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Content Distribution Network Interconnection (CDNI) Problem Statement
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Abstract

Content Delivery Networks (CDNs) provide numerous benefits: reduced delivery cost for cacheable content, improved quality of experience for end users and increased robustness of delivery. For these reasons they are frequently used for large-scale content delivery. As a result, existing CDN providers are scaling up their infrastructure and many Network Service Providers (NSPs) are deploying their own CDNs. It is generally desirable that a given content item can be delivered to an end user regardless of that user's location or attachment network. This creates a requirement for interconnecting standalone CDNs so they can interoperate as an open content delivery infrastructure for the end-to-end delivery of content from Content Service Providers (CSPs) to end users. However, no standards or open specifications currently exist to facilitate such CDN interconnection.

The goal of this document is to outline the problem area for the IETF with a view towards creating a working group. This working group would work on interoperable and scalable solutions for CDN interconnection.

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

Status of this Memo

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1. Introduction

The volume of video and multimedia content delivered over the Internet is rapidly increasing and expected to continue doing so in the future. In the face of this growth, Content Delivery Networks (CDNs) provide numerous benefits: reduced delivery cost for cacheable content, improved quality of experience for end users and increased robustness of delivery. For these reasons CDNs are frequently used for large-scale content delivery. As a result, existing CDN providers are scaling up their infrastructure and many Network Service Providers (NSPs) are deploying their own CDNs. It is generally desirable that a given content item can be delivered to an end user regardless of that user's location or attachment network. This creates a requirement for interconnecting standalone CDNs so they can interoperate as an open content delivery infrastructure for the end-to-end delivery of content from Content Service Providers (CSPs) to end users. However, no standards or open specifications currently exist to facilitate such CDN interconnection.

The goal of this document is to outline the problem area for the IETF with a view towards creating a working group. This working group would work on interoperable and scalable solutions for CDN interconnection.

1.1. Terminology

This document uses the following terms:

Content: Any form of digital data. One important form of Content

with additional constraints on Distribution and Delivery is continuous media (i.e. where there is a timing relationship between source and sink).

Metadata: Metadata in general is data about data.

Content Metata: this is metadata about content. It may vary in depth from merely identifying the content (e.g. title or other information to populate a program guide), to providing a complete index of different scenes in a movie or providing business rules detailing how the content may be displayed, copied, or sold and it can include policies to control the distribution and delivery of the content.

Content Distribution Metadata: Content Distribution Metadata is the subset of the Metadata pertaining to rules that control how the content is to be distributed and delivered by CDNs.

User: The 'real' user of the system, typically a human but maybe some combination of hardware and/or software emulating a human (e.g. for

automated quality monitoring etc.)

Network Service Provider (NSP): Provides network-based connectivity/ services to Users.

Content Service Provider (CSP): Provides a Content Service to Users. A CSP may own the content made available as part of the Content Service, or may license content rights from another party.

Content Service: The service offered by a Content Service Provider. The Content Service encompasses the complete service which may be wider than just the delivery of items of Content, e.g. the Content Service also includes any middleware, key distribution, program guide, etc. which may not require any direct interaction with the CDN.

Content Distribution Network (CDN) / Content Delivery Network (CDN): A type of network in which the content network elements are arranged for more effective delivery of content to User Agents. Typically a CDN consists of a Request Routing system, a Distribution System and a set of Surrogates.

CDN Provider: The service provider who operates a CDN.

CDN Interconnect (CDNI): The set of interfaces over which two or more CDNs communicate with each other in order to achieve the delivery of content to users by surrogates in one CDN (the downstream CDN) on behalf of another CDN (the upstream CDN).

Over-the-top (OTT): A service, e.g. a CDN, operated over the Internet rather than by a particular NSP.

Surrogate: A device/function that interacts with other elements of the CDN for the control and distribution of Content within the CDN and interacts with User Agents for the delivery of the Content.

Request Routing System: The function within a CDN responsible for steering or directing a content request received directly from an end user to a suitable Surrogate.

Distribution System: the function within a CDN responsible for distributing Content Distribution Metadata as well as content inside the CDN (e.g. down to the surrogates)

Delivery: the function within CDN surrogates responsible for delivering a piece of content to the end user. For example, delivery may be based on HTTP progressive download or HTTP adaptive streaming.

Logging System: the function within a CDN responsible for collecting measurement and recording of distribution and delivery activities. The information recorded by the logging system may be used for various purposes including charging (e.g. of the CSP), analytics and monitoring.

1.2. CDN Background

Readers are assumed to be familiar with the architecture, features and operation of CDNs. For readers less familiar with the operation of CDNs, the following resources may be useful:

- RFC 3040 [RFC3040] describes many of the component technologies that are used in the construction of a CDN
- Taxonomy [TAXONOMY] compares the architecture of a number of CDNs

- o RFC 3466 [RFC3466] and RFC 3570 [RFC3570] are the output of the IETF Content Delivery Internetworking (CDI) working group which was closed in 2003.

Note: Some of the terms used in this document are similar to terms used the above referenced documents. When reading this document terms should be interpreted as having the definitions provided in Section 1.1.

2. CDN Interconnect Use Cases

An increasing number of NSPs are deploying CDNs in order to deal cost-effectively with the growing usage of on-demand video services and other content delivery applications.

CDNs allow caching of content closer to the edge so that a given item of content can be delivered by a CDN surrogate (i.e. a cache) to multiple end users without transiting multiple times through the network core (i.e from the content origin to the cache). This contributes to bandwidth cost reductions for the NSP. CDNs also enable replication of popular content across many surrogates, which enables content to be served to large numbers of users concurrently. This also helps dealing with situations such as flash crowds and denial of service attacks.

The CDNs deployed by NSPs are not just restricted to the delivery of content to support the Network Service Provider's own 'walled garden' services, such as delivery of IPTV services to Set Top Boxes, but are also used for delivery of content to other devices including PCs, tablets, mobile phones etc.

Traditional CDNs have operated as over-the-top providers of digital

content distribution services, operating as an overlay on the Internet. More recently, Network Service Providers have begun to operate their own CDNs by deploying CDN devices within their network infrastructure.

Some service providers operate over multiple geographies and federate multiple affiliate NSPs. These NSPs typically operate independent CDNs. As they evolve their services (e.g. for seamless support of

content services to nomadic users across affiliate NSPs) there is a need for interconnection of these CDNs. However there are no open specifications, nor common best practices, defining how to achieve such CDN interconnection.

CSPs have a desire to be able to get (some of their) content to very large number of users and/or over many/all geographies and/or with a high quality of experience, all without having to maintain direct business relationships with many different CDN providers. Some NSPs are considering interconnecting their respective CDNs (as well as possibly over-the-top CDNs) so that this collective infrastructure can address the requirements of CSPs in a cost effective manner. In particular, this would enable the CSPs to benefit from on-net delivery (i.e. within the Network Service Provider's own network/CDN footprint) whenever possible and off-net delivery otherwise without requiring the CSPs having to maintain direct business relationships with all the CDNs involved in the delivery. Again, for this requirement, CDN operators (NSPs or over-the-top) are faced with a lack of open specifications and best practices.

Finally, NSPs have often deployed CDNs as specialized cost-reduction projects within the context of a particular service or environment, some NSPs operate separate CDNs for separate services. For example, there may be a CDN for managed IPTV service delivery, a CDN for web-TV delivery and a CDN for video delivery to Mobile terminals. As NSPs integrate their service portfolio, there is a need for interconnecting these CDNs. Again, NSPs face the problem of lack of open interfaces for CDN interconnection.

3. Gap Analysis of relevant Standardization Activities

3.1. IETF Concluded CDI Working Group

The Content Distribution Internetworking (CDI) Working Group was formed in the IETF following a BoF in December 2000 and closed in mid 2003.

For convenience, here is an extract from the CDI WG charter [CDI-Charter]:

"

- The goal of this working group is to define protocols to allow the interoperation of separately-administered content networks.
- A content network is an architecture of network elements, arranged for efficient delivery of digital content. Such content includes, but is not limited to, web pages and images delivered via HTTP, and streaming or continuous media which are controlled by RTSP.
- The working group will first define requirements for three modes of content internetworking: interoperation of request-routing systems, interoperation of distribution systems, and interoperation of accounting systems. These requirements are intended to lead to a follow-on effort to define protocols for interoperation of these systems.
- In its initial form, the working group is not chartered to deliver those protocols [...]

"

Thus, the CDI WG touched on the same problem space as the present document.

The CDI WG published 3 Informational RFCs:

- RFC 3466 [RFC3466] - "A Model for Content Internetworking (CDI)".
- RFC 3568 [RFC3568] - "Known Content Network (CN) Request-Routing Mechanisms".
- RFC 3570 [RFC3570] - "Content Internetworking (CDI) Scenarios".

Although the market, design and requirements placed on CDNs has changed since 2003, the RFCs above provide a reasonable starting point and framework for discussing CDN Interconnect.

However, in accordance with its initial charter, the CDI WG did not define any protocols or interfaces to actually enable CDN Interconnection and at that time (2003) there was not enough industry interest and real life requirements to justify rechartering the WG to conduct the corresponding protocol work.

3.2. IRTF P2P Research Group

Some information on CDN interconnection motivations and technical issues were presented in the P2P RG at IETF 77. The presentation can be found in [P2PRG-CDNI].

3.3. ETSI

ETSI is the European Telecommunications Standards Institute. ETSI produces standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and internet technologies.

3.3.1. TISPAN

TISPAN (Telecommunications and Internet converged Services and Protocols for Advanced Networking) is an ETSI technical committee creating Next Generation Networks (NGN) specifications.

TISPAN has published two IPTV specifications, one of which is based on IMS. An extension of these specifications is being designed with a CDN architecture supporting VoD for delivery to TISPAN devices (UEs) or regular PCs. The use cases allow for hierarchically and geographically distributed CDN scenarios, along with multi-CDN cooperation. As a result, the architecture contains reference points to support interconnection of other TISPAN CDNs. There is no intent to support heterogeneous interconnection at this point. Also, this effort is focusing on managed IPTV services.

The protocols phase has not yet started, and thus no protocols have yet been defined.

3.3.2. MCD

MCD (Media Content Distribution) is the ETSI technical committee "in charge of guiding and coordinating standardization work aiming at the successful overall development of multimedia systems (television and communication) responding to the present and future market requests on media content distribution".

MCD created a specific work item on interconnection of heterogeneous CDNs ("CDN Interconnection, use cases and requirements") in March 2010. However, no protocol level work has yet started in MCD for CDN Interconnect.

3.4. ATIS IIF

ATIS ([ATIS]) is the Alliance for Telecommunications Industry Solutions.

IIF is the IPTV Interoperability Forum (within ATIS) that develops requirements, standards, and specifications for IPTV.

The IIF is developing the "IPTV Content on Demand (CoD) Service"

specification. This includes use of a CDN (referred to in ATIS IIF CoD as the "Content Distribution and Delivery Functions") for support of a Content on Demand (CoD) Service as part of a broader IPTV service. However, this only covers the case of a managed IPTV service (in particular where the CDN is administered by the IPTV service provider) and does not cover the use, or interconnection, of multiple CDNs.

The "IPTV Content on Demand (CoD) Service" specification defines a reference point (C2) and the corresponding HTTP-based data plane protocol for content acquisition between an authoritative origin server and the CDN. While this protocol has not been explicitly specified for content acquisition across CDNs, it could be a candidate (in addition to others such as standard HTTP) for content acquisition between CDNs in a CDN Interconnect environment.

3.5. Open IPTV Forum (OIPF)

"The Open IPTV Forum has developed an end-to-end solution to allow any consumer end-device, compliant to the Open IPTV Forum specifications, to access enriched and personalised IPTV services either in a managed or a non-managed network. To that end, the Open IPTV Forum focuses on standardising the user-to-network interface (UNI) both for a managed and a non-managed network" [OIPF-Overview].

OIPF has defined specifications for Content Metadata, however they specify a definition for IPTV service related metadata and do not include a metadata definition or interface that could be used between CDNs.

3.6. ITU-T

Text to be added in a future version of this document.

3.7. OCEAN

OCEAN (http://www.ict-ocean.eu/) is an EU funded research project that started in February 2010. Some of its objectives are relevant to CDNI, for example "design a new content delivery framework" and

"foster multi-vendor solutions", however others are much more implementation orientated, e.g. "self-learning caching algorithms" and "media-aware congestion control mechanisms".

OCEAN has not yet defined any protocols for CDN Interconnection.

3.8. CableLabs VoD Metadata

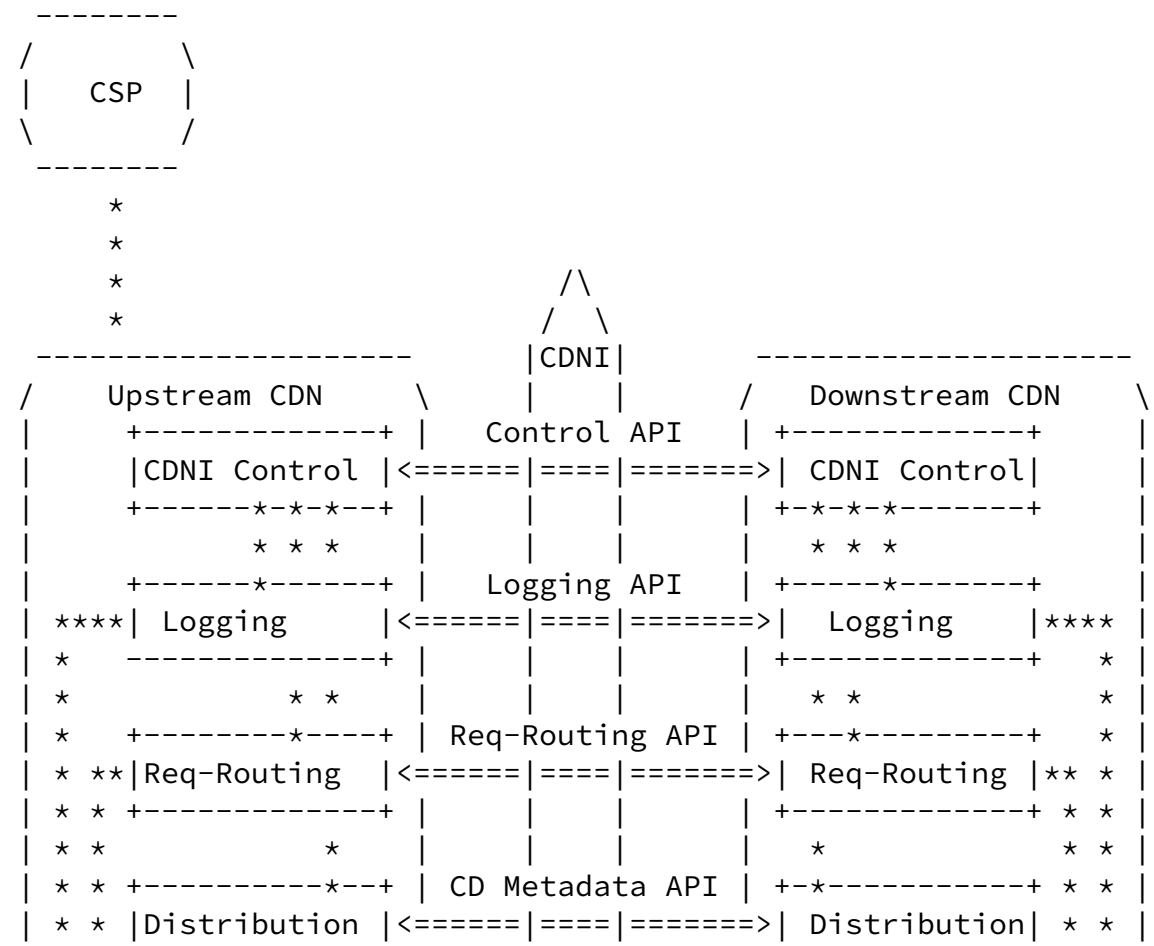
"Founded in 1988 by cable operating companies, Cable Television Laboratories, Inc. (CableLabs) is a non-profit research and development consortium that is dedicated to pursuing new cable telecommunications technologies and to helping its cable operator members integrate those technical advancements into their business objectives." [CableLabs]

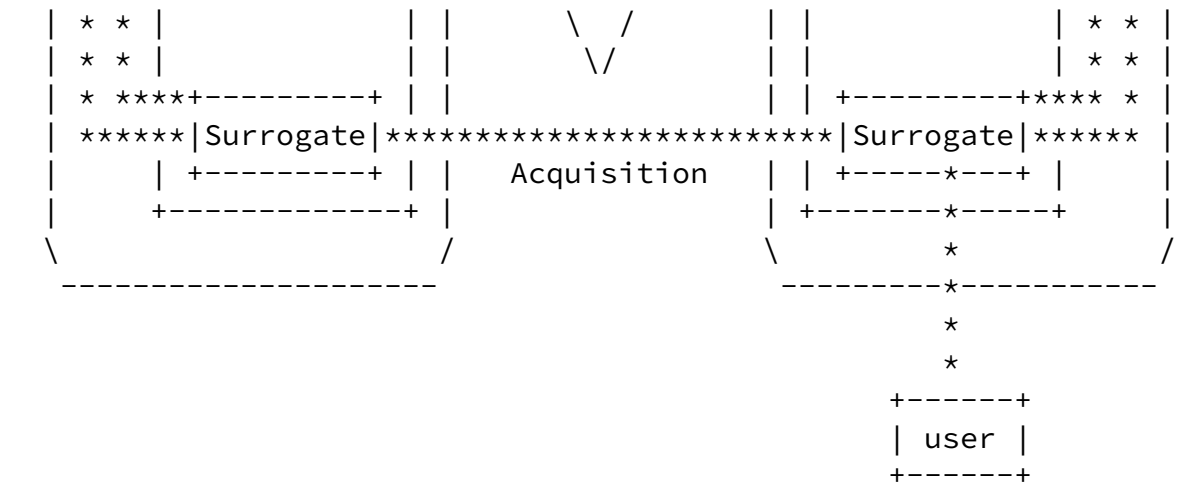
Cable Labs has defined specifications for CoD Content Metadata as part of its VOD Metadata project. "The VOD Metadata project is a cable television industry and cross-industry-wide effort to specify the metadata and interfaces for distribution of video-on-demand (VOD) material from multiple content providers to cable operators." [CableLabs-Metadata]

However, while the CableLabs work specifies an interface between a content provider and a service provider running a CDN, it does not include an interface that could be used between CDNs.

4. CDN Interconnect Problem Area for IETF

Interconnecting CDNs involves many different functions and components being integrated to some degree. Only some of those require standardization. Out of those, only some fit within the expertise and charter of the IETF. The problem area proposed for IETF work is illustrated in Figure 1. The candidate goals (and respectively the non-goals) for IETF work on CDN Interconnection are discussed in Section 4.1 (and respectively Section 4.2).


CSP
Upstream CDN
Downstream CDN
CDNI
Control API
CDNI Control
CDNI Control
Logging API
Logging
Logging
Req-Routing API
Req-Routing
Req-Routing
CD Metadata API
Distribution
Distribution



<==> interfaces inside the scope of CDNI

**** interfaces outside the scope of CDNI

Figure 1: CDNI Problem Area

4.1. Candidate CDNI Goals for IETF

Listed below are parts of the problem space that are proposed to be addressed by a potential CDNI working group in the IETF:

- Specification of a control plane architecture for CDN Interconnect.
- Specification of the APIs and protocols required to Interconnect a pair of CDNs (where a given CDN may support multiple interconnects with different CDNs). This is expected to comprise (but possibly grouped in a different manner):
  - CDNI Control API: This API allows the "CDNI Control" system in interconnected CDNs to communicate. This API may support the following:
    - allows an upstream CDN and downstream CDN to establish, update or terminate their CDNI relationship
    - allows bootstrapping of the other CDNI APIs (e.g. API address discovery and establishment of security associations)

    + allows configuration of the other CDNI APIs (e.g. Upstream CDN specifies information to be reported through the Logging API)
    + allows the downstream CDN to communicate information about its delivery capabilities, resources and policies
    + allows bootstrapping of the interface between CDNs for content acquisition (even if that interface itself is outside the scope of the CDNI work)
  * Request-Routing API: This API allows the Request-Routing system in interconnected CDNs to communicate to ensure that an end-user request can be (re)directed from an upstream CDN to a surrogate in the downstream CDN, in particular where selection responsibilities may be split across CDNs (for example the upstream CDN may be responsible for selecting the downstream CDN while the downstream CDN may be responsible for selecting the actual surrogate within that CDN).
  * Content Distribution Metadata Signaling API: This API allows the Distribution system in interconnected CDNs to communicate to ensure content distribution metadata can be exchanged across CDNs. For example, the distribution metadata information may include information about desired distribution policy (e.g. prepositioning vs dynamic acquisition) and about content access policy (e.g. allowed/blocked time/geography, authorization checks to be performed at delivery time). It may also contain information about where/how to acquire the content. This may also include content management (e.g. deletion of Content from caches) across interconnected CDNs. It is expected that the specification of this API will comprise (i) specification of a schema for Content Distribution Metadata as well as (ii) specification/selection of a signaling protocol (quite possibly

an existing IETF protocol) to signal the actual Content Distribution Metadata encoded as per the schema.
  * Logging API: This API allows the Logging system in interconnected CDNs to communicate the relevant activity logs in order to allow log consuming applications to operate in a multi-CDN environments. For example, an upstream CDN may collect delivery logs from a downstream CDN in order to perform consolidated charging of the CSP. Similarly, an upstream CDN may collect delivery logs from a downstream CDN in order to provide consolidated reporting and monitoring to the CSP.
- Scalability of the CDNI protocols & approach.

4.2. Non-Goals for IETF

Listed below are aspects of content delivery that the authors propose be kept outside of the scope of a potential CDNI working group:

- The interface between Content Service Provider and the Authoritative CDN (i.e. the upstream CDN contracted by the CSP for delivery by this CDN or by its downstream CDNs).
- The delivery interface between the delivering CDN surrogate and the enduser, such as streaming protocols.
- The content acquisition interface between CDNs (i.e. the dataplane interface for actual delivery of a piece of content from one CDN to the other). This is expected to use existing protocols such as HTTP or protocols defined in other forums for content acquisition between an origin server and a CDN (e.g. HTTP-based C2 reference point of ATIS IIF CoD).
- User Authentication. User authentication and authorization are the responsibility of the Content Service Provider.
- Content preparation, including encoding and transcoding. The CDNI architecture aims at allowing distribution across interconnected CDNs of content treated as opaque objects. Interpretation and processing of the objects, as well as optimised delivery of these objects by the surrogate to the enduser are outside the scope of CDNI.
- Digital Right Management (DRM). DRM is an end-to-end issue between Origin and User-Agent.
- applications consuming CDNI logs (e.g. charging, analytics, reporting,...)
- Internal CDN Protocols. i.e. protocols within one CDN.
- Scalability of individual CDNs. While scalability of the CDNI protocols/approach is in scope, how an individual CDN scales is out of scope.
- actual criteria and algorithms for selection of CDN or Surrogate by Request-Routing systems.
- Surrogate algorithms - e.g. how to acquire content or cache replacement algorithms. Content management (e.g. Content Deletion) is in scope but the internal algorithms used by a cache

to determine when to no longer cache an item of Content (in the absence of any specific metadata to the contrary) is out of scope.

- Element management interfaces
- commercial, business and legal aspects related to the

interconnections of CDNs.

5. Relationship to relevant IETF Working Group

5.1. ALTO

As stated in the ALTO Working Group charter [ALTO-Charter]:

"The Working Group will design and specify an Application-Layer Traffic Optimization (ALTO) service that will provide applications with information to perform better-than-random initial peer selection. ALTO services may take different approaches at balancing factors such as maximum bandwidth, minimum cross-domain traffic, lowest cost to the user, etc. The WG will consider the needs of BitTorrent, tracker-less P2P, and other applications, such as content delivery networks (CDN) and mirror selection."

In particular, the ALTO service could be used by a CDN Request Routing system to improve its selection of a CDN surrogate to serve a particular user request. See [I-D.penno-alto-cdn] for a detailed discussion on how CDN Request Routing can be used as an integration point of ALTO into CDNs. It is possible that the ALTO service could be used in the same manner in a multi-CDN environment based on CDN Interconnect. For example, an upstream CDN may take advantage of the ALTO service in its decision for selecting a downstream CDN to which a user request should be delegated.

However, the work of ALTO is complementary to and does not overlap with the work proposed in this document because the integration between ALTO and a CDN would fall under "algorithms for selection of CDN or Surrogate by Request-Routing systems" in Section 4.2

6. IANA Considerations

This document makes no request of IANA.

Note to RFC Editor: this section may be removed on publication as an RFC.

7. Security Considerations

This document describes a problem faced by CDN Providers and does not itself introduce any new security considerations.

However, maintaining the security of the content itself, its associated metadata (including distribution and delivery policies) and the CDNs distributing and delivering it are critical requirements for both CDN Providers and their customers and any work on CDN Interconnection must provide sufficient mechanisms to maintain the security of the overall system of interconnected CDNs as well as the information (content, metadata, logs, etc) distributed and delivered through any CDN Interconnects.

8. Acknowledgements

The authors would like to thank David Ferguson, Julien Maisonneuve, Mahesh Viveganandhan and Bruce Davie for their early review comments and contributions to the text.

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