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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

Next Generation Networks – Frameworks and functional architecture models

Distributed service networking content distribution functions

Recommendation ITU-T Y.2084

International Telecommunication Union

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Recommendation ITU-T Y.2084

Distributed service networking content distribution functions

Summary

Recommendation ITU-T Y.2084 specifies the functions for distributed service networking (DSN) content distribution functions (CDFs), taking into account the requirements and capabilities for DSN as described in Recommendation ITU-T Y.2206 and the architecture for DSN as described in Recommendation ITU-T Y.2080.

The main objective of this Recommendation is to provide guidance regarding the design of content-oriented services and applications making use of DSN CDF.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.2084	2015-06-13	13	11.1002/1000/12511

Keywords

CDF, content distribution function, distributed service networking, DSN, functional description, information flows, reference point.

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1 Scope

This Recommendation specifies the distributed service networking (DSN) content distribution functions (CDFs) in detail, including:

– the detail functions of DSN CDF;

– the description of reference points related to DSN CDF;

– the information flow related to DSN CDF.

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.1910] Recommendation ITU-T Y.1910 (2008), *IPTV functional architecture*.

[ITU-T Y.2012] Recommendation ITU-T Y.2012 (2010), *Functional requirements and architecture of next generation networks*.

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

[ITU-T Y.2080] Recommendation ITU-T Y.2080 (2012), *Functional architecture for distributed service networking*.

[ITU-T Y.2206] Recommendation ITU-T Y.2206 (2010), *Requirements for distributed service networking capabilities*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 buffer map [ITU-T Y.2080]: A map indicating the availability of chunks which can be shared with other DSN nodes.

3.1.2 chunk [ITU-T Y.2080]: A basic unit of data resulting from partitioning a content file into defined component parts. A DSN node may use a chunk as a unit of storage, advertisement and exchange among peers.

3.1.3 content node [b-ITU-T Y Suppl.10]: A DSN node which can be used for the media content distribution, storage and/or caching, etc.

3.1.4 distributed service networking [ITU-T Y.2206]: An overlay network which provides distributed and manageable capabilities to support various multimedia services.

3.1.5 DSN node [ITU-T Y.2206]: A node used in DSN providing distributed functionalities, including distributed routing and distributed storage.

3.1.6 functional entity [ITU-T Y.2012]: An entity that comprises an indivisible set of specific functions. Functional entities are logical concepts, while groupings of functional entities are used to describe practical, physical implementations.

3.1.7 video on demand (VoD) [ITU-T Y.1910]: A service in which the end user can, on demand, select and view video content and where the end user can control the temporal order in which the video content is viewed (e.g., the ability to start the viewing, pause, fast forward, rewind).

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 cache: A device that has been set up to store content (e.g., web pages, files, videos and audios) that has been accessed by users on a network. A user trying to access content that has already been stored on the cache will be sent the stored version instead of downloading the content from the content source again.

3.2.2 content delivery network: A content delivery network (CDN) is a system of distributed servers that deliver content (e.g., web pages, files, videos and audios) to users based on pre-defined criteria such as the geographic locations of users, the status of the content delivery server and the IP network connection.

3.2.3 live streaming: A video service in which a continuous stream flows in real time from the service provider to the terminal device and the user cannot control the temporal order in which content is played.

3.2.4 P2P cache: A computer or network device that has been set up to store peer-to-peer (P2P) content (e.g., file chunks, video chunks, audio chunks) that is popular and has been accessed by users. It works similar to cache. The only difference is that P2P cache supports P2P protocol and serves P2P content. Sometimes, cache and P2P cache could be co-located in the same device.

3.2.5 P2P CDN: The content delivery network (CDN) in which content is delivered in the mode of P2P; the delivery may be from CDN server to users or from CDN servers to CDN servers.

NOTE – Delivering in the mode of P2P means that the content is sliced into chunks, and the copies of the chunks are stored in multiple CDN servers. Users or CDN servers can download chunks of the content from multiple CDN servers.

4 Abbreviation and acronyms

This Recommendation uses the following abbreviations and acronyms:

CDF Content Distribution Function

CDN Content Delivery Network

CP Content Provider

CP-FE Content Processing Functional Entity

CSAF Content Service Application Function

CS-FE Cache/Storage Functional Entity

DBC-FE Distribution Control Functional Entity

DD-FE Distribution and Delivery Functional Entity

DLC-FE Delivery Control Functional Entity

DSN Distributed Service Networking

EF End-user Function

ER-FE Error Recovery Functional Entity

FE Functional Entity

GSLB Global Server Load Balancer

ISP Internet Service Provider

MF Management Function

P2P Peer-to-Peer

RLF Resource Location Function

SLB Server Load Balancer

SP Service Provider

TOCF Traffic Optimization Control Function

UE User Equipment

UGC User Generated Content

URL Uniform Resource Locator

VoD Video on Demand

5 Conventions

In this Recommendation the following conventions apply:

1） The meaning of functions is as follows:

Functions: In the context of DSN content distribution function, "Functions" are defined as a functional group composed of functional entities and is represented by the following symbol:

2) DSN network means the network constructed based on DSN.

6 Functional description of DSN CDF

This clause describes the CDF functions, reference points related to CDF, and typical information flows.

6.1 CDF functions

CDF mainly performs the following functions:

1) Content ingestion
   - DSN CDF supports automatic and manual content ingestion from the content service application function (CSAF).

2) Content cache/store
   - DSN CDF supports storing content in the form of chunks.
   - DSN CDF supports time-to-live for stored content.

NOTE 1 – Some content stored by CDF may be available only within a certain window of time. Providing a time-to-live value for stored data can reduce management overhead by avoiding "delete" commands sent to CDF storage.

- DSN CDF supports deletion of stored content.

NOTE 2 – A DSN node should be able to explicitly remove particular content (e.g., expired content).

3) Content processing

- DSN CDF supports content chunking and reassembly of chunks.
- DSN CDF supports content pre-processing before content distribution.

NOTE 3 – DSN CDF may perform content adaptation for different types of terminals and network environments.

4) Content transmission

- DSN CDF enables the content to be transferred in the form of chunks.
- DSN CDF supports buffer map exchanges between other CDFs and end-user functions (EFs).
- DSN CDF supports content distribution between CDFs

NOTE 4 – A DSN CDF can directly fetch data from other DSN CDFs. This helps to avoid additional transfers across Internet service provider (ISP) network links where possible.

- DSN CDF support content distribution to EFs.

NOTE 5 – DSN CDF supports centralized content distribution and distributed content distribution. Centralized content distribution means content is directly distributed from one specific DSN CDF, to all EFs, which require the content, without distributing to other DSN CDF nodes. Distributed content distribution means content is first distributed from one DSN CDF to other DSN CDFs located close to EFs, and is then distributed from these DSN CDFs to the requesting EFs.

- DSN CDF supports content delivery control. The delivery control can be per-application, per-peer or per-data.

NOTE 6 – An example for per-application control: one CDF node may run a video on demand (VoD) application and a live-streaming application simultaneously. The CDF node can control the delivery rate for different applications.

NOTE 7 – An example for per-peer control: application policy may indicate that certain peers have higher bandwidth. The CDF node should be able to satisfy such requirements.

NOTE 8 – An example for per-data control: application policy may indicate certain data is delivered with a higher priority. For example, chunks at the beginning part of a VoD content file are delivered at a higher rate so that the user can watch videos immediately when they are selected, while the chunks at the middle or rear part of the VoD content file is delivered at a lower rate, because there is enough time for the user to download the chunks.

- DSN CDF provides integrity checks and error recovery in content delivery.
- DSN CDF supports negotiation of content delivery protocol between other CDFs and EFs.

NOTE 9 – Because of particular application requirements and deployment considerations, different applications may support different protocols. DSN CDF is able to select an appropriate protocol.

- DSN CDF performs content access control.

NOTE 10 – A DSN CDF specifies access control policies for other DSN nodes (e.g., other CDF nodes, EF nodes). The authorized DSN nodes may read from or write to the DSN CDF.

- DSN CDF maintains and reports the flow statistics information to the management function (MF) for accounting or contribution statistics.

6.2 Reference points

Figure 6-1 illustrates the reference points related to CDF.

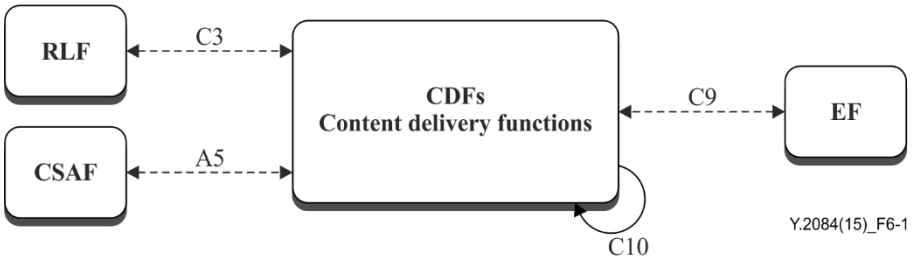

Figure 6-1 – Reference points related to CDF

6.2.1 Reference point C3

The reference point C3 is between the CDF and the resource location function (RLF).

This reference point is used by the CDF to:

- register content to RLF;
- request RLF for content location information;
- report the status of a node in which CDF resides to RLF. The status information includes: CPU usage, memory usage, disk usage and network interface usage, etc.;
- report event related information to RLF, e.g., report that the load of the node in which CDF resides reached its threshold;
- report content related information to RLF, e.g., the content availability or content popularity, etc.

6.2.2 Reference point C9

The reference point C9 is between CDF and EF.

This reference point is used by EF to:

- query a buffer map from CDF;
- request content from CDF.

6.2.3 Reference point C10

The reference point C10 is between CDFs.

This reference point is used by CDF to:

- query a buffer map from another CDF;
- request content from another CDF.

6.2.4 Reference point A5

The reference point A5 is between the CDF and the CSAF.

This reference point is used by CSAF to:

- direct the CDF to process (e.g., transcoding, encryption) content.

6.3 Information flows

6.3.1 Flow of content delivery from CDF to EF

Figure 6-2 shows the flow of content delivery from CDF to EF.

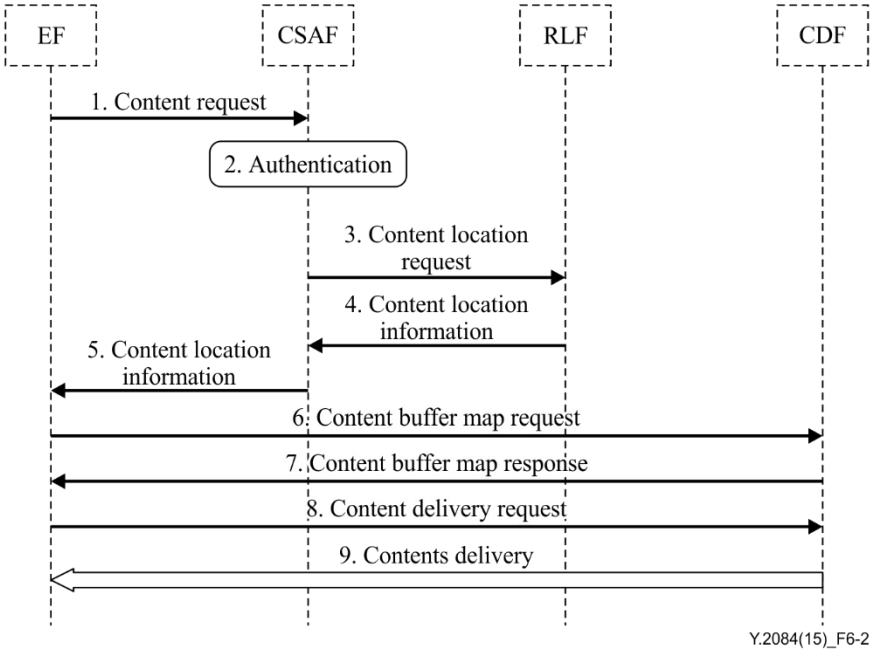

Figure 6-2 – Flow of content delivery

1) EF interacts with CSAF to request specified content with the content ID.
2) CSAF checks the authentication information of EF.
3) If the authentication succeeds, CSAF requests from RLF the location information of the content.
4) RLF sends the optimized location information of the content node(s) to CSAF. This information can be a peer list with the address of the content node(s).

NOTE – For the details of RLF getting optimal content nodes, refer to clause I.2.2 in [ITU-T Y.2080].

5) CSAF forwards the content location information to EF.
6) EF chooses preferred content node(s) from the peer list, and interacts with CDF to request the buffer map of the content.
7) CDF returns the buffer map of the requested content to EF.
8) According to the buffer map, EF requests from CDF a certain chunk of the requested content.
9) CDF sends the requested content chunk to EF.

6.3.2 Flow of content registration

Figure 6-3 shows the flow of content registration. This flow assumes that the user authentication has been finished.

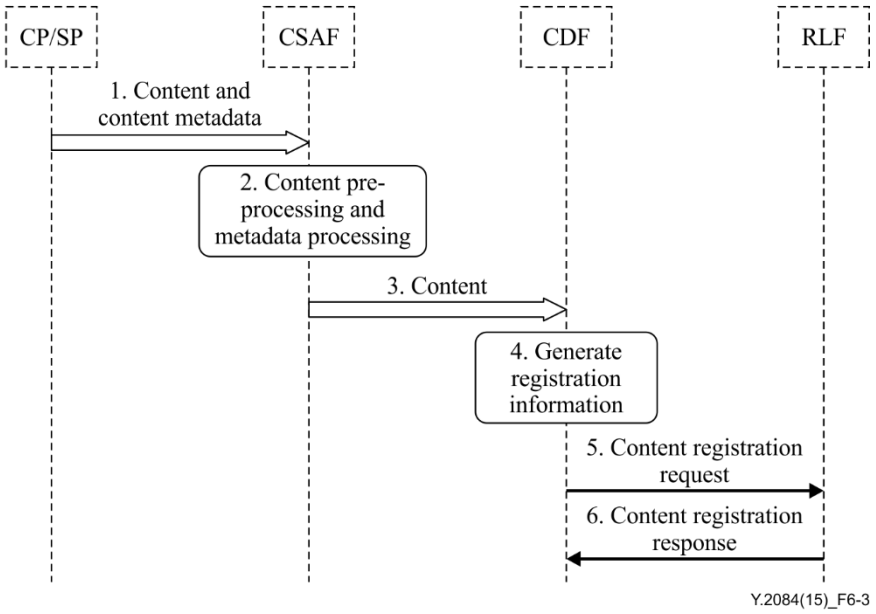

Figure 6-3 – Flows of content registration

1) The content provider (CP) provides the content and metadata to CSAF.

2) CSAF handles the metadata processing and content pre-processing procedures.

NOTE – The metadata processing includes the ID generation and the process of title, brief introduction, price, etc. The content pre-processing includes chunking, watermarking, advertising-inserting, format conversion, resolution conversion, etc.

3) CSAF ingests the content to CDF for further content distribution.

4) CDF generates the registration information, which includes the content ID and location of the content.

5) CDF initiates a content registration request to RLF.

6) RLF stores the registration information, and sends a response to inform CDF of the result.

6.3.3 Flow of buffer map requesting

Figure 6-4 shows the flow of the CDF requesting a buffer map from another CDF.

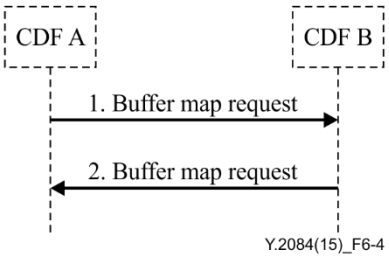

Figure 6-4 – Flow of CDF requesting buffer map from another CDF

1) CDF A sends a buffer map request to CDF B; the buffer map request contains the content ID.

2) CDF B returns the buffer map response to CDF A, indicating the content chunks it contains.

NOTE – After retrieving the buffer map, CDF A can send a request to CDF B to download the selected content chunks.

6.3.4 Flow of content distribution between CDFs

Figure 6-5 shows the procedures for content distribution between CDFs. This procedure applies when certain content is requested to be distributed from one CDF to another CDF. The CSAF initiates the content distribution from CDF 2 to CDF 1.

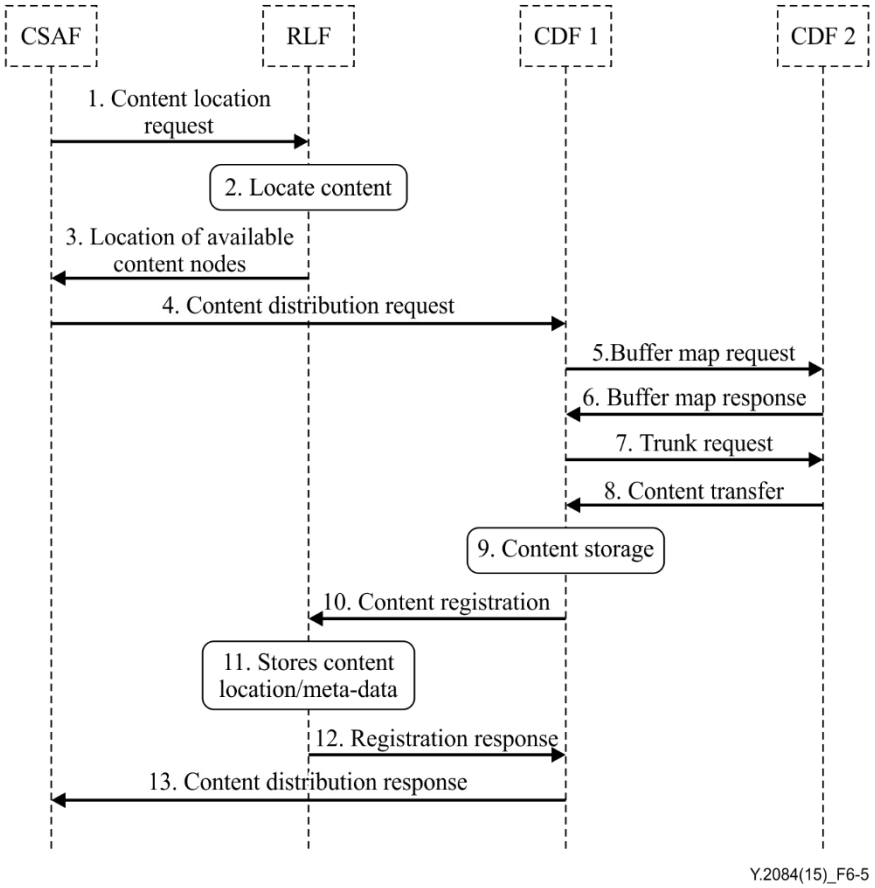

Figure 6-5 – Flow of content distribution between CDFs

1) CSAF requests from RLF the location information of content needed to be distributed.
2) RLF locates the requested content.
3) RLF replies to CSAF with the location of available content nodes.

NOTE – There may be more than one node; this flow takes CDF2 as an example. Other nodes follow the same procedure.

4) CSAF requests CDF 1 to retrieve content from CDF 2. This request should contain the location information of CDF 2.
5) CDF 1 sends a buffer map request to CDF 2. The buffer map request contains the content ID.
6) CDF 2 returns the buffer map to CDF 1, indicating the content chunks it contains.
7) CDF 1 sends a request to CDF 2 to download the selected chunks.
8) The content is transferred from CDF 2 to CDF 1.
9) CDF 1 stores the received content.
10) When content delivery finishes, CDF 1 initiates a content registration request to RLF. The request message contains the content ID and the location of the content.
11) When RLF receives the content registration request, it stores the content location.
12) RLF sends a response to inform CDF 1 that content has been registered.
13) CDF 1 sends a response to inform CSAF that the content has been distributed to CDF 1.

6.3.5 Flow of content time-to-live management

Figure 6-6 shows the procedures for content time-to-live management. This procedure applies for both content from the CP/service provider (SP) and the user generated content (UGC) content.

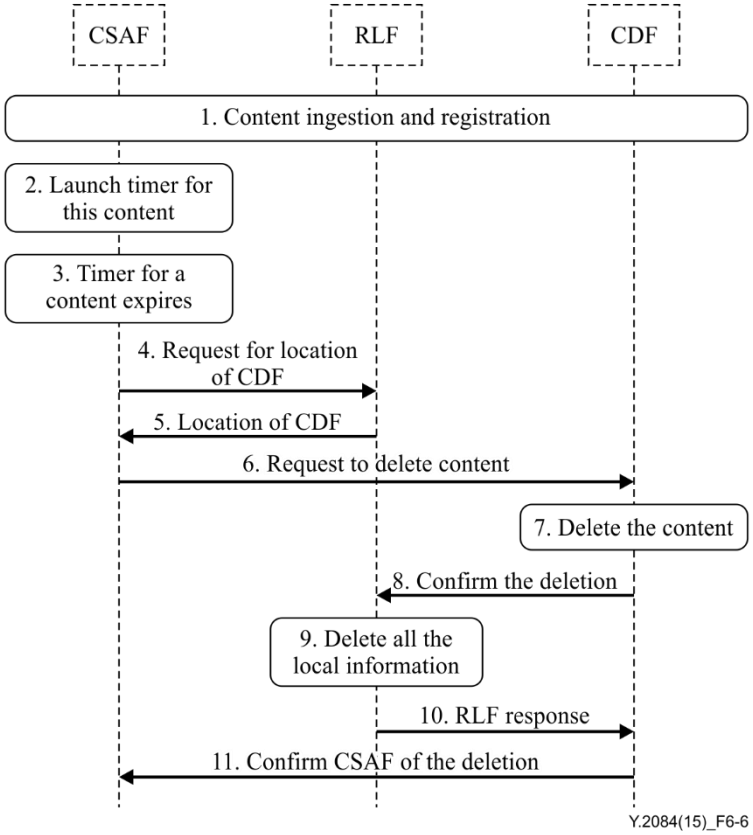

Figure 6-6 – Flows of content time-to-live management

1) CSAF registers content to RLF as described in clause 6.3.2.
2) CSAF stores the time-to-live information and launches a timer for the specific content.
3) When the timer for this content expires, CSAF recognizes that it is time for this content to be deleted.
4) CSAF requests from RLF the CDF's location information for the expired content.
5) RLF returns the CDF's location information to CSAF.
6) CSAF requests all the related CDFs to delete the expired content.
7) CDF deletes the expired content.
8) When content is successfully deleted, CDF confirms the content deletion to RLF.
9) When RLF receives all CDF deletion confirmations, RLF deletes local information for this content.
10) RLF informs CDF of the deletion results.
11) CDF informs CSAF of the final content deletion.

6.3.6 Flow of content deletion

Figure 6-7 shows the procedures for content deletion. This procedure applies for both content from the CP/SP and the UGC content.

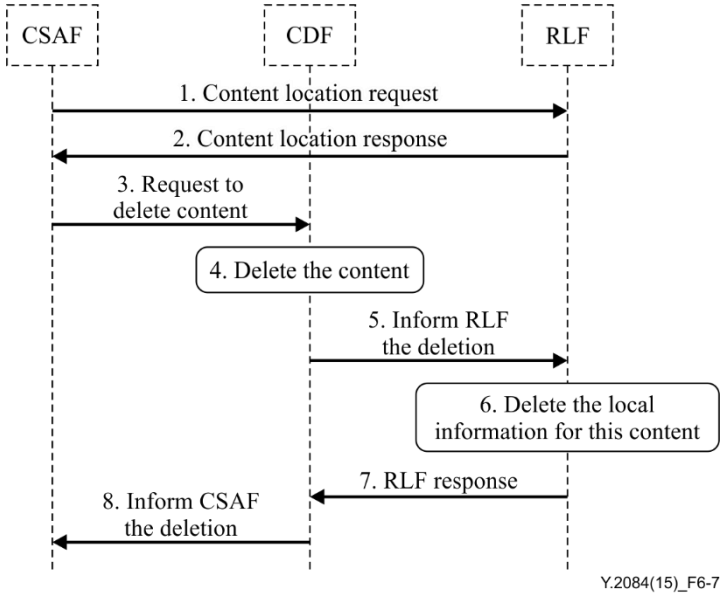

Figure 6-7 – Flow of content deletion

1) CSAF requests from RLF the content location to be deleted.
2) RLF returns the location information to CSAF.
3) CSAF requests the CDF to delete the content.
4) CDF deletes the content.
5) CDF informs RLF of the deletion.
6) RLF deletes local information for this content.
7) RLF returns the deletion result to CDF.
8) CDF informs CSAF of the content deletion.

7 Security considerations

Security considerations are not addressed in this Recommendation.

Appendix I

Detailed functional entity description of CDF

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

As described in [ITU-T Y.2080], RLF is the function responsible for the optimized source selection and geographical content distribution. Compared to the CDF of NGN [ITU-T Y.2019], there is less functionality in the CDF of DSN, which is more focused on data transmission and delivery (e.g., cache/storage, content transcoding, encryption, accessing authorization, flow control), and the functions of content location and distribution are taken over by the RLF. When a DSN content service provider wants to set up a content service, upon DSN networks, it only needs to follow the reference points and information flow descriptions among CDF and other functions, but leaves the functions inside CDF to its own implementation.

An illustration of the detailed functional entity (FE) description of CDF is given in this appendix only for better understanding of CDF functionalities. The functional architecture of DSN CDF references most parts of the definitions and descriptions from CDF of NGN [ITU-T Y.2019]. The major difference is that in DSN networks the content location and distribution are taken over by the RLF.

I.1 Functional architecture of CDF

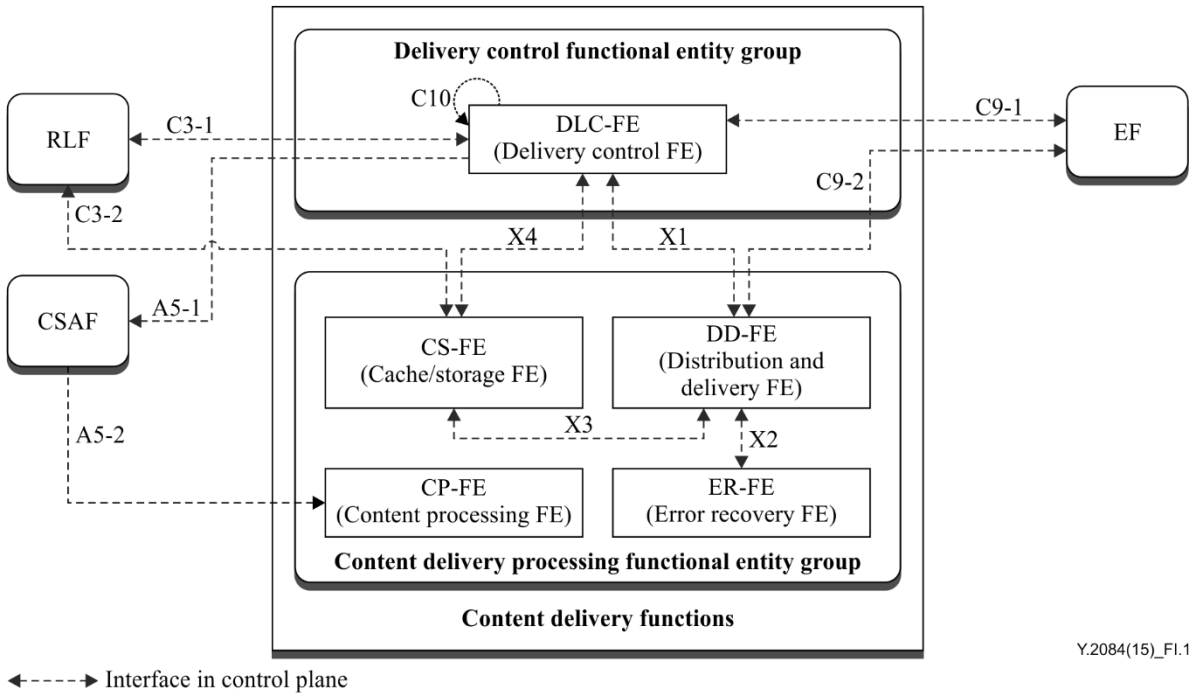

Figure I.1 – CDF functional architecture

Figure I.1 describes the detailed CDF architecture with FEs; it is compatible with the CDF architecture.

Further, each FE group includes several FEs:

– The DLC FE group includes delivery control functional entity (DLC-FE);

– The content deliver processing (CDP) FE group includes cache/storage (CS), distribution and delivery (DD), error recovery (ER), and content processing functional entities.

I.2 Functional entities of CDF

I.2.1 Delivery control functional entity

The DLC-FE handles control functional entities related to the content delivery processing FE (CDP-FE) group.

The DLC-FE supports content accessing authorization checks to the FEs, which belong to delivery processing FE groups.

The DLC-FE is responsible for setting up sessions (e.g., content resource and media negotiation) for media content delivery.

The DLC-FE manages the rate of transmission from the FEs, which belong to delivery processing FE groups, to recipients.

The DLC-FE manages interaction with the EFs for service such as trick mode.

The DLC-FE generates charging information based on traffic billing or content billing and reports it to CSAF.

The DLC-FE generates a buffer map based on buffer status information received from the cache/storage functional entity (CS-FE).

I.2.2 Cache/storage functional entity

The CS-FE is responsible for caching or storing the content in order to support time-shifted stream-based services, as well as file-based services.

The CS-FE reports its content and load status information to the distribution control functional entity (DBC-FE) in RLF.

I.2.3 Error recovery functional entity

The error recovery functional entity (ER-FE) serves to improve reliability in cases where network functions cannot provide sufficient quality of service (QoS). It generates additional information for a content stream, either proactively or on request, such that the recipients or senders, which have the error recovery functionality, can recover the content.

The ER-FE relies on other CDF to deliver the additionally generated information. It also relies on the availability of EF.

The ER-FE is selectively applied by forward error correction (FEC) or by retransmission.

I.2.4 Distribution and delivery functional entity

The distribution and delivery functional entity (DD-FE) is responsible for receiving the content from the CSAF and other FEs which belong to content delivery processing functional entity group, as well as distributing the content resource, which includes live streams or files, among the separate instances of FEs which belongs to content delivery processing functional entity group.

The DD-FE is also responsible for delivering the content to the EF under the control of DBC-FE and DLC-FE.

The DD-FE supports content retransmission potentially triggered by the ER-FE.

The DD-FE executes the flow control policy made by the delivery control functional entity.

The DD-FE selectively supports content tracing.

I.2.5 Content processing functional entity

The content processing functional entity (CP-FE) performs content processing under the control of the CSAF. The main functionalities are:

- content transcoding;
- content encryption;
- other functionalities, such as: watermarking, advertising-insertion into streams, format conversion, resolution conversion, editing, etc.

I.3 Reference points and interfaces

I.3.1 Reference point X1

The reference point X1 is between the DLC-FE and the DD-FE.

This reference point allows DLC-FE and DD-FE to interact for content accessing authorization.

This reference point allows DLC-FE to control DD-FE to send the requested data to the end users.

I.3.2 Reference point X2

The reference point X2 is between the DD-FE and the ER-FE.

This reference point is used for ER-FE to trigger content retransmission to DD-FE.

I.3.3 Reference point X3

The reference point X3 is between the CS-FE and the DD-FE.

This reference point is used for CS-FE to store content to DD-FE.

I.3.4 Reference point X4

The reference point X4 is between the CS-FE and the DLC-FE.

This reference point is used to request buffer status information from CS-FE and to give the buffer status information to DLC-FE.

Appendix II

Use cases of DSN CDF and information flow for different scenarios

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

This appendix illustrates how CDF is implemented in different scenarios such as: cache, content delivery network (CDN), peer-to-peer (P2P) cache and P2P CDF.

NOTE – For the following use cases, RLF acts as different entities depending on the service. In P2P scenarios, RLF acts as a tracker for the streaming services, such as live streaming, VoD and file downloading. While in non-P2P scenarios, RLF acts as an entity similar to DNS for web browser service, and acts as a global server load balancer (GSLB)/server load balancer (SLB) for the streaming services.

II.1 Traditional cache

II.1.1 Web browser

Figure II.1 shows the flow for user equipment (UE) to access web browser service through cache.

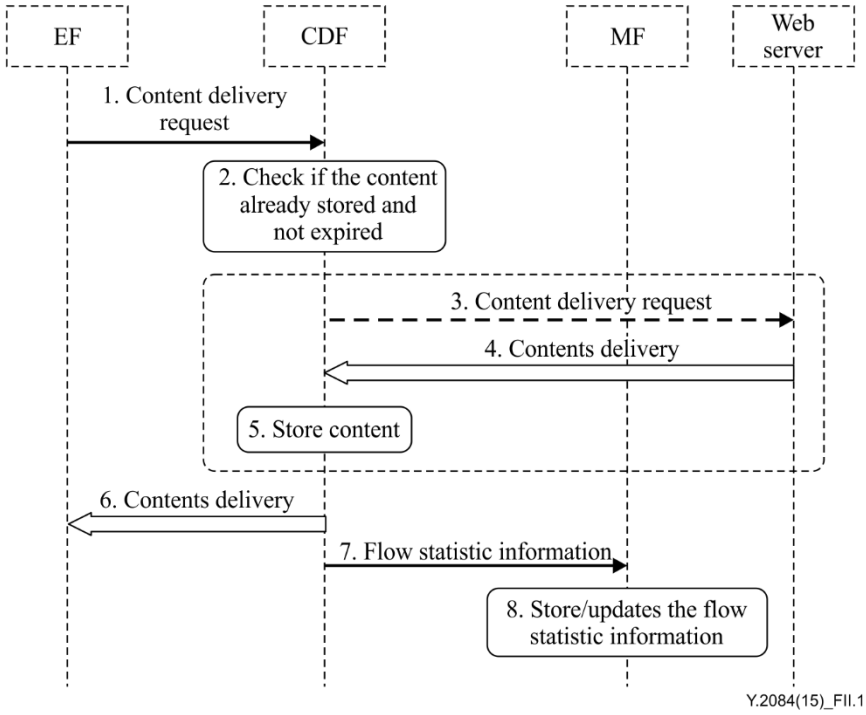

Figure II.1 – Flow of accessing web browsing service through traditional cache

1) EF requests the URI resource from a web server; the CDF acts as cache and heads off the request.
2) CDF checks if the resource is already stored; if CDF has stored the valid resource, go directly to step 6.
3) If CDF has not stored the resource or the stored resource is expired, CDF requests the resource based on the requested URI from the real web server.
4) Web server will forward the requested resource to CDF.
5) CDF stores the resource temporarily for the next EF requesting the same resource.
6) CDF forwards the requested resource to the EF.
7) At this time, CDF treats this content delivery as finished, and sends the flow statistic information to MF.

8) MF stores or updates the flow statistic information.

II.1.2 Live streaming

Figure II.2 shows the flow for a UE to access a live streaming service through traditional cache.

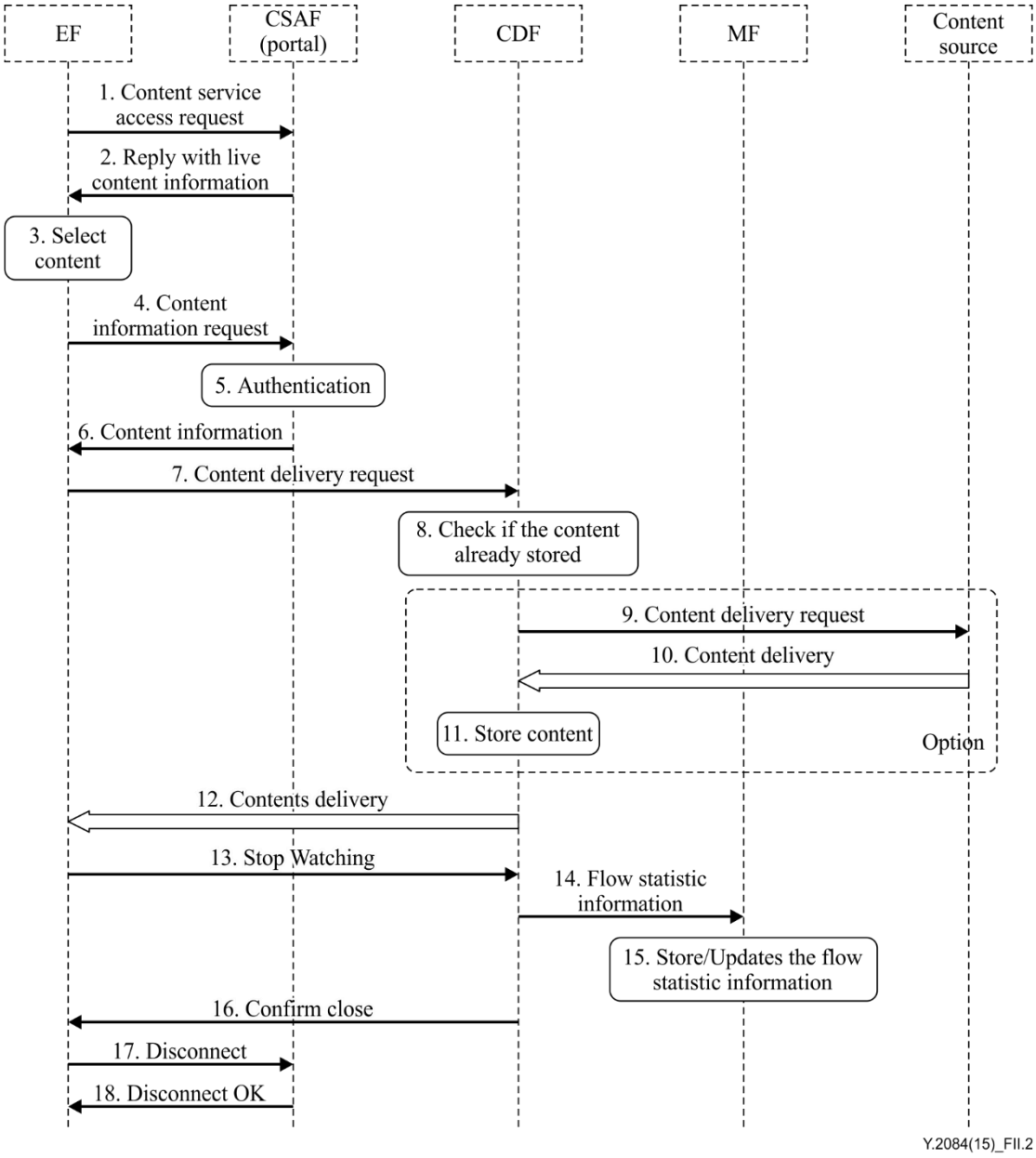

Figure II.2 – Flow of accessing live streaming service through traditional cache

1) EF sends a content service access request to CSAF to get the live streaming service information (including the available channels, the price of the channels, the introduction of the channels, etc.). The ID and device type of the EF are included in the content service access request. The content service access request may also include the authentication information of the user.

2) CSAF replies EF with the information list of channels. EF may present the information to the user.

NOTE – The information list contains the information related to the specific channel or video which CSAF needs to send to EF and it is used in the procedures of live streaming service and VoD service. The information

list consists of two categories of information: 1) service information which includes the playback rate, resolution, audio and video codec, brief introduction and the payment information. 2) location information which includes identification and address information of CDFs which EF will request.

3) EF selects the channel.

4) EF sends a content location request to CSAF to get the location information of the available content node. The content ID is included in the request. The request may also include the ID of the EF and authentication information.

5) CSAF checks the authentication information of EF.

6) If the authentication succeeds, CSAF forwards the content information to EF.

7) EF requests the content from the content source; the CDF acting as cache heads off the request.

8) CDF checks if the content is already stored; if CDF has stored the valid content, go directly to step 12.

9) If CDF has not stored the content, it requests the content from the content source.

10) Content source forwards the content to the CDF.

11) CDF stores the content temporarily for the next EF requesting the same content.

12) CDF forwards the content to the EF.

13) At the end of the viewing session, EF closes the streaming session.

14) When content delivery has finished, CDF sends the flow statistic information to MF.

15) MF stores or updates the flow statistic information.

16) CDF sends a confirm message to EF to confirm that the session is closed.

17) EF sends a disconnect message to CSAF to close the application session for this live steaming service.

18) CSAF confirms this close.

II.1.3 VoD and file downloading

The high-level sequence of flows for a UE to access VoD and file downloading service through traditional cache is similar to clause II.1.2 flows, except that the content type that EF requests is different. Refer to clause II.1.2 as this clause does not repeat the flows.

II.2 Traditional CDN

II.2.1 Web browser

Figure II.3 shows the flow for a UE to access web browsing service through traditional CDN.

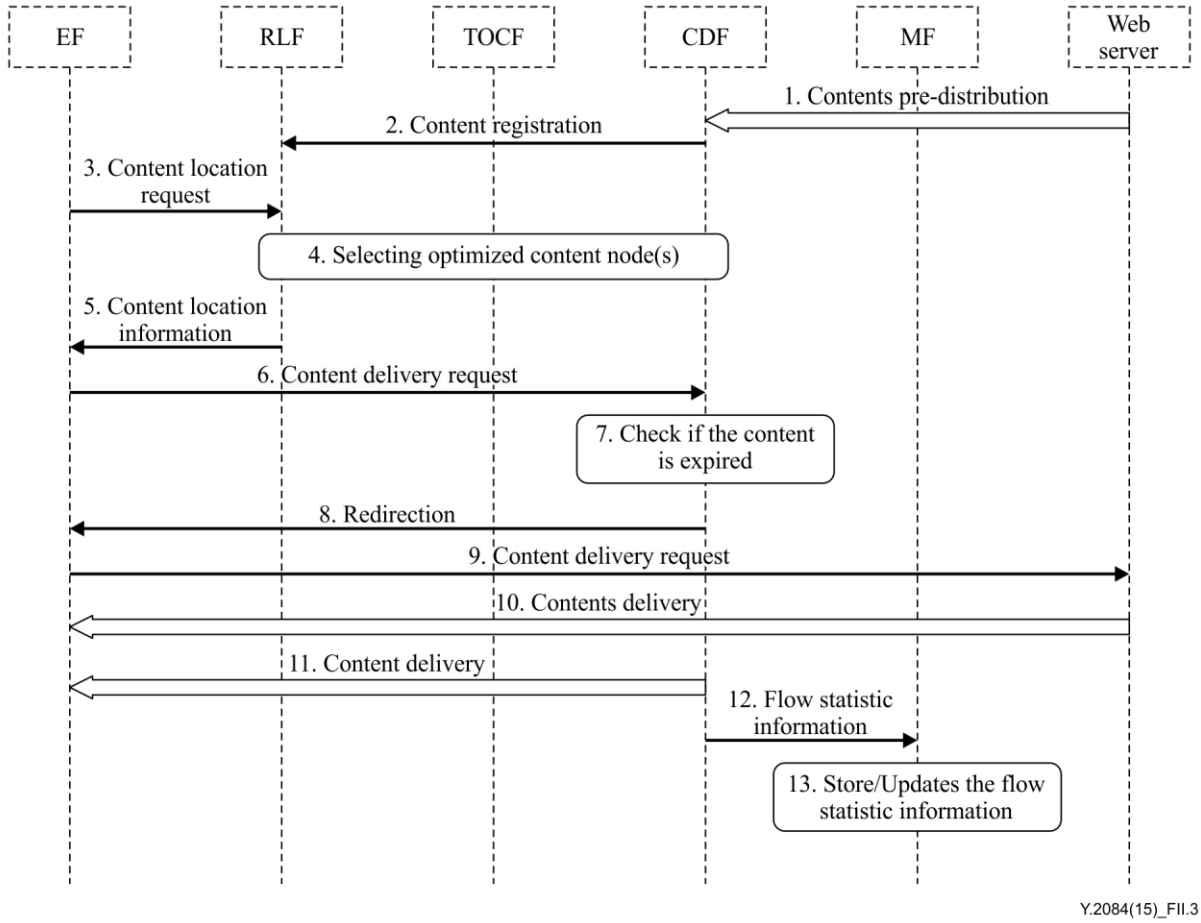

Figure II.3 – Flow of accessing web browsing service through traditional CDN

1) Web server pre-distributes the resource to CDF.

2) CDF registers the content to RLF.

NOTE – Refer to clause 6.3.2 for the flow of content registration.

3) EF sends a content location request to RLF to get the location information of available content nodes. The request URI is included in the request. The request may also include the ID of the EF and authentication information.

4) RLF interacts with traffic optimization control function (TOCF) to request optimized location information. RLF selects the optimal content nodes based on the information from TOCF.

5) RLF sends the optimized location information of the content nodes to EF.

6) EF requests the content from the CDF.

7) CDF checks whether the resource is expired; if CDF has stored the valid resource, go directly to step 11.

8) If CDF has not stored the resource or the resource stored is expired, CDF responds to EF with redirection to the requested URI from the source web server.

9) EF requests the original content from the source web server.

10) The web server forwards the requested resource to EF.

11) If CDF has stored the resource, CDF forwards the requested resource to EF.

12) Content delivery finishes, and then CDF sends the flow statistic information to MF.

13) MF stores or updates the flow statistic information.

II.2.2 Live streaming

Figure II.4 shows the flow for a UE to access live streaming service through traditional CDN.

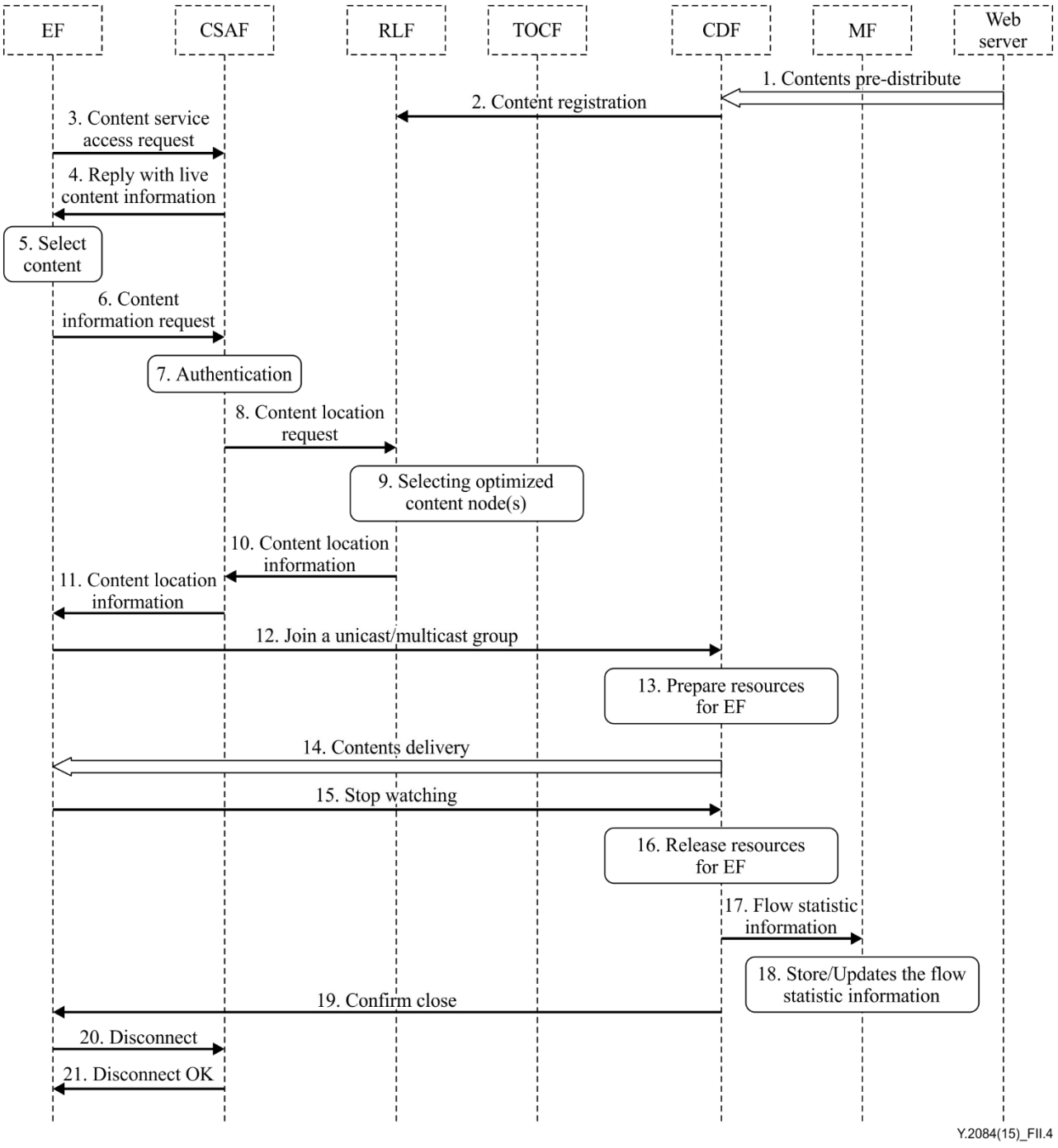

Figure II.4 – Flow of accessing live streaming service through traditional CDN

1) Web server pre-distributes the resource to other CDF(s).

2) CDF contacts RLF to register the content received.

3) EF sends a content service access request to CSAF to get the live streaming service information (including the available channels, the price of the channels, the introduction of the channels, etc.). The ID and device type of the EF are included in the content service access request. The content service access request may also include the authentication information of the user.

4) CSAF replies to EF with the information list of channels. EF may present the information to the user.

5) EF selects the channel.

6) EF sends a content location request to CSAF to get the location information of available content nodes. The content ID is included in the request. The request may also include the ID of the EF and authentication information.

7) CSAF checks the authentication information of EF.

8) If the authentication succeeded, CSAF requests the location information of the content from RLF.

9) RLF interacts with TOCF to request optimized location information. RLF selects optimal content nodes based on the information from TOCF.

10) RLF sends the optimized location information of the content nodes to the CSAF. The information can be a peer list with the address of the content nodes.

11) CSAF forwards the content location information to EF.

12) EF chooses preferred content node(s) from the peer list, and interacts with the CDF to join the unicast/multicast group for receive content of the channel.

13) When the request is received, CDF prepares resources for serving the EF.

14) When CDF is ready, CDF delivers the content of the channel to the requesting EF.

15) At the end of the viewing session, EF closes the streaming session.

16) CDF releases the resource related to the EF.

17) Content delivery finishes and CDF sends the flow statistic information to MF.

18) MF stores or updates the flow statistic information.

19) CDF sends a confirm message to EF to confirm that the session is closed.

20) EF sends a disconnect message to CSAF to close the application session for this live steaming service.

21) CSAF confirms the close.

II.2.3 VoD

Figure II.5 shows the flow for a UE to access VoD service through traditional CDN.

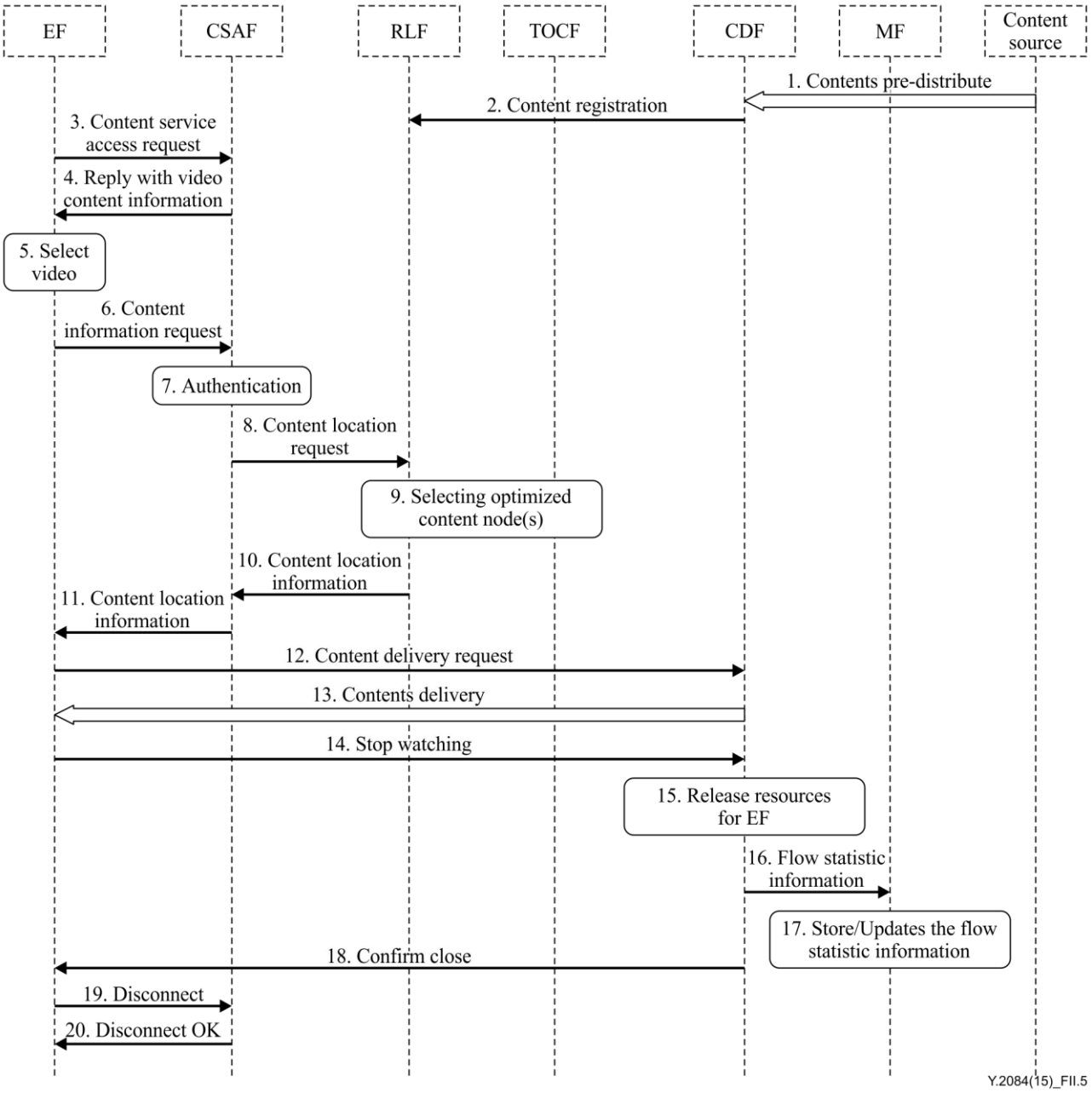

Figure II.5 – Flows of accessing VoD service through traditional CDN

1) Content source pre-distributes the resource to other CDF(s).

2) CDF contacts RLF to register the content received.

3) EF sends a content service access request to CSAF to get the VoD service information (including the available videos, the price of the videos, the introduction of the videos, etc.). The ID and device type of the EF are included in the content service access request. The content service access request may also include the authentication information of the user.

4) CSAF replies to EF with the information list of videos. EF may present this information to the user.

5) EF selects the video.

6) EF sends a content location request to CSAF to get the location information of available content nodes. The content ID is included in the request. The request may also include the ID of the EF and authentication information.

7) CSAF checks the authentication information of EF.

8) If the authentication succeeds, CSAF requests the location information of the content from RLF.

9) RLF interacts with TOCF to request optimized location information. RLF selects optimal content nodes based on the information from TOCF.

10) RLF sends the optimized location information of the content nodes to the CSAF. The information can be a peer list with the address of the content nodes.

11) CSAF forwards the content location information to EF.

12) EF chooses a preferred content node from the peer list, and requests a certain chunk of this content from CDF.

13) CDF sends the requested chunk to EF.

14) At the end of the viewing session, the EF closes the streaming session.

15) CDF releases the resource related to the EF.

16) Content delivery finishes and CDF sends the flow statistic information to MF.

17) MF stores or updates the flow statistic information.

18) CDF sends a confirm message to EF to confirm that the session is closed.

19) EF sends a disconnect message to CSAF to close the application session for this VOD service.

20) CSAF confirms this close.

II.2.4 File downloading

The flow for a UE to access file downloading service through traditional CDN is similar clause II.2.3 flow except the content type EF requests are different. Refer to clause II.2.3 as this clause does not repeat the flows.

II.3 P2P cache

II.3.1 Live streaming

The flow for P2P cache live streaming is shown in Figure II.6. In this case, different EFs joining the same live stream will always request the same content. The first content request from the EF is forwarded by CDF to remote nodes possessing the content. A remote node could be either a remote CDF, which has already cached the content, or a remote peer, which provides the original content.

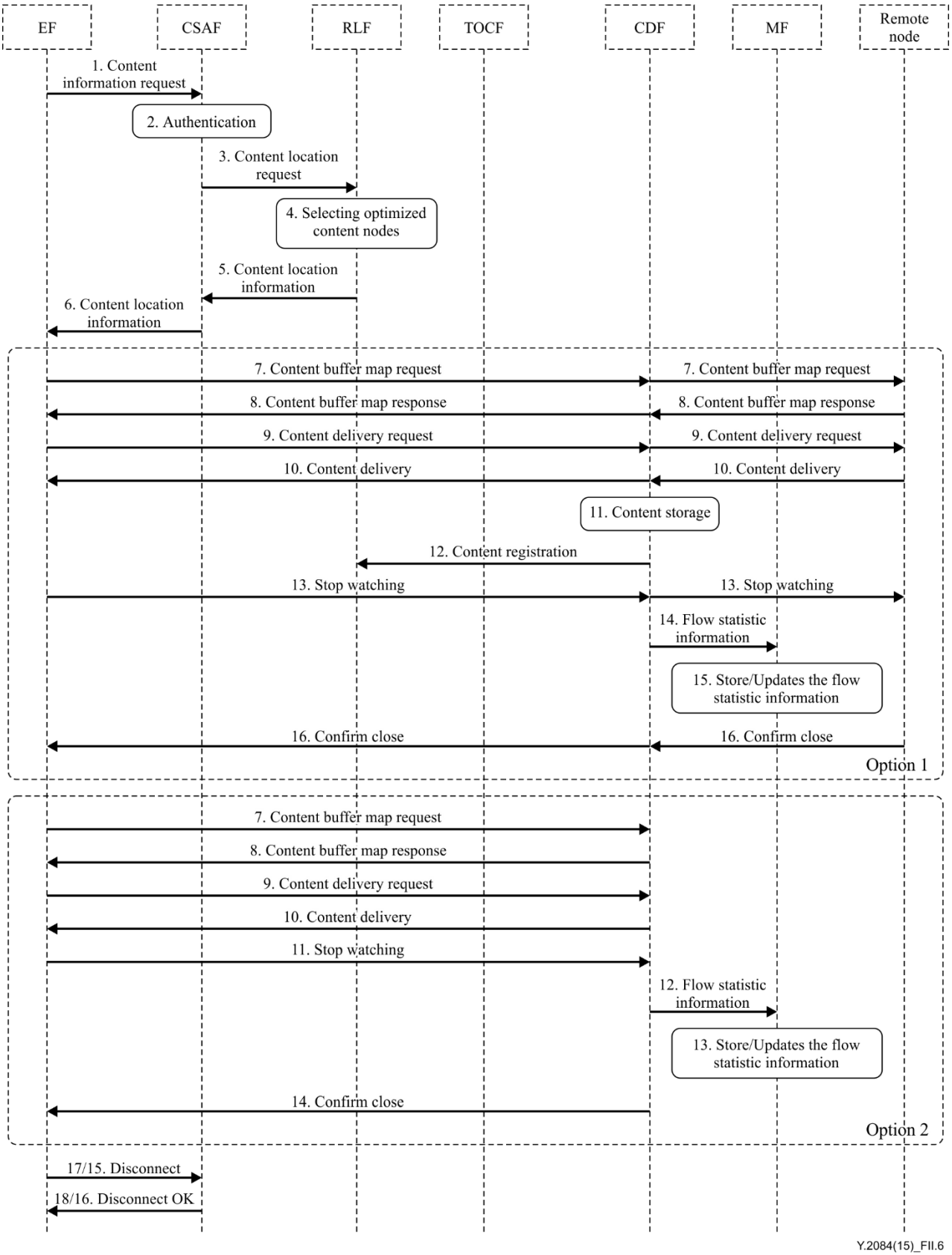

Figure II.6 – Flow of accessing live streaming service through P2P cache

1) EF sends CSAF a live content request. It sends a content information request to CSAF to get the location information of available content nodes. The content ID is included in the request. The request may also include the ID of the EF and authentication information.

2) CSAF checks the authentication information of EF.

3) If the authentication succeeds, CSAF requests the location information of the content from RLF.

4) RLF interacts with TOCF to request optimized location information. RLF selects optimal content nodes based on the information from TOCF.

5) RLF sends the optimized location information of the content nodes to the CSAF. The information can be a peer list with the address of the content nodes.

6) CSAF forwards the peer list information to EF. If there is no content stored in CDF, CSAF forwards the remote peer list information to EF. If CDF has stored the current content, CSAF forwards the information of CDF to EF.

Option 1: Current content is not yet stored in CDF.

7) EF chooses a group of preferred peers (e.g., content nodes, UEs or remote CDFs that have cached the content and are located near the UE) from the peer list and interacts with those peers to request the buffer map of the content. These requests are transparently redirected to the CDF, which passes these requests on to a remote P2P user.

8) The remote P2P user sends the content buffer map information back to EF, similar to step 7; the response is transparently intercepted by CDF.

9) EF requests the remote node to deliver the content, similar to step 7; the request is redirected to CDF and then be passed on to the remote node.

10) The remote node, which has the content, sends the content data back to EF, similar to step 8; the content data is intercepted by CDF.

11) CDF stores the content for the next EFs.

12) CDF registers the content to RLF.

13) EF sends a request to the remote node to stop watching the live content, similar to step 7; the request is redirected to CDF and then be passed on to the remote node.

14) CDF discovers that the remote node stops to deliver the content. It sends flow statistic information to MF.

15) MF stores or updates the flow statistic information.

16) The remote node sends a confirm message to EF to confirm that the session is closed.

17) EF sends a disconnect message to CSAF to close the application session for this live steaming service.

18) CSAF confirms this close.

Option 2: Current content is stored in CDF. The peer list obtained from CSAF includes the address of CDF as a peer serving the content for EF.

7) EF sends a request for the content buffer map to CDF.

8) CDF returns the content buffer map information to EF.

9) EF requests CDF to deliver the content.

10) CDF delivers the stored content to EF.

11) When EF stops watching the content, it sends a request to CDF.

12) CDF stops the content delivery and sends flow statistic information to MF.

13) MF stores or updates the flow statistic information.

14) CDF sends a confirm message to EF to confirm that the session is closed.

15) EF sends a disconnect message to CSAF to close the application session for this live steaming service.

16) CSAF confirms this close.

NOTE – EF may interact with multiple remote nodes at the same time.

II.3.2 VoD and file downloading

The flow for P2P cache VoD usage is shown in Figure II.7.

In this case, different EFs may request different VoD/file contents or different parts of the same VoD/file content.

NOTE 1 – VoD content must be constantly received by EFs and presented to an end user. File downloading does not require continuity. It does not matter which part of the file content is received first. File downloading will be successfully finished as long as all the parts of the file content are received, regardless of the receiving sequence. End users served by these two services should have different strategies in request sending and jitter buffering.

NOTE 2 – EF may interact with multiple remote nodes at the same time; this flow illustration only uses one.

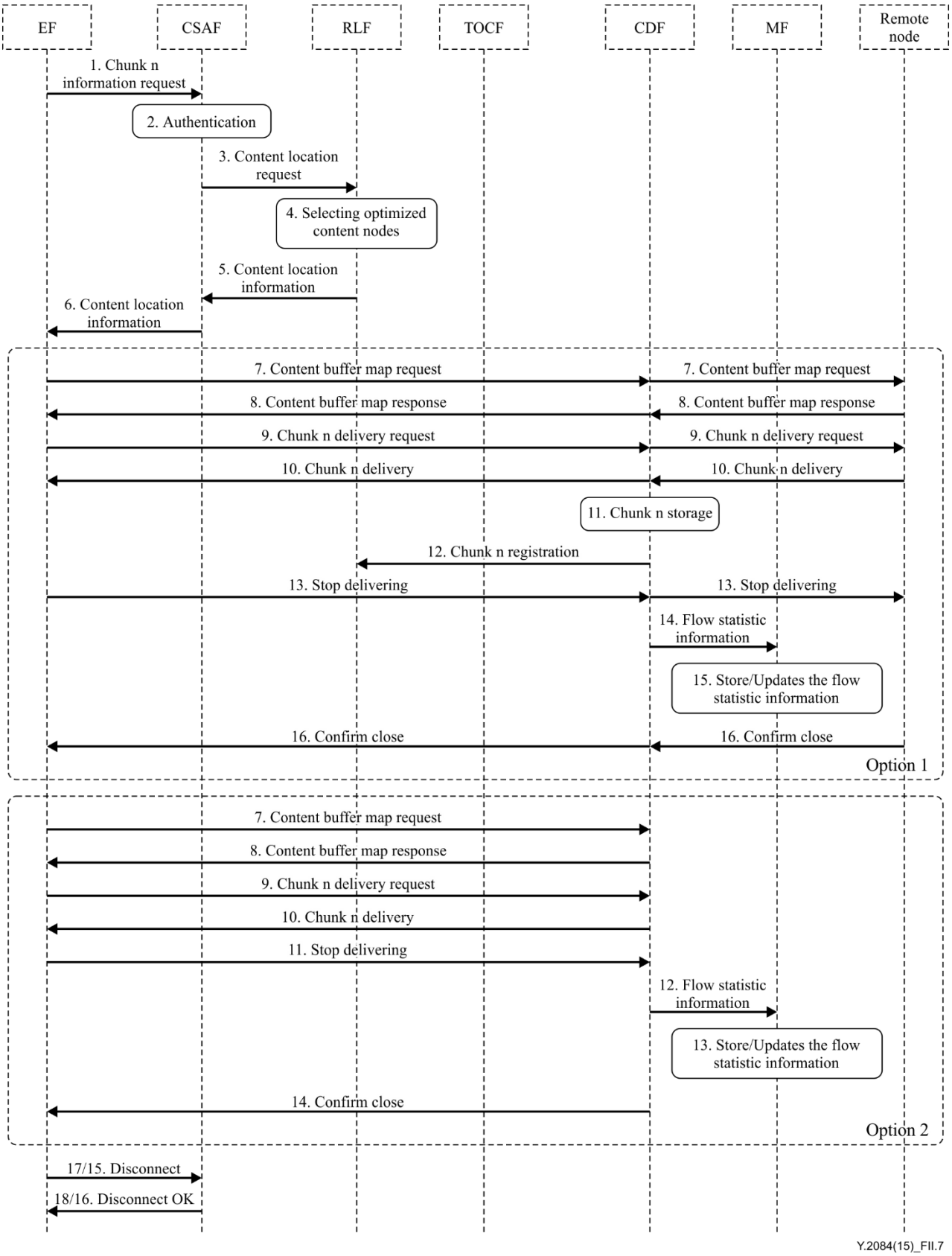

Figure II.7 – Flow of accessing VoD and file downloading service through P2P cache

1) EF is in a streaming/file downloading process. It sends a content information request to CSAF to get the location information of available content nodes. The content ID is included in the request. The request may also include the ID of the EF and authentication information.

2) CSAF checks the authentication information of EF.

3) If the authentication succeeds, CSAF requests the location information of the content from RLF.

4) RLF interacts with TOCF to request optimized location information. RLF selects optimal content nodes based on the information from TOCF.

5) RLF sends the optimized location information of the content nodes to the CSAF. The information can be a peer list with the address of the content nodes.

6) CSAF forwards the peer list information to EF. If there is no content stored in CDF, CSAF will forward the peer list information to EF. If CDF has stored the current content, CSAF will forward the information of CDF to EF.

Option 1: Chunk n is not yet stored in CDF.

7) EF chooses a group of preferred peers (both content nodes and UEs) from the peer list, and interacts with these peers to request the buffer map of the content. These requests will be transparently redirected to the CDF, which will pass these requests on to a remote P2P user.

8) The remote P2P user sends the content buffer map information back to EF, similar to step 7, the response will be transparently intercepted by CDF.

9) EF requests the remote node to deliver chunk n of the content, similar to step 7, the request will be redirected to CDF and will then be passed on to the remote node.

10) The remote node, which has the content, sends chunk n of the content data back to EF, similar to step 8, the content data will be intercepted by CDF.

11) CDF stores chunk n for the next EFs.

12) CDF registers chunk n to RLF.

13) EF sends a request to the remote node to stop streaming the current content, similar to step 7, the request will be redirected to CDF and will then be passed on to the remote node.

14) CDF finds out that the remote node stops delivering the content. It sends flow statistic information to MF.

15) MF stores or updates the flow statistic information.

16) The remote node sends a confirm message to EF to confirm that the session is closed.

17) EF sends a disconnect message to CSAF to close the application session for this VoD/file downloading service.

18) CSAF confirms this close.

Option 2: Chunk n is stored in CDF. The peer list obtained from CSAF includes the address of CDF as a peer serving the content for EF.

7) EF requests the buffer map from CDF.

8) CDF returns the buffer map to EF.

9) EF requests CDF to deliver chunk n.

10) CDF sends its stored chunk n to EF.

11) If EF finishes or interrupts the streaming of the content, it sends a request to CDF to stop delivering the content.

12) CDF sends flow statistic information to MF.

13) MF stores or updates the flow statistic information.

14) CDF sends a confirm message to EF to confirm that the session is closed.

15) EF sends a disconnect message to CSAF to close the application session for this VoD/file downloading service.

16) CSAF confirms this close.

II.4 P2P CDN

II.4.1 Live streaming

Figure II.8 shows the flow for a UE to access live streaming service through CDN with P2P model.

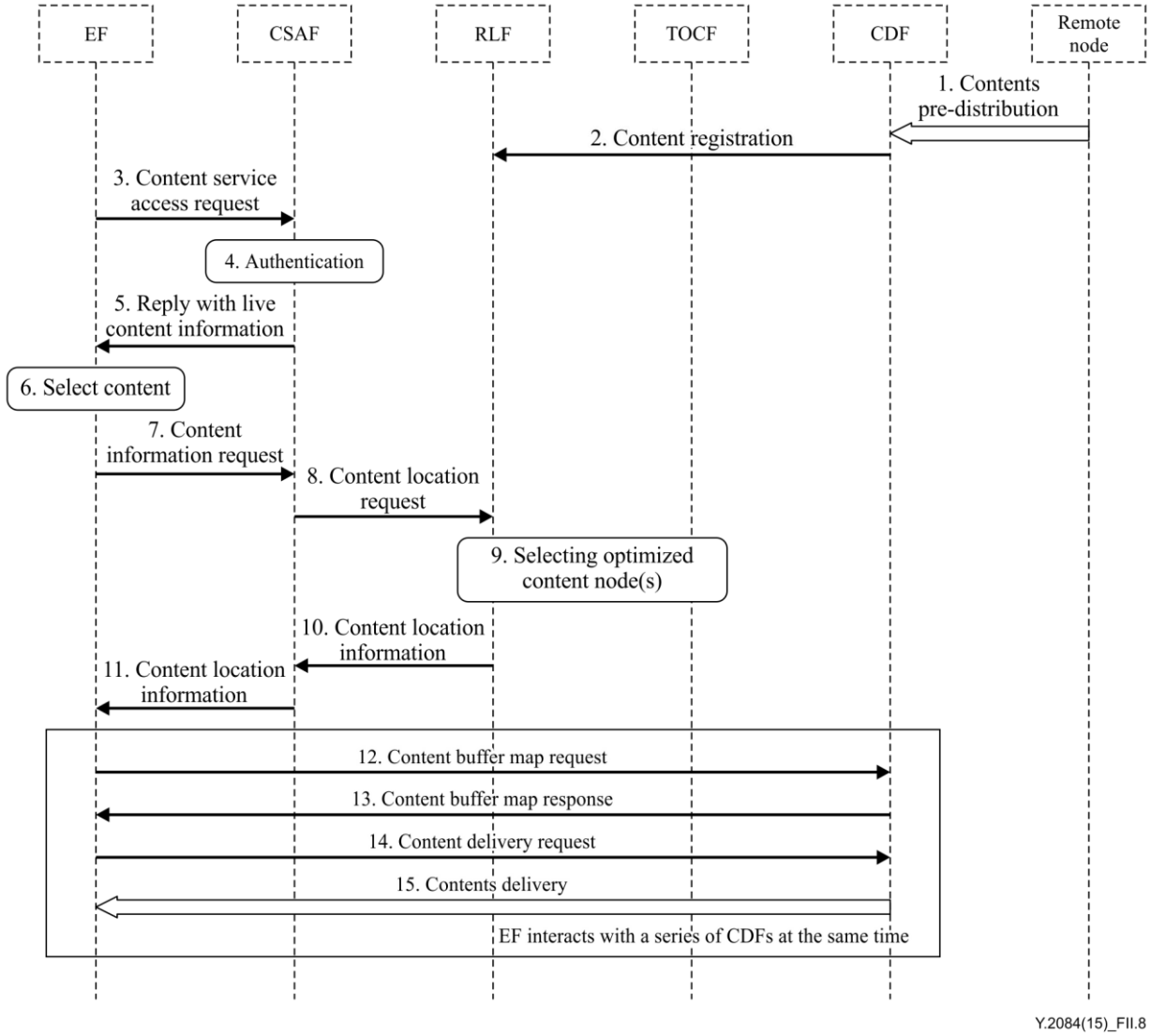

Figure II.8 – Flow of accessing live streaming service through P2P CDN

1) Remote node pre-distributes the resource to CDF.
2) CDF registers the content to RLF.
3) EF sends a content service access request to CSAF to get the live streaming service information (including the available channels, the price of the channels, the introduction of the channels, etc.). The ID and device type of the EF are included in the content service access request. The content service access request may also include the authentication information of the user.
4) CSAF checks the authentication information of EF.
5) CSAF replies to EF with the channel list which includes the information of payment and channel description. EF may present the information to the user.
6) EF selects the channel.

7) EF sends a content location request to CSAF to get the location information of available content nodes. The content ID is included in the request. The request may also include the ID of the EF and authentication information.

8) CSAF requests the location information of the content from RLF.

9) RLF interacts with TOCF to request optimized location information.

10) RLF sends the optimized location information of the peers (both content nodes and UEs) to the CSAF. This information can be a peer list with the address of the peers (both content nodes and UEs).

11) CSAF forwards the content location information to EF.

12) EF interacts with the CDFs to request the buffer map of the content.

13) CDFs return the buffer map of this content to EF.

14) According to the buffer maps, EF requests chunks from multiple CDFs.

15) CDFs deliver the content of the channel to the requesting EF.

II.4.2 VoD

Figure II.9 shows the flow for a UE to access VoD service through CDN with P2P model.

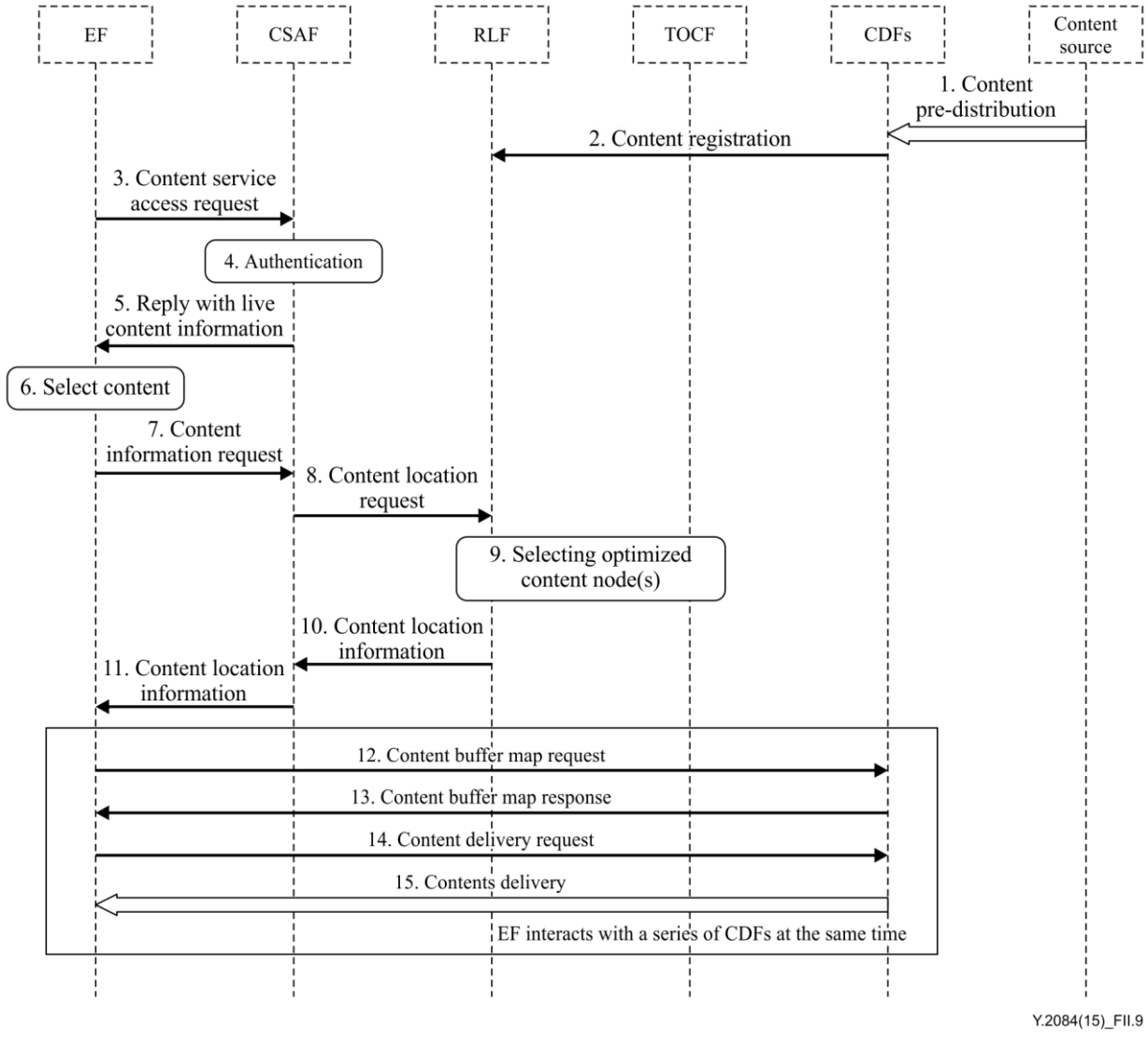

Figure II.9 – Flow of accessing VoD service through P2P CDN

1) Content source pre-distributes the resource to CDF.

2) CDF contacts RLF to register the content received.

3) EF sends a content service access request to CSAF to get the VoD service information (including the available videos, the price of the videos, the introduction of the videos, etc.). The ID and device type of the EF are included in the content service access request. The content service access request may also include the authentication information of the user.

4) CSAF checks the authentication information of EF.

5) CSAF replies to EF with the video list which includes the information of payment, video description. EF may present the information to the user.

6) EF selects the video.

7) EF sends a content location request to CSAF to get the location information of available content nodes. The content ID is included in the request. Since the video EF chooses may be pay video and different users may have different watch permissions for different videos, the request may also include the ID of the EF and authentication information.

8) CSAF requests the location information of the content from RLF.

9) RLF interacts with TOCF to request optimized location information.

10) RLF sends the optimized location information of the peers (both content nodes and UEs) to the CSAF. This information can be a peer list with the address of the peers (both content nodes and UEs).

NOTE – The way to implement procedures 6-8 is optional, the content location request can be sent by EF or CSAF.

11) CSAF forwards the content location information to EF.

12) EF interacts with the CDFs to request the buffer map of the content.

13) CDFs return the buffer map of this content to EF.

14) According to the buffer maps and the video play schedule, EF requests chunks from multiple CDFs.

15) CDFs send the requested chunks to EF.

II.4.3 File downloading

The flows for a UE to access file downloading service through CDN with P2P model is similar to clause II.4.2 flows except that the content type EF requests are different. Refer to clause II.4.2; this clause does not repeat the flows.

II.5 Integration

In implementations, DSN CDF could also be used as the integration of the above four basic usages: integration of cache and CDN, integration of P2P cache and P2P CDN, integration of cache and P2P cache, integration of CDN and P2P CDN.

There are usually two types of integration. One type is that two basic usages are co-located together in one DSN CDF, which chooses specific usage based on requests from the EFs. For example, CDF could be the integration of cache and P2P cache. If an EF requests HTTP content, CDF will act as a traditional cache to store the content from web servers for EFs' additional requests. If an EF requests P2P content, CDF could act as a P2P cache. Another example could be the integration of cache and CDN, in which case CDF acts as a CDN which has already obtained certain content from an original server. However, when an EF requests content that the CDF doesn't have, the CDF will act as a traditional cache to get and store the content from the server.

The other type of integration is that two basic usages could be implemented in serial in one network to make content distribution more efficient. For example, a content distribution network could use CDFs as cache to store content from original content servers, and then use CDFs as CDN to distribute the content from caches to the edge of the network. This implementation could effectively reduce traffic from CDFs to original content servers.

Bibliography

[b-ITU-T Y Suppl.10] ITU-T Y-series Recommendations – Supplement 10 (2010), *ITU-T Y.2000-series – Supplement on distributed service network (DSN) use cases*.

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