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CDNI Footprint and Capabilities Advertisement using ALTO
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Abstract

Network Service Providers (NSPs) are currently considering to deploy Content Delivery Networks (CDNs) within their networks. As a consequence of this development, there is a need for interconnecting these local CDNs. The necessary interfaces for inter-connecting CDNs are currently being defined in the Content Delivery Networks Interconnection (CDNI) WG. This document focuses on the CDNI Footprint & Capabilities Advertisement interface (FCI). Specifically, this document outlines how the solutions currently being defined in the Application Layer Traffic Optimization (ALTO) WG can facilitate Footprint & Capabilities Advertisement in a CDNI context, i.e. how the CDNI FCI can be realised with the ALTO protocol. Concrete examples of how ALTO can be integrated within CDNI request routing and in particular in the process of selecting a downstream CDN are given. The examples in this document are based on the use cases and examples currently being discussed in the CDNI WG.

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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] envisions four interfaces to be standardized within the IETF for CDN interconnection:

- CDNI Request Routing Interface

- CDNI Metadata Interface
- CDNI Logging Interface
- CDNI Control Interface

This document focuses solely on the CDNI Request Routing Interface, which can be further divided into two interfaces (see [RFC6707] for a detailed description): the CDNI Request Routing Redirection interface (RI), and the CDNI Footprint & Capabilities Advertisement interface (FCI). This document presents how one may use ALTO as a protocol for CDNI Footprint & Capabilities Advertisement. Concrete examples of how the CDNI FCI can be implemented with the ALTO protocol [I-D.ietf-alto-protocol] are given. The examples used in this document are based on the use cases and request routing proposals currently being discussed in the CDNI WG [RFC6770] [I-D.peterson-CDNI-strawman] and in the ALTO WG [I-D.jenkins-alto-cdn-use-cases].

A previous version of this document [I-D.seedorf-alto-for-cdni] contained detailed examples of actual request routing and surrogate selection with ALTO, i.e. how ALTO could be used for implementing the CDNI Request Routing Redirection interface (RI). This version solely focuses on implementing the CDNI Footprint & Capabilities Advertisement interface (FCI) with ALTO, i.e. the selection of a downstream CDN and how ALTO can support such downstream CDN selection.

Throughout this document, we use the terminology for CDNI defined in [I-D.ietf-cdni-problem-statement].

2. ALTO within CDNI Request Routing

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:

- A) Determining if the downstream CDN is willing to accept a delegated content request
- B) Redirecting the content request coming from an upstream CDN to the proper entry point or entity in the downstream CDN

More precisely, in [I-D.ietf-cdni-framework] the request routing interface is broadly divided into two functionalities:

- 1) the asynchronous advertisement of footprint and capabilities by a dCDN that allows a uCDN to decide whether to redirect particular user requests to that dCDN (the CDNI FCI)

- 2) the synchronous operation of actually redirecting a user request (the CDNI RI)

Application Layer Traffic Optimization (ALTO) 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 "algorithms for selection of CDN or Surrogate by Request-Routing systems" [I-D.ietf-cdni-problem-statement]. Yet, there have not been concrete proposals so far on how to use ALTO in the context of CDN interconnection. This document tries to close this gap by giving some examples on how ALTO could be used within CDNI request routing.

3. Assumptions and High-Level Design Considerations

In this section we list some assumptions and design issues to be considered when using ALTO for the CDNI Footprint and Capabilities Advertisement interface

3.1. General Assumptions and Consideration

Below we list some general assumptions and considerations:

- As explicitly being out-of-scope for CDNI [I-D.ietf-cdni-problem-statement], the examples used in this document assume that ingestion of content or acquiring content

across CDNs is not part of request routing as considered within CDNI standardization work. The focus of using ALTO (as considered in this document) is hence on request routing only, assuming that the content (desired by the end user) is available in the downstream CDN (or can be aquired by the downstream CDN by some means).

- Federation Model: "Footprint and Capabilities Advertisement" and in general CDN request routing depends on the federation model among the CDN providers. Designing a suitable solution thus depends on whether a solution is needed for different settings, where CDNs consist of both NSP CDNs (serving individual ASes) and general, traditional CDNs (such as Akamai). We assume that CDNI is not designed for a setting where only NSP CDNs each serve a single AS only.

- In this document, we assume that the upstream CDN (uCDN) makes the decision on selecting a downstream CDN, based on information that each downstream CDN has made available to the upstream CDN. Further, we assume that in principle more than one dCDN may be suitable for a given end-user request (i.e. different dCDNs may claim "overlapping" footprints). The uCDN hence potentially has to select among several candidate downstream CDNs for a given end user request.

- It is not clear what kind(s) of business, contract, and operational relationships two peering CDNs may form. For the Internet, we see provider-customer and peering as two main relations; providers may use different charging models (e.g., 95-percentile, total volume) and may provide different SLAs. Given such unknown characteristics of CDN peering business agreements, we should design the protocol to support as much diverse potential business and operational models as possible.

3.2. Semantics for Footprint/Capabilities Advertisment

The CDNI document on "Footprint and Capabilities Semantics" [I-D.spp-cdni-rr-foot-cap-semantics] 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. Here we briefly summarize the key points of the semantics of Footprint and Capabilities (for a detailed discussion, the reader is referred to [I-D.spp-cdni-rr-foot-cap-semantics]):

- Often, 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.

- 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.

- It seems clear that "coverage/reachability" types of footprint must be supported within CDNI. The following such types of footprint are mandatory and must be supported by the CDNI FCI:

  * 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.

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

- The following capabilities seem useful 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 aquiring content from a uCDN)
  - Redirection Mode (e.g., DNS Redirection vs. HTTP Redirection as discussed in [I-D.ietf-cdni-framework])
  - 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)

4. Selection of a Downstream CDN with ALTO

Under the considerations stated in Section 3, ALTO can help the upstream CDN provider to select a proper downstream CDN provider for a given end user request as follows: Each downstream CDN provider hosts an ALTO server which provides ALTO information (i.e. ALTO network maps and ALTO cost maps [I-D.ietf-alto-protocol]) to an ALTO client at the upstream CDN provider. Network maps provided by each of several candidate downstream CDNs can provide information to the upstream CDN provider about each dCDN's "coverage/reachability" as well as capabilities.

4.1. Footprint and Capabilities Advertisement using ALTO Network Map and PID Properties

Conceptually, the foorprint and capabilities interface of a dCDN is easy to specify: It is a function that given an endhost, returns if the dCDN is willing to serve the endhost, and the capabilities available to that endhost (e.g., "delivery-protocol": ["HTTP","RMTP"], "acquisition-protocol": ["HTTP"], "redirection-mode": ["HTTP-redirect"], "loggin-mechanism": ["TBD"], and "meta-capabilities": [""]).

Specifiying the preceding for each endhost can be redundant, and one may use PIDs defined in ALTO. Specifically, an ALTO network map contains a "set of Network Location groupings" [I-D.ietf-alto-protocol]. The groupings are defined in the form of so-called "PIDs". A PID is an identifier to group network location endpoints, e.g. IP-addresses in the form of prefixes (see section 4 in [I-D.ietf-alto-protocol] for details).

Applying the basic idea of ALTO PIDs to the preceding, abstract mapping specification, by aggregating endhosts with the same capabilities in the same PID, we obtain CDNi FCI using ALTO Network Maps as simply (1) a Network Map which defines a set of PIDs, and (2) a PID Property Map [draft-roome-alto-pid-properties] that defines the properties of each PID, where the properties define the capabilities.

With the preceding Network Map and PID Property Map, the upstream CDN provider can easily match a given end user request with the footprint and capabilities of the downstream CDN providers. Whenever the footprint and/or capabilities of a dCDN change, the ALTO server of the dCDN changes its data, and the uCDN can obtain the update through ALTO incremental updates. Future extensions to ALTO to add notifications can be integrated when they become available.

In particular, this document does not define how a dCDN aggregates the endhosts into PIDs, to allow flexibility in (anticipated) updates.

In this document, we define the following PID properties, which each must be a JSON array, to convey all mandatory capabilities (see Section 3.2):

- delivery-protocol
- acquisition-protocol
- redirection-mode
- loggin-mechanism
- meta-capabilities

To complement the preceding capabilities mapping, we require that an uCDN has access to ALTO Network Map(s) that can map from an endhost to Country Code and AS Number. Such mapping may or may not be specific to CDNI but can be a general mapping. Specifically, the uCDN should have access to ALTO Network Map(s) with Properties include:

- country-code
- asn

4.2. Conveying additional information with ALTO Cost Maps

An ALTO cost map contains costs between defined groupings of a corresponding network map (i.e. costs between PIDs): "An ALTO Cost Map defines Path Costs pairwise amongst sets of source and destination Network Locations" [I-D.ietf-alto-protocol]. This concept enables the provider of a cost map to express (and quantify) preferences of a destination network location with respect to a given source network location.

In the context of CDNI, the ALTO cost map concept is an extensive tool to convey additional information about the footprint or capabilties of a downstream CDN. The cost map concept provides a means for a downstream CDN provider to convey numeric values associated with a PID, e.g. in order to convey metrics associated with a footprint or a capability. This may be useful for future, non-mandatory types of footprint or capabilties.

One way to use ALTO cost maps would have these maps of the type N-to-m, i.e. 'costs' are expressed for each of N end user source PIDs to m dCDN request router PIDs. Semantically, a source PID in a CDNI ALTO cost map is thus the end user location, whereas a destination PID is a (group of) request router(s) to which the uCDN redirects the end user request. Note that this perspective is driven by the CDNI request routing. An alternative way - seen from the perspective of content retrieval - would be to have a m-to-N cost map where the source is always the dCDN and the destination is the end user (with the semantic "if the source dCDN would deliver content to an end user in the destination PID, the costs would be the following). With explicit destination PIDs reflecting different entries to the same dCDN, the dCDN can convey shortcut or differentiaed quality of services.

4.3. Example of Selecting a Downstream CDN based on ALTO Maps

In the following, we will outline an example of dCDN selection by a uCDN based on ALTO maps provided by dCDNs. Consider the following example: An upstream CDN (uCDN) has agreed on CDN interconnection with several downstream CDNs (dCDN-a, dCDN-b, and dCDN-c). Each of these downstream CDNs runs an ALTO server to provide aforementioned ALTO information. Whenever the upstream CDN receives a request from an end user and has determined that this request is best served by an interconnected dCDN, the uCDN uses ALTO maps to make a redirection decision. For a given request, assume that only the ALTO network maps provided by dCDN-a and dCDN-c include the endhost. The uCDN first looks up the PIDs of the endhost in the two network maps from the two dCDNs, then search the PID properties to find out the capabilities of each dCDN for the endhost. If only one dCDN supports the required capabilities, then the uCDN chooses the dCDN. Otherwise, if Cost Maps are available to provide additional server

selection information (e.g., a Cost Map defining latency), the uCDN picks the dCDN with better cost performance.

4.4. Advantages of using ALTO

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

- 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 additonal 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.

- The semantics of an ALTO network 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.

- ALTO cost maps are suitable to express various types of numeric values and can hence be used by an upstream CDN to obtain metrics for capabilities associated with a given dCDN for a given foorprint. Further, an ALTO cost map could also convey relevant network topology information other than simply routing hops or reachability. This facilitiates advanced and more sophisticated selection of a downstream CDN based on various metrics by the upstream CDN and increases flexibility to cover different use cases and business models for CDN interconnection.

- Flexible granularity: The concept of the PID and ALTO network/cost maps allows for different degrees of granularity. This enables a dCDN to differentiate the delivery quality for serving an end user request on a fine granularity depending on the end user location (and not only express delivery quality e.g. on an AS-level). It remains at the discretion of each dCDN how fine-granular the ALTO network and cost maps are that it publishes.

- ALTO maps can be signed and hence provide inherent integrity protection (see Section 6)

5. Useful ALTO extensions for CDNI Request Routing

It is envisioned that yet-to-be-defined ALTO extensions will be standardized that make the ALTO protocol more suitable and useful for applications other than the originally considered P2P use case [I-D.marocco-alto-next]. Some of these extensions to the ALTO protocol would be useful for ALTO to be used as a protocol within CDNI request routing, and in particular within the "Footprint and Capabilities Advertisment" part of the CDNI request routing interface.

The following proposed extensions to ALTO would be beneficial to facilitate CDNI request routing with ALTO as outlined in Section 4:

- 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 request 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. A proposal for server-initiated ALTO updates can be found in [I-D.marocco-alto-ws]. A discussion of incremental ALTO updates can be found in [I-D.schwan-alto-incr-updates].

- Content Availability on Hosts: A dCDN might want to express CDN capabilties in terms of certain content types (e.g. codecs/ formats, or content from certain content providers). A new endpoint property for ALTO that would be able to express such "content availability" would enable a dCDN to make available such information to an upstream CDN. This would enable a uCDN to determine if a given dCDN actually has the capabilities for a given request with respect to the type of content requested.

- Resource Availability on Hosts or Links: The capabilities on links (e.g. maximum bandwidth) or caches (e.g. average load) might be useful information for an upstream CDN for optimized dowmstream 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.

6. 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 maps (see 8.2.2. of [I-D.ietf-alto-protocol]. ALTO thus provides a proper means for protecting the integrity of footprint advertisment information.

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

7. Summary and Outlook

This document presented conrete examples of how ALTO can be used within the downstream CDN selection of CDNI Request Routing. Further, the document provides arguments why ALTO is a meaningful protocol in this context. Essentially, ALTO network and cost maps are a means to provide detailed and various types of information to an upstream CDN, in order to facilitate well-considered downstream CDN selection.

The intention of this document is to find consensus in the CDNI WG that ALTO is a useful protocol for CDNI request routing, and that ALTO has many benefits for proper selection of a downstream CDN. The overall objective is to form agreement on how ALTO should be used within the CDNI request routing protocol. It is the intention to capture the outcome of such continuing discussions in future versions of this document.

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