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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) WG is defining a set of protocols to inter-connect 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 is the CDNI Request Routing Footprint & Capabilities Advertisement interface (FCI) [RFC7336]. [RFC8008] has defined precisely the semantics of FCI and provided guidelines on the FCI protocol, but the exact protocol is explicitly outside the scope of that document. In this document, we define an FCI protocol using the Application-Layer Traffic Optimization (ALTO) protocol.

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## [1.](#) Introduction

Many Network Service Providers (NSPs) are currently considering or have already started to deploy Content Delivery Networks (CDNs) within their networks. As a consequence of this development, there is a need for interconnecting these local CDNs. Content Delivery Networks Interconnection (CDNI) has the goal of standardizing protocols to enable such interconnection of CDNs [[RFC6707](#)].

The CDNI problem statement [[RFC6707](#)] defines four interfaces to be standardized within the IETF for CDN interconnection:

- o CDNI Request Routing Interface
- o CDNI Metadata Interface
- o CDNI Logging Interface
- o CDNI Control Interface

The main purpose of the CDNI Request Routing Interface is described in [[RFC6707](#)] as follows: "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:

- o determining if the downstream CDN (dCDN) is willing to accept a delegated content request;
- o 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:

- o CDNI Footprint & Capabilities Advertisement interface (FCI): the advertisement from a dCDN to a uCDN or a query from a uCDN to a dCDN for the uCDN to decide whether to redirect particular user requests to that dCDN;
- o CDNI Request Routing Redirection interface (RI): the synchronous operation of actually redirecting a user request.

This document focuses solely on CDNI FCI, with a goal to specify a new Application-Layer Traffic Optimization (ALTO) [[RFC7285](#)] service called "CDNI FCI Map Service", to transport and update CDNI FCI objects, which are defined in a separate document in [[RFC8008](#)] and to describe a mechanism for filtering CDNI FCI map on capabilities or footprints.

Throughout this document, we use the terminology for CDNI defined in [[RFC6707](#)] and [[RFC8008](#)].

## **2. Background**

The design of CDNI FCI transport using ALTO depends on 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 for the CDNI FCI. It thus 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.

- o Footprint and capabilities are tied together and cannot be interpreted independently from each other. In such cases, i.e. where capabilities must be expressed on a per footprint basis, it may be beneficial to combine footprint and capabilities advertisement. [RFC8008] integrates footprint and capabilities with an approach of "capabilities with footprint restrictions".
- o Given that a large part of Footprint and Capabilities Advertisement will actually happen in contractual agreements, the semantics of CDNI Footprint and Capabilities advertisement refer 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 it has prior agreed to serve in a contract with a uCDN. Hence, server push and incremental encoding will be necessary techniques.
- o Multiple types of footprints are defined in [RFC8006]:

- \* List of ISO Country Codes
- \* List of AS numbers
- \* Set of IP-prefixes

A "set of IP-prefixes" must be able to contain full IP addresses, i.e., a /32 for IPv4 and a /128 for IPv6, and also 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 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.

- o The following capabilities are defined as "base" capabilities, i.e. ones that are needed in any case and therefore constitute mandatory capabilities to be supported by the CDNI FCI:
  - \* Delivery Protocol (e.g., HTTP vs. RTMP)
  - \* Acquisition Protocol (for acquiring content from a uCDN)
  - \* Redirection Mode (e.g., DNS Redirection vs. HTTP Redirection as discussed in [\[RFC7336\]](#))
  - \* Capabilities related to CDNI Logging (e.g., supported logging mechanisms)
  - \* Capabilities related to CDNI Metadata (e.g., authorization algorithms or support for proprietary vendor 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 these applications cannot measure themselves [\[RFC5693\]](#).

Originally, ALTO was motivated by the huge amount of cross-ISP traffic generated by P2P applications [\[RFC5693\]](#). Recently, however, ALTO is also being considered for improving the request routing in CDNs [\[I-D.jenkins-alto-cdn-use-cases\]](#). In this context, it has also been proposed to use ALTO for selecting an entry-point in a downstream NSP's network (see [section 3.4](#) "CDN delivering Over-The-Top of a NSP's network" in [\[I-D.jenkins-alto-cdn-use-cases\]](#)). Also, 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:

- o CDN request routing is done at the application layer. 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.
- o The semantics of an ALTO network map are 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.
- o Security: ALTO maps can be signed and hence provide inherent integrity protection (see [Section 9](#)).
- 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.
- o 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.
- o Filtered network map: The ALTO Map Filtering Service (see [\[RFC7285\]](#) for details) would allow a uCDN to query only for parts of an ALTO map.
- o Server-initiated Notifications and Incremental Updates: In case the footprint or the capabilities of a downstream CDN change abruptly (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](#)].

- 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 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.
- 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 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.

### **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**

If a CDNI FCI map does not depend on other resources, the "meta" field of a CDNI FCI map response **MUST** include the "vtag" field defined in [Section 10.3 of \[RFC7285\]](#), which provides the version tag of the retrieved CDNI FCI map. If a CDNI FCI map response depends on a resource such a network map, it **MUST** include the "dependent-vtags" field, whose value is an array to indicate the version tag of the resource used, where the 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 CDNI FCIMapData object is a JSON object, and it includes only one property "capabilities" and whose value is an array of BaseAdvertisementObject objects. The syntax and semantics of BaseAdvertisementObject are well defined in [Section 5.1 of \[RFC8008\]](#). BaseAdvertisementObject object consists of capability-type, capability-value and footprints. And footprints are defined in [Section 4.2.2.2 of \[RFC8006\]](#).

The ALTO client MUST interpret footprints appearing multiple times as if they appeared only once. If no footprint restriction list is specified (or an empty list is specified), the ALTO client MUST understand that all footprint types are reset to "global" coverage.

Note: Further optimization of BaseAdvertisement objects to effectively provide the advertisement of capabilities with footprint restrictions is certainly possible, however, it is not necessary for the basic interconnection of CDNs. The note here is for completeness, however, the specifics of such mechanisms are outside the scope of this document.

### [3.7.](#) Examples

#### [3.7.1.](#) IRD Example

Below is an example IRD announcing two network maps, one CDNI FCI map without dependency, one CDNI FCI map depending on a network map, one filtered CDNI FCI map, 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", "countrycode", "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",
    "accpets" : "application/alto-propmapparams+json",
    "capabilities" : {
      "domain-types" : [ "ipv4", "ipv6", "countrycode", "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.

```

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 a benefit of using a JSON merge patch to encode a big update and using a JSON patch to encode a small update.

```

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-fci-stream

data: { ... full 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: ]
```

## **[4.](#) CDNI FCI Map using ALTO Network Map**

### **[4.1.](#) Introduce 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. To enable such referencing to ALTO network maps, a new CDNI Footprint Type "`altonetworkmap`" is defined (see also [Section 8.1](#)).

All `altonetworkmap` entries MUST be of type `PIDName` (as defined in [\[RFC7285\]](#), where `PIDName` corresponds to a PID in the ALTO network map referenced by the resource ID of the network map listed in "`dependent-vtags`" field).

### **[4.2.](#) Examples**

#### **[4.2.1.](#) IRD Example**

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

#### **[4.2.2.](#) ALTO Network Map for CDNI FCI Footprints Example**

Below is an example network map that 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". And we present two patches here. The first one of it 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/cdnifcimap 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: { "op": "remove",
    data: "path": "/cdni-fci-map/capabilities/2/footprints/0/
    data: footprint-value/1",
  data: }
data: ]
```

## 5. Filtered CDNI FCI Map using Capabilities

This document defines a new service named "Filtered CDNI FCI Map Service". The semantic of a Filtered CDNI FCI Map is that given some capabilities, which footprints have at least one of these capabilities. And a filtered CDNI FCI map is a CDNI FCI map for which an ALTO client may supply additional capabilities to limit the scope of the resulting CDNI FCI map. 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 at [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-cdni-filter", 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, 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. The ALTO client SHOULD avoid the same entries appearing in "cdni-fci-capabilities" multiple times. If the "cdni-fci-capabilities" field is not present, the ALTO server MUST interpret it as a request for the full CDNI FCI Map. If a "capability-type" or a "capability-value" is not defined, the ALTO server MUST ignore this capability. If it is the only capability in the list, 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 format 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. For example, if a CDNI FCI capability in "cdni-fci-capabilities" is Delivery Protocol capability object with "http/1.1" in its field "delivery-protocols" and the original full CDNI FCI map has two CDNI FCI objects whose capabilities are Delivery Protocol capability objects with ["http/1.1"] and ["http/1.1", "https/1.1"] in their field "delivery-protocols" respectively, both of these two CDNI FCI objects MUST be returned. If the input parameters contain a CDNI capability object that is not currently defined, the ALTO server MUST behave as if the CDNI capability object did not appear in the input parameters.

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 is filtering the full CDNI FCI map example in [Section 3.7.2](#).

```
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"
    }
  },
  "cdnifci-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: "http/1.1"



```
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**

In this section, we describe how ALTO clients look up properties for individual footprints. Our design decision here is to use ALTO unified property map service to query footprint properties because we do not want to introduce extra complexity and ALTO unified property map defined in [[I-D.ietf-alto-unified-props-new](#)] already meets the requirement. A footprint is a group of entities, and CDNI capabilities can be regarded as properties of a footprint. Unified property map is used to provide properties for collections of entities such as CIDRs or PIDs. So every footprint can be presented as a set of entities, and we will describe it in details in [Section 6.1](#). In addition, two resource types Property Maps and Filtered Property Maps are already well-defined in [[I-D.ietf-alto-unified-props-new](#)].

A unified property map that includes "cdni-fci-capabilities" property registered in [Section 8](#) builds the inverted index of a CDNI FCI map. The building process consists of two steps: firstly, each footprint object is represented as a set of unified property map entities in a domain; secondly, each unified property map entity is mapped into a list of property objects including CDNI capabilities.

### **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 8](#).

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"
```

#### [6.1.1.1](#). 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.

##### [6.1.1.1.1](#). Domain Name

asn

##### [6.1.1.1.2](#). 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](#)].

##### [6.1.1.1.3](#). 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. Protocol Errors**

Protocol errors are handled as specified in [Section 8.5](#) of the ALTO protocol [[RFC7285](#)].

Here we explain the error-handling mechanism of filtered CDNI FCI map:

- o E\_SYNTAX covers all cases of syntax errors of filtered CDNI FCI map queries.
- o When the syntax of queries is correct, there may be some errors in queries' semantics. Such Cases can be covered by E\_INVALID\_FIELD\_VALUE:
  - \* The value of "capability-type" is null;
  - \* The value of "capability-value" is null;
  - \* The value of "capability-value" is inconsistent with "capability-type".

The error-handling mechanism of query footprints is the same as the error-handling mechanism of ALTO Unified Property Map Service described in [[I-D.ietf-alto-unified-props-new](#)].

## **8. IANA Considerations**

### **8.1. 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.]

### 8.2. 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 <a href="#">Section 6.1.1.2</a>	None
countrycode	See <a href="#">Section 6.1.2.2</a>	None

Table 2: ALTO Entity Domain

### 8.3. 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

## 9. Security Considerations

One important security consideration is the proper authentication of advertisement information provided by a downstream CDN. The ALTO protocol provides a specification for a signature of ALTO information (see [Section 15 of \[RFC7285\]](#)). ALTO thus provides a proper mechanism for protecting the integrity of FCI information.



More Security Considerations will be discussed in a future version of this document.

## **10. Acknowledgments**

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