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Content Delivery Network Interconnection (CDNI) Request Routing: CDNI Footprint and Capabilities Advertisement using ALTO draft-ietf-alto-cdni-request-routing-alto-04

Abstract

The Content Delivery Networks Interconnection (CDNI) framework [RFC6707] defines a set of protocols to interconnect CDNs, to achieve multiple goals such as extending the reach of a given CDN to areas that are not covered by that particular CDN. One component that is needed to achieve the goal of CDNI described in [RFC7336] is the CDNI Request Routing Footprint & Capabilities Advertisement interface (FCI). [RFC8008] defines precisely the semantics of FCI and provides guidelines on the FCI protocol, but the exact protocol is explicitly outside the scope of that document. In this document, we follow the guidelines to define an FCI protocol using the Application-Layer Traffic Optimization (ALTO) protocol.

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1. Introduction

The ability to interconnect multiple content delivery networks (CDNs) has many benefits, including increased coverage, capability, and reliability. The Content Delivery Networks Interconnection (CDNI) framework [RFC6707] defines four interfaces to achieve interconnection of CDNs: (1) the CDNI Request Routing Interface; (2) the CDNI Metadata Interface; (3) the CDNI Logging Interface; and (4) the CDNI Control Interface.

Among the four interfaces, the CDNI Request Routing Interface provides key functions, as specified in [RFC6707]: "The CDNI Request Routing interface enables a Request Routing function in an Upstream CDN to query a Request Routing function in a Downstream CDN to determine if the Downstream CDN is able (and willing) to accept the delegated Content Request. It also allows the Downstream CDN to control what should be returned to the User Agent in the redirection message by the upstream Request Routing function." On a high level, the scope of the CDNI Request Routing Interface, therefore, contains two main tasks: (1) determining if the downstream CDN (dCDN) is willing to accept a delegated content request; (2) redirecting the content request coming from an upstream CDN (uCDN) to the proper entry point or entity in the downstream CDN.

Correspondingly, the request routing interface is broadly divided into two functionalities: (1) CDNI Footprint & Capabilities Advertisement interface (FCI); (2) CDNI Request Routing Redirection interface (RI). Since this document focuses on the first functionality, CDNI FCI, we will describe it in a more detailed way. CDNI FCI is an advertisement from a dCDN to a uCDN (push) or a query from a uCDN to a dCDN (pull) so that the uCDN knows whether it can redirect a particular user request to that dCDN.

A key component in defining CDNI FCI is defining objects describing the footprints and capabilities of a dCDN. Such objects are already in [RFC8008]. A protocol to transport and update such objects between a uCDN and a dCDN, however, is not defined. Hence, the scope of this document is to define such a protocol by introducing a new Application-Layer Traffic Optimization (ALTO) [RFC7285] service called "CDNI FCI Map Service".

There are multiple benefits in using ALTO as a transport protocol, as we discuss in Section 2.2.

The rest of this document is organized as follows. Section 2 provides non-normative background on both CDNI FCI and ALTO. Section 3 introduces the most basic service, called CDNI FCI Map, to realize CDNI FCI using ALTO. Section 4 demonstrates a key benefit of using ALTO: the ability to integrate CDNI FCI with ALTO network maps. Such integration provides a new granularity to describe footprints. Section 5 builds on filtered ALTO maps to introduce filtered CDNI FCI maps using capabilities so that a uCDN can get footprints with given capabilities instead of getting the full map which can be huge. Section 6 further shows a benefit of using ALTO: the ability to query footprint properties using ALTO unified properties. In this way, a uCDN can effectively fetch capabilities of some footprints in which it is interested. IANA and security considerations are discussed in Section 7 and Section 8 respectively.

Throughout this document, we use the terminology for CDNI defined in [RFC6707], [RFC8006], [RFC8008] and we use the terminology for ALTO defined in [RFC7285], [I-D.ietf-alto-unified-props-new].

2. Background

The design of CDNI FCI transport using ALTO depends on the understanding of both FCI semantics and ALTO. Hence, we start with a review of both.

2.1. Semantics of FCI Advertisement

The CDNI document on "Footprint and Capabilities Semantics" [RFC8008] defines the semantics of CDNI FCI, and provides guidance on what Footprint and Capabilities mean in a CDNI context and how a protocol solution should in principle look like. The definitions in [RFC8008] depend on [RFC8006]. Here we briefly summarize key related points of [RFC8008] and [RFC8006]. For a detailed discussion, the reader is referred to the RFCs.

- Footprint and capabilities are tied together and cannot be interpreted independently from each other. Hence, capabilities must be expressed on a per footprint basis. [RFC8008] integrates footprint and capabilities with an approach of "capabilities with footprint restrictions".

- Given that a large part of Footprint and Capabilities Advertisement will actually happen in contractual agreements, the semantics of CDNI Footprint and Capabilities advertisement refers to answering the following question: what exactly still needs to be advertised by the CDNI FCI? For instance, updates about temporal failures of part of a footprint can be useful information to convey via the CDNI request routing interface. Such information would provide updates on information previously agreed in contracts between the participating CDNs. In other words, the CDNI FCI is a means for a dCDN to provide changes/updates regarding a footprint and/or capabilities that it has prior agreed to serve in a contract with a uCDN. Hence, server push and incremental encoding will be necessary techniques.

- Multiple types of footprints (ipv4cidr, ipv6cidr, asn and countrycode) are defined in [RFC8006].

- A "Set of IP-prefixes" can contain both full IP addresses (i.e., a /32 for IPv4 and a /128 for IPv6) and IP prefixes with an arbitrary prefix length. There must also be support for multiple IP address versions, i.e., IPv4 and IPv6, in such a footprint.

- For all of these mandatory-to-implement footprint types, footprints can be viewed as constraints for delegating requests to a dCDN: A dCDN footprint advertisement tells the uCDN the limitations for delegating a request to the dCDN. For IP prefixes or ASN(s), the footprint signals to the uCDN that it should consider the dCDN a candidate only if the IP address of the request routing source falls within the prefix set (or ASN, respectively). The CDNI specifications do not define how a given uCDN determines what address ranges are in a particular ASN. Similarly, for country codes, a uCDN should only consider the dCDN

a candidate if it covers the country of the request routing source. The CDNI specifications do not define how a given uCDN determines the country of the request routing source. Multiple footprint constraints are additive, i.e., the advertisement of different types of footprint narrows the dCDN candidacy cumulatively.

- The following capabilities are defined as "base" capabilities; that is, they are required in all cases and therefore constitute mandatory capabilities to be supported by the CDNI FCI: (1) Delivery Protocol; (2) Acquisition Protocol; (3) Redirection Mode; (4) Capabilities related to CDNI Logging; (5) Capabilities related to CDNI Metadata.

2.2. ALTO Background and Benefits

Application-Layer Traffic Optimization (ALTO) [RFC7285] is an approach for guiding the resource provider selection process in distributed applications that can choose among several candidate resources providers to retrieve a given resource. By conveying network layer (topology) information, an ALTO server can provide important information to "guide" the resource provider selection process in distributed applications. Usually, it is assumed that an ALTO server conveys information that these applications cannot or have difficulty to measure themselves [RFC5693].

Originally, ALTO was motivated by optimizing cross-ISP traffic generated by P2P applications [RFC5693]. Recently, however, ALTO is also being considered for improving the request routing in CDNs [I-D.jenkins-alto-cdn-use-cases]. The CDNI problem statement explicitly mentions ALTO as a candidate protocol for "actual algorithms for selection of CDN or Surrogate by Request-Routing systems" [RFC6707].

The following reasons make ALTO a suitable candidate protocol for downstream CDN selection as part of CDNI request routing and in particular for an FCI protocol:

- ALTO is a protocol specifically designed to improve application layer traffic (and application layer connections among hosts on the Internet) by providing additional information to applications that these applications could not easily retrieve themselves. For CDNI, this is exactly the case: a uCDN wants to improve application layer CDN request routing by using dedicated information (provided by a dCDN) that the uCDN could not easily obtain otherwise. ALTO can help a uCDN to select a proper dCDN by first providing dCDNs' capabilities as well as footprints (see

Section 3) and then providing costs of surrogates in a dCDN by ALTO cost maps.

- The semantics of an ALTO network map is an exact match for the needed information to convey a footprint by a downstream CDN, in particular if such a footprint is being expressed by IP-prefix ranges. Please see Section 4.

- Security: Identifications between uCDNs and dCDNs are extremely important. ALTO maps can be signed and hence provide inherent integrity protection. Please see Section 8.

- RESTful-Design: The ALTO protocol has undergone extensive revisions in order to provide a RESTful design regarding the client-server interaction specified by the protocol. A CDNI FCI interface based on ALTO would inherit this RESTful design. Please see Section 3.

- Error-handling: The ALTO protocol has undergone extensive revisions in order to provide sophisticated error-handling, in particular regarding unexpected cases. A CDNI FCI interface based on ALTO would inherit this thought-through and mature error-handling. Please see Section 5.

- Filtered map service: The ALTO map filtering service would allow a uCDN to query only for parts of an ALTO map. For example, filtered unified property map service can enable a uCDN to query properties of a part of footprints in an effective way (see Section 6).

- Server-initiated Notifications and Incremental Updates: When the footprint or the capabilities of a downstream CDN change (i.e., unexpectedly from the perspective of an upstream CDN), server-initiated notifications would enable a dCDN to directly inform an upstream CDN about such changes. Consider the case where - due to failure - part of the footprint of the dCDN is not functioning, i.e., the CDN cannot serve content to such clients with reasonable QoS. Without server-initiated notifications, the uCDN might still use a very recent network and cost map from dCDN, and therefore redirect requests to dCDN which it cannot serve. Similarly, the possibility for incremental updates would enable efficient conveyance of the aforementioned (or similar) status changes by the dCDN to the uCDN. The newest design of ALTO supports server pushed incremental updates [I-D.ietf-alto-incr-update-sse].

- Content Availability on Hosts: A dCDN might want to express CDN capabilities in terms of certain content types (e.g., codecs/formats, or content from certain content providers). The new

endpoint property for ALTO would enable a dCDN to make such information available to an upstream CDN. This would enable a uCDN to determine if a given dCDN actually has the capabilities for a given request with respect to the type of content requested.

- Resource Availability on Hosts or Links: The capabilities on links (e.g. maximum bandwidth) or caches (e.g. average load) might be useful information for an upstream CDN for optimized downstream CDN selection. For instance, if a uCDN receives a streaming request for content with a certain bitrate, it needs to know if it is likely that a dCDN can fulfill such stringent application-level requirements (i.e., can be expected to have enough consistent bandwidth) before it redirects the request. In general, if ALTO could convey such information via new endpoint properties, it would enable more sophisticated means for downstream CDN selection with ALTO. ALTO Path Vector Extension [I-D.ietf-alto-path-vector] is designed to allow ALTO clients to query information such as capacity regions for a given set of flows.

3. CDNI FCI Map

The ALTO protocol is based on an ALTO Information Service Framework which consists of several services, where all ALTO services are "provided through a common transport protocol, messaging structure and encoding, and transaction model" [RFC7285]. The ALTO protocol specification [RFC7285] defines several such services, e.g. the ALTO map service.

This document defines a new ALTO Map Service called "CDNI FCI Map Service" which conveys JSON objects of media type "application/alto-cdnifcimap+json". These JSON objects are used to transport BaseAdvertisementObject objects defined in [RFC8008]; this document specifies how to transport such BaseAdvertisementObject objects via the ALTO protocol with the ALTO "CDNI FCI Map Service". Given that the "CDNI FCI Map Service" is very similar in structure to the two already defined map services (network maps and cost maps), the specification of CDNI FCI Map below uses the same specification structure for Cost Map specification in Section 11.2.3 of [RFC7285] when specifying cost maps.

3.1. Media Type

The media type of the CDNI FCI Map is "application/alto-cdnifcimap+json".

3.2. HTTP Method

A CDNI FCI map resource is requested using the HTTP GET method.

3.3. Accept Input Parameters

None.

3.4. Capabilities

None.

3.5. Uses

The resource ID of the resource based on which the CDNI FCI map will be defined. For example, if a CDNI FCI map depends on a network map, the resource ID of the network map MUST be included in "uses" field. Please see Section 4 for details. If the CDNI FCI map does not depend on any other resources, "uses" field MUST NOT appear.

3.6. Response

The "meta" field of a CDNI FCI map response MUST include the "vtag" field defined in Section 10.3 of [RFC7285]. This field provides the version of the retrieved CDNI FCI map.

If a CDNI FCI map response depends on a resource such as a network map, it MUST include the "dependent-vtags" field, whose value is an array to indicate the version tags of the resources used, where each resource is specified in "uses" of the IRD. The current defined dependent resource is only network map, and the usage of it is described in Section 4.

The data component of an ALTO CDNI FCI map response is named "cdni-fci-map", which is a JSON object of type CDNIFCIMapData:

```
object {
    CDNIFCIMapData cdni-fci-map;
} InfoResourceCDNIFCIMap : ResponseEntityBase;

object {
    BaseAdvertisementObject capabilities<1..*>;
} CDNIFCIMapData
```

Specifically, a CDNIFCIMapData object is a JSON object that includes only one property named "capabilities", whose value is an array of BaseAdvertisementObject objects.

The syntax and semantics of BaseAdvertisementObject are well defined in Section 5.1 of [RFC8008]. A BaseAdvertisementObject object includes multiple properties, including capability-type, capability-value and footprints, where footprints are defined in Section 4.2.2.2 of [RFC8006].

To be self-contained, we give a non-normative specification of BaseAdvertisementObject below. As mentioned above, the normative specification of BaseAdvertisementObject is in [RFC8008]

```
    object {
        JSONString capability-type;
        JSONValue capability-value;
        Footprint footprints<0..*>;
    } BaseAdvertisementObject;

    object {
        JSONString footprint-type;
        JSONString footprint-value<1..*>;
    } Footprint
```

For each BaseAdvertisementObject, the ALTO client MUST interpret footprints appearing multiple times as if they appeared only once. If footprints in a BaseAdvertisementObject is null or empty or not appearing, the ALTO client MUST understand that the capabilities in this BaseAdvertisementObject have the "global" coverage.

Note: Further optimization of BaseAdvertisement objects to effectively provide the advertisement of capabilities with footprint restrictions is certainly possible. For example, these two examples below both describe that the dCDN can provide capabilities ["http/1.1", "https/1.1"] for the same footprints. However, the latter one is smaller in its size.

EXAMPLE 1

```
   {
      "meta" : {...},
      "cdni-fci-map": {
        "capabilities": [
          {
            "capability-type": "FCI.DeliveryProtocol",
            "capability-value": {
              "delivery-protocols": [
                "http/1.1"
              ]
            },
            "footprints": [
              <Footprint objects>
```

```
            ]
          },
          {
            "capability-type": "FCI.DeliveryProtocol",
            "capability-value": {
              "delivery-protocols": [
                "https/1.1"
              ]
            },
            "footprints": [
              <Footprint objects>
            ]
          }
        ]
      }
    }
```

EXAMPLE 2

```
   {
      "meta" : {...},
      "cdni-fci-map": {
        "capabilities": [
          {
            "capability-type": "FCI.DeliveryProtocol",
            "capability-value": {
              "delivery-protocols": [
                "https/1.1",
                "http/1.1"
              ]
            },
            "footprints": [
              <Footprint objects>
            ]
          }
        ]
      }
    }
```

Since such optimizations are not necessary for the basic interconnection of CDNs, the specifics of such mechanisms are outside the scope of this document.

3.7. Examples

3.7.1. IRD Example

Below is the information resource directory (IRD) of a simple, example ALTO server. The server provides both base ALTO information resources (e.g., network maps) and CDNI FCI information resources (e.g., CDNI FCI map), demonstrating a single, integrated environment.

Specifically, the IRD announces two network maps, one CDNI FCI map without dependency, one CDNI FCI map depending on a network map, one filtered CDNI FCI map to be defined in Section 5, one unified property map including "cdni-fci-capabilities" as its entities' property, one filtered unified property map including "cdni-fci-capabilities" and "pid" as its entities' properties, and two update stream services (one for updating CDNI FCI maps, and the other for updating property maps).

```
  GET /directory HTTP/1.1
  Host: alto.example.com
  Accept: application/alto-directory+json,application/alto-error+json
```

```
{
  "meta" : { ... },
  "resources": {
    "my-default-network-map": {
      "uri" : "http://alto.example.com/networkmap",
      "media-type" : "application/alto-networkmap+json"
    },
    "my-eu-netmap" : {
      "uri" : "http://alto.example.com/myeunetmap",
      "media-type" : "application/alto-networkmap+json"
    },
    "my-default-cdnifci-map": {
      "uri" : "http://alto.example.com/cdnifcimap",
      "media-type": "application/alto-cdnifcimap+json"
    },
    "my-filtered-cdnifci-map" : {
      "uri" : "http://alto.example.com/cdnifcimap/filtered",
      "media-type" : "application/alto-cdnifcimap+json",
      "accepts" : "application/alto-cdnifcimapfilter+json",
      "uses" : [ "my-default-cdnifci-map" ]
    },
    "my-cdnifci-map-with-network-map-footprints": {
      "uri" : "http://alto.example.com/networkcdnifcimap",
      "media-type" : "application/alto-cdnifcimap+json",
      "uses" : [ "my-eu-netmap" ]
    },
    "cdnifci-property-map" : {
      "uri" : "http://alto.example.com/propmap/full/cdnifci",
```

```
      "media-type" : "application/alto-propmap+json",
      "capabilities" : {
        "domain-types" : [ "ipv4", "ipv6", "coutrycode", "asn" ],
        "prop-types" : [ "cdni-fci-capabilities" ]
      }
    },
    "filtered-cdnifci-property-map" : {
      "uri" : "http://alto.example.com/propmap/lookup/cdnifci-pid",
      "media-type" : "application/alto-propmap+json",
      "accepts" : "application/alto-propmapparams+json",
      "capabilities" : {
        "domain-types" : [ "ipv4", "ipv6", "coutrycode", "asn" ],
        "prop-types" : [ "cdni-fci-capabilities", "pid" ]
       }
    },
    "update-my-cdni-fci-maps" : {
      "uri": "http:///alto.example.com/updates/cdnifcimaps",
      "media-type" : "text/event-stream",
      "accepts" : "application/alto-updatestreamparams+json",
      "uses" : [
        "my-default-network-map",
        "my-eu-netmap",
        "my-default-cdnifci-map",
        "my-filtered-cdnifci-map"
        "my-cdnifci-map-with-network-map-footprints"
      ],
      "capabilities" : {
        "incremental-change-media-types" : {
          "my-default-network-map" : "application/json-patch+json",
          "my-eu-netmap" : "application/json-patch+json",
          "my-default-cdnifci-map" :
          "application/merge-patch+json,application/json-patch+json",
          "my-filtered-cdnifci-map" :
          "application/merge-patch+jso,application/json-patch+json",
          "my-cdnifci-map-with-network-map-footprints" :
          "application/merge-patch+json,application/json-patch+json"
        }
      }
    },
    "update-my-props": {
      "uri" : "http://alto.example.com/updates/properties",
      "media-type" : "text/event-stream",
      "uses" : [
        "cdnifci-property-map",
        "filtered-cdnifci-property-map"
      ],
      "capabilities" : {
        "incremental-change-media-types": {
```

```
            "cdnifci-property-map" :
            "application/merge-patch+json,application/json-patch+json",
            "filtered-cdnifci-property-map":
            "application/merge-patch+json,application/json-patch+json"
          }
        }
      }
    }
  }
```

3.7.2. Basic Example

In this example, we demonstrate a simple CDNI FCI map; this map does not depend on other resources. There are three BaseAdvertisementObjects in this map and these objects' capabilities are http/1.1 delivery protocol, [http/1.1, https/1.1] delivery protocol and https/1.1 acquisition protocol respectively.

```
GET /cdnifcimap HTTP/1.1
Host: alto.example.com
Accept: application/alto-cdnifcimap+json,application/alto-error+json
```

```
    HTTP/1.1 200 OK
    Content-Length: XXX
    Content-Type: application/alto-cdnifcimap+json
    {
      "meta" : {
        "vtag": {
          "resource-id": "my-default-cdnifci-map",
          "tag": "da65eca2eb7a10ce8b059740b0b2e3f8eb1d4785"
        }
      },
      "cdni-fci-map": {
        "capabilities": [
          {
            "capability-type": "FCI.DeliveryProtocol",
            "capability-value": {
              "delivery-protocols": [
                "http/1.1"
              ]
            },
            "footprints": [
              <Footprint objects>
            ]
          },
          {
            "capability-type": "FCI.DeliveryProtocol",
            "capability-value": {
```

```
                "delivery-protocols": [
                  "https/1.1",
                  "http/1.1"
                ]
              },
              "footprints": [
                <Footprint objects>
              ]
            },
            {
              "capability-type": "FCI.AcquisitionProtocol",
              "capability-value": {
                "acquisition-protocols": [
                  "https/1.1"
                ]
              },
              "footprints": [
                <Footprint objects>
              ]
            }
          ]
        }
      }
```

3.7.3. Incremental Updates Example

A benefit of using ALTO to provide CDNI FCI maps is that such maps can be updated using ALTO incremental updates. Below is an example that also shows the benefit of having both JSON merge patch and JSON patch to encode updates.

At first, an ALTO client requests the ALTO server updates for "my-default-cdnifci-map", and the ALTO server returns the "control-uri" followed by the full CDNI FCI map. Then when there is a huge change in footprint objects in delivery-protocol http/1.1, the ALTO server uses JSON merge patch to encode the change and sends it to the ALTO client. Later on, the ALTO server notifies the ALTO client that "ipv4:192.0.2.0/24" is added into the footprints in delivery-protocol http/1.1 by sending the change encoded by JSON patch to the ALTO client.

```
  POST /updates/cdnifcimaps HTTP/1.1
  Host: alto.example.com
  Accept: text/event-stream,application/alto-error+json
  Content-Type: application/alto-updatestreamparams+json
  Content-Length: ###

  { "add": {
```

```
        "my-cdnifci-stream": {
            "resource-id": "my-default-cdnifci-map"
        }
    }

    HTTP/1.1 200 OK
    Connection: keep-alive
    Content-Type: text/event-stream

    event: application/alto-updatestreamcontrol+json
    data: {"control-uri":
    data: "http://alto.example.com/updates/streams/3141592653589"}

    event: application/alto-cdnifcimap+json,my-default-cdnifci-map
    data: { ... full CDNI FCI map ... }

    event: application/merge-patch+json,my-default-cdnifci-map
    data: {
    data:   "meta": {
    data:     "vtag": {
    data:       "tag": "dasdfa10ce8b059740bddsfasd8eb1d47853716"
    data:     }
    data:   },
    data:   {
    data:     "capability-type": "FCI.DeliveryProtocol",
    data:     "capability-value": {
    data:       "delivery-protocols": [
    data:         "http/1.1"
    data:       ]
    data:     },
    data:     "footprints": [
    data:       <Footprint objects that are different from
    data:        footprint objects in delivery-protocols http/1.1>
    data:     ]
    data:   }
    data: }

    event: application/json-patch+json,my-default-cdnifci-map
    data: [
    data:   {
    data:     "op": "replace",
    data:     "path": "/meta/vtag/tag",
    data:     "value": "a10ce8b059740b0b2e3f8eb1d4785acd42231bfe"
    data:   },
    data:   { "op": "add",
    data:     "path": "/cdni-fci-map/capabilities/0/footprints/-",
    data:     "value": "ipv4:192.0.2.0/24"
    data:   }
```

```
    data: ]
```

4. CDNI FCI Map using ALTO Network Map

4.1. Network Map Footprint Type: altonetworkmap

In addition to the already defined CDNI footprint types (e.g., ipv4cidr, ipv6cidr, asn, countrycode), ALTO network maps can be a type of FCI footprint.

Specifically, CDNI footprints using ALTO network maps should use a new CDNI Footprint Type called "altonetworkmap".

"altonetworkmap" footprint type indicates that the corresponding footprint value is a list of PIDNames as defined in [RFC7285]. These PIDNames are references of PIDs in a network map resource. Hence a CDNI FCI map with "altonetworkmap" footprints depends on a network map. For such a CDNI FCI map, the "dependent-vtag" field with a reference to a network map it depends on MUST be included in it (see the example in Section 4.2.3).

4.2. Examples

4.2.1. IRD Example

We use the same IRD example given in Section 3.7.1.

4.2.2. ALTO Network Map for CDNI FCI Footprints Example

Below is an example network map whose resource id is "my-eu-netmap", and this map is referenced by the CDNI FCI map example in Section 4.2.3.

```
GET /networkmap HTTP/1.1
Host: http://alto.example.com/myeunetmap
Accept: application/alto-networkmap+json,application/alto-error+json
```

```
HTTP/1.1 200 OK
Content-Length: XXX
Content-Type: application/alto-networkmap+json

{
  "meta" : {
    "vtag": [
      {"resource-id": "my-eu-netmap",
       "tag": "3ee2cb7e8d63d9fab71b9b34cbf764436315542e"
      }
    ]
  },
  "network-map" : {
    "south-france" : {
      "ipv4" : [ "192.0.2.0/24", "198.51.100.0/25" ]
    },
    "germany" : {
      "ipv4" : [ "192.0.3.0/24"]
    }
  }
}
```

4.2.3. ALTO Network Map Footprints in CDNI FCI Map

In this example, we show a CDNI FCI map that depends on a network map described in Section 4.2.2.

```
GET /networkcdnifcimap HTTP/1.1
Host: alto.example.com
Accept: application/alto-cdnifcimap+json,application/alto-error+json
```

```
HTTP/1.1 200 OK
Content-Length: 618
Content-Type: application/alto-cdnifcimap+json

{
  "meta" : {
    "dependent-vtags" : [
      {
        "resource-id": "my-eu-netmap",
        "tag": "3ee2cb7e8d63d9fab71b9b34cbf764436315542e"
      }
    ]
  },
  "cdni-fci-map": {
    "capabilities": [
      { "capability-type": "FCI.DeliveryProtocol",
        "capability-value": [
          "http/1.1"
        ]
      },
      { "capability-type": "FCI.DeliveryProtocol",
        "capability-value": [
        "values": [
          "https/1.1"
        ],
        "footprints": [
          { "footprint-type": "altonetworkmap",
            "footprint-value": [
              "germany",
              "south-france"
            ]
          }
        ]
      }
    ]
  }
}
```

4.2.4. Incremental Updates Example

In this example, the ALTO client is interested in changes of "my-cdnifci-map-with-network-map-footprints". Considering two changes, the first one is to change footprints of http/1.1 Delivery Protocol capability, and the second one is to remove "south-france" from the footprints of https/1.1 delivery protocol capability.

```
POST /updates/cdnifcimaps HTTP/1.1
Host: alto.example.com
```

```
Accept: text/event-stream,application/alto-error+json
Content-Type: application/alto-updatestreamparams+json
Content-Length: ###

{ "add": {
    "my-network-map-cdnifci-stream": {
        "resource-id": "my-cdnifci-map-with-network-map-footprints"
    }
}

HTTP/1.1 200 OK
Connection: keep-alive
Content-Type: text/event-stream

event: application/alto-updatestreamcontrol+json
data: {"control-uri":
data: "http://alto.example.com/updates/streams/3141592653590"}

event: application/alto-cdnifcimap+json,my-fci-stream
data: { ... full CDNI FCI map ... }

event: application/merge-patch+json,my-fci-stream
data: {
data:   "meta": {
data:     "dependent-vtags" : [
data:      {
data:        "resource-id": "my-eu-netmap",
data:        "tag": "3ee2cb7e8d63d9fab71b9b34cbf764436315542e"
data:      }
data:     ],
data:     "vtag": {
data:       "tag": "dasdfa10ce8b059740bddsfasd8eb1d47853716"
data:     }
data:   },
data:   {
data:     "capability-type": "FCI.DeliveryProtocol",
data:     "capability-value": {
data:       "delivery-protocols": [
data:         "http/1.1"
data:       ]
data:     },
data:     "footprints": [
data:       <Footprint objects that are different from
data:        footprint objects in delivery-protocols http/1.1>
data:     ]
data:   }
data: }
```

```
event: application/json-patch+json,my-fci-stream
data: [
data:   {
data:     "op": "replace",
data:     "path": "/meta/vtag/tag",
data:     "value": "a10ce8b059740b0b2e3f8eb1d4785acd42231bfe"
data:   },
data:   { "op": "remove",
data:     "path": "/cdni-fci-map/capabilities/2/footprints/0/
data:       footprint-value/1",
data:   }
data: ]
```

5. Filtered CDNI FCI Map using Capabilities

Section 3 and Section 4 describe CDNI FCI Map Service which can be used to enable a uCDN to get capabilities with footprints constrains from dCDNs. However, always getting full CDNI FCI maps from dCDNs is very inefficient, hence we introduce a new service named "Filtered CDNI FCI Map Service" to allow a client to filter a CDNI FCI map using a client-given set of capabilities. For each entry of the CDNI FCI map, only if the entry contains at least one of the client-given capabilities will it be returned to the client. The relationship between a filtered CDNI FCI map and a CDNI FCI map is similar to the relationship between a filtered network/cost map and a network/cost map.

5.1. Media Type

Since a filtered CDNI FCI map is still a CDNI FCI map, it uses the media type defined for CDNI FCI maps in Section 3.1.

5.2. HTTP Method

A filtered CDNI FCI map is requested using the HTTP POST method.

5.3. Accept Input Parameters

The input parameters for a filtered CDNI FCI map are supplied in the entity body of the POST request. This document specifies the input parameters with a data format indicated by the media type "application/alto-cdnifcifilter+json" which is a JSON object of type ReqFilteredCDNIFCIMap, where:

```
object {
    JSONString capability-type;
    JSONValue capability-value;
} CDNIFCICapability;

object {
    [CDNIFCICapability cdni-fci-capabilities<0..*>;]
} ReqFilteredCDNIFCIMap;
```

with fields:

capability-type: The same as Base Advertisement Object's capability-type defined in Section 5.1 of [RFC8008].

capability-value: The same as Base Advertisement Object's capability-value defined in Section 5.1 of [RFC8008].

cdni-fci-capabilities: A list of CDNI FCI capabilities defined in Section 5.1 of [RFC8008] for which footprints are to be returned. If a list is empty or not appearing, the ALTO server MUST interpret it as a request for the full CDNI FCI Map. The ALTO server MUST interpret entries appearing in a list multiple times as if they appeared only once. If a "capability-type" or a "capability-value" is not defined, the ALTO server MUST ignore this capability. If there is only one capability in the list and its "capability-type" or "capability-value" is not defined, the ALTO server MUST return nothing.

5.4. Capabilities

None.

5.5. Uses

The resource ID of the CDNI FCI map based on which the filtering is performed.

5.6. Response

The response MUST indicate an error, using ALTO protocol error handling specified in Section 8.5 of the ALTO protocol [RFC7285], if the request is invalid.

Specifically, a filtered CDNI FCI map request can be invalid as follows:

o The value of "capability-type" is null;

- The value of "capability-value" is null;
- The value of "capability-value" is inconsistent with "capability-type".

When the request is invalid, the ALTO server MUST return an "E_INVALID_FIELD_VALUE" error defined in Section 8.5.2 of [RFC7285], and the "value" field of the error message SHOULD indicate this CDNI FCI capability.

The ALTO server return a filtered CDNI FCI map for a valid request. The format of a filtered CDNI FCI map is the same as an unfiltered CDNI FCI map. See Section 3.6 for the format.

The returned CDNI FCI map MUST contain only BaseAdvertisementObject objects whose CDNI capability object is the superset of one of CDNI capability object in "cdni-fci-capabilities". Specifically, that a CDNI capability object A is the superset of another CDNI capability object B means that these two CDNI capability objects have the same capability type and mandatory properties in capability value of A MUST include mandatory properties in capability value of B semantically. See Section 5.7.2 for a concrete example.

The version tag included in the "vtag" field of the response MUST correspond to the full CDNI FCI map resource from which the filtered CDNI FCI map is provided. This ensures that a single, canonical version tag is used independently of any filtering that is requested by an ALTO client.

5.7. Examples

5.7.1. IRD Example

We use the same IRD example by Section 3.7.1.

5.7.2. Basic Example

This example filters the full CDNI FCI map in Section 3.7.2 by selecting only http/1.1 delivery protocol capability. Only the first two BaseAdvertisementObjects in the full map will be returned because the first object's capability is http/1.1 delivery protocol and the second object's capability is http/1.1 and https/1.1 delivery protocols which is the superset of http/1.1 delivery protocol.

```
POST /cdnifcimap/filtered HTTP/1.1
HOST: alto.example.com
Content-Type: application/cdnifilter+json
Accept: application/alto-cdnifcimap+json

{
  "cdni-fci-capabilities": [
    {
      "capability-type": "FCI.DeliveryProtocol",
      "capability-value": {
        "delivery-protocols": [
           "http/1.1"
        ]
      }
    }
  ]
}
```

```
HTTP/1.1 200 OK
Content-Length: XXX
Content-Type: application/alto-cdnifcimap+json
{
  "meta" : {
    "vtag": {
      "resource-id": "my-default-cdnifci-map",
      "tag": "da65eca2eb7a10ce8b059740b0b2e3f8eb1d4785"
    }
  },
  "cdni-fci-map": {
    "capabilities": [
      {
        "capability-type": "FCI.DeliveryProtocol",
        "capability-value": {
          "delivery-protocols": [
            "http/1.1"
          ]
        },
        "footprints": [
          <Footprint objects>
        ]
      },
      {
        "capability-type": "FCI.DeliveryProtocol",
        "capability-value": {
          "delivery-protocols": [
            "https/1.1",
            "http/1.1"
          ]
        },
        "footprints": [
          <Footprint objects>
        ]
      }
    ]
  }
}
```

5.7.3. Incremental Updates Example

In this example, the ALTO client only cares about the updates of one Delivery Protocol object whose value is "http/1.1". So it adds its limitation of capabilities in "input" field of the POST request.

```
POST /updates/cdnifcimaps HTTP/1.1
Host: fcialtoupdate.example.com
Accept: text/event-stream,application/alto-error+json
```

```
Content-Type: application/alto-updatestreamparams+json
Content-Length: ###

{ "add": {
    "my-fci-stream": {
        "resource-id": "my-filtered-cdnifci-map",
        "input": {
          "cdni-fci-capabilities": [
          {
            "capability-type": "FCI.DeliveryProtocol",
            "capability-value": {
              "delivery-protocols": [
                "http/1.1"
              ]
            }
          }
        ]
      }
    }
  }
}

HTTP/1.1 200 OK
Connection: keep-alive
Content-Type: text/event-stream

event: application/alto-updatestreamcontrol+json
data: {"control-uri":
data: "http://alto.example.com/updates/streams/3141592653590"}

event: application/alto-cdnifcimap+json,my-fci-stream
data: { ... full filtered CDNI FCI map ... }

event: application/merge-patch+json,my-fci-stream
data: {
data:   "meta": {
data:     "vtag": {
data:       "tag": "dasdfa10ce8b059740bddsfasd8eb1d47853716"
data:     }
data:   },
data:   {
data:     "capability-type": "FCI.DeliveryProtocol",
data:     "capability-value": {
data:       "delivery-protocols": [
data:         "http/1.1"
data:       ]
data:     },
data:     "footprints": [
```

```
data:       <Footprint objects that are different from
data:        footprint objects in delivery-protocols http/1.1>
data:     ]
data:   }
data: }

event: application/json-patch+json,my-fci-stream
data: [
data:   {
data:     "op": "replace",
data:     "path": "/meta/vtag/tag",
data:     "value": "a10ce8b059740b0b2e3f8eb1d4785acd42231bfe"
data:   },
data:   { "op": "add",
data:     "path": "/cdni-fci-map/capabilities/0/footprints/-",
data:     "value": "ipv4:192.0.2.0/24"
data:   }
data: ]
```

6. Query Footprint Properties using ALTO Unified Property Service

Above sections describe how a uCDN can get the whole capabilities and footprints from dCDNs and how a uCDN can get the footprints of given capabilities. But there is another important case which is how a uCDN can get properties (i.e., capabilities) of given footprints.

The most natrual way to solve this problem is to use ALTO unified property map defined in [I-D.ietf-alto-unified-props-new] since footprints can be easily presented as groups of entities and Filtered Property Maps are already well-defined. In this section, we describe how ALTO clients look up properties for individual footprints. We firstly describe how to represent footprint objects as unified property map entities, and then we provide examples of the full property map, the filtered property map and the incremental updates.

6.1. Representing Footprint Objects as Unified Property Map Entities

A footprint object has two properties: footprint-type and footprint-value. A footprint-value is an array of footprint values conforming to the specification associated with the registered footprint type ("ipv4cidr", "ipv6cidr", "asn", and "countrycode"). Since each unified property map entity has a unique address and each pair of footprint-type and a footprint value determines a group of unique addresses, a footprint object can be represented as a set of entities according to their different footprint-type and footprint values. However, [I-D.ietf-alto-unified-props-new] only defines IPv4 Domain and IPv6 Domain which represent footprint-type "ipv4cidr" and

"ipv6cidr" respectively. To represent footprint-type "asn" and "countrycode", this document registers two new domains in Section 7.

Here gives an example of representing a footprint object as a set of unified property map entities.

{"footprint-type": "ipv4cidr", "footprint-value": ["192.0.2.0/24", "198.51.100.0/24"]} --> "ipv4:192.168.2.0/24", "ipv4:198.51.100.0/24"

6.1.1. ASN Domain

This document specifies a new domain in addition to the ones in [I-D.ietf-alto-unified-props-new]. ASN is the abbreviation of Autonomous System Number.

6.1.1.1. Domain Name

asn

6.1.1.2. Domain-Specific Entity Addresses

The entity address of asn domain is encoded as a string consisting of the characters "as" (in lowercase) followed by the ASN [RFC6793].

6.1.1.3. Hierarchy and Inheritance

There is no hierarchy or inheritance for properties associated with ASN.

6.1.2. COUNTRYCODE Domain

This document specifies a new domain in addition to the ones in [I-D.ietf-alto-unified-props-new].

6.1.2.1. Domain Name

countrycode

6.1.2.2. Domain-Specific Entity Addresses

The entity address of countrycode domain is encoded as an ISO 3166-1 alpha-2 code [ISO3166-1] in lowercase.

6.1.2.3. Hierarchy and Inheritance

There is no hierarchy or inheritance for properties associated with country codes.

6.2. Examples

6.2.1. IRD Example

We use the same IRD example given by Section 3.7.1.

6.2.2. Property Map Example

This example shows a full unified property map in which entities are footprints and entities' property is "cdni-fci-capabilities".

```
GET /propmap/full/cdnifci HTTP/1.1
HOST: alto.example.com
Accept: application/alto-propmap+json,application/alto-error+json
```

```
HTTP/1.1 200 OK
Content-Length: ###
Content-Type: application/alto-propmap+json

{
  "property-map": {
    "meta": {
      "dependent-vtags": [
        {"resource-id": "my-default-cdnifci-map",
         "tag": "7915dc0290c2705481c491a2b4ffbec482b3cf62"}
      ]
    },
    "countrycode:us": {
      "cdni-fci-capabilities": [{"capability-type":,
                                 "capability-value":}]
    },
    "ipv4:192.0.2.0/24": {
      "cdni-fci-capabilities": [{"capability-type":,
                                 "capability-value":}]
    },
    "ipv4:198.51.100.0/24": {
      "cdni-fci-capabilities": [{"capability-type":,
                                 "capability-value":}]
    },
    "ipv6:2001:db8::/32": {
      "cdni-fci-capabilities": [{"capability-type":,
                                 "capability-value":}]
    },
    "asn:as64496": {
      "cdni-fci-capabilities": [{"capability-type":,
                                 "capability-value":}]
    }
  }
}
```

6.2.3. Filtered Property Map Example

In this example, we use filtered property map service to get "pid" and "cdni-fci-capabilities" properties for two footprints "ipv4:192.0.2.0/24" and "ipv6:2001:db8::/32".

```
POST /propmap/lookup/cdnifci-pid HTTP/1.1
HOST: alto.example.com
Content-Type: application/alto-propmapparams+json
Accept: application/alto-propmap+json,application/alto-error+json
Content-Length:

{
  "entities": [
    "ipv4:192.0.2.0/24",
    "ipv6:2001:db8::/32"
  ],
  "properties": [ "cdni-fci-capabilities", "pid" ]
}

HTTP/1.1 200 OK
Content-Length: ###
Content-Type: application/alto-propmap+json

{
  "property-map": {
    "meta": {
      "dependent-vtags": [
         {"resource-id": "my-default-cdnifci-map",
           "tag": "7915dc0290c2705481c491a2b4ffbec482b3cf62"},
         {"resource-id": "my-default-networkmap",
           "tag": "7915dc0290c2705481c491a2b4ffbec482b3cf63"}
      ]
    },
    "ipv4:192.0.2.0/24": {
      "cdni-fci-capabilities": [{"capability-type":,
                                 "capability-value":}],
      "pid": "pid1"
    },
    "ipv6:2001:db8::/32": {
      "cdni-fci-capabilities": [{"capability-type":,
                                 "capability-value":}],
       "pid": "pid3"
    }
  }
}
```

6.2.4. Incremental Updates Example

In this example, here is a client want to request updates for the properties "cdni-fci-capabilities" and "pid" for two footprints "ipv4:192.0.2.0/24" and "ipv6:2001:db8::/32".

```
POST /updates/properties HTTP/1.1
```

```
Host: alto.example.com
Accept: text/event-stream,application/alto-error+json
Content-Type: application/alto-updatestreamparams+json
Content-Length: ###

{ "add": {
  "property-map-including-capability-property": {
    "resource-id": "filtered-cdnifci-property-map",
      "input": {
        "properties": ["cdni-fci-capabilities", "pid"],
        "entities": [
          "ipv4:192.0.2.0/24",
          "ipv6:2001:db8::/32"
        ]
      }
    }
}

HTTP/1.1 200 OK
Connection: keep-alive
Content-Type: text/event-stream

event: application/alto-updatestreamcontrol+json
data: {"control-uri":
data: "http://alto.example.com/updates/streams/1414213562373"}

event: application/alto-cdnifcimap+json,my-fci-stream
data: { ... full filtered unified property map ... }

event: application/merge-patch+json,my-fci-stream
data: {
data:   "property-map":
data:   {
data:     "meta": {
data:       "dependent-vtags": [
data:         {"resource-id": "my-default-cdnifci-map",
data:          "tag": "2beeac8ee23c3dd1e98a73fd30df80ece9fa5627"},
data:         {"resource-id": "my-default-networkmap",
data:          "tag": "7915dc0290c2705481c491a2b4ffbec482b3cf63"}
data:       ]
data:     },
data:     "ipv4:192.0.2.0/24":
data:     {
data:       "cdni-fci-capabilities":
data:         [{"capability-type":,"capability-value":}]
data:     }
data:   }
data: }
```

```
event: application/json-patch+json,my-fci-stream
data: {[
data: {
data:   { "op": "replace",
data:       "path": "/meta/dependent-vtags/0/tag",
data:       "value": "61b23185a50dc7b334577507e8f00ff8c3b409e4"
data:   },
data:   { "op": "replace",
data:       "path": "/property-map/ipv4:192.0.2.0/124/",
data:       "value": "pid5"
data:   }
data: }
data: ]}
```

7. IANA Considerations

7.1. CDNI Metadata Footprint Type Registry

Footprint Type	Description	Specification
altonetworkmap	A list of PID-names	RFCthis

Table 1: CDNI Metadata Footprint Type

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

7.2. ALTO Entity Domain Registry

As proposed in Section 9.2 of [I-D.ietf-alto-unified-props-new], "ALTO Entity Domain Registry" is requested. Besides, two new domains are to be registered, listed in Table 2.

Identifier	Entity Address Encoding	Hierarchy & Inheritance
asn	See Section 6.1.1.2	None
countrycode	See Section 6.1.2.2	None

Table 2: ALTO Entity Domain

7.3. ALTO CDNI FCI Property Type Registry

The "ALTO CDNI FCI Property Type Registry" is required by the ALTO Entity Domain "asn", "countrycode", "pid", "ipv4" and "ipv6", listed in Table 3.

Identifier	Intended Semantics
cdni-fci-capabilities	An array of CDNI FCI capability objects

Table 3: ALTO CDNI FCI Property Type

8. Security Considerations

Although CDNI FCI Map resource defined in this document is relatively different from other existed resources defined in the base protocol, the Security Considerations of the base protocol (Section 15 of RFC7285) still apply.

For authenticity and Integrity of ALTO information, an attacker may disguise itself as an ALTO server in a dCDN, and it may provide false capabilities and footprints to an ALTO client in a uCDN by the CDNI FCI map. Such false information may lead a uCDN to select a wrong dCDN to serve user requests or even block uCDNs utilizing some dCDNs in good condition.

For potential undesirable guidance from authenticated ALTO information, dCDNs can provide a uCDN with limited capabilities and smaller footprint coverage so that dCDNs can avoid transferring traffic for a uCDN which they should have to transfer.

For confidentiality of ALTO information, an attacker may infer the whole and exact capabilities and footprints of a dCDN by means of pretending it is one of different uCDNs of a dCDN respectively, getting different CDNI FCI maps from a dCDN and combining these maps together.

For privacy for ALTO users, querying footprint properties using ALTO unified property may expose network location identifiers (IP addresses or fine-grained PIDs) to the ALTO server in a dCDN. In such case, a dCDN may potentially monitor and analyze user behaviors and communication patterns of uCDNs' customers.

For availability of ALTO services, an attacker may get the potential huge full CDNI FCI maps from an ALTO server in a dCDN continuously to run out of bandwidth resources of that ALTO server or may query

filtered CDNI FCI services with complex capabilities to run out of computation resources of an ALTO server.

Protection Strategies described in RFC 7285 can solve problems mentioned above well. However, the isolation of full/filtered CDNI FCI maps should also be considered.

If a dCDN signs agreements with multiple uCDNs, it must isolate full/filtered CDNI FCI maps for different uCDNs in that uCDNs will not redirect requests which should not have to served by this dCDN to this dCDN and it may not disclose extra information to uCDNs.

To avoid this risk, a dCDN may consider generating URIs of different full/filtered CDNI FCI maps by hashing its company ID, a uCDN's company ID as well as their agreements. And it needs to avoid expoing all full/filtered CDNI FCI maps resources in one of its IRDs.

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10. References

10.1. Normative References

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