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N.B. Sopher
O. Finkelman
Qwilt
S. Mishra
Verizon
J.K. Robertson
Qwilt
A. Arolovitch
Viasat

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Content Delivery Network Interconnection (CDNI) Control Interface / Triggers 2nd Edition
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Abstract

This document obsoletes RFC8007. The document describes the part of Content Delivery Network Interconnection (CDNI) Control interface that allows a CDN to trigger activity in an interconnected CDN that is configured to deliver content on its behalf. The upstream CDN MAY use this mechanism to request that the downstream CDN preposition, invalidate and/or purge metadata and/or content. The upstream CDN MAY monitor the status of activity that it has triggered in the downstream CDN.

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

[RFC6707] introduces the problem scope for Content Delivery Network Interconnection (CDNI) and lists the four categories of interfaces that may be used to compose a CDNI solution (Control, Metadata, Request Routing, and Logging).

[RFC7336] expands on the information provided in [RFC6707] and describes each of the interfaces and the relationships between them in more detail.

The CDNI Control Interface / Triggers 1st edition [RFC8007], deprecated by this document, describes the "CI/T" interface -- "CDNI Control Interface / Triggers". It does not consider those parts of the Control interface that relate to the configuration, bootstrapping, or authentication of CDN Interconnect interfaces.

Section 4 of [RFC7337] identifies the requirements specific to the CI/T interface; requirements applicable to the CI/T interface are CI-1 to CI-6.

This document is a second edition of the CDNI Control Interface / Triggers, which defines a new version, "v2", of the interface objects. The new version aims to support REST [REST] architectural style in a way that improves the interface's flexibility, extensibility and interoperability, and allows encoding of the interface using OpenAPI. The new objects replace the main CI/T objects as follows:

* The "ci-trigger-command" object and its matching "ci-trigger-status" object are replaced with "ci-trigger.v2" object representing a trigger resource

* The "ci-trigger-collection" object is replaced with "ci-trigger-collection.v2" that is expanded to support filtering by trigger state and trigger labels

The second edition of the CI/T interface further allows the use of separate Control interface endpoints for content and metadata.

The document also provides a trigger extension mechanism that MAY be used to provide further instruction on the trigger execution.

This second edition also includes cascaded CDN error propagation and extended trigger status reporting for improved trigger execution monitoring, as well as the use of external object lists for improved scale and integration of trigger-based APIs with existing content workflows.

* Section 2 outlines the model for the CI/T interface at a high level.

* Section 3 defines the CI/T interface offered by the downstream CDN.

* Section 4 defines the encoding of the standard CI/T objects and introduces trigger spec and trigger extension types.

* Section 5 describes the FCI capabilities objects used to inform on the supported CI/T-related capabilities.

* Section 6 contains example messages.

1.1. Terminology

This document reuses the terminology defined in [RFC6707] and uses "uCDN" and "dCDN" as shorthand for "upstream CDN" and "downstream CDN", respectively.

Additionally, the following terms are used throughout this document and are defined as follows:

* HLS - HTTP Live Streaming

* DASH - Dynamic Adaptive Streaming Over HTTP

* MSS - Microsoft Smooth Streaming

The keywords "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

2. Model for CDNI Triggers

2.1. REST Architecture

The CI/T interface utilizes HTTP/1.1 protocol [RFC9112] and follows the principles of the Representational State Transfer (REST) architectural style. uCDN, in its capacity of a CI/T interface client requests dCDN to carry out an action ("trigger") related to metadata or content stored by dCDN on behalf of uCDN.

dCDN, as a CI/T interface server, governs the triggers as a set of resources, which can be dynamically created and deleted, and whose state can be retrieved and/or modified by uCDN. Each such trigger is identified by a unique Uniform Resource Identifier (URI) is defined in Section 4.2 of [RFC9110].

Once a trigger is created, uCDN can retrieve its representation from dCDN or request the trigger to be modified by transferring an updated representation of it to dCDN. The CI/T interface supports the representation of trigger resources using JSON [RFC8259].

This RESTful data model built around a common "trigger" resource replaces the command-oriented model of [RFC8007], wherein uCDN passed commands to dCDN using "ci-trigger-command" objects, and dCDN generated "ci-trigger-status" objects in response.

2.2. HTTP Methods

Section 9.3 of [RFC9110] defines the set of methods in HTTP. The CI/T interface uses some of these methods for resource creation, retrieval of resource state, modification of resources, and deletion of resources. The HTTP methods not listed here are not supported by the CI/T interface.

* GET - used to retrieve the current state of a resource. The GET method doesn’t cause any state change on the server side.

* POST - used to request that the target resource process the representation enclosed in the request. If a resource has been created on the server as a result of successfully processing a POST request, the server sends a 201 ("Created") response containing a Location header field that contains an identifier for the newly created resource.

* DELETE - used to request the server remove the target resource.

* HEAD - used to request metadata associated with the target resource, in the form of HTTP response headers that would have been sent if the GET method was used instead. The HEAD method can be used to verify that the target resource exists on the server.

2.3. Trigger

To request that an action be carried out by dCDN, uCDN requests to create a trigger resource. If dCDN accepts the request, it creates a new trigger resource and returns its unique URI to uCDN. uCDN MUST use this URI for all requests associated with the created trigger resource.

Note that the version of the trigger resources that uCDN requests to create MUST match the version of CI/T trigger objects reported as supported by dCDN.

The CI/T interface supports the following types of trigger action:

* preposition - used to instruct dCDN to fetch metadata from the uCDN or content from any origin including uCDN.

* invalidate - used to instruct dCDN to revalidate specific metadata or content before reusing it.

* purge - used to instruct dCDN to delete specific metadata or content.

Note that additional action types can be defined and registered in the future.

The trigger resource has a "state" attribute. dCDN creates new triggers in the "pending" state. Once dCDN starts processing a trigger, the trigger state is set to "active". Once the trigger processing is complete, the state is set to either "complete" or "failed", depending on the processing outcome.

uCDN MAY request dCDN to cancel a trigger. If such a request is accepted, the trigger state is changed to "cancelling", and when the cancellation is complete, the trigger state changes to "cancelled".

For a full description of the trigger resource, please refer to Section 4.1.

2.4. Trigger Access Control and Multi-Tenancy

dCDN MUST only allow uCDN access to the trigger resources it created.

dCDN MUST be able to associate content objects referenced in a trigger created by uCDN with the delivery CDNI metadata objects in its possession that are associated with the same uCDN. These CDNI metadata objects include HostIndex, HostMatch, HostMetadata, PathMatch, PatternMatch, and PathMetadata, as described in Section 3.1 of [RFC8006].

If such association between a trigger and pre-existing delivery metadata cannot be established, dCDN MUST reject it.

Furthermore, dCDN SHOULD reject trigger from uCDN A that seeks to preposition the delivery metadata objects, that are in conflict with the pre-existing metadata objects belonging to another uCDN B.

2.5. Trigger Collection

A trigger collection is a resource that represents all trigger resources, belonging to a particular uCDN. dCDN maintains one trigger collection resource for each uCDN. Each uCDN only has access to its own collection resource. dCDN supports retrieval of multiple representations of the trigger collection resource. The supported trigger collection representations are listed in Section 4.2 and include filtering of triggers by state and label. Note that additional trigger collection representations can be defined in the future.

2.6. Session Overview

Figure 1 is an example showing the basic message flow in a CI/T interface session used by the uCDN to trigger activity in dCDN and for uCDN to discover the status of that activity. Only successful triggering is shown. Please note that the example below uses simplified trigger identifiers for brevity. It is recommended that the actual implementation utilies unique UUID identifiers as specified in [RFC9562]. Examples of the messages are shown in Section 6.

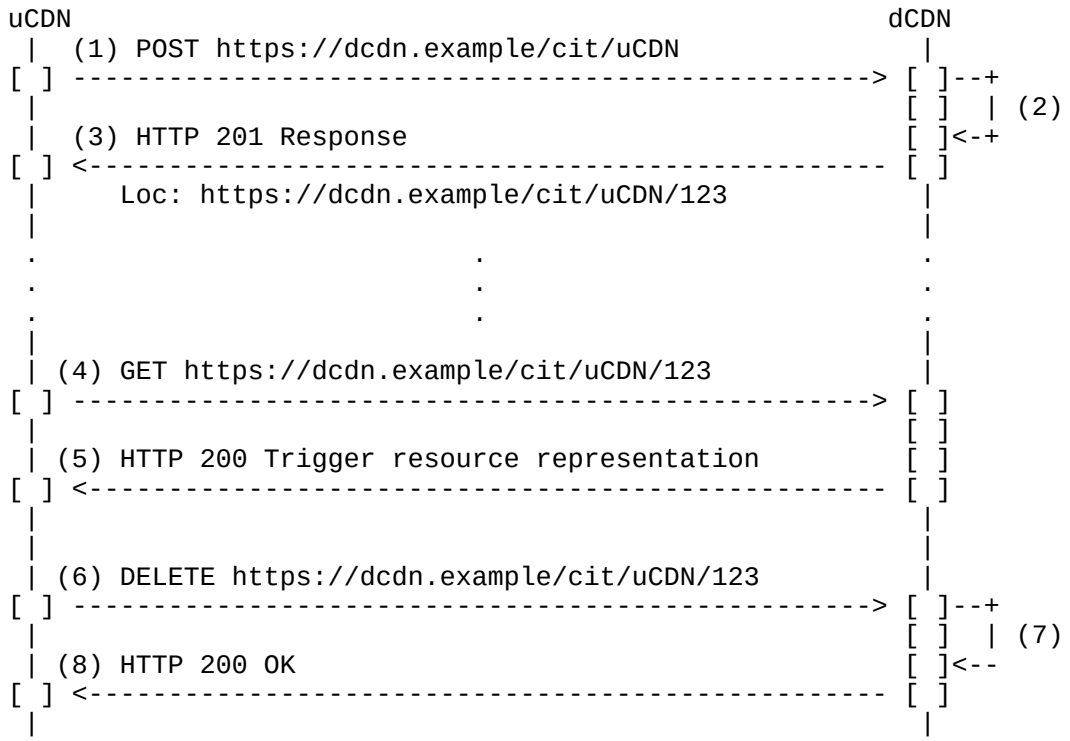


Figure 1: Basic CDNI Message Flow for Triggers

The steps in Figure 1 are as follows:

1. uCDN requests to create a new trigger resource by POSTing its representation to the trigger collection resource with a well-known URI "https://dcdn.example/cit/uCDN".

2. dCDN authenticates the request, validates the trigger resource in it, and if the request is accepted, creates a new trigger resource.

3. dCDN responds to uCDN with an HTTP 201 ("Created") response status and the location of the trigger resource.

4. uCDN MAY query, possibly repeatedly, the trigger resource in dCDN.

5. dCDN responds to each query with the current trigger resource representation, including the trigger state, that reflects the progress of the uCDN request.

6. Once the trigger reaches a terminal state ("complete", "failed" or "cancelled"), uCDN MAY request to delete the trigger resource.

7. dCDN validates the request and the trigger resource state. If successful, the trigger resource is removed by the server, and subsequent requests for this resource MUST result in 404 ("Not Found").

8. dCDN responds to the deletion request with a 200 ("OK") status code.

2.7. Trigger Processing

2.7.1. Timing and Order

uCDN MAY place limits on the timing and order of execution of a trigger through optional TimePolicy (Section 4.1.3.3.2) and/or ExecutionPolicy (Section 4.1.3.3.3) extensions. If neither of these extensions are present in the trigger resource, the timing and order of the trigger execution is under dCDN’s control, including the start time, pacing of the activity in the network, and order in which dCDN chooses to process pending triggers.

The CI/T "invalidate" and "purge" trigger actions MUST be applied to all data acquired before dCDN begins the trigger processing (i.e., enters "active" state). dCDN implementation SHOULD apply "invalidate" and "purge" triggers to content acquisition that is in progress when the trigger becomes active, to avoid placing purged or invalidated content into the cache upon completion of the content acquisition. dCDN SHOULD NOT apply CI/T "invalidate" and "purge" actions to data acquired after the trigger processing started, but this may not always be achievable, so uCDN cannot count on that.

If uCDN wishes to invalidate or purge content and then immediately preposition replacement content at the same URLs, it SHOULD ensure that dCDN has completed the invalidate/purge before initiating the prepositioning. Otherwise, there is a risk that the dCDN prepositions the new content, then immediately invalidates or purges

it (as a result of the two uCDN requests running in parallel). uCDN MAY use the Execution Policy (Section 4.1.3.3.3) extension to condition the start of preposition trigger processing on completion of the earlier invalidate/purge trigger(s).

2.7.2. Scope

Each trigger can operate on multiple metadata and content elements. These elements are targeted by specifying both their subject (i.e., "metadata" or "content") as well as specification method (e.g., URL Regexes) and value.

Multiple representations of an HTTP resource may share the same URL. Triggers that invalidate or purge metadata or content apply to all resource representations with matching URLs.

2.7.3. Results

Possible trigger states are defined in Section 4.1.5.

Trigger state MUST NOT be reported as "complete" until all operations listed in the trigger have been completed successfully. The reasons for failure, and URLs or patterns affected, SHOULD be made available in the trigger state representation. For more details, see Section 3.7.

2.8. Trigger Extensibility

The CDNI Control Interface / Triggers 1st edition [RFC8007] defines a set of properties and objects used by the trigger commands. This 2nd edition defines an extension mechanism to the triggers interface that enables applications to add instructions for finer control over the trigger execution, for example indicating a time window in which to execute the trigger. This document specifies a generic trigger extension object wrapper for managing individual CDNI trigger extensions in an opaque manner.

All trigger extensions are optional, and it is thus the responsibility of the extension specification to define a consistent default behavior for the case the extension is not present.

All trigger extensions MUST be registered in the IANA "CDNI CI/T Trigger Extensions" registry (see Section 7.6).

This document also defines an initial set of trigger extension objects and registers them in the IANA "CDNI CI/T Trigger Extensions" registry:

JSON String	Description
location-policy	Allowing the control over the locations in which the trigger is executed.
time-policy	Allowing the scheduling of a trigger to run in a specific time window.
execution-policy	Allowing the control over the order and timing in which triggers are executed.

Table 1

2.9. Multiple Interconnected CDNs

In a network of interconnected CDNs, a single uCDN will originate a given item of metadata and associated content. It MAY distribute that metadata and content to one or more dCDNs, which in turn distributes that metadata and content to additional dCDNs located further downstream.

A transit CDN is a dCDN that passes on CDNI Metadata and content to dCDNs located further downstream.

dCDN that creates trigger resources at the request of such transit CDN MUST associate the triggers with the transit CDN from which it receives the request, regardless of where the trigger request may heve originated.

A "diamond" configuration is one where dCDN can potentially acquire metadata and content originated in one uCDN from that uCDN itself and an transit CDN, or via more than one transit CDN.

The "diamond" configuration may create configuration consistency problems, where dCDN may end up in posession of multiple, potentially conflicting metadata obhects belonging to multiple uCDNs, that match the same content request. The conflict may arise due to the differences in trigger processing by the transit CDNs and/or variances in trigger propagation time across different path in the "diamond" topology.

Because of that the "diamond" configuration is considered to be a configuration error. A dCDN that receives identical trigger creation requests from multiple uCDNs SHOULD reject duplicate trigger requests, as described in Section 2.4.

Security considerations are discussed further in Section 8.

If dCDN is also acting as uCDN in a cascade, it MUST forward trigger requests to any dCDNs that may be affected. The trigger state MUST NOT be reported as "complete" by a transit CDN until it is "complete" in all of its dCDNs and in the transit CDN itself. If a trigger is reported as "processed" in the transit CDN or any one of its dCDNs, transit CDNs MUST report the trigger as "processed" as well. If a trigger is reported as "failed" by the transit CDN or any one of its dCDNs, the transit CDN must report the trigger as "failed" only after its processing is finished in it and all of its dCDNs. A cancelled trigger MUST be reported as "cancelling" until it has been reported as "cancelled", "complete", or "failed" by all dCDNs in a cascade.

2.10. Loop Detection and Prevention

Given three CDNs, A, B, and C, if CDNs B and C delegate delivery of CDN A’s content to each other, CDN A’s trigger creation requests could be passed between CDNs B and C in a loop. More complex networks of CDNs could contain similar loops involving more hops.

When such CDN topologies become possible, it is RECOMMENDED that CDNs participating in it utilize a CDN Provider ID (PID) (Section 4.3.3) to detect and prevent loops as follows:

* uCDNs that originate a new trigger request SHOULD specify their CDN provider ID using the trigger "cdn-path" attribute (see Section 4.1 for details).

* A dCDN that receives a trigger creation request that contains a "cdn-path" attribute SHOULD check it for its own CDN PID. If dCDN’s PID is already present and dCDN is not the CDN initiating the trigger, this condition likely indicates a loop. In such case, dCDN MUST reject the trigger, which would result in a trigger rejection being returned to the originating uCDN. If dCDN receives a trigger that it itself originated, dCDN MAY process the trigger as required.

* A dCDN that cascades trigger requests to additional dCDNs (so-called "transit CDN") SHOULD NOT reject triggers that have CDN PID of its downstream CDNs in their CDN path, allowing each CDN to do their own loop detection.

* Transit CDNs MUST append their CDN PID to the CDN path of a trigger before sending it to its downstream CDNs.

* dCDNs SHOULD advertise their CDN provider ID to uCDNs using the "cdn-id" attribute of the trigger collection (Section 4.2) resource.

3. CDNI Trigger Interface

This section describes an interface to enable uCDN to trigger activity in dCDN.

The CI/T interface builds on top of HTTP, so dCDNs may make use of any HTTP feature when implementing the CI/T Interface. For example, dCDN SHOULD make use of HTTP's caching mechanisms to reduce uCDN's trigger status polling overhead by indicating the modification status of a requested resource representation.

dCDNs MAY implement separate CI/T interfaces per Section 4.1.2.2, i.e., one CI/T interface for trigger operations on metadata and another for operations on content. In this case, dCDN MUST advertise separate interface endpoints via Section 5.1.

All dCDNs implementing CI/T MUST support the HTTP GET, HEAD, POST, and DELETE methods as defined in [RFC9110].

The only resource representation specified in this document is JSON [RFC8259]. It MUST be supported by uCDN and by dCDN.

The CI/T interface uses a root URI for the retrieval of the trigger collection resource and creation of new triggers. The mechanism for discovery of that URL is part of the CI/T interface bootstrapping and is outside the scope of this document.

uCDN requests to create a new trigger resource by POSTing its representation to the trigger collection resource URI, discovered at the time of interface bootstrapping, e.g., "https://dcdn.example/cit/ucdn/triggers". If the request is accepted by dCDN, it creates a new trigger resource and returns its URI to uCDN in an HTTP 201 ("Created") response.

Once created, the new trigger URI also becomes available via the trigger collection resource described in Section 4.2. Additionally, uCDN may discover the URIs of multiple trigger collection representations by retrieving the trigger collection resource, which is accessible at the interface root URI. This means that the URIs for all trigger resources and trigger collection representations can be discovered by uCDN, so dCDNs are free to assign whatever structure they desire to the URIs for CI/T resources. Therefore, uCDNs MUST NOT make any assumptions regarding the structure of CI/T URIs or the mapping between CI/T objects and their associated URIs. The URIs

used in the examples in this document are purely illustrative and are not intended to impose a definitive structure on CI/T interface implementations.

3.1. Creating Triggers

To create a new trigger, uCDN makes an HTTP POST request with the trigger representation to the trigger collection resource URI. The trigger representation MUST include the mandatory attributes of the trigger resource (Section 4.1).

uCDN MAY also optionally specify optional trigger v2 specification attributes, namely trigger labels and trigger extensions, as well as the optional "cdn-path" attribute of the trigger resource.

dCDN validates the trigger resource representation sent by uCDN. If the representation is malformed or uCDN does not have sufficient access rights, dCDN MUST either respond with an appropriate 4xx HTTP error code and not create a trigger resource or create a trigger resource with a "failed" state and an appropriate Error.v2 Description (Section 4.1.6.1).

The new trigger resource is created in a "pending" state. If successful, The HTTP response to the uCDN trigger creation request MUST have status code 201 ("Created") and MUST convey the URI of the newly created trigger resources in the Location response header field [RFC9110]. The HTTP response SHOULD include the updated representation of the trigger resource. This is particularly important in cases where dCDN processed the trigger immediately.

Once a trigger resource has been created, dCDN MUST NOT reuse its URI, even after the trigger resource has been fully removed. It is therefore recommended that dCDN utilize unique UUID identifiers as specified in [RFC9562].

dCDN SHOULD provide continuous updates of the trigger processing progress by responding with updated trigger resource representations to subsequent uCDN requests sent to the created trigger URI. If the dCDN is unable to do that, it MUST indicate that it has accepted the request but will not be providing further status updates. To do this, it MUST set the trigger state to "processed" at creation time. In this case, CI/T processing should continue as if it were a request in the "complete" state. In this case, dCDN SHOULD also provide an estimated completion time for the request by using the trigger "etime" property.

Otherwise, dCDN MUST set the state of the new trigger to "pending". Once trigger processing has started, the status MUST be changed to "active". Finally, once the trigger processing is complete, the trigger state MUST be set to "complete" or "failed".

Once created, trigger resources can be cancelled, modified, or deleted by uCDN, subject to the constraints described below.

3.2. Modifying Triggers

Modification of existing triggers is useful for uCDN to correct an error in trigger specification or trigger extension(s) that may govern when the trigger is to be processed.

uCDN can request modification of an existing trigger resource by sending an updated trigger representation to the trigger URI using HTTP POST command.

dCDN MAY accept modifications of the trigger specifications, trigger extensions and trigger labels, when the trigger is in a "pending" state, i.e., dCDN didn’t start its processing yet.

dCDN MAY also accept a request to change the trigger state subject to the following constraints:

* the requested state is "cancelled", and the trigger was in either "pending" or "active" state when dCDN receives the request

* the requested state is "active", and the trigger was in a "pending" state when dCDN received the request

Section 3.3 describes the processing of the trigger cancellation requests in detail. uCDN MAY request to set the trigger state to "active" to prompt dCDN to re-examine the trigger resource and start its processing immediately.

dCDN MUST respond to the trigger modification request appropriately. Thus, the HTTP status code 200 ("OK") should be returned if the modification has been processed, 202 ("Accepted") if the command has been accepted but the modification is not fully complete yet, 404 ("Not Found") when the trigger resource does not exist, 409 ("Conflict") when the trigger resource is in a state that doesn’t allow the requested modification, 501 ("Not Implemented") if the modification is not supported by dCDN or an appropriate 4xx HTTP error code in case of a malformed request.

In case of successful 2xx response, dCDN MUST provide the updated trigger resource representation in the response body.

3.3. Cancelling Triggers

uCDN MAY request cancellation of a trigger by requesting its state to be set to "cancelled", as described in Section 3.2. dCDN MUST respond to such request, however, the actual cancellation of a trigger resource is optional to implement.

dCDN MUST respond to the trigger cancellation request appropriately. dCDN MUST respond with the HTTP status code 200 ("OK") if the trigger processing has been cancelled and the trigger state has been set to "cancelled", 202 ("Accepted") if the command has been accepted but the trigger processing has not been cancelled yet, 404 ("Not Found") when the trigger resource does not exist, or 501 ("Not Implemented") if cancellation is not supported by dCDN.

If cancellation of a "pending" trigger is accepted by dCDN, dCDN SHOULD NOT start the processing of that activity. Requesting a cancellation of a "pending" trigger does not, however, guarantee that the corresponding activity will not be started, because uCDN cannot control the timing of that activity. Processing could, for example, start after the POST is sent by uCDN but before that request is processed by dCDN.

If cancellation of an "active" or "processed" trigger is accepted by dCDN, dCDN SHOULD stop processing the trigger. However, as with the cancellation of a "pending" trigger, dCDN does not guarantee that the trigger processing doesn’t run to completion in the meantime.

If uCDN cannot stop the trigger processing immediately after receiving the request from uCDN to do so, it MUST set the trigger state to "cancelling" and provide this state in the trigger representation in its response. If the trigger processing is stopped before its normal completion, the trigger state MUST be set to "cancelled".

Cancellation of a "complete", "failed" or "cancelled" trigger requires no processing in dCDN. Its state MUST NOT be changed.

3.4. Checking Status

uCDN has two ways to check the progress of its triggers’ processing, as described in Section 3.4.1 and Section 3.4.2.

To allow uCDN to use client-side caching of all triggers and trigger collections, each resource representation sent by dCDN SHOULD include at least one of the following response headers: "ETag" or "Last-Modified". The dCDN should respond with the HTTP 304 ("Not Modified") status code and no response body for conditional resource

requests using the 'If-None-Match' and/or 'If-Modified-Since' headers, as specified in Section 13 of [RFC9110], if it does not have a more recent resource representation.

dCDN SHOULD also use the cache control headers for responses to GET requests for its resources to indicate the frequency at which it recommends that uCDN and/or intermediate proxies should poll for change. If provided, uCDN should match the frequency of polling to the cache control information provided by dCDN.

3.4.1. Polling Trigger Collections

uCDN MAY fetch the trigger collection or one of the filtered representations of it. This makes it possible for uCDN to poll the status of all trigger resources or selected trigger subsets, filtered by trigger state or by trigger label. In this way, uCDN can monitor trigger state changes by polling the representation of the trigger collection filtered by trigger state.

3.4.1.1. Extended view representation

If dCDN advertises support for extended status, uCDN MAY request the extended trigger collection representation, which embeds full representations of trigger resources in the collection resource. The extended representation is supported for all filtered representations of the trigger collection, so it is possible to retrieve all trigger resource representations for a specific trigger state (e.g., all triggers in a "pending" state).

uCDN SHOULD request the extended representation by passing the query string parameter "status=extended" when requesting a trigger collection resource or one of its filtered representations. dCDN SHOULD appropriately respond to the request for extended status with HTTP Status 200 ("OK") when such request can be satisfied, with error code 501 ("Not Implemented") if the capability has not been implemented or advertised, and 400 ("Bad Request") when dCDN encounters a malformed query format.

By default, trigger resources are represented in the trigger collection with their resource URI only.

3.4.2. Polling Triggers

uCDN has a URI provided by dCDN at the trigger creation time. Alternatively, uCDN MAY discover trigger resource URI by retrieving the trigger collection resource and/or one of its filtered representations. It may fetch an up-to-date representation of the trigger resource at any time using an HTTP GET request, including changes in the trigger state, as well as the outcome of the trigger processing.

3.5. Deleting Triggers

uCDN MAY request the deletion of trigger resources at any time using the HTTP DELETE method, as defined in the CDNI Control Interface / Triggers 1st edition [RFC8007],

Once deleted, the deleted trigger MUST be removed from all representations of the trigger collection. Subsequent requests to the trigger resource URI MUST be rejected by dCDN with HTTP error 404 ("Not Found").

The effect of deletion is similar to cancellation, except that the trigger resource becomes unavailable after the deletion is complete. For this reason, uCDN SHOULD cancel triggers rather than delete them when uCDN needs to access the trigger status after the trigger processing is stopped.

If a "pending" trigger is deleted, dCDN SHOULD NOT start the processing of that activity. Deleting a "pending" trigger does not, however, guarantee that its processing has not started, because uCDN cannot control the timing of that activity. Processing may, for example, start after the DELETE is sent by uCDN but before that request is processed by dCDN.

When an "active" or "processed" trigger is deleted, the dCDN SHOULD stop processing it. However, as with the deletion of a "pending" trigger, dCDN does not guarantee this.

Deletion of a "complete", "cancelled" or "failed" trigger no processing in dCDN.

dCDN MUST respond to the trigger deletion request appropriately. dCDN MUST respond with the HTTP status code 200 ("OK") without a response body if the trigger has been deleted immediately. 202 ("Accepted") if the command has been accepted but the trigger has not been deleted yet. 404 ("Not Found") when the trigger resource does not exist, or 501 ("Not Implemented") if deletion is not supported by dCDN.

The trigger state MUST be set to "cancelling" while dCDN is processing a deletion request asynchronously.

3.6. Expiry of Triggers

dCDN MAY automatically delete trigger resources sometime after they reach a terminal state (one of "complete", "processed", "failed", or "cancelled"). In this case, after dCDN has removed such a trigger, it MUST respond to subsequent requests for it with the HTTP error 404 ("Not Found") and remove it from the trigger collection resource.

If dCDN does remove triggers in a terminal state automatically, it MUST report the expiry timeout period, using an attribute "staleresourcetime" of the trigger collection resource (see Section 4.2 for details.

It is RECOMMENDED that dCDN sets its staleresourcetime to at least 24 hours. It is further RECOMMENDED that uCDN sets its trigger polling period to less than this period, so it doesn’t miss trigger status updates before the "complete" or "failed" triggers are expired by dCDN.

3.7. Error Handling

dCDN MAY reject CI/T interface requests by responding with 4xx or 5xx HTTP status codes. For example, uCDN MAY respond with 400 ("Bad Request") if the request is malformed, or 403 ("Forbidden") or 404 ("Not Found") if the request could not be properly authenticated or if uCDN is trying to act on another CDN’s resources.

If any part of the trigger processing fails, the trigger SHOULD be reported as "failed" once its activity is complete or if no further errors will be reported. The "errors" property in the trigger will be used to enumerate which actions failed and the reasons for failure, and can be present while the trigger is still "pending" or "active" if the trigger processing is still running for some URLs or patterns in the trigger specs.

Once a request has been accepted, processing errors are reported in the trigger using a list of Error.v2 Descriptions. Each Error.v2 Description is used to report errors against one or more of the URLs or patterns in the trigger specification.

If a Surrogate affected by a trigger is offline in the dCDN or dCDN is unable to pass a trigger on to any of its cascaded dCDNs:

* If the trigger is abandoned by dCDN, dCDN SHOULD report an error.

* A CI/T "invalidate" command may be reported as "complete" when Surrogates that may have the data are offline. In this case, Surrogates MUST NOT use the affected data without first revalidating it when they are back online.

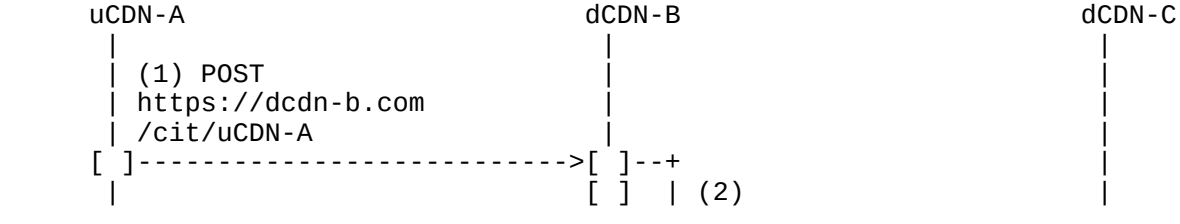
* CI/T "preposition" and "purge" commands can be reported as "processed" if affected caches are offline and the activity will complete when they return to service.

* Otherwise, dCDN SHOULD keep the trigger "pending" or "active" state until either the trigger is acted upon or uCDN chooses to cancel it.

3.7.1. Error Propagation

This subsection explains the mechanism for enabling uCDN to trace an error back to dCDN in which it occurred. CDNI triggers may be propagated over a chain of downstream CDNs. For example, an upstream CDN A (uCDN-A) that is delegating to a downstream CDN B (dCDN-B) and dCDN-B is delegating to a downstream CDN C (dCDN-C). Triggers sent from uCDN-A to dCDN-B may be redistributed from dCDN-B to dCDN-C, and errors can occur anywhere along the path. Therefore, it might be essential for uCDN-A which sets the trigger to be able to trace back an error to the downstream CDN where it occurred. This document adds a mechanism to propagate the PID of dCDN where the fault occurred, back to the uCDN by adding the PID to the error.v2 description. When dCDN-B propagates a trigger further to the downstream dCDN-C, it MUST also propagate back the errors received in the trigger status resource from dCDN-C by adding them to the errors array in its status resource to be sent back to the originating uCDN-A. While propagating back the errors dCDN-B MAY also specify dCDN-C PID, indicating to which CDN the error specifically relates. The trigger originating upstream CDN then receives an array built of the errors that occurred in all the CDNs along the execution path, where each error MAY carry its own CDN identifier.

Figure 2 below is an example showing the message flow used by uCDN-A to trigger activity in dCDN-B, followed by dCDN-C, as well as the discovery of the status of that activity, including the Error Propagation.



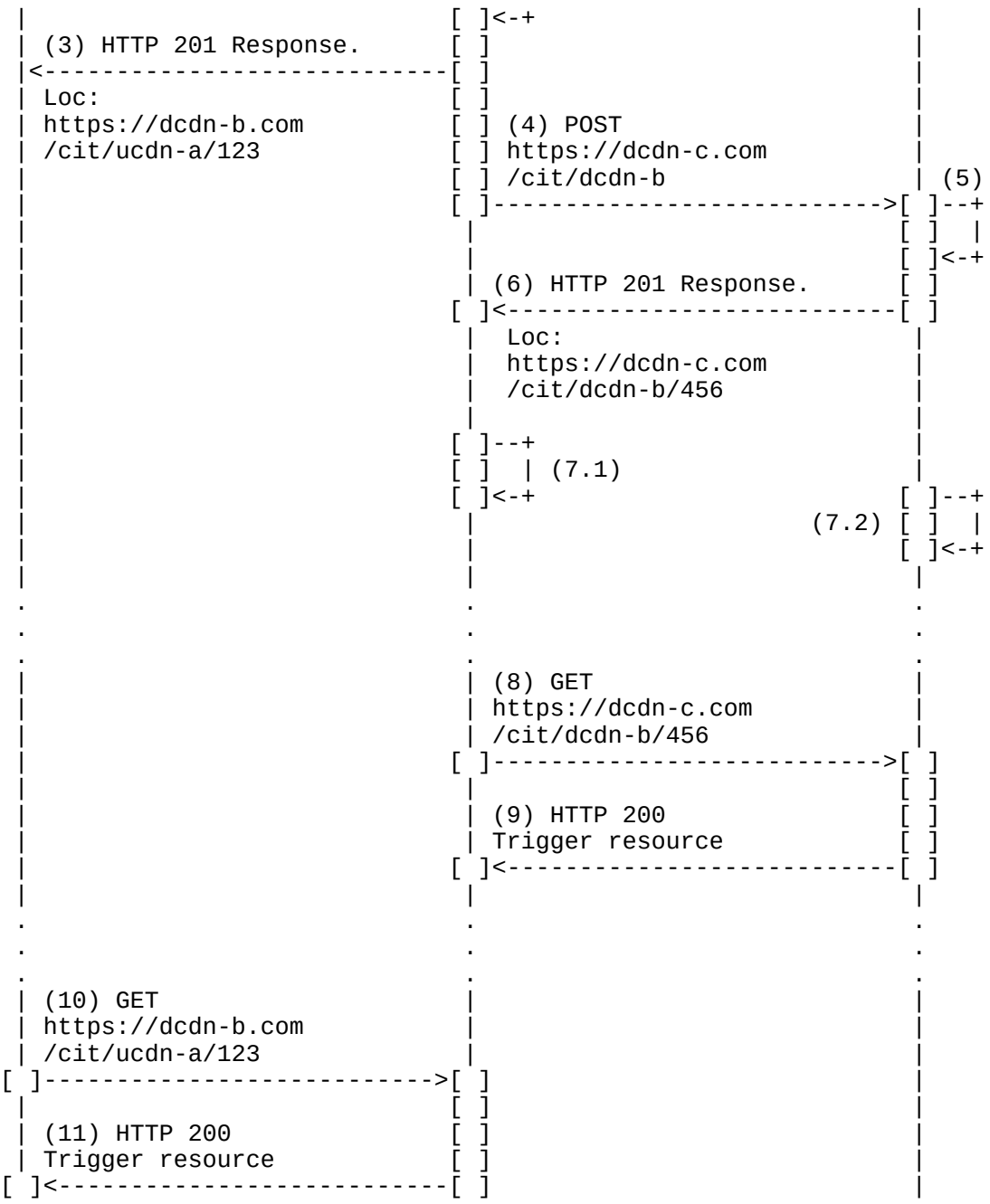


Figure 2: CDNI Message Flow for Triggers, Including Error Propagation

The steps in Figure 2 are as follows:

1. uCDN-A creates a trigger in dCDN-B by POSTing a new trigger representation to "https://dcdn-b.com/cit/ucdn-a".

2. dCDN-B authenticates the request, validates the trigger creation request, and, if it accepts the request, creates a new trigger resource.

3. dCDN-B responds to uCDN-A with an HTTP 201 ("Created") response status and the location of the newly created trigger.

4. dCDN-B creates a trigger in dCDN-C by POSTing the newly received trigger representation to "https://dcdn-c.com/cit/dcdn-b".

5. dCDN-C authenticates the request, validates the trigger creation request, and, if it accepts the request, creates a new trigger resource.

6. dCDN-C responds to dCDN-B with an HTTP 201 ("Created") response status and the location of the newly created trigger resource.

7. dCDN-C acts upon the trigger. However, the command fails at dCDN-C as, for example, the trigger definition contains an "action" type that is not supported by dCDN-C. dCDN-C’s action is depicted by 7.2 in the diagram, while 7.1 shows dCDN-B acting on its own trigger.

8. dCDN-B queries, possibly repeatedly, the trigger resource in dCDN-C.

9. dCDN-C responds with the trigger resource representation, describing the progress or results of the trigger processing. In the described flow, the trigger state is "failed", with an Error.v2 Description object holding "eunsupported" Error Code reflecting the reason.

10. uCDN-A queries, possibly repeatedly, the trigger status in dCDN-B.

11. dCDN-B responds with the updated trigger resource representation, describing the progress or results of trigger processing. In the flow described above, the trigger state is "failed", and the "eunsupported" error received in the trigger status from dCDN-C is propagated along with dCDN-C PID by adding it to the errors array in dCDN-B’s status resource to be sent back to the originating uCDN-A.

4. CI/T Object Properties and Encoding

Trigger, trigger collection and their properties are encoded using JSON, as defined in Section 4.1, and Section 4.2, respectively. When sending the JSON-based representation of these resources, the MIME media type "application/cdni" MUST be used, with parameter "ptype" values as defined below and in Section 7.1.

Names in JSON are case-sensitive. The names and literal values specified in the present document MUST always use lowercase.

JSON types, including "object", "array", "number", and "string", are defined in [RFC8259].

Unrecognized name/value pairs in JSON objects SHOULD NOT be treated as an error by either uCDN or dCDN. They SHOULD be ignored during processing and passed on by dCDN to any further dCDNs in a cascade.

4.1. Trigger Resource

Trigger resource is encoded as a JSON object and MUST use a MIME media type of "application/cdni; ptype=ci-trigger.v2". Please note that dCDN MUST include all existing trigger attributes in the trigger resource representation when requested by uCDN. The trigger resource contains the following name/value pairs:

Name: action
Description: Defines the type of the CI/T trigger action.

Value: Trigger action type, as defined in Section 4.1.1.

Mandatory: It is optional for trigger updates, otherwise mandatory.

Name: specs
Description: Array of trigger specs representing the trigger’s targets, as described in Section 4.1.2.

Value: Array of GenericTriggerSpec objects (see Section 4.1.2.1).

Mandatory: It is optional for trigger updates, otherwise mandatory. Furthermore, when mandatory, the list MUST NOT be empty.

Name: extensions
Description: Array of trigger extensions, as described in Section 4.1.3.

Value: Array of GenericTriggerExtension objects (see Section 4.1.3.2).

Mandatory: No. The default is no extensions.

Name: labels
Description: Array of trigger labels, as described in Section 4.1.4.

Value: Array of trigger labels. Each label is a key-value pair, encoded as a JSON string, with "=" separator. The label key and value parts MUST contain up to 63 characters each, MUST begin with a letter or a number, and MAY contain letters, numbers, hyphens, dots, and underscores.

Mandatory: No. The default is no labels.

Name: cdn-path
Description: The chain of CDN PIDs of CDNs that have already created this trigger resource.

Value: Non-empty array of JSON strings, where each string is a CDN PID as defined in Section 4.3.3.

Mandatory: No. The default is no CDN path.

Name: ctime
Description: The time at which the trigger resource was received by the dCDN. The time is determined by dCDN; there is no requirement to synchronize clocks between interconnected CDNs.

Value: Time, as defined in Section 4.3.4 of [RFC8006].

Mandatory: dCDN MUST specify in trigger status representations. It is ignored when included in trigger representations sent by uCDN.

Name: mtime
Description: The time at which the trigger resource was last modified. The time is determined by dCDN; there is no requirement to synchronize clocks between interconnected CDNs.

Value: Time, as defined in Section 4.3.4 of [RFC8006].

Mandatory: dCDN MUST specify in trigger status representations. It is ignored when included in trigger representations sent by uCDN.

Name: etime
Description: The estimate of the time at which dCDN expects to complete the trigger processing. Time is determined by dCDN; there is no requirement to synchronize clocks between interconnected CDNs.

Value: Time, as defined in Section 4.3.4 of [RFC8006].

Mandatory: dCDN MAY specify in trigger status representations. It is ignored when included in trigger representations sent by uCDN.

Name: state
Description: The current trigger state.

Value: Trigger state, as defined in Section 4.1.5.

Mandatory: dCDN MUST include trigger state in the trigger resource representations it sends. The trigger state defaults to "pending" when a trigger is created and is optional in trigger updates sent by uCDN.

Name: state-reason
Description: A human-readable explanation for the object state.

Value: A JSON string, the human-readable reason.

Mandatory: No. dCDN MAY include the trigger reason in the trigger resource representations it sends.

Name: errors
Description: Descriptions of errors that have occurred while processing the trigger.

Value: An array of Error.v2 Descriptions, as defined in Section 4.1.6.1. An empty array is allowed and is equivalent to omitting "errors" from the object.

Mandatory: No. dCDN SHOULD include this attribute in the trigger resource representations it sends when the trigger is in a "failed" state. Mandatory: No.

Name: total-objects-count
Description: Total aggregate number of objects affected by the trigger, e.g., number of objects purged, invalidated or prepositioned as a result of trigger processing. It is RECOMMENDED that dCDN maintains this attribute as a cumulative counter across all of its nodes, without de-duplicating the

same objects processed in multiple nodes. The primary purpose of this attribute is to help uCDN identify abnormal trigger processing results, e.g., a purge or preposition trigger that impacted a lower number of objects than expected. dCDN MAY provide an updated object count as the trigger processing progresses in an "active" trigger state.

Value: Integer.

Mandatory: No. This attribute is "optional-to-implement". When supported, dCDN SHOULD include this attribute in the trigger resource representations requested by uCDN.

Name: total-objects-size
Description: Total aggregate size of objects affected by the trigger, in bytes. It is RECOMMENDED that dCDN maintains this attribute as a cumulative counter across all of its nodes, without de-duplicating the same objects processed in multiple nodes. As with "total-objects-count" attribute above, the primary purpose of this attribute is to help uCDN identify abnormal trigger processing results. dCDN MAY provide an updated object size as the trigger processing progresses in "active" trigger state.

Value: Integer.

Mandatory: No. This attribute is "optional-to-implement". When supported, dCDN SHOULD include this attribute in the trigger resource representations requested by uCDN.

Name: objects
Description: List of objects derived by dCDN when processing the trigger.

Value: An array of ObjectList (Section 4.3.2) objects. dCDN SHOULD provide the list of objects it used as input for processing the trigger with Section 4.1.2.8, provided that dCDN advertised support for extended status (Section 5.5). An empty array is allowed and is equivalent to omitting "objects" from the trigger representation. This field is intended to provide the list of all objects used in processing. The objects that failed to process SHOULD be specified using the Error.v2 Description resource.

Mandatory: No. dCDN MAY send this attribute in its trigger resource representation when available and the capability is advertised via FCI as described above.

4.1.1. Trigger Action

A trigger action is used in a trigger resource to describe trigger actions. It was initially referred to in [RFC8007] as "Trigger Type".

All trigger actions MUST be registered in the IANA "CDNI CI/T Trigger Types" registry (see Section 7.2).

dCDN receiving a request containing a trigger action that it does not recognize or does not support MUST reject the request by creating a trigger with a "failed" state and the "errors" array containing an Error.v2 Description with error "eunsupported" (see Section 4.1.6.2).

The following trigger actions are defined by this document:

JSON String	Description
preposition	A request for dCDN to acquire metadata or content.
invalidate	A request for dCDN to invalidate metadata or content. After servicing this request, dCDN will not use the specified data without first revalidating it using, for example, an "If-None-Match" HTTP request. dCDN need not erase the associated data.
purge	A request for dCDN to erase metadata or content. After servicing the request, the specified data MUST NOT be held on dCDN (dCDN should reacquire the metadata or content from uCDN if it needs it).

Table 2

4.1.2. Trigger Specs

The CDNI Control Interface / Triggers 1st edition [RFC8007] defines a set of properties and objects used by the trigger commands to specify the targets upon which the trigger is applied. This document modifies the trigger interface objects so it has a list of trigger specs. Such structure improves the interface’s extensibility and flexibility. Furthermore, the document defines a generic trigger spec object that acts as a wrapper for managing individual CDNI trigger specs in an opaque manner, allowing future extension of the

interface.

All trigger specs MUST be registered in the IANA "CDNI CI/T Trigger Specs" registry (see Section 7.3).

dCDN receiving a trigger creation request containing a trigger spec that it does not recognize or does not support MUST reject the request by creating a trigger resource with "failed" state and the "errors" array containing an Error.v2 Description with error "espec" (see Section 4.1.6.2).

This document also defines an initial set of trigger spec objects and registers them in the IANA "CDNI CI/T Trigger Specs" registry:

JSON String	Description
urls	Allowing the specification of trigger targets via URLs.
ccids	Allowing the specification of trigger targets via CCIDs content grouping, as defined in section 4.2.8 [RFC8006].
uri-pattern-match	Allowing the specification of trigger targets via [RFC3986] URI patterns.
uri-regex-match	Allowing the specification of trigger targets via regexes matching their URI, as defined in Section 4.1.2.7.
content-objectlist	Allowing the specification of trigger targets via an object list and an object list type.

Table 3

Each trigger usually refers to the targets by the target URLs, using a "urls" trigger spec object or some aggregating spec such as the "url-regex-match". If content URLs are transformed by a transit CDN in a cascade, that transit CDN MUST similarly transform URLs in triggers it passes to its dCDNs.

When processing a trigger, CDNs MUST ignore the URL scheme (HTTP or HTTPS) in comparing URLs. For example, for a CI/T "invalidate" or "purge" action, content MUST be invalidated or purged regardless of the protocol clients used to request it.

4.1.2.1. Generic Spec Object

A trigger resource, as defined in Section 4.1, includes an array of trigger spec objects. Each trigger spec object contains properties that are used as trigger target selection directives for dCDN when processing the trigger, e.g., content URLs or metadata URL patterns. Each such trigger spec is a specialization of a CDNI GenericTriggerSpec object. The GenericTriggerSpec object abstracts the basic information required for trigger distribution from the specifics of any given property (i.e., property semantics, enforcement options, etc.).

The semantics of the trigger specs list is additive, i.e., the trigger applies to any object matching one of the listed specs.

A GenericSpecObject object is a wrapper for managing individual CDNI trigger specs in an opaque manner.

It is encoded as a JSON object containing the following name/value pairs:

Name: trigger-subject
Description: Case-insensitive CDNI trigger subject.

Value: String containing the type of the subject matching the generic-trigger-spec-value property, such as "content" or "metadata" as defined in Section 4.1.2.2.

Mandatory: Yes.

Name: generic-trigger-spec-type
Description: Case-insensitive CDNI trigger spec type.

Value: String containing the spec type of the object contained in the generic-trigger-spec-value property (see table in Section 4.1.2).

Mandatory: Yes.

Name: generic-trigger-spec-value
Description: A CDNI trigger spec object.

Value: Defined by the value of the generic-trigger-spec-type property.

Mandatory: Yes.

The structure of a JSON-serialized GenericTriggerSpec object, containing a specific trigger spec is illustrated below:

```
{
  "generic-trigger-spec-type":
     <Type of this trigger spec>,
  "generic-trigger-spec-value":
      {
        <properties of this trigger spec object>
      },
   "generic-trigger-spec-subject":
     <Category of this trigger spec subject>

}
```

4.1.2.2. Trigger Subject

Because the scope of the trigger may relate to either metadata as well as content, the "trigger spec object" also specifies the trigger's target subject (i.e., metadata or content) against which to match.

All trigger subjects MUST be registered in the IANA "CDNI CI/T Trigger Subjects" registry (see Section 7.4).

dCDN receiving a trigger creation request containing a trigger subject that it does not recognize or does not support MUST reject the request by creating a trigger resource with a "failed" state and the "errors" array containing an Error.v2 Description with error "esubject" (see Section 4.1.6.2).

This document also defines an initial set of trigger subject values and registers them in the IANA "CDNI CI/T Trigger Subjects" registry:

JSON String	Description
metadata	Indicating the trigger target specification refers to Metadata object(s), as defined at [RFC8006].
content	Indicating the trigger target specification refers to client-facing content objects.

Table 4

4.1.2.3. Spec Constraints

There are certain constraints in the way the trigger specs can be combined with trigger subject and trigger actions:

Trigger spec types	Trigger subject: "content" and "metadata"	Trigger action: "preposition", "purge" and "invalidate"
urls	Any	Any
ccids	"content" only	"purge" or "invalidate"
uri-pattern-match	Any	"purge" or "invalidate"
uri-regex-match	Any	"purge" or "invalidate"
content-objectlist	Any	Any

Table 5: Summary of trigger spec constraints

4.1.2.4. URLs Spec

The "urls" spec type allows uCDN to manage uCDN content or metadata objects held by dCDN based on the objects' URLs.

The URLs spec is encoded as a JSON object containing the following name/value pairs:

Name: urls
Description: An array of URLs over which the trigger MUST be executed.

Value: A JSON array of URLs represented as JSON strings.

Mandatory: Yes.

Name: url-type
Description: Type of URL used.

Value: URL Type as defined in Section 4.3.1.

Mandatory: No. When omitted or empty, the "published" URL type is assumed.

Below is an example of a JSON-serialized URLs spec object, matching the metadata at metadata.example.com/a/b/c.

```
{
  "trigger-subject": "metadata",
  "generic-trigger-spec-type": "urls",
  "generic-trigger-spec-value": {
    "urls": [ "https://metadata.example.com/a/b/c" ],
    "url-type": "published"
  }
}
```

4.1.2.5. CCIDs Spec

The "ccids" spec type allows uCDN to specify the Content Collection IDentifier (CCID) of content to which the trigger applies. The CCID is a grouping of content as defined by [RFC8006]. The "ccids" spec type is valid only for the content spec subject (see Section 4.1.2.2).

CCIDs spec is encoded as a JSON object containing the following name/value pairs:

Name: ccids
Description: An array of Content Collection IDentifiers over which the trigger MUST be executed.

Value: A JSON array of strings, where each string is a Content Collection IDentifier.

Mandatory: Yes.

4.1.2.6. URI Pattern Match Spec

The "uri-pattern-match" spec type allows uCDN to manage uCDN content or metadata objects held by dCDN based on the objects' URI pattern. The value is a UriPatternMatch object, as defined in Section 4.1.2.6.1.

4.1.2.6.1. UriPatternMatch

A UriPatternMatch consists of a string pattern to match against a URI, and flags describing the type of match.

It is encoded as a JSON object containing the following name/value pairs:

Name: pattern
Description: A pattern for URI matching.

Value: A JSON string representing the pattern. The pattern can contain the wildcards "*" and "?", where "*" matches any sequence of [RFC3986] pchar or "/" characters (including the empty string) and "?" matches exactly one [RFC3986] pchar character. The three literals "$", "*", and "?" MUST be escaped as "$$", "$*" and "$?" (where "$" is the designated escape character). All other characters are treated as literals.

Mandatory: Yes.

Name: case-sensitive
Description: Flag indicating whether or not case-sensitive matching should be used.

Value: One of the JSON values "true" (the matching is case sensitive) or "false" (the matching is case insensitive).

Mandatory: No; default is "false", i.e., a case-insensitive match.

Name: match-query-string
Description: Flag indicating whether to include the query part of the URI when compared against the pattern.

Value: One of the JSON values "true" (the full URI including the query part should be compared against the given pattern) or "false" (the query part of the URI should be dropped before comparison with the given pattern).

Mandatory: No; default is "false". The query part of the URI should be dropped before comparison with the given pattern.

Name: url-type
Description: Type of URLs to match.

Value: URL Type as defined in Section 4.3.1.

Mandatory: No. When omitted or empty, "published" URL type is assumed.

Example of case-sensitive prefix match against "https://www.example.com/trailers/":

```
{
  "pattern": "https://www.example.com/trailers/*",
  "case-sensitive": true
}
```

4.1.2.7. URI Regex Match Spec

The "uri-regex-match" spec type allows uCDN to manage content or metadata objects held by dCDN based on the objects' URI regex.

4.1.2.7.1. RegexMatch

A RegexMatch consists of a regular expression string a URI is matched against, and flags describing the type of match. It is encoded as a JSON object with the following properties:

Name: regex
Description: A regular expression for URI matching.

Value: A regular expression to match against the URI, i.e., against the path-absolute and the query string parameters [RFC3986]. The regular expression string MUST be compatible with POSIX [POSIX.1] Section 9 Extended Regular Expressions. This regular expression MUST be evaluated in the POSIX locale (POSIX [POSIX.1] Section 7.2).

Note: Because '\' has a special meaning in JSON [RFC8259] as the escape character within JSON strings, the regular expression character '\' MUST be escaped as '\\'.

Mandatory: Yes.

Name: case-sensitive
Description: Flag indicating whether or not case-sensitive matching should be used.

Value: JSON boolean. Either "true" (the matching is case-sensitive) or "false" (the matching is case insensitive).

Mandatory: No; default is "false", i.e., a case-insensitive match.

Name: match-query-string
Description: Flag indicating whether to include the query part of the URI when compared against the regex.

Value: JSON Boolean. Either "true" (the full URI, including the query part, should be compared against the regex) or "false" (the query part of the URI should be dropped before comparison with the given regex).

Mandatory: No; default is "false". The query part of the URI MUST be dropped before comparison with the given regex. This makes the regular expression simpler and safer for cases in which the query parameters are not relevant to the match.

Name: url-type
Description: Type of URLs to match against.

Value: URL Type as defined in Section 4.3.1.

Mandatory: No. When omitted or empty, "published" URL type is assumed.

Example of a case-sensitive, no query parameters, regex match against is below.

Please note that some lines in the example are wrapped for clarity.

```
"^(https:\/\/video\.example\.com)\/([a-z])\/
 movie1\/([1-7])\/*(index.m3u8|\d{3}.ts)$"
```

```
{
  "regex": "^(https:\\/\\/video\\.example\\.com)\\/([a-z])\\/
           movie1\\/([1-7])\\/*(index.m3u8|\\d{3}.ts)$",
  "case-sensitive": true,
  "match-query-string": false
}
```

This regex matches URLs of the domain "video.example.com" where the path structure is /(single lower case letter)/(name-of-title)/(single digit between 1 to 7)/(index.m3u8 or a 3 digit number with ts extension). For example:

https://video.example.com/d/movie1/5/index.m3u8

or

https://video.example.com/k/movie1/4/013.ts

4.1.2.8. Object List Spec

The "objectlist" spec type allows uCDN to manage content or metadata held by dCDN based on structured object lists. The Object List spec type is valid only for the content spec subject (see Section 4.1.2.2).

An object list is encoded as a JSON object with the following properties:

Name: objects
Description: An array of objects to be used in the trigger

Value: Array of ObjectList (Section 4.3.2) objects

Mandatory: Yes.

4.1.3. Trigger Extensions

A "trigger" object, as defined in Section 4.1 includes an optional array of trigger extension objects. A trigger extension contains properties that are used as directives for dCDN when executing the trigger command, e.g., location policies, time policies, and so on. Each such CDNI trigger extension is a specialization of a CDNI GenericTriggerExtension object. The GenericTriggerExtension object abstracts the basic information required for trigger distribution from the specifics of any given property (i.e., property semantics, enforcement options, etc.). All trigger extensions are optional, and it is thus the responsibility of the extension specification to define a consistent default behavior for extensions supported by dCDN when not specified by uCDN.

4.1.3.1. Enforcement Options

The trigger enforcement options concept is in accordance with the metadata enforcement options as defined in Section 3.2 of [RFC8006].

The GenericTriggerExtension object defines the properties contained within it as well as whether or not the properties are "mandatory-to-enforce". If dCDN does not understand or support a mandatory-to-enforce property, dCDN MUST NOT execute the trigger command. If the extension is not mandatory-to-enforce, then that GenericTriggerExtension object can be safely ignored and the trigger command can be processed in accordance with the rest of the CDNI trigger spec.

Although a CDN MUST NOT execute a trigger command if a mandatory-to-enforce extension cannot be enforced, it could still be safe for a transit CDN (tCDN) to redistribute that trigger (the "safe-to-redistribute" property) to another CDN without modification, provided the tCDN does not needs to do trigger processing of its own and only pass the trigger to one or more dCDNs. For example, in the cascaded CDN case, a transit CDN (tCDN) could convey mandatory-to-enforce trigger extension to dCDN. For a trigger extension that does not require customization or translation (i.e., trigger extension that is safe-to-redistribute), the data representation received off the wire MAY be stored and redistributed without being understood or supported by tCDN. However, for trigger extension that requires translation, transparent redistribution of uCDN trigger values might not be appropriate. Certain trigger extensions can be safely, though perhaps not optimally, redistributed unmodified. For example, preposition command might be executed in suboptimal times for some geographies if transparently redistributed, but it might still work.

Redistribution safety MUST be specified for each GenericTriggerExtension listed. If a CDN does not understand or support a given GenericTriggerExtension object that is not safe-to-redistribute, the CDN MUST set the "incomprehensible" flag to true for that GenericTriggerExtension object before redistributing it. The "incomprehensible" flag signals to dCDN that trigger metadata was not properly transformed by the tCDN. A CDN MUST NOT attempt to execute a trigger with an extension that has been marked as "incomprehensible" by uCDN.

tCDNs MUST NOT change the value of mandatory-to-enforce or safe-to-redistribute when propagating a trigger to dCDN. Although a tCDN can set the value of "incomprehensible" to true, a tCDN MUST NOT change the value of "incomprehensible" from true to false.

Table 6 describes the action to be taken by a tCDN for the different combinations of mandatory-to-enforce ("MtE") and safe-to-redistribute ("StR") properties when the tCDN either does or does not understand the trigger extension object in question:

MtE	StR	Extension object understood by tCDN	Trigger action
False	True	True	Can execute and redistribute.
False	True	False	Can execute and redistribute.
False	False	False	Can execute. MUST set "incomprehensible" to true when redistributing.
False	False	True	Can execute. Can redistribute after transforming the trigger extension (if the CDN knows how to do so safely); otherwise, MUST set "incomprehensible" to true when redistributing.
True	True	True	Can execute and redistribute.
True	True	False	MUST NOT execute but can redistribute, provided own processing is not required.
True	False	True	Can execute. Can redistribute after transforming the trigger extension (if the CDN knows how to do so safely); otherwise, MUST set "incomprehensible" to true when redistributing.
True	False	False	MUST NOT execute. May redistribute, provided own processing is not required. MUST set "incomprehensible" to true when redistributing.

Table 6: Action to be taken by a tCDN for the different combinations of MtE and StR properties

Table 7 describes the action to be taken by dCDN for the different combinations of mandatory-to-enforce and "incomprehensible" ("Incomp") properties, when dCDN either does or does not understand the trigger extension object in question:

MtE	Incomp	Extension object understood by dCDN	Trigger action
False	False	True	Can execute.
False	True	True	Can execute but MUST NOT interpret/apply any trigger extension marked as "incomprehensible".
False	False	False	Can execute.
False	True	False	Can execute but MUST NOT interpret/apply any trigger extension marked as "incomprehensible".
True	False	True	Can execute.
True	True	True	MUST NOT execute.
True	False	False	MUST NOT execute.
True	True	False	MUST NOT execute.

Table 7: Action to be taken by dCDN for the different combinations of MtE and Incomp properties

4.1.3.2. GenericExtensionObject

A GenericTriggerExtension object is a wrapper for managing individual CDNI Trigger extensions in an opaque manner.

It is encoded as a JSON object containing the following name/value pairs:

Name: generic-trigger-extension-type
Description: Case-insensitive CDNI trigger extension object type.

Value: String containing the CDNI Extension Type [RFC7736] of the object contained in the "generic-trigger-extension-value" property (see table in Section 2.8).

Mandatory: Yes.

Name: generic-trigger-extension-value
Description: CDNI trigger extension object.

Value: Defined by the value of the "generic-trigger-extension-type" property above.

Mandatory: Yes.

Name: mandatory-to-enforce
Description: Flag identifying whether or not the enforcement of this trigger extension is mandatory.

Value: Boolean.

Mandatory: No. The default is to treat the trigger extension as mandatory to enforce (i.e., a value of True).

Name: safe-to-redistribute
Description: Flag identifying whether or not this trigger extension can be safely redistributed without modification, even if the CDN fails to understand the extension.

Value: Boolean.

Mandatory: No. The default is to allow transparent redistribution (i.e., a value of True).

Name: incomprehensible
Description: Flag identifying whether or not any CDN in the chain of delegation has failed to understand and/or failed to properly transform this trigger extension object. Note: This flag only applies to trigger extension objects whose "safe-to-redistribute" property has a value of False.

Value: Boolean.

Mandatory: No. The default is comprehensible (i.e., a value of False).

The structure of a JSON-serialized GenericTriggerExtension object containing a specific trigger extension object is illustrated below:

```
{
  "generic-trigger-extension-type":
     <Type of this trigger extension object>,
  "generic-trigger-extension-value":
      {
        <properties of this trigger extension object>
      },
  "mandatory-to-enforce": <bool>,
  "safe-to-redistribute": <bool>,
  "incomprehensible": <bool>
}
```

4.1.3.3. Trigger Extension Objects

The objects defined below are intended to be used in the GenericTriggerExtension object's generic-trigger-extension-value field as defined in Section 4.1.3.2, and their generic-trigger-extension-type property MUST be set to the appropriate Extension Type as defined in Section 2.8.

4.1.3.3.1. LocationPolicy Extension

A content operation may be relevant for a specific geographical region or need to be excluded from a specific region. In this case, the trigger should be applied only to parts of the network that are either "included" or "not excluded" by the location policy. Note that the restrictions here are on the cache location rather than the client location.

The LocationPolicy object defines which CDN or cache locations for which the trigger command is relevant.

Example use cases:

* Preposition: Certain contracts allow for prepositioning or availability of contracts in all regions except for certain excluded regions in the world, including caches. For example, some content cannot ever knowingly touch servers in a specific country, including cached content. Therefore, these regions MUST be excluded from a prepositioning operation.

* Purge: In certain cases, content may have been located on servers in regions where the content must not reside. In such cases, a purge operation to remove content specifically from that region is required.

Object specification:

Name: locations
Description: An Access List that allows or denies (blocks) the trigger execution per cache location.

Value: Array of LocationRule objects (see Section 4.2.2.1 of [RFC8006]).

Mandatory: Yes.

Name: url-type
Description: Type of URL used in the ObjectList(s).

Value: URL Type as defined in Section 4.3.1.

Mandatory: No. When omitted or empty, the "published" URL type is assumed.

If a location policy object is not listed within the trigger command, the default behavior is to execute the trigger in all available caches and locations of dCDN.

The trigger command is allowed, or denied, for a specific cache location according to the action of the first location whose footprint matches that cache’s location. If two or more footprints overlap, the first footprint that matches against the cache’s location determines the action a CDN MUST take. If the "locations" property is an empty list or if none of the listed footprints match the location of a specific cache location, then the result is equivalent to a "deny" action.

The following is an example of a JSON-serialized generic trigger extension object containing a location policy object that allows the trigger execution in the US but blocks its execution in Canada:

```
{
  "generic-trigger-extension-type": "location-policy",
  "generic-trigger-extension-value": {
    "locations": [
      {
        "action": "allow",
        "footprints": [{
          "footprint-type": "countrycode",
          "footprint-value": [ "us" ]
        }]
      },
      {
        "action": "deny",
        "footprints": [{
          "footprint-type": "countrycode",
          "footprint-value": [ "ca" ]
        }]
      }
    ]
  },
  "mandatory-to-enforce": true,
  "safe-to-redistribute": true,
  "incomprehensible": false
}
```

4.1.3.3.2. TimePolicy Extension

uCDN may wish to perform content management operations on dCDN on a specific schedule. The TimePolicy extension allows uCDN to instruct dCDN to execute the trigger command in a desired time window. For example, a content provider may wish to pre-populate a new episode at off-peak time so that it would be ready on caches at prime time when the episode is released for viewing. A scheduled operation enables uCDN to direct dCDN in what time frame to execute the trigger.

This specification supports region-by-region time scheduling when used in conjunction with the Location Policy defined in Section 4.1.3.3.1. uCDN can trigger separate commands for different geographical regions using a different schedule for each region. This allows uCDN to control the execution time per region.

Object specification:

Name: unix-time-window
Description: A UNIX epoch time window in which the trigger SHOULD be executed.

Value: TimeWindow object using UNIX epoch timestamps (see Section 4.2.3.2 of [RFC8006]).

Mandatory: No, but exactly one of either "unixEpochWindow" or "utcWindow" MUST be present.

Name: utc-window
Description: A UTC time window in which the trigger SHOULD be executed.

Value: UTCWindow object as defined in Section 4.1.3.3.2.1.

Mandatory: No, but exactly one of either "unixEpochWindow" or "utcWindow" MUST be present.

If a time policy object is not listed within the trigger command, the default behavior is to execute the trigger in a time frame most suitable to dCDN taking under consideration other constraints and / or obligations.

Example of a JSON-serialized generic trigger extension object containing a time policy object that schedules the trigger execution to a window between 09:00 01/01/2000 UTC and 17:00 01/01/2000 UTC, using the "unix-time-window" property:

```
{
   "generic-trigger-extension-type": "time-policy",
   "generic-trigger-extension-value":
    {
      "unix-time-window": {
         "start": 946717200,
         "end": 946746000
      }
    },
   "mandatory-to-enforce": true,
   "safe-to-redistribute": true,
   "incomprehensible": false
}
```

4.1.3.3.2.1. UTCWindow

A UTCWindow object describes a time range in UTC or UTC and a zone offset that can be applied by a TimePolicy.

It is encoded as a JSON object containing the following name/value pairs:

Name: start

Description: The start time of the window.

Value: Internet date and time as defined in [RFC3339].

Mandatory: No. but at least one of either "start" or "end" MUST be present and non-empty.

Name: end
Description: The end time of the window.

Value: Internet date and time as defined in [RFC3339].

Mandatory: No. but at least one of either "start" or "end" MUST be present and non-empty.

Example JSON-serialized UTCWindow object that describes a time window from 02:30 01/01/2000 UTC to 04:30 01/01/2000 UTC:

```
{
  "start": "2000-01-01T02:30:00.00Z",
  "end": "2000-01-01T04:30:00.00Z"
}
```

Example JSON-serialized UTCWindow object that describes a time window in New York time zone offset UTC-05:00 from 02:30 01/01/2000 to 04:30 01/01/2000:

```
{
  "start": "2000-01-01T02:30:00.00-05:00",
  "end": "2000-01-01T04:30:00.00-05:00"
}
```

4.1.3.3.3. ExecutionPolicy Extension

Unless specified otherwise, dCDN is at liberty to decide how to choose trigger commands for execution from all pending commands, whether to process trigger commands sequentially or in parallel, immediately upon acceptance, or with a delay in batches. uCDN may wish to control trigger processing in more detail, including the order of execution, dependencies, and concurrency.

Example use cases:

* Priority: uCDN may have multiple trigger commands in "pending" and/or "active" mode. For example, trigger commands with policy constraints, a large number of content objects affected, or other dCDN business logic may take a long time to execute. uCDN may wish to prescribe the order in which dCDN picks up its trigger

commands for execution from the "pending" queue, by indicating a relative priority of each trigger. The priority would affect the selection of trigger commands specific to the requesting uCDN. dCDN may separately prioritize triggers from multiple uCDNs subject to its business logic. Multiple priority-related use cases exist:

- uCDN needs to introduce an urgent "purge" or "invalidate" trigger into an existing queue of trigger commands to correct wrong versions of content objects published by it

- uCDN needs to indicate which content objects should be prepositioned, purged, or invalidated first, for example prepositioning newer released content before prepositioning updates to an existing catalog

* Prerequisite: In some cases, uCDN may wish to indicate what trigger commands should be processed and completed before another trigger command is processed. For example, uCDN may want to rectify incorrectly published content by purging content objects and then prepositioning them again. In this case, uCDN may want the preposition trigger command to be processed only after the purge trigger command has been processed because the concurrent processing of these triggers may cause the new version of these content objects to be purged. Alternatively, uCDN may wish to condition the execution of purge or invalidation triggers upon the completion or cancellation of long-running preposition triggers to avoid race conditions that would result from processing these in parallel. The prerequisite requirement implies that a previous trigger reaches one of the following states:

  - "complete" or "processed" for successful completion

  - "failed" for failed processing

  - "cancelled" for completion of cancellation

* Urgency: uCDN may wish to indicate that dCDN should process a trigger command without delay. This requirement is separate and additional to priority, as priority indicates the order in which triggers should be processed, yet does not prescribe how soon each trigger should be executed. dCDN MAY reject such requests for urgent processing using "ereject" error code. This can happen due to dCDN’s internal business logic (e.g., batch-driven purge and invalidation), or due to dependencies on other triggers that could not be completed by dCDN immediately. In such a case uCDN should either modify the request by removing prerequisites or cancel such pending triggers before re-trying the request.

uCDN may combine multiple options in the same trigger command. dCDN should consider the following when processing such commands:

* dCDN MUST reject triggers that are dependent on other pending triggers with lower priority to prevent deadlocks.

* When introducing an urgent trigger uCDN SHOULD indicate a priority that is equal to or higher than the highest priority among the pending triggers that belong to the same uCDN. dCDN MUST reject urgent triggers that have lower priority than other pending triggers of the same uCDN.

* dCDN MUST reject an urgent trigger that has pending triggers as its prerequisite. dCDN MAY reject an urgent trigger that has triggers in an "active" or "cancelling" state as its prerequisite, such as when such triggers are deemed to take a long time to complete or cancel.

When combining ExtensionPolicy with Section 4.1.3.3.2, TimePolicy governs the time window when the trigger can execute, while ExecutionPolicy controls the order of trigger execution within their respective windows. The following error conditions should be considered by dCDN:

* When a trigger is marked urgent, but its TimePolicy extension doesn’t allow immediate processing, it should be rejected by dCDN.

* When a trigger has a TimePolicy extension and is also dependent on another trigger with a TimePolicy extension, that specifies an execution window (directly or via a chain of dependency) that doesn’t start until after the depending trigger’s execution window ends, such a trigger should be rejected.

The ExtensionPolicy extension is encoded as a JSON object containing the following name/value pairs:

Name: priority
Description: Relative weight of the trigger. When picking a trigger for execution from all pending triggers posted by each uCDN, dCDN MUST choose the trigger with the highest priority first.

Value: Integer from -100 to 100.

Mandatory: No. The value defaults to zero if omitted.

Name: depends

Description: Links to trigger resources that the current trigger depends on. Indicates which triggers should fully finish processing before starting execution of the current trigger. The triggers need to be in one of the following states to be considered finished: "complete", "processed", "failed" or "cancelled".

Value: A JSON array of zero or more URLs, represented as JSON strings.

Mandatory: No. In case of a missing or an empty list, no dependencies are assumed.

Name: urgent
Description: Indicates whether the trigger should be immediately moved to the "active" state upon acceptance. In the absence of this flag, dCDN is at liberty to choose the time for trigger execution, e.g., batch processing.

Value: Boolean.

Mandatory: No. The default is to handle the trigger as not urgent.

The following is an example of a JSON-serialized generic extension trigger object containing an execution policy object that specifies trigger priority of 100, marks the trigger as urgent and makes its execution dependent on the completion of the previously created triggers:

```
{
  "generic-trigger-extension-type": "execution-policy",
  "generic-trigger-extension-value":
  {
    "priority": 100,
    "depends": [
     "https://dcdn.example/cit/b1467469-3cf3-4613-8629-814cd938f30b",
     "https://dcdn.example/cit/c73a9911-298b-4ee3-bbab-03bce07b7d5c"
    ],
    "urgent": true
  }
}
```

4.1.4. Trigger Labels

Trigger labels provide a framework for uCDN to associate an array of key-value pairs with trigger resources.

The labels may be used to simplify the management of a large number of triggers by grouping related triggers, and tracking their status using label-based filtering of the trigger collection resource (see Section 4.2 for more details). In this case the label values remain fully opaque to dCDN and serve for trigger grouping purposes only.

Alternatively, trigger labels may be used by uCDN to pass to dCDN information to be used for the trigger processing. For example, in the case of uCDN and dCDN utilizing non-standard configuration metadata objects, uCDN may use trigger labels to help dCDN identify the appropriate configuration section where the trigger should be applied. uCDN may also use the labels to pass to dCDN freeform content metadata to inform dCDN cache management operations.

4.1.5. Trigger State

The trigger state describes the current state of the triggered activity. It MUST be one of the JSON strings in the following table:

JSON String	Description
pending	The trigger has not yet been acted upon.
active	The trigger is currently being acted upon.
complete	The trigger processing completed successfully.
processed	The trigger has been created, and no further status update will be made (can be used in cases where completion cannot be confirmed).
failed	The trigger processing could not be completed.
cancelling	The trigger processing is still in progress, but the trigger has been cancelled by uCDN.
cancelled	The trigger was cancelled by uCDN.

Table 8

Along with the trigger state, the trigger resource has a state reason property, allowing dCDN to provide additional information for the trigger state. For example, dCDN may indicate that the trigger state

is "pending" due to one of the execution prerequisites not being fulfilled. Such a prerequisite may be specified via one of the extensions.

4.1.6. Trigger Errors

4.1.6.1. Error.v2 Description

An Error.v2 Description is used to report the failure of a trigger. It is encoded as a JSON object with the following name/value pairs:

Name: error
Value: Error Code, as defined in Section 4.1.6.2.

Mandatory: Yes.

Name: description
Description: A human-readable description of the error.

Value: A JSON string, the human-readable description.

Mandatory: No.

Name: specs
Description: Array of trigger spec objects from the corresponding "specs" array in the trigger resource. Only those specs to which the error applies are listed.

Value: Array of trigger specs, as defined in Section 4.1.2, where each spec object MUST be exactly as it appears in the trigger resource.

Mandatory: Yes.

Name: extensions
Description: Array of trigger extension objects copied from the corresponding "extensions" array in the trigger resource. Only those extensions to which the error applies are included, but those extensions MUST be exactly as they appear in the trigger resource.

Value: Array of GenericTriggerExtension objects, where each extension object is copied from the "extensions" array values in the trigger resource.

Mandatory: No. The "extensions" array SHOULD be used only if the error relates to extension objects. Property omission should be interpreted as "the error is not related to any extension".

Name: cdn-id
Description: The CDN PID of the CDN where the error occurred. The "cdn-id" property is used by the originating uCDN or by the propagating dCDN to distinguish in which CDN the error occurred.

Value: A non-empty JSON string, where the string is a CDN PID as defined in Section 4.3.3

Mandatory: Yes. dCDN may use its own CDN PID if it does not want to expose the CDN PIDs of dCDNs.

Name: objects
Description: List of objects that failed to be processed during trigger execution.

Value: An array of ObjectList (Section 4.3.2) objects. dCDN SHOULD provide the list of objects that it failed to process during trigger execution with Section 4.1.2.8, provided that dCDN advertised support for extended status (Section 5.5).

Mandatory: No. An empty array is allowed and is equivalent to omitting "objects" from the Error.v2 Description.

Example of a JSON-serialized Error.v2 Description object reporting a malformed object list :

```
{
  "error": "econtent",
  "description": "Failed to parse HLS object list",
  "specs": [{
    "trigger-subject": "content",
    "generic-trigger-spec-type": "content-objectlist",
    "generic-trigger-spec-value": {
      "objects": [{
        "href": "https://www.example.com/hls/title/index.m3u8",
        "type": "hls"
      }]
   }}
  ],
  "objects": [{
    "href": "https://www.example.com/hls/title/index.m3u8",
    "type": "hls"
  }],
  "cdn": "AS64500:0"
}
```

Example of a JSON-serialized Error.v2 Description object reporting an unsupported extension object:

```
{
  "errors": [{
    "error": "eextension",
    "description": "unrecognized extension location-policy",
    "specs": [{
      "trigger-subject": "content",
      "generic-trigger-spec-type": "urls",
      "generic-trigger-spec-value": {
        "urls": [
          "https://www.example.com/a/b/c/1",
          "https://www.example.com/a/b/c/2"
        ]
      }
    }],
    "extensions": [{
      "generic-trigger-extension-type": "location-policy",
      "generic-trigger-extension-value": {
        "locations": [{
          "action": "deny",
          "footprints": [{
              "footprint-type": "countrycode",
              "footprint-value": [ "ca" ]
            }]
          }]
        }
    }],
    "cdn": "AS64500:0"
  }]
}
```

4.1.6.2. Error Code

This type is used by dCDN to report failures in trigger processing. All Error Codes MUST be registered in the IANA "CDNI CI/T Error Codes" registry (see Section 7.7). Unknown Error Codes MUST be treated as fatal errors, and the request MUST NOT be automatically retried without modification.

The following Error Codes are defined by this document and MUST be supported by an implementation of the CI/T v2 interface.

Error Code	Description	Registration
emeta	dCDN was unable to acquire and/or does not have metadata required to fulfill the request.	RFCthis

econtent	dCDN was unable to acquire content (CI/T "preposition" commands only).	RFCthis
eperm	uCDN does not have permission to create the trigger as requested(for example, the data is owned by another CDN).	RFCthis
ereject	dCDN is not willing to process the trigger (for example, a "preposition" request for content at a time when dCDN would not accept Request Routing requests from uCDN).	RFCthis
ecdn	An internal error in dCDN or one of its dCDNs.	RFCthis
ecancelled	uCDN cancelled the request.	RFCthis
eunsupported	The trigger resource used an "action type" that is not supported by dCDN. No action was taken by dCDN other than to create a trigger in a "failed" state.	RFCthis
espec	An error occurred while parsing a generic trigger spec, or that the specific trigger spec is not supported by the CDN.	RFCthis
esubject	An error occurred while parsing a trigger subject, or that the specific trigger subject is not supported by the CDN.	RFCthis
eextension	An error occurred while parsing a generic trigger extension, or that the specific extension is not supported by the CDN.	RFCthis

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4.2. Trigger Collection Resource

As described in Section 2.1, dCDN maintains RESTful trigger resources that represent an action ("trigger") uCDN requests dCDN to carry out.

A collection of trigger resources represents all triggers created by the dCDN at the request of a uCDN, and is by itself a RESTful resource. dCDN MUST make the trigger collection resource available to each uCDN, and MUST maintain it, adding and removing triggers from the collection as the triggers are created (Section 3.1) by uCDN and are either deleted (Section 3.5) by uCDN or expire (Section 3.6). When dCDN first instantiates the CI/T interface for a uCDN, the trigger collection resource is empty.

Trigger resources in a collection are usually represented using their unique URIs. Note that the collection may refer to CI/T Resources from several versions of CI/T objects, i.e., a subsequent call for the retrieval of the relevant trigger resource may provide objects of various MIME media types: ci-trigger-status as defined in [RFC8007], ci-trigger.v2 defined in this document, or objects of future CI/T objects versions, based on the version of the JSON object used to create the trigger.

To request the creation of a new trigger resource, uCDN POSTs the new trigger representation to the trigger collection resource.

To allow uCDN to check the status of multiple triggers in a single request, dCDN MAY maintain optional representations of the trigger collection, which contain a subset of all triggers, filtered using a parameter. These filtered collection representations are "optional-to-implement", but if they are implemented, dCDN MUST include links to them in the trigger collection resource.

dCDN MAY provide filtered representations of the trigger collection per trigger state (Section 4.1.5). If implemented, dCDN SHOULD provide a separate filtered collection representation for every trigger state, and advertise these representations in the trigger collection.

dCDN MAY further provide filtered collection representations per trigger label, as specified by uCDN when creating a trigger resource (Section 4.1). If implemented, dCDN SHOULD provide a separate filtered collection representation for every unique trigger label in

use by the uCDN, and advertise these representations in the collection of all trigger resources. dCDN MUST update the filtered label representations as trigger labels are added or removed by uCDN.

All trigger collection representations MUST use a MIME media type of "application/cdni; ptype=ci-trigger-collection.v2".

A trigger collection is encoded as a JSON object containing the following name/value pairs:

Name: triggers
Description: Links to triggers in the collection.

Value: A JSON array of zero or more URLs, represented as JSON strings.

Mandatory: Yes.

Name: staleresourcetime
Description: The length of time for which dCDN guarantees to keep a completed trigger resource. After this time, dCDN SHOULD delete the trigger resource and all references to it from the collection.

Value: A JSON number, which must be a positive integer, representing time in seconds.

Mandatory: Yes, in the collection of all triggers if dCDN deletes stale entries. If the property is present in the filtered collection representation, it MUST have the same value as in the collection of all triggers.

Name: coll-state
Description: Array of Section 4.2.1 objects.

Value: An array of JSON-encoded filtered collection representation objects, with one entry for each trigger state, as specified in Section 4.1.5.

Mandatory: Mandatory in the trigger collection resources, if dCDN implements the per-state filtered representations of the triggers collection. Otherwise, optional.

Name: coll-label
Description: Array of Section 4.2.1 objects.

Value: An array of JSON-encoded filtered collection representation objects, with one entry for each unique label key-value, as specified by uCDN, using the "labels" attribute of a trigger resource (see Section 4.1 for details).

Mandatory: Mandatory in the trigger collection resources, if dCDN implements the per-label filtered representations of the triggers collection. Otherwise, optional.

Name: all-triggers
Description: Array of all triggers in the collection. Should be returned only when an extended trigger collection view is requested as described in Section 3.4.1.1.

Value: An array of JSON-encoded triggers.

Mandatory: No. The "all-triggers" SHOULD only be used by dCDN that supports and advertises the appropriate extended status for trigger collections (see Section 5.5 for details).

Name: cdn-id
Description: The CDN PID of dCDN.

Value: A JSON string, dCDN’s CDN PID, as defined in Section 4.3.3.

Mandatory: No.

4.2.1. Filtered Representations

The filtered representation object describes a particular filtered representation of triggers. Currently, it supports filtering by trigger state and trigger label. In the future, further filtering capabilities may be added. It is encoded as a JSON object containing the following name/value pairs:

Name: state
Description: Trigger state matching the filtered collection representation.

Value: A trigger state, as defined in Section 4.1.5.

Mandatory: One of the "state" or "label" should be present.

Name: label
Description: Trigger label matching the filtered collection.

Value: A trigger label, as defined in Section 4.1.

Mandatory: One of the "state" or "label" should be present.

Name: uri
Description: URI of the filtered collection representation matching the filtering parameters.

Value: A URI represented as a JSON string.

Mandatory: Yes.

4.3. Other CI/T Objects and Properties

This section describes common CI/T objects, which are used as part of the specification of several other CI/T objects, and their encodings.

4.3.1. URL Type

This type is used by uCDN to indicate how to interpret URLs referenced by trigger specs that use URLs, such as Section 4.1.2.4, Section 4.1.2.6, Section 4.1.2.7, and Section 4.1.2.8.

One option for uCDN to use in triggers is published URLs, which are used by end users. When using this URL type, uCDN MUST provide configuration metadata objects related to these URLs before creating a trigger option referencing these URLs. When this is not the case, dCDN MUST return the error code "emeta".

When processing published URLs in "preposition" trigger action, dCDN MUST invoke processing of metadata objects it would have invoked in content acquisition to satisfy an end-user request, e.g., SourceMetadata (see Section 4.2.1 of [RFC8006]).

Another type of URL in common use is a private URL, which is based on cache keys that are dynamically constructed via lightweight processing of various properties of the HTTP request and/or response. As an example, an origin might specify a cache key as a value returned in a specific HTTP response header.

As an example, uCDN may prefer to use such private URLs in "purge" or "invalidate" trigger actions to simplify processing.

dCDNs implementing the CI/T interface MUST support the "published" URL type. dCDN MAY support the additional "private" URL type. In this case, dCDN SHOULD advertise the private URL type support via FCI using Section 5.4. If the private URL is not supported by dCDN, it SHOULD reject the trigger creation request using "eunsupported" Error Code. If both URL types are supported by dCDN, uCDN MUST use only one URL type in each trigger.

The following URL types are defined by this document and MUST be supported by the implementation of the CI/T interface:

URL Type	Description	Registration
published	Published URL used by end users to access content	RFCthis
private	Private URLs used by dCDN to look up content objects in cache	RFCthis

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4.3.2. ObjectList

ObjectList is a metadata object describing lists of objects that can be used in the context of CI/T v2 trigger spec, trigger status resources, and other contexts as required. The ObjectList object can either embed the lists of objects or point to external URL(s) that hold such lists. ObjectList allows the specification of an object list type, providing instructions on the interpretation of the object list format.

ObjectLists MAY be recursive, i.e., including references to secondary manifests, including references to HLS, MPEG-DASH or MSS manifests as well as additional JSON-encoded ObjectLists, etc. The party consuming the object list MUST parse all recursions based on the object list type property. When doing so, the consuming party should also detect potential loops when the descendant ObjectList points back to the parent ObjectList.

In the case of uCDN accessing ObjectList objects referencing external URLs published by dCDN, both parties SHOULD comply with the CI/T interface security requirements (see Section 8.1 for details). When dCDN accesses external URLs referenced by ObjectLists supplied by uCDN, for example as part of trigger spec, dCDN MUST match these URLs with source metadata objects, published by uCDN, such as SourceMetadata objects specified in Section 4.2.1 of [RFC8006], and use these metadata objects for content acquisition if a match was found.

ObjectLists MAY combine regular objects and secondary ObjectLists in the same object. Please note that when embedding non-JSON object lists directly in ObjectList, absolute URLs MUST be provided at all times and the text SHOULD be encoded per the JSON grammar specification [ECMA404], including explicit newline encoding. When uCDN accesses ObjectList metadata resources published by uCDN, the same interface authentication and authorization requirements would apply, as when accessing the interface itself.

ObjectList is encoded as an array of per-object records in JSON format as follows:

External HLS manifest:

```
[
  {
    "href": "https://example.com/hls/a36f764e/index.m3u8",
    "type": "hls"
  }
]
```

External object list in text format:

```
[
  {
    "href": "https://example.com/hls/35cdc008/assets",
    "type": "text"
  }
]
```

List of external manifests and objects of mixed types:

```
[
  {
    "href": "https://example.com/hls/35cdc008/index.m3u8",
    "type": "hls"
  },
  {
    "href": "https://example.com/dash/35cdc008/main.mpd",
    "type": "dash"
  },
  {
    "href": "https://example.com/dash/35cdc008/files.json",
    "type": "json"
  }
]
```

Embedded JSON-encoded object list:

```
[
  {
    "data": [
      {
        "href": "https://example.com/hls/35cdc008/index.m3u8",
        "type": "hls"
      },
      {
        "href": "https://example.com/dash/35cdc008/main.mpd",
        "type": "dash"
      },
      {
        "href": "https://example.com/img/35cdc008/thumb-l.jpg",
        "size": 10260
      },
      {
        "href": "https://example.com/img/35cdc008/thumb-s.jpg",
        "size": 1453
      }
    ],
    "type": "json"
  }
]
```

Embedded HLS manifest:

Please note that some lines in the example are wrapped for clarity.

```
[
  {
    "data": "#EXTM3U\n
#EXT-X-STREAM-INF:BANDWIDTH=150000,RESOLUTION=416x234,
  CODECS=\"avc1.42e00a,mp4a.40.2\"\n
http://example.com/low/index.m3u8\n
#EXT-X-STREAM-INF:BANDWIDTH=240000,RESOLUTION=416x234,
  CODECS=\"avc1.42e00a,mp4a.40.2\"\n
http://example.com/lo_mid/index.m3u8\n
#EXT-X-STREAM-INF:BANDWIDTH=440000,RESOLUTION=416x234,
  CODECS=\"avc1.42e00a,mp4a.40.2\"\n
http://example.com/hi_mid/index.m3u8\n
#EXT-X-STREAM-INF:BANDWIDTH=640000,RESOLUTION=640x360,
  CODECS=\"avc1.42e00a,mp4a.40.2\"\n
http://example.com/high/index.m3u8\n
#EXT-X-STREAM-INF:BANDWIDTH=64000,
  CODECS=\"mp4a.40.5\"\n
http://example.com/high/index.m3u8\n",
    "type": "hls"
  }
]
```

The ObjectList properties are as follows:

Name: data
: Description: List of objects in one of the recognized formats.

  Value: JSON String.

  Mandatory: No. Either "data" or "href" MUST be set.

Name: href
: Description: URL pointing to an external object list or object in one of the recognized formats.

  Value: A URL represented as a JSON String

  Mandatory: No. Either "data" or "href" MUST be set.

Name: type
: Description: Object list type to be used when parsing and interpreting this object list. By default, each record in the list is assumed to represent an object that does not require additional processing.

  Value: ObjectListType (see Section 4.3.2).

  Mandatory: Yes.

4.3.2.1. ObjectList Type

ObjectListType objects are used to specify the registered type of ObjectList objects (see Section 7.5), used in trigger spec, trigger objects, and Error.v2 Description objects.

The following table defines the initial ObjectListType JSON string values

JSON string	Description	Specification	Protocol Specification
hls	HTTP Live Streaming	RFCthis	RFC 8216 [RFC8216]
mss	Microsoft Smooth Streaming	RFCthis	MSS [MSS]
dash	Dynamic Adaptive Streaming over HTTP (MPEG-DASH)	RFCthis	MPEG-DASH [MPEG-DASH]
json	JSON-serialized object list	RFCthis	JSON (Section 4.3.2.2)
text	Object list in text format	RFCthis	Text (Section 4.3.2.3)

Table 11

[RFC Editor: Please replace RFCthis with the published RFC number for this document.]

4.3.2.2. JSON Serialized Object List

This ObjectList type specifies a collection of objects encoded in JSON format, where each entry is encoded as an ObjectEntry (Section 4.3.2.4) object. The entries in the JSON object list MAY have an object list type specified, allowing for a recursive object list structure.

4.3.2.3. Text Object List

Unlike the JSON Serialized Object List (Section 4.3.2.2), the text-based object list will not support a recursive object list structure and every object specified in it SHOULD be acted upon without additional processing.

4.3.2.4. ObjectEntry

ObjectEntry is a metadata object describing an object and its associated metadata, to be used in JSON-encoded ObjectList (Section 4.3.2) objects.

The following is an example of JSON-serialized ObjectEntry objects:

```
[
  {
    "href": "https://example.com/hls/35cdc008/index.m3u8",
    "type": "hls"
  },
  {
    "href": "https://example.com/dash/35cdc008/main.mpd",
    "type": "dash"
  },
  {
    "href": "https://example.com/img/35cdc008/thumb-l.jpg",
    "size": 102600
  },
  {
    "href": "https://example.com/img/35cdc008/thumb-s.jpg",
    "size": 14535
  }
]
```

The ObjectEntry properties are as follows:

Name: href
: Description: Object URL

  Value: A URL represented as a JSON string.

  Mandatory: Yes.

Name: type
: Description: ObjectList type to be used when processing this object. By default, the ObjectEntry object is assumed to represent an object and does not require additional processing.

Value: ObjectListType (see Section 4.3.2.1).

Mandatory: No.

Name: size
Description: Object size, in bytes. Can be used to decide to download the object based on size. For example, dCDN may ignore objects that are too small or too large.

Value: Integer.

Mandatory: No.

4.3.3. CDN Provider ID

The CDN PID consists of the two characters "AS" followed by the CDN provider's Autonomous System number [RFC1930], then a colon (":") and an additional qualifier that is used to guarantee uniqueness in case a particular AS has multiple independent CDNs deployed -- for example, "AS64496:0".

If the CDN provider has multiple ASes, the same AS number SHOULD be used in all messages from that CDN provider, unless there are multiple distinct CDNs.

If the CDNI Request Routing Redirection interface (RI) described in [RFC7975] is implemented by dCDN, the CI/T interface and the RI SHOULD use the same CDN PID.

5. Footprint and Capabilities

This section covers the FCI objects required for the advertisement of the specs, extensions, and properties introduced in this document.

5.1. CI/T Endpoint Capability Object

The CI/T trigger endpoint capability object is used to advertise one or more CI/T interface endpoints along with CI/T interface versions supported by these endpoints. The capability type is "FCI.CITEndpoints". Version 1, as originally defined in [RFC8007], is the default if this capability is not explicitly declared.

A CI/T Endpoints capability object is encoded as an array of JSON objects containing the following name/value pairs:

Name: trigger-endpoint-uri
Description: CI/T endpoint URI

Value: A URL represented as a JSON string.

Mandatory: Yes.

Name: trigger-versions
Description: A list of CI/T versions supported by the trigger endpoint.

Value: An array of JSON strings.

Mandatory: Yes.

Name: trigger-subject
Description: Array of trigger subjects supported by the trigger endpoint.

Value: An array of Strings containing the type of the subject matching the generic-trigger-spec-value property, such as "content" or "metadata" as defined in Section 4.1.2.2.

Mandatory: No. A missing or empty "trigger-subject" list means that all trigger subjects are supported by the endpoint. dCDN SHOULD advertise only one endpoint for every trigger subject and CI/T interface version pair. If more than one interface endpoint supports the same trigger subject and CI/T interface version (e.g., CI/T version 2 interface for content objects), uCDN SHOULD be able to use any of the advertised CI/T interface endpoints interchangeably.

5.1.1. CI/T Endpoints Capability Object Serialization

The following shows an example of the CI/T Endpoints Capability object serialization for dCDN that supports versions 2 and 2.1 of the CI/T interface.

```
{
  "capabilities": [
    {
      "capability-type": "FCI.CITEndpoints",
      "capability-value": {
        "trigger-endpoint-uri":
          "https://dcdn.example/configuration/",
        "trigger-versions": [ "1" ],
        "trigger-subjects": "metadata"
      },
      "footprints": {
        "footprint-type": "countrycode",
        "footprint-value": [ "us" ]
      }
    },
    {
      "capability-type": "FCI.CITEndpoints",
      "capability-value": {
        "trigger-endpoint-uri":
          "https://dcdn.example/cache-management/",
        "trigger-versions": [ "2", "2.1" ],
        "trigger-subjects": "content"
      },
      "footprints": {
        "footprint-type": "countrycode",
        "footprint-value": [ "us" ]
      }
    }
  ]
}
```

5.2. CI/T Trigger Scope Capability Object

The CI/T supports several trigger actions for different trigger subjects as defined in Section 4.1.1 and Section 4.1.2.2. Additional actions, as well as subjects, may be defined in the future. The trigger scope capability object is used to indicate support for a trigger action for a subject. It further specifies the trigger generic spec types that may be used for selecting the targets the triggers are applied on, along with the supported trigger generic extension types.

The "trigger-scope-capability" object matches the "FCI.CITScope" capability type and is encoded as a JSON object containing the following name/value pairs:

Name: trigger-action
Description: The supported CDNI CI/T trigger action.

Value: A string corresponding to an entry from the "CDNI CI/T Trigger Types" registry Section 7.2, which corresponds to a CDNI CI/T trigger action.

Mandatory: Yes.

Name: trigger-subject
Description: The supported CDNI CI/T trigger subject.

Value: A string corresponding to an entry from the "CDNI CI/T Trigger Subjects" registry Section 7.4, which corresponds to a CDNI CI/T trigger subject.

Mandatory: Yes.

Name: trigger-specs
Description: A list of supported CDNI CI/T GenericSpecObject types for trigger action and subject.

Value: List of strings corresponding to entries from the "CDNI CI/T Trigger Specs" registry Section 7.3, which correspond to CDNI CI/T GenericSpecObject objects.

Mandatory: No. The default in case of a missing or an empty list MUST be interpreted as "no GenericExtensionObject types supported". A non-empty list MUST be interpreted as containing "the only GenericExtensionObject types that are supported".

Name: trigger-extensions
Description: A list of supported CDNI CI/T GenericExtensionObject types for trigger action and subject.

Value: List of strings corresponding to entries from the "CDNI CI/T Trigger Extension" registry Section 7.6, which corresponds to a CDNI CI/T GenericExtensionObject object.

Mandatory: No. The default in case of a missing or an empty list MUST be interpreted as "no GenericExtensionObject types are supported". A non-empty list MUST be interpreted as containing "the only GenericExtensionObject types that are supported".

5.2.1. CI/T Trigger Scope Capability Object Serialization

The following shows an example of a JSON-serialized CI/T Trigger Scope Capability object serialization for dCDN that supports the preposition and invalidation of content, using "urls" and "ccids" generic spec types, with "time-policy" but only for the "preposition" action. Note that in this example, purge is not supported, and no actions involving metadata are supported either.

```
{
  "capabilities": [{
    "capability-type": "FCI.CITScope",
    "capability-value": {
      "trigger-scope-capabilities": [
        {
          "trigger-action": "preposition",
          "trigger-subject": "content",
          "trigger-specs": [ "urls", "ccids" ],
          "trigger-extensions": [ "time-policy" ]
        },
        {
          "trigger-action": "invalidate",
          "trigger-subject": "content",
          "trigger-specs": [ "urls", "ccids" ]
        }
      ]
    },
    "footprints": {
      "footprint-type": "countrycode",
      "footprint-value": [ "us" ]
    }
  }]
}
```

5.3. CI/T Object List Type Capability Object

Given an object list being supported by dCDN, the CI/T Object List Type capability object is used to indicate support for one or more Object List types listed in Section 7.5 by the type property of the "ObjectList" object. The capability type is "FCI.CITObjectListType".

Name: object-list-types

Description: A list of supported ObjectList types.

Value: An array of Section 4.3.2.1.

Mandatory: No. In case of a missing or an empty list, MUST be interpreted as no ObjectList types are supported.

5.3.1. CI/T Object List Type Capability Object Serialization

The following shows an example of a JSON-serialized CI/T Object List Type Capability object serialization for dCDN that supports "hls" and "dash".

```
{
  "capabilities": [{
    "capability-type": "FCI.CITObjectListType",
    "capability-value": {
      "object-list-types": [ "hls", "dash", "json" ]
    },
    "footprints": {
      "footprint-type": "countrycode",
      "footprint-value": [ "us" ]
    }
  }]
}
```

5.4. CI/T Private URL Capability Object

The CI/T Private URL capability object is used to indicate support for operations on private URLs (see Section 4.3.1 for details). The capability type is "FCI.CITPrivateUrlType".

Name: private-url-type-support

Description: Indicate whether private URL type is supported by dCDN.

Value: Boolean.

Mandatory: No. In case of missing or an empty attribute, MUST be interpreted as no support for private URLs.

5.4.1. CI/T Private URL Type Capability Object Serialization

The following shows an example of a JSON-serialized CI/T Private URL Type Capability object serialization for dCDN that supports the private URL type in URL-based trigger spec types.

```
{
  "capabilities": [{
    "capability-type": "FCI.CITPrivateUrlType",
    "capability-value": { "private-url-type-support": true },
    "footprints": {
      "footprint-type": "countrycode",
      "footprint-value": [ "us" ]
    }
  }]
}
```

5.5. CI/T Extended Status Capability Object

The CI/T extended trigger status capability object is used to indicate support for extended trigger status. The extended trigger status is returned upon uCDN request and includes:

* "objects" attribute in the trigger object

* "objects" attribute in Error.v2 description object

* "all-triggers" attribute in the trigger collection object

The capability type is "FCI.CITExtendedStatus".

Name: extended-status-objects
Description: List of CI/T objects that support extended attributes.

Value: An array of JSON strings listing CI/T objects.

Mandatory: No. By default, in case of a missing or an empty list, no extended attribute objects are supported.

5.5.1. CI/T Private URL Type Capability Object Serialization

The following shows an example of a JSON-serialized CI/T Extended Status Type Capability object serialization for dCDN that supports extended status in trigger, Error.v2 description, and trigger collections objects.

```
{
  "capabilities": [{
    "capability-type": "FCI.CITExtendedStatus",
    "capability-value": {
      "extended-status-objects": [
        "trigger-state",
        "error-v2-description",
        "trigger-collection"
      ]
    },
    "footprints": {
      "footprint-type": "countrycode",
      "footprint-value": [ "us" ]
    }
  }]
}
```

6. Examples

This section provides examples of using the CI/T interface and its features.

The discovery of the CI/T interface is out of the scope of this document. In an implementation, all CI/T URLs are under the control of the dCDN. uCDN MUST NOT attempt to ascribe any meaning to individual elements of the path.

In examples in this section, the root URI "https://dcdn.example/cit/" is used as the location of the trigger collection resource, and the CDN PID of uCDN is "AS64496:1".

6.1. Creating Triggers

6.1.1. Preposition

Below is an example of a "preposition" trigger creation. uCDN sends HTTP POST request to the trigger collection URI with the trigger representation in the request body.

Note that pattern-based or label-based specs like "uri-pattern-match", "uri-regex-match" and "ccids" are not allowed to be used with "preposition" trigger action, where dCDN MUST have a clear list of objects to obtain.

REQUEST:

```
POST /cit HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
Content-Type: application/cdni; ptype=ci-trigger.v2
Content-Length: 622

{
  "action": "preposition",
  "specs": [
    {
      "trigger-subject": "metadata",
      "generic-trigger-spec-type": "urls",
      "generic-trigger-spec-value": {
      "urls": [ "https://metadata.example.com/a/b/c" ]
           }
    },
    {
      "trigger-subject": "content",
      "generic-trigger-spec-type": "urls",
      "generic-trigger-spec-value": {
        "urls": [
          "https://www.example.com/a/b/c/1",
          "https://www.example.com/a/b/c/2",
          "https://www.example.com/a/b/c/3",
          "https://www.example.com/a/b/c/4"
        ]
      }
    }
  ],
  "cdn-path": [ "AS64496:1" ]
}
```

RESPONSE:

```
HTTP/1.1 201 Created
Date: Sun, 27 Oct 2024 08:48:10 GMT
Content-Length: 710
Content-Type: application/cdni; ptype=ci-trigger.v2
Location: https://dcdn.example/cit/3f2d259d-a980-4742-beeb-9392a58129f5
Server: example-server/0.1

{
  "ctime": 1730119690,
  "etime": 1730119750,
```

```
   "mtime": 1730119690,
   "state": "pending",
   "action": "preposition",
   "specs": [
     {
       "trigger-subject": "metadata",
       "generic-trigger-spec-type": "urls",
       "generic-trigger-spec-value": {
         "urls": [ "https://metadata.example.com/a/b/c" ]
       }
     },
     {
       "trigger-subject": "content",
       "generic-trigger-spec-type": "urls",
       "generic-trigger-spec-value": {
         "urls": [
           "https://www.example.com/a/b/c/1",
           "https://www.example.com/a/b/c/2",
           "https://www.example.com/a/b/c/3",
           "https://www.example.com/a/b/c/4"
         ]
       }
     }
   ],
   "cdn-path": [ "AS64496:1" ]
 }
```

6.1.2. Invalidate

Below is an example of a CI/T "invalidate" trigger creation. This trigger instructs the dCDN to revalidate:

* the metadata objects with URLs prefixed by "https://metadata.example.com/a/b/" using case-insensitive matching

* a single content object identified by the URL "https://www.example.com/a/index.html"

* the content objects with URLs prefixed by "https://www.example.com/a/b/" using case-sensitive matching

REQUEST:

```
POST /cit HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
```

```
Content-Type: application/cdni; ptype=ci-trigger.v2
Content-Length: 783

{
  "action": "invalidate",
  "specs": [
     {
        "trigger-subject": "metadata",
        "generic-trigger-spec-type": "uri-pattern-match",
        "generic-trigger-spec-value": {
           "pattern": "https://metadata.example.com/a/b/*"
        }
     },
     {
        "trigger-subject": "content",
        "generic-trigger-spec-type": "urls",
        "generic-trigger-spec-value": {
           "urls": [
              "https://www.example.com/a/index.html"
           ]
        }
     },
     {
        "trigger-subject": "content",
        "generic-trigger-spec-type": "uri-pattern-match",
        "generic-trigger-spec-value": {
           "pattern": "https://www.example.com/a/b/*",
           "case-sensitive": true
        }
     }
  ],
  "cdn-path": [ "AS64496:1" ]
}

RESPONSE:

HTTP/1.1 201 Created
Date: Sun, 27 Oct 2024 08:48:11 GMT
Content-Length: 807
Content-Type: application/cdni; ptype=ci-trigger.v2
Location: https://dcdn.example/cit/327df5b8-1df8-4cff-92f8-fda27774c171
Server: example-server/0.1

{
  "ctime": 1730119691,
  "etime": 1730119751,
  "mtime": 1730119691,
  "state": "pending",
```

```
   "action": "invalidate",
   "specs": [
     {
       "trigger-subject": "metadata",
       "generic-trigger-spec-type": "uri-pattern-match",
       "generic-trigger-spec-value": {
         "pattern": "https://metadata.example.com/a/b/*"
       }
     },
     {
       "trigger-subject": "content",
       "generic-trigger-spec-type": "urls",
       "generic-trigger-spec-value": {
         "urls": [ "https://www.example.com/a/index.html" ]
       }
     },
     {
       "trigger-subject": "content",
       "generic-trigger-spec-type": "uri-pattern-match",
       "generic-trigger-spec-value": {
         "pattern": "https://www.example.com/a/b/*",
         "case-sensitive": true
       }
     }
   ],
   "cdn-path": [ "AS64496:1" ]
 }
```

6.1.3. Invalidation with Regex

In the following example, a CI/T "invalidate" trigger uses the Regex property to specify the range of content objects for invalidation, the trigger is rejected by dCDN due to regex complexity, and an appropriate error is reflected in the response.

Please note that some lines in the example are wrapped for clarity.

REQUEST:

```
POST /cit HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
Content-Type: application/cdni; ptype=ci-trigger.v2
Content-Length: 392

{
  "action": "invalidate",
```

```
  "specs": [{
    "trigger-subject": "content",
    "generic-trigger-spec-type": "uri-regex-match",
    "generic-trigger-spec-value": {
      "regex": "^(https:\\/\\/video\\.example\\.com)\\/
        ([a-z])\\/movie1\\/([1-7])\\/*(index.m3u8|\\d{3}.ts)$",
      "case-sensitive": true,
      "match-query-string": false
    }
  }],
  "cdn-path": [ "AS64496:0" ]
}

RESPONSE:

HTTP/1.1 201 Created
Date: Sun, 27 Oct 2024 08:48:12 GMT
Content-Length: 960
Content-Type: application/cdni; ptype=ci-trigger.v2
Location: https://dcdn.example/cit/991b9fb9-d0be-4d05-be06-64c0e5c5a5f9
Server: example-server/0.1

{
  "errors": [{
    "specs": [{
      "trigger-subject": "content",
      "generic-trigger-spec-type": "uri-regex-match",
      "generic-trigger-spec-value": {
      "regex": "^(https:\\/\\/video\\.example\\.com)\\/([a-z])\
        \/movie1\\/([1-7])\\/*(index.m3u8|\\d{3}.ts)$",
        "case-sensitive": true,
        "match-query-string": false
      }
    }],
    "description": "dCDN rejected a regex due to complexity",
    "error": "ereject",
    "cdn": "AS64500:0"
  }],
  "ctime": 1730119692,
  "etime": 1730119692,
  "mtime": 1730119692,
  "state": "failed",
  "action": "invalidate",
  "specs": [{
    "trigger-subject": "content",
    "generic-trigger-spec-type": "uri-regex-match",
    "generic-trigger-spec-value": {
      "regex": "^(https:\\/\\/video\\.example\\.com)\\/([a-z])\
```

```
        \/movie1\\/([1-7])\\/*(index.m3u8|\\d{3}.ts)$",
      "case-sensitive": true,
      "match-query-string": false
    }
  }],
  "cdn-path": [ "AS64496:0" ]
}
```

6.1.4. Preposition with ObjectLists

In the following example, a CI/T "preposition" trigger uses the ObjectList property to specify the full media library of a specific content. The command fails due to object list parse error and an appropriate error is reflected in the response.

REQUEST:

```
POST /cit HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
Content-Type: application/cdni; ptype=ci-trigger.v2
Content-Length: 328

{
  "action": "preposition",
  "specs": [{
    "trigger-subject": "content",
    "generic-trigger-spec-type": "content-objectlist",
    "generic-trigger-spec-value": {
      "objects": [{
        "href": "https://www.example.com/hls/title/index.m3u8",
        "type": "hls"
      }]
    }
  }],
  "cdn-path": [ "AS64496:0" ]
}
```

RESPONSE:

```
HTTP/1.1 201 Created
Date: Sun, 27 Oct 2024 08:48:13 GMT
Content-Length: 829
Content-Type: application/cdni; ptype=ci-trigger.v2
Location: https://dcdn.example/cit/86633e6e-d2da-4185-a285-b3d087a5d711
Server: example-server/0.1
```

```
 {
   "errors": [{
     "specs": [{
       "trigger-subject": "content",
       "generic-trigger-spec-type": "content-objectlist",
       "generic-trigger-spec-value": {
         "objects": [{
           "href": "https://www.example.com/hls/title/index.m3u8",
           "type": "hls"
         }}
     }],
     "description": "dCDN was not able to parse the object list",
     "error": "econtent",
     "cdn": "AS64500:0"
   }],
   "ctime": 1730119693,
   "etime": 1730119693,
   "mtime": 1730119693,
   "state": "failed",
   "action": "preposition",
   "specs": [{
     "trigger-subject": "content",
     "generic-trigger-spec-type": "content-objectlist",
     "generic-trigger-spec-value": {
       "objects": [{
         "href": "https://www.example.com/hls/title/index.m3u8",
         "type": "hls"
       }]
     }
   }],
   "cdn-path": [ "AS64496:0" ]
 }
```


6.2. Changing, Cancelling and Deleting Triggers

6.2.1. Modifying Triggers

uCDN can modify triggers while they are in a "pending" state. One example of this might be to adjust a trigger’s "specs" and/or "labels" attributes. In the below example, uCDN updates a trigger created earlier by removing the metadata portion of the trigger spec and adding trigger labels. dCDN responds with a 200 ("OK") response containing the updated trigger representation.

REQUEST:

```
POST /cit/3f2d259d-a980-4742-beeb-9392a58129f5 HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
Content-Type: application/cdni; ptype=ci-trigger.v2
Content-Length: 401

{
  "specs": [
    {
      "trigger-subject": "content",
      "generic-trigger-spec-type": "urls",
      "generic-trigger-spec-value": {
        "urls": [
          "https://www.example.com/d/e/f/1",
          "https://www.example.com/d/e/f/2",
          "https://www.example.com/d/e/f/3",
          "https://www.example.com/d/e/f/4"
        ]
      }
    }
  ],
  "labels": [
    "type=video"
  ]
}
```

RESPONSE:

```
HTTP/1.1 200 OK
Date: Sun, 27 Oct 2024 08:48:14 GMT
Content-Length: 520
Content-Type: application/cdni; ptype=ci-trigger.v2
Server: example-server/0.1

{
  "ctime": 1730119694,
  "etime": 1730119754,
  "mtime": 1730119694,
  "state": "pending",
  "action": "preposition",

  "specs": [
    {
      "trigger-subject": "content",
      "generic-trigger-spec-type": "urls",
```

```
        "generic-trigger-spec-value": {
          "urls": [
            "https://www.example.com/d/e/f/1",
            "https://www.example.com/d/e/f/2",
            "https://www.example.com/d/e/f/3",
            "https://www.example.com/d/e/f/4"
          ]
        }
      }
    ],
    "labels": [
      "type=video"
    ]
  }
```

6.2.2. Cancelling Triggers

uCDN can cancel triggers that are not in a terminal state by requesting to update the trigger state to "cancelled". In case of asynchronous processing, dCDN will respond by setting the trigger state to "cancelling" and update it "cancelled" when the cancellation is complete.

REQUEST:

```
POST /cit/3f2d259d-a980-4742-beeb-9392a58129f5 HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
Content-Type: application/cdni; ptype=ci-trigger.v2
Content-Length: 27

{
  "state": "cancelled"
}
```

RESPONSE:

```
HTTP/1.1 200 OK
Date: Sun, 27 Oct 2024 08:48:15 GMT
Content-Length: 523
Content-Type: application/cdni; ptype=ci-trigger.v2
Server: example-server/0.1

{
  "ctime": 1730119695,
  "etime": 1730119755,
  "mtime": 1730119695,
  "state": "cancelling",
  "action": "preposition",

  "specs": [
    {
      "trigger-subject": "content",
      "generic-trigger-spec-type": "urls",
      "generic-trigger-spec-value": {
        "urls": [
          "https://www.example.com/d/e/f/1",
          "https://www.example.com/d/e/f/2",
          "https://www.example.com/d/e/f/3",
          "https://www.example.com/d/e/f/4"
        ]
      }
    }
  ],
  "labels": [
    "type=video"
  ]
}
```

6.2.3. Deleting Triggers

uCDN can delete completed and failed triggers to reduce the size of the collections, as described in Section 3.5. For example, to delete the "preposition" trigger from earlier examples:

REQUEST:

```
DELETE /cit/3f2d259d-a980-4742-beeb-9392a58129f5 HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
```

RESPONSE:

```
HTTP/1.1 204 No Content
Date: Sun, 27 Oct 2024 08:48:16 GMT
Content-Length: 0
Content-Type: text/html; charset=UTF-8
Server: example-server/0.1
```

6.3. Examining Trigger Status

Once triggers have been created, uCDN can check their status as shown in the following examples.

6.3.1. Collection of All Triggers

uCDN can fetch the collection of all triggers it has created that have not yet been deleted or expired. After the trigger operations described in Section 6.1 and Section 6.2 above, this collection might look as follows:

REQUEST:

```
GET /cit HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
```

RESPONSE:

```
HTTP/1.1 200 OK
Content-Length: 341
Expires: Sun, 27 Oct 2024 08:49:18 GMT
Server: example-server/0.1
ETag: "936094426920308378"
Last-Modified: Sun, 27 Oct 2024 08:40:17 GMT
```

```
   Cache-Control: max-age=60
   Date: Sun, 27 Oct 2024 08:48:18 GMT
   Content-Type: application/cdni; ptype=ci-trigger-collection.v2

   {
     "cdn-id": "AS64496:0",
     "coll-state": [
       {
         "state": "pending",
         "uri": "/cit/state/pending"
       },
       {
         "state": "active",
         "uri": "/cit/state/active"
       },
       {
         "state": "complete",
         "uri": "/cit/state/complete"
       },
       {
         "state": "processed",
         "uri": "/cit/state/processed"
       },
       {
         "state": "failed",
         "uri": "/cit/state/failed"
       },
       {
         "state": "cancelling",
         "uri": "/cit/state/cancelling"
       },
       {
         "state": "cancelled",
         "uri": "/cit/state/cancelled"
       }
     ],
     "coll-label": [
       {
         "label": "type=video",
         "uri": "/cit/labels/type=video"
       }
     ],
     "staleresourcetime": 86400,
     "triggers": [
       "https://dcdn.example/cit/327df5b8-1df8-4cff-92f8-fda27774c171",
       "https://dcdn.example/cit/991b9fb9-d0be-4d05-be06-64c0e5c5a5f9",
       "https://dcdn.example/cit/86633e6e-d2da-4185-a285-b3d087a5d711"
     ]
```

```
}
```

6.3.2. Filtering of Trigger Collection

Before the dCDN starts processing the remaining trigger shown above, it will appear in the collection of pending triggers. For example:

REQUEST:

```
GET /cit/state/pending HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
```

RESPONSE:

```
HTTP/1.1 200 OK
Content-Length: 123
Expires: Sun, 27 Oct 2024 08:49:19 GMT
Server: example-server/0.1
ETag: "4331492443626270781"
Last-Modified: Sun, 27 Oct 2024 08:40:17 GMT
Cache-Control: max-age=60
Date: Sun, 27 Oct 2024 08:48:19 GMT
Content-Type: application/cdni; ptype=ci-trigger-collection.v2
327df5b8-1df8-4cff-92f8-fda27774c171
{
  "staleresourcetime": 86400,
  "triggers": [
    "https://dcdn.example/cit/327df5b8-1df8-4cff-92f8-fda27774c171"
  ]
}
```

At this point, if no other triggers had been created, the filtered collection for failed triggers would hold the two failed triggers shown above while other filtered representations would be empty. For example:

REQUEST:

```
GET /cit/state/complete HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
```

RESPONSE:

```
HTTP/1.1 200 OK
Content-Length: 51
Expires: Sun, 27 Oct 2024 08:49:20 GMT
Server: example-server/0.1
ETag: "7958041393922269003"
Last-Modified: Sun, 27 Oct 2024 08:48:17 GMT
Cache-Control: max-age=60
Date: Sun, 27 Oct 2024 08:48:20 GMT
Content-Type: application/cdni; ptype=ci-trigger-collection.v2

{
  "staleresourcetime": 86400,
  "triggers": []
}
```

REQUEST:

```
GET /cit/state/failed HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
```

RESPONSE:

```
HTTP/1.1 200 OK
Content-Length: 191
Expires: Sun, 27 Oct 2024 08:49:21 GMT
Server: example-server/0.1
ETag: "4331492443626270781"
Last-Modified: Sun, 27 Oct 2024 08:48:13 GMT
Cache-Control: max-age=60
Date: Sun, 27 Oct 2024 08:48:19 GMT
Content-Type: application/cdni; ptype=ci-trigger-collection.v2

{
  "staleresourcetime": 86400,
  "triggers": [
    "https://dcdn.example/cit/991b9fb9-d0be-4d05-be06-64c0e5c5a5f9"
    "https://dcdn.example/cit/86633e6e-d2da-4185-a285-b3d087a5d711"
  ]
}
```

6.3.3. Individual Trigger Resources

uCDN can also examine individual triggers:

REQUEST:

```
GET /cit/327df5b8-1df8-4cff-92f8-fda27774c171 HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
```

RESPONSE:

```
HTTP/1.1 200 OK
Content-Length: 545
Expires: Sun, 27 Oct 2024 08:49:22 GMT
Server: example-server/0.1
ETag: "554385204989405469"
Last-Modified: Sun, 27 Oct 2024 08:48:17 GMT
Cache-Control: max-age=60
```

```
Date: Sun, 27 Oct 2024 08:48:22 GMT
Content-Type: application/cdni; ptype=ci-trigger.v2

{
  "ctime": 1730119691,
  "etime": 1730119751,
  "mtime": 1730119691,
  "state": "pending",
  "action": "invalidate",
  "specs": [
    {
      "trigger-subject": "metadata",
      "generic-trigger-spec-type": "uri-pattern-match",
      "generic-trigger-spec-value": {
        "pattern": "https://metadata.example.com/a/b/*"
      }
    },
    {
      "trigger-subject": "content",
      "generic-trigger-spec-type": "urls",
      "generic-trigger-spec-value": {
        "urls": [ "https://www.example.com/a/index.html" ]
      }
    },
    {
      "trigger-subject": "content",
      "generic-trigger-spec-type": "uri-pattern-match",
      "generic-trigger-spec-value": {
        "pattern": "https://www.example.com/a/b/*",
        "case-sensitive": true
      }
    }
  ]
}
```

6.3.4. Polling for Changes in Status

uCDN SHOULD use the ETags and/or Last-Modified headers when polling for changes in trigger collections or the status of individual triggers, as shown in the following examples:

```
REQUEST:

GET /cit/state/pending HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
If-None-Match: "4331492443626270781"
If-Modified-Since: Sun, 27 Oct 2024 08:40:23 GMT

RESPONSE:
HTTP/1.1 304 Not Modified
Content-Length: 0
Expires: Sun, 27 Oct 2024 08:49:21 GMT
Server: example-server/0.1
ETag: "4331492443626270781"
Last-Modified: Sun, 27 Oct 2024 08:48:17 GMT
Cache-Control: max-age=60
Date: Sun, 27 Oct 2024 08:48:23 GMT
Content-Type: application/cdni; ptype=ci-trigger-collection.v2

REQUEST:

GET /cit/327df5b8-1df8-4cff-92f8-fda27774c171 HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
If-None-Match: "6990548174277557683"
If-Modified-Since: Sun, 27 Oct 2024 08:49:10 GMT

RESPONSE:

HTTP/1.1 304 Not Modified
Content-Length: 0
Expires: Sun, 27 Oct 2024 08:49:24 GMT
Server: example-server/0.1
ETag: "554385204989405469"
Last-Modified: Sun, 27 Oct 2024 08:48:17 GMT
Cache-Control: max-age=60
Date: Sun, 27 Oct 2024 08:48:24 GMT
Content-Type: application/cdni; ptype=ci-trigger.v2
```

When the trigger processing is complete, the contents of the filtered collections will be updated. dCDN SHOULD also update the "ETag" and/or "Last-Modified" response headers - whichever was previously sent - when delivering the updated collection representations. dCDN SHOULD also use cache control headers, like "Expires" and "Cache-Control", to indicate how caching of the resource representation should happen by uCDN and intermediate proxies. For example, when the two example triggers are complete, the collections of pending and complete triggers look as follows:

REQUEST:

```
GET /cit/state/pending HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
```

RESPONSE:

```
HTTP/1.1 200 OK
Content-Length: 51
Expires: Sun, 27 Oct 2024 08:49:25 GMT
Server: example-server/0.1
ETag: "1337503181677633762"
Last-Modified: Sun, 27 Oct 2024 08:48:17 GMT
Cache-Control: max-age=60
Date: Sun, 27 Oct 2024 08:48:25 GMT
Content-Type: application/cdni; ptype=ci-trigger-collection.v2

{
  "staleresourcetime": 86400,
  "triggers": []
}
```

REQUEST:

```
GET /cit/state/complete HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
```

RESPONSE:

```
HTTP/1.1 200 OK
Content-Length: 193
Expires: Sun, 27 Oct 2024 08:49:26 GMT
Server: example-server/0.1
ETag: "4481489539378529796"
```

```
   Last-Modified: Sun, 27 Oct 2024 08:48:17 GMT
   Cache-Control: max-age=60
   Date: Sun, 27 Oct 2024 08:48:26 GMT
   Content-Type: application/cdni; ptype=ci-trigger-collection.v2

   {
     "staleresourcetime": 86400,
     "triggers": [
       "https://dcdn.example/cit/327df5b8-1df8-4cff-92f8-fda27774c171"
     ]
   }
```

6.4. Extensions

6.4.1. Execution Policy Extension

This subsection illustrates the uses of the Execution Policy extension. uCDN can create a dependency between triggers. For example, a preposition trigger should only be processed by dCDN after a previous purge trigger has been completed.

```
 REQUEST:

 POST /cit HTTP/1.1
 User-Agent: example-user-agent/0.1
 Host: dcdn.example
 Accept: */*
 Content-Type: application/cdni; ptype=ci-trigger.v2
 Content-Length: 294

 {
   "action": "purge",
   "specs": [{
     "trigger-subject": "content",
     "generic-trigger-spec-type": "content-objectlist",
     "generic-trigger-spec-value": {
       "objects": [{
         "href": "https://www.example.com/hls/1a910c8e/index.m3u8",
         "type": "hls"
       }]
      }
   }]
 }

 RESPONSE:

 HTTP/1.1 201 Created
 Date: Sun, 27 Oct 2024 08:48:27 GMT
```

```
Content-Length: 385
Content-Type: application/cdni; ptype=ci-trigger.v2
Location: https://dcdn.example/cit/564cc45e-9099-4a37-b95e-60342f2647ba
Server: example-server/0.1

{
  "ctime": 1730119707,
  "etime": 1730119767,
  "mtime": 1730119707,
  "state": "pending",
  "action": "purge",
  "specs": [{
    "trigger-subject": "content",
    "generic-trigger-spec-type": "content-objectlist",
    "generic-trigger-spec-value": {
      "objects": [{
        "href": "https://www.example.com/hls/1a910c8e/index.m3u8",
        "type": "hls"
      }]
     }
  }]
}
```

REQUEST:

```
POST /cit HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
Content-Type: application/cdni; ptype=ci-trigger.v2
Content-Length: 527

{
  "action": "preposition",
  "specs": [{
    "trigger-subject": "content",
    "generic-trigger-spec-type": "content-objectlist",
    "generic-trigger-spec-value": {
      "objects": [{
        "href": "https://www.example.com/hls/09000b67/index.m3u8",
        "type": "hls"
      }]
     }
  }],
  "extensions": [
    "generic-trigger-extension-type": "execution-policy",
    "generic-trigger-extension-value": {
```

```
      "depends": [
        "https://dcdn.example/cit/564cc45e-9099-4a37-b95e-60342f2647ba"
      ]
    }
  ]
}
```

RESPONSE:

```
HTTP/1.1 201 Created
Date: Sun, 27 Oct 2024 08:48:28 GMT
Content-Length: 467
Content-Type: application/cdni; ptype=ci-trigger.v2
Location: https://dcdn.example/cit/f6dde35f-703f-49e9-bb80-4964dff3bca5
Server: example-server/0.1

{
  "ctime": 1730119708,
  "etime": 1730119768,
  "mtime": 1730119708,
  "state": "pending",
  "action": "preposition",
  "specs": [{
    "trigger-subject": "content",
    "generic-trigger-spec-type": "content-objectlist",
    "generic-trigger-spec-value": {
      "objects": [{
        "href": "https://www.example.com/hls/09000b67/index.m3u8",
        "type": "hls"
      }]
     }
  }],
  "extensions": [
    "generic-trigger-extension-type": "execution-policy",
    "generic-trigger-extension-value": {
      "depends": [
        "https://dcdn.example/cit/564cc45e-9099-4a37-b95e-60342f2647ba"
      ]
    }
  ]
}
```

uCDN can also stagger long-running triggers to control processing order. In the following example, uCDN creates a preposition trigger with higher priority, which dCDN should pick up for execution before the earlier triggers.

REQUEST:

```
POST /cit HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
Content-Type: application/cdni; ptype=ci-trigger.v2

{
  "action": "preposition",
  "specs": [{
    "trigger-subject": "content",
    "generic-trigger-spec-type": "content-objectlist",
    "generic-trigger-spec-value": {
      "objects": [{
        "href": "https://www.example.com/hls/b89d49df/index.m3u8",
        "type": "hls"
     }]
    }
  }],
  "extensions": [
    "generic-trigger-extension-type": "execution-policy",
    "generic-trigger-extension-value": { "priority": 100 }
   ]
}
```

RESPONSE:

```
HTTP/1.1 201 Created
Date: Sun, 27 Oct 2024 08:48:30 GMT
Content-Length: 526
Content-Type: application/cdni; ptype=ci-trigger.v2
Location: https://dcdn.example/cit/e5483c4a-7c8e-4820-91c8-3c0a9f2edba8
Server: example-server/0.1

{
  "ctime": 1730119710,
  "etime": 1730119770,
  "mtime": 1730119710,
  "state": "pending",
  "action": "preposition",
  "specs": [{
    "trigger-subject": "content",
    "generic-trigger-spec-type": "content-objectlist",
    "generic-trigger-spec-value": {
      "objects": [{
        "href": "https://www.example.com/hls/b89d49df/index.m3u8",
        "type": "hls"
```

```
      }]
     }
   }],
   "extensions": [
     "generic-trigger-extension-type": "execution-policy",
     "generic-trigger-extension-value": { "priority": 100 }
    ]
 }
```

6.4.2. Extensions with Error Propagation

In the following example, a CI/T "preposition" command uses two extensions to control the way the trigger is executed. In this example, the receiving dCDN, identified as "AS64500:0", does not support the first extension in the extensions array. dCDN "AS64500:0" further distributes this trigger to another downstream CDN that is identified as "AS64501:0", which does not support the second extension in the extensions array. The error is propagated from "AS64501:0" to "AS64500:0" and the errors.v2 array reflects both errors.

REQUEST:

```
POST /cit HTTP/1.1
User-Agent: example-user-agent/0.1
Host: dcdn.example
Accept: */*
Content-Type: application/cdni; ptype=ci-trigger.v2
Content-Length: 1249

{
  "action": "preposition",
  "specs": [{
    "trigger-subject": "content",
    "generic-trigger-spec-type": "content-objectlist",
    "generic-trigger-spec-value": {
      "objects": [{
        "href": "https://www.example.com/hls/title/index.m3u8",
        "type": "hls"
      }]
    }
  }],
  "extensions": [
    {
      "generic-trigger-extension-type": "location-policy",
      "generic-trigger-extension-value": {
        "locations": [
          {
```

```
              "action": "allow",
              "footprints": [{
                  "footprint-type": "countrycode",
                  "footprint-value": [ "us" ]
              }]
            },
            {
              "action": "deny",
              "footprints": [{
                 "footprint-type": "countrycode",
                 "footprint-value": [ "ca" ]
              }]
            }
          ]
        },
        "mandatory-to-enforce": true,
        "safe-to-redistribute": true
      },
      {
        "generic-trigger-extension-type": "time-policy",
        "generic-trigger-extension-value": {
          "unix-time-window": {
            "start": 1730174400,
            "end": 1730260800
          }
        },
        "mandatory-to-enforce": true,
        "safe-to-redistribute": true
      }
    ],
    "cdn-path": [ "AS64496:0" ]
  }

  RESPONSE:

  HTTP/1.1 201 Created
  Date: Sun, 27 Oct 2024 08:48:31 GMT
  Content-Length: 2595
  Content-Type: application/cdni; ptype=ci-trigger.v2
  Location: https://dcdn.example/cit/bcca1cde-ddf0-47db-b859-6a2c043baaa9
  Server: example-server/0.1

  {
    "errors": [
      {
        "extensions": [{
          "generic-trigger-extension-type": "location-policy",
          "generic-trigger-extension-value": {
```

```
          "locations": [
            {
              "action": "allow",
              "footprints": [{
                  "footprint-type": "countrycode",
                  "footprint-value": [ "us" ]
                }]
            },
            {
              "action": "deny",
              "footprints": [{
                  "footprint-type": "countrycode",
                  "footprint-value": [ "ca" ]
                }]
            }
          ]
        },
        "mandatory-to-enforce": true,
        "safe-to-redistribute": true
      }],
      "description": "unrecognized extension type",
      "error": "eextension",
      "cdn": "AS64500:0"
    },
    {
      "extensions": [{
        "generic-trigger-extension-type": "time-policy",
        "generic-trigger-extension-value": {
          "unix-time-window": {
            "start": 1730174400,
            "end": 1730260800
          }
        },
        "mandatory-to-enforce": true,
        "safe-to-redistribute": true
      }],
      "description": "unrecognized extension type",
      "error": "eextension",
      "cdn": "AS64501:0"
    }
  ],
  "ctime": 1730119691,
  "etime": 1730119691,
  "mtime": 1730119691,
  "state": "failed",
  "action": "preposition",
  "specs": [{
    "trigger-subject": "content",
```

```
     "generic-trigger-spec-type": "content-objectlist",
     "generic-trigger-spec-value": {
       "objects": [{
         "href": "https://www.example.com/hls/title/index.m3u8",
         "type": "hls"
       }]
     }
   }],
   "extensions": [
     {
       "generic-trigger-extension-type": "location-policy",
       "generic-trigger-extension-value": {
         "locations": [
           {
             "action": "allow",
             "footprints": [{
               "footprint-type": "countrycode",
               "footprint-value": [ "us" ]
             }]
           },
           {
             "action": "deny",
             "footprints": [{
               "footprint-type": "countrycode",
               "footprint-value": [ "ca" ]
             }]
           }
         ]
       },
       "mandatory-to-enforce": true,
       "safe-to-redistribute": true
     },
     {
       "generic-trigger-extension-type": "time-policy",
       "generic-trigger-extension-value": {
         "unix-time-window": {
           "start": 1730174400,
           "end": 1730260800
         }
       },
       "mandatory-to-enforce": true,
       "safe-to-redistribute": true
     }
   ],
   "cdn-path": [ "AS64496:0" ]
 }
```

7. IANA Considerations

7.1. CDNI Payload Type Parameter Registrations

All references to RFC 8007 in the IANA registries should be replaced with references to this document, apart from references associated with the following registrations:

Payload Type	Specification
ci-trigger-command	RFC 8007
ci-trigger-status	RFC 8007
ci-trigger-collection	RFC 8007

Table 12

The IANA is requested to register the following new Payload Types in the "CDNI Payload Types" registry defined by [RFC7736], for use with the "application/cdni" MIME media type.

Payload Type	Specification
ci-trigger.v2	RFCthis
ci-trigger-collection.v2	RFCthis
FCI.CITObjectsVersion	RFCthis
FCI.CITScope	RFCthis
FCI.CITObjectListType	RFCthis

Table 13

[RFC Editor: Please replace RFCthis with the published RFC number for this document.]

7.1.1. CDNI ci-trigger.v2 Payload Type

Purpose: The purpose of this payload type is to define a new CI/T trigger object (and any associated capability advertisement)

Interface: CI/T

Encoding: see Section 4.1

7.1.2. CDNI ci-trigger-collection.v2 Payload Type

Purpose: The purpose of this payload type is to define a new CI/T trigger collection object (and any associated capability advertisement)

Interface: CI/T

Encoding: see Section 4.2

7.1.3. CDNI FCI CI/T Payload Types

7.1.3.1. CDNI FCI CI/T Endpoints Payload Type

Purpose: The purpose of this payload type is to distinguish FCI advertisement objects for CI/T Endpoints objects

Interface: FCI

Encoding: see Section 5.1

7.1.3.2. CDNI FCI CI/T Trigger Scope Payload Type

Purpose: The purpose of this payload type is to distinguish FCI advertisement objects for CI/T trigger scope

Interface: FCI

Encoding: see Section 5.2.1

7.1.3.3. CDNI FCI CI/T Object List Type Payload Type

Purpose: The purpose of this payload type is to distinguish FCI advertisement objects for CI/T Object List Type objects

Interface: FCI

Encoding: see Section 5.3

7.2. "CDNI CI/T Trigger Types" Registry For Trigger Actions

In [RFC8007] the IANA was requested to create a new "CDNI CI/T Trigger Types" registry under the "Content Delivery Network Interconnection (CDNI) Parameters" registry group.

Additions to the "CDNI CI/T Trigger Types" registry are made via the RFC Required policy as defined in [RFC8126].

In this second edition of the interface, trigger types are referred to as "trigger actions". The "Trigger Types" registry is used for action definitions. Furthermore, this document, and specifically Section 4.1.1, reuses the definition of "trigger types" as defined in [RFC8007] as trigger actions, and provide their specifications, with no modification compared to [RFC8007].

7.3. "CDNI CI/T Trigger Specs" Registry

The IANA is requested to create a new "CDNI CI/T Trigger Specs" registry in the "Content Delivery Networks Interconnection (CDNI) Parameters" registry group. The "CDNI CI/T Trigger Specs" namespace defines the valid trigger targets’ spec values in Section 4.1.2, used by the trigger spec object.

Additions to the "CDNI CI/T Trigger Specs" registry are made via the RFC Required policy as defined in [RFC8126].

The initial contents of the "CDNI CI/T Trigger Specs" registry comprise the names and descriptions listed in Section 4.1.2, with this document acting as the specification.

7.4. "CDNI CI/T Trigger Subjects" Registry

The IANA is requested to create a new "CDNI CI/T Trigger Subjects" registry in the "Content Delivery Networks Interconnection (CDNI) Parameters" registry group. The "CDNI CI/T Trigger Subjects" namespace defines the valid trigger targets’ subject values in Section 4.1.2.2, used by the trigger spec object.

Additions to the "CDNI CI/T Trigger Subjects" registry are made via the RFC Required policy as defined in [RFC8126].

The initial contents of the "CDNI CI/T Trigger Subjects" registry comprise the names and descriptions listed in Section 4.1.2.2, with this document acting as the specification.

7.5. "CDNI CI/T Object List Types" Registry

The IANA is requested to create a new "CDNI CI/T Object List Types" registry in the "Content Delivery Networks Interconnection (CDNI) Parameters" registry group. The "CDNI CI/T Object List Types" namespace defines the valid object list type values in Section 4.3.2.1, used by the Object List object.

Additions to the "CDNI CI/T Object List Types" registry are made via the RFC Required policy as defined in [RFC8126].

The initial contents of the "CDNI CI/T Object List Types" registry comprise the names and descriptions listed in Section 4.3.2.1, with this document acting as the specification.

7.6. "CDNI CI/T Trigger Extensions" Registry

The IANA is requested to create a new "CDNI CI/T Trigger Extensions" registry in the "Content Delivery Networks Interconnection (CDNI) Parameters" registry group. The "CDNI CI/T Trigger Extensions" namespace defines the valid trigger targets' extension values in Section 2.8, used by the trigger spec object.

Additions to the "CDNI CI/T Trigger Extensions" registry are made via the RFC Required policy as defined in [RFC8126].

The initial contents of the "CDNI CI/T Trigger Extensions" registry comprise the names and descriptions listed in Section 2.8, with this document acting as the specification.

7.7. "CDNI CI/T Error Codes" Registry

In [RFC8007] the IANA was requested to create a new "CDNI CI/T Error Codes" registry under the "Content Delivery Network Interconnection (CDNI) Parameters" registry group.

Additions to the "CDNI CI/T Error Codes" registry are made via the Specification Required policy as defined in [RFC8126]. The Designated Expert will verify that new Error Code registrations do not duplicate existing Error Code definitions (in name or functionality), prevent gratuitous additions to the namespace, and prevent any additions to the namespace that would impair the interoperability of CDNI implementations.

In this second edition of the interface, the definitions of the Error Codes from [RFC8007] are without change. Additionally, the IANA is requested to register three additional error codes, "espec", "esubject", and "eextension", with the specification as defined in Section 4.1.6.2.

7.8. "CDNI CI/T URL Types" Registry

The IANA is requested to create a new "CDNI CI/T URL types" registry in the "Content Delivery Networks Interconnection (CDNI) Parameters" registry group. The "CDNI CI/T URL Types" namespace defines the valid URL type values in Section 4.3.1, used by Section 4.1.2.4, Section 4.1.2.6, Section 4.1.2.7, and Section 4.1.2.8.

The initial contents of the "CDNI CI/T Trigger Extensions" registry comprise the names and descriptions listed in Section 4.3.1, with this document acting as the specification.

8. Security Considerations

The CI/T interface provides a mechanism to allow uCDN to generate requests into dCDN and to inspect its own CI/T requests and their current states. The CI/T interface does not allow access to, or modification of, uCDN or dCDN metadata relating to content delivery or to the content itself. It can only control the presence of that metadata in dCDN, and the processing work and network utilization involved in ensuring that presence.

By examining "preposition" requests to dCDN, and correctly interpreting content and metadata URLs, an attacker could learn the uCDN’s or content owner’s predictions for future content popularity. By examining "invalidate" or "purge" requests, an attacker could learn about changes in the content owner’s catalog.

By injecting CI/T triggers, an attacker or a misbehaving uCDN would generate work in dCDN and uCDN as they process those requests. So would a man-in-the-middle attacker modify valid trigger requests generated by uCDN. In both cases, that would decrease dCDN’s caching efficiency by causing it to unnecessarily acquire or reacquire content metadata and/or content.

dCDN implementation of CI/T MUST restrict the actions of uCDN to the data corresponding to that uCDN. Failure to do so would allow uCDNs to detrimentally affect each other’s efficiency by generating unnecessary acquisition or reacquisition load.

An origin that chooses to delegate its delivery to a CDN is trusting that CDN to deliver content on its behalf; the interconnection of CDNs is an extension of that trust to dCDNs. That trust relationship is a commercial arrangement, outside the scope of the CDNI protocols. So, while a malicious CDN could deliberately generate load on dCDN using the CI/T interface, the protocol does not otherwise attempt to address malicious behavior between interconnected CDNs.

8.1. Authentication, Authorization, Confidentiality, Integrity Protection

A CI/T implementation MUST support Transport Layer Security (TLS) transport for HTTP (HTTPS) as per [RFC9110].

TLS MUST be used by the server side (dCDN) and the client side (uCDN) of the CI/T interface, including the authentication of the remote end, unless alternate methods are used to ensure the security of the information in the CI/T interface requests and responses (such as setting up an IPsec tunnel between the two CDNs or using a physically secured internal network between two CDNs that are owned by the same corporate entity).

The use of TLS for transport of the CI/T interface allows dCDN and uCDN to authenticate each other using the TLS client authentication and TLS server authentication.

Once dCDN and uCDN have mutually authenticated each other, TLS allows:

* dCDN and uCDN to authorize each other (to ensure that they are receiving trigger requests from, or responding to, an authorized CDN).

* CDNI commands and responses to be transmitted with confidentiality.

* Protection of the integrity of CDNI commands and responses.

When TLS is used, the general TLS usage guidance in [RFC9325] MUST be followed.

The mechanisms for access control are dCDN-specific and are not standardized as part of this CI/T specification.

HTTP requests that attempt to access or operate on CI/T data belonging to another CDN MUST be rejected using, for example, HTTP 403 ("Forbidden") or 404 ("Not Found"). This is intended to prevent unauthorized users from generating unnecessary load in dCDNs or uCDNs due to revalidation, reacquisition, or unnecessary acquisition.

When deploying a network of interconnected CDNs, the possible inefficiencies related to the diamond configuration discussed in Section 2.9 should be considered.

8.2. Denial of Service

This document does not define a specific mechanism to protect against Denial-of-Service (DoS) attacks on the CI/T interface. However, CI/T endpoints can be protected against DoS attacks through the use of TLS transport and/or via mechanisms outside the scope of the CI/T interface, such as firewalling or the use of Virtual Private Networks (VPNs).

Depending on the implementation, triggered activity may consume significant processing and bandwidth in dCDN. A malicious or faulty uCDN could use this to generate unnecessary load in dCDN. dCDN should consider mechanisms to avoid overload -- for example, by rate-limiting acceptance or processing of triggers, or by performing batch processing.

8.3. Privacy

The CI/T protocol does not carry any information about individual end users of a CDN; there are no privacy concerns for end users.

The CI/T protocol does carry information that could be considered commercially sensitive by CDN operators and content owners. The use of mutually authenticated TLS to establish a secure session for the transport of CI/T data, as discussed in Section 8.1, provides confidentiality while the CI/T data is in transit and prevents parties other than the authorized dCDN from gaining access to that data. dCDN MUST ensure that it only exposes CI/T data related to uCDN to clients it has authenticated as belonging to that uCDN.

9. References

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Authors' Addresses

Nir B. Sopher
Qwilt
6, Ha'harash
Hod HaSharon 4524079
Israel
Email: nir@apache.org

Ori Finkelman
Qwilt
6, Ha'harash
Hod HaSharon 4524079
Israel
Email: ori.finkelman.ietf@gmail.com

Sanjay Mishra
Verizon
13100 Columbia Pike
Silver Spring, MD 20904
United States of America
Email: sanjay.mishra@verizon.com

Jay K. Robertson
Qwilt
275 Shoreline Dr Ste 510
Redwood City, CA 94065
United States of America
Email: jayrobertson@acm.org

Alan Arolovitch
Viasat
1295 Beacon Street Unit 249
Brookline, MA 02446
United States of America
Email: alan.arolovitch@gmail.com