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**Content Delivery Network Interconnection (CDNI) Request Routing: CDNI
Footprint and Capabilities Advertisement using ALTO
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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. This document defines an FCI protocol using the Application-Layer Traffic Optimization (ALTO) protocol, following the guidelines defined in [RFC8008].

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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 the 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." At a high level, the scope of the CDNI Request Routing Interface, therefore, contains two main tasks: (1) determining if the dCDN (downstream CDN) is willing to accept a delegated content request, and (2) redirecting the content request coming from a uCDN (upstream CDN) to the proper entry point or entity in the dCDN.

Correspondingly, the request routing interface is broadly divided into two functionalities: (1) the CDNI Footprint & Capabilities Advertisement interface (FCI) defined in [\[RFC8008\]](#), and (2) the CDNI Request Routing Redirection interface (RI) defined in [\[RFC7975\]](#). Since this document focuses on the first functionality (CDNI FCI), below is more details about it.

Specifically, CDNI FCI allows both an advertisement from a dCDN to a uCDN (push) and 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 defined 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 Service".

There are multiple benefits in using ALTO as a transport protocol, as discussed 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 Service", 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 new granularity to describe footprints. [Section 5](#) introduces "Filtered CDNI FCI Service" to allow a uCDN to get footprints with given capabilities instead of getting the full resource, which can be large. [Section 6](#) further shows another benefit of using ALTO: the ability to query footprint properties using ALTO unified properties. In this way, a uCDN can effectively fetch capabilities of footprints in which it is interested. IANA and security considerations are discussed in [Section 7](#) and [Section 8](#) respectively.

2. Background

The design of CDNI FCI transport using ALTO depends on the understanding of both FCI semantics and ALTO. Hence, this document starts with a non-normative review for both. The review uses the terminologies for CDNI as defined in [\[RFC6707\]](#), [\[RFC8006\]](#) and [\[RFC8008\]](#); those for ALTO as defined in [\[RFC7285\]](#) and [\[I-D.ietf-alto-unified-props-new\]](#).

2.1. Semantics of FCI Advertisement

[RFC8008] (CDNI "Footprint and Capabilities Semantics") defines the semantics of CDNI FCI, provides guidance on what Footprint and Capabilities mean in a CDNI context, and specifies the requirements on the CDNI FCI transport protocol. The definitions in [RFC8008] depend on [RFC8006]. Below is a non-normative review of key related points of [RFC8008] and [RFC8006]. For detailed information and normative specification, the reader is referred to these two RFCs.

- o Multiple types of mandatory-to-implement 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 or 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.
- o Multiple initial types of capabilities are defined in [RFC8008] including (1) Delivery Protocol, (2) Acquisition Protocol, (3) Redirection Mode, (4) Capabilities related to CDNI Logging, and (5) Capabilities related to CDNI Metadata. They are required in all cases and therefore considered as mandatory-to-implement capabilities for all CDNI FCI implementations.
- o Footprint and capabilities are defined together and cannot be interpreted independently from each other. Specifically, [RFC8008] integrates footprint and capabilities with an approach of "capabilities with footprint restrictions", by expressing capabilities on a per footprint basis.
- o Specifically, for all 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.

- o Given that a large part of Footprint and Capabilities Advertisement may 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 FCI. 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 (downstream CDN) to provide changes/updates regarding a footprint and/or capabilities that it has prior agreed to serve in a contract with a uCDN (upstream CDN). Hence, server push and incremental encoding will be necessary techniques.

2.2. ALTO Background and Benefits

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

Originally, ALTO was motivated by optimizing cross-ISP traffic generated by P2P applications [[RFC5693](#)]. However, ALTO can also be used for improving the request routing in CDNs. In particular, the CDNI problem statement [[RFC6707](#)] explicitly mentions ALTO as a candidate protocol for "actual algorithms for selection of CDN or Surrogate by Request-Routing systems".

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

- o 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. This matches the need of CDNI: a uCDN wants to improve application layer CDN request routing by using information (provided by a dCDN) that the uCDN could not easily obtain otherwise. Hence, 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.
- o The semantics of an ALTO network map is an exact match for the needed information to convey a footprint by a dCDN, in particular,

if such a footprint is being expressed by IP-prefix ranges.
Please see [Section 4](#).

- o Security: The identification between uCDNs and dCDNs is an important requirement. ALTO maps can be signed and hence provide inherent integrity protection. Please see [Section 8](#).
- o 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](#).
- o Error-handling: The ALTO protocol provides extensive error-handling in the whole request and response process (see [Section 8.5 of \[RFC7285\]](#)). A CDNI FCI interface based on ALTO would inherit this this extensive error-handling framework. Please see [Section 5](#).
- o Filtered map service: The ALTO map filtering service would allow a uCDN to query only for parts of an ALTO map. For example, the ALTO filtered property map service can enable a uCDN to query properties of a part of footprints efficiently (see [Section 6](#)).
- o Server-initiated Notifications and Incremental Updates: When the footprint or the capabilities of a dCDN change (i.e., unexpectedly from the perspective of a uCDN), server-initiated notifications would enable a dCDN to inform a uCDN about such changes directly. 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 recent network and cost map from the dCDN, and therefore redirect requests to the 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](#)].
- o 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 a uCDN. This would enable a uCDN to determine whether a dCDN actually has the capabilities for a given type of content requested.

- o 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 a uCDN for optimized dCDN 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 dCDN 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 Service

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 Service called "CDNI FCI Service" which conveys JSON objects of media type "application/alto-cdnifci+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 Service". Similar to other ALTO services, this document defines the ALTO information resource for the "CDNI FCI Service" as follows.

3.1. Media Type

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

3.2. HTTP Method

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

3.3. Accept Input Parameters

None.

3.4. Capabilities

None.

3.5. Uses

The "uses" field SHOULD NOT appear unless the CDNI FCI resource depends on some ALTO information resources. If the CDNI FCI resource has some dependent resources, the resource IDs of its dependent resources MUST be included into the "uses" field. This document only defines one potential dependent resource for the CDNI FCI resource. See [Section 4](#) for details of when and how to use it. Future documents may extend the CDNI FCI resource and allow other dependent resources.

3.6. Response

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

If a CDNI FCI response depends on an ALTO information resource, 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 its IRD entry.

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

```
object {
  CDNIFCIData cdni-fci;
} InfoResourceCDNIFCI : ResponseEntityBase;

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

Specifically, a CDNIFCIData 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, below is a non-normative specification of BaseAdvertisementObject. 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": {
    "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": {
    "capabilities": [
      {
        "capability-type": "FCI.DeliveryProtocol",
        "capability-value": {
          "delivery-protocols": [
            "https/1.1",
            "http/1.1"
          ]
        },
        "footprints": [
          <Footprint objects>
        ]
      }
    ]
  }
}

```

Since such optimizations are not required 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 related information

resources (e.g., CDNI FCI resource), demonstrating a single, integrated environment.

Specifically, the IRD announces two network maps, one CDNI FCI resource without dependency, one CDNI FCI resource depending on a network map, one filtered CDNI FCI resource to be defined in [Section 5](#), one property map including "cdni-fci-capabilities" as its entity property, one filtered property map including "cdni-fci-capabilities" and "pid" as its entity properties, and two update stream services (one for updating CDNI FCI resources, 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

HTTP/1.1 200 OK
Content-Length: 3650
Content-Type: application/alto-directory+json
```

```
{
  "meta" : {
    "default-alto-network-map": "my-default-network-map"
  },
  "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": {
      "uri" : "http://alto.example.com/cdnifci",
      "media-type": "application/alto-cdnifci+json"
    },
    "my-cdnifci-with-pid-footprints": {
      "uri" : "http://alto.example.com/networkcdnifci",
      "media-type" : "application/alto-cdnifci+json",
      "uses" : [ "my-eu-netmap" ]
    },
    "my-filtered-cdnifci" : {
      "uri" : "http://alto.example.com/cdnifci/filtered",
      "media-type" : "application/alto-cdnifci+json",
      "accepts" : "application/alto-cdnifcifilter+json",
      "uses" : [ "my-default-cdnifci" ]
    }
  }
}
```

```
},
"cdnifci-property-map" : {
  "uri" : "http://alto.example.com/propmap/full/cdnifci",
  "media-type" : "application/alto-propmap+json",
  "uses": [ "my-default-cdni" ],
  "capabilities" : {
    "mappings": {
      "ipv4": [ "my-default-cdni.cdni-fci-capabilities" ],
      "ipv6": [ "my-default-cdni.cdni-fci-capabilities" ],
      "countrycode": [

        "my-default-cdni.cdni-fci-capabilities" ],
      "asn": [ "my-default-cdni.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",
  "uses": [ "my-default-cdni", "my-default-network-map" ],
  "capabilities" : {
    "mappings": {
      "ipv4": [ "my-default-cdni.cdni-fci-capabilities",
        "my-default-network-map.pid" ],
      "ipv6": [ "my-default-cdni.cdni-fci-capabilities",
        "my-default-network-map.pid" ],
      "countrycode": [
        "my-default-cdni.cdni-fci-capabilities" ],
      "asn": [ "my-default-cdni.cdni-fci-capabilities" ],
    }
  }
},
"update-my-cdni-fci" : {
  "uri": "http:///alto.example.com/updates/cdnifci",
  "media-type" : "text/event-stream",
  "accepts" : "application/alto-updatestreamparams+json",
  "uses" : [
    "my-default-network-map",
    "my-eu-netmap",
    "my-default-cdnifci",
    "my-filtered-cdnifci",
    "my-cdnifci-with-pid-footprints"
  ],
  "capabilities" : {
    "incremental-change-media-types" : {
      "my-default-network-map" : "application/json-patch+json",
      "my-eu-netmap" : "application/json-patch+json",
    }
  }
}
```



```
"meta" : {
  "vtag": {
    "resource-id": "my-default-cdnifci",
    "tag": "da65eca2eb7a10ce8b059740b0b2e3f8eb1d4785"
  }
},
"cdni-fci": {
  "capabilities": [
    {
      "capability-type": "FCI.DeliveryProtocol",
      "capability-value": {
        "delivery-protocols": [
          "http/1.1"
        ]
      },
      "footprints": [
        {
          "footprint-type": "ipv4cidr",
          "footprint-value": [ "192.0.2.0/24" ]
        }
      ]
    },
    {
      "capability-type": "FCI.DeliveryProtocol",
      "capability-value": {
        "delivery-protocols": [
          "https/1.1",
          "http/1.1"
        ]
      },
      "footprints": [
        {
          "footprint-type": "ipv4cidr",
          "footprint-value": [ "198.51.100.0/24" ]
        }
      ]
    },
    {
      "capability-type": "FCI.AcquisitionProtocol",
      "capability-value": {
        "acquisition-protocols": [
          "https/1.1"
        ]
      },
      "footprints": [
        {
          "footprint-type": "ipv4cidr",
          "footprint-value": [ "203.0.113.0/24" ]
        }
      ]
    }
  ]
}
```

```

    }
  ]
}

```

[3.7.3.](#) Incremental Updates Example

A benefit of using ALTO to provide CDNI FCI resources is that such resources 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 updates for "my-default-cdnifci", and the ALTO server returns the "control-uri" followed by the full CDNI FCI response. Then when there is a change in the delivery-protocols in that http/1.1 is removed (from [http/1.1, https/1.1] to only https/1.1) due to maintenance of the https/1.1 clusters, the ALTO server regenerates the new CDNI FCI resource and pushes the full replacement to the ALTO client. Later on, the ALTO server notifies the ALTO client that "192.0.2.0/24" is added into the "ipv4" footprint object for delivery-protocol https/1.1 by sending the change encoded by JSON patch to the ALTO client.

```

POST /updates/cdnifci HTTP/1.1
Host: alto.example.com
Accept: text/event-stream,application/alto-error+json
Content-Type: application/alto-updatestreamparams+json
Content-Length: 92

```

```

{ "add": {
  "my-cdnifci-stream": {
    "resource-id": "my-default-cdnifci"
  }
}
}

```

```

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-cdnifci+json,my-cdnifci-stream
data: { ... full CDNI FCI resource ... }
```

```
event: application/alto-cdnifci+json,my-cdnifci-stream
data: {
  data: { "meta": {
    data: { "vtag": {
      data: { "tag": "dasdfa10ce8b059740bddsfasd8eb1d47853716"
    }
  }
},
  data: { "cdni-fci": {
    data: { "capabilities": [
      data: {
        data: { "capability-type": "FCI.DeliveryProtocol",
          data: { "capability-value": {
            data: { "delivery-protocols": [
              data: { "https/1.1"
            ]
          }
        },
        data: { "footprints": [
          data: { "footprint-type": "ipv4cidr",
            data: { "footprint-value": [ "203.0.113.0/24" ]
          }
        ]
      }
},
    data: { ... other FCI advertisement object ... }
  }
}
data: }
```

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

4. CDNI FCI Service using ALTO Network Map

4.1. Network Map Footprint Type: altopid

The ALTO protocol defines a concept called PID to represent a group of IPv4 or IPv6 addresses which can be applied the same management policy. The PID is an alternative to the pre-defined CDNI footprint types (i.e., ipv4cidr, ipv6cidr, asn, and countrycode).

Specifically, a CDNI FCI resource can depend on an ALTO network map resource and use a new CDNI Footprint Type called "altopid" to compress its CDNI Footprint Payload.

Specifically, the "altopid" 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 with "altopid" footprints depends on a network map. For such a CDNI FCI map, the resource id of its dependent network map MUST be included in the "uses" field of its IRD entry, and the "dependent-vtag" field with a reference to this network map MUST be included in its response (see the example in [Section 4.2.3](#)).

4.2. Examples

4.2.1. IRD Example

The examples below use the same IRD 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 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: 309
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": [ "203.0.113.0/24" ]
    }
  }
}
```

4.2.3. ALTO PID Footprints in CDNI FCI

This example shows a CDNI FCI resource that depends on a network map described in [Section 4.2.2](#).

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

```
HTTP/1.1 200 OK
Content-Length: 712
Content-Type: application/alto-cdnifci+json
```

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

4.2.4. Incremental Updates Example

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

```
POST /updates/cdnifci HTTP/1.1
Host: alto.example.com
Accept: text/event-stream,application/alto-error+json
Content-Type: application/alto-updatestreamparams+json
Content-Length: 183
```

```
{ "add": {
  "my-eu-netmap-stream": {
    "resource-id": "my-eu-netmap"
  },
  "my-netmap-cdnifci-stream": {
    "resource-id": "my-cdnifci-with-pid-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-networkmap+json,my-eu-netmap-stream
data: { ... full Network Map of my-eu-netmap ... }
```

```
event: application/alto-cdnifci+json,my-netmap-cdnifci-stream
data: { ... full CDNI FCI resource ... }
```

```
event: application/json-patch+json,my-netmap-cdnifci-stream
data: [
data:   { "op": "replace",
data:     "path": "/meta/vtag/tag",
data:     "value": "dasdfa10ce8b059740bddsfasd8eb1d47853716"
data:   },
data:   { "op": "add",
data:     "path":
data:       "/cdni-fci/capabilities/0/footprints/0/footprint-value/-",
data:     "value": "germany"
data:   }
data: ]
```

```
event: application/json-patch+json,my-netmap-cdnifci-stream
data: [
data:   { "op": "replace",
data:     "path": "/meta/vtag/tag",
data:     "value": "a10ce8b059740b0b2e3f8eb1d4785acd42231bfe"
```

```
data:  },
data:  { "op": "remove",
data:    "path":
data:      "/cdni-fci/capabilities/1/footprints/0/footprint-value/1"
data:    }
data:  ]
```

5. Filtered CDNI FCI using Capabilities

[Section 3](#) and [Section 4](#) describe CDNI FCI Service which can be used to enable a uCDN to get capabilities with footprints constraints from dCDNs. However, since always getting full CDNI FCI resources from dCDNs is inefficient, this document introduces a new service named "Filtered CDNI FCI Service", to allow a client to filter a CDNI FCI resource using a client-given set of capabilities. For each entry of the CDNI FCI response, an entry will only be returned to the client if it contains at least one of the client given capabilities. The relationship between a filtered CDNI FCI resource and a CDNI FCI resource is similar to the relationship between a filtered network/cost map and a network/cost map.

5.1. Media Type

A filtered CDNI FCI resource uses the same media type defined for the CDNI FCI resource in [Section 3.1](#).

5.2. HTTP Method

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

5.3. Accept Input Parameters

The input parameters for a filtered CDNI FCI resource 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-cdnifcfilter+json" which is a JSON object of type ReqFilteredCDNIFCI, where:

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

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

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 resource. The ALTO server MUST interpret entries appearing in a list multiple times as if they appeared only once. If the ALTO server does not define any footprints for a CDNI capability, it MUST omit this capability from the response.

[5.4.](#) Capabilities

None.

[5.5.](#) Uses

The resource ID of the CDNI FCI resource 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 request is invalid if:

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

- o the value of "capability-value" is inconsistent with "capability-type".

When a 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 returns a filtered CDNI FCI resource for a valid request. The format of a filtered CDNI FCI resource is the same as a full CDNI FCI resource (See [Section 3.6.](#))

The returned CDNI FCI resource 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 resource from which the filtered CDNI FCI resource 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

The examples below use the same IRD example as in [Section 3.7.1.](#)

[5.7.2.](#) Basic Example

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

```
POST /cdnifci/filtered HTTP/1.1
HOST: alto.example.com
Accept: application/alto-cdnifci+json
Content-Type: application/cdnifilter+json
Content-Length: 180
```



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

```
HTTP/1.1 200 OK
Content-Length: 544
Content-Type: application/alto-cdnifci+json
```

```
{
  "meta" : {
    "vtag": {
      "resource-id": "my-default-cdnifci",
      "tag": "da65eca2eb7a10ce8b059740b0b2e3f8eb1d4785"
    }
  },
  "cdni-fci": {
    "capabilities": [
      {
        "capability-type": "FCI.DeliveryProtocol",
        "capability-value": {
          "delivery-protocols": [
            "https/1.1",
            "http/1.1"
          ]
        }
      },
      {
        "footprints": [
          {
            "footprint-type": "ipv4cidr",
            "footprint-value": [ "198.51.100.0/24" ]
          }
        ]
      }
    ]
  }
}
```

5.7.3. Incremental Updates Example

In this example, the ALTO client only cares about the updates of one advertisement object for delivery protocol capability whose value includes "https/1.1". So it adds its limitation of capabilities in "input" field of the POST request.

```

POST /updates/cdnifci HTTP/1.1
Host: fcialtoupdate.example.com
Accept: text/event-stream,application/alto-error+json
Content-Type: application/alto-updatestreamparams+json
Content-Length: 350

```

```

{
  "add": {
    "my-filtered-fci-stream": {
      "resource-id": "my-filtered-cdnifci",
      "input": {
        "cdni-fci-capabilities": [
          {
            "capability-type": "FCI.DeliveryProtocol",
            "capability-value": {
              "delivery-protocols": [ "https/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-cdnifci+json,my-filtered-fci-stream
data: { ... filtered CDNI FCI resource ... }

```

```

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

```

6. Query Footprint Properties using ALTO Property Map Service

Besides the requirement of retrieving footprints of given capabilities, another common requirement for uCDN is to query CDNI capabilities of given footprints.

Considering each footprint as an entity with properties including CDNI capabilities, a natural way to satisfy this requirement is to use the ALTO property map as defined in [\[I-D.ietf-alto-unified-props-new\]](#). This section describes how ALTO clients look up properties for individual footprints. First, it describes how to represent footprint objects as entities in the ALTO property map. Second, it provides examples of the full property map and the filtered property map supporting CDNI capabilities, and their incremental updates.

6.1. Representing Footprint Objects as 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"). Considering each ALTO entity defined in [\[I-D.ietf-alto-unified-props-new\]](#) also has two properties: entity domain type and domain-specific identifier, a straightforward approach to represent a footprint as an ALTO entity is to regard its footprint-type as an entity domain type, and its footprint value as a domain-specific identifier. According to [\[I-D.ietf-alto-unified-props-new\]](#), "ipv4" and "ipv6" are two predefined entity domain types, which can be used to represent "ipv4cidr" and "ipv6cidr" footprints respectively. However, no existing entity domain type can represent "asn" and "countrycode" footprints. To represent footprint-type "asn" and "countrycode", this document registers two new domains in [Section 7](#) in addition to the ones in [\[I-D.ietf-alto-unified-props-new\]](#).

Here is an example of representing a footprint object as a set of entities in the ALTO property map.

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

6.1.1. ASN Domain

The ASN domain associates property values with Autonomous Systems in the Internet.

6.1.1.1. Entity Domain Type

asn

6.1.1.2. Domain-Specific Entity Identifiers

The entity identifier of an entity in an asn domain is encoded as a string consisting of the characters "as" (in lowercase) followed by the Autonomous System Number [[RFC6793](#)].

6.1.1.3. Hierarchy and Inheritance

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

6.1.2. COUNTRYCODE Domain

The COUNTRYCODE domain associates property values with countries.

6.1.2.1. Entity Domain Type

countrycode

6.1.2.2. Domain-Specific Entity Identifiers

The entity identifier of an entity in a 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

The examples use the same IRD example given by [Section 3.7.1](#).

6.2.2. Property Map Example

This example shows a full 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: 1546
Content-Type: application/alto-propmap+json
```

```
{
  "property-map": {
    "meta": {
      "dependent-vtags": [
        { "resource-id": "my-default-cdnifci",
          "tag": "7915dc0290c2705481c491a2b4ffbec482b3cf62"}
      ]
    },
    "countrycode:us": {
      "my-default-cdnifci.cdni-fci-capabilities": [
        { "capability-type": "FCI.DeliveryProtocol",
          "capability-value": {
            "delivery-protocols": ["http/1.1"]}
        }
      ],
    },
    "ipv4:192.0.2.0/24": {
      "my-default-cdnifci.cdni-fci-capabilities": [
        { "capability-type": "FCI.DeliveryProtocol",
          "capability-value": {
            "delivery-protocols": ["http/1.1"]}
        }
      ],
    },
    "ipv4:198.51.100.0/24": {
      "my-default-cdnifci.cdni-fci-capabilities": [
        { "capability-type": "FCI.DeliveryProtocol",
          "capability-value": {
            "delivery-protocols": ["https/1.1", "http/1.1"]}
        }
      ],
    },
    "ipv4:203.0.113.0/24": {
      "my-default-cdnifci.cdni-fci-capabilities": [
        { "capability-type": "FCI.AcquisitionProtocol",
          "capability-value": {
            "acquisition-protocols": ["http/1.1"]}
        }
      ],
    },
    "ipv6:2001:db8::/32": {
      "my-default-cdnifci.cdni-fci-capabilities": [
```

```
    { "capability-type": "FCI.DeliveryProtocol",
      "capability-value": {
        "delivery-protocols": ["http/1.1"]}
    },
    "asn:as64496": {
      "my-default-cdnifci.cdni-fci-capabilities": [
        { "capability-type": "FCI.DeliveryProtocol",
          "capability-value": {
            "delivery-protocols": ["https/1.1", "http/1.1"]}
        }
      ]
    }
  }
}
```

6.2.3. Filtered Property Map Example

This example uses the 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: 185
```

```
{
  "entities": [
    "ipv4:192.0.2.0/24",
    "ipv6:2001:db8::/32"
  ],
  "properties": [ "my-default-cdnifci.cdni-fci-capabilities",
                  "my-default-networkmap.pid" ]
}
```

```
HTTP/1.1 200 OK
Content-Length: 804
Content-Type: application/alto-propmap+json
```

```
{
  "property-map": {
    "meta": {
      "dependent-vtags": [
        {"resource-id": "my-default-cdnifci",
         "tag": "7915dc0290c2705481c491a2b4ffbec482b3cf62"},
        {"resource-id": "my-default-networkmap",
         "tag": "7915dc0290c2705481c491a2b4ffbec482b3cf63"}
      ]
    },
    "ipv4:192.0.2.0/24": {
      "my-default-cdnifci.cdni-fci-capabilities": [
        {"capability-type": "FCI.DeliveryProtocol",
         "capability-value": {"delivery-protocols": ["http/1.1"]}},
        "my-default-networkmap.pid": "pid1"
      ],
    },
    "ipv6:2001:db8::/32": {
      "my-default-cdnifci.cdni-fci-capabilities": [
        {"capability-type": "FCI.DeliveryProtocol",
         "capability-value": {"delivery-protocols": ["http/1.1"]}},
        "my-default-networkmap.pid": "pid3"
      ],
    }
  }
}
```


6.2.4. Incremental Updates Example

In this example, the client is interested in updates for the properties "cdni-fci-capabilities" and "pid" of two footprints "ipv4:192.0.2.0/24" and "countrycode:fr".

```

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: 341

{ "add": {
  "fci-propmap-stream": {
    "resource-id": "filtered-cdnifci-property-map",
    "input": {
      "properties": [ "my-default-cdnifci.cdni-fci-capabilities",
                    "my-default-networkmap.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-cdnifci+json,fci-propmap-stream
data: { ... filtered property map ... }

event: application/merge-patch+json,fci-propmap-stream
data: {
data:   "property-map": {
data:     "meta": {
data:       "dependent-vtags": [
data:         { "resource-id": "my-default-cdnifci",
data:           "tag": "2beeac8ee23c3dd1e98a73fd30df80ece9fa5627"},
data:         { "resource-id": "my-default-networkmap",
data:           "tag": "7915dc0290c2705481c491a2b4ffbec482b3cf63"}
data:       ]
data:     },
data:   },

```

```

data:      "ipv4:192.0.2.0/24": {
data:      "my-default-cdnifci.cdni-fci-capabilities": [
data:      { "capability-type": "FCI.DeliveryProtocol",
data:      "capability-value": {
data:      "delivery-protocols": ["http/1.1", "https/1.1"]}}}
data:      }
data:    }
data:  }
data: }

event: application/json-patch+json,fci-propmap-stream
data: [
data:  { "op": "replace",
data:    "path": "/meta/dependent-vtags/0/tag",
data:    "value": "61b23185a50dc7b334577507e8f00ff8c3b409e4"
data:  },
data:  { "op": "replace",
data:    "path":
data:    "/property-map/countrycode:fr/my-default-networkmap.pid",
data:    "value": "pid5"
data:  }
data: ]
    
```

7. IANA Considerations

7.1. CDNI Metadata Footprint Type Registry

As proposed in [Section 7.2 of \[RFC8006\]](#), "CDNI Metadata Footprint Types" registry is requested. A new footprint type is to be registered, listed in Table 1.

Footprint Type	Description	Specification
altopid	A list of PID-names	Section 4 of 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 Type Registry

As proposed in Section 11.2 of [\[I-D.ietf-alto-unified-props-new\]](#), "ALTO Entity Domain Type Registry" is requested. Two new entity domain types 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 Types

7.3. ALTO Entity Property Type Registry

As proposed in Section 11.3 of [[I-D.ietf-alto-unified-props-new](#)], "ALTO Entity Property Type Registry" is required. A new entity property type is to be registered, 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

As an extension of the base ALTO protocol ([\[RFC7285\]](#)), this document fits into the architecture of the base protocol. And hence Security Considerations of the base protocol ([Section 15 of \[RFC7285\]](#)) fully apply when this extension is provided by an ALTO server.

In the context of CDNI FCI, additional security considerations should be included as follows:

- o For authenticity and integrity of ALTO information, an attacker may disguise itself as an ALTO server for a dCDN, and provide false capabilities and footprints to a uCDN using the CDNI FCI service. Such false information may lead a uCDN to (1) select an incorrect dCDN to serve user requests, or (2) skip uCDNs in good conditions.
- o For potential undesirable guidance from authenticated ALTO information, a dCDN can provide a uCDN with limited capabilities and smaller footprint coverage so that the dCDN can avoid transferring traffic for a uCDN which they should have to transfer.

- o For confidentiality and privacy of ALTO information, footprint properties integrated with ALTO unified property may expose network location identifiers (e.g., IP addresses or fine-grained PIDs).
- o For availability of ALTO services, an attacker may conduct service degradation attacks using services defined in this document to disable ALTO services of a network. It may request potentially large, full CDNI FCI resources from an ALTO server in a dCDN continuously, to consume the bandwidth resources of that ALTO server. It may also query filtered property map services with many smaller individual footprints, to consume the computation resources of the ALTO server.

Although protection strategies as described in [Section 15 of \[RFC7285\]](#) should be applied to address aforementioned security considerations, one additional information leakage risk introduced by this document could not be addressed by these strategies. In particular, if a dCDN signs agreements with multiple uCDNs without any isolation, this dCDN may disclose extra information of one uCDN to another one. In that case, one uCDN may redirect requests which should not have to be served by this dCDN to it.

To reduce the risk, a dCDN should isolate full/filtered CDNI FCI resources for different uCDNs. It could consider generating URIs of different full/filtered CDNI FCI resources by hashing its company ID, a uCDN's company ID as well as their agreements. A dCDN should avoid exposing all full/filtered CDNI FCI resources in one of its IRDs.

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10. Contributors

Mr. Xiao Shawn Lin is an author of an early version of this document, with many contributions.

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