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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

Next Generation Networks – Enhancements to NGN

Unified management of content delivery networks

Recommendation ITU-T Y.2305

International Telecommunication Union

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Recommendation ITU-T Y.2305

Unified management of content delivery networks

Summary

Recommendation ITU-T Y.2305 specifies requirements, mechanisms and security considerations for unified management of multiple content delivery networks (CDNs), in order to support simple and optimized interconnection between different CDNs.

This Recommendation provides a technical solution of a CDN manager with capabilities of content synchronization, user's request routing and other related unified management functionalities, to build up a global CDN.

History

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Recommendation ITU-T Y.2305

Unified management of content delivery networks

1 Scope

This Recommendation specifies unified management of content delivery networks (CDNs), with the following aspects:

- scenarios for unified management of CDNs;
- requirements including request routing-related, CDN content, status, network-related, and charging-related descriptions;
- mechanisms including the framework, procedures and other related functions for unified management of CDNs;
- security considerations for unified management of CDNs.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.2019] ITU-T Recommendation Y.2019 (2010), *Content delivery functional architecture in NGN*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 charging [b-ITU-T Q.825]: The set of functions needed to determine the price assigned to the service utilization.

3.1.2 content [b-ITU-T H.780]: A combination of audio, still image, graphic, video, or data.

NOTE – A variety of formats is classified as the "data" (e.g., text, encoded values, multimedia description language introduced by [b-ITU-T H.760]).

3.1.3 content provider [b-ITU-T Y.1910]: The entity that owns or is licensed to sell content or content assets.

3.1.4 end user [b-ITU-T Y.1910]: The actual user of the products or services.

3.1.5 service [b-ITU-T Y.2091]: A set of functions and facilities offered to a user by a provider.

3.1.6 service provider [b-ITU-T M.1400]: A general reference to an operator that provides telecommunication services to customers and other users, either on a tariff or contract basis. A service provider may or may not operate a network. A service provider may or may not be a customer of another service provider.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 content storage metadata: The descriptive information of what the name of the content is and which content delivery network (CDN) it is stored in.

NOTE – Often this metadata takes the form of an identifier and location (CDN name) that the content illustrates.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ACL Access Control List

AS Application Server

CDN Content Delivery Network

CNAME Canonical Name

CP Content Provider

DNS Domain Name System

EPC Evolved Packet Core

FCDN Fixed Content Delivery Network

IP Internet Protocol

KPI Key Performance Indicator

MCDN Mobile Content Delivery Network

NGN Next Generation Network

QoS Quality of Service

RAN Radio Access Network

SLA Service Level Agreement

URL Uniform Resource Locator

5 Convention

In this Recommendation:

The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keywords "is prohibited from" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus this requirement need not be present to claim conformance.

The keywords "is not recommended" indicate a requirement which is not recommended but which is not specifically prohibited. Thus, conformance with this specification can still be claimed even if this requirement is present.

The keywords "can optionally" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network

operator or service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

6 Introduction

6.1 Motivation for unified management of CDNs

Nowadays there are many kinds of CDN operator in the network, including specific service providers who provide CDN rental service for Internet content, and traditional telecom operators with self-built CDN for their self-own services or third parties' services. There are also some operators who build and operate CDNs in different regions of the network independently.

Different CDNs (owned by one or multiple operators) provide content services for users in their own independent domains, and the drawbacks of lacking interconnection between them are as follows:

- the content inside a CDN is only enjoyed by users in CDN's own domain, and such content cannot be shared by other users by cross-domain mechanisms, which leads to insufficient resource utilization;
- in an overloading or bandwidth-constrained scenario, one independent CDN cannot realize the best load balance without dispatching users' requests across domains;
- for an operator who is short of content inside his own CDN, it takes time and endeavour to introduce Internet content one content provider (CP) by CP, so that the operator cannot maximize the benefits of the investment in a short time.

This Recommendation discusses unified management of multiple CDNs, which aims to provide a technical solution of a CDN manager above CDNs and interconnections among CDNs, by introducing capabilities of content synchronization, user request routing, and other related unified management functionalities, to build up a global CDN.

The CDN described in this Recommendation follows the capabilities of content delivery identified in [ITU-T Y.2019].

Figure 1 illustrates the basic scheme of unified management of CDNs.

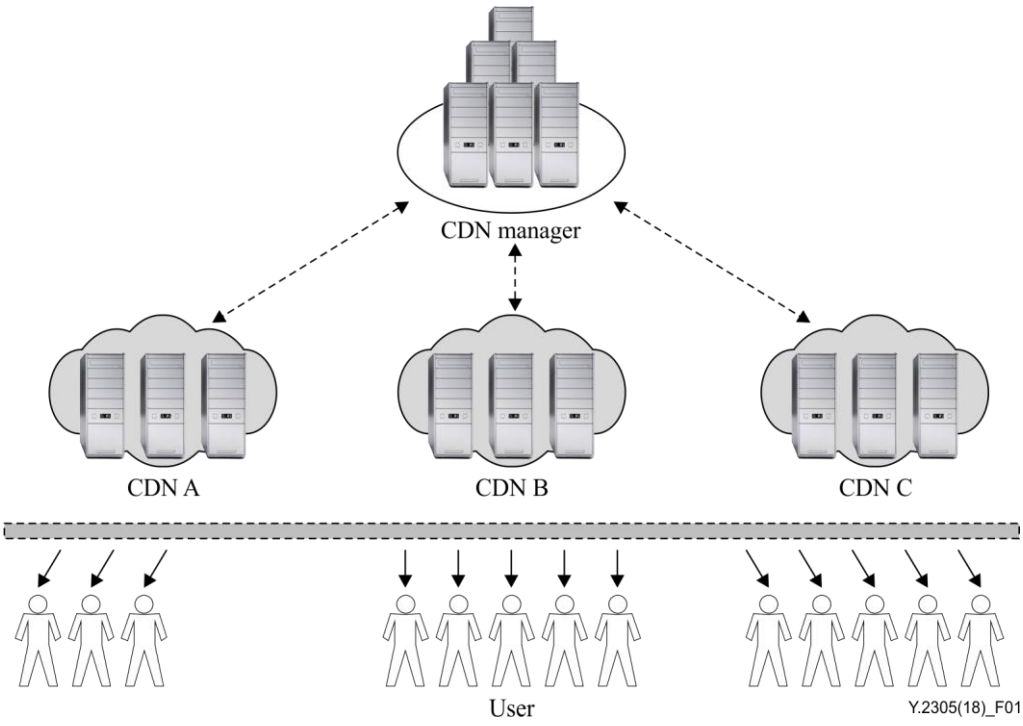

Figure 1 – Basic scheme of unified management of CDNs

NOTE – The CDNs in Figure 1 can be attributed to one or more operators. The CDN manager can be attributed to one operator that operates one or more CDNs or can be attributed to a third party that does not operate any CDN.

6.2 Scenarios for unified management of CDNs

6.2.1 Content synchronization between CDNs

Figure 2 shows the scenario for content synchronization among CDNs.

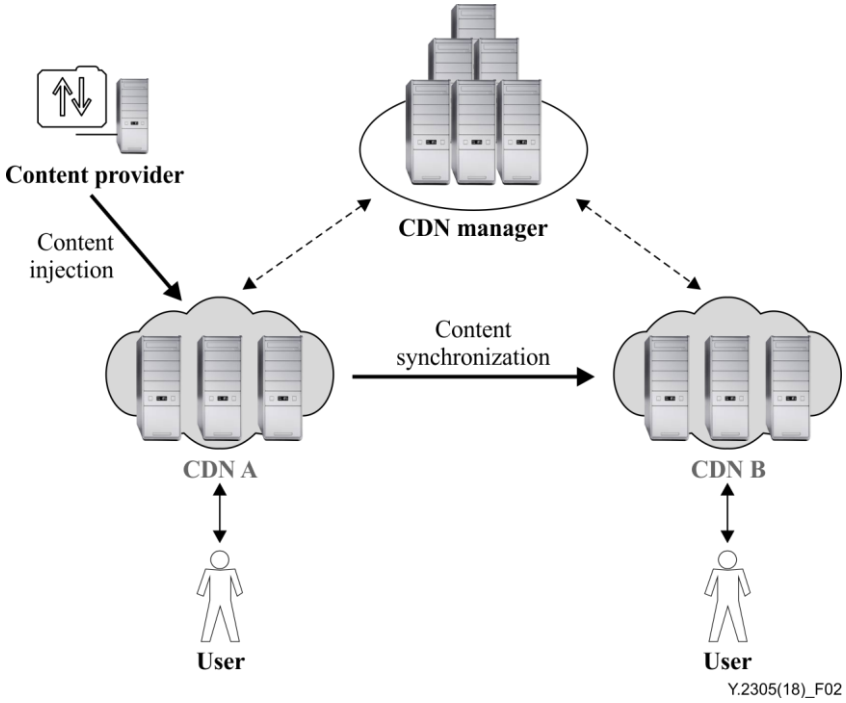

Figure 2 – Scenario of content synchronization between CDNs

In the scenario of content synchronization between CDNs, first, the CP injects its new content into CDN A to which it subscribes. Second, under the synchronization control of the CDN manager, CDN A duplicates and transfers this content to CDN B, and then a user in the domain of CDN B can effective access the new content.

6.2.2 Request routing under dispatch control of CDN manager

Figure 3 shows a scenario for request routing under the dispatch control of the CDN manager.

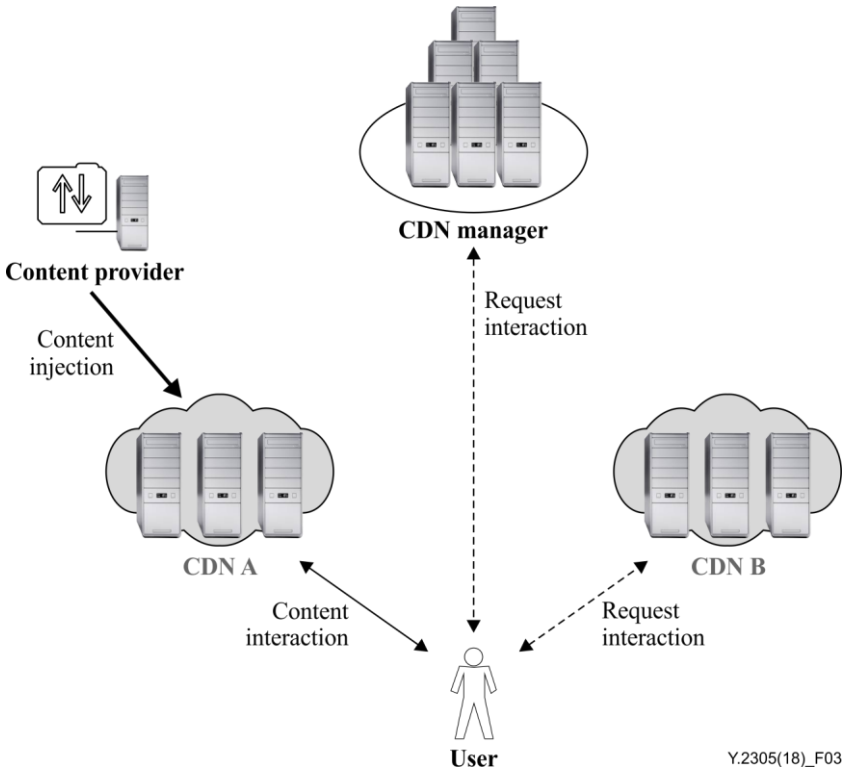

Figure 3 – Scenario for request routing under the dispatch control of the CDN manager

In this scenario, first, a CP injects its new contents into CDN A, but these contents are not synchronized to CDN B. Second, when a user in the CDN B domain sends a request for these new contents to CDN B, the request is redirected to CDN A, under the dispatch control of the CDN manager, to obtain the contents the user requests.

7 Requirements for unified management of CDNs

7.1 Request routing

A CDN manager is required to route end user content requests globally among several CDNs. The features of global request routing include:

- routing end user content requests to the destination cache server in one CDN according to the traffic control policy pre-defined in the CDN manager;

NOTE – Traffic control policy can allow, for example, the allocation of network resources or steering of traffic concerning the load of cache servers and CDNs, location, time and a service level agreement (SLA) agreed by CPs.

- supporting mechanisms of both domain name system (DNS) canonical name (CNAME) and uniform resource locator (URL)forward processes to route end user content requests.

7.2 Routing policy management

- A CDN manager is required to support the following kinds of routing polices:
  - dispatching requests according to the domain name or destination Internet protocol (IP) address in a user request and being supportive of routing requests with a particular domain name to a particular CDN system;
  - dispatching requests according to the source IP address of a user and being supportive of routing requests with a particular source IP address (segment) to a particular CDN system;

- the CDN manager is required to support a default policy, that all the requests are routed to a particular CDN;
- the CDN manager is required to support a general policy for abnormal scenarios, when the CDN manager loses control of a CDN or if a CDN breaks down, all requests are routed to another CDN;
- the CDN manager is required to manage policies according to operational requirements.

7.3 Requirements for CDN status management

The CDN manager is required to actively monitor the online or offline status of a dispatch subsystem and cache servers in CDN periodically and map the information to the general status of availability of the CDN.

7.4 Requirements for content storage metadata management

- The CDN manager is required to create a new content storage metadata when a CP injects new content into a CDN.
- The CDN manager is required to update the content storage metadata when content is synchronized between different CDNs.
- The CDN manager is required to provide content storage metadata according to requests from the CDN.
- The CDN manager is required to delete the content storage metadata when content is deleted in all CDNs.

NOTE – Content storage metadata includes a set of information about the content stored in CDNs, including identifier (e.g., domain name, hash value), location (e.g., CDN A)

7.5 Requirements of network management

A CDN manager is required to support network-related management capabilities with the following aspects:

- receiving service logs generated by cache servers and dispatch sub-systems in a CDN;
- receiving service performance reports from the CDN and generating a global key performance indicator (KPI) report to a CP by domain granularity;
- receiving equipment performance report from the CDN;
- monitoring alarm status of the CDN.

7.6 Requirements of charging

A CDN manager is required to support charging features that include the following aspects:

- charging policy management and enforcement;
- generating data records according to charging policies or traffic or content properties (content type, size, encoding, bitrates and application-specific parameters, such as video resolution and frame rate).

NOTE 1 – Traffic flows may have different charging rates, e.g., some flows from a particular CP may be free of charge, while other traffic flows are charged at normal rates.

NOTE 2 – If user traffic was routed to a cache server deployed in a CDN, it is the cache server's responsibility to generate the traffic data records and interact with the CDN manager for effective charging record generation.

NOTE 3 – "Traffic data records" in this Recommendation are charging records according to the charging policy and traffic parameters, while "charging data record" is a specific term used for charging of communication or traffic. To avoid confusion, the term traffic data record is used in this Recommendation.

NOTE 4 – Traffic data records do not contain any private user data.

8 Mechanisms for unified management of CDNs

8.1 Framework for unified management of CDNs

Figure 4 shows the framework for unified management of CDNs:

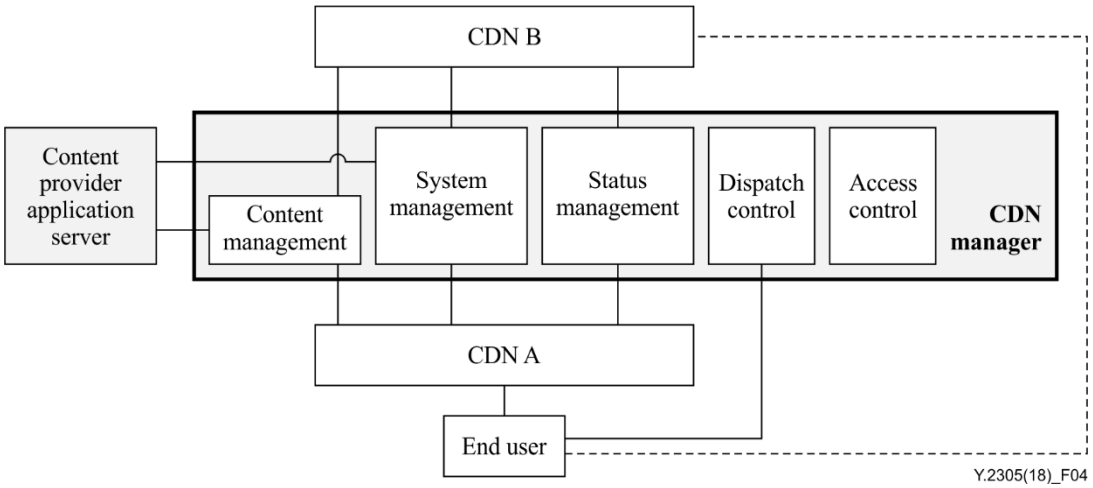

Figure 4 – Framework for unified management of CDNs

NOTE – The lines between the end user, CDN A and CDN B indicate that the end user is able to send content requests and receive the content from CDN A and CDN B. The continuous line means CDN A is primary for the end user. The dotted line means CDN B is a candidate for the end user.

In this framework, the CDN manager plays a key role in unified management of CDNs, in which the modules described in clauses 8.1.1 to 8.1.5 are identified.

8.1.1 Content management

This module creates, provides, processes and synchronizes the information of content in CDNs, with the following specific functionalities:

- receiving the creation request from the CP's application server (AS) when new content is injected into a CDN;
- creating content storage metadata according to the creation request, which includes what the content's name is and which CDN it is stored in;
- receiving the updating request from CDNs when the content is synchronized between them;
- updating content storage metadata according to the updating request;
- receiving the deletion request from a CDN when content is removed;
- deleting content storage metadata according to the deletion request;
- receiving the enquiry request from a CDN;
- providing content storage metadata to a CDN according to the enquiry request.

8.1.2 Status management

This module receives, provides, processes and synchronizes the status of CDNs, with the following specific functionalities:

- updating online or offline status of a CDN, including online or offline status of dispatch subsystem and cache servers in this CDN;
- mapping online or offline status of a CDN to this CDN's general status of availability;
- receiving the enquiry request of a CDN availability status from other CDNs;

– providing the required CDN availability status according to the enquiry request.

8.1.3 Dispatch control

This module routes content requests from an end user, with the following specific functionalities:

– receiving the content request from an end user;

– providing the destination CDN to end users according to the content request from end users.

8.1.4 Access control

This module provides the capability for IP access control to enable the CDN manager to be connected with external legal CDNs, with the following functionalities:

– transmitting data packages from certificated CDNs and end users in the access control list (ACL);

– supporting creation, reading, updating and deletion of the ACL.

8.1.5 System management

This module is in charge of routing policy management, network-related management and generation of charging information, with the following functionalities:

– supporting creation, reading, updating and deletion of routing policies;

– receiving service logs and equipment performance report from CDNs;

– monitoring alarm status of CDNs;

– generating a global KPI report in the service domain;

– generating charging information according to the KPI report;

– providing the KPI report and charging information to the CP AS.

8.2 Procedures of unified management on CDNs

8.2.1 Content management

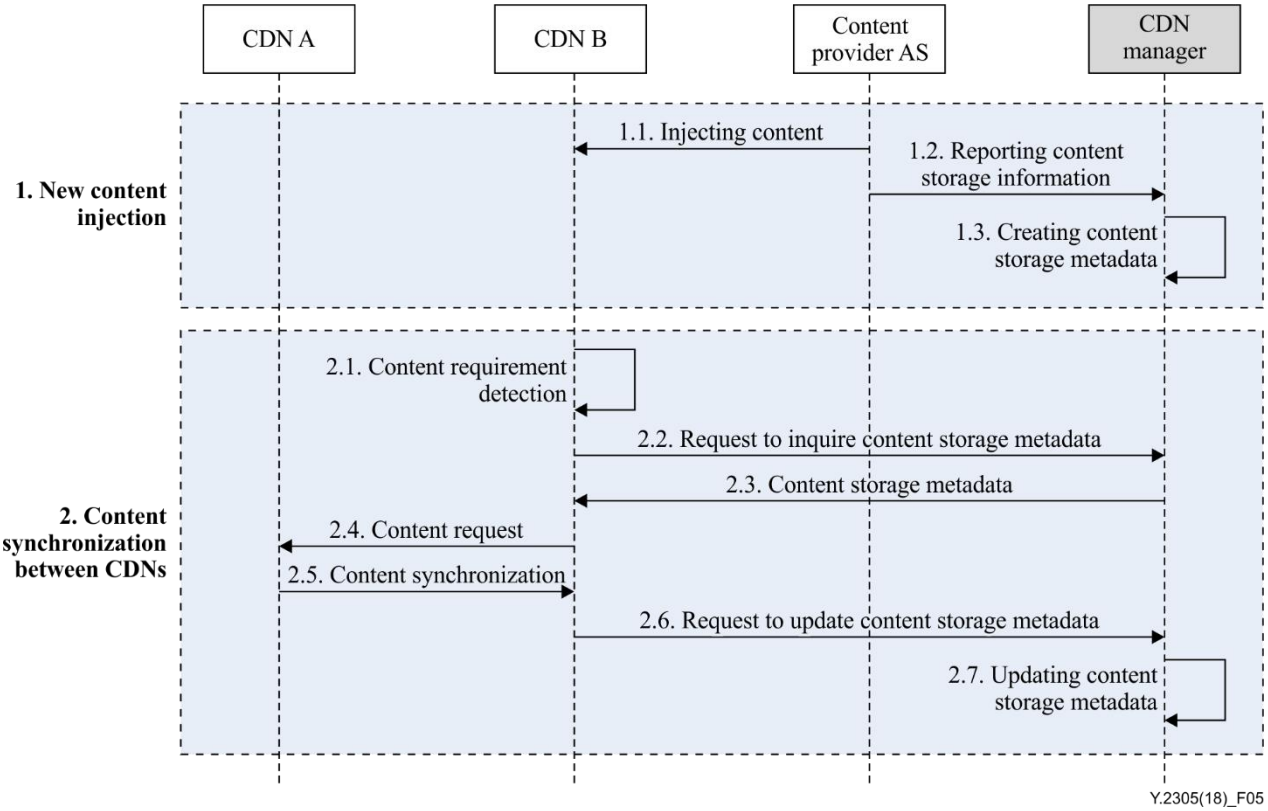

Figure 5 – Procedures for content management

i New content injection

i.1 A CP injects new content into a CDN.

i.2 The CP reports the descriptive information of what the content name is and which CDN it is stored in to the CDN manager.

i.3 The CDN manager creates the content storage metadata according to the report from the CP.

ii Content synchronization between CDNs

ii.1 CDN B detects some content that is very popular, but not stored locally, and generates a requirement for this content.

ii.2 CDN B sends a content storage metadata request to CDN manager.

ii.3 The CDN manager responds to CDN B with the requested metadata, which indicates the content is stored in CDN A.

ii.4 CDN B resolves the metadata and sends the request to CDN A to get the content.

ii.5 CDN A transfers the content to CDN B.

ii.6 CDN B reports the descriptive information of what the content name is and which CDN it is stored in to the CDN manager.

ii.7 The CDN manager creates the content storage metadata according to the report from CDN B.

8.2.2 Status management

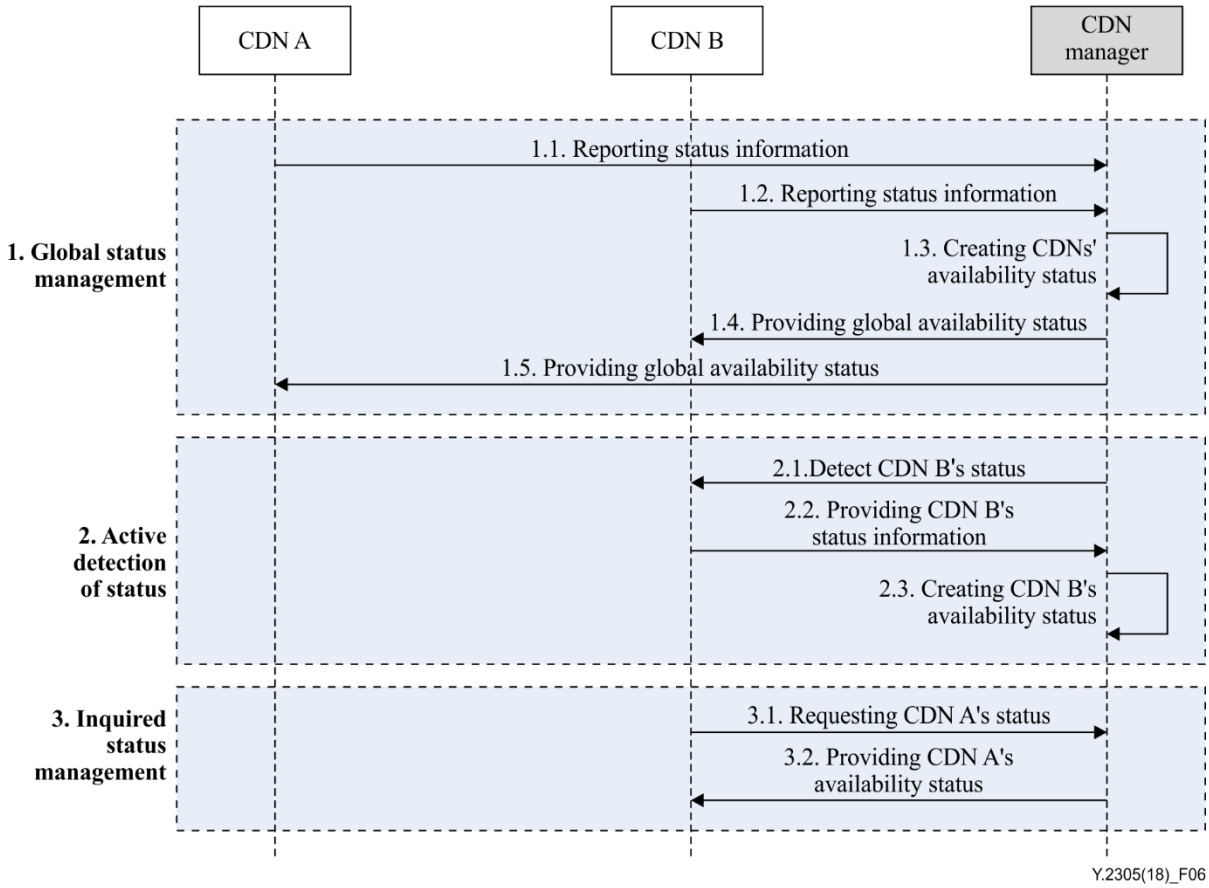

Figure 6 – Procedure for status management

i Global status management

i.1 CDN A reports the online/offline status to the CDN manager periodically.

i.2 CDN B reports the online/offline status to the CDN manager periodically

i.3 The CDN manager maps the online/offline status of each CDN to the general status of availability of this CDN, and creates the global availability status of all CDNs.

i.4 The CDN manager provides the global availability status to CDN A.

i.5 The CDN manager provides the global availability status to CDN B.

ii Active detection of status

ii.1 The CDN manager detects the online/offline status of CDN B.

ii.2 CDN B replies with the status information to the CDN manager.

ii.3 The CDN manager maps the status of CDN B to general status of availability of this CDN.

iii Enquired status management

iii.1 CDN B sends an availability status of CDN A request to the CDN manager.

iii.2 The CDN manager provides the availability status of CDN A to CDN B.

8.2.3 Request routing

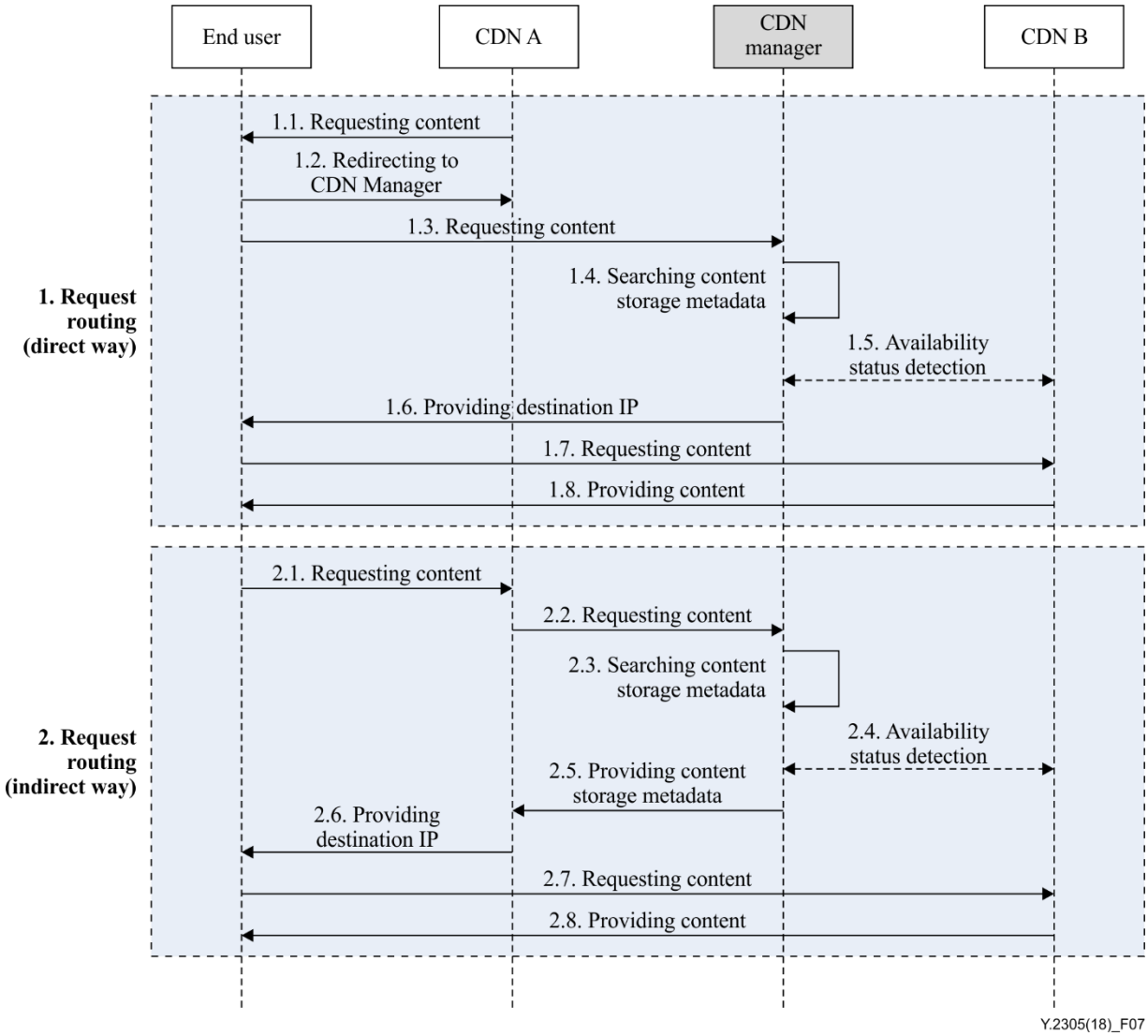

Figure 7 – Procedure of request routing

i Request routing (direct way)

i.1 An end user requests access to the content in CDN A.

i.2 CDN A does not store the requested content, and redirects the end user to the CDN manager.

i.3 The end user sends the content request to the CDN manager.

i.4 The CDN manager searches the content storage metadata and finds out the content is stored in CDN B.

i.5 The CDN manager actively detects the availability status of CDN B (see 8.2.2-ii).

i.6 The CDN manager provides the destination IP address (where the requested content is stored in CDN B) to the end user.

i.7 The end user sends a request for the content to CDN B.

i.8 CDN B responds with the content to the end user.

ii Request routing (indirect way)

ii.1 An end user requests access to the content in CDN A.

ii.2 CDN A does not store the requested content, but requests the content storage metadata from the CDN manager.

ii.3 The CDN manager searches the content storage metadata and discovers that the content is stored in CDN B.

ii.4 The CDN manager actively detects the availability status of CDN B (see 8.2.2-ii).

ii.5 The CDN manager provides the content storage metadata to CDN A.

ii.6 CDN A resolves the metadata and replies with the destination IP address to the end user.

ii.7 The end user sends a request for the content to CDN B. **ii.8**CDN B responds with the content to the end user.

9 Security considerations for unified management of CDNs

The security considerations for unified CDNs management are aligned with the content delivery functional architecture security requirements of the next generation network (NGN) according to [ITU-T Y.2019], with the following additions:

- the CDN manager is required to provide security mechanisms for managed CDNs that are authorized and authenticated legally, avoiding connexion to any CDN from a third party;
- the CDN manager is required to provide protected ACLs to prevent tampering or hacking by illegal parties;
- the CDN manager is required to provide secure authentication and authorization mechanisms for CPs who sign a SLA with the operator of the CDN manager.

Appendix I

Use cases of unified management of CDNs

(This appendix does not form an integral part of this Recommendation.)

I.1 Use case I: Control capability 1 – content sharing

Content caching has gained rapid growth of interest as a solution to improve content accessibility and quality of service (QoS) as well as to accelerate responses to user requests. Traditionally, CPs deploy lots of servers in the datacentres as fixed content delivery networks (FCDNs), to improve the experience for fixed network users, which attracts CPs to inject their content into FCDNs.

The fast development of smart phones and pads means that users now often watch videos on these smart terminals. Recently, telecom carriers have established mobile content delivery networks (MCDNs) on which content cache servers are deployed, such as radio access networks (RANs) or an evolved packet core (EPC), to improve experience for mobile users.

Subject to the storage volume of the servers deployed in mobile networks, content with highest popularity should be placed on cache servers in RANs or an EPC, while, content with low popularity should be placed on cache servers deployed in the FCDNs. Therefore, the CDN manager should provide the capability to implement content sharing between different CDNs.

NOTE – Content popularity (which may depend on not only content itself, but also the profiles of the viewers) can be determined by the frequency of the user requests and the review duration of the contents. Therefore, user mobility may cause the content in the cache to change frequently, resulting in inefficiency in content caching. Therefore, the data analytics function needs to analyse the data related to both content and users in order to accurately determine or predict content popularity.

Figure I.1 depicts content sharing between different CDNs.

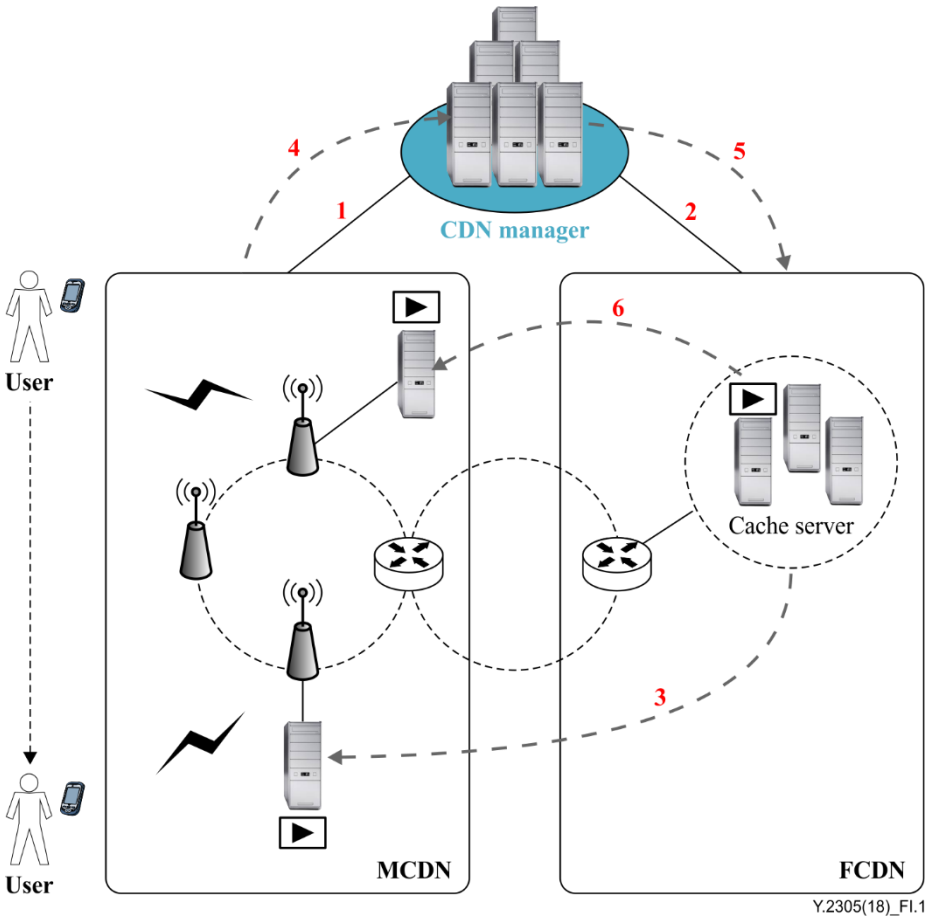

Figure I.1 – Content sharing between different CDNs

i.1 Lots of mobile users watch videos on mobile networks. The MCDN notifies the CDN manager to transfer the content from the FCDN.

i.2 The CDN manager requests the FCDN to transfer the content.

i.3 The FCDN transfers the content to the related server deployed in the MCDN.

i.4 When the MCDN notices that users have moved to another base station, then the MCDN requests the CDN manager to transfer content to the new server.

i.5 The CDN manager requests the FCDN to transfer the content.

i.6 The FCDN transfers the content to the new server deployed in the MCDN.

I.2 Use case II: Control capability 2 – request routing (direct way)

If a user wants to access contents stored in a certain CDN, the CDN manager provides a direct solution to route the user DNS request to the appropriate cache server in this CDN.

Figure I.2 shows a specific case of request routing (direct way) under the control of the CDN manager.

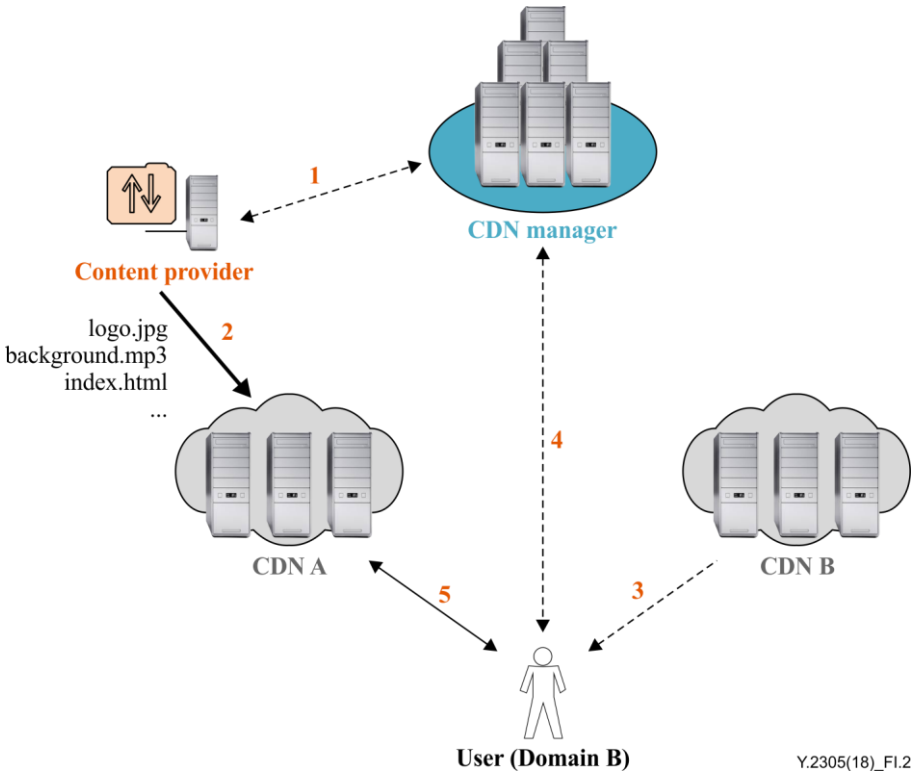

Figure I.2 – Request routing (direct way) under the control of the CDN manager

The following is the specific process.

1 When the CP is ready to inject its new content (e.g., newLogo.png) into CDN A (provided by the operator), it interacts with the CDN manager to get the permission to inject contents into CDN A.

2 If it is allowed, the CP injects new content into CDN A;

3 A user (who is in the domain of CDN B) in the operator's network requests the "newLogo.png" (e.g., whose domain name is "xxx.com") of the CP. The user sends a DNS request (for the resolution of xxx.com) to CDN B. CDN B detects that the target content is not stored locally and redirects this request to the CDN manager (by responding to the user to resend it to the CDN manager).

4 The user resends the DNS request (for the resolution of xxx.com) to the CDN manager. The CDN manager detects the requested content (newLogo.png with a domain name xxx.com) is stored in CDN A, and responds with CDN A as the request's destination to the user.

5 The user sends the DNS request (for the resolution of xxx.com) to CDN A, and after a series of processes inside CDN, finally gets the newLogo.png from a suitable cache server.

I.3 Use case III: Control capability 2 – request routing (indirect way)

In contrast to use case II, in this case, the CDN manager does not participate in the user requesting routing activity. The request of the user (who is in the domain of CDN B) is directly routed by CDN B to the CDN A cache server that stores the target content, according to the content storage metadata and availability status of CDN A provided by the CDN manager.

Figure I.3 shows a specific case of request routing (indirect way) under the control of the CDN manager.

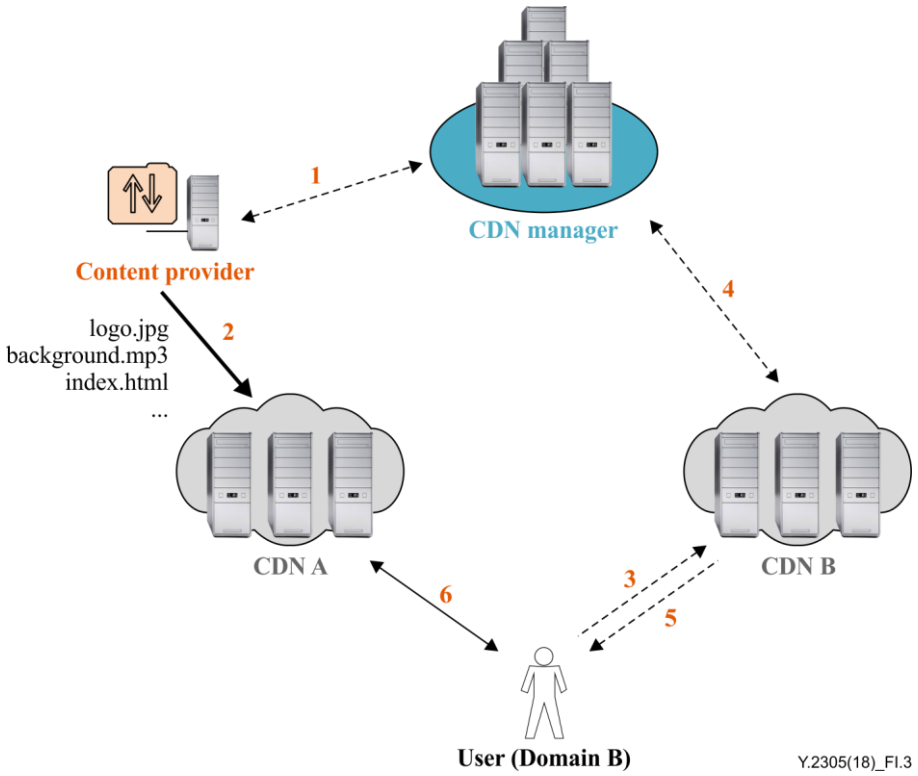

Figure I.3 – Request routing (indirect way) under the control of the CDN manager

The following is the specific process.

1 When the CP is ready to inject its new content (e.g., newLogo.png) into CDN A (provided by the operator), it interacts with the CDN manager to get the permission to inject contents into CDN A.

2 If it is allowed, the CP injects new content into CDN A.

3 A user (who is in the domain of CDN B) requests the newLogo.png (e.g., whose domain name is xxx.com) of the CP. The user sends a DNS request (for the resolution of xxx.com) to CDN B.

4 CDN B addresses this content storage metadata request to the CDN manager. The CDN manager detects the content is in CDN A and responds with the content storage metadata (identifier and location of the content included) and the availability status of CDN A to CDN B.

5 CDN B examines the content storage metadata and status. If CDN A is available, CDN B responds with CDN A as the request's destination to the user.

6 The user sends the DNS request (for the resolution of xxx.com) to CDN A, and after a series of processes inside CDN, finally gets the newLogo.png from a suitable cache server.

I.4 Use case IV: Management capability

In this use case, the CDN manager receives operational information both from CPs and CDNs, which are intended to be managed globally by the CDN manager.

Figure I.4 shows interactions between the CP, CDN manager and CDN.

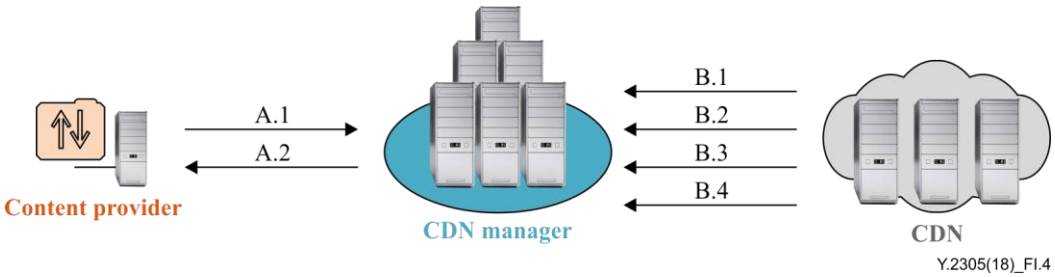

Figure I.4 – Interactions between the content provider, CDN manager and CDN

The following are specific items with examples provided by each part.

- Between CP and CDN manager:
  - A.1: The CDN manager receives content identifications and their locations from a CP.

    For example, if CP A injects new content (with domain name xxx.com) into CDN A, it will report this domain name (xxx.com) as an identification, and content location (CDN A) to the CDN manager.
  - A.2: The CDN manager provides KPIs to a CP by domain granularity.

    For example, contents with domain name xxx.com have already stored in a CDN that is managed by the CDN manager, and the CDN manager provides indicators of xxx.co' to the CP according to its requirements.

Domain name	Request times	Success rate	…
xxx.com	132,65	96.3%	…
…	…	…	…

- Between CDN and the CDN manager:
  - B.1:The CDN manager receives a service performance report from the CDN.

    For example, the CDN reports operation and service information regularly to the CDN manager.

Key	Value
CDN Name	CDN A
Service Traffic Volume	96,236,863 GB
Source Traffic Volume	612,963 GB
Hit Rate	83%
…	…

  - B.2: The CDN manager receives an alarm status from the CDN.

    For example, in particular conditions, such as one cache server's utilization ratio of hardware reaching the alarm line (90%), the CDN reports related information to the CDN manager, to avoid further content injection into this server.
  - B.3: The CDN manager receives service logs from the CDN.

    For example, CDNs collect service logs generated by cache servers and upload them to the CDN manager.
  - B.4: The CDN manager receives the online/offline status from the CDN.

    For example, the CDN manager detects heartbeat messages from the CDN to determine whether the CDN is alive.

Appendix II

Introduction of a DNS CNAME and URL forwarding mechanism

(This appendix does not form an integral part of this Recommendation.)

II.1 DNS CNAME

CNAME records can be used to alias one name to another [b-IETF RFC 2219].

For example, if a content/service provider owns a server with IP address 10.1.1.1, it might normally be accessed through "xxx.com" (DNS A record). This provider may also want to access it through "yyy.com". One way is to add a CNAME record that points "yyy.com" to "xxx.com". During a visit to "yyy.com", a user will see the exact same content as "xxx.com".

DNS CNAME has the following advantages:

- several CNAMEs can point to one DNS A record;
- when an IP address is changed, the provider just needs to change the DNS A record accordingly, without changing any CNAME.

II.2 URL forwarding

URL forwarding allows a provider to redirect, or "point", its domain name to a URL [b-IETF RFC 7231]. This is useful when the provider wants multiple domain names to go to the same website, or make use of an existing website.

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