Network Working Group B. Niven-Jenkins
Internet-Draft Velocix (Alcatel-Lucent)
Intended status: Informational F. Le Faucheur
Expires: May 3, 2012 Cisco
N. Bitar
Verizon
October 31, 2011

Content Distribution Network Interconnection (CDNI) Problem Statement
draft-ietf-cdni-problem-statement-01

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 End 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 of CDN interconnection (CDNI) for the IETF.

Table of Contents

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 End User's location or attachment network. However, the footprint of a given CDN in charge of delivering a given content may not expand close enough to the End User's current location or attachment network to realize the cost benefit and user experience that a more distributed CDN would provide. This creates a requirement for interconnecting standalone CDNs so that their collective CDN footprint can be leveraged for the end-to-end delivery of content from Content Service Providers (CSPs) to End Users. For example, a CSP could contract with an "authoritative" CDN for the delivery of content and that authoritative CDN could contract with one or more downstream CDN(s) to distribute and deliver some or all of the content on behalf of the authoritative CDN. The formation and details of any business relationships between a CSP and a CDN and between one CDN and another CDN are out of scope of this document. However, no standards or open specifications currently exist to facilitate such CDN interconnection.

The goal of this document is to outline the problem area of CDN interconnection (CDNI) for the IETF. Section 2 discusses the use cases for CDN interconnection. Section 3 presents the CDNI model and problem area being considered by the IETF. Section 4 describes each CDNI interface individually and highlights example candidate protocols that could considered for reuse or leveraging to implement the CDNI interfaces. Section 5 provides a gap analysis against the work of other standards organizations. Section 6 describes the relationships between the CDNI problem space and other relevant IETF Working Groups.

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 Metadata: This is metadata about Content. Content Metadata comprises:

1. Metadata that is relevant to the distribution of the content (and therefore relevant to a CDN involved in the delivery of that content). We refer to this type of metadata as "Content Distribution Metadata". See also the definition of Content Distribution Metadata.
2. Metadata that is associated with the actual Content (and not directly relevant to the distribution of that Content) or content representation. For example, such metadata may include information pertaining to the Content's genre, cast, rating, etc as well as information pertaining to the Content representation's resolution, aspect ratio, etc.

Content Distribution Metadata: The subset of Content Metadata that is relevant to the distribution of the content. This is the metadata required by a CDN in order to enable and control content distribution and delivery by the CDN. In a CDN Interconnection environment, some of the Content Distribution Metadata may have an intra-CDN scope (and therefore need not be communicated between CDNs), while some of the Content Distribution Metadata have an inter-CDN scope (and therefore needs to be communicated between CDNs).

CDNI Metadata: Content Distribution Metadata with inter-CDN scope. For example, CDNI Metadata may include geo-blocking information (i.e. information defining geographical areas where the content is to be made available or blocked), availability windows (i.e. information defining time windows during which the content is to be made available or blocked) and access control mechanisms to be enforced (e.g. URI signature validation). CDNI Metadata may also include information about desired distribution policy (e.g. prepositioned vs dynamic acquisition) and about where/how a CDN can acquire the content. CDNI Metadata may also include content management information (e.g. request for deletion of Content from Surrogates) across interconnected CDNs.

Dynamic content acquisition: Dynamic content acquisition is where a CDN acquires content from the content source in response to an End User requesting that content from the CDN. In the context of CDN Interconnection, dynamic acquisition means that a downstream CDN does not acquire the content from content sources (including upstream CDNs) until a request for that content has been delegated to the

downstream CDN by an Upstream CDN.

Dynamic CDNI metadata acquisition: In the context of CDN Interconnection, dynamic CDNI metadata acquisition means that a downstream CDN does not acquire CDNI metadata for content from the upstream CDN until a request for that content has been delegated to the downstream CDN by an Upstream CDN.

Pre-positioned content acquisition: Content Pre-positioning is where a CDN acquires content from the content source prior to or independent of any End User requesting that content from the CDN. In the context of CDN interconnection the Upstream CDN instructs the Downstream CDN to acquire the content from content sources (including upstream CDNs) in advance of or independent of any End User requesting it.

Pre-positioned CDNI Metadata acquisition: In the context of CDN Interconnection, CDNI Metadata pre-positioning is where the Downstream CDN acquires CDNI metadata for content prior to or independent of any End User requesting that content from the Downstream CDN.

End User (EU): 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.)

User Agent (UA): Software (or a combination of hardware and software) through which the End User interacts with a Content Service. The User Agent will communicate with a Content Service for the selection of content and one or more CDNs for the delivery of the Content. Such communication is not restricted to HTTP and may be via a variety of protocols. Examples of User Agents (non-exhaustive) are: Browsers, Set Top Boxes (STBs), dedicated content applications (e.g. media players), etc.

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

Content Service Provider (CSP): Provides a Content Service to End Users (which they access via a User Agent). 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): Network infrastructure in which the network elements cooperate at layers 4 through layer 7 for more effective delivery of Content to User Agents. Typically a CDN consists of a Request Routing system, a Distribution System (that includes a set of Surrogates), a Logging System and a CDN control system.

CDN Provider: The service provider who operates a CDN. Note that a given entity may operate in more than one role. For example, a company may simultaneously operate as a Content Service Provider, a Network Service Provider and a CDN Provider.

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

Authoritative CDN: A CDN which has a direct relationship with a CSP for the distribution & delivery of that CSP's content.

Upstream CDN: For a given End User request, the CDN (within a pair of directly interconnected CDNs) that redirects the request to the other CDN.

Downstream CDN: For a given End User request, the CDN (within a pair of directly interconnected CDNs) to which the request is redirected by the other CDN (the Upstream CDN). Note that in the case of successive redirections (e.g. CDN1-->CDN2-->CDN3) a given CDN (e.g. CDN2) may act as the Downstream CDN for a redirection (e.g. CDN1-->CDN2) and as the Upstream CDN for the subsequent redirection of the same request (e.g. CDN2-->CDN3).

Over-the-top (OTT): A service, e.g. a CDN, operated by a different operator than the NSP to which the users of that service are attached.

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 receiving a content request from a User Agent, obtaining and maintaining necessary information about a set of candidate surrogates or candidate CDNs, and for selecting and redirecting the user to the appropriate surrogate or CDN. To enable CDN Interconnection, the Request Routing System must also be capable of handling User Agent

content requests passed to it by another CDN.

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

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

Logging System: The function within a CDN responsible for collecting the 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:

- o RFC 3040 [RFC3040] describes many of the component technologies that are used in the construction of a CDN.
- o 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 of a network so that a given item of content can be delivered by a CDN Surrogate (i.e. a cache) to multiple User Agents (and their End Users) without transiting multiple times through the network core (i.e from the content origin to the surrogate). This contributes to bandwidth cost reductions for the NSP and to improved quality of experience for the

End Users. CDNs also enable replication of popular content across many surrogates, which enables content to be served to large numbers of User Agents 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 IP delivery of television services to Set Top Boxes, but are also used for delivery of content to other devices including PCs, tablets, mobile phones etc.

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 End 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 (or having to extend their own CDN to a large number of locations). 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 to maintain direct business relationships with all the CDNs involved in the delivery. Again, for this requirement, CDN providers (NSPs or over-the-top CDN operators) are faced with a lack of open specifications and best practices.

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.

For operational reasons (e.g. disaster, flash crowd) or commercial reasons, an over-the-top CDN may elect to make use of another CDN (e.g. an NSP CDN with on-net Surrogates for a given footprint) for serving a subset of the user requests (e.g. requests from users

attached to that NSP). Again, for this requirement, CDN providers (over-the-top CDN providers or NSPs) are faced with a lack of open specifications and best practices.

Use cases for CDN Interconnection are further discussed in [I-D.ietf-cdni-use-cases].

3. CDN Interconnect Model & Problem Area for IETF

Interconnecting CDNs involves interactions among multiple different functions and components that form each CDN. Only some of those require standardization. This section discusses the problem area for the IETF work on CDN Interconnection. The CDNI model and problem area defined for IETF work is illustrated in Figure 1.

```
     --------
    /        \
    |   CSP  |
    \        /
     --------
         *
         *
         *                         /\
         *                        /  \
     ----------------------      |CDNI|        ----------------------
    /     Upstream CDN     \     |    |       /    Downstream CDN    \
    |      +-------------+ | Control Interface| +-------------+      |
    |*******   Control   |<======|====|========>|   Control   *******|
    |*     +------*----*-+ |     |    |       | +-*----*------+     *|
    |*            *    *   |     |    |       |   *    *            *|
    |*     +------*------+ | Logging Interface| +------*------+     *|
    |* *****   Logging   |<======|====|========>|   Logging   ***** *|
    |* *   +-*-----------+ |     |    |       | +-----------*-+   * *|
    |* *     *         *   | Request Routing  |   *         *     * *|
  .....*...+-*---------*-+ |    Interface     | +-*---------*-+...*.*...
  . |* * *** Req-Routing |<======|====|========>| Req-Routing *** * *| .
  . |* * * +-------------+.|     |    |       | +-------------+ * * *| .
  . |* * *                 .  CDNI Metadata   |                 * * *| .
  . |* * * +-------------+ |.   Interface     | +-------------+ * * *| .
  . |* * * | Distribution|<==.===|====|========>| Distribution| * * *| .
  . |* * * |             | |  .   \  /        | |             | * * *| .
  . |* * * |+---------+  | |   .   \/         | |  +---------+| * * *| .
  . |* * ***| +---------+| |    ....Request......+---------+ |*** * *| .
  . |* *****+-|Surrogate|************************|Surrogate|-+***** *| .
  . |*******  +---------+| |   Acquisition    | |+----------+ *******| .
  . |      +-------------+ |                  | +-------*-----+      | .
  . \                     /                  \         *            / .
  .  ----------------------                    ---------*------------  .
  .                                                     *              .
  .                                                     * Delivery     .
  .                                                     *              .
  .                                                 +--*---+          .
  ..............Request.............................| User |..Request..
                                                    | Agent|
                                                    +------+

  <==>  interfaces inside the scope of CDNI
  ****  interfaces outside the scope of CDNI
  ....  interfaces outside the scope of CDNI
```

Figure 1: CDNI Problem Area

Listed below are the four interfaces required to interconnect a pair

of CDNs and that constitute the problem space that is proposed to be addressed by a potential CDNI working group in the IETF. The use of the term "interface" is meant to encompass the protocol over which CDNI data representations (e.g. CDNI Metadata records) are exchanged as well as the specification of the data representations themselves (i.e. what properties/fields each record contains, its structure, etc.).

- o CDNI Control interface: This interface allows the "CDNI Control" system in interconnected CDNs to communicate. This interface may support the following:
  * Allow bootstrapping of the other CDNI interfaces (e.g. interface address/URL discovery and establishment of security associations).
  * Allow configuration of the other CDNI interfaces (e.g. Upstream CDN specifies information to be reported through the CDNI Logging interface).
  * Allow the downstream CDN to communicate static (or fairly static) information about its delivery capabilities and policies.
  * Allow bootstrapping of the interface between CDNs for content acquisition (even if that interface itself is outside the scope of the CDNI work).
  * Allow upstream CDN to initiate or request specific actions to be undertaken in the downstream CDN. For example, this may include the following capabilities:
    + Allow an upstream CDN to request that content files and/or CDNI Metadata that it previously shared, be purged from, or invalidated in, a downstream CDN. Support for content deletion or invalidation from a CDN is a key requirement for some Content Service Providers in order, amongst other use cases for content deletion, to support the content rights agreements they have negotiated. Today's CDNs use proprietary control interfaces to enable CSPs to remove content cached in the CDN and therefore there is a need to have a similar but standardized content deletion capability between interconnected CDNs.
    + Allow an upstream CDN to initiate Pre-positioned content acquisition and/or Pre-positioned CDNI Metadata acquisition in a downstream CDN.
- o CDNI Request Routing interface: This interface allows the Request Routing systems 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 downstream CDN). In particular, the

CDN Request Routing interface, may support the following:

* Allow the upstream CDN to query the downstream CDN at request routing time before redirecting the request to the downstream CDN.
* Allow the downstream CDN to provide to the upstream CDN (static or dynamic) information (e.g. resources, footprint, load) to facilitate selection of the downstream CDN by the upstream CDN request routing system when processing subsequent content requests from User Agents.

- CDNI Metadata distribution interface: This interface allows the Distribution system in interconnected CDNs to communicate to ensure CDNI Metadata can be exchanged across CDNs. See Section 1.1 for definition and examples of CDNI Metadata.
- CDNI Logging interface: This interface 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 or for settlement purposes across CDNs. Similarly, an upstream CDN may collect delivery logs from a downstream CDN in order to provide consolidated reporting and monitoring to the CSP.

Note that the actual grouping of functionalities under these four interfaces is considered tentative at this stage and may be changed after further study (e.g. some subset of functionality be moved from one interface into another).

The above list covers a significant potential problem space, in part because in order to interconnect two CDNs there are several 'touch points' that require standardization. However, it is expected that the CDNI interfaces need not be defined from scratch and instead can very significantly reuse or leverage existing protocols: this is discussed further in Section 4. Also, it is expected that the items above will be prioritized so that the CDNI Working Group can focus (at least initially) on the most essential and urgent work.

As part of the development of the CDNI interfaces and solutions it will also be necessary to agree on common mechanisms for how to identify and name the data objects that are to be interchanged between interconnected CDNs, as well as how to describe which policy should be used when doing so.

Some NSPs have started to perform experiments to explore whether their CDN use cases can already be addressed with existing CDN implementations. One set of such experiments is documented in [I-D.bertrand-cdni-experiments]. The conclusions of those experiments are that while some basic limited CDN Interconnection

functionality can be achieved with existing CDN technology, the current lack of any standardized CDNI interfaces/protocols such as those discussed in this document is preventing the deployment of production CDN Interconnection solutions with the necessary level of functionality.

The acquisition of content between interconnected CDNs is out of scope for CDNI and deserves some additional explanation. The consequence of such a decision is that the CDNI WG is focussed on only defining the control plane for CDNI; and the CDNI data plane (i.e. the acquisition & distribution of the actual content objects) will not be addressed by the CDNI WG. The rationale for such a decision is that CDNs today typically already use standardized protocols such as HTTP, FTP, rsync, etc. to acquire content from their CSP customers and it is expected that the same protocols could be used for acquisition between interconnected CDNs. Therefore the problem of content acquisition is considered already solved and all that is required from specifications developed by the CDNI WG is to describe within the CDNI Metadata where to go and which protocol to use to retrieve the content.

4. Design Approach for Realizing the CDNI APIs

This section expands on how CDNI interfaces can reuse and leverage existing protocols before describing each CDNI interface individually and highlighting example candidate protocols that could considered for reuse or leveraging to implement the CDNI interfaces. This discussion is not intended to pre-empt any WG decision as to the most appropriate protocols, technologies and solutions to select to solve CDNI but is intended as an illustration of the fact that the CDNI interfaces need not be created in a vacuum and that reuse or leverage of existing protocols is likely possible.

The four CDNI interfaces (CDNI Control interface, CDNI Request Routing interface, CDNI Metadata interface, CDNI Logging interface) described in Section 3 within the CDNI problem area are all control plane interfaces operating at the application layer (Layer 7 in the OSI network model). Since it is not expected that these interfaces would exhibit unique session, transport or network requirements as compared to the many other existing applications in the Internet, it is expected that the CDNI interfaces will be defined on top of existing session, transport and network protocols.

Although a new application protocol could be designed specifically for CDNI we assume that this is unnecessary and it is recommended that existing application protocols be reused or leveraged (HTTP [RFC2616], Atom Publishing Protocol [RFC5023], XMPP [RFC6120], for

example) to realize the CDNI interfaces.

4.1. CDNI Request Routing Interface

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.

The CDNI Request Routing interface needs to offer a mechanism for an upstream CDN to issue a "Redirection Request" to a downstream CDN. The Request Routing interface needs to be able to support scenarios where the initial User Agent request to the upstream CDN is received over DNS as well as over a content specific application protocol (e.g. HTTP, RTSP, RTMP, etc.).

Therefore a Redirection Request needs to contain information such as:

- o The protocol (e.g. DNS, HTTP) over which the upstream CDN received the initial User Agent request.
- o Additional details of the User Agent request that are required to perform effective Request Routing by the Downstream CDN. For DNS this would typically be the IP address of the DNS resolver making the request on behalf of the User Agent. For requests received over content specific application protocols the Redirection Request could contain significantly more information related to the original User Agent request but at a minimum would need to contain the User Agent's IP address, the equivalent of the HTTP Host header and the equivalent of the HTTP abs_path defined in [RFC2616].

It should be noted that, the CDNI architecture needs to consider that a downstream CDN may receive requests from User Agents without first receiving a Redirection Request from an upstream CDN, for example because:

- o User Agents (or DNS resolvers) may cache DNS or application responses from Request Routers.
- o Responses to Redirection Requests over the Request Routing interface may be cacheable.
- o Some CDNs may want broader policies, e.g. CDN B agrees to always take CDN A's delegated redirection requests, in which case the necessary redirection details are exchanged out of band (of the CDNI interfaces), e.g. configured.

On receiving a Redirection Request, the downstream CDN will use the

information provided in the request to determine if it is able (and willing) to accept the delegated content request and needs to return the result of its decision to the upstream CDN.

Thus, a Redirection Response from the downstream CDN needs to contain information such as:

- o Status code indicating acceptance or rejection (possibly with accompanying reasons).
- o Information to allow redirection by the Upstream CDN. In the case of DNS-based request routing, this is expected to include the equivalent of a DNS record(s) (e.g. a CNAME) that the upstream CDN should return to the requesting DNS resolver. In the case of application based request routing, this is expected to include the application specific redirection response(s) to return to the requesting User Agent. For HTTP requests from User Agents this could be in the form of a URI that the upstream CDN could return in a HTTP 302 response.

The CDNI Request Routing interface is therefore a fairly straightforward request/response interface and could be implemented over any number of request/response protocols. For example, it may be implemented as a WebService using one of the common WebServices methodologies (XML-RPC, HTTP query to a known URI, etc.). This removes the need for the CDNI WG to define a new protocol for the request/response element of the CDNI Request Routing interface. Thus, the CDNI WG would be left only with the task of specifying:

- o The recommended request/response protocol to use along with any additional semantics and procedures that are specific to the CDNI Request Routing interface (e.g. handling of malformed requests/ responses).
- o The syntax (i.e representation/encoding) of the redirection requests and responses.
- o The semantics (i.e. meaning and expected contents) of the redirection requests and responses.

Additionally, as discussed in Section 3, the CDNI Request Routing interface is also expected to enable a downstream CDN to provide to the upstream CDN (static or dynamic) information (e.g. resources, footprint, load) to facilitate selection of the downstream CDN by the upstream CDN request routing system when processing subsequent content requests from User Agents. It is expected that such functionality of the CDNI request Routing could be specified by the CDNI WG with significant leveraging of existing IETF protocols supporting the dynamic distribution of reachability information (for example by leveraging existing routing protocols) or supporting application level queries for topological information (for example by

leveraging ALTO).

4.2. CDNI Metadata Interface

The CDNI Metadata interface enables the Metadata function in a downstream CDN to obtain CDNI Metadata from an upstream CDN so that the downstream CDN can properly process and respond to:

- o Redirection Requests received over the CDNI Request Routing interface.
- o Content Requests received directly from User Agents.

The CDNI Metadata interface needs to offer a mechanism for an Upstream CDN to:

- o Distribute/update/remove CDNI Metadata to a Downstream CDN.

and/or to allow a downstream CDN to:

- o Make direct requests for CDNI Metadata records where the downstream CDN knows the identity of the Metadata record(s) it requires.
- o Search for CDNI Metadata records where the downstream CDN does not know the specific Metadata record(s) it requires but does know some property of the record it is searching for. For example, it may know the value of the HTTP Host header received in a HTTP request and it wants to obtain the CDNI Metadata for that host so that it can determine how to further process the received HTTP request.

The CDNI Metadata interface is therefore similar to the CDNI Request Routing interface because it is a request/response interface with the potential addition that CDNI Metadata search may have more complex semantics than a straightforward Request Routing redirection request. Therefore, like the CDNI Request Routing interface, the CDNI Metadata interface may be implemented as a WebService using one of the common WebServices methodologies (XML-RPC, HTTP query to a known URI, etc.) or possibly using other existing protocols such as XMPP [RFC6120]. This removes the need for the CDNI WG to define a new protocol for the request/response element of the CDNI Metadata interface.

Thus, the CDNI WG would be left only with the task of specifying:

- o The recommended request/response protocol to use along with any additional semantics that are specific to the CDNI Metadata interface (e.g. handling of malformed requests/responses).
- o The syntax (i.e representation/encoding) of the CDNI Metadata records that will be exchanged over the interface.

- o The semantics (i.e. meaning and expected contents) of the individual properties of a Metadata record.
- o How the relationships between different CDNI Metadata records are represented.

4.3. CDNI Logging Interface

The CDNI Logging interface enables details of logs or events to be exchanged between interconnected CDNs, where events could be:

- o Log lines related to the delivery of content (similar to the log lines recorded in a web server's access log).
- o Real-time or near-real time events before, during or after content delivery, e.g. content Start/Pause/Stop events, etc.
- o Operations and diagnostic messages.

Within CDNs today, logs and events are used for a variety of purposes in addition to real-time and non real-time diagnostics and auditing by the CDN Provider and its customers. Specifically CDNs use logs to generate Call Data Records (CDRs) for passing to billing and payment systems and to real-time (and near real-time) analytics systems. Such use cases place requirements on the CDNI Logging interface to support guaranteed and timely delivery of log messages between interconnected CDNs. It may also be necessary to be able to prove the integrity of received log messages.

Several protocols already exist that could potentially be used to exchange CDNI logs between interconnected CDNs including SNMP Traps, syslog, ftp, HTTP POST, etc. although it is likely that some of the candidate protocols may not be well suited to meet all the requirements of CDNI. For example SNMP traps pose scalability concerns and SNMP does not support guaranteed delivery of Traps and therefore could result in log records being lost and the consequent CDRs and billing records for that content delivery not being produced as well as that content delivery being invisible to any analytics platforms.

Although it is not necessary to define a new protocol for exchanging logs across the CDNI Logging interface, the CDNI WG would still need to specify:

- o The recommended protocol to use.
- o A default set of log fields and their syntax & semantics. Today there is no standard set of common log fields across different content delivery protocols and in some cases there is not even a standard set of log field names and values for different implementations of the same delivery protocol.

- A default set of events that trigger logs to be generated.

4.4. CDNI Control Interface

The CDNI Control interface allows the "CDNI Control" system in interconnected CDNs to communicate. The exact inter-CDN control functionality required to be supported by the CDNI Control interface is less well defined than the other three CDNI interfaces at this time.

However, as discussed in Section 3, the CDNI Control interface may be required to support functionality similar to the following:

- Allow an upstream CDN and downstream CDN to establish, update or terminate their CDNI interconnection.
- Allow bootstrapping of the other CDNI interfaces (e.g. protocol address discovery and establishment of security associations).
- Allow configuration of the other CDNI interfaces (e.g. Upstream CDN specifies information to be reported through the CDNI Logging interface).
- Allow the downstream CDN to communicate static information about its delivery capabilities, resources and policies.
- Allow bootstrapping of the interface between CDNs for content acquisition (even if that interface itself is outside the scope of the CDNI work).

It is expected that for the Control interface also, existing protocols can be reused or leveraged. Those will be considered once the requirements for the Control interface have been refined.

5. Gap Analysis of relevant Standardization Activities

There are a number of other standards bodies and industry forums that are working in areas related to CDNs, and in some cases related to CDNI. This section outlines any potential overlap with the work of the CDNI WG and any component that could potentially be reused by CDNI.

A number of standards bodies have produced specifications related to CDNs, for example:

- TISPAN has a dedicated specification for CDN.
- OIPF and ATIS specify the architecture and the protocols of an IPTV solution. Although OIPF and ATIS specifications include the interaction with a CDN, the CDN specifications are coupled with their IPTV specifications.
- CableLabs, SNIA and ITU have defined (or are working on) definitions for content related metadata definitions and specification for its distribution. However, they do not include

metadata specific to the distribution of content within a CDN or between interconnected CDNs.

- IETF CDI WG (now concluded) touched on the same problem space as the present document. 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.

Although some of the specifications describe multi-CDN cooperation or include reference points for interconnecting CDNs, none of them specify in sufficient detail all the CDNI interfaces and CDNI Metadata representations required to enable even a base level of CDN Interconnection functionality to be implemented.

The following sections will summarize the existing work of the standard bodies listed earlier against the CDNI problem space. Section 5.1 summarises existing interfaces that could be leveraged for content acquisition between CDNs and Section 5.2 summarises existing metadata specifications that may be applicable to CDNI. To date we are not aware of any standardisation activities in the areas of the remaining CDNI interfaces (CDNI Request Routing, CDNI Control and CDNI Logging).

5.1. Content Acquisition across CDNs and Delivery to End User (Data plane)

A number of standards bodies have completed work in the areas of content acquisition interface between a CSP and a CDN, as well as as on the delivery interface between the surrogate and the User Agent. Some of this work is summarized below.

TISPAN, OIPF and ATIS have specified IPTV and/or CoD services, including the data plane aspects (typically different flavors of RTP/RTCP and HTTP) to obtain content and deliver it to User Agents. For example, :

- The OIPF data plane includes both RTP and HTTP flavors (HTTP progressive download, HTTP Adaptive streaming [_3GP-DASH]).
- The ATIS specification "IPTV Content on Demand (CoD) Service" [ATIS-COD] 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 these protocols have not been explicitly specified for content acquisition across CDNs, they are suitable (in addition to others such as standard HTTP) for content acquisition between CDNs in a CDN Interconnection environment. Therefore for the purpose of the CDNI WG there are already multiple existing data plane protocols that can

be used for content acquisition across CDNs.

Similarly, there are multiple existing standards (e.g. the OIPF data plane mentioned above, HTTP adaptive streaming [_3GP-DASH]) or public specifications (e.g. vendor specific HTTP Adaptive streaming specifications) so that content delivery can be considered already solved (or at least sufficiently addressed in other forums

Thus, specification of the content acquisition interface between CDNs and the delivery interface between the surrogate and the User Agent are out of scope for CDNI. CDNI may only concern itself with the negotiation/selection aspects of the acquisition protocol to be used in a CDN interonnect scenario.

5.2. CDNI Metadata

CableLabs, ITU, OIPF and TV-Anytime have work items dedicated to the specification of content metadata:

o CableLabs 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.

o ITU Study Group 16 has started work on a number of draft Recommendations (H.IPTV-CPMD, H.IPTV-CPMD, HSTP.IPTV-CMA, HSTP.IPTV-UMCI) specifying metadata for content distribution in IPTV services.

o An Open IPTV Terminal receives the technical description of the content distribution from the OIPF IPTV platform before receiving any content. The Content distribution metadata is sent in the format of a TV-Anytime XSD including tags to describes the location and program type (on demand or Live) as well as describing the time availability of the on demand and live content.

However the specifications outlined above do not include metadata specific to the distribution of content within a CDN or between interconnected CDNs, for example geo-blocking information, availability windows, access control mechanisms to be enforced by the surrogate, how to map an incoming content request to a file on the origin server or acquire it from the upstream CDN etc.

The CDMI standard ([SNIA-CDMI]) from SNIA defines metadata that can

be associated with data that is stored by a cloud storage provider. While the metadata currently defined do not match the need of a CDN Interconnection solution, it is worth considering CDMI as one of the existing pieces of work that may potentially be leveraged for the CDNI Metadata interface (e.g by extending the CDMI metadata to address more specific CDNI needs).

6. Relationship to relevant IETF Working Groups

6.1. 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 can be used by a CDN Request Routing system to improve its selection of a CDN surrogate to serve a particular User Agent request (or to serve a request from another surrogate). [I-D.jenkins-alto-cdn-use-cases] describes a number of use cases for a CDN to be able to obtain network topology and cost information from an ALTO server(s) and [I-D.penno-alto-cdn] discusses how CDN Request Routing could 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 Interconnection. 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 described in this document because the integration between ALTO and a CDN is an internal decision for a specific CDN and is therefore out of scope for the CDNI WG. One area for further study is whether additional information should be provided by an ALTO service to facilitate CDNI CDN selection.

6.2. DECADE

The DECADE Working Group [DECADE-Charter] is addressing the problem of reducing traffic on the last-mile uplink, as well as backbone and transit links caused by P2P streaming and file sharing applications.

It addresses the problem by enabling an application endpoint to make content available from an in-network storage service and by enabling other application endpoints to retrieve the content from there.

Exchanging data through the in-network storage service in this manner, instead of through direct communication, provides significant gain where:

- o The network capacity/bandwidth from in-network storage service to application endpoint significantly exceeds the capacity/bandwidth from application endpoint to application endpoint (e.g. because of an end-user uplink bottleneck); and
- o Where the content is to be accessed by multiple instances of application endpoints (e.g. as is typically the case for P2P applications).

While, as is the case for any other data distribution application, the DECADE architecture and mechanisms could potentially be used for exchange of CDNI control plane information via an in-network-storage service (as opposed to directly between the entities terminating the CDNI interfaces in the neighbor CDNs), we observe that:

- o CDNI would operate as a "Content Distribution Application" from the DECADE viewpoint (i.e. would operate on top of DECADE).
- o There does not seem to be obvious benefits in integrating the DECADE control plane responsible for signaling information relating to control of the in-network storage service itself, and the CDNI control plane responsible for application-specific CDNI interactions (such as exchange of CDNI metadata, CDNI request redirection, transfer of CDNI logging information).
- o There would typically be limited benefits in making use of a DECADE in-network storage service because the CDNI interfaces are expected to be terminated by a very small number of CDNI clients (if not one) in each CDN, and the CDNI clients are expected to benefit from high bandwidth/capacity when communicating directly to each other (at least as high as if they were communicating via an in-network storage server).

The DECADE in-network storage architecture and mechanisms may theoretically be used for the acquisition of the content objects themselves between interconnected CDNs. It is not expected that this would have obvious benefits in typical situations where a content object is acquired only once from an Upstream CDN to a Downstream CDN (and then distributed as needed inside the Downstream CDN). But it might have benefits in some particular situations. Since the acquisition protocol between CDNs is outside the scope of the CDNI work, this question is left for further study.

The DECADE in-network storage architecture and mechanisms may potentially also be used within a given CDN for the distribution of the content objects themselves among surrogates of that CDN. Since the CDNI work does not concern itself with operation within a CDN, this question is left for further study.

Therefore, the work of DECADE may be complementary to but does not overlap with the CDNI work described in this document.

6.3. PPSP

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

"The Peer-to-Peer Streaming Protocol (PPSP) working group develops two signaling and control protocols for a peer-to-peer (P2P) streaming system for transmitting live and time-shifted media content with near real-time delivery requirements." and "The PPSP WG designs a protocol for signaling and control between trackers and peers (the PPSP "tracker protocol") and a signaling and control protocol for communication among the peers (the PPSP "peer protocol"). The two protocols enable peers to receive streaming data within the time constraints required by specific content items."

Therefore PPSP is concerned with the distribution of the streamed content itself along with the necessary signaling and control required to distribute the content. As such, it could potentially be used for the acquisition of streamed content across interconnected CDNs. But since the acquisition protocol is outside the scope of the work proposed for CDNI, we leave this for further study. Also, because of its streaming nature, PPSP is not seen as applicable to the distribution and control of the CDNI control plane and CDNI data representations.

Therefore, the work of PPSP may be complementary to but does not overlap with the work described in this document for CDNI.

7. IANA Considerations

This document makes no request of IANA.

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

8. Security Considerations

Distribution of content by a CDN comes with a range of security

considerations such as how to enforce control of access to the content by users in line with the CSP policy. These security aspects are already dealt with by CDN Providers and CSPs today in the context of standalone CDNs. However, interconnection of CDNs introduces a new set of security considerations by extending the trust model (i.e. the CSP "trusts" a CDN that "trusts" another CDN).

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 CSPs 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.

9. Acknowledgements

The authors would like to thank Andre Beck, Gilles Bertrand, Mark Carlson, Bruce Davie, David Ferguson, Yiu Lee, Kent Leung, Will Li, Kevin Ma, Julien Maisonneuve, Guy Meador, Emile Stephan, Oskar van Deventer and Mahesh Viveganandhan for their review comments and contributions to the text.

10. References

10.1. Normative References

10.2. Informative References

[ALTO-Charter]
"IETF ALTO WG Charter (http://datatracker.ietf.org/wg/alto/charter/)".

[ATIS] "ATIS (http://www.atis.org/)".

[ATIS-COD]
"ATIS IIF: IPTV Content on Demand Service, January 2011 (http://www.atis.org/iif/_Com/Docs/Task_Forces/ARCH/ATIS-0800042.pdf)".

[CDI-Charter]
"IETF CDI WG Charter (http://www.ietf.org/wg/concluded/cdi)".

[CableLabs]

"CableLabs (http://www.cablelabs.com/about/)".

[CableLabs-Metadata]
"CableLabs VoD Metadata Project Primer (http://www.cablelabs.com/projects/metadata/primer/)".

[DECADE-Charter]
"IETF DECADE WG Charter (http://datatracker.ietf.org/wg/decade/charter/)".

[I-D.bertrand-cdni-experiments]
Bertrand, G., Faucheur, F., and L. Peterson, "Content Distribution Network Interconnection (CDNI) Experiments", draft-bertrand-cdni-experiments-01 (work in progress), August 2011.

[I-D.ietf-cdni-use-cases]
Bertrand, G., Emile, S., Watson, G., Burbridge, T., Eardley, P., and K. Ma, "Use Cases for Content Delivery Network Interconnection", draft-ietf-cdni-use-cases-00 (work in progress), September 2011.

[I-D.jenkins-alto-cdn-use-cases]
Niven-Jenkins, B., Watson, G., Bitar, N., Medved, J., and S. Previdi, "Use Cases for ALTO within CDNs", draft-jenkins-alto-cdn-use-cases-01 (work in progress), June 2011.

[I-D.penno-alto-cdn]
Penno, R., Medved, J., Alimi, R., Yang, R., and S. Previdi, "ALTO and Content Delivery Networks", draft-penno-alto-cdn-03 (work in progress), March 2011.

[MPEG-DASH]
"Information technology - MPEG systems technologies - Part 6: Dynamic adaptive streaming over HTTP (DASH), (DIS version), February 2011 http://mpeg.chiariglione.org/working_documents.htm#MPEG-B".

[OIPF-Overview]
"OIPF Release 2 Specification Volume 1 - Overview", September 2010.

[P2PRG-CDNI]
Davie, B. and F. Le Faucheur, "Interconnecting CDNs aka "Peering Peer-to-Peer" (http://www.ietf.org/proceedings/77/slides/P2PRG-2.pdf)",

March 2010.

[PPSP-Charter]
"IETF PPSP WG Charter (http://datatracker.ietf.org/wg/ppsp/charter/)".

[RFC2616] Fielding, R., Gettys, J., Mogul, J., Frystyk, H., Masinter, L., Leach, P., and T. Berners-Lee, "Hypertext Transfer Protocol -- HTTP/1.1", RFC 2616, June 1999.

[RFC3040] Cooper, I., Melve, I., and G. Tomlinson, "Internet Web Replication and Caching Taxonomy", RFC 3040, January 2001.

[RFC3466] Day, M., Cain, B., Tomlinson, G., and P. Rzewski, "A Model for Content Internetworking (CDI)", RFC 3466, February 2003.

[RFC3568] Barbir, A., Cain, B., Nair, R., and O. Spatscheck, "Known Content Network (CN) Request-Routing Mechanisms", RFC 3568, July 2003.

[RFC3570] Rzewski, P., Day, M., and D. Gilletti, "Content Internetworking (CDI) Scenarios", RFC 3570, July 2003.

[RFC5023] Gregorio, J. and B. de hOra, "The Atom Publishing Protocol", RFC 5023, October 2007.

[RFC6120] Saint-Andre, P., "Extensible Messaging and Presence Protocol (XMPP): Core", RFC 6120, March 2011.

[SNIA-CDMI]
"SNIA CDMI (http://www.snia.org/tech_activities/standards/curr_standards/cdmi)".

[TAXONOMY]
Pathan, A., "A Taxonomy and Survey of Content Delivery Networks (http://www.gridbus.org/reports/CDN-Taxonomy.pdf)", 2007.

[Y.1910] "ITU-T Recomendation Y.1910 "IPTV functional architecture"", September 2008.

[Y.2019] "ITU-T Recomendation Y.2019 "Content delivery functional architecture in NGN"", September 2010.

[_3GP-DASH]
"Transparent end-to-end Packet-switched Streaming Service (PSS); Progressive Download and Dynamic Adaptive Streaming

over HTTP (3GP-DASH)
http://www.3gpp.org/ftp/Specs/html-info/26247.htm".

Appendix A. Additional Material

Note to RFC Editor: This appendix is to be removed on publication as an RFC.

A.1. 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:

- o 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).
- o The delivery interface between the delivering CDN surrogate and the User Agent, such as streaming protocols.
- o The request interface between the User Agent and the request-routing system of a given CDN. Existing IETF protocols (e.g. HTTP, RTSP, DNS) are commonly used by User Agents to request content from a CDN and by CDN request routing systems to redirect the User Agent requests. The CDNI working group need not define new protocols for this purpose. Note however, that the CDNI control plane interface may indirectly affect some of the information exchanged through the request interface (e.g. URI).
- o The content acquisition interface between CDNs (i.e. the data plane 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). The CDN Interconnection solution may only concern itself with the agreement/negotiation aspects of which content acquisition protocol is to be used between two interconnected CDNs in view of facilitating interoperability.
- o End User/User Agent Authentication. End User/User Agent authentication and authorization are the responsibility of the Content Service Provider.
- o 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 optimized delivery of these objects by the surrogate to the End User are outside the scope of CDNI.
- o Digital Rights Management (DRM). DRM is an end-to-end issue between a content protection system and the User Agent.

- o Applications consuming CDNI logs (e.g. charging, analytics, reporting,...).
- o Internal CDN interfaces & protocols (i.e. interfaces & protocols within one CDN).
- o Scalability of individual CDNs. While scalability of the CDNI interfaces/approach is in scope, how an individual CDN scales is out of scope.
- o Actual algorithms for selection of CDNs or Surrogates by Request Routing systems (however, some specific parameters required as input to these algorithms may be in scope when they need to be communicated across CDNs).
- o Surrogate algorithms. For example caching algorithms and content acquisition methods are outside the scope of the CDNI work. Content management (e.g. Content Deletion) as it relates to CDNI content management policies, 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.
- o Element management interfaces.
- o Commercial, business and legal aspects related to the interconnections of CDNs.

A.2. Related standardization activities

A.2.1. IETF CDI Working Group (Concluded)

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]:

"

- o The goal of this working group is to define protocols to allow the interoperation of separately-administered content networks.
- o 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.
- o 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.

o 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:

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

A.2.2. 3GPP

3GPP was the first organization that released a specification related to adaptive streaming over HTTP. 3GPP Release 9 specification on adaptive HTTP streaming was published in March 2010, and there have been some bug fixes on this specification since the publication. In addition, 3GPP is preparing an extended version for Release 10, which is scheduled to be published later in 2011. This release will include a number of clarifications, improvements and new features.

[_3GP-DASH] is defined as a general framework independent of the data encapsulation format. It has support for fast initial startup and seeking, adaptive bitrate switching, re-use of HTTP origin and cache servers, re-use of existing media playout engines, on-demand, live and time-shifted delivery. It specifies syntax and semantics of Media Presentation Description (MPD), format of segments and delivery protocol for segments. It does not specify content provisioning, client behavior or transport of MPD.

The content retrieved by a client using [_3GP-DASH] adaptive streaming could be obtained from a CDN but this is not discussed or specified in the 3GPP specifications as it is transparent to [_3GP-DASH] operations. Similarly, it is expected that [_3GP-DASH] can be used transparently from the CDNs as a delivery protocol (between the delivering CDN surrogate and the User Agent) in a CDN Interconnection environment. [_3GP-DASH] could also be a candidate for content acquisition between CDNs in a CDN Interconnection environment.

A.2.3. ISO MPEG

Within ISO MPEG, the Dynamic Adaptive Streaming over HTTP (DASH) ad-hoc group adopted the 3GPP Release 9 [_3GP-DASH] specification as a

starting point and has made some improvements and extensions. Similar to 3GPP SA4, the MPEG DASH ad-hoc group has been working on standardizing the manifest file and the delivery format. Additionally, the MPEG DASH ad-hoc group has also been working on the use of MPEG-2 Transport Streams as a media format, conversion from/to existing file formats, common encryption, and so on. The MPEG DASH specification could also be a candidate for delivery to the User Agent and for content acquisition between CDNs in a CDN Interconnection environment. The Draft International Standard (DIS) version [MPEG-DASH] is currently publicly available since early February 2011.

In the 95th MPEG meeting in January 2011, the DASH ad-hoc group decided to start a new evaluation experiment called "CDN-EE". The goals are to understand the requirements for MPEG DASH to better support CDN-based delivery, and to provide a guidelines document for CDN operators to better support MPEG DASH streaming services. The ongoing work is still very preliminary and does not currently target looking into CDN Interconnection use cases.

A.2.4. ATIS IIF

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

ATIS 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 service provider) and does not cover the use, or interconnection, of multiple CDNs.

A.2.5. CableLabs

"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]

CableLabs has defined specifications for CoD Content Metadata as part of its VOD Metadata project.

A.2.6. ETSI MCD

ETSI 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. MCD very recently created a working group to progress this work item. However, no protocol level work has yet started in MCD for CDN Interconnection.

A.2.7. ETSI TISPAN

ETSI TISPAN has published two sets of IPTV specifications, one of which is based on IMS. In addition, TISPAN is about to complete the specifications of a CDN architecture supporting delivery of various content services such as time-shifted TV and VoD 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. The protocol definition phase for the corresponding CDN architecture was kicked-off at the end of 2010. In line with its long history of leveraging IETF protocols, ETSI could potentially leverage CDNI interfaces developed in the IETF for their related protocol level work on interconnections of CDNs.

A.2.8. ITU-T

SG13 is developing standards related to the support of IPTV services (i.e.. multimedia services such as television/VoD/audio/text/graphics/data delivered over IP-based managed networks).

ITU-T Recommendation Y.1910 [Y.1910] provides the description of the IPTV functional architecture. This architecture includes functions and interfaces for the distribution and delivery of content. This architecture is aligned with the ATIS IIF architecture.

Based upon ITU-T Rec. Y.1910, ITU-T Rec. Y.2019 [Y.2019] describes in more detail the content delivery functional architecture. This architecture allows CDN Interconnection: some interfaces (such as D3, D4) at the control level allow relationships between different CDNs, in the same domain or in different domains. Generic procedures are described, but the choice of the protocols is open.

A.2.9. Open IPTV Forum (OIPF)

The Open IPTV Forum has developed an end-to-end solution to allow any OIPF terminal to access enriched and personalized IPTV services either in a managed or a non-managed network[OIPF-Overview]. Some OIPF services (such as Network PVR) may be hosted in a CDN.

To that end, the Open IPTV Forum specification is made of 5 parts:

- Media Formats including HTTP Adaptive Streaming
- Content Metadata
- Protocols
- Terminal (Declarative or Procedural Application Environment)
- Authentication, Content Protection and Service Protection

A.2.10. TV-Anytime Forum

Version 1 of the TV-Anytime Forum specifications were published as ETSI TS 102 822-1 through ETSI TS 102 822-7 "Broadcast and On-line Services: Search, select, and rightful use of content on personal storage systems ("TV-Anytime")". It includes the specification of content metadata in XML schemas (ETSI TS 102 822-3) which define technical parameters for the description of CoD and Live contents. The specification is referenced by DVB and OIPF.

The TV-anytime Forum was closed in 2005.

A.2.11. SNIA

The Storage Networking Industry Association (SNIA) is an association of producers and consumers of storage networking products whose goal is to further storage networking technology and applications.

SNIA has published the Cloud Data Management Interface (CDMI) standard ([SNIA-CDMI]).

"The Cloud Data Management Interface defines the functional interface that applications will use to create, retrieve, update and delete data elements from the Cloud. As part of this interface the client will be able to discover the capabilities of the cloud storage offering and use this interface to manage containers and the data that is placed in them. In addition, metadata can be set on containers and their contained data elements through this interface."

A.3. Related Research Projects

A.3.1. 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].

A.3.2. OCEAN

OCEAN (http://www.ict-ocean.eu/) is an EU funded research project that started in February 2010 for 3 years. Some of its objectives are relevant to CDNI. It aims, among other things, at designing a new architectural framework for audiovisual content delivery over the Internet, defining public interfaces between its major building blocks in order to foster multi-vendor solutions and interconnection between Content Networks (the term "Content Networks" corresponds here to the definition introduced in [RFC3466], which encompasses CDNs).

OCEAN has not yet published any open specifications, nor common best practices, defining how to achieve such CDN interconnection.

A.3.3. Eurescom P1955

Eurescom P1955 was a 2010 research project involving a four European Network operators, which studied the interests and feasibility of interconnecting CDNs by firstly elaborating the main service models around CDN interconnection, as well as analyzing an adequate CDN interconnection technical architecture and framework, and finally by providing recommendations for telcos to implement CDN interconnection. The Eurescom P1955 project ended in July 2010.

The authors are not aware of material discussing CDN interconnection protocols or interfaces made publically available as a deliverable of this project.

Authors' Addresses

Ben Niven-Jenkins
Velocix (Alcatel-Lucent)
326 Cambridge Science Park
Milton Road, Cambridge CB4 0WG
UK

Email: ben@velocix.com

Francois Le Faucheur
Cisco Systems
Greenside, 400 Avenue de Roumanille
Sophia Antipolis 06410
France

Phone: +33 4 97 23 26 19
Email: flefauch@cisco.com

Nabil Bitar
Verizon
40 Sylvan Road
Waltham, MA 02145
USA

Email: nabil.bitar@verizon.com