

Recommendation
ITU-T F.744.5 (09/2023)

SERIES F: Non-telephone telecommunication services

Multimedia services

**Requirements for content delivery networks
based on peer-to-peer technology**



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Recommendation ITU-T F.744.5

Requirements for content delivery networks based on peer-to-peer technology

Summary

Recommendation ITU-T F.744.5 describes the requirements for a peer-to-peer content delivery network (P2P CDN). It specifies the overall functional architecture, domains and functional role relationships, functional blocks and their mutual relationships, service provision requirements, availability requirements, scalability requirements and security considerations. P2P CDN provides a scalable and elastic CDN function pool of shareable terminal device computing resources, storage resources and uplink bandwidth to save loads of the current CDN and improve user experience.

History *

Edition	Recommendation	Approval	Study Group	Unique ID
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Keywords

Content delivery network (CDN), P2P, streaming service.

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Recommendation ITU-T F.744.5

Requirements for content delivery networks based on peer-to-peer technology

1 Scope

This Recommendation specifies the general functional requirements for a content delivery network based on peer-to-peer technology (P2P CDN).

This Recommendation encompasses the following key aspects:

- General functional framework;
- Interaction between function blocks;
- Service provision and management requirements;
- Availability, scalability and security requirements;
- Scenarios for P2P CDN service (provided in Appendix I).

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.

None.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 content delivery network [b-ITU-T Y.2084]: 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.

3.1.2 static content [b-ITU-T F.744.2]: Contents that changes infrequently. This type of content is not changed with the requests of users.

3.1.3 peer-to-peer content delivery network (P2P CDN) [b-ITU-T Y.2084]: 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.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AR	Augmented Reality
CDN	Content Delivery Network
CMS	Content Management System
FTP	File Transfer Protocol
HD	High Definition
IDC	Internet Data Centre
IP	Internet Protocol
IPTV	Internet Protocol Television
LAN	Local Area Network
MAN	Metropolitan Area Network
P2P CDN	Peer-to-Peer Content Delivery Network
RTMP	Real-Time Messaging Protocol
RTSP	Real-Time Streaming Protocol
SD	Standard Definition
SDK	Software Development Kit
STB	Set-Top-Box
VoD	Video on Demand
VR	Virtual Reality

5 Conventions

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

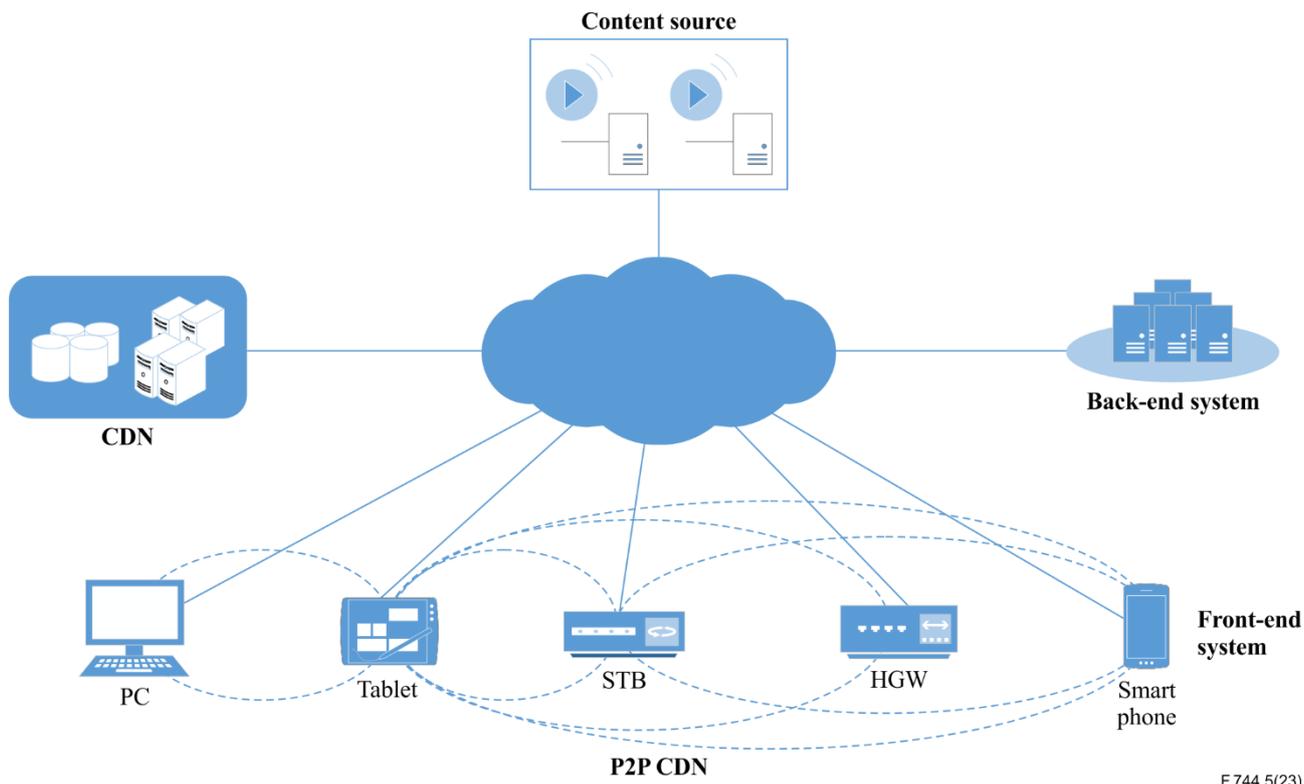
6 Overview

P2P CDN, as a specific CDN model providing content delivery services, solves the problem of the network traffic growth brought by multimedia content. Along with the rapid advance of computer-related technologies, how to efficiently provide multimedia content for a large number of heterogeneous users on the Internet, especially videos, has become a noticeable issue.

A peer to peer (P2P) approach, where peers collaborate with one another to reduce server loading, provides a feasible solution for the scalability issue. It has recently become a popular alternative to CDN to cope with the growing demand of end users. In P2P scheme, a peer acts not only as a client to receive services but also as a server to forward services to other peers. Using peer-to-peer (P2P) technology, the traditional CDN will be able to provide superior service and reduce construction and maintenance costs. Figure 1 illustrates the basic concept of P2P CDN.

Furthermore, intelligent terminal devices such as smart set-top-boxes (STBs), smartphones and smart home-gateways, can install various kinds of application plugin or software to deploy new service

functions. The computing and storage capability of these terminal devices are enhanced dramatically, and a large number of idle computing and storage resources can be utilized. Therefore, P2P CDN is more likely to be implemented.



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Figure 1 – Basic concept of P2P CDN

7 Objectives

P2P CDN is a paradigm using peer-to-peer technology for content delivery for various multimedia services. P2P CDN provides a scalable and elastic CDN function pool of shareable terminal devices computing resources, storage resources and uplink bandwidth to save the loads of current CDN and improve user experience.

The following are the advantages of applying P2P CDN:

- Reducing the cost of CDN. The main cost of the current CDN provider is to purchase servers, bandwidth and to rent IDC. P2P CDN utilizes some idle resources of terminal devices and uplink bandwidth, which the end users have already invested in. It greatly reduces the cost of CDN.
- Improving user experience. Because the nodes of P2P CDN are located in terminal devices, users may receive content from their own terminal devices, instead of from CDN nodes deployed in the network. Alternatively, other users may receive content from fellow users' terminal devices which are located in the same local area network (LAN) or metropolitan area network (MAN), instead of receiving it from the CDN nodes deployed in the backbone network which is far away from the user-end. Receiving contents from terminal devices close to the users may bring ultra-low-latency, high throughput, multi-direction traffic and provide the experience of lossless content delivery. When content is hotter, i.e. requested by more users, the user experience will be improved when P2P CDN technology is applied.

The widespread use of P2P CDN may bring new business models and new business ecology.

- Ultra-high-definition video service is now widespread. One of the main causes holding back ultra-high-definition video from being widespread in earlier years was the cost of CDN and

the quality of delivery for the current CDN. With the cheap cost and high quality of delivery of P2P CDN, ultra-high-definition video services may be developed and may be widespread in the future.

- Bringing new profit for telecom operators. Users usually only use the downlink bandwidth of broadband, and the uplink bandwidth has not been used until now. P2P CDN can be used to create a new business model and bring new profit using the uplink bandwidth. Telecom operators can sell the P2P CDN services to vendors and return some profit to users who provide terminal devices and uplink bandwidth of P2P CDN.

8 Requirements

8.1 General requirements

8.1.1 Functional framework requirements

FR-01: The P2P-CDN system is required to consist of two parts, which are the front-end system and the back-end system.

FR-02: The front-end system is recommended to consist of millions of intelligent terminal devices installing the P2P software application.

FR-03: The front-end system is recommended to include two functions. One is providing the delivery function which is sharing the content of their own system, while at the same time delivering the content to other peers. The other is utilizing the contents which are shared by peers.

FR-04: The back-end system is recommended to include the following functional blocks: system management functions, service control functions, resource control functions and resource delivery functions.

The general function blocks of P2P CDN are illustrated in Figure 2.

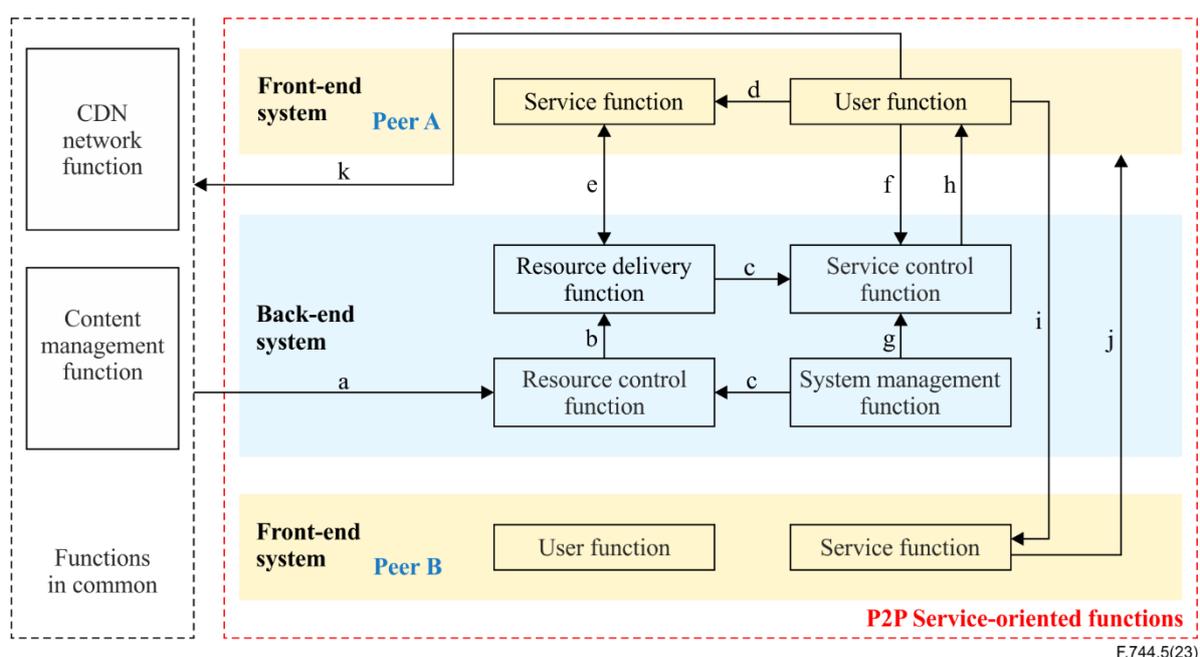


Figure 2 – General functional framework of P2P CDN

In the functional framework of P2P CDN, each peer serves as both a server and a user, providing services to other nodes, while also enjoying the services provided by other nodes. Figure 2 shows the interaction between each function block when "Peer A" requests content resources from a peer. The following steps describe the interaction between the function blocks:

- a) The content resource is injected from the content management system (CMS) into the CDN.
- b) The deployment of resources from back-end systems to front-end systems.
- c) The synchronization of resource deployment information to the service control function and the resource control function.
- d) Peer A's media player triggers the service function.
- e) The back-end system pre-deploys resources to the service module of the front-end system, and the front-end system provides feedback on the resource list to the back-end system.
- f) The user module of the front-end system requests CDN content resources from the back-end system.
- g) The back-end system's service control module returns scheduling information and selects multiple nodes (P2P CDN nodes) to provide services to the front-end system based on access requirements and resource lists.
- h) The service control module feedbacks the node list to the front-end system.
- i) The Peer A user requests content resources from multiple nodes including Peer B.
- j) Peer B provides Peer A with the requested content resources.
- k) If the resources accessed by Peer A do not exist in Peer B, they are required to be obtained through the CDN network.

8.1.2 Requirement for the system management function

SMF-01: The system management block of P2P CDN is required to manage each P2P CDN peer, including terminal equipment, data monitoring and system operation. Its management function includes:

- Peer nodes management;
- Content management;
- Resource monitoring;
- Operation and maintenance management;
- Statistical analysis.

8.1.3 Requirements for service control functions

SCF-01: Service control functions are responsible for the overall P2P CDN business request and scheduling. The processing of the P2P CDN content distribution service is based on the user's usage requirements. If the access resources are not available, then the controller will trace to the existing CDN network to obtain the source.

SCF-02: The service function block of P2P CDN is required to respond to the content service of peer nodes. It is required to deploy the docking resource, realizing the downloading of the resource content from the resource deployment block. In the meantime, the service function should provide capabilities, which can interact with the background management system, and realize resource information reporting of peer nodes.

8.1.4 Requirements for the resource delivery function

RDF-01: P2P CDN is required to support the content distribution processing function. The deployment resources can be pushed and pulled according to the requirements. The resource predeployment pre-deploys the content resources to the P2P service block. After the P2P block is deployed successfully, the resources are pre-deployed. And the resource predeployment and scheduling control blocks are synchronized.

8.1.5 Requirements for the resource control function

RCF-01: The resource control function is in charge of the resource scheduling of peer nodes. The scheduling server chooses multiple peer points (P2P CDN nodes) to provide services according to the return scheduling of the resource list and dispatches CDN services. The process contains basic resource parameters: the number of P2P CDN nodes, storage space, user concurrency and network traffic.

8.2 Service provision requirements

8.2.1 Video service

VS-01: P2P CDN is required to have the capabilities of supporting the content distribution for a variety of video services through various kinds of terminal devices, including IPTV-based live broadcast, AR, VR and on-demand video service.

VS-02: P2P CDN is recommended to support ultra-high definition HD (such as 8K, 4K), HD, SD and multiple streams of IPTV, PC, mobile device video services.

8.2.2 Storage service

P2P CDN is required to have the capabilities of storing/cacheing static contents within their service coverage area.

8.2.3 Accelerating service.

P2P CDN is recommended to support the file acceleration download service and the web acceleration service.

8.2.4 Data transmission service

P2P CDN is recommended to have the capabilities of supporting multiple protocols including HTTPs, HTTP1.0, HTTP2.0, RTSP, RTMP and FTP.

8.3 Availability requirements

8.3.1 Requirements for network access availability

NSA-01: P2P CDN is required to preserve the architecture and functions of the original CDN system while introducing the P2P technology to distribute and transmit the media streaming by controlling and managing the edge nodes.

NSA-02: According to this backbone aggregation and edge distributed architecture, the P2P CDN is recommended to be divided into several areas, which are called P2P autonomous domains. The data exchange from users is limited to the domain in which they are located, and the inter-domain exchange is avoided as much as possible.

NSA-03: The P2P CDN is recommended to be divided into several autonomous regions according to the following principles:

- The autonomous domains are required to be divided according to the geographical area where the CDN edge node is located.
- The IP addresses range of the users in the same domain is required to be the same as the range of the user IP address pool served by the CDN nodes.
- The hotspot area is to be combined properly with the unpopular area and the network bandwidth of the unpopular area used to alleviate the network pressure in the hotspot area and improve the overall concurrency and network utilization efficiency.
- The P2P autonomous domains are required to be divided according to the actual characteristics of the system network.

- The logical P2P autonomous domain is added to enhance the capacity of the overload P2P autonomous domain which serves a backup function.

8.3.2 Requirements for service performance

SP-01: P2P CDN is required to achieve the function of on-demand streaming, live broadcasting and file downloading services. The requirements for service performance can be defined as: service success rate, service responding time, network packet loss rate and the jitter of streaming.

8.3.3 Requirements for device performance

DP-01: All devices accessing the P2P CDN are recommended to be able to transform the service quality by the following indicators: concurrency, network bandwidth, storage capacity, number of nodes and regional coverage.

DP-02: All devices accessing the P2P CDN are recommended to support cloud deployment, using a common x86 server, and to support hardware and software separation.

DP-03: All devices accessing the P2P CDN are recommended to satisfy the ability to serve multiple network protocols.

8.4 Scalability requirements

8.4.1 Requirements for system scalability

SS-01: The P2P CDN system is required to maintain high scalability so that when a large number of requests suddenly arrive at the media server, the system can still serve each request within a reasonable delay without breakdown.

SS-02: The P2P CDN system is required to be designed in modules. By modifying the interfaces between modules, a P2P CDN is more scalable for service expansion.

8.4.2 Requirements for central node scalability

CNS-01: The P2P CDN is required to break the limitation of a centralized architecture of a CDN, which is related to the number of data centres coupled with the available exit/transit bandwidth from these data centres.

CNS-02: The P2P CDN is required to add a P2P management centre to provide centralized management functions for the entire system, enabling the unified management and monitoring of all CDN edge nodes.

8.4.3 Requirements for edge node scalability

The P2P CDN is recommended to access various kinds of devices that can provide the front-end system function defined in clause 8.1. The edge nodes of a P2P CDN are required to be able to embed the P2P CDN software development kit (SDK), supporting the registration function, information uploading function, service distribution function and load testing function.

8.4.4 Requirement for the expansion of a new service

The P2P CDN is required to be updatable, including the hardware, software and P2P plugin, supporting future emerging video services such as adaptive streaming media services.

8.4.5 Requirement for redundancy

The P2P CDN is required to provide redundancy and to have a certain fault tolerance mechanism when providing services to the terminal through the network.

- The P2P CDN is required to support service redundancy between peers. If the node that the user in the region of cannot provide services for some reason, such as the node performance having reached the limit value, the node being broken down or the node having no content.

- The P2P CDN is required to provide link redundancy, either the dual-link redundancy of control and media or the external service dual link.
- The P2P CDN is required to provide storage redundancy, guaranteeing the high availability of peer node storage.

8.5 Service management requirements

8.5.1 Requirements for network analysis

NA-01: The P2P CDN is required to have the capability of statistically analysing the services provided by the content providers.

NA-02: The P2P CDN is required to have the capability of analysing the carrier networks' performance data detected and provide the statistical performance reports about the carrier networks.

8.5.2 Requirements for resource management

RM-01: The P2P CDN is required to have the capacity of the data storage/cacheing, and the capacity of providing their data storage/cacheing spaces to the consumers.

RM-02: The P2P CDN is required to build related functions or capabilities of the original resources needed while providing services that needs the tracing of the original resources, based on the related cooperation protocols between the P2P CDN providers and the content providers.

RM-03: The P2P CDN is required to have the capabilities of redirecting the content consumer requests to the peer nodes near the request content consumers.

9 Security requirements

9.1 Content copyright protection requirements

CCPR-01: The P2P CDN is required to protect the content copyright when the P2P data flow is initiated between terminals based on the scheduling service system. Since scheduling service instructions and file blocks between peer nodes are transmitted through proprietary protocols, it can also effectively achieve copyright protection of content.

CCPR-02: The P2P CDN is required to protect the cache content after accessing P2P services even if the terminal is compromised, so attackers cannot directly find the specific path for storing content.

9.2 Terminal security protection requirements

TSPR-01: The P2P CDN is recommended to guard against peers that may attempt to inject or distribute malicious content within the network. Measures such as reputation systems, trust mechanisms and content validation can help identify and isolate malicious peers or unauthorized content.

TSPR-02: The P2P CDN is recommended to employ security measures to prevent unauthorized peers from joining the network. Authentication protocols and encryption can be utilized to ensure that only trusted peers can participate in the P2P network.

9.3 Content tamper-proof requirements

CTPR-01: The P2P CDN is required to validate the data during content localization in P2P peer nodes; data is discarded when validation fails. Therefore, as long as the hash digest value of the original resource is consistent, it can ensure that the transmitted content resource is theoretically tamper-free.

CTPR-02: Since content is distributed across multiple peers, ensuring the authenticity and integrity of the content becomes crucial. The P2P CDN is recommended to employ measures such as content signing, digital signatures and hash verification to verify the integrity of chunks and prevent unauthorized modifications or tampering.

Appendix I

Scenarios for P2P CDN

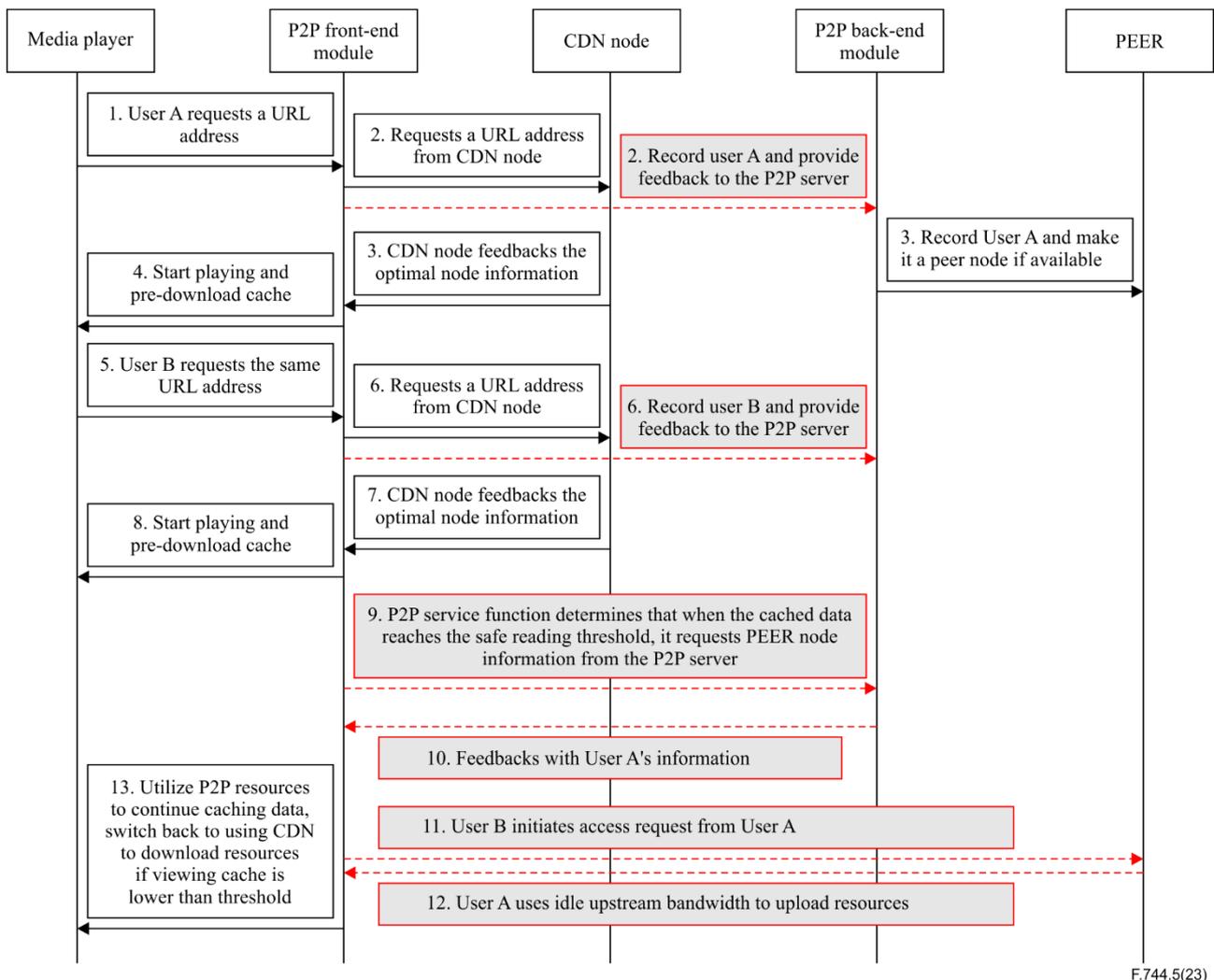
(This appendix does not form an integral part of this Recommendation)

I.1 P2P CDN video-on-demand service

Nowadays, P2P CDN technology has been widely used in video-on-demand (VoD) services and has been developed rapidly, breaking the limitation of traditional CDN, effectively improving resource utilization and realizing the construction of a system platform with high service quality at lower infrastructure costs.

The implementation of P2P CDN technology in the VoD system, compared with traditional VoD systems based on traditional client/server architecture, has several advantages. Firstly, it enhances system stability by leveraging the scalability of content providers and reducing payload during backbone network traffic congestion. Secondly, instead of relying solely on centralized servers, the content is distributed across multiple peers. If a particular server or node becomes unavailable, the content can still be accessed. Thirdly, it ensures the user's quality of service by utilizing a multi-path downloading program that retrieves clips from peer nodes, effectively preventing server response slowness or service termination caused by the increasing number of nodes in traditional CDNs.

Figure I.1 illustrates the workflow of P2P CDN implementation in the VoD service.



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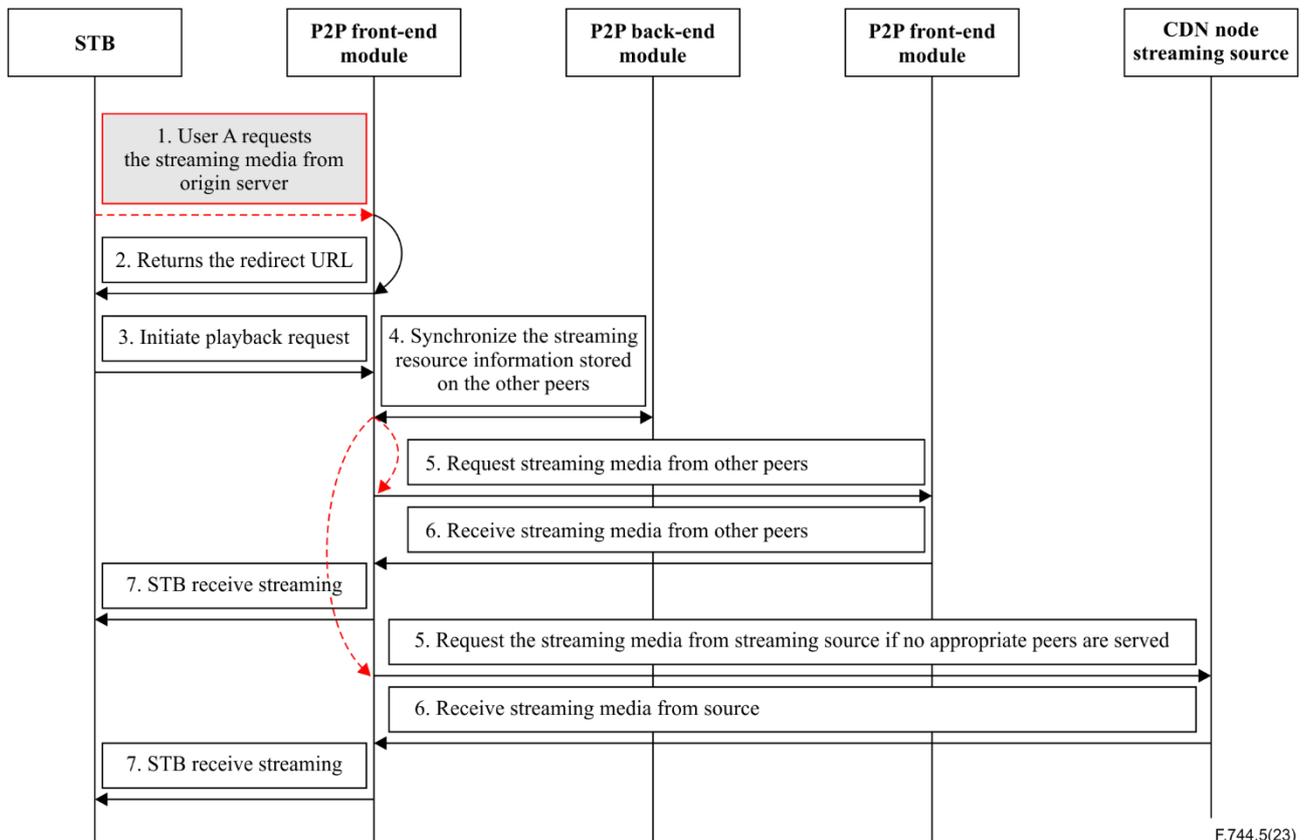
Figure I.1 – Workflow for P2P CDN VoD service

I.2 P2P CDN live-streaming service

Live streaming has the potential to generate huge amounts of traffic as its popularity with users' increases. Most content providers have opted for direct distribution using content delivery networks (CDN) even though low-cost delivery can be achieved using peer-to-peer (P2P) architecture.

The implementation of P2P CDN technology in live-streaming services has several advantages. P2P CDN leverages the distributed nature of peers to improve redundancy and reliability. If one peer goes offline or experiences connectivity issues, other peers can compensate by serving the content. Since the video content is distributed across multiple peers, viewers can retrieve chunks from nearby sources rather than relying solely on a central server. This localized content delivery can decrease the distance data has to travel, resulting in lower latency and faster video playback.

Figure I.2 illustrates the workflow of P2P CDN implementation in the live-streaming service.



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Figure I.2 – Workflow for P2P CDN live-streaming service

Bibliography

- [b-ITU-T F.744.2] Recommendation ITU-T F.744.2 (2018), *Framework and interfaces for multimedia content delivery network*.
- [b-ITU-T Y.2084] Recommendation ITU-T Y.2084 (2015), *Distributed service networking content distribution functions*.

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