CDNI Request Routing with ALTO
draft-seedorf-cdni-request-routing-alto-03

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 focusses on the Request
   Routing Interface of CDNI, and more specifically on how the solutions
   currently being defined in the Application Layer Traffic Optimization
   (ALTO) WG can improve CDNI request routing. The overall intention
   behind this document is to foster discussions (in the CDNI as well as
   in the ALTO WG) regarding if, how, and under what conditions ALTO can
   be useful to optimize CDNI request routing. As basis for this
   discussion, this document provides concrete examples of how ALTO can
   be integrated within CDNI request routing and in particular in the
   process of selecting a downstream CDN. The examples in this document
   are based on the use cases and examples currently being discussed in
   the CDNI WG.

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Table of Contents

[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 [I-D.ietf-cdni-problem-statement].

The CDNI problem statement envisions four interfaces to be standardized within the IETF for CDN interconnection [I-D.ietf-cdni-problem-statement]:

o CDNI Request Routing Interface

o CDNI Metadata Interface

o CDNI Logging Interface

o CDNI Control Interface

This document focusses solely on the CDNI Request Routing Interface. In particular, this document shows concrete examples of how ALTO [RFC5693] can be integrated in CDNI request routing. The goal of this document is to show in what cases ALTO can benefit CDNI request routing, giving concrete examples and explaining how ALTO improves CDNI request routing in each of these examples. The examples used in this document are based on the use cases and request routing proposals currently being discussed in the CDNI WG [I-D.ietf-cdni-use-cases] [I-D.peterson-CDNI-strawman] and in the ALTO WG [I-D.jenkins-alto-cdn-use-cases]. The overall rationale of this document is to foster discussions (in the CDNI as well as in the ALTO WG) regarding if, how, and under what conditions ALTO can be useful to optimize CDNI request routing. Most importantly, the document has the goal of finding consensus regarding which part of the CDNI request routing interface can use ALTO.

A previous version of this document [I-D.seedorf-alto-for-cdni] contained detailed examples of actual request routing and surrogate selection with ALTO. This version solely focuses on 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 [I-D.ietf-cdni-problem-statement] 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 and to allow the downstream CDN to control
what the upstream Request Routing function should return to the User
Agent in the redirection message". On a high level, the scope of the
CDNI Request Routing Interface therefore contains two main tasks:

o A) Determining if the downstream CDN is willing to accept a
   delegated content request

o 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:

o 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;

o 2) the synchronous operation of actually redirecting a user
   request.

Accorduing to consensus found at the CDNI working group session at
IETF-82, we refer to 1) as "Request Routing Interface - Footprint and
Capabilities Advertisement" and 2) as "Request Routing Interface -
Redirection" in this document. A previous version of this document
[I-D.seedorf-alto-for-cdni] provided some concrete examples how ALTO
could be used for the actual "redirection" part of the request
routing interface. Based on feedback received from the CDNI working
group (mostly at the IETF-82 meeting), this document solely focuses
on the "Footprint and Capabilities Advertisement" part of the request
routing interface. In particular, the scope of the current version
of this document is to show how ALTO [RFC5693] can be used for
selecting a downstream CDN. Thus, the scope of the current document
is to provide examples and discuss how a downstream CDN can advertise
its footprint and other information by means of ALTO.

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 CDNI "footprint and capabilities
   advertisement":

   o 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).

   o 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.

   o Many CDNs can claim that they can serve any host on the Internet
      due to Internet connectivity. For example, even if an NSP CDN A
      does not have surrogate servers inside network C, A can
      legitimately claim that it can serve customers inside network C.
      Hence, what a downstream CDN should inform an upstream CDN is
      performance and capability, and not (only) reachability or
      coverage. Although one may turn performance into (binary)
      reachability by defining a threshold, the metric can be content-
      dependent (image, video, files) or artificial. The requirement of
      conveying performance and capability is consistent with the
      context: after all, the foundation of the CDN business is to
      improve user QoE.

   o 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.

o The term "footprint" has not been precisely defined by the CDNI
   working group yet [I-D.spp-cdni-rr-foot-cap-semantics]. In this
   document we assume that some notion of IP prefix-range is suitable
   to define a footprint of a downstream CDN. Thus, a dCDN footprint
   may be expressed as an IP-prefix range that a given dCDN claims it
   can cover. However, in principle any host can reach any other
   host on the Internet. Thus, simple "coverage" of IP-prefix ranges
   seems insufficient for a uCDN to make a choice of a dCDN (see
   [I-D.spp-cdni-rr-foot-cap-semantics] for a discussion of this
   issue). The uCDN needs additional information that is "tagged
   along" (either implicitly or explicitly) with such a coverage
   footprint. Such additonal information has the prupose of
   conveying to the uCDN more information about a footprint, so that
   the uCDN can judge/assess the delivery quality that is associated
   with a given dCDN footprint (or part of that footprint, in the
   likely case that the delivery quality is not the same for a whole
   dCDN footprint).

o 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.

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. A network map provided by each
of several candidate downstream CDNs can provide information to the
upstream CDN provider about each dCDN's "coverage" footprint, e.g.
regarding geopgraphical coverage, the (exact or rough) location of
"surrogates", the IP-prefix ranges the dCDN claims it can "cover"
with "good" delivery quality, or similar. Additional ALTO network
maps or cost maps can provide an upstream CDN provider additional
information about the footprint each individual dCDN offers, e.g. the
"cost" or quality associated with delivering certain content via the
downstream CDN which provided such a map. "Cost" in this context is
a generic term; many types of costs are possible and can be useful in
the context of CDNI request routing (see Section 4.3 for a detailed
discussion), e.g. average link load, expected delay, or monetary
costs.

4.1. Footprint Advertisement with ALTO Network Map

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).

The concept of an ALTO network map (and the PIDs contained therein)
is a natural and straightforward candidate for CDNI fooprint
advertisement: The downstream CDN provider groups the IP-addresses in
its footprint into PIDs and makes these groupings available to an
upstream CDN via an ALTO network map. With such a network map, the
upstream CDN provider can easily match a given end user request with
the footprint of the downstream CDN provider to see if a given
downstream CDN can in principle provide "coverage" for the IP-address
of the end user. Whenever the footprint changes, the downstream CDN
creates an updated network map and makes it available via its ALTO
server.

4.2. Resource Capabilities Advertisement with ALTO Network Maps

Out of many potentially useful capabilities, it seems mandatory to
support resource capabilities (see further the discussion in
[I-D.spp-cdni-rr-foot-cap-semantics]). For instance, the delivery
protocols supported by a downstream CDN are important to know for an

upstreamn CDN to make a selection decision. Further, certain
resource capabilities may only be supported in a partial footprint of
a given downstream CDN (e.g. a certain delivery protocol may only be
available at a subset of a given overall dCDN footprint). ALTO
network maps can convey such resource capabilities via PID names.
For instance, an additional network map provided by a dCDN can group
the dCDN's coverage footprint into several PIDs, where each PID name
has a certain "resource capability" semantic.

4.3. Using ALTO maps to convey Additional Information for Downstream CDN Selection

Additonal information (so that the uCDN can judge/assess the delivery
quality that is associated with a given dCDN footprint it received in
a network map from the dCDN) can be conveyed to a uCDN with
additional ALTO network maps or ALTO cost maps that the dCDN will
provide via its ALTO server. 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 facilitate selection of the "best" downstream CDN because it
enables the upstream CDN provider to assess a candidate downstream
CDN based on other factors besides simply network coverage (coverage
footprint). Most importantly, the cost map concept provides a means
for a downstream CDN provider to convey a multitude of dynamically
changing information which the upstream CDN provider cannot measure
itself (or only roughly estimate) otherwise.

For instance, the following types of "delivery cost" can be conveyed
by a downstream CDN provider via ALTO for each combination of source
PID and destination PID:

o Latency: the expected/average RTT

o Bandwidth: the maximum bandwidth (e.g. due too bottlenecks)

o Monetary Costs: The amount of actual monetary costs the downstream
   CDN provider would charge for the delivery of content to a given
   destination (see also [I-D.liu-cdni-cost])

Normally, an ALTO cost map defines "costs" pairwise among two PIDs
[I-D.ietf-alto-protocol]. In the current scope of the CDNI working
group, however, the destination of a request routing redirection will

always be the request router of the selected downstream CDN (as
direct redirection to dCDN surrogates is currently out of scope of
the CDNI work). The destination PID in an ALTO cost map offered by a
dCDN is thus always (i.e. in all entries) the same. Moreover, this
destination PID semantically refers to the whole dCDN (or to its
request router, as the decision where to route within the dCDN is
outside the scope of the CDNI request routing interface). Therefore,
a corresponding ALTO network map for footprint coverage offered by a
dCDN should always contain a special PID that covers the whole
footprint of the dCDN, i.e. the overall, whole prefix range the dCDN
claims it can cover (obviously, it can additonally contain smaller
prefix ranges in other PIDs, so that a cost map can have pairwise
costs entries of these smaller-scale source PIDs to the overall dCDN
coverage PID).

Note that such ALTO cost maps are always of the type N-to-1, i.e.
"costs" are expressed for each of N end user source PIDs to 1 single
dCDN request router PID. Semantically, the source PID in a CDNI ALTO
cost map is thus the end user location, whereas the destination is
the request router 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 1-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).

Alternatively to using cost maps for expressing delivery quality for
a given coverage footprint, ALTO networks map could be used. In this
case, an additional network map provided by the dCDN groups the
dCDN's coverage footprint into several PIDs, where each PID name has
a certain "quality" semantic. In other words, all IP-prefixes in a
certain PID have the same "quality", and the meaning of this quality
is expressed by the PID name.

4.4. 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 each dCDN. In the example, an
ALTO network map "NM_cov" is used to express the overall "coverage"
footprint of each dCDN. In addition (as outlined in Section 4.3),
each dCDN provides one or more ALTO cost maps "CM_1", "CM_2", ...,
"CM_n" to express the delivery "costs"/quality associated with each
PID in the corresponding "NM_cov" coverage footprint network map.

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 information about what locations it can deliver content to
(coverage footprint) by means of a network map "NM_cov" and at which
"cost" (additional delivery quality information) by means of one or
more cost maps "CM_1", "CM_2", ..., "CM_n". uCDN has downloaded from
each candidate downstream CDN "NM_cov" and one or more ALTO cost maps
(e.g. by using the "Filtered Cost Map" option and different "cost-
types" as specified in 7.7.3.2. of [I-D.ietf-alto-protocol]). The
ALTO network map provides "coverage" (footprint) for each downstream
CDN as aggregated network locations in the form of ALTO PIDs. The
cost maps provide the upstream CDN information regarding the delivery
quality the selection of each individual downstream CDN would imply
depending on the given location of an end user request.

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, "NM_cov(dCDN-a)" and "NM_cov(dCDN-c)", indicate
that these downstream CDNs can deliver content to the location of the
request. In this case, the ALTO costs maps received from dCDN-a and
dCDN-c provide useful additional information to the upstream CDN in
order to make a selection decision regarding either dCDN-a or dCDN-c.
For instance, if both downstream CDNs have provided two ALTO cost
maps "CM_monetary" and "CM_latency" - one regarding monetary costs
and one regarding expected latency for delivery - uCDN can make a
downstream CDN selection based on its preferences: If one downstream
CDN can deliver cheaper, but the other faster, ALTO cost maps provide
such information in detail to the upstream CDN. This enables the
upstream CDN to make a well-considered downstream CDN selection. In
particular, the uCDN decision may take into account different
delivery quality indicators or other factors (which can be weighted
by the upstream CDN to make a decision).

4.5. Advantages of using ALTO

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

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 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.

o 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.

o ALTO cost maps are suitable to express various types of delivery
   "cost" and can hence be used by an upstream to judge the delivery
   quality associated with a given dCDN for a given end user request.
   Further, an ALTO cost map can 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.

o 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.

o 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:

   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 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].

   o 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.

   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 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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