html/draft-reddy-dots-data-channel";
}

container identifier {
     description "top level container for identifiers";
         list alias {
              key alias-name;
              description "list of identifiers";
              leaf alias-name {
                 type string;
                 description "alias name";
              }
              leaf-list ip {
                 type inet:ip-address;
                 description "IP address";
              }
              leaf-list prefix {
                 type inet:ip-prefix;
                 description "prefix";
              }
              list port-range {
                 key "lower-port upper-port";
                 description "Port range. When only lower-port is present,
                              it represents a single port.";
                 leaf lower-port {
                    type inet:port-number;
                    mandatory true;
                    description "lower port";
                 }
                 leaf upper-port {
                    type inet:port-number;
                    must ". >= ../lower-port" {
                      error-message
                      "The upper-port must be greater than or
                       equal to lower-port";
                    }
                    description "upper port";
                 }
```

```
                    }
                    leaf-list traffic-protocol {
                       type uint8;
                       description "Internet Protocol number";
                    }
                    leaf-list FQDN {
                      type inet:domain-name;
                      description "FQDN";
                    }
                    leaf-list URI {
                      type inet:uri;
                      description "URI";
                    }
                    leaf-list E.164 {
                       type string;
                       description "E.164 number";
                    }
                }
    }
  }
 <CODE ENDS>
```

3.1.3. Filter Model and structure

This document uses the Access Control List (ACL) YANG data model [I-D.ietf-netmod-acl-model] for the configuration of filtering rules. ACL is explained in Section 1 of [I-D.ietf-netmod-acl-model].

Examples of such configuration include:

- Black-list management, which enables a DOTS client to inform the DOTS server about sources from which traffic should be suppressed.
- White-list management, which enables a DOTS client to inform the DOTS server about sources from which traffic should always be accepted.
- Filter management, which enables a DOTS client to install or remove traffic filters, dropping or rate-limiting unwanted traffic and permitting white-listed traffic.

3.2. Identifiers

3.2.1. Create Identifiers

A POST request is used to create identifiers, such as names or aliases, for resources for which a mitigation may be requested. Such identifiers may then be used in subsequent DOTS signal channel exchanges to refer more efficiently to the resources under attack (Figure 3).

```
POST /restconf/data/ietf-dots-data-channel-identifier HTTP/1.1
Host: {host}:{port}
Content-Format: "application/yang.api+json"
{
 "ietf-dots-data-channel-identifier:identifier": {
   "alias": [
     {
       "alias-name": "string",
       "ip": [
         "string"
       ],
       "prefix": [
         "string"
       ],
       "port-range": [
         {
           "lower-port": integer,
           "upper-port": integer
         }
       ],
       "traffic-protocol": [
         integer
       ],
       "FQDN": [
         "string"
       ],
       "URI": [
         "string"
       ],
       "E.164": [
         "string"
       ]
     }
   ]
 }
}
```

Figure 3: POST to create identifiers

The header parameters are described below:

alias-name: Name of the alias. This is a mandatory attribute.
traffic-protocol: Internet Protocol numbers. This is an optional attribute.
port-range: The port range, lower-port for lower port number and upper-port for upper port number. For TCP, UDP, SCTP, or DCCP:

the range of ports (e.g., 80 to 8080). This is an optional attribute.

ip: IP addresses are separated by commas. This is an optional attribute.

prefix: Prefixes are separated by commas. This is an optional attribute.

FQDN: Fully Qualified Domain Name, is the full name of a system, rather than just its hostname. For example, "venera" is a hostname, and "venera.isi.edu" is an FQDN. This is an optional attribute.

URI: Uniform Resource Identifier (URI). This is an optional attribute.

E.164: E.164 number. This is an optional attribute.

In the POST request at least one of the attributes ip or prefix or FQDN or URI MUST be present. DOTS agents can safely ignore Vendor-Specific parameters they don’t understand.

Figure 4 shows a POST request to create alias called "https1" for HTTP(S) servers with IP addresses 2002:db8:6401::1 and 2002:db8:6401::2 listening on port 443.

```
POST /restconf/data/ietf-dots-data-channel-identifier HTTP/1.1
Host: www.example.com
Content-Format: "application/yang.api+json"
{
  "ietf-dots-data-channel-identifier:identifier": {
    "alias": [
      {
        "alias-name": "Server1",
        "traffic-protocol": [
          6
        ],
        "ip": [
          "2002:db8:6401::1",
          "2002:db8:6401::2"
        ],
        "port-range": [
          {
            "lower-port": 443
          }
        ]
      }
    ]
  }
}
```

Figure 4: POST to create identifiers

The DOTS server indicates the result of processing the POST request using HTTP response codes. HTTP 2xx codes are success, HTTP 4xx codes are some sort of invalid requests and 5xx codes are returned if the DOTS server has erred or it is incapable of accepting the alias. Response code 201 (Created) will be returned in the response if the DOTS server has accepted the alias. If the request is missing one or more mandatory attributes then 400 (Bad Request) will be returned in the response or if the request contains invalid or unknown parameters then 400 (Invalid query) will be returned in the response. The HTTP response will include the JSON body received in the request.

The DOTS client can use the PUT request (Section 4.5 in [RFC8040]) to create or modify the aliases in the DOTS server.

3.2.2. Delete Identifiers

A DELETE request is used to delete identifiers maintained by a DOTS server (Figure 5).

```
  DELETE /restconf/data/ietf-dots-data-channel-identifier:identifier\
         /alias=Server1 HTTP/1.1
  Host: {host}:{port}
```

Figure 5: DELETE identifier

In RESTCONF, URI-encoded path expressions are used. A RESTCONF data resource identifier is encoded from left to right, starting with the top-level data node, according to the "api-path" rule defined in Section 3.5.3.1 of [RFC8040]. The data node in the above path expression is a YANG list node and MUST be encoded according to the rules defined in Section 3.5.1 of [RFC8040].

If the DOTS server does not find the alias name conveyed in the DELETE request in its configuration data, then it responds with a 404 (Not Found) error response code. The DOTS server successfully acknowledges a DOTS client’s request to remove the identifier using 204 (No Content) in the response.

3.2.3. Retrieving Installed Identifiers

A GET request is used to retrieve the set of installed identifiers from a DOTS server (Section 3.3.1 in [RFC8040]). Figure 6 shows how to retrieve all the identifiers that were instantiated by the DOTS client. The content parameter and its permitted values are defined in Section 4.8.1 of [RFC8040].

```
GET /restconf/data/ietf-dots-data-channel-identifier:identifier?\
    content=config HTTP/1.1
Host: {host}:{port}
Accept: application/yang-data+json
```

Figure 6: GET to retrieve all the installed identifiers

Figure 7 shows response for all identifiers on the DOTS server.

```
{
 "ietf-dots-data-channel-identifier:identifier": [
  {
    "alias": [
      {
        "alias-name": "Server1",
        "traffic-protocol": [
          6
        ],
        "ip": [
          "2002:db8:6401::1",
          "2002:db8:6401::2"
        ],
        "port-range": [
          {
            "lower-port": 443
          }
        ]
      }
    ]
  },
  {
    "alias": [
      {
        "alias-name": "Server2",
        "traffic-protocol": [
          6
        ],
        "ip": [
          "2002:db8:6401::10",
          "2002:db8:6401::20"
        ],
        "port-range": [
          {
            "lower-port": 80
          }
        ]
      }
    ]
  }
 ]
}
```

Figure 7: Response body

If the DOTS server does not find the alias name conveyed in the GET request in its configuration data, then it responds with a 404 (Not Found) error response code.

3.3. Filtering Rules

The DOTS server either receives the filtering rules directly from the DOTS client or via the DOTS gateway. If the DOTS client signals the filtering rules via the DOTS gateway then the DOTS gateway validates if the DOTS client is authorized to signal the filtering rules and if the client is authorized propagates the rules to the DOTS server. Likewise, the DOTS server validates if the DOTS gateway is authorized to signal the filtering rules. To create or purge filters, the DOTS client sends HTTP requests to the DOTS gateway. The DOTS gateway validates the rules in the requests and proxies the requests containing the filtering rules to a DOTS server. When the DOTS gateway receives the associated HTTP response from the DOTS server, it propagates the response back to the DOTS client.

The following APIs define means for a DOTS client to configure filtering rules on a DOTS server.

3.3.1. Install Filtering Rules

A POST request is used to push filtering rules to a DOTS server. Figure 8 shows a POST request example to block traffic from 10.10.10.1/24, destined to 11.11.11.1/24. The ACL JSON configuration for the filtering rule is generated using the ACL YANG data model defined in [I-D.ietf-netmod-acl-model] and the ACL configuration XML for the filtering rule is specified in Section 4.3 of [I-D.ietf-netmod-acl-model]. This specification updates the ACL YANG data model defined in [I-D.ietf-netmod-acl-model] to support rate-limit action.

```
POST /restconf/data/ietf-access-control-list HTTP/1.1
Host: www.example.com
Content-Format: "application/yang.api+json"
{
 "ietf-access-control-list:access-lists": {
    "acl": [
        {
             "acl-name": "sample-ipv4-acl",
             "acl-type": "ipv4",
             "access-list-entries": {
                 "ace": [
                     {
                         "rule-name": "rule1",
                         "matches": {
                             "source-ipv4-network": "10.10.10.1/24",
                             "destination-ipv4-network": "11.11.11.1/24"
                          },
                          "actions": {
                              "deny": [null]
                          }
                      }
                  ]
             }
        }
    ]
 }
}
```

Figure 8: POST to install filterng rules

The header parameters defined in [I-D.ietf-netmod-acl-model] are discussed below:

acl-name: The name of access-list. This is a mandatory attribute.
acl-type: Indicates the primary intended type of match criteria (e.g. IPv4, IPv6). This is a mandatory attribute.
protocol: Internet Protocol numbers. This is an optional attribute.
source-ipv4-network: The source IPv4 prefix. This is an optional attribute.
destination-ipv4-network: The destination IPv4 prefix. This is an optional attribute.
actions: "deny" or "permit" or "rate-limit". "permit" action is used to white-list traffic. "deny" action is used to black-list traffic. "rate-limit" action is used to rate-limit traffic, the allowed traffic rate is represented in bytes per second indicated in IEEE floating point format [IEEE.754.1985]. If actions

attribute is not specified in the request then the default action is "deny". This is an optional attribute.

The DOTS server indicates the result of processing the POST request using HTTP response codes. HTTP 2xx codes are success, HTTP 4xx codes are some sort of invalid requests and 5xx codes are returned if the DOTS server has erred or it is incapable of configuring the filtering rules. Response code 201 (Created) will be returned in the response if the DOTS server has accepted the filtering rules. If the request is missing one or more mandatory attributes then 400 (Bad Request) will be returned in the response or if the request contains invalid or unknown parameters then 400 (Invalid query) will be returned in the response.

The DOTS client can use the PUT request to create or modify the filtering rules in the DOTS server.

3.3.2. Remove Filtering Rules

A DELETE request is used to delete filtering rules from a DOTS server (Figure 9).

```
DELETE /restconf/data/ietf-access-control-list:access-lists/acl-name\
       =sample-ipv4-acl&acl-type=ipv4 HTTP/1.1
Host: {host}:{port}
```

Figure 9: DELETE to remove the filtering rules

If the DOTS server does not find the access list name and access list type conveyed in the DELETE request in its configuration data, then it responds with a 404 (Not Found) error response code. The DOTS server successfully acknowledges a DOTS client’s request to withdraw the filtering rules using 204 (No Content) response code, and removes the filtering rules as soon as possible.

3.3.3. Retrieving Installed Filtering Rules

The DOTS client periodically queries the DOTS server to check the counters for installed filtering rules. A GET request is used to retrieve filtering rules from a DOTS server. Figure 10 shows how to retrieve all the filtering rules programmed by the DOTS client and the number of matches for the installed filtering rules.

```
GET /restconf/data/ietf-access-control-list:access-lists?content=all HTTP/1.1
Host: {host}:{port}
Accept: application/yang-data+json
```

Figure 10: GET to retrieve the configuration data and state data for the filtering rules

If the DOTS server does not find the access list name and access list type conveyed in the GET request in its configuration data, then it responds with a 404 (Not Found) error response code.

4. IANA Considerations

This specification registers new parameters for the DOTS data channel and establishes registries for mappings to JSON attributes.

4.1. DOTS Data Channel JSON Attribute Mappings Registry

A new registry will be requested from IANA, entitled "DOTS data channel JSON attribute Mappings Registry". The registry is to be created as Expert Review Required.

4.2. Registration Template

JSON Attribute:
: JSON attribute name.

Description:
: Brief description of the attribute.

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.

4.3. Initial Registry Contents

- JSON Attribute: "alias-name"
- Description: Name of alias.
- Change Controller: IESG
- Specification Document(s): this document

- JSON Attribute: "traffic-protocol"
- Description: Internet protocol numbers.
- Change Controller: IESG

- Specification Document(s): this document

- JSON Attribute: "port-range"
- Description: The port range, lower-port for lower port number and upper-port for upper port number. For TCP, UDP, SCTP, or DCCP: the range of ports (e.g., 80 to 8080).
- Change Controller: IESG
- Specification Document(s): this document

- JSON Attribute: "lower-port"
- Description: Lower port number for port range.
- Change Controller: IESG
- Specification Document(s): this document

- JSON Attribute: "upper-port"
- Description: Upper port number for port range.
- Change Controller: IESG
- Specification Document(s): this document

- JSON Attribute: "ip"
- Description: IP address.
- Change Controller: IESG
- Specification Document(s): this document

- JSON Attribute: "prefix"
- Description: IP prefix
- Change Controller: IESG
- Specification Document(s): this document

- JSON Attribute: "FQDN"
- Description: Fully Qualified Domain Name, is the full name of a system, rather than just its hostname. For example, "venera" is a hostname, and "venera.isi.edu" is an FQDN.
- Change Controller: IESG
- Specification Document(s): this document

- JSON Attribute: "URI"
- Description: Uniform Resource Identifier (URI).
- Change Controller: IESG
- Specification Document(s): this document

- JSON Attribute: "E.164"
- Description: E.164 number.
- Change Controller: IESG
- Specification Document(s): this document

5. Contributors

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6. Security Considerations

Authenticated encryption MUST be used for data confidentiality and message integrity. TLS based on client certificate MUST be used for mutual authentication. The interaction between the DOTS agents requires Transport Layer Security (TLS) with a cipher suite offering confidentiality protection and the guidance given in [RFC7525] MUST be followed to avoid attacks on TLS.

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.

Special care should be taken in order to ensure that the activation of the proposed mechanism won't have an impact on the stability of the network (including connectivity and services delivered over that network).

Involved functional elements in the cooperation system must establish exchange instructions and notification over a secure and authenticated channel. Adequate filters can be enforced to avoid that nodes outside a trusted domain can inject request such as deleting filtering rules. Nevertheless, attacks can be initiated from within the trusted domain if an entity has been corrupted. Adequate means to monitor trusted nodes should also be enabled.

7. Acknowledgements

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Distributed Denial-of-Service Open Threat Signaling (DOTS) Signal Channel
draft-reddy-dots-signal-channel-09

Abstract

This document specifies a mechanism that a DOTS client can use to signal that a network is under a Distributed Denial-of-Service (DDoS) attack to an upstream DOTS server so that appropriate mitigation actions are undertaken (including, blackhole, drop, rate-limit, or add to watch list) on the suspect traffic. The document specifies the DOTS signal channel including Happy Eyeballs considerations. The specification of the DOTS data channel is elaborated in a companion document.

Table of Contents

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.

In many cases, it may not be possible for an network administrators to determine the causes of an attack, but instead just realize that certain resources seem to be under attack. This document, which adheres to the DOTS architecture [I-D.ietf-dots-architecture], proposes that, in such cases, the DOTS client just inform its DOTS server(s) that the network is under a potential attack and that the mitigator monitors traffic to the network to mitigate any possible attacks. This cooperation between DOTS agents contributes to ensure a highly automated network that is also robust, reliable and secure.

Protocol requirements for DOTS signal channel are obtained from DOTS requirements [I-D.ietf-dots-requirements].

This document satisfies all the use cases discussed in [I-D.ietf-dots-use-cases] except the Third-party DOTS notifications use case in Section 3.2.3 of [I-D.ietf-dots-use-cases] which is an optional feature and not a core use case. Third-party DOTS notifications are not part of the DOTS requirements document. Moreover, the DOTS architecture does not assess whether that use case may have an impact on the architecture itself and/or the DOTS trust model.

This is a companion document to the DOTS data channel specification [I-D.reddy-dots-data-channel].

2. Notational Conventions and Terminology

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

(D)TLS: For brevity this term is used for statements that apply to both Transport Layer Security [RFC5246] and Datagram Transport Layer Security [RFC6347]. Specific terms will be used for any statement that applies to either protocol alone.

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

3. Solution Overview

Network applications have finite resources like CPU cycles, number of processes or threads they can create and use, maximum number of simultaneous connections it can handle, 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 fashion. However, an attacker may be able to prevent an application from performing its intended task by causing the application to exhaust the finite supply of a specific resource.

TCP DDoS SYN-flood, for example, is a memory-exhaustion attack on the victim and ACK-flood is a CPU exhaustion attack on the victim ([RFC4987]). Attacks on the link are carried out by sending enough traffic such that the link becomes excessively congested, and legitimate traffic suffers high packet loss. Stateful firewalls can also be attacked by sending traffic that causes the firewall to hold excessive state and the firewall runs out of memory, and can no longer instantiate the state required to pass legitimate flows. Other possible DDoS attacks are discussed in [RFC4732].

In each of the cases described above, the possible arrangements between the DOTS client and DOTS server to mitigate the attack are discussed in [I-D.ietf-dots-use-cases]. An example of network diagram showing a deployment of these elements is shown in Figure 1. Architectural relationships between involved DOTS agents is explained in [I-D.ietf-dots-architecture]. In this example, the DOTS server is operating on the access network.

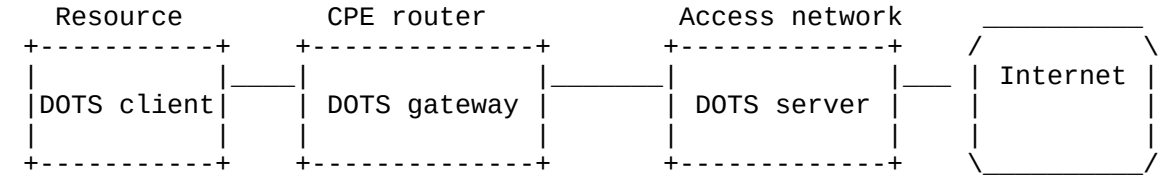

Figure 1

The DOTS server can also be running on the Internet, as depicted in Figure 2.

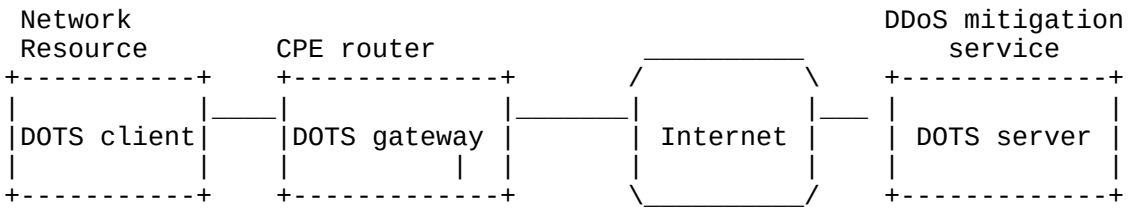

Figure 2

In typical deployments, the DOTS client belongs to a different administrative domain than the DOTS server. For example, the DOTS client is a web server serving content owned and operated by an domain, while the DOTS server is owned and operated by a different domain providing DDoS mitigation services. That domain providing DDoS mitigation service might, or might not, also provide Internet access service to the website operator.

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 the DOTS server or indirectly via a DOTS gateway.

This document focuses on the DOTS signal channel.

4. Happy Eyeballs for DOTS Signal Channel

DOTS signaling can happen with DTLS [RFC6347] over UDP and TLS [RFC5246] over TCP. A DOTS client can use DNS to determine the IP address(es) of a DOTS server or a DOTS client may be provided with the list of DOTS server IP addresses. The DOTS client MUST know a DOTS server's domain name; hard-coding the domain name of the DOTS server into software is NOT RECOMMENDED in case the domain name is not valid or needs to change for legal or other reasons. The DOTS client performs A and/or AAAA record lookup of the domain name and the result will be a list of IP addresses, each of which can be used to contact the DOTS server using UDP and TCP.

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 can 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, the DOTS client will fail to establish a DTLS session with the DOTS server and will, then, have to fall back to TLS over TCP incurring significant connection delays. [I-D.ietf-dots-requirements] discusses that DOTS

client and server will have to support both connectionless and connection-oriented protocols.

To overcome these connection setup problems, the DOTS client can try connecting to the DOTS server using both IPv6 and IPv4, and try both DTLS over UDP and TLS over TCP in a fashion similar to the Happy Eyeballs mechanism [RFC6555]. These connection attempts are performed by the DOTS client when its initializes, and the client uses that information for its subsequent alert to the DOTS server. In order of preference (most preferred first), it is UDP over IPv6, UDP over IPv4, TCP over IPv6, and finally TCP over IPv4, which adheres to address preference order [RFC6724] and the DOTS preference that UDP be used over TCP (to avoid TCP's head of line blocking).

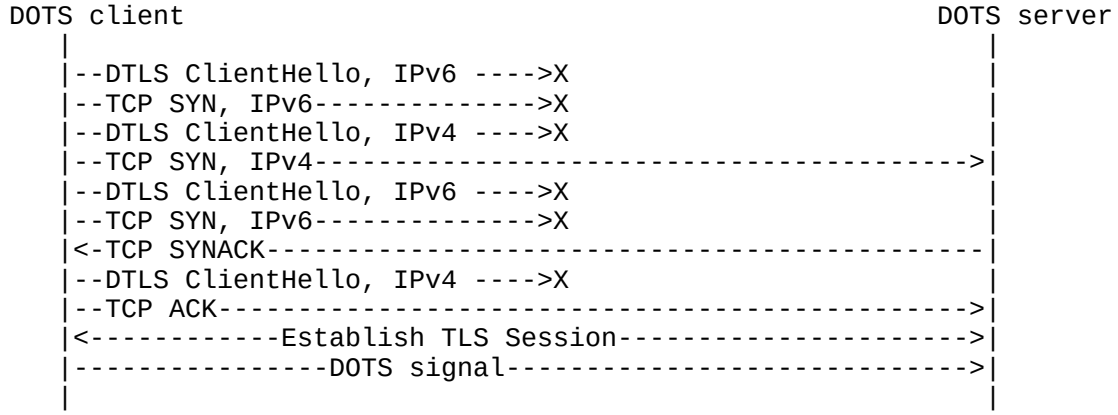

Figure 3: Happy Eyeballs

In reference to Figure 3, 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 is dropped by a middle box but has little impact to the DOTS client because there is no long delay before using IPv4 and TCP. The IPv6 path and UDP over IPv6 and IPv4 is retried until the DOTS client gives up.

5. DOTS Signal Channel

5.1. Overview

Constrained Application Protocol (CoAP) [RFC7252] is used for DOTS signal channel (Figure 4). COAP was designed according to the REST architecture, and thus exhibits functionality similar to that of HTTP, it is quite straightforward to map from CoAP to HTTP and from HTTP to CoAP. CoAP has been defined to make use of both DTLS over

UDP and TLS over TCP [I-D.ietf-core-coap-tcp-tls]. The advantages of COAP are: (1) Like HTTP, CoAP is based on the successful REST model, (2) CoAP is designed to use minimal resources, (3) CoAP integrates with JSON, CBOR or any other data format, (4) asynchronous message exchanges, (5) includes a congestion control mechanism (6) allows configuration of message transmission parameters specific to the application environment (including dynamically adjusted values, see Section 4.8.1 in [RFC7252]) etc.

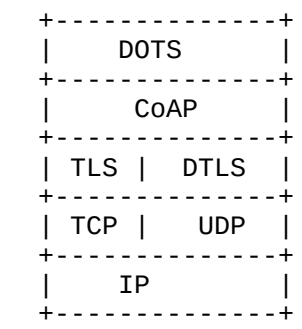

Figure 4: Abstract Layering of DOTS signal channel over CoAP over (D)TLS

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 client SHOULD re-use the (D)TLS session.

Concise Binary Object Representation (CBOR) [RFC7049] is a binary encoding designed for small code and message size, CBOR encoded payloads are used to convey signal channel specific payload messages that convey request parameters and response information such as errors. This specification uses the encoding rules defined in [I-D.ietf-core-yang-cbor] for representing DOTS signal channel configuration data defined using YANG (Section 5.2) as CBOR data.

5.2. DOTS Signal YANG Model

5.2.1. Mitigation Request Model structure

This document defines the YANG module "ietf-dots-signal", which has the following structure:

```
   module: ietf-dots-signal
       +--rw mitigation-scope
          +--rw scope* [policy-id]
             +--rw policy-id            int32
             +--rw target-ip*           inet:ip-address
             +--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 FQDN*                inet:domain-name
             +--rw URI*                 inet:uri
             +--rw E.164*               string
             +--rw alias*               string
             +--rw lifetime?            int32
```

5.2.2. Mitigation Request Model

<CODE BEGINS> file "ietf-dots-signal@2016-11-28.yang"

```
module ietf-dots-signal {
      namespace "urn:ietf:params:xml:ns:yang:ietf-dots-signal";
      prefix "signal";
      import ietf-inet-types {
          prefix "inet";
      }
     organization "Cisco Systems, Inc.";
     contact "Tirumaleswar Reddy <tireddy@cisco.com>";

     description
       "This module contains YANG definition for DOTS
       signal sent by the DOTS client to the DOTS server";

     revision 2016-11-28 {
       reference
       "https://tools.ietf.org/html/draft-reddy-dots-signal-channel";
     }

     container mitigation-scope {
          description "top level container for mitigation request";
          list scope {
             key policy-id;
             description "Identifier for the mitigation request";
             leaf policy-id {
                type int32;
                description "policy identifier";
              }
              leaf-list target-ip {
```

```
                type inet:ip-address;
                description "IP address";
            }
            leaf-list target-prefix {
                type inet:ip-prefix;
                description "prefix";
            }
            list target-port-range {
                key "lower-port upper-port";
                description "Port range. When only lower-port is present,
                             it represents a single port.";
                leaf lower-port {
                   type inet:port-number;
                   mandatory true;
                   description "lower port";
                }
                leaf upper-port {
                   type inet:port-number;
                       must ". >= ../lower-port" {
                         error-message
                         "The upper-port must be greater than or
                          equal to lower-port";
                       }
                       description "upper port";
                }
            }
            leaf-list target-protocol {
                type uint8;
                description "Internet Protocol number";
            }
            leaf-list FQDN {
                 type inet:domain-name;
                 description "FQDN";
            }
            leaf-list URI {
                type inet:uri;
                description "URI";
            }
            leaf-list E.164 {
                 type string;
                 description "E.164 number";
            }
            leaf-list alias {
                type string;
                description "alias name";
            }
            leaf lifetime {
                type int32;
```

```
                    description "lifetime";
                }
            }
        }
    }
<CODE ENDS>
```

5.2.3. Session Configuration Model structure

This document defines the YANG module "ietf-dots-signal-config", which has the following structure:

```
module: ietf-dots-signal-config
    +--rw signal-config
       +--rw policy-id?            int32
       +--rw heartbeat-interval?   int16
       +--rw max-retransmit?       int16
       +--rw ack-timeout?          int16
       +--rw ack-random-factor?    decimal64
```

5.2.4. Session Configuration Model

<CODE BEGINS> file "ietf-dots-signal-config@2016-11-28.yang"

```
module ietf-dots-signal-config {
     namespace "urn:ietf:params:xml:ns:yang:ietf-dots-signal-config";
     prefix "config";
     organization "Cisco Systems, Inc.";
     contact "Tirumaleswar Reddy <tireddy@cisco.com>";

     description
       "This module contains YANG definition for DOTS
       signal channel session configuration";

     revision 2016-11-28 {
       reference
       "https://tools.ietf.org/html/draft-reddy-dots-signal-channel";
     }

     container signal-config {
          description "top level container for DOTS signal channel session
                       configuration";
          leaf policy-id {
              type int32;
              description "Identifier for the DOTS signal channel
                           session configuration data";
          }
          leaf heartbeat-interval {
              type int16;
              description "heartbeat interval";
          }
          leaf max-retransmit {
              type int16;
              description "Maximum number of retransmissions";
          }
          leaf ack-timeout {
              type int16;
              description "Initial retransmission timeout value";
          }
          leaf ack-random-factor {
              type decimal64 {
              fraction-digits 2;
              }
              description "Random factor used to influence the timing of
                           retransmissions";
        }
      }
}
```

<CODE ENDS>

5.3. Mitigation Request

The following APIs define the means to convey a DOTS signal from a DOTS client to a DOTS server:

PUT requests: are used to convey the DOTS signal from a DOTS client to a DOTS server over the signal channel, possibly traversing a DOTS gateway, indicating the DOTS client's need for mitigation, as well as the scope of any requested mitigation (Section 5.3.1). DOTS gateway act as a CoAP-to-CoAP Proxy (explained in [RFC7252]). PUT requests are also used by the DOTS client to convey mitigation efficacy updates to the DOTS server (Section 5.3.4).

DELETE requests: are used by the DOTS client to withdraw the request for mitigation from the DOTS server (Section 5.3.2).

GET requests: are used by the DOTS client to retrieve the DOTS signal(s) it had conveyed to the DOTS server (Section 5.3.3).

Reliability is provided to the requests and responses by marking them as Confirmable (CON) 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]. Reliability is provided to the responses by marking them as Confirmable (CON) messages. The DOTS server can either piggyback the response in the acknowledgement message or if the DOTS server is not able to 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 then in turn needs to be acknowledged by the DOTS client (see Sections 5.2.1 and Sections 5.2.2 in [RFC7252]).

DOTS agents should follow the data transmission guidelines discussed in Section 3.1.3 of [I-D.ietf-tsvwg-rfc5405bis] and control transmission behavior by not sending on average more than one UDP datagram per RTT to the peer DOTS agent. Requests marked by the DOTS client as Non-confirmable messages are sent at regular intervals until a response is received from the DOTS server and if the DOTS client cannot maintain a RTT estimate then it SHOULD NOT send more than one Non-confirmable request every 3 seconds, and SHOULD use an even less aggressive rate when possible (case 2 in Section 3.1.3 of [I-D.ietf-tsvwg-rfc5405bis]).

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 to which to correlate this response, making the retransmission an unexpected message; 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 in [RFC7252] for more details).

5.3.1. Convey DOTS Signals

When suffering an attack and desiring DoS/DDoS mitigation, a DOTS signal is sent by the DOTS client to the DOTS server. A PUT request is used to convey a DOTS signal to the DOTS server (Figure 5, illustrated in JSON diagnostic notation). The DOTS server can enable mitigation on behalf of the DOTS client by communicating the DOTS client's request to the mitigator and relaying any mitigator feedback to the requesting DOTS client. The PUT request and response are marked as Non-confirmable messages.

```
Header: PUT (Code=0.03)
Uri-Host: "host"
Uri-Path: ".well-known"
Uri-Path: "version"
Uri-Path: "dots-signal"
Uri-Path: "signal"
Content-Type: "application/cbor"
{
  "mitigation-scope": {
    "scope": [
      {
        "policy-id": integer,
        "target-ip": [
           "string"
         ],
        "target-prefix": [
           "string"
         ],
        "target-port-range": [
           {
             "lower-port": integer,
             "upper-port": integer
           }
         ],
         "target-protocol": [
           integer
         ],
         "FQDN": [
           "string"
         ],
         "URI": [
           "string"
         ],
         "E.164": [
           "string"
         ],
         "alias": [
           "string"
         ],
        "lifetime": integer
      }
    ]
  }
}
```

Figure 5: PUT to convey DOTS signals

The parameters are described below.

policy-id: Identifier for the mitigation request represented using an integer. This identifier MUST be unique for each mitigation request bound to the DOTS client, i.e., the policy-id parameter value in the mitigation request needs to be unique relative to the policy-id parameter values of active mitigation requests conveyed from the DOTS client to the DOTS server. This identifier MUST be generated by the DOTS client. This document does not make any assumption about how this identifier is generated. This is a mandatory attribute.

target-ip: A list of IP addresses under attack. IP addresses are separated by commas. This is an optional attribute.

target-prefix: A list of prefixes under attack. Prefixes are separated by commas. Prefixes are represented using CIDR notation [RFC4632]. This is an optional attribute.

target-port-range: A list of ports under attack. The port range, lower-port for lower port number and upper-port for upper port number. When only lower-port is present, it represents a single port. For TCP, UDP, SCTP, or DCCP: the range of ports (e.g., 1024-65535). This is an optional attribute.

target-protocol: A list of protocols under attack. Internet Protocol numbers. This is an optional attribute.

FQDN: A list of Fully Qualified Domain Names. Fully Qualified Domain Name (FQDN) is the full name of a system, rather than just its hostname. For example, "venera" is a hostname, and "venera.isi.edu" is an FQDN. This is an optional attribute.

URI: A list of Uniform Resource Identifiers (URI). This is an optional attribute.

E.164: A list of E.164 numbers. This is an optional attribute.

alias: A list of aliases (see Section 3.1.1 in [I-D.reddy-dots-data-channel]). This is an optional attribute.

lifetime: Lifetime of the mitigation request in seconds. 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. The default lifetime of the mitigation request is 3600 seconds (60 minutes) -- 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. A lifetime of zero indicates indefinite lifetime for the mitigation request. The server MUST always indicate the actual lifetime in the response. This is an optional attribute in the request.

The CBOR key values for the parameters are defined in Section 6. The IANA Considerations section defines how the CBOR key values can be allocated to standards bodies and vendors. In the PUT request at least one of the attributes target-ip or target-prefix or FQDN or URI or alias MUST be present. DOTS agents can safely ignore Vendor-Specific parameters they don’t understand. The relative order of two

mitigation requests from a DOTS client is determined by comparing their respective policy-id values. The mitigation request with higher numeric policy-id value has higher precedence (and thus will match before) than the mitigation request with lower numeric policy-id value.

In both DOTS signal and data channel sessions, the DOTS client MUST authenticate itself to the DOTS server (Section 9). The DOTS server couples the DOTS signal and data channel sessions using the DOTS client identity, 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 then the DOTS server returns 4.00 (Bad Request) in the response. The DOTS server couples the DOTS signal channel sessions using the DOTS client identity, the DOTS server uses policy-id parameter value to detect duplicate mitigation requests.

Figure 6 shows a PUT request example to signal that ports 80, 8080, and 443 on the servers 2002:db8:6401::1 and 2002:db8:6401::2 are being attacked (illustrated in JSON diagnostic notation).

```
Header: PUT (Code=0.03)
Uri-Host: "www.example.com"
Uri-Path: ".well-known"
Uri-Path: "v1"
Uri-Path: "dots-signal"
Uri-Path: "signal"
Content-Format: "application/cbor"
{
  "mitigation-scope": {
    "scope": [
      {
        "policy-id": 12332,
        "target-ip": [
           "2002:db8:6401::1",
           "2002:db8:6401::2"
         ],
        "target-port-range": [
          {
            "lower-port": 80
          },
          {
            "lower-port": 443
          },
          {
             "lower-port": 8080
          }
         ],
```

```
            "target-protocol": [
              6
            ]
          }
        ]
      }
    }
```

The CBOR encoding format is shown below:

```
a1                                      # map(1)
   01                                   # unsigned(1)
   a1                                   # map(1)
      02                                # unsigned(2)
      81                                # array(1)
         a4                             # map(4)
            03                          # unsigned(3)
            19 302c                     # unsigned(12332)
            04                          # unsigned(4)
            82                          # array(2)
               70                       # text(16)
                  323030323a6462383a363430313a3a31 # "2002:db8:6401::1"
               70                       # text(16)
                  323030323a6462383a363430313a3a32 # "2002:db8:6401::2"
            05                          # unsigned(5)
            83                          # array(3)
               a1                       # map(1)
                  06                    # unsigned(6)
                  18 50                 # unsigned(80)
               a1                       # map(1)
                  06                    # unsigned(6)
                  19 01bb               # unsigned(443)
               a1                       # map(1)
                  06                    # unsigned(6)
                  19 1f90               # unsigned(8080)
            08                          # unsigned(8)
            81                          # array(1)
               06                       # unsigned(6)
```

Figure 6: POST for DOTS signal

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. 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. If the DOTS server does not find the policy-id parameter value conveyed in the PUT request in its configuration data then the server MAY accept the mitigation request, and a 2.01 (Created) response is returned to the DOTS client, and the DOTS server will try to mitigate the attack. If the DOTS server finds the policy-id parameter value conveyed in the PUT request in its configuration data then the server MAY update the mitigation request, and a 2.04 (Changed) response is returned to indicate a successful updation of the mitigation request. If the request is missing one or more mandatory attributes, then 4.00 (Bad Request) will be returned in the response or if the request contains invalid or unknown parameters then 4.02 (Invalid query) will be returned in the response. For responses indicating a client or server error, the payload explains the error situation of the result of the requested action (Section 5.5 in [RFC7252]).

5.3.2. Withdraw a DOTS Signal

A DELETE request is used to withdraw a DOTS signal from a DOTS server (Figure 7). The DELETE request and response are marked as Confirmable messages.

```
  Header: DELETE (Code=0.04)
  Uri-Host: "host"
  Uri-Path: ".well-known"
  Uri-Path: "version"
  Uri-Path: "dots-signal"
  Uri-Path: "signal"
  Content-Format: "application/cbor"
  {
    "mitigation-scope": {
      "scope": [
        {
          "policy-id": integer
        }
      ]
    }
  }
```

Figure 7: Withdraw DOTS signal

If the DOTS server does not find the policy-id parameter value conveyed in the DELETE request in its configuration data, then it responds with a 4.04 (Not Found) error response code. The DOTS server successfully acknowledges a DOTS client’s request to withdraw the DOTS signal using 2.02 (Deleted) response code, and ceases mitigation activity as quickly as possible.

5.3.3. Retrieving a DOTS Signal

A GET request is used to retrieve information and status of a DOTS signal from a DOTS server (Figure 8). If the DOTS server does not find the policy-id parameter value conveyed in the GET request in its configuration data, then it responds with a 4.04 (Not Found) error response code. The GET request is marked as Non-confirmable message. The 'c' (content) parameter and its permitted values defined in [I-D.ietf-core-comi] can be used to retreive non-configuration data or configuration data or both.

1) To retrieve all DOTS signals signaled by the DOTS client.

```
Header: GET (Code=0.01)
Uri-Host: "host"
Uri-Path: ".well-known"
Uri-Path: "version"
Uri-Path: "dots-signal"
Uri-Path: "signal"
Observe : 0
```

2) To retrieve a specific DOTS signal signaled by the DOTS client. The configuration data in the response will be formatted in the same order it was processed at the DOTS server.

```
Header: GET (Code=0.01)
Uri-Host: "host"
Uri-Path: ".well-known"
Uri-Path: "version"
Uri-Path: "dots-signal"
Uri-Path: "signal"
Observe : 0
Content-Format: "application/cbor"
{
  "mitigation-scope": {
    "scope": [
      {
        "policy-id": integer
      }
    ]
  }
}
```

Figure 8: GET to retrieve the rules

Figure 9 shows a response example of all the active mitigation requests associated with the DOTS client on the DOTS server and the mitigation status of each mitigation request.

```
{
  "mitigation-scope":[
    {
      "scope": [
        {
          "policy-id": 12332,
          "target-protocol": [
              17
           ],
          "lifetime":1800,
          "status":2,
          "bytes_dropped": 134334555,
          "bps_dropped":  43344,
          "pkts_dropped": 333334444,
          "pps_dropped": 432432
        }
      ]
    },
    {
      "scope": [
        {
          "policy-id": 12333,
          "target-protocol": [
              6
           ],
          "lifetime":1800,
          "status":3
          "bytes_dropped": 0,
          "bps_dropped":  0,
          "pkts_dropped": 0,
          "pps_dropped": 0
        }
      ]
    }
  ]
}
```

Figure 9: Response body

The mitigation status parameters are described below.

bytes_dropped: The total dropped byte count for the mitigation request. This is a optional attribute.
bps_dropped: The average dropped bytes per second for the mitigation request. This is a optional attribute.
pkts_dropped: The total dropped packet count for the mitigation request. This is a optional attribute.

pps_dropped: The average dropped packets per second for the mitigation request. This is a optional attribute.
status: Status of attack mitigation. The 'status' parameter is a mandatory attribute.

The various possible values of 'status' parameter are explained below:

Parameter value	Description
1	Attack mitigation is in progress (e.g., changing the network path to re-route the inbound traffic to 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.

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. A DOTS client that is no longer interested in receiving notifications from the DOTS server can simply "forget" the observation. The notification response is marked as Non-confirmable message. When the DOTS server then 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.

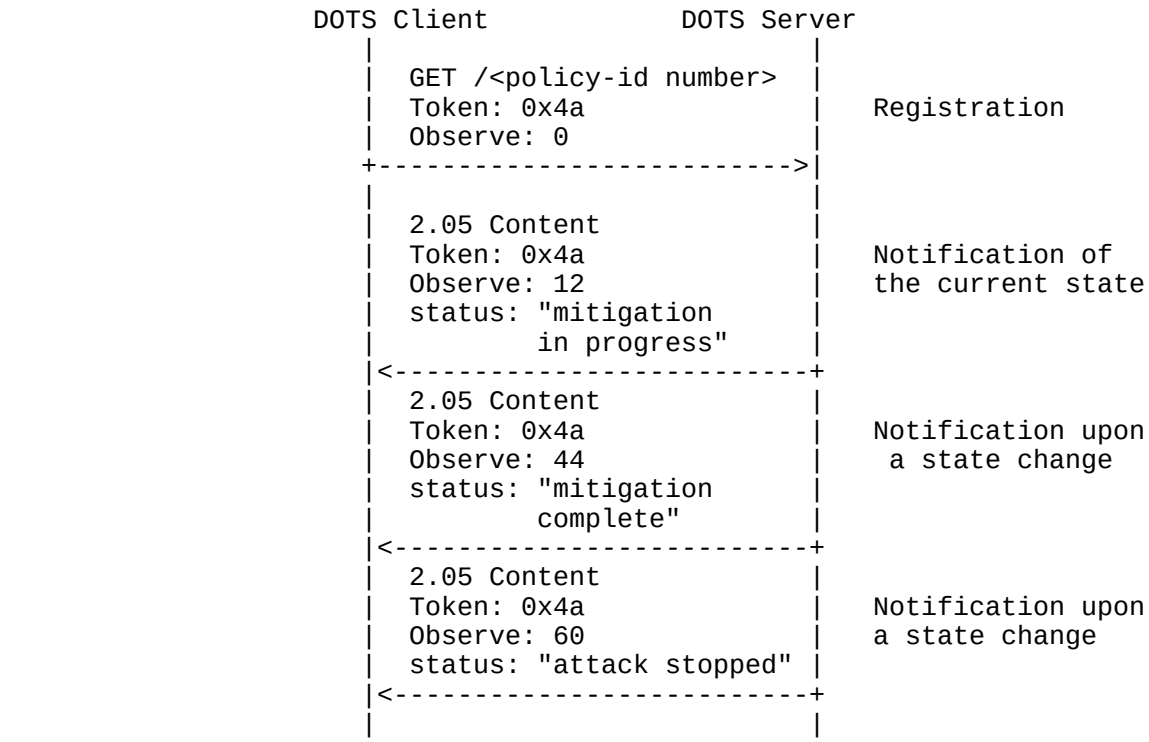

Figure 10: Notifications of attack mitigation status

5.3.3.1. Mitigation Status

A DOTS client retrieves the information about a DOTS signal at frequent intervals to determine the status of an attack. 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, and the DOTS client recalls the mitigation request.

A DOTS client should react to the status of the attack from the DOTS server and not the fact that it has recognized, using its own means, that the attack has been mitigated. This ensures that the DOTS client does not recall a mitigation request in a premature fashion 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 and the attack is not completely averted.

5.3.4. Efficacy Update from DOTS Client

While DDoS mitigation is active, a DOTS client MAY frequently transmit DOTS mitigation efficacy updates to the relevant DOTS server. An PUT request (Figure 11) is used to convey the mitigation efficacy update to the DOTS server. The PUT request MUST include all the parameters used in the PUT request to convey the DOTS signal (Section 5.3.1). The PUT request and response are marked as Non-Confirmable messages.

```
Header: PUT (Code=0.03)
Uri-Host: "host"
Uri-Path: ".well-known"
Uri-Path: "version"
Uri-Path: "dots-signal"
Uri-Path: "signal"
Content-Format: "application/cbor"
{
 "mitigation-scope": {
   "scope": [
     {
       "policy-id": integer,
       "target-ip": [
          "string"
        ],
       "target-port-range": [
          {
            "lower-port": integer,
            "upper-port": integer
          }
        ],
        "target-protocol": [
          integer
        ],
        "FQDN": [
          "string"
        ],
        "URI": [
          "string"
        ],
        "E.164": [
          "string"
        ],
        "alias": [
          "string"
        ],
       "lifetime": integer,
       "attack-status": integer
     }
   ]
 }
}
```

Figure 11: Efficacy Update

The 'attack-status' parameter is a mandatory attribute. The various possible values contained in the 'attack-status' parameter are explained below:

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

The DOTS server indicates the result of processing the PUT request using CoAP response codes. The response code 2.04 (Changed) will be returned in the response if the DOTS server has accepted the mitigation efficacy update. If the DOTS server does not find the policy-id parameter value conveyed in the PUT request in its configuration data then the server MAY accept the mitigation request and will try to mitigate the attack, resulting in a 2.01 (Created) Response Code. The 5.xx response codes are returned if the DOTS server has erred or is incapable of performing the mitigation.

5.4. DOTS Signal Channel Session Configuration

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

a. Heartbeat interval: DOTS agents regularly send heartbeats to each other after mutual authentication in order to keep the DOTS signal channel open.
b. Acceptable signal loss ratio: Maximum retransmissions, retransmission timeout value and other message transmission parameters for the DOTS signal channel.

5.4.1. Discover Acceptable Configuration Parameters

A GET request is used to obtain acceptable configuration parameters on the DOTS server for DOTS signal channel session configuration. Figure 12 shows how to obtain acceptable configuration parameters for the server. The GET request and response are marked as Confirmable messages.

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

Figure 12: GET to retrieve configuration

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

```
Content-Format: "application/cbor"
 {
   "heartbeat-interval": {"MinValue": integer, "MaxValue" : integer},
   "max-retransmit": {"MinValue": integer, "MaxValue" : integer},
   "ack-timeout": {"MinValue": integer, "MaxValue" : integer},
   "ack-random-factor": {"MinValue": number, "MaxValue" : number}
  }
```

Figure 13: GET response body

5.4.2. Convey DOTS Signal Channel Session Configuration

A POST request is used to convey the configuration parameters for the signaling channel (e.g., heartbeat interval, maximum retransmissions etc). Message transmission parameters for CoAP are defined in Section 4.8 of [RFC7252]. If the DOTS agent wishes to change the default values of message transmission parameters then it should follow the guidence 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 signaling channel session configuration is applicable to a single DOTS signal channel session between the DOTS agents. The POST request and response are marked as Confirmable messages.

```
Header: POST (Code=0.02)
Uri-Host: "host"
Uri-Path: ".well-known"
Uri-Path: "version"
Uri-Path: "dots-signal"
Uri-Path: "config"
Content-Format: "application/cbor"
{
 "signal-config": {
   "policy-id": integer,
   "heartbeat-interval": integer,
   "max-retransmit": integer,
   "ack-timeout": integer,
   "ack-random-factor": number
 }
}
```

Figure 14: POST to convey the DOTS signal channel session configuration data.

The parameters are described below:

policy-id: Identifier for the DOTS signal channel session configuration data represented as an integer. This identifier MUST be generated by the DOTS client. This document does not make any assumption about how this identifier is generated. This is a mandatory attribute.

heartbeat-interval: Heartbeat interval to check the DOTS peer health. 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 intial 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.

In the POST request at least one of the attributes heartbeat-interval or max-retransmit or ack-timeout or ack-random-factor MUST be present. The POST request with higher numeric policy-id value overrides the DOTS signal channel session configuration data installed by a POST request with a lower numeric policy-id value.

Figure 15 shows a POST request example to convey the configuration parameters for the DOTS signal channel.

```
Header: POST (Code=0.02)
Uri-Host: "www.example.com"
Uri-Path: ".well-known"
Uri-Path: "v1"
Uri-Path: "dots-signal"
Uri-Path: "config"
Content-Format: "application/cbor"
{
  "signal-config": {
   "policy-id": 1234534333242,
   "heartbeat-interval": 30,
   "max-retransmit": 7,
   "ack-timeout": 5,
   "ack-random-factor": 1.5
  }
}
```

Figure 15: POST to convey the configuration parameters

The DOTS server indicates the result of processing the POST request using CoAP response codes. The CoAP response will include the CBOR body received in the request. Response code 2.01 (Created) will be returned in the response if the DOTS server has accepted the configuration parameters. If the request is missing one or more mandatory attributes then 4.00 (Bad Request) will be returned in the response or if the request contains invalid or unknown parameters then 4.02 (Invalid query) will be returned in the response. Response code 4.22 (Unprocessable Entity) will be returned in the response if any of the heartbeat-interval, max-retransmit, target-protocol, ack-timeout and ack-random-factor attribute values is not acceptable to the DOTS server. The DOTS server in the error response conveys the minumum and maximum attribute values acceptable by the DOTS server. The DOTS client can re-try and send the POST request with updated attribute values acceptable to the DOTS server.

```
Content-Format: "application/cbor"
{
   "heartbeat-interval": {"MinValue": 15, "MaxValue" : 60},
   "max-retransmit": {"MinValue": 3, "MaxValue" : 15},
   "ack-timeout": {"MinValue": 1, "MaxValue" : 30},
   "ack-random-factor": {"MinValue": 1.0, "MaxValue" : 4.0}
}
```

Figure 16: Error response body

5.4.3. Delete DOTS Signal Channel Session Configuration

A DELETE request is used to delete the installed DOTS signal channel session configuration data (Figure 17). The DELETE request and response are marked as Confirmable messages.

```
Header: DELETE (Code=0.04)
Uri-Host: "host"
Uri-Path: ".well-known"
Uri-Path: "version"
Uri-Path: "dots-signal"
Uri-Path: "config"
Content-Format: "application/cbor"
{
  "signal-config": {
   "policy-id": integer
  }
}
```

Figure 17: DELETE configuration

If the DOTS server does not find the policy-id parameter value conveyed in the DELETE request in its configuration data, then it responds with a 4.04 (Not Found) error response code. The DOTS server successfully acknowledges a DOTS client’s request to remove the DOTS signal channel session configuration using 2.02 (Deleted) response code.

5.4.4. Retrieving DOTS Signal Channel Session Configuration

A GET request is used to retrieve the installed DOTS signal channel session configuration data from a DOTS server. Figure 18 shows how to retrieve the DOTS signal channel session configuration data. The GET request and response are marked as Confirmable messages.

```
Header: GET (Code=0.01)
Uri-Host: "host"
Uri-Path: ".well-known"
Uri-Path: "version"
Uri-Path: "dots-signal"
Uri-Path: "config"
Content-Format: "application/cbor"
{
  "signal-config": {
   "policy-id": integer
  }
}
```

Figure 18: GET to retrieve configuration

5.5. Redirected Signaling

Redirected Signaling is discussed in detail in Section 3.2.2 of [I-D.ietf-dots-architecture]. If the DOTS server wants to redirect the DOTS client to an alternative DOTS server for a signaling session then the response code 3.00 (alternate server) will be returned in the response to the client. The DOTS server can return the error response code 3.00 in response to a POST or PUT 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 can mark the notification response conveying the alternate server address as a a Confirmable message to request an acknowledgement from the DOTS client.

The DOTS server in the error response conveys the alternate DOTS server FQDN, and the alternate DOTS server IP addresses and TTL (time to live) values in the CBOR body.

```
{
    "alt-server": "string",
    "alt-server-record": [
      {
        "addr": "string",
        "TTL" : integer,
      }
    ]
}
```

Figure 19: Error response body

The parameters are described below:

alt-server: FQDN of alternate DOTS server.

addr: IP address of alternate DOTS server.
TTL: Time to live represented as an integer number of seconds.

Figure 20 shows a 3.00 response example to convey the DOTS alternate server www.example-alt.com, its IP addresses 2002:db8:6401::1 and 2002:db8:6401::2, and TTL values 3600 and 1800.

```
{

    "alt-server": "www.example-alt.com",
    "alt-server-record": [
      {
        "TTL" :  3600,
        "addr": "2002:db8:6401::1"
      },
      {
        "TTL" :  1800,
        "addr": "2002:db8:6401::2"
      }
    ]
}
```

Figure 20: Example of error response body

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

5.6. Heartbeat Mechanism

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 alive firewall or NAT bindings. This probing reduces the frequency of needing a new handshake when a DOTS signal needs to be conveyed to the DOTS server. In DOTS over UDP, heartbeat messages can be exchanged between the DOTS agents using the "COAP ping" mechanism (Section 4.2 in [RFC7252]). The DOTS agent sends an Empty Confirmable message and the peer DOTS agent will respond by sending an Reset message. In DOTS over TCP, heartbeat messages can be exchanged between the DOTS agents using the Ping and Pong messages (Section 4.4 in [I-D.ietf-core-coap-tcp-tls]). The DOTS agent sends

an Ping message and the peer DOTS agent will respond by sending an single Pong message.

6. Mapping parameters to CBOR

All parameters in DOTS signal channel are mapped to CBOR types as follows and are given an integer key value to save space.

Parameter name	CBOR key	CBOR major type of value
mitigation-scope	1	5 (map)
scope	2	5 (map)
policy-id	3	0 (unsigned)
target-ip	4	4 (array)
target-port-range	5	4
lower-port	6	0
upper-port	7	0
target-protocol	8	4
FQDN	9	4
URI	10	4
E.164	11	4
alias	12	4
lifetime	13	0
attack-status	14	0
signal-config	15	5
heartbeat-interval	16	0
max-retransmit	17	0
ack-timeout	18	0
ack-random-factor	19	7
MinValue	20	0
MaxValue	21	0
status	22	0
bytes_dropped	23	0
bps_dropped	24	0
pkts_dropped	25	0
pps_dropped	26	0

Figure 21: CBOR mappings used in DOTS signal channel message

7. (D)TLS Protocol Profile and Performance considerations

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 machine-in-the-middle and protocol downgrade. These are general attacks on (D)TLS and not

specific to DOTS over (D)TLS; please 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 encryption of DOTS using (D)TLS is virtually a green-field deployment DOTS agents MUST implement only (D)TLS 1.2 or later.

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

- DOTS agents MUST support DTLS record replay detection (Section 3.3 in [RFC6347]) to protect against replay attacks.
- DOTS client can use (D)TLS session resumption without server-side state [RFC5077] to resume session and convey the DOTS signal.
- Raw public keys [RFC7250] which reduce the size of the ServerHello, and can be used by servers that cannot obtain certificates (e.g., DOTS gateways on private networks).

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

- TLS False Start [RFC7918] which reduces round-trips by allowing the TLS second flight of messages (ChangeCipherSpec) to also contain the DOTS signal.
- 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.
- TCP Fast Open [RFC7413] can reduce the number of round-trips to convey DOTS signal.

7.1. MTU and Fragmentation Issues

To avoid DOTS signal message fragmentation and the consequently 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. The length of the URL MUST NOT exceed 256 bytes. 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-ip' parameter could be

split into multiple lists and each list conveyed in a new POST 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 absolutely ensure that there is no IP fragmentation. If IPv4 support on unusual networks is a consideration and 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 up to 576 bytes should never need to be fragmented, thus sending a maximum of 500 bytes of DOTS signal over a UDP datagram will generally avoid IP fragmentation.

8. (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.rescorla-tls-dtls13] is based on the TLS 1.3 protocol and provides equivalent security guarantees. (D)TLS 1.3 provides two basic handshake modes of interest to DOTS signal channel:

- Absent packet loss, a full handshake in which the DOTS client is able to send the DOTS signal message after one round trip and the DOTS server immediately after receiving the first DOTS signal message from the client.
- 0-RTT mode in which the DOTS client can authenticate itself and send DOTS signal message on its first flight, 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 SHOULD establish a (D)TLS session with the DOTS server during peacetime and share a PSK. During DDOS attack, the DOTS client can use the (D)TLS session to convey the DOTS signal message and if there is no response from the server after multiple re-tries then the DOTS client can resume the (D)TLS session in 0-RTT mode using PSK. A simplified TLS 1.3 handshake with 0-RTT DOTS signal message exchange is shown in Figure 22.

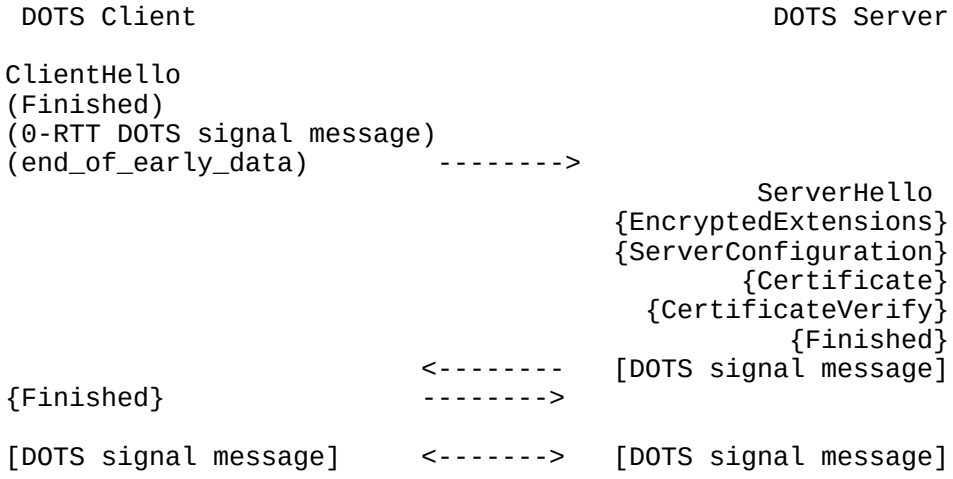

Figure 22: TLS 1.3 handshake with 0-RTT

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

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

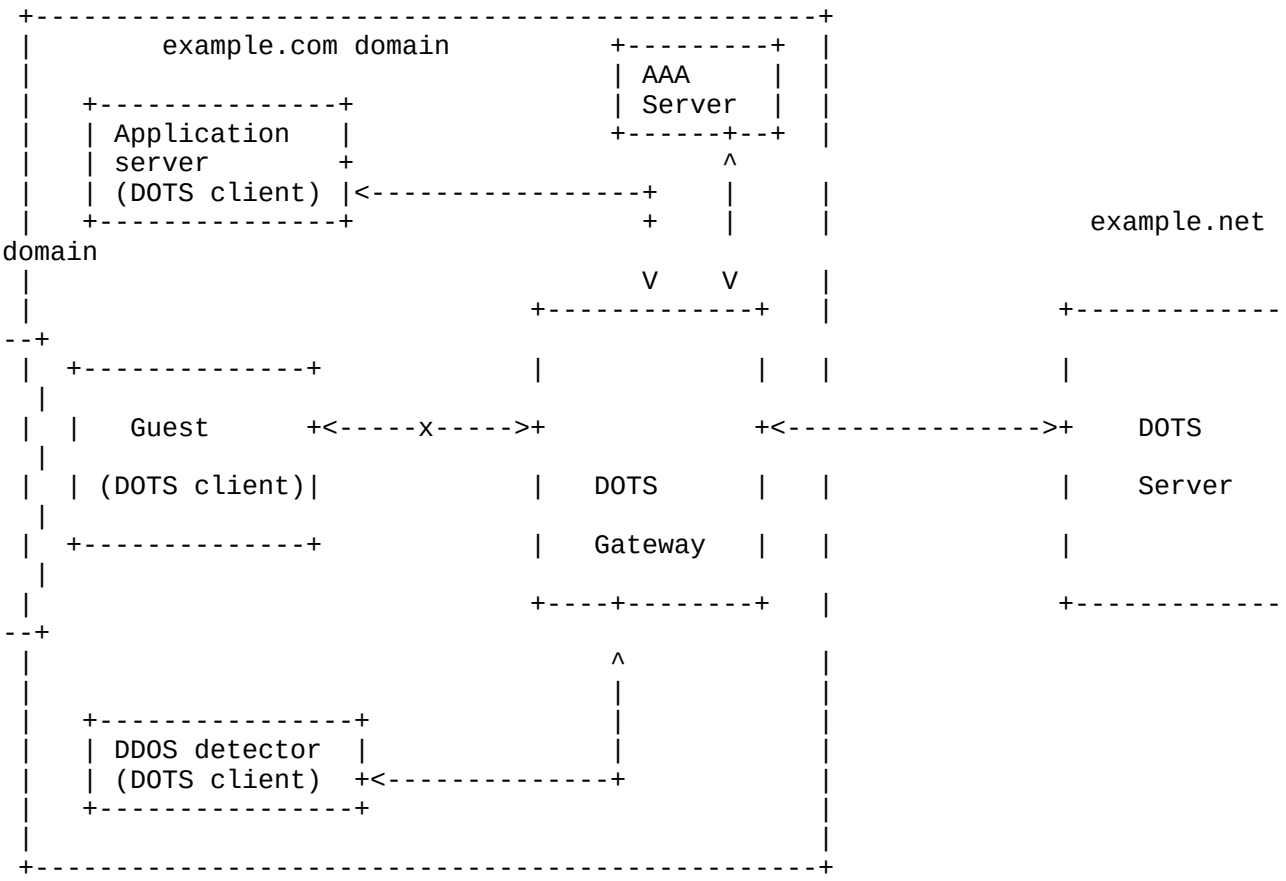

Figure 23: Example of Authentication and Authorization of DOTS Agents

In the example depicted in Figure 23, the DOTS gateway and DOTS clients within the 'example.com' domain mutually authenticate with each other. 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 detector to request DDOS mitigation, but does not permit the user of type 'guest' to request DDOS mitigation.

Also, DOTS gateway and DOTS server MUST perform mutual authentication 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 23, the DOTS server only allows the DOTS gateway to request mitigation for 'example.com' domain and not for other domains.

10. IANA Considerations

This specification registers new parameters for DOTS signal channel and establishes registries for mappings to CBOR.

10.1. DOTS signal channel CBOR Mappings Registry

A new registry will be requested from IANA, entitled "DOTS signal channel CBOR Mappings Registry". The registry is to be created as Expert Review Required.

10.1.1. Registration Template

Parameter name:
: Parameter names (e.g., "target_ip") in the DOTS signal channel.

CBOR Key Value:
: Key value for the parameter. The key value MUST be an integer in the range of 1 to 65536. The key values in the range of 32768 to 65536 are assigned for 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.

10.1.2. Initial Registry Contents

- Parameter Name: "mitigation-scope"
- CBOR Key Value: 1
- CBOR Major Type: 5
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: "scope"
- CBOR Key Value: 2
- CBOR Major Type: 5
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: "policy-id"
- CBOR Key Value: 3
- CBOR Major Type: 0

- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name:target-ip
- CBOR Key Value: 4
- CBOR Major Type: 4
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: target-port-range
- CBOR Key Value: 5
- CBOR Major Type: 4
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: "lower-port"
- CBOR Key Value: 6
- CBOR Major Type: 0
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: "upper-port"
- CBOR Key Value: 7
- CBOR Major Type: 0
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: target-protocol
- CBOR Key Value: 8
- CBOR Major Type: 4
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: "FQDN"
- CBOR Key Value: 9
- CBOR Major Type: 4
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: "URI"
- CBOR Key Value: 10
- CBOR Major Type: 4
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: "E.164"
- CBOR Key Value: 11
- CBOR Major Type: 4

- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: alias
- CBOR Key Value: 12
- CBOR Major Type: 4
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: "lifetime"
- CBOR Key Value: 13
- CBOR Major Type: 0
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: attack-status
- CBOR Key Value: 14
- CBOR Major Type: 0
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: signal-config
- CBOR Key Value: 15
- CBOR Major Type: 5
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: heartbeat-interval
- CBOR Key Value: 16
- CBOR Major Type: 0
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: max-retransmit
- CBOR Key Value: 17
- CBOR Major Type: 0
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: ack-timeout
- CBOR Key Value: 18
- CBOR Major Type: 0
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: ack-random-factor
- CBOR Key Value: 19
- CBOR Major Type: 7

- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: MinValue
- CBOR Key Value: 20
- CBOR Major Type: 0
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: MaxValue
- CBOR Key Value: 21
- CBOR Major Type: 0
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: status
- CBOR Key Value: 22
- CBOR Major Type: 0
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: bytes_dropped
- CBOR Key Value: 23
- CBOR Major Type: 0
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: bps_dropped
- CBOR Key Value: 24
- CBOR Major Type: 0
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: pkts_dropped
- CBOR Key Value: 25
- CBOR Major Type: 0
- Change Controller: IESG
- Specification Document(s): this document

- Parameter Name: pps_dropped
- CBOR Key Value: 26
- CBOR Major Type: 0
- Change Controller: IESG
- Specification Document(s): this document

11. Security Considerations

Authenticated encryption MUST be used for data confidentiality and message integrity. (D)TLS based on client certificate MUST be used for mutual authentication. 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.

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.

Special care should be taken in order to ensure that the activation of the proposed mechanism won’t have an impact on the stability of the network (including connectivity and services delivered over that network).

Involved functional elements in the cooperation system must establish exchange instructions and notification over a secure and authenticated channel. Adequate filters can be enforced to avoid that nodes outside a trusted domain can inject request such as deleting filtering rules. Nevertheless, attacks can be initiated from within the trusted domain if an entity has been corrupted. Adequate means to monitor trusted nodes should also be enabled.

12. Contributors

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