## **3GPP SA4 MBS SWG Post SA4#129-e *S4aI240185r01***

**Online, 10th October 2024** *revision of* S4aI240160

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| ***Proposed change affects:*** | UICC apps |  | ME | **X** | Radio Access Network |  | Core Network | **X** |

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| ***Category:*** |  |  | | | | | ***Release:*** | | |  |
|  | *Use one of the following categories:* ***F*** *(correction)* ***A*** *(mirror corresponding to a change in an earlier release)* ***B*** *(addition of feature),* ***C*** *(functional modification of feature)* ***D*** *(editorial modification)*  Detailed explanations of the above categories can be found in 3GPP [TR 21.900](http://www.3gpp.org/ftp/Specs/html-info/21900.htm). | | | | | | | | *Use one of the following releases: Rel-8 (Release 8) Rel-9 (Release 9) Rel-10 (Release 10) Rel-11 (Release 11) … Rel-17 (Release 17) Rel-18 (Release 18) Rel-19 (Release 19)  Rel-20 (Release 20)* | |
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| ***Reason for change:*** | | Document the FS\_AMD key topic “c) Multi-Access and Multi-CDN Delivery” description and collaboration scenarios. | | | | | | | | |
|  | |  | | | | | | | | |
| ***Summary of change:*** | | Addition of new clause 5.x Multi-CDN and Multi-Access Media Delivery including sub-clause structure and headings. Addition of prose for Description and Collaboration Scenarios. | | | | | | | | |
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| ***Consequences if not approved:*** | | FS\_AMD objectives not achieved. | | | | | | | | |
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| ***Clauses affected:*** | | 2, 5.x (NEW) | | | | | | | | |
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|  | | **Y** | **N** |  | | | |  | | |
| ***Other specs*** | |  | **X** | Other core specifications | | | |  | | |
| ***affected:*** | |  | **X** | Test specifications | | | |  | | |
| ***(show related CRs)*** | |  | **X** | O&M Specifications | | | |  | | |
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| ***Other comments:*** | |  | | | | | | | | |
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| ***This CR's revision history:*** | | S4-240591: SA4#127-bis-e, description and collaboration scenarios  S4-240844: updates with comments received at SA4#127-e-bis  S4aI240052: updated to match proposed template and address pending comments.  S4al240894: S4al240052 endorsed at SA4 post 127-bis-e and comments/changes accepted for ease of reading. Updates with comments received at SA4 post 127-bis-e and introduction of candidate solutions. More background on candidate solution is contained in S4-240895. Multi-access media delivery overview and collaboration scenarios have been moved to S4-241082.  S4-241230: updates to address pending comments.  S4-241273: updates to address pending comments.  S4al240095: S4-241273 endorsed at SA4#128. Comments/changes accepted for ease of reading. CMMF candidate solution architecture and reference point descriptions added.  S4al240107: CMMF candidate solution architecture and reference point descriptions replaced with options to incorporate CMMF within the existing 5GMS architecture.  S4al240114: Edits from BBC. Endorsed by MBS SWG.  S4-241588: Addition of CMMF background information and addresses outstanding comments.  S4-241665: Reorginization of content to fit within the existing template and updates to address received comments.  S4aI240120: updates to CMMF architecture and high-level call flows.  S4aI240138: Updates to CMMF’s introduction to include more details concerning the expected overhead CMMF induces as well as an example architecture and call flow used to deliver CMMF content for the trial where the included performance metrics were collected. Further updates to the CMMF architecture and high-level call flows to address outstanding comments.  S4al240145: Incorporates edits and captures additional BBC comments.  S4aI240160**:** Updates to CMMF’s architecture mapping and high-level flowcall sections. Addition of CMMF gap analysis.  S4aI240185: Updates to address comments from BBC and Qualcomm. | | | | | | | | |

## FIRST CHANGE

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## SECOND CHANGE

## 3.3 Abbreviations

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SAND Server-Assisted Network Delivery

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## THIRD CHANGE (All new text)

## 5.19 Multi-CDN media delivery

### 5.19.1 Description

#### 5.19.1.1 Introduction

Media streaming applications conventionally obtain content from a single source or endpoint over a single path within a network. Each source, or endpoint, may consist of a single server located within the network or an entire network of servers (e.g., a Content Distribution Network (CDN)). Operating in this manner imposes several limitations:

1. Performance is constrained to that of the source/endpoint and path chosen. Whatever the limits on network bandwidth and latency between the client and that source/endpoint are directly translated to the client’s achievable Quality of Service (QoS) and Quality of Experience (QoE).

2 Disruptions or degraded performance caused by the source/endpoint in use or on any of the network links between the client and source/endpoint can lead to poor user experience, often in the form of lower playback quality, rebuffering, or complete playback failure.

This study considers integration of different technologies into the 5G Media Streaming System that addresses these, and similar, issues by allowing media streaming applications to efficiently access content across multiple sources/endpoints and/or multiple access networks. Different client implementations may then beneficially use the content on these multiple sources or networks concurrently, potentially guided by service or network provider. In addition, formats and techniques for generating content for multiple sources/endpoints or multiple access network delivery such as MPEG-DASH Part 9 (ReAP) [DASH9] may be considered. Further extensions include the ability for a client to use multiple access networks at the same time to support media delivery. Study of integration of different technologies into the 5G Media Streaming System is of relevance to address content provisioning, content hosting, impacts on user plane reference points M2 and M4, and on media session handling at reference point M5 as well as potential benefits in terms of quality and resource usage.

For the purposes of this study, the terms "CDN", "source", "endpoint", and "service location" are used interchangeably. They each refer to a single entity within the network consisting of one or more physical hosts where content is made accessible to streaming media clients. Each individual entity may be distinguishable from the others through differences in configuration (e.g., different domain names, hosting configuration, etc.).

#### 5.19.1.2 Challenges Multi-CDN deployments aim to address

CDNs are often used by content distributors to globally scale delivery of their content to end-users. These networks consist of a number of Points of Presence (PoPs) located at various locations around the networks’ edge. These PoPs help load-balance delivery of content as well as improve Quality of Service (QoS) by reducing the distance/latency between every client and the content they are accessing. In many cases, content distributors employ multiple CDNs to leverage the strengths of one CDN over another in every location those CDNs have a PoP. For example, a client experiencing degraded performance while using one CDN may switch to another that is offering better performance at that time and location. As another example, a content distributor may prefer one CDN over another at a given time to reduce delivery costs and/or meet monthly contractual commitments. These multi-CDN deployments aim to solve content delivery issues that exist when only one CDN is used; but the benefits they provide may not be fully realized because of the various challenges experienced and underlying methods used to stream content to every client.

Challenges multi-CDN deployments and architectures aim to address may include:

1. *Sustained CDN-/network-wide service disruptions* where network access, connectivity or QoS is severely degraded. Examples may include cases where an entire CDN’s network is degraded because of a network-wide misconfiguration or power failure. The duration of these events may last minutes to hours and affect a majority of the client population. Examples of recorded instances can be found in [UNPKG24], [NET23], [FSLY21], [AKAM21], [NET22], and [VZ19].

2. *Intermittent or short-term disruptions affecting QoS for an individual or small group of clients.* Examples include short periods of congestion within the network, isolated HTTP request/response failures or delays caused by application server congestion, etc. The following discusses these in greater detail: [DEMX01], [DEMX02], [IEEE01], [ACM01], [MHV01], [VAS01], and [MWS23]

3. *Augmentation of one CDN's performance with that of another to achieve a level of performance that neither can provide on its own.* An example is a peer-to-peer CDN where each peer has limited uplink capacity and is unable to satisfactorily service client demand on its own.

The following clauses summarize some of the approaches that can be used to enable multi-CDN or multi-source/endpoint delivery to mitigate the challenges described above. Some of these solutions may be implemented over the top of the 5GMS System in such a way that content hosted within the 5GMS System is treated as a single CDN/source/endpoint, while others exist outside of the 5GMS System (e.g., commercial CDNs, etc.).

#### 5.19.1.3 Multi-CDN delivery with DNS-based switching

##### 5.19.1.3.1 Functional description of DNS-based switching

Multi-CDN delivery using a DNS server to perform switching between CDNs is a popular way to improve the delivery of services. In this solution, an Application Provider selects the source, or endpoint, media players stream from by updating Domain Name System (DNS) records with pointers to the appropriate content source/endpoint. This approach is convenient since it is transparent to the media player.

In this case the media player does the following:

1. *Segment or MPD request:* The media player selects a Media Presentation Description (MPD) or a media segment to download, along with its associated URL. The domain name contained within this URL is typically generic to the Application Provider’s service, rather than to a specific CDN or content source/endpoint. Furthermore, this domain name is typically an alias to a canonical domain that can be resolved by obtaining the associated CNAME record within DNS.

2. *DNS resolution:* The media player first initiates a DNS lookup to resolve the domain name contained within the URL selected in step 1. This process ultimately returns with the IP address(es) required to establish the appropriate transport session(s) needed to request and download the MPD or media segment. The media player sends a DNS query to a DNS resolver (typically located within the ISP’s network). Depending on the status of the DNS resolver’s cache, the resolver may forward this query to an authoritative DNS server. In the case where a CNAME record is obtained by the DNS resolver, the canonical domain name contained in the CNAME record is resolved. This process continues until the appropriate A (IPv4 address) or AAAA (IPv6 address) DNS record is obtained. The DNS resolver finally responds to the media player’s DNS query with the resolved IP address(es) associated with the domain name contained within the original URL.

3. The media player establishes a transport session (e.g., TCP session) with the server associated with the IP address(es) returned by the DNS resolver. In the case where multiple IP addresses are returned in response to the prior DNS query, establishment of a transport session to the first IP address listed in the DNS query response is attempted. If unsuccessful, an attempt to establish a transport session with the second IP address listed in the DNS query response is attempted. This process continues until establishment of a transport session is successful or all attempts to each of the returned IP address have failed.

4. *HTTP request and content delivery:* The media player requests and obtains the MPD or media segment from the remote endpoint of the established transport session via HTTP.

The process, outlined above, which the media player follows is no different than what it would normally do to request and stream content. However, the functionality to switch sources, or endpoints, in this multi-CDN approach is implemented by changing the DNS records used to resolve the DNS queries in step 2 above. As mentioned above, the domain name of the URL used by the media player is typically setup as an alias in a DNS CNAME record where the canonical domain name contained in this record points to the location where the content should be streamed. An Application Service may change this DNS CNAME record so that the canonical domain name points to a different location (e.g., a different CDN, source, or endpoint). Determination of the canonical name used in the DNS CNAME record may be based on criteria such as performance (e.g., latency, bit rate, etc.), cost, geographic location, etc.

##### 5.19.1.3.2 DNS-based switching requirements on multi-CDN delivery

##### 5.19.1.3.3 DNS-based switching performance

#### 5.19.1.4 Multi-CDN delivery with DASH-based client-side switching

##### 5.19.1.4.1 Functional description of DASH-based client-side switching

In the specific case of MPEG-DASH, the same steps as in clause 5.19.1.3.1 may be applied, but some preceding steps can be implemented to select CDN or URL in the DASH Media Presentation Description.

The usage of multiple base URLs and consistent resolution is also described in the 3GPP DASH profile specified in clause 8.6 of TS 26.247 [40]. In DASH, it is possible to use a relative base URL to point to files on a relative path, or one could use an absolute base URL that contain the full base path to be used. For multi-CDN usage the absolute base URL path is typically used.

The Media Presentation Description can contain different BaseURL elements that enable fetching segments from different locations. In this case the media player (DASH client) can apply some additional logic, such as based on its historical data or assigned priorities in the Media Presentation Description to select a base URL. This base URL can then be combined with the relative path for the media segment’s full URL. This way, the media player can, by interpreting the media presentation description, decide on the URL to use for the request for the media segment or Media Presentation Description. After this step, the steps in clause 5.19.1.3.1 are followed.

To summarize, the following steps may be followed by the media player for media segment requests using the base URL in the Media Presentation Description before the step of multi-CDN delivery with a DNS server in clause 5.19.1.3.1.

1. Check the different base URLs in the Media Presentation Description that apply to the segment.

2. Check which base URL has the highest priority for usage, based on internal logic of the media player. In case a previous request has failed, another base URL may be selected, as before.

3. Combine the base URL with the relative path obtained for the media segment.

4. Apply the steps as described in clause 5.19.1.3.1.

This approach is applied in profiles for DASH used in the industry, such as DVB-DASH [103285].

An example of handling error responses and using multiple base URLs is shown in figure 5.19.1.1.4.1-1.

A diagram of a program

Description automatically generated

Figure 5.19.1.4.1-1: A media player combining baseURL changes,  
MPD update and live edge calculation as in [103285]

In this case, the step may include reloading the Media Presentation description and recalculating the live edge (in case a DASH dynamic media presentation is used) to obtain again the relative request URL and make sure it is valid.

The media segment is requested again, and in this case there should not be an error reponse.

In case of an error response the process may be repeated.

##### 5.19.1.4.2 DASH-based client-side switching requirements on multi-CDN delivery

##### 5.19.1.4.3 DASH-based client-side switching performance

#### 5.19.1.5 Multi-CDN delivery using a Content Steering Server

##### 5.19.1.5.1 Functional description of multi-CDN delivery using a Content Steering Server

There is no equivalent base URL feature available when using HTTP Live Streaming (HLS) [87] for media delivery. Instead, a mechanism known as *HLS Content Steering* was developed by Apple to support downloads from different pathways.

This feature uses an external Content Steering server to provide server paths to HLS clients allowing them to change the path of the requests. An HLS playlist may contain a tag to indicate information about the content steering server location (e.g. the tag #EXT-X-CONTENT-STEERING with SERVER-URI attribute indicates the steering server URI using this tag). An HLS client can than use this URI to request the steering manifest that includes information about the different pathway URIs (CDN paths) and suggested priority.

This approach has recently also been considered for use with MPEG-DASH by the DASH Industry Forum’s content steering architecture [DIFCS], so it is potentially applicable to DASH as well as HLS.

##### 5.19.1.5.2 Content Steering Server requirements on multi-CDN delivery

##### 5.19.1.5.3 Content Steering Server performance

#### 5.19.1.6 Multi-CDN delivery using SAND4M

##### 5.19.1.6.1 Functional description of multi-CDN delivery using SAND4M

3GPP DASH as specified in clause 13.10 of TS 26.247 [40], defines the *Server-Assisted Network Delivery* (SAND) functionality that enabling SAND for Multi-Network support (SAND4M). The primary use case for SAND for Multi-Network Access resulted from the distribution of DASH content over MBMS or other networks, for which the MBMS Client acts as a DASH server or DASH-Aware Network Element (DANE) in order to provide DASH formats to the DASH client in a manner compatible with TS 26.247 [40].

Clause 13.10 of TS 26.247 [40] specifies required and recommended functions for both a DANE and a DASH client. Despite the requirements of this mode having been designed to fulfill the SAND functionalities, it is not restricted to this use case: this mode may also be used in other contexts, in particular when using multiple networks for distribution and dynamic steering across the network. Specifically, the following cases are considered potentially relevant to the topic of multi-CDN delivery:

- Not all resources announced in the presentation manifest (e.g. MPEG-DASH MPD) are always accessible on all networks, e.g. broadcast resource is unavailable when the UE is outside broadcast coverage.

- Not all resources are available on all networks all the time.

- Networks may have different availability times.

- Networks go down dynamically and may re-appear.

- The DANE may issue preferences for one network.

- The information may be established via in-band and out-of-band channels.

##### 5.19.1.6.2 SAND4M requirements on multi-CDN delivery

##### 5.19.1.6.3 SAND4M performance

#### 5.19.1.7 Coded Multi-source Media Format (CMMF)

##### 5.19.1.7.1 Functional description of CMMF

Coded Multi-source Media Format (CMMF) [CMMF] is an extensible container format designed to facilitate the management and interchange of audio-visual media and metadata in one or more coded representations (e.g., encoded with application-layer, forward error correction (FEC), linear, network, or channel codes). The coded media representations supported by CMMF enable the efficient use of multi-source, multi-path, and multi-access connectivity for network-delivered media applications. The use of CMMF does not replace the basic media streaming architectures and procedures already defined. Rather, it is intended to supplement them to provide additional capabilities.

A typical Video-on-Demand (VoD) MPEG-DASH HTTP adaptive streaming system is set up similarly to the non-shaded blocks shown in figure 5.19.1.3.6.1-1. Source media (e.g. audio/video elementary streams) are segmented and encoded into multiple representations, each with a different quality and bit rate. These segments are packaged together using MPEG-DASH (or HLS) and stored on an origin server located within the network. One or more CDNs are set up to distribute and deliver this content to an OTT service provider’s customer base. These CDNs obtain every requested MPEG-DASH (or HLS) segment from an origin server, caches these segments at their respective network edges, and deliver these segments to clients.

Enabling multisource delivery using CMMF within this existing delivery architecture can be accomplished through the addition of a CMMF Bitstream Generator/Source before segments are delivered to the CDNs, and a CMMF Receiver on each client, as illustrated by the shaded boxes in figure 5.19.1.7.1-1.

A diagram of a diagram of a computer

Description automatically generated

Figure 5.19.1.7.1-1: MPEG-DASH with CMMF Delivery System Example

While Figure 5.19.1.3.6.1-1 shows the CMMF Bitstream Generator/Source between the Origin Server and the CDNs (i.e., CMMF bitstreams are created on demand), the CMMF Bitstream Generator/Source can just as easily be located between the MPEG-DASH Packager and the Origin Server. In the former case, the original MPEG-DASH segments are stored on the Origin Server and CMMF representations of those segments are cached on each CDN. In the latter case, the CMMF Bitstream Generator/Source creates multiple CMMF representations of each segment produced by the MPEG-DASH Packager and stores them on the Origin Server for later retrieval by a CDN.

In this system, the Application Service Provider is responsible for segmenting, encoding, and packaging the media. It is also responsible for creating a presentation manifest (MPD, shown in figure 15.19.1.7.1-2) that contains relative URLs to the files/segments (shown in a dotted outline) that make up the adaptation sets. This information is transferred from the Application Service Provider to the media player (using a method preferred by the Application Service Provider) and is used by the media player to determine which segments are to be downloaded (via the CMMF Receiver) and played.

A diagram of a data flow

Description automatically generated with medium confidence

Figure 15.19.1.7.1-2: Example MPEG-DASH MPD

The Application Service Provider in this example is also responsible for determining and setting up the delivery system (i.e., the CDNs) to distribute CMMF-encoded media. Information about this setup is captured within the CMMF Configuration Information as a list of host URLs to each of the CDNs. It is important to note that both the MPEG‑DASH master manifest and the CMMF Configuration Information is required to download the media. In this example, it is assumed that the Application Service Provider is utilizing two CDNs and each segment listed in the MPEG-DASH MPD is encoded and packaged into two unique CMMF bitstreams/objects, one intended for the first CDN and the other for the second CDN according to the list of host URLs provided in the CMMF Configuration Information. An example of this is shown in figure 15.19.1.7.1-3. Furthermore, example bitstream/object constructions can be found in annex C of [CMMF].

A diagram of a computer

Description automatically generated

Figure 15.19.1.7.1-3: CMMF bitstreams/objects generated  
to deliver the MPEG-DASH packaged content

The process for streaming this content is shown in figure 15.19.1.7.1-4.

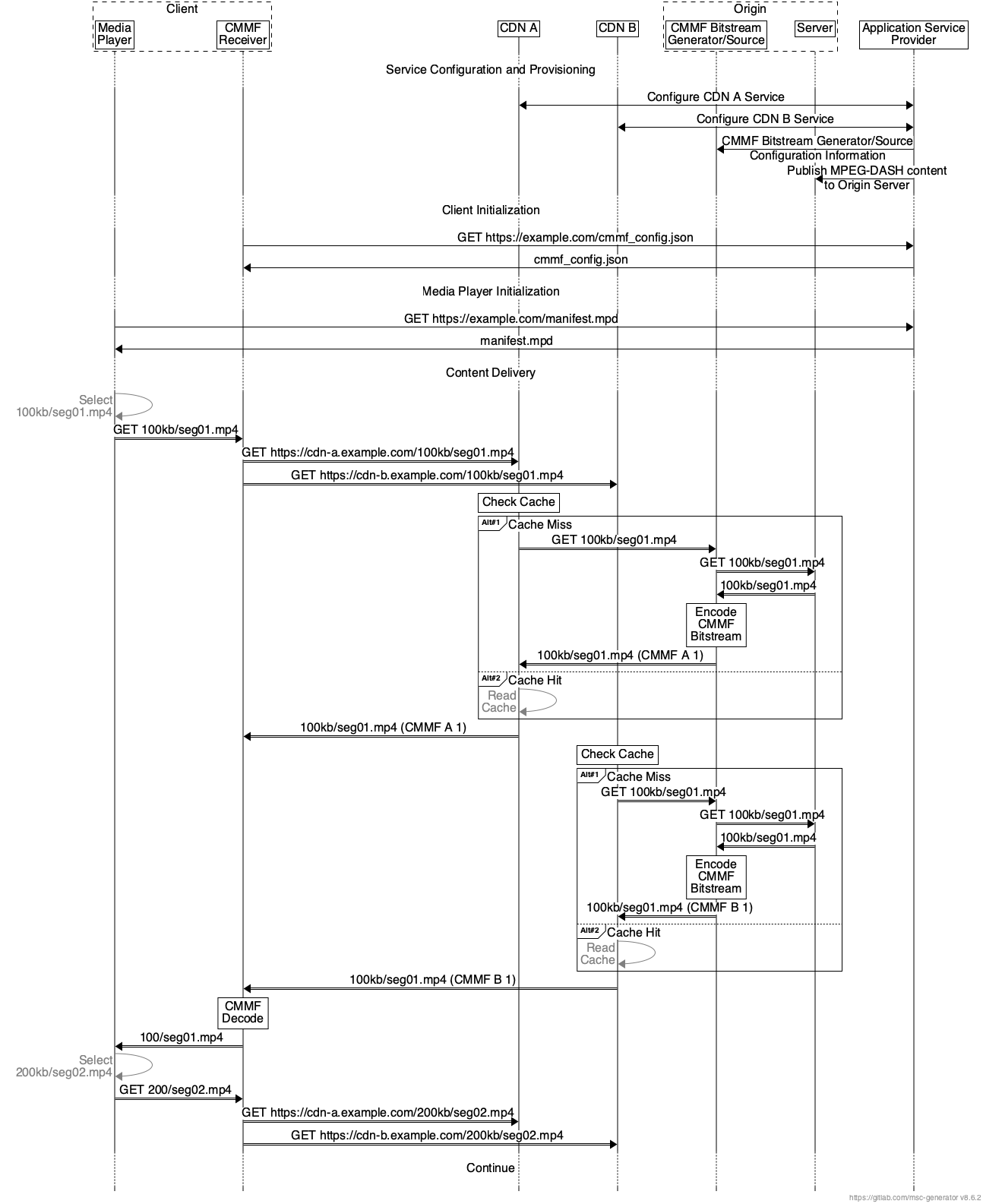


Figure 15.19.1.7.1-4: CMMF request and content delivery example for MPEG-DASH

An Application Service Provider first configures and provisions the CMMF service. The first steps are configuration of multiple CDNs. This configuration includes defining each CDN’s service domain names, origin host (e.g., the domain name of the CMMF Bitstream Generator/Source), caching policies, etc. The Application Service Provider also configures the CMMF Bitstream Generator/Source. This configuration includes the definition of necessary information for the CMMF Bitstream Generator/Source to properly encode and generate CMMF objects. Per [CMMF], this may include:

- the definition of a code type and code construction parameters,

- the definition of a CMMF profile,

- information about source object construction (e.g., fragmented HLS/MPEG-DASH segments, etc.),

- the location where source media can be found, etc.

The final step of this process is to publish MPEG-DASH and/or HLS content to an origin server (e.g., AWS S3 bucket).

Upon client initialization, the CMMF Receiver requests the CMMF Configuration Information (in this case it is stored as a JSON file) from the Application Service Provider. This information communicates a list of host URLs specifying the locations for which the client can retrieve CMMF encoded content for every segment listed within the master manifest file. In this case, this list includes the domain names used during the CDN configuration step.

Upon media player/delivery session initialization, the media player retrieves and parses the presentation manifest (MPD) from the Application Service Provider and chooses the adaptation set(s) it wishes to stream. Once selected, the media player requests the appropriate segment from the CMMF Receiver using the relative URL communicated in the master manifest. The CMMF Receiver joins the relative URL with each of the host URLs from the CMMF Configuration Information file and requests two distinct CMMF bitstreams of that segment from the two available CDNs. Assuming the appropriate CMMF bitstream is cached, the CDN begins delivery. Otherwise, the CDN requests the segment from the CMMF Bitstream Generator/Source. At which point, the original segment is pulled from storage, encoded, and delivered to the CDN and to the client. The CMMF Receiver downloads the two CMMF bitstreams of that segment until it is capable of decoding. These downloads are performed using an appropriate strategy based on the underlying network protocols in use and network conditions. Once enough CMMF-encoded content has been received, the CMMF Receiver decodes the segment and delivers it to the media player. The media player selects the next segment to be downloaded and the process repeats.

In the case of a third CDN being introduced, a new CMMF bitstream can be generated and cached without replacing or modifying the existing CMMF bitstreams already cached in the initial two CDNs. All that is required is an update to the host URL list managed by the Application Service Provider.

##### 5.19.1.7.2 CMMF requirements on multi-CDN delivery

Based on the description in the previous clause, multi-CDN and/or multi-access media delivery using CMMF requires preparation of the content to be served to a population of clients and clients that can access and download from multiple sources in parallel. Specifically,

1. The ability to create CMMF-encoded media objects and distribute/stripe these (in addition to possibly distributing the original source media such as MPEG-DASH or HLS media segments) across multiple client-accessible network locations (e.g., 5GMS Application Servers, CDNs, etc.).

Accessing content from multiple sources/endpoints within the network simultaneously requires that each network source/endpoint be populated with a unique CMMF bitstream/object containing the content being requested. A CMMF network source/endpoint is one that can be individually addressable or reachable (i.e., it is recommended that there exists a one-to-one mapping between the set of individually addressable or reachable sources/endpoints and the set of CMMF bitstreams/objects for each CMMF encoded piece of content). Source/endpoint types may be entire CDN distributions, single points-of-presence (PoPs) within a single CDN distribution, or standalone servers. For example, a single CDN which replicates content across their PoPs and uses DNS or anycast to route traffic to the PoPs within their network would be considered one source/endpoint. Alternatively, a CDN that enables clients to reach individual PoPs within their network may allow for each PoP to be an CMMF source/endpoint assuming each PoP can be populated with a unique CMMF bitstream/object.

Various methods for creating unique CMMF bitstreams/objects for each CMMF network source/endpoint exist. The necessary CMMF bitstreams/objects can be created offline (e.g., at the time the video/audio is encoded and packaged) and stored on an origin server for later retrieval by the CMMF network sources/endpoint. They can also be created on demand using a cloud-based or edge-based just-in-time encoder as client requests are received.

Detailed examples for preparing original source media for delivery from multiple serving endpoints using CMMF are provided in [CMMF]. In general, the processing required to create CMMF bitstreams/objects is minimal (and scalable) allowing for a wide range of available implementation options.

2. The capability for clients to access, efficiently download, and decode information collected from the partially received CMMF-encoded media bitstreams/objects obtained in parallel from multiple network endpoints where CMMF-encoded media objects (and possibly original source media) are stored/cached.

These capabilities can be implemented as a plug-in similar to the MBMS Client shown in clause 4.6.1 of [TS26510] to simplify integration into existing platforms and players, or they can be implemented directly within the streaming media player located on each client. When downloading content (e.g., a segment that is intended to be played), a CMMF client will connect to multiple sources/endpoints and request the CMMF bitstream/object associated with that content from each. Any one of these CMMF bitstreams/objects do not need to be obtained in their entirety, nor does any byte-level scheduling need to occur (e.g., each CMMF bitstream/object can be transmitted from their beginning to their end). Rather, a client only needs to obtain enough information from all of the transmitted CMMF bitstreams/objects so that it can decode the content those bitstreams/objects carry.

The methods used to efficiently download media using CMMF from multiple sources/endpoints are heavily dependent on the underlying network and transport protocols used to deliver CMMF-encoded bitstreams/objects, as well as the implementation of the CMMF-enabled client. For streaming use cases utilizing either HTTP/1.1 [3] or HTTP/2 [4] over TCP, total overhead (i.e., total amount of data egressed from all of the sources/endpoints (including HTTP and CMMF headers) with respect to the size of the original source media object) has been demonstrated to be between 0.5-3% when downloading 1080p, 4-second MPEG-DASH segments encoded at approximately 5 Mbps (it should be highlighted that this is roughly on-par with the overhead induced by in-market media players related to downloading multiple bit rates of the same segment and (obviously) rendering only one during playback). Overhead when using other network/transport protocols or different implementations may differ.

Likewise, the number of requests sent by a CMMF-enabled client to each CMMF endpoint can also be considered overhead. Various strategies can be employed depending on the capabilities or limitations of the underlying transport protocols and network. Cases where the client is limited (e.g., it is using HTTP/1.1 [3] to obtain CMMF-encoded content where the client can only make requests serially and cancel them by closing the underlying TCP connection) may require a different strategy than cases where a more advanced protocol is used (e.g., HTTP/2 [4]).

- In the case where HTTP/1.1 is used as the application protocol, one strategy to download CMMF-encoded content while limiting the amount of extra data downloaded as well as avoiding cancelling requests may be to make several byte range requests to each CMMF endpoint where these byte range requests are sized appropriately for the observed network conditions and the amount of data that is still required at that time. A current, state-of-the-art implementation of this strategy generates between three and six requests to each CMMF endpoint (depending on the network conditions) while downloading 1080p, 4-second MPEG-DASH segments encoded at approximately 5 Mbps.

- In cases where the client is using an underlying protocol suite with more features (e.g., HTTP/2 over TCP or HTTP/3 [5] over QUIC [32]), those features may allow for different strategies. A strategy that uses flow control features available within HTTP/2 achieves the same download as mentioned above while only sending one request to each CMMF endpoint.

Of course, other strategies exist, and the approach they take to obtain CMMF-encoded content from multiple CMMF endpoints is dependent on the network protocols used, the underlying networks’ capabilities, and the overall use case.

The complexity and client device impacts of decoding received CMMF bitstreams/objects has also been demonstrated to be minimal. While the decode complexity is dependent on the CMMF code type used (CMMF [CMMF] supports a variety of different code types including general deterministic and random linear codes (RLC), the 3GPP Raptor code specified in RFC 5053 [RFC5053] as defined in TS 26.346 [26346], RaptorQ as specified in RFC 6330 [RAPTORQ], and Reed-Solomon as specified in RFC 5110 [RSFEC]), CMMF has been demonstrated on over 4000 unique client device models without issue.

##### 5.19.1.7.3 CMMF performance

To understand some of the advantages of using CMMF for streaming media, CMMF was implemented and trialed on a commercial streaming platform from approximately September 2022 through September 2023. This platform offers a large content library, streamed to a world-wide customer base where the majority of the content had a maximum bit rate of 5 Mbps or less (the median maximum bit rate available was approximately 3.5 Mbps while over 70% of all sessions had a maximum possible bit rate of 5 Mbps or less). Approximately 5%–50% of the traffic on selected device types was streamed using CMMF while the remainder of the traffic was streamed using a popular conventional server-side switching/DNS-based multi-CDN implementation. Both the CMMF multi-source and the conventional multi-CDN approach used three tier 1 CDNs. CMMF clients downloaded content from each CDN in parallel, while the "conventional" clients switched between the three based on input from the multi-CDN switching platform. Performance measurements for all traffic were collected using an industry-leading performance measurement platform. This data includes session-level information about relevant QoE key performance indicators (KPIs). In addition, supplemental QoS information was collected for only those sessions using CMMF multi-source as a delivery method.

A summary of the amount of traffic measured for each delivery method during this trial is provided in table 5.19.1.7.3-1. This and subsequent tables only show traffic measured for Android clients streaming over cellular networks from January 1 through July 26, 2023. Furthermore, only those sessions where the mean edge cache hit rate is greater than 50% are considered. For CMMF traffic, this was determined using the supplemental QoS information collected for each CMMF session. For conventional traffic, this supplemental information was not available on a session-by-session basis since this traffic bypassed the functionality added when implementing CMMF within the player. Rather, it was confirmed, via querying each CDN utilized, that the mean edge cache hit rates for all conventional traffic was greater than 95%. This estimate of the edge cache hit rate was also validated in a separate experiment where conventional traffic was routed through the new CMMF player functionality so that QoS metrics (including cache hit status) could be collected. Unfortunately, the volume of CMMF traffic and the diversity of the content streamed during the trial made it very difficult to keep CDN caches warm with CMMF encoded content. Trying to match multi-source and conventional edge cache hit rates on a one-to-one basis was not possible. As a result, the threshold established above provides sufficient data to provide statistically significant results; but it also implicitly favors conventional delivery since those sessions were more often served by the CDNs’ edge.

Table 5.19.1.7.3-1: CMMF real-world multi-CDN trial summary. Only sessions measured on cellular networks and running Android are shown

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Delivery method | Hours watched | Number of playback sessions | Number of unique devices | Number of unique countries | Minutes watched per unique device |
| Conventional | 25,026.92 | 120,269 | 23,752 | 178 | 63.22 |
| CMMF | 14,013.76 | 44,081 | 12,534 | 141 | 67.08 |

An overview of the performance improvements multi-source delivery provided over conventional multi-CDN switching for various QoE KPI’s is shown in table 5.19.1.3.6.3-2. The table provides the mean value of the relevant KPI plus/minus one standard deviation. In general, double-digit gains were observed across all key QoE performance indicators showing that CMMF enabled multi-source delivery can drastically improve the quality of streamed media.

Table 5.19.1.7.3-2: Real-world multi-CDN QoE performance results

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Delivery method | Normalized average session bit rate (% of max session bit rate)  (NOTE 1) | Playback start-up time (s)  (NOTE 2) | Connection-induced rebuffering ratio (%)  (NOTE 3) | Start-up failure rate (%) | Playback failure rate (%) |
| Conventional | 83.70 ± 28.08 | 3.40 ± 10.08 | 0.28 ± 1.78 | 0.51 | 1.22 |
| CMMF | 94.31 ± 16.23 | 1.83 ± 9.34 | 0.19 ± 1.17 | 0.07 | 0.59 |
| Difference | 10.61 ± 32.43 | -1.57 ± 13.74 | -0.09 ± 2.13 | -0.44 | -0.63 |
| Gain | + 12.68% | - 46.18% | - 32.14% | -86.27 % | - 51.64% |
| NOTE 1: The normalized average session bit rate is defined as the average bit rate measured during a session divided by the maximum bit rate listed in the session’s content manifest. Only sessions without a start-up or video playback failure, a playing time greater than or equal to 60 seconds, playback completed at least 10% of the content, and the maximum bit rate as defined by the sessions’ corresponding manifest was available. These statistics are weighted using the sessions’ duration.  NOTE 2: Only sessions without a start-up or playback failure and a start-up time greater than 0 seconds.  NOTE 3: Only sessions without a start-up or playback failure, a playing time greater than or equal to 60 seconds, and playback completed at least 10% of the content. These statistics are weighted using the sessions’ duration. | | | | | |

The empirical CDFs for the content normalized average session bit rate, start-up time, and connection-induced rebuffering ratio are provided in figures 5.19.1.7.3-1, 5.19.1.6.3-2, and 5.19.1.7.3-3 respectively. These results were collected using a system similar to that presented in clause 15.19.1.7.1.

Figure 5.19.1.7.3-1 shows that 60% of the sessions, regardless of delivery method, experienced an average session playback bit rate close to the maximum possible based on the content being played. However, CMMF multi-source delivery was able to lift more of those clients that could not reach the highest bit rate further up the bit rate ladder than conventional delivery.

A graph showing a blue and red line

Description automatically generated

Figure 5.19.1.7.3-1: Empirical CDF of the content normalized average session bit rate

Figure 5.19.1.7.3-2 shows that CMMF multi-source delivery was able to significantly reduce the playback start-up time as well. For example, only 10.4% of the CMMF sessions experienced a startup time greater than 3 seconds compared to 29.0% of the conventional sessions.

A graph of a line graph

Description automatically generated with medium confidence

Figure 5.19.1.7-2: Empirical CDF of the video startup time

Finally, figure 5.19.1.7.3-3 shows that CMMF multi-source delivery reduced the number of sessions that experienced a connection-induced rebuffering event from 22.4% to 14.9% in addition to reducing the total duration of rebuffering given a rebuffering event occurred.

A graph showing the value of a product

Description automatically generated with medium confidence

Figure 5.19.1.3.6.3-3: Empirical CDF of the connection-induced rebuffering ratio (CIRR)

### 5.19.2 Collaboration scenarios

#### 5.19.2.1 Multi-source media delivery

In this scenario, the 5GMSd Client requests adaptive media streaming content from two or more 5GMSd AS endponts. These 5GMS AS endpoints are functionally identical and differ only in configuration and potentially in the content that they host. The 5GMSd Client may choose one 5GMSd AS endpoint or use multiple simultaneously. This allows the network load to be distributed across the 5GMSd AS endpoints and M4d downlink transports, the cost to be optimized, as well as the QoS to be improved.

As an example, a 5GMS System Operator may provide a video streaming service where media is streamed from a 5GMSd AS endpoint deployed within its Trusted DN. To manage peak demand, it may choose to offload a fraction of the total traffic to an externally deployed 5GMSd AS. The quality of the streaming service in this case may be required to be equivalent regardless of whether media is streamed from the 5GMSd AS deployed within the Trusted DN or that deployed externally. By enabling traffic to be offloaded to an externally deployed 5GMSd AS, the 5GMS System Operator may be able to optimize the costs of hosting and delivering media by exploiting third-party capacity during peak periods to deliver content in a stable and consistent manner.

The client’s Media Session Handler discovers the URLs of these 5GMSd AS endpoints from the 5GMSd Application Function (AF), either through a Media Entry Point or from a separate piece of metadata. QoE metrics from the 5GMSd Client may be used by the 5GMSd AF to determine the best 5GMSd AS endpoint(s) for each Media Player to use when streaming media.

Figure 5.19.2.1-1 shows an example collaboration scenario where the Media Player in a 5GMSd Client communicates with multiple 5GMSd AS instances to stream media. Each 5GMSd AS instance has no direct communication with its peers; rather it communicates directly with the 5GMSd Application Provider via reference point M2d and with the 5GMSd AF (not depicted) via reference point M3d.

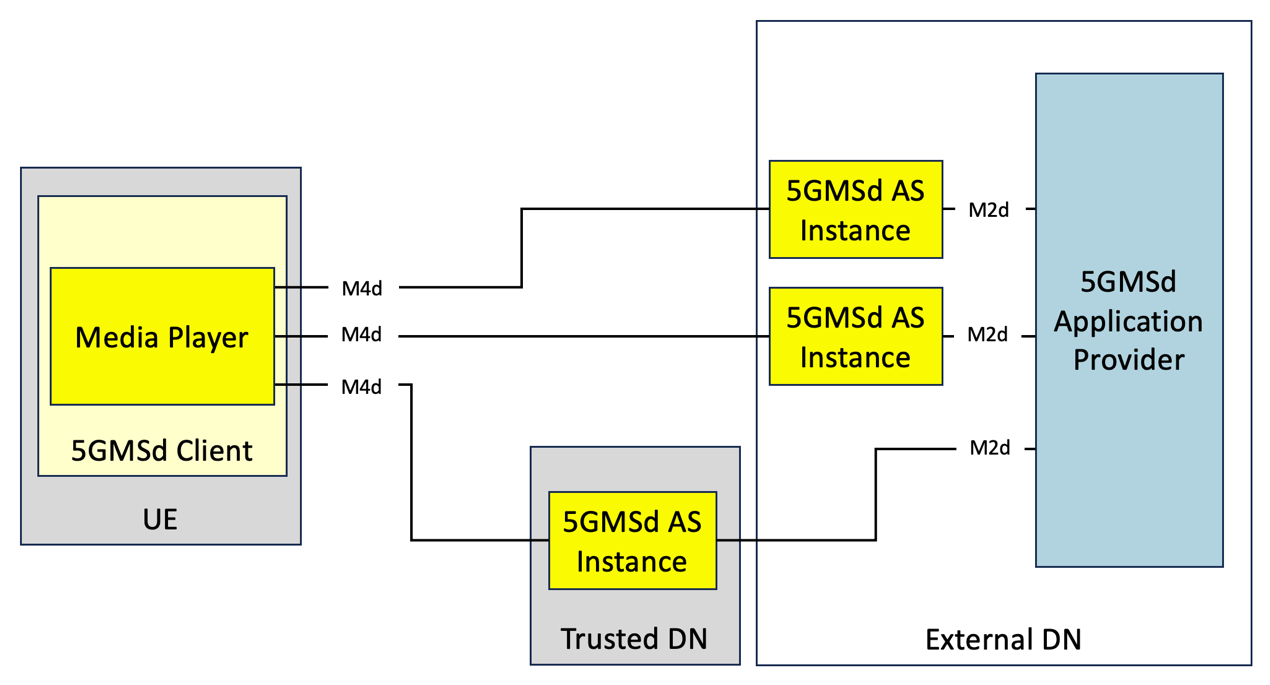


Figure 5.19.2.1-1: Multi-CDN media delivery within 5G system

#### 5.19.2.2 Joint multi-source and multi-access media delivery

In this scenario, the 5GMSd Client is directly connected to multiple data networks or access networks (e.g., an unmanaged Wi‑Fi network and the 5G network), as described in clause 5.18. The Media Player in the 5GMSd Client requests adaptive media streaming content from two or more 5GMSd AS endpoints. The Media Player may choose one endpoint or use multiple simultaneously. This allows the 5GMSd Client to distribute network load across access networks and 5GMSd AS instances, optimize costs, as well as improve QoS.

The client’s Media Session Handler discovers the URLs of these 5GMSd AS endpoints from the 5GMSd AF, either through a Media Entry Point or from a separate piece of metadata. QoE metrics from the 5GMSd Client may be used by the 5GMSd AF to determine the best 5GMSd AS instance for each Media Player to use when streaming media.

Figure 5.19.2.2-1 shows an example collaboration scenario where the Media Player is consuming media from multiple 5GMSd AS endpoints through different data networks. Neither data network nor the deployed 5GMSd AS instances has direct communication with its peers. Rather, each 5GMSd AS instance communicates with the 5GMSd Application Provider at reference point M2d and with the 5GMSd AF (not depicted) via reference point M3d.

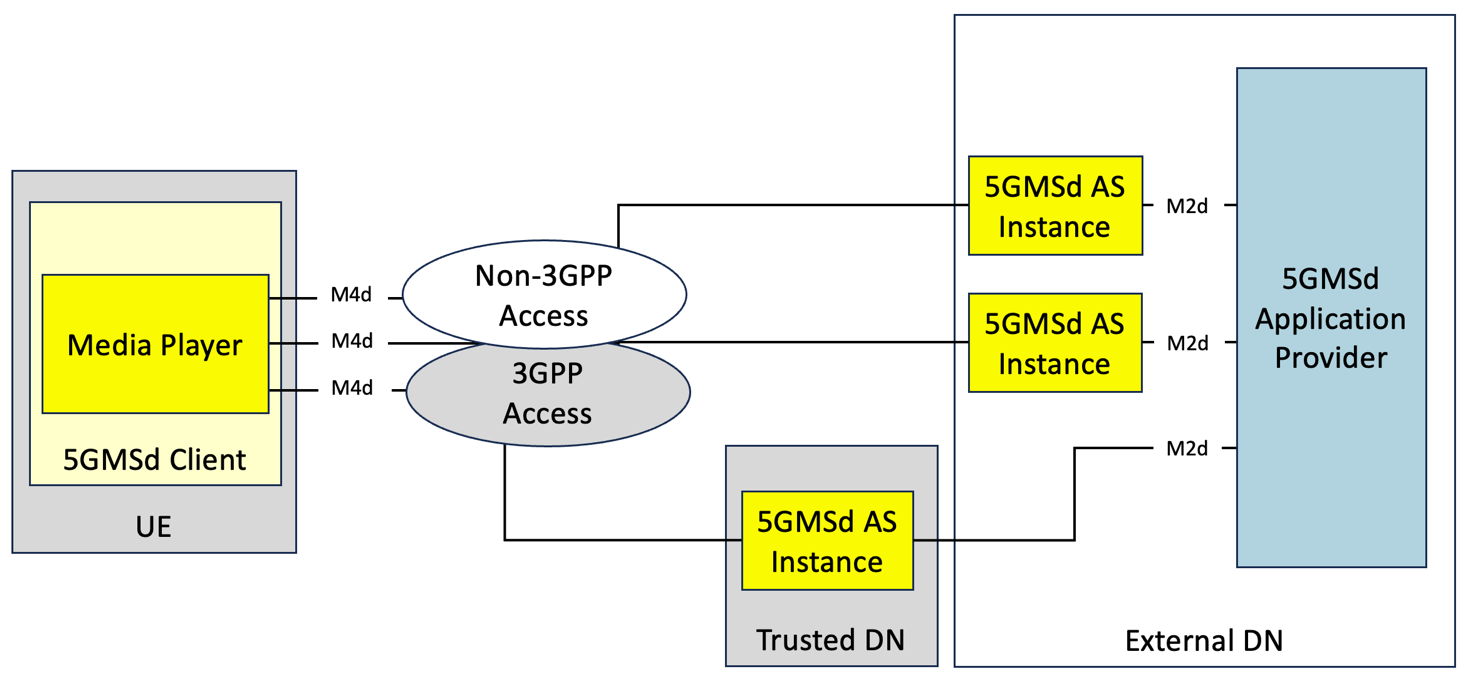


Figure 5.19.2.2-1: Multi-access media delivery within 5G system

### 5.19.3 Architecture mappings

#### 5.19.3.1 Architecture mapping #1: Over-the-top (OTT) multi-source delivery

##### 5.19.3.1.1 General architecture mapping

A general architecture mapping for the case where the 5GMSd Application Provider supplements media delivery over the 5GMS System with externally configured sources (e.g., CDNs) is shown in figure 5.19.3.1.1-1. In this architecture, the 5GMS System is configured and provisioned to deliver media from a single content source/endpoint (i.e., 5GMSd AS); and additional sources/endpoints are configured and provisioned by the 5GMSd Application Provider independent of the 5GMS System. With minor exceptions (as noted below), the use of multi-source delivery is largely transparent to the 5GMS System.



Figure 5.19.3.1.1-1: General architecture mapping for Over-The-Top (OTT) multi-source delivery.

A description of the functions and reference points specific to multi-source delivery shown in figure 5.19.3.1.1-1 are provided below. Gaps between these descriptions and the architecture specified in clause 4.2 of TS 26.501 [15] are highlighted in **boldface**.

The following functions are defined:

- *5GMSd Application Provider:* A 5GMSd Application Provider as defined in clause 4.2 of TS 26.501 [15]. **The 5GMSd Application Provider is responsible for overall configuration and operation of the multi-source delivery session. This includes selecting the multi-source delivery approach used to deliver content from multiple endpoints, configuring all endpoints (both within the 5GMS System and external to it), preparing all content for multi-source delivery, operation of any management functions required by the multi-source delivery approach in use, etc.** Specific subfunctions that may be used include:

- *Content Preparation:* For multi-source approaches that require content preparation (e.g., content manifest manipulation, CMMF object creation, etc.), the 5GMSd Application Provider is responsible for preparing the content prior to its distribution to the service location/endpoint.

**-** *Content service location(s)/endpoints(s):* The 5GMSd Application Provider is responsible for configuration and provisioning of all service locations/endpoints external to the 5GMS System and available to Media Players at reference point M4d′. An example of an external service location/endpoint may include a commercial CDN. Furthermore, **each Content Distribution is required to be uniquely addressable and reachable by 5GMSd Clients (e.g., each service location/endpoint, whether external or not, has a unique domain name or base URL).**

- Online Service Location/Endpoint Management: Depending on the multi-source approach in use, some form of management function may be required. An example may include a Content Steering Server [DIFCS]. The 5GMSd Application Provider is responsible for operation of this function.

- *5GMSd AF:* A 5GMSd AF as defined in clause 4.2 of TS 26.501 [15]. The 5GMSd Application Provider provisions the Content Hosting feature for downlink media delivery. Furthermore, the Content Hosting Configuration defines one or more Distribution Configurations (clause 8.8.3.1 of TS 26.510 [26510]). Each Distribution Configuration is assigned a base URL (i.e., one that includes a scheme, authority and, optionally, path segments) from which content is made available to 5GMSd Clients at reference point M4d. See clause 8.8.3.1 of TS 26.510 [26510] for further details. Details about the provisioned Content Hosting Configuration are made available to the 5GMSd Client’s Media Session Handler at reference point M5d via the Service Access Information (clause 9.2 of TS 26.510 [26510]) and the 5GMSd Application Provider via the Maf\_Provisioning API at reference point M1d.

- *5GMSd AS:* An Application Server as defined in clause 4.2 of TS 26.501 [15]. Content Hosting is provisioned and configured on the 5GMSd AS by the 5GMSd AF using the Mas\_Configuration API at reference point M3d. The provisioned Content Distribution ingests content from the 5GMSd Application Provider at reference point M2d and makes this content available to 5GMSd Clients at reference point M4d. Each provisioned Content Distribution may be located on a single physical host or span multiple physical hosts as required.

*- 5GMSd-Aware Application:* A 5GMSd-Aware Application as defined in clause 4.2 of TS 26.501 [15]. The 5GMSd-Aware Application is responsible for communicating with the 5GMSd Application Provider at reference point M8d to obtain any necessary configuration information required to access media **from multiple service locations/endpoints. This information may include the necessary information required by the specific multi-source approach in use, base URLs of the configured Content Distributions, URLs of any provisioned multi-source management functions, etc.** The 5GMSd-Aware Application is also responsible for any configuration of the Media Player **needed to enable multi-source delivery** via reference point M7d.

- 5GMSd Client: A 5GMSd Client as defined in clause 4.2 of TS 26.501 [15]. **Depending on the specific multi-source approach used to deliver media, the 5GMSd Client may require additional functionality than is currently specified. Any differences to the architecture shown here to enable these multi-source delivery approaches are expanded upon in clause 5.19.3.1.2.** The 5GMSd Client contains two subfunctions:

*- Media Session Handler:* A Media Session Handler as defined in clause 4.2 of TS 26.501 [15]. The Media Session Handler communicates with the 5GMSd AF at reference point M5d to establish, control, and support delivery of media from Content Distributions provisioned within the 5GMS System.

- *Media Player:* A Media Player as defined in clause 4.2 of TS 26.501 [15]. **The Media Player communicates with the 5GMSd AS at reference point M4d and external service location(s)/endpoint(s) at reference point M4d′ to download content. The Media Player may also include a Media Access Client subfunction required to operate when using a specific multi-source delivery approach (e.g., switching logic, CMMF decoder, etc.). Specifics are provided in clause 5.19.3.1.2.**

The following reference points are defined:

- M1d (5GMSd Provisioning API): 5GMSd Provisioning API as defined in clause 4.2 of TS 26.501 [15].

- M2d (5GMSd Ingest API): 5GMSd content ingest interactions as defined in clause 4.2 of TS 26.501 [15].

- M3d: Internal API as defined in clause 4.2 of TS 26.501 [15].

- M4d (Media Streaming APIs): Media Streaming interactions as defined in clause 4.2 of TS 26.501 [15].

- M4d′ (Media Streaming APIs): Media Streaming and in-band metrics reporting interactions as described in clause 5.19.3.1.2.4 below.

- M5d (Media Session Handling API): Media Session Handling API as defined in clause 4.2 of TS 26.501 [15].

- M6d (UE Media Session Handling APIs): UE Media Session Handling APIs as defined in clause 4.2 of TS 26.501 [15]. **See description of reference point M8d below.**

- M7d (UE Media Player APIs): UE Media Player APIs as defined in clause 4.2 of TS 26.501 [15]. **See description of reference point M8d below.**

- M8d (Application API): Application interface as defined in clause 4.2 of TS 26.501 [15]. **In the case where the 5GMSd AS is deployed in an external DN and is not directly configured by the 5GMSd AF (the collaboration scenario depicted in clause A.4 of TS 26.501 [15]), service information (e.g., service location/endpoint base URLs, multi-service location/endpoint delivery configuration information, CMMF Configuration Information, etc.) are communicated from the 5GMSd Application Provider to the 5GMSd-Aware Application via reference point M8d. This information is provided to the Media Session Handler at reference point M6d to be combined with the corresponding Service Access Information obtained from the 5GMSd AF over reference point M5d, or it may be provided directly to the Media Player over reference point M7d.**

- M11d (UE Media Player APIs and UE Media Session Handling APIs): UE Media Player APIs and UE Media Session Handling APIs as defined in clause 4.2 of TS 26.501 [15]. **Any necessary information obtained from the Service Access Information at reference point M5d or from the 5GMSd-Aware Application at reference point M6d to configure the Media Player for multi-source media delivery is provided at reference point M11d. This information may be dependent on the multi-source delivery approach used. Further details are provided in clause 5.19.3.1.2.**

Variations of this general architecture are possible depending on the use case and configuration of the network.

##### 5.19.3.1.2 Multi-source approach-specific architecture mappings

###### 5.19.3.1.2.1 Overview

Depending on the approach used to implement multi-source functionality, the functions and reference points discussed in clause 5.19.3.1.1 may be used differently. These are expanded upon in subsequent clauses.

###### 5.19.3.1.2.2 DNS-based switching

Multi-source delivery using DNS to switch between provisioned service locations/endpoints as described in clause 5.19.1.3 can be realized using the architecture depicted in figure 5.19.3.1.1-1. As an example, the Online Service Location/Endpoint Management function within the 5GMSd Application Provider is used to collect performance metrics from the population of 5GMSd Clients, to make decisions on when 5GMSd Clients should switch to a different service location/endpoint, and to update the appropriate DNS records accordingly, should it determine switching is necessary. Additional 5GMSd Client functionality is not needed if these metrics are reported to the 5GMSd Application Provider via reference point M8d after exposure to the 5GMSd-Aware Application via reference point M7d (see clause 13.2.6 of TS 26.512 [16]). However, modifications to the client may be necessary if those metrics need to be sent via reference point M4d′.

###### 5.19.3.1.2.3 MPEG-DASH client-side switching

Multi-source delivery using MPEG-DASH client-side switching as described in clause 5.19.1.4 may be realized using the architecture depicted in figure 5.19.3.1.1-1. However, additional functionality in the Media Player is required (if not already implemented) to switch between the available Content Distributions (or service locations) as necessary. As described in clause 5.19.1.4, MPEG-DASH client-side switching is signalled using service location decorators within the manifest (i.e., MPD). These service location decorators may be added to each MPD using the 5GMSd Application Provider’s Content Preparation subfunction prior to distribution of those MPDs to 5GMSd Clients.

###### 5.19.3.1.2.4 Content Steering Server driven switching

Multi-source delivery using a Content Steering Server as described in clause 5.19.1.5 may be realized using the architecture as shown in figure 5.19.3.1.1-1. In this case, the 5GMSd Application Provider implements the Content Steering Server within the Online Service Location/Endpoint Management subfunction. The Content Steering Server’s location is signalled privately via reference point M8d or in the content presentation manifest (i.e., MPD). Additional functionality within the Media Player is required (if not already implemented) to switch between provisioned service locations/endpoint accessible via reference points M4d and M4d′, in addition to the functionality to communicate with the Content Steering Server via reference point M4d′.

###### 5.19.3.1.2.5 SAND4M multi-source delivery

Editor’s Note: Determination of how SAND4M multi-source delivery can be realized within the architecture shown in Figure 5.19.3.1.1-1 requires further study.

###### 5.19.3.1.2.6 CMMF-based multi-source delivery

Several options exist when implementing CMMF as described in clause 5.19.1.7 within the architecture shown in figure 5.19.3.1.1-1. These are expanded upon below.

5.19.3.1.2.6.1 CMMF-enabled 5GMS client architecture

Implementing multi-source delivery using CMMF requires modifications to the 5GMSd client architecture. At minimum, a UE must be able to download CMMF bitstreams/objects from multiple service locations/endpoints (including 5GMSd Content Distributions) simultaneously and be able to decode the received bitstreams/objects. Options for implementing multi-source delivery using CMMF within the UE include:

1. *CMMF Client Proxy.* This option implements multi-source using CMMF within the UE as a proxy between the Media Player and each CMMF service location/endpoint (which may be a 5GMSd Content Distribution at reference point CMMF-1). The proxy consists of a CMMF Client and a Media Server. Once the Media Session Handler of the 5GMSd Client has configured the CMMF Client via reference point CMMF-2, the Media Player may request source content via the Media Server using reference point CMMF-3. Once a request is received, the CMMF Client downloads different CMMF encoded representations of the requested content via reference point(s) CMMF-1 and/or CMMF-1′ (these reference points are functionally equivalent to reference points M4d and M4d′ respectively despite terminating on a different logical function in the UE), decodes the received CMMF bitstreams/objects, and replies to the Media Player with the requested source content via CMMF-3. This option is illustrated in figure 5.19.3.1.2.6.1-1.

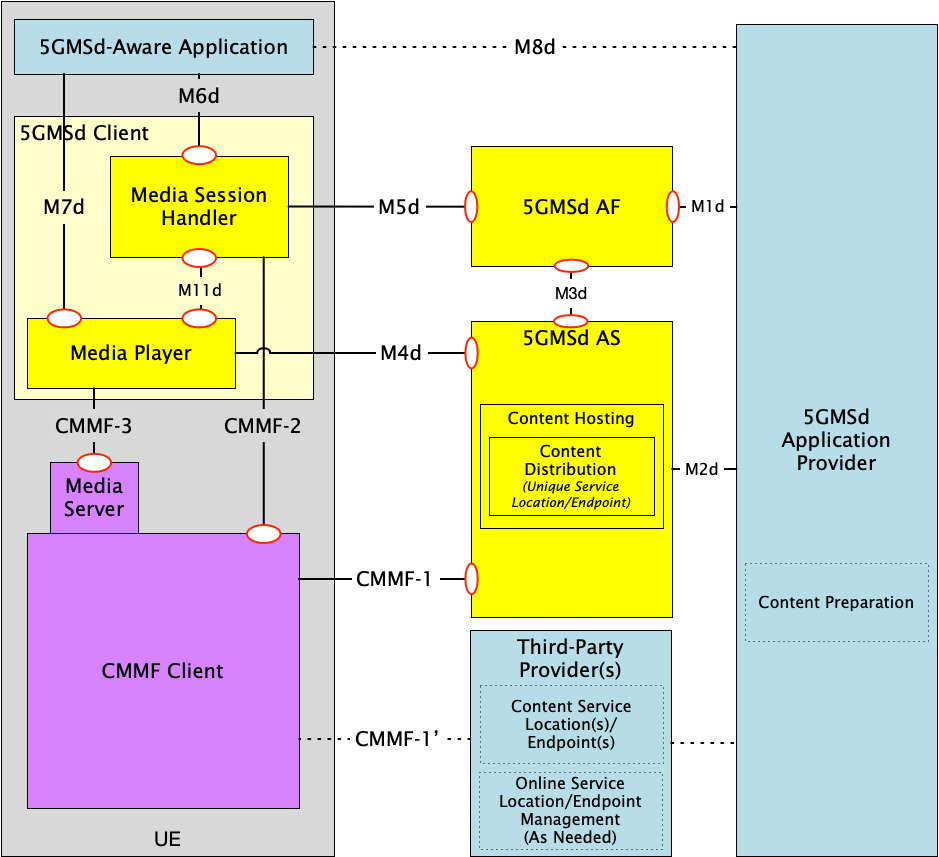


Figure 5.19.3.1.2.6.1-1: Client architecture #1 for integration of CMMF within the 5GMS Client where CMMF is implemented as a client proxy

2. *CMMF decoder integrated within the Media Player.* This option implements CMMF within the Media Player itself. An example is provided in figure 5.19.3.1.2.6.1-2 depicting CMMF integrated within the DASH-based 5GMSd Client specified in clause 13.2 of TS 26.512 [16]. The architecture and operation of the 5GMS Client is similar to that in [16] with the following exceptions:

a. *Download*: Downloads source content objects and/or CMMF bitstreams/objects from one or more service location(s)/endpoint(s) in parallel.

b. *Request Scheduling:* Performs the same function as defined in clause 13.2 of [16] with the addition of managing concurrent requests sent over reference point M4d and CMMF-1′ during the download of CMMF-encoded bitstreams/objects.

c. *Throughput Estimation:* Estimates the throughput from each individual service location/endpoint (including 5GMSd Content Distributions at reference point M4) in addition to estimating the aggregated throughput from all these service locations/endpoints.

d. *CMMF Receiver/Decoder:* Temporarily stores and jointly decodes CMMF bitstreams/objects as they are downloaded. Once decoded, the source content objects are moved to the Media Playback Management and Protection Controller subfunctions. The CMMF Receiver/Decoder subfunction also provides status updates containing decode progress to each active download function for the purposes of managing/terminating in-process downloads.

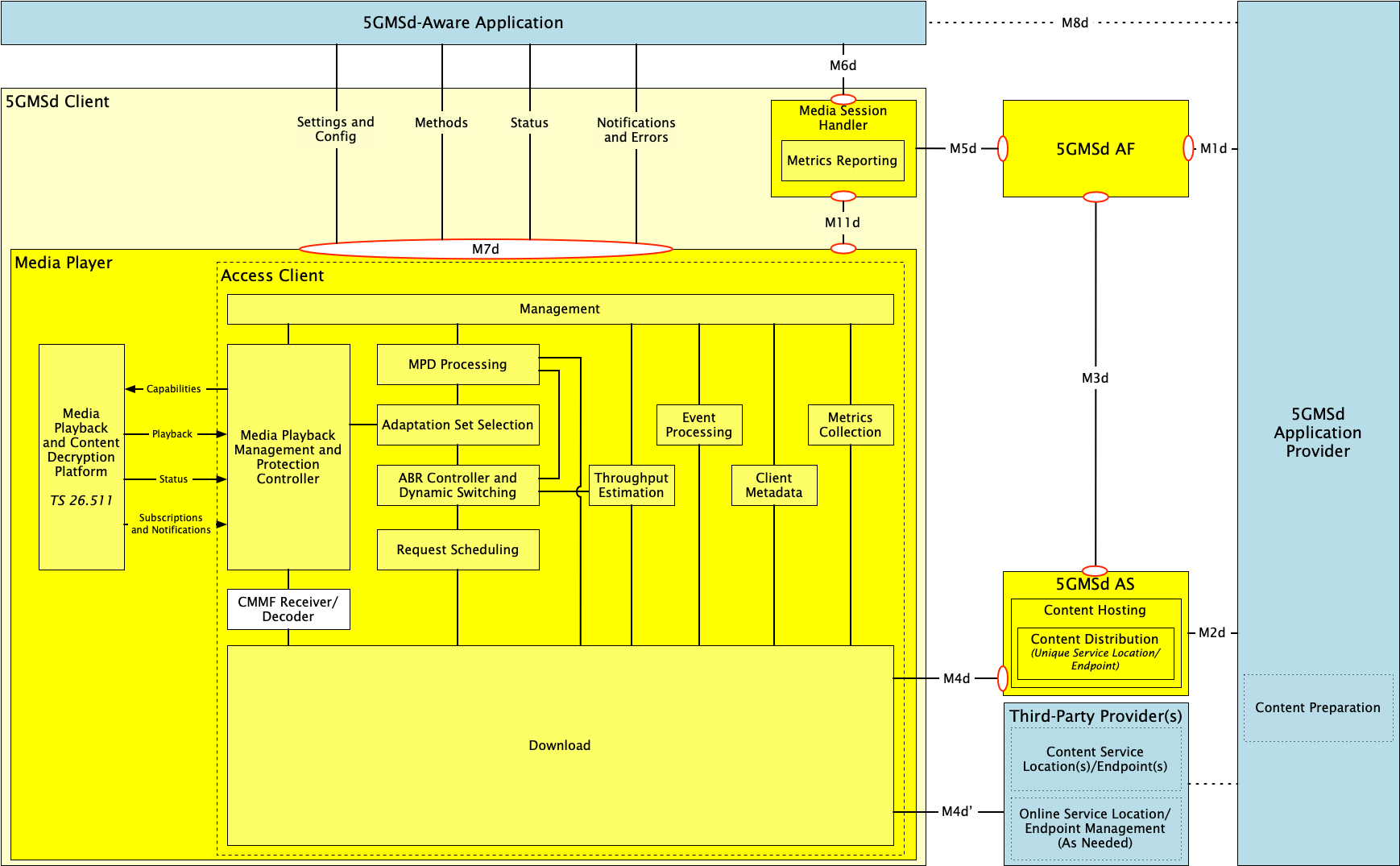


Figure 5.19.3.1.2.6.1-2: Client architecture #2 for integration of CMMF within the 5GMS Client where CMMF is integrated directly within the Media Player

5.19.3.1.2.6.2 5GMSd Client configuration for downlink media streaming using CMMF

CMMF supplements existing media streaming architectures (e.g., MPEG-DASH, etc.) to enable clients to obtain media from multiple endpoints in parallel. Enabling this functionality requires, at a minimum, information concerning where and how CMMF-encoded media can be accessed on one or more service location(s)/endpoint(s) within the network(s).

This *CMMF client configuration information* may be conveyed to the CMMF Client (assuming client architecture #1 in clause 5.19.3.1.2.6.1) or to the Media Player (assuming client architecture #2 in clause 5.19.3.1.2.6.1) in the 5GMSd Client either:

1. Privately by the 5GMSd Application Provider via a 5GMSd-Aware Application at reference point M8d.

- For client architecture #1, this information may be provided to the Media Session Handler via reference point M6d and then on to the CMMF Client via reference point CMMF‑2.

- For client architecture #2, this information may be provided directly to the Media Player via reference point M7d or routed through the Media Session Handler via reference point M6d followed by reference point M11d.

This option is relevant when the CMMF client configuration information is relatively static and is not frequently updated.

2. Contained within a Media Entry Point specified by an existing media streaming framework that is understood by the Media Player (e.g., as additional XML elements or attributes within an MPEG-DASH MPD). This option is relevant when the CMMF client configuration information is relatively static and is not frequently updated.

3. Over reference M4d′ from the Online Service Location/Endpoint Management subfunction (e.g. a Content Steering Server) when more active or extensive management is required. This option is relevant when the CMMF client configuration information is dynamic and may be frequently updated.

The CMMF client configuration information is the set of parameters and addresses which are needed by a 5GMSd Client to activate and control the reception of a CMMF-enabled media downlink media streaming session, primarily information concerning how the CMMF Client (client architecture #1) or Media Player (client architecture #2) accesses one or more CMMF-encoded objects, each containing a different encoded representation of the original source media to be played, from the available service locations/endpoints hosting this content (some of which may be 5GMSd Content Distributions at reference point M4d).

Other CMMF client configuration information that are outside the scope of the present document may also be provided and/or required based on implementation. This may include additional configurable parameters such as load-balancing policies that influence client behaviour when downloading from multiple CMMF endpoints, information about the CMMF profile in use, etc.

5.19.3.1.2.6.3 CMMF content preparation and distribution

CMMF content preparation and distribution is the overall responsibility of the 5GMSd Application Provider in this architecture mapping.

- The 5GMSd Application Provider configures and provisions resources to deliver media using CMMF across both external and trusted data networks. For the architecture shown in figure 5.19.3.1.1-1, CMMF-encoded media delivery is transparent to both the 5GMSd AS at reference point M4d and to any third-party CDN at reference point M4d′/CMMF-1′.

- The 5GMSd Application Provider prepares all CMMF bitstreams/objects intended to be distributed across every service location/endpoint (including 5GMSd Content Distribution) whether or not located within the 5GMS System.

- Hosting of CMMF-encoded media within the 5GMS System follows the established architecture (see clause 4.2 of TS 26.501 [15]) and procedures (see clause 5.2 of [15]) for downlink 5G Media Streaming.

- CMMF-enabled 5GMSd Clients accessing CMMF-encoded media hosted on one or more service locations/endpoints where the media is replicated (rather than different CMMF-encoded representations of that media) treat the set of service endpoints/locations as a single CMMF endpoint. CMMF endpoints established in external Data Networks configured and provisioned by the 5GMSd Application Provider can be used to supplement at reference point M4d′/CMMF-1′ the 5GMS-delivered media at reference point M4d.

5.19.3.1.2.6.4 CMMF object addressing and URL handling

The capability to locate and access multiple CMMF-encoded media objects (each containing different encoded representations of the same original source media) and/or the original source media across multiple service locations/endpoints is required by Media Players to effectively acquire streaming content. Furthermore, the creation of these CMMF-encoded media representations may be dynamic where the 5GMSd Application Provider is creating and caching new CMMF-encoded media objects on demand. Having robust and extensible methods for addressing each CMMF-encoded media object, including the original source media, is necessary to ensure the proper operation of coded multi-source media delivery. At least two approaches exist for addressing these media. Each approach can be used independently or a hybrid of the two can be used in combination.

1. *Unique URL path names.* Each CMMF-encoded media object containing a different representation of the same original source media object, as well as the original source media object itself, is assigned a unique URL path (i.e., there exists a one-to-one mapping between each CMMF-encoded media object or original source media object and each URL path). For example, every URL contains a unique path to a unique CMMF-encoded media object and original source media object. Table 5.19.3.1.2.6.4-1 provides examples of possible URL path formats where the differences in each URL are emphasised in **boldface**. This approach enables multiple CMMF-encoded media objects, each containing a different representation of the same original source media object, to be hosted side by side at a single service location/endpoint (or CMMF endpoint) if desired.

Definition of the patterns used may be defined by a CMMF URL template that aids in mapping the URLs obtained from a content manifest (e.g., MPD) to CMMF-encoded media resources that are available via reference points M4d, CMMF-1 or M4d′ (client architecture #2). In addition to this CMMF URL template, the CMMF endpoint URLs may also be required by the CMMF Client (client architecture #1) or Media Player (client architecture #2) to construct a complete URL needed to fetch CMMF-encoded content.

Table 5.19.3.1.2.6.4-1: Approach #1 example URLs assigned to each unique CMMF-encoded media object and original source media object

|  |  |
| --- | --- |
| Object description | Path examples |
| Original source media object (e.g., media object referenced within an MPEG-DASH MPD or HLS manifest) | /1080p/4mbps/1.m4s |
| CMMF-encoded media object containing representation A of the original source media object | Example 1: /1080p/4mbps/1.m4s**.cmmf-a** Example 2: /1080p/4mbps/**cmmf-a/**1.m4s |
| CMMF-encoded media object containing representation B of the original source media object | Example 1: /1080p/4mbps/1.m4s**.cmmf-b** Example 2: /1080p/4mbps/**cmmf-b/**1.m4s |
| … | … |

2. *Unique URL authority names.* Each CMMF-encoded media object containing a different representation of the same original source media object, as well as the original source media object itself, are each assigned a unique URL where they all share a common URL path, but their URLs differ in the authority (host name and/or port subcomponents per section 3.2 of RFC 3986 [104]). Table 5.19.3.1.2.6.4-2 provides examples of possible URLs where the differences in each URL are emphasised in **boldface**; and the approach is also illustrated in figure 15.19.1.7.1-3.

URL assignment following this method requires that each service location/endpoint (CMMF endpoint) hosts one, and only one, representation of the original source media. That representation may be the original source media object itself, or a CMMF-encoded media object created from the original source media object. While this approach limits how CMMF-encoded media is distributed within the 5GMS System, it may also simplify content preparation and hosting management by eliminating the need to track and manage creation and placement of CMMF-encoded media objects across service locations/endpoints because it is implied that each and every uniquely addressable Content Distribution (CMMF endpoint) hosts a different representation of the original source media (whether that is the original source media object itself or a CMMF-encoded media object created from the original source media object).

Table 5.19.3.1.2.6.4-2: Approach #2 example URLs assigned to each unique CMMF-encoded media object and original source media object

|  |  |
| --- | --- |
| Object description | Path examples |
| Original source media object (e.g., media object referenced within an MPEG-DASH or HLS manifest) | //**5gms-as-1/**1080p/4mbps/1.m4s |
| CMMF-encoded media object containing representation A of the original source media object | //**5gms-as-2/**1080p/4mbps/1.m4s |
| CMMF-encoded media object containing representation B of the original source media object | //**5gms-as-3/**1080p/4mbps/1.m4s |
| … | … |

#### 5.19.3.2 Architecture mapping #2: 5GMS-integrated multi-source delivery

##### 5.19.3.2.1 General architecture mapping

A general architecture mapping for the case where the multi-source delivery is integrated within the 5GMS System is shown in figure 5.19.3.2.1-1. In this architecture, the 5GMS System is configured and provisioned to deliver media from one or more content sources/endpoints (i.e., Content Distributions) located within the 5GMS System.

A screenshot of a computer

Description automatically generated

Figure 5.19.3.2.1-1: General architecture mapping for 5GMS-integrated multi-source delivery.

A description of the functions and reference points specific to multi-source delivery shown in figure 5.19.3.2.1-1 are provided below. Gaps between these descriptions and the architecture specified in clause 4.2 of TS 26.501 [15] are highlighted in **boldface**.

The following functions are defined:

- *5GMSd Application Provider:* A 5GMSd Application Provider as defined in clause 4.2 of TS 26.501 [15]. The 5GMSd Application Provider provisions the 5GMS System for multi-source media delivery at reference point M1d. The 5GMSd Application Provider provisions the 5GMSd AF with Content Preparation Template(s) (clause 5.2.5 of TS 26.510 [26510]) as required by the multi-source delivery approach used; in addition to providing the 5GMSd AF with a Content Hosting Configuration (clause 5.2.8 of TS 26.510 [26510]) which indicates one or more Distribution Configurations, **one for each intended service location/endpoint**.

- *5GMSd AF:* An Application Function as defined in clause 4.2 of TS 26.501 [15]. The following 5GMSd AF subfunctions are used to enable multi-service location/endpoint capabilities within the 5GMS System:

- *Content Preparation provisioning:* For cases where the 5GMSd AS is required to process content ingested at reference point M2d, the necessary content processing operations are described by Content Preparation Templates provisioned within the 5GMSd AF by the 5GMSd Application Provider at reference point M1d. These Content Preparation Templates are referenced by the Distribution Configuration(s) indicated within the Content Hosting Configuration. **Examples of Content Preparation Templates for the purposes of multi-service location/endpoint delivery may include manifest (e.g., MPD) manipulation to update service location references, CMMF encoding and packaging, etc.**

- *Content Hosting provisioning:* The 5GMSd Application Provider provisions the Content Hosting feature for downlink media delivery. For cases where multiple service locations/endpoints are needed, the Content Hosting Configuration defines multiple Distribution Configurations. Each Distribution Configuration is assigned a base URL (i.e., one that includes a scheme, authority and, optionally, path segments) from which content is made available to 5GMSd Clients at reference point M4d. This base URL is chosen by the 5GMSd AF when the Content Hosting Configuration is provisioned. Furthermore, provisioned Content Preparation Templates are referenced by each configured Distribution as needed to perform any necessary content preparation required to enable multi-service location/endpoint operation. See clause 8.8.3.1 of TS 26.510 [26510] for further details. **The format and/or detailed specification of the Content Preparation Template depends on the multi-source delivery approach used.** Details of the Media Entry Point specified in each Distribution Configuration in the provisioned Content Hosting Configuration are made available to the 5GMSd Client Media Session Handler at reference point M5d via the Service Access Information.

- *MQTT Broker:* Optionally, the 5GMSd AF may provide an MQTT Broker (clause 10.2 of TS 26.510 [26510]) for the purposes of managing MQTT notification channels that are used by the 5GMSd AF to notify the 5GMSd Client Media Session Handler about updates to the Service Access Information available at reference point M5d. Updates triggering a notification may include changes to the Distribution Configuration(s) defined in the Content Hosting Configuration such as updates to the Distribution Configuration base URL(s).

- *5GMSd AS:* An Application Server as defined in clause 4.2 of TS 26.501 [15]. The following 5GMSd AS subfunctions are used to enable multi-service location/endpoint operations within the 5GMS System.

- *Content Hosting:* Content Hosting is configured in the 5GMSd AS by the 5GMSd AF using the Mas\_Configuration API at reference point M3d. For cases where multiple service locations/endpoints are needed, multiple Content Distributions are configured where each is assigned a unique base URL by the 5GMSd AF. In some cases, a Content Distribution may prepare ingested content prior to making it available to 5GMSd Clients at reference point M4d. Examples of content preparation for multi-service point/endpoint delivery may include manifest (e.g., MPD) manipulation to update service location/endpoint references, CMMF encoding and packaging, etc. Furthermore, each configured Content Distribution may be instantiated on a different physical host as needed to improve reliability and robustness of the 5GMSd System in the cases of hardware failure, network congestion, etc.

- ***Online Service Location/Endpoint Management:* Optionally, an Online Service Location/Endpoint Management subfunction is configured by the 5GMSd AF to support multi-service point/endpoint use cases where more complex management is required than the 5GMSd AF can provide. For example, a Content Steering Server [DIFCS] is needed to steer 5GMSd Clients to specific service locations/endpoints based on application-specific rules and/or performance requirements. 5GMSd Clients communicate with this subfunction over reference point M4d, and the subfunction can receive input from the 5GMSd Application Provider over reference point M2d.**

- *5GMSd-Aware Application:* A 5GMSd-Aware Application as defined in clause 4.2 of TS 26.501 [15].

- *5GMSd Client:* A Media Client as defined in clause 4.2 of TS 26.501 [15]. The following 5GMSd Client subfunctions are used to enable multi-service locations/endpoint operations within the 5GMS System.

- *Media Session Handler:* A Media Session Handler as defined in clause 4.2 of TS 26.501 [15]. The Media Session Handler obtains complete Service Access Information from the 5GMSd AF via reference point M5d. This Service Access Information contains information regarding the service location/endpoint of each provisioned Content Distribution in the form of Media Entry Points. This information can be made available to the Media Player at reference point M11d to enable multi-service location/endpoint delivery. Optionally, the Media Session Handler may subscribe to an MQTT notification channel established by the 5GMSd AF for the purpose of signaling changes to the Service Access Information (including the changes to the provisioned Media Entry Points) at reference point M5d.

- *Media Player:* A Media Player as defined in clause 4.2 of TS 26.501 [15]. **The Media Player is provided with information about each of the provisioned service locations/endpoints (Media Entry Points) either by the Media Session Handler at reference point M11d or else by the 5GMSd-Aware Application at reference point M7d.** **This information is provided to the Media Player’s subfunctions, such as the Media Access Client. The Media Access Client uses this information for the purposes of accessing content over reference point M4d from one or more provisioned Content Distributions. For example, this information may be used by the Media Access Client to switch between available Content Distributions or, in the case of CMMF delivery, to download from multiple Content Distributions simultaneously. In the case where an active 5GMSd AS Online Service Location/Endpoint Management subfunction exists in the 5GMSd AS, the Media Access Function communicates with this subfunction via reference point M4d to influence its selection of the appropriate Content Distribution(s) in the 5GMSd AS from which it should access and download content.**

The following reference points are defined:

- M1d (5GMSd Provisioning API): 5GMSd Provisioning API as defined in clause 4.2 of TS 26.501 [15].

- M2d (5GMSd Ingest API): 5GMSd content ingest interactions as defined in clause 4.2 of TS 26.501 [15].

- M3d: Internal API as defined in clause 4.2 of TS 26.501 [15].

- M4d (Media Streaming APIs): Media Streaming interactions as defined in clause 4.2 of TS 26.501 [15]. The 5GMSd Client connects to the 5GMSd AS and streams from one **or more** configured Content Distributions. **In addition, the 5GMSd Client may provide performance metrics and service location/endpoint management information to the Online Service Location/Endpoint Management function configured within the 5GMSd AS as described in clause 5.19.3.2.2.4 below. In cases where performance metrics are reported at this reference point, the reported metrics may be in lieu of or in addition to any reporting the Media Session Handler performs over reference point M5d.**

- M5d (Media Session Handling API): Media Session Handling API as defined in clause 4.2 of TS 26.501 [15]. The Media Session Handling API is used to provide Service Access Information to the Media Session Handler. This Service Access Information includes references to the Media Entry Point indicated in each of the provisioned Content Distributions. **Furthermore, this Service Access Information may be augmented to provide additional information necessary to operate an integrated multi-source delivery platform within the 5GMS System. Further details are provided in clause 5.19.3.2.2.**

- M6d (UE Media Session Handling APIs): UE Media Session Handling APIs as defined in clause 4.2 of TS 26.501 [15]. **See description of reference point M8d.**

- M7d (UE Media Player APIs): UE Media Player APIs as defined in clause 4.2 of TS 26.501 [15]. **See description of reference point M8d.**

- M8d (Application API): Application interface as defined in clause 4.2 of TS 26.501 [15]. **In the case where the 5GMSd AS is deployed in an external DN and is not directly configured by the 5GMSd AF (the collaboration scenario depicted in clause A.4 of TS 26.501 [15]), service information (e.g., service location/endpoint base URLs, multi-service location/endpoint delivery configuration information, CMMF Configuration Information, etc.) may be communicated from the 5GMSd Application Provider to the 5GMSd-Aware Application via reference point M8d. This information is provided to the Media Session Handler at reference point M6d to be combined with the corresponding Service Access Information obtained from the 5GMSd AF over reference point M5d, or it may be provided directly to the Media Player over reference point M7d. In the case where the 5GMSd AS is deployed in an external DN and is directly configured by the 5GMSd AF (the collaboration scenario depicted in clause A.5 of TS 26.501 [15]), service information may be communicated either at reference point M8d or as part of the Service Access Information provided by the 5GMSd AF at reference point M5d.**

- M11d (UE Media Player APIs and UE Media Session Handling APIs): UE Media Player APIs and UE Media Session Handling APIs as defined in clause 4.2 of TS 26.501 [15]. **Any necessary information obtained from the Service Access Information at reference point M5d or from the 5GMSd-Aware Application at reference point M6d to configure the Media Player for multi-source media delivery is provided at reference point M11d. This information may be dependent on the multi-source delivery approach used. Further details are provided in clause 5.19.3.2.2.**

Variations of this general architecture, including the combination of this architecture and the one discussed in clause 5.19.3.1.1, are possible depending on the use case and network configuration.

##### 5.19.3.2.2 Multi-source approach specific architecture mappings

###### 5.19.3.2.2.1 Overview

Depending on the approach used to implement multi-source functionality, the functions and reference points discussed in clause 5.19.3.2.1 may be used differently. These are expanded upon in subsequent clauses.

###### 5.19.3.2.2.2 DNS-based switching

Multi-source delivery using DNS to switch between provisioned Content Distributions as described in clause 5.19.1.3 can be realized using the architecture depicted in figure 5.19.3.2.1-1. Upon provisioning of each Content Distribution in a Content Hosting Configuration, the 5GMSd AF assigns a canonical Fully-Qualified Domain Name (FQDN) where this Content Distribution is accessible via reference point M4d. An alias domain name may also be specified by the 5GMSd Application Provider for use in the URL of the Media Entry Point and/or media. This alias is then used within a DNS CNAME record where the record’s name references the canonical Content Distribution FQDN. Either the 5GMSd AS Online Service Location/Endpoint Management subfunction or another 5GMS System function can update these DNS CNAME records when it determines switching to a different Content Distribution is necessary. No additional 5GMSd Client functionality is needed to implement this approach.

###### 5.19.3.2.2.3 MPEG-DASH client-side switching

Multi-source delivery using MPEG-DASH client-side switching as described in clause 5.19.1.4 may be realized using the architecture depicted in figure 5.19.3.2.1-1. However, additional functionality in the Media Player is required (if not already implemented) to switch between the available Content Distributions as necessary.

Two approaches are possible:

1. MPEG-DASH client-side switching is signalled using service location decorators within the manifest (i.e., MPD) as described in clause 5.19.1.4. These service location decorators may be added to each MPD using a provisioned Content Preparation subfunction that modifies each MPD prior their delivery over reference M4d.

2. A list of the provisioned Content Distribution base URLs or domain names, is made available to the Media Access Client by the Media Session Handler over reference point M11d, this list of base URLs having been retrieved from the Service Access Information obtained from the 5GMSd AF over reference point M5d. The Media Player selects one of the available base URLs from the list and joins it to the path URL of the media to be streamed.

###### 5.19.3.2.2.4 Content Steering Server driven switching

Multi-source delivery using a Content Steering Server as described in clause 5.19.1.5 may be realized using the architecture depicted in figure 5.19.3.2.1-1. In this case, the Content Steering Server is implemented within the Online Service Location/Endpoint Management subfunction of the 5GMSd AS. The Content Steering Server’s location is signalled in the content presentation manifest (i.e., MPD). Additional functionality within the Media Player is required (if not already implemented) to switch between provisioned Content Distributions accessible via reference point M4d, in addition to the functionality to communicate with the Content Steering Server via reference point M4d.

###### 5.19.3.2.2.5 SAND4M multi-source delivery

Editor’s Note: Determination of how SAND4M multi-source delivery can be realized within the architecture shown in Figure 5.19.3.2.1-1 requires further study.

###### 5.19.3.2.2.6 CMMF-based multi-source delivery

Several options exist when implementing CMMF as described in clause 5.19.1.7 within the architecture shown in figure 5.19.3.2.1-1. These are expanded upon below.

5.19.3.2.2.6.1 CMMF-enabled 5GMS client architecture

The 5GMSd Client architecture options described in clause 5.19.3.1.2.6.1 also support the use of CMMF delivery within the general architecture shown in figure 5.19.3.2.1-1.

5.19.3.2.2.6.2 5GMSd Client configuration for downlink media streaming using CMMF

CMMF supplements existing media streaming architectures (e.g., MPEG-DASH, etc.) to enable clients to obtain media from multiple endpoints in parallel. Enabling this functionality requires, at a minimum, information concerning where and how CMMF-encoded media can be accessed on one or more service location(s)/endpoint(s) within the network(s).

This *CMMF client configuration information* may be conveyed to the CMMF Client (assuming client architecture #1 in clause 5.19.3.1.2.6.1) or to the Media Player in the 5GMSd Client (assuming client architecture #2 in clause 5.19.3.1.2.6.1) either:

1. By the 5GMSd AF to the Media Session Handler as Service Access Information (e.g. Media Entry Point metadata) made available at reference point M5d. The Media Session Handler may then provide this information to the CMMF Client (assuming client architecture #1) via reference point CMMF-2 or to the Media Player (assuming client architecture #2) via reference point M11d. This option is relevant when the CMMF client configuration information is relatively static and is not frequently updated.

2. Contained within a Media Entry Point specified by an existing media streaming framework that is understood by the Media Player (e.g., as additional XML elements or attributes within an MPEG-DASH MPD). This option is relevant when the CMMF client configuration information is relatively static and is not frequently updated.

3. Over reference point M4d from the Online Service Location/Endpoint Management subfunction of the 5GMSd AS (e.g. a Content Steering Server) when more active or extensive management is required. This option is relevant when the CMMF client configuration information is dynamic and may be frequently updated.

The CMMF client configuration information is the set of parameters and addresses which are needed by a 5GMSd Client to activate and control the reception of a CMMF-enabled media downlink media streaming session, primarily information concerning how the CMMF Client (client architecture #1) or Media Player (client architecture #2) accesses one or more CMMF-encoded objects, each containing a different encoded representation of the original source media to be played, from the available Content Distributions hosting this content.

* For option 1 above, additions to the Service Access Information defined in clause 4.2.3 of TS 26.501 [15] may be needed to enable the use of CMMF. This additional information can be used along with existing Service Access Information (e.g., a Media Entry Point document such as an MPEG-DASH MPD) to construct proper URLs that enable the download of CMMF-encoded content from each 5GMSd AS Content Distribution (CMMF endpoint).
* For option 2 above, additional XML elements or attributes in the MPEG-DASH MPD are needed to enable the use of CMMF. This additional information is then used along with the base URLs provided in the MPEG-DASH MPD (i.e., service locations) to construct proper URLs to download CMMF-encoded content from each 5GMSd AS Content Distribution (CMMF endpoint).

Other CMMF client configuration information that are outside the scope of the present document may also be provided and/or required based on implementation. This may include additional configurable parameters such as load-balancing policies that influence client behaviour when downloading from multiple CMMF endpoints, information about the CMMF profile in use, etc.

5.19.3.2.2.6.3 CMMF content preparation and distribution

CMMF configuration, provisioning, and hosting is the overall responsibility of the 5GMSd Application Provider in this architecture mapping.

- The 5GMSd Application Provider may configure and provision resources to deliver media using CMMF across both external and trusted data networks.

- For the general architecture shown in figure 5.19.3.2.1-1, CMMF content preparation and/or hosting is performed by the 5GMS System. The 5GMSd Application Provider configures and provisions 5GMS System resources (e.g., 5GMSd AF, 5GMSd AS, etc.) via reference point M1d to prepare and/or deliver CMMF-encoded media. The 5GMSd Application Provider specifies CMMF content preparation (e.g., CMMF encoding, etc.) and/or hosting by network-side components of the 5GMS System according to a provisioned CMMF Content Preparation Template. In such cases, individual 5GMSd AS Content Distributions operate as separate CMMF endpoints for the purposes of CMMF-enabled media delivery, assuming the 5GMS System has been appropriately configured and provisioned to ensure CMMF-encoded media is not replicated between available Content Distributions.

- 5GMSd Client configuration information is provided to the 5GMSd Client from the 5GMS AF in Service Access Information obtained via reference point M5d.

The provisioning step allows a 5GMSd Application Provider to configure information about its CMMF content preparation and hosting requirements for media streaming sessions using 5GMS resources. The following information is made available and/or configurable over reference point M1d:

* Endpoint locations or base URLs outside the 5GMS System, if any, that support CMMF delivery.
* Information necessary for configuring the preparation of CMMF-encoded media within 5GMSd AS Content Distributions. This includes any necessary CMMF bitstream/object preparation parameters as defined in [CMMF] required to properly encode and package media within CMMF bitstreams/objects. Examples may include CMMF code type, CMMF profile, etc.
* Information necessary for configuring the hosting of CMMF-encoded media on the 5GMSd AS in the form of a Content Hosting Configuration containing one or more Content Distributions.
  + Each Content Distribution is configured with a unique base URL or FQDN.
  + Each Content Distribution may also be configured with a Content Preparation Template describing how to create CMMF bitstreams/objects from ingested media.

- CMMF object and original source object URL handling parameters describing the method and/or format used to assign URLs to CMMF objects created within the 5GMS System. More detail is provided in clause 5.19.3.1.2.6.4.

Once provisioned, the 5GMSd AF allocates and manages the set of Content Distributions (including Content Preparation resources, if necessary) needed for the creation and/or hosting of CMMF bitstreams/objects generated from media provided by the 5GMSd Application Provider at reference point M2d. The 5GMSd AF ensures that each Content Distribution (acting as a single individual CMMF endpoint) is configured to distribute unique CMMF bitstreams/objects created from the original source media to CMMF-enabled UEs.

CMMF multi-source delivery supports several content preparation and hosting workflows. These include:

1. *5GMSd Application Provider Content Preparation.* In this option, it is the responsibility of the 5GMS Application Provider to encode and package source content within CMMF bitstreams/objects prior to delivery of that content separately to each 5GMSd AS Content Distribution via reference point M2d, or to each external service location/endpoint (e.g., commercial CDN). This is outlined in clause 5.19.3.1.2.6.3 above.

2. *Centralized 5GMSd Content Preparation*. In this option, a single, primary 5GMSd AS instance encodes and packages source content that has been ingested at reference point M2d into CMMF bitstreams/objects according to a (yet to be defined) configuration provided by a Content Preparation Template. The CMMF bitstreams/objects created during this media processing task may be delivered directly to the 5GMSd Client (via instances of reference point M4d), delivered to another (secondary) 5GMSd AS instance (via instances of reference point M10d), or delivered to a 5GMSd AS instance located in an external, possibly untrusted, Data Network. These CMMF bitstreams/objects may then be cached and/or forwarded onward. This primary 5GMSd AS instance is responsible for creation of all CMMF encoded representations used to deliver content from multiple sources. This is illustrated in figure 5.19.3.2.2.6.3-1 below. The secondary 5GMSd AS instance may be deployed either in the Trusted DN, in an Edge DN or in an External DN.

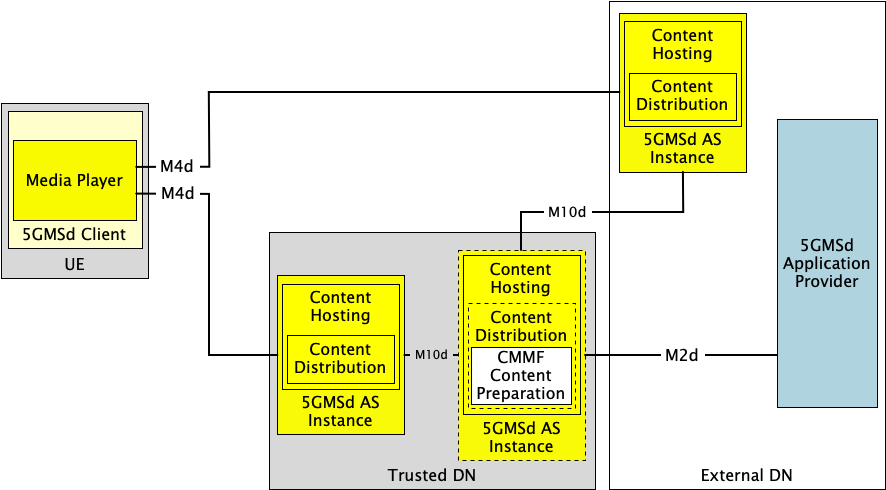


Figure 5.19.3.2.2.6.3-1: Option #2 for deploying CMMF within 5GMS  
where a single, primary 5GMSd AS instance performs all CMMF content preparation.

3. *Decentralized 5GMSd Content Preparation.* The possibility also exists to distribute the CMMF media processing across 5GMSd AS instances such that each one is only responsible for creation of a single CMMF representation which it intends to cache and/or deliver to a 5GMSd Client via an instance of reference point M4d. In this option, each 5GMSd AS instance provisioned with the Content Preparation Template may receive original source content or CMMF-encoded content from either the 5GMSd Application Provider at reference point M2d or from another 5GMSd AS instance via an instance of reference point M10d. This received content is then processed to create a new, unique CMMF-encoded representation which can be used in conjunction with others during a multi-source download. Similarly, an externally deployed 5GMSd AS Content Distribution may be configured by the 5GMSd Application Provider (by private means, denoted M2d′) to perform a similar media processing task to create its own CMMF-encoded representation. This is illustrated in figure 5.19.3.2.2.6.3-2 below.

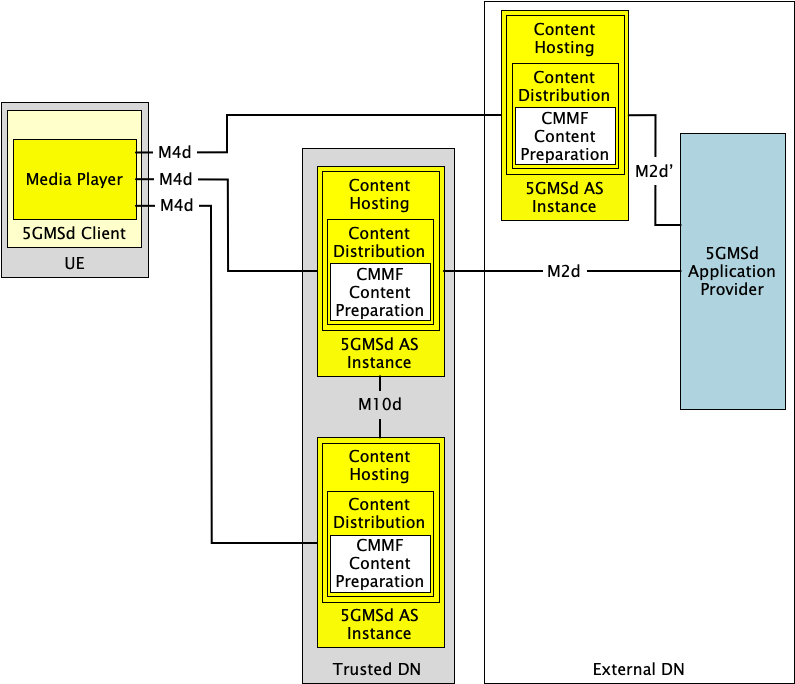


Figure 5.19.3.2.2.6.3-2: Option #3 for deploying CMMF within 5GMS  
where each 5GMSd AS Content Distribution performs independent CMMF content preparation.

A combination of the above options is also possible where some aspect of all three exist within a physical realization of the network.

5.19.3.2.2.6.4 CMMF object addressing and URL handling

Details regarding how CMMF objects are addressed and how their URLs are handled are described in clause 5.19.3.1.2.6.4.

The use of one approach over another may be influenced by the method in which CMMF content is prepared and distributed within the 5GMS System.

- For content preparation options #1 and #2 in clause 5.19.3.2.2.6.3, where CMMF content preparation is centralized within either the 5GMS Application Provider or within a single primary 5GMSd AS instance, assigning unique URL path names to each original source media object and each CMMF-encoded media object can be easily implemented and managed according to object addressing Approach #1 in clause 5.19.3.1.2.6.4.

- Object addressing Approach #2, where each CMMF-encoded media object representation is assigned a different URL authority name, may be appropriate when CMMF content preparation is performed in a decentralized manner as shown in content preparation option #3 of clause 5.19.3.2.2.6.3. In these cases, no central management is necessary once the 5GMS System has been configured to prepare CMMF-encoded content or assign URLs and track the location of that content.

### 5.19.4 High-level call flows

#### 5.19.4.1 Over-the-top multi-source for downlink Media Streaming

##### 5.19.4.1.1 General high-level call flows

The procedures defined in clause 5 of TS 26.501 [15] generally apply to the architecture described in clause 5.19.3.1 of the present document. However, the procedure(s) for unicast downlink Media Streaming session establishment defined in clause 5.2 of TS 26.501 [15] are dependent on the multi-source approach in use. Any differences are expanded upon further in subsequent clauses.

##### 5.19.4.1.2 Multi-source approach specific high-level call flows

###### 5.19.4.1.2.1 Overview

Depending on the approach used to implement multi-source functionality, the procedures for unicast downlink Media Streaming session establishment may differ from those defined in clause 5.2 of TS 26.501 [15]. For the purposes of this study, only differences in the DASH streaming procedures (clause 5.2.3 in TS 26.501 [15]) are shown below.

###### 5.19.4.1.2.2 DNS-based switching

The procedure for streaming MPEG-DASH content using DNS-based switching to determine which content service location/endpoint (including 5GMSd Content Distribution) is used at any one time is shown in figure 5.19.4.1.2.2-1. For this procedure, the following assumptions apply:

- URLs describing the Media Entry Point(s) and media use an alias domain name that can be resolved using DNS.

- 5GMSd Application Provider can create/modify/update DNS CNAME records.

- 5GMSd Client can report performance metrics to an Online Service Location/Management subfunction within the 5GMSd Application Provider for the purposes of determining if switching from one Content Distribution to another is necessary.

- Media hosted in each content service location/endpoint (including 5GMSd Content Distribution) is identical (i.e., media is replicated across these content service locations/endpoints).

Differences from the baseline procedure in clause 5.2.3 of TS 26.501 [15] are highlighted in **boldface**.

NOTE: defined in

Msc-generator~|version=8.6.1~|lang=signalling~|size=1180x1802~|text=# Over-the-top (OTT) multi-source delivery~n# High-level call flow~n# Procedures for downlink Media Streaming~n# General~ndefstyle delta [text.color=blue, text.bold=yes, tag.text.color=blue, line.color=blue];~n~nApp: 5GMSd-Aware\nApplication;~nC: 5GMSd Client {~n~4MP: Media\nPlayer;~n~4MSH: Media\nSession\nHandler;~n};~nAF: 5GMSd AF;~nAS: 5GMSd AS {~n~4AS_CD: Content\nDistribution\n(A);~n};~nDNS [delta]: DNS;~nTP [delta]: Third-Party Provider(s) {~n~4AP_CD [delta]: Content\nService\nLocation /\nEndpoint\n(B);~n~4AP_M [delta]: Online Service\nLocation /\nEndpoint\nManagment;~n};~nAP_AP: 5GMSd\nApplication\nProvider;~n~n~nvspace 5;~nbox DNS..AP_M [tag=~qopt~q, delta]:~n{~n~4AP_M~l~gDNS [delta]: 0: Update service DNS CNAME\nrecord to content service\nlocation/endpoint A/B~n~6[arrow.type=dot];~n};~n~nvspace 5;~nbox App..AP_AP [collapsed=yes]: 1: Service Announcement and Content Discovery~n{~n~4App-~gAP_AP: Get media session information;~n~4AP_AP-~gApp: List of media session URLs\n\-(List of Entry URLs with additional metadata);~n};~n~nbox App..App: 2: Select\nMedia Content;~n~nApp-~gMSH: 3: Initiate Media Playback\n\-(Media Player Entry);~n~nbox MSH..AF [tag=~qopt~q]~n{~n~4MSH~l-~gAF [arrow.type=dot]: 4: Service Access\nInformation acquisition;~n};~n~nMSH-~gMP: 5: Start media playback\n\-(Entry URL);~n~nMP~l~gDNS [arrow.type=dot, delta]: 5a: Resolve MPD URL Domain;~nbox MP..AP_CD [tag=~qalt~q]: \I\[MPD URL Resolves to Content Service Location/Endpoint A\]~n{~n~4MP~l~gAS_CD: 6: Establish transport session for the manifest;~n}~n~2.. [tag=~q~q, delta]: \I\[MPD URL Resolves to Content Service Location/Endpoint B\]~n{~n~4MP~l~gAP_CD [delta]: 6bis: Establish transport session for the manifest;~n};~n~nvspace 5;~nbox MP..AP_CD [tag=~qalt~q]: \I\[MPD URL Resolves to Content Service Location/Endpoint A\]~n~n{~n~4MP-~gAS_CD: 7: Request MPD (Entry Point);~n~4AS_CD-~gMP: 8: OK\n\-(MPD);~n}~n.. [tag=~q~q, delta]: \I\[MPD URL Resolves to Content Service Location/Endpoint B\]~n{~n~4MP-~gAP_CD [delta]: 7bis: Request MPD (Entry Point);~n~4AP_CD-~gMP [delta]: 8bis: OK\n\-(MPD);~n};~n~nvspace 5;~nbox MP--MP: 9: Process\nMPD;~n~nvspace 5;~nMP-~gMSH: 10: MPD Rx Notification;~n~nvspace 5;~n.. [tag=~qopt~q]~n{~n~4MP~l~gAP_AP: 11: DRM License acquisition;~n};~n~nvspace 5;~nbox MP--MP: 12: Configure playback\npipeline;~n~n.. [tag=~qopt~q]:~n{~n~4AP_M~l~gDNS [arrow.type=dot, delta]: 12a: Update service DNS CNAME\nrecord to content service\nlocation/endpoint A/B;~n};~n~nMP~l~gDNS [arrow.type=dot, delta]: 12b: Resolve Content URL Domain;~n..: \I\[Content URL Resolves to Content Service Location/Endpoint A\]~n~2[tag=~qalt~q]~n{~n~4MP~l~gAS_CD: 13: Establish transport session for content\n\-(optional Transport Session Parameters);~n}~n..: \I\[Content URL Resolves to Content Service Location/Endpoint B\]~n~2[tag=~q~q, delta]~n{~n~4MP~l~gAP_CD [delta]: 13bis: Establish transport session for content\n\-(optional Transport Session Parameters);~n};~n~nMP-~gMSH: 14: Notification\n\-(Transport Session Parameters);~n~n.. [tag=~qloop~q]:~n{~n~4box MP..AP_CD: \I\[Content URL Resolves to Content Service Location/Endpoint A\]~n~6[tag=~qalt~q]~n~4{~n~8MP-~gAS_CD: 15: Request Initialization Information(s);~n~8AS_CD-~gMP: 16: OK\n\-(Initialization Informations(s));~n~4}~n~6.. [tag=~q~q, delta]: \I\[Content URL Resolves to Content Service Location/Endpoint B\]~n~4{~n~8MP-~gAP_CD [delta]: 15bis: Request Initialization Information(s);~n~8AP_CD-~gMP [delta]: 16bis: OK\n\-(Initialization Informations(s));~n~4};~n~9~3~n};~n~nvspace 5;~nbox MP..AP_CD [tag=~qalt~q]: \I\[Content URL Resolves to Content Service Location/Endpoint A\]~n{~n~4MP-~gAS_CD: 17: Request Media Segment(s);~n~4AS_CD-~gMP: 18: Media Content;~n}~n.. [tag=~q~q, delta]: \I\[Content URL Resolves to Content Service Location/Endpoint B\]~n{~n~4MP-~gAP_CD [delta]: 17bis: Request Media Segment(s);~n~4AP_CD-~gMP [delta]: 18bis: Media Content;~n};~n~nvspace 5;~nMP-~gAP_M [delta]: 18a: Report performance KPIs;~n~n...: 19: Repeat;~|

Figure 5.19.4.1.2.2-1: High-level procedure for DASH content using DNS-based switching

Editor’s Note: Metadata required to modify the above procedure is included as alt-text within the figure. See <https://msc-generator.gitlab.io/msc-generator/Alt_002dtext-embedding.html> for more details.

The steps for this procedure are largely the same as that shown in clause 5.2.3 of TS 26.501 [15]. The only differences are:

0. **An Online Service Location/Endpoint Management subfunction, operated by a Third-Party Provider that is directly managed by the 5GMSd Application Provider, optionally updates the DNS CNAME record with the content service location/endpoint 5GMSd Clients should access to stream content.**

NOTE 1: These updates are independent of any 5GMSd Client activity, and the 5GMSd Application Provider**/Third-Party Provider** can execute this update at any time.

5a. The step showing that the Media Player resolves the domain names of the URLs for the manifest and content is explicitly shown. These steps already occur during transport session establishment and do not indicate the Media Player needs to do anything different than what is described in clause 5.2.3 of TS 26.501 [15].

6bis. **The source location/endpoint is different depending on the outcome of the DNS resolution when establishing the transport session.**

7bis. **The target source location/endpoint for the MPD request is different depending on the outcome of the DNS resolution.**

8bis. **The source location/endpoint responding to the MPD request is different depending on the outcome of the DNS resolution.**

12a. **An Online Service Location/Endpoint Management subfunction, operated by a Third-Party Provider that is directly managed by the 5GMSd Application Provider, optionally updates the DNS CNAME record with the content service location/endpoint 5GMSd Clients should access to stream content.**

NOTE 2: These updates are independent of any 5GMSd Client activity, and the 5GMSd Application Provider/Third-Party Provider can execute this update at any time.

12b. The step showing that the Media Player resolves the domain names of the URLs for the manifest and content is explicitly shown. These steps already occur during transport session establishment and do not indicate the Media Player needs to do anything different than what is described in clause 5.2.3 of TS 26.501 [15].

13bis. **The target source location/endpoint is different depending on the outcome of the DNS resolution when establishing the transport session.**

15bis. **The source location/endpoint for requesting initialization segments is different depending on the outcome of the DNS resolution.**

16bis. **The source location/endpoint responding to initialization segment requests is different depending on the outcome of the DNS resolution.**

17bis. **The source location/endpoint for requesting media segments is different depending on the outcome of the DNS resolution.**

18bis. **The source location/endpoint responding to media segment requests is different depending on the outcome of the DNS resolution.**

18a. **Media Player reports performance KPIs to the Third-Party’s Online Service Location/Endpoint Management subfunction. This reporting is necessary so that the subfunction can make informed decisions on whether and when to switch to a different service location/endpoint or not (see step 12a).**

###### 5.19.4.1.2.3 MPEG-DASH client-side switching

Streaming MPEG-DASH content using MPEG-DASH client-side switching to determine which Content Distribution and/or content service location/endpoint to stream media from is shown in figure 5.19.4.1.2.3-1.

For this procedure, the following assumptions apply:

- The 5GMSd Application Provider has included the appropriate service location decorators within the MPD that describe where the Media Player can access and download media.

- Media hosted in each Content Distribution and/or content service location/endpoint is identical (i.e., media is replicated across Content Distributions and content service locations/endpoints).

Differences from the baseline procedure in clause 5.2.3 of TS 26.501 [15] are highlighted in **boldface**.

NOTE: The indicated modifications to the baseline procedure can also be extended to the other procedures contained within clause 5.2 of TS 26.501 [15].

Msc-generator~|version=8.6.1~|lang=signalling~|size=779x1196~|text=# Over-the-top (OTT) multi-source delivery~n# High-level call flow~n# Procedures for downlink Media Streaming~n# General~nhscale=auto;~ndefstyle delta [text.color=blue, text.bold=yes, tag.text.color=blue, tag.text.bold=yes, tag.line.color=blue, line.color=blue, arrow.color=blue];~n~n~nApp: 5GMSd-Aware\nApplication;~nC: 5GMSd Client {~n~4MP: Media\nPlayer;~n~4MSH: Media\nSession\nHandler;~n};~nAF: 5GMSd AF;~nAS: 5GMSd AS {~n~4AS_CD [delta]: Content\nDistribution\n(A);~n};~nTP [delta]: Third-Party\nProvider(s) {~n~4AP_CD [delta]: Content\nService\nLocation/\nEndpoint\n(B);~n};~nAP_AP: 5GMSd\nApplication\nProvider;~n~n~nvspace 5;~nApp--AP_AP [collapsed=yes]: Steps 1-12 from clause 5.2.3 of TS 26.501 \[15\]~n{ box; };~nhide App, AF, AP_AP;~n~nvspace 5;~nMP--MP [delta]: 12a: Select\nservice location\nfrom MPD;~n~nvspace 5;~n-- [tag=~qalt~q]: \I\[Content Service Location/Endpoint A Selected\]~n{~n~4MP~l~gAS_CD: 13: Establish transport session for content\n\-(optional Transport Session Parameters);~n~4MP-~gMSH: 14: Notification\n\-(Transport Session Parameters);~n~4-- [tag=~qloop~q]:~n~4{~n~8MP-~gAS_CD: 15: Request Initialization Information(s);~n~8AS_CD-~gMP: 16: OK\n\-(Initialization Informations(s));~n~4};~n}~n~2-- [tag=~q~q, delta]: \I\[Content Serivce Location/Endpoint B Selected\]~n{~n~4MP~l~gAP_CD [delta]: 13bis: Establish transport session for content\n\-(optional Transport Session Parameters);~n~4MP-~gMSH [delta, delta]: 14bis: Notification\n\-(Transport Session Parameters);~n~4-- [tag=~qloop~q, delta]:~n~4{~n~8MP-~gAP_CD [delta]: 15bis: Request Initialization Information(s);~n~8AP_CD-~gMP [delta]: 16bis: OK\n\-(Initialization Informations(s));~n~4};~n};~n~nvspace 15;~n-- [tag=~qloop~q]: \I\[19: Repeat\]~n{~n~4MP..MP [delta]: 16a: Select different\nservice location\nfrom MPD;~n~n~4vspace 5;~n~4-- [tag=~qalt~q]: \I\[Content Service Location/Endpoint A Selected\]~n~4{~n~8box MP..AS_CD [tag=~qopt~q, delta]: \I\[Transport session does not already exist\]~9~9~9~9~9~9~9~9~9~9~9~9~5~n~8{~n~9~3MP~l~gAS_CD [delta]: 16b: Establish transport session for content\n\-(optional Transport Session Parameters);~n~9~3MP-~gMSH [delta]: 16c: Notification\n\-(Transport Session Parameters);~n~8};~n~8MP-~gAS_CD: 17: Request Media Segment(s);~n~8AS_CD-~gMP: 18: Media Content;~n~4}~n~6-- [tag=~q~q, delta]: \I\[Content Serivce Location/Endpoint B Selected\]~n~4{~n~8box MP..AP_CD [tag=~qopt~q, delta]: \I\[Transport session does not already exist\]~2~n~8{~n~9~3MP~l~gAP_CD [delta]: 16b-bis: Establish transport session for content\n\-(optional Transport Session Parameters);~n~9~3MP-~gMSH [delta]: 16c-bis: Notification\n\-(Transport Session Parameters);~n~8};~n~8MP-~gAP_CD [delta]: 17bis: Request Media Segment(s);;~n~8AP_CD-~gMP [delta]: 18bis: Media Content;~n~4};~n};~|

Figure 5.19.4.1.2.3-1: High-level procedure for DASH content using MPEG-DASH client-side switching

Editor’s Note: Metadata required to modify the above procedure is included as alt-text within the figure. See <https://msc-generator.gitlab.io/msc-generator/Alt_002dtext-embedding.html> for more details.

The steps for this procedure are largely the same as that shown in clause 5.2.3 of TS 26.501 [15]. The only differences are:

**12a. The Media Player selects a service location/endpoint from the MPD for retrieving initialisation segments.**

NOTE: The Media Player may establish a separate transport session for each media component (audio, video, etc) and possibly additional transport sessions for other media representations. This detail is omitted from figure 5.19.4.1.2.3-1 for the sake of simplicity.

**15bis.The source location/endpoint for requesting initialisation segments is different depending on the Media Player’s service location selection in step 12a.**

**16bis. The source location/endpoint responding to initialisation segment requests is different depending on the Media Player’s service location selection in step 12a.**

**16a. The Media Player may select a different service location/endpoint from the MPD for retrieving media segments.**

**16b. If a transport session with the service location/endpoint selected in step 16a does not already exist, the Media Player establishes one.**

**16c. The Media Player notifies the Media Session Handler of any updates to the transport session parameters.**

**16b-bis. As step 16b except that the source location/endpoint for requesting media segments is different depending on the Media Player’s service location selection in step 16a.**

**16c-bis. As step 16c except that the source location/endpoint responding to nedia segment requesta is different depending on the Media Player’s service location selection in step 16a.**

For progressive download or on-demand streaming, the call flows documented in clauses 5.7.3 and 5.7.4 of TS 26.501 [15] apply. In the case of client-side CDN switching, the Dynamic Policy resource in step 8 of clause 5.7.3 and step 15 of clause 5.7.4 declares a separate Application Data Flow description for each 5GMSd AS endpoint to which the Media Player connects at reference point M4d.

By having multiple Application Data Flow descriptions, Dynamic Policies can be instantiated that cover the multiple paths related to the multi-source deployment.

NOTE: In the case of on-demand streaming, it is straightforward to declare each 5GMSd AS endpoint address up front when the Dynamic Policy is instantiated, based on information in the Media Player Entry (MPD). In the case of live content and changing content, however, the 5GMSd AS endpoint addresses could change dynamically.

###### 5.19.4.1.2.4 Content Steering Server driven switching

Streaming MPEG-DASH content using Content Steering Server driven switching to determine which Content Distribution and/or content service location/endpoint to stream media from is shown in figure 5.19.4.1.2.4-1. For this procedure, the following assumptions apply:

- The 5GMSd Application Provider has included the appropriate service location decorators within the MPD that describe where the Media Player can access and download media. This also includes the location of the Content Steering Server.

- The Media Player conforms to [DIFCS].

- Media hosted in each Content Distribution and/or content service location/endpoint is identical (i.e., media is replicated across Content Distributions and content service locations/endpoints).

Differences from the baseline procedure in clause 5.2.3 of TS 26.501 [15] are highlighted in **boldface**.

NOTE: The indicated modifications to the baseline procedure can also be extended to the other procedures contained within clause 5.2 of TS 26.501 [15].

Msc-generator~|version=8.6.1~|lang=signalling~|size=932x1327~|text=# Over-the-top (OTT) multi-source delivery~n# High-level call flow~n# Procedures for downlink Media Streaming~n# General~nhscale=auto;~ndefstyle delta [text.color=blue, text.bold=yes, tag.text.color=blue, tag.text.bold=yes, tag.line.color=blue, line.color=blue, arrow.color=blue];~n~n~nApp: 5GMSd-Aware\nApplication;~nC: 5GMSd Client {~n~4MP: Media\nPlayer;~n~4MSH: Media\nSession\nHandler;~n};~nAF: 5GMSd AF;~nAS: 5GMSd AS {~n~4AS_CD [delta]: Content\nDistribution\n(A);~n};~nTP [delta]: Third-Party\nProvider(s) {~n~4AP_CD [delta]: Content\nService\nLocation /\nEndpoint\n(B);~n~4AP_M [delta]: Online Service\nLocation /\nEndpoint\nManament\n\-(Content Steering Server);~n};~nAP_AP: 5GMSd\nApplication\nProvider;~n~n~nApp--AP_AP [collapsed=yes]: Steps 1-12 from clause 5.2.3 of TS 26.501 \[15\]~n{ box; };~nhide App, AF, AP_AP;~n~nvspace 5;~nMP~l-~gAP_M [arrow.type=dot, delta]: 12a: Obtain content steering feedback;~nMP--MP [delta]: 12b: Process feedback and\nselect content service\nlocation/endpoint;~n~nvspace 5;~3~n-- [tag=~qalt~q]: \I\[Content Service Location/Endpoint A Selected\]~n{~n~4.. [tag=~qopt~q]: \I\[Transport session does not already exist\]~n~4{~n~8MP~l~gAS_CD: 13: Establish transport session for content\n\-(optional Transport Session Parameters);~n~4};~n~4MP-~gMSH: 14: Notification\n\-(Transport Session Parameters);~n~4MP-~gAS_CD: 15: Request Initialization Information(s);~n~4AS_CD-~gMP: 16: OK\n\-(Initialization Informations(s));~n~9~9~6~n}~n~2-- [tag=~q~q, delta]: \I\[Content Serivce Location/Endpoint B Selected\]~9~9~3~n{~n~4.. [tag=~qopt~q, delta]: \I\[Transport session does not already exist\]~n~4{~n~8MP~l~gAP_CD [delta]: 13bis: Establish transport session for content\n\-(optional Transport Session Parameters);~n~4};~n~4MP-~gMSH [delta]: 14bis: Notification\n\-(Transport Session Parameters);~n~4MP-~gAP_CD [delta]: 15bis: Request Initialization Information(s);~n~4AP_CD-~gMP [delta]: 16bis: OK\n\-(Initialization Informations(s));~n};~n~nvspace 15;~n-- [tag=~qloop~q]: \I\[19: Repeat\]~n{~n~4~n~4vspace 5;~n~4MP~l-~gAP_M [arrow.type=dot, delta]: 16a: Obtain content steering feedback;~n~4~n~4vspace 5;~n~4MP..MP [delta]: 16b: Process feedback\nand select different\ncontent service\nlocation/endpoint;~n~4~n~4vspace 5;~n~4MP--AP_CD [tag=~qalt~q]: \I\[Content Service Location/Endpoint A Selected\]~n~4{~n~8MP..AS_CD [tag=~qopt~q, delta]: \I\[Transport session does not already exist\]~9~9~9~9~9~9~9~3~n~8{~n~9~3MP~l~gAS_CD [delta]: 16c: Establish transport session for content\n\-(optional Transport Session Parameters);~n~9~3MP-~gMSH [delta]: 16d: Notification\n\-(Transport Session Parameters);~n~8};~n~8MP-~gAS_CD: 17: Request Media Segment(s);~n~8AS_CD-~gMP: 18: Media Content;~n~4}~n~4-- [tag=~q~q, delta]: \I\[Content Serivce Location/Endpoint B Selected\]~n~4{~n~8MP..AP_CD [tag=~qopt~q, delta]: \I\[Transport session does not already exist\]~n~8{~n~9~3MP~l~gAP_CD [delta]: 16c-bis: Establish transport session for content\n\-(optional Transport Session Parameters);~n~9~3MP-~gMSH [delta]: 16d-bis: Notification\n\-(Transport Session Parameters);~n~8};~n~8MP-~gAP_CD [delta]: 17bis: Request Media Segment(s);;~n~8AP_CD-~gMP [delta]: 18bis: Media Content;~n~4};~n};~n~|

Figure 5.19.4.1.2.4-1: High-level procedure for DASH content using Content Steering Server driven switching

Editor’s Note: Metadata required to modify the above procedure is included as alt-text within the figure. See <https://msc-generator.gitlab.io/msc-generator/Alt_002dtext-embedding.html> for more details.

The steps for this procedure are largely the same as that shown in clause 5.2.3 of TS 26.501 [15]. The only differences are:

**12a. The Media Player requests and receives Steering Instruction from the Content Steering Server per [DIFCS].**

**12b. The Media Player selects a service location/endpoint using feedback obtained from the Content Steering Server.**

13.NOTE: The Media Player may establish a separate transport session for each media component (audio, video, etc) and possibly additional transport sessions for other media representations. This detail is omitted from figure 5.19.4.1.2.4-1 for the sake of simplicity.

**15bis. The source location/endpoint for requesting initialisation segments is different depending on the Media Player’s service location selection in step 12a.**

**16bis.The source location/endpoint respinding to initialisation segment requests is different depending on the Media Player’s service location selection in step 12a.**

**16a. The Media Player requests and receives Steering Instruction from the Content Steering Server per [DIFCS].**

**16b. The Media Player selects a service location/endpoint using feedback obtained from the Content Steering Server.**

**16c. If a transport session with the service location/endpoint selected in step 16b does not already exist, the Media Player establishes one.**

**16d. The Media Player notifies the Media Session Handler of any updates to the transport session parameters.**

**16c-bis. As step 16c except that the source location/endpoint is different depending on the Media Player’s service location selection in step 18a.**

**16d-bis. As step 16d except that the source location/endpoint is different depending on the Media Player’s service location selection in step 18a.**

###### 5.19.4.1.2.5 SAND4M multi-source delivery

Editor’s Note: High-level call flows describing how SAND4M can be used to enable multi-source delivery requires further study.

###### 5.19.4.1.2.6 CMMF-based multi-source delivery

The intent of CMMF is to supplement existing downlink streaming procedures, rather than replace them entirely. As such, minimal changes to the procedures provided in clause 5 of TS 26.501 [15] are necessary. Enabling multi-source media delivery using CMMF within existing downlink media delivery workflows can generally be realised through the following:

1. CMMF-encoded media objects, and possibly original source media (e.g., MPEG-DASH or HLS media segments), are striped across multiple uniquely addressable service endpoints/locations, which may include 5GMSd AS Content Distributions as well as third-party CDNs. Each service endpoint/location containing the same CMMF-encoded media object (or stripe) of the media (i.e., the CMMF-encoded media object is replicated across multiple service endpoints/locations, which may be 5GMSd AS instances) is considered a single CMMF endpoint. Within the architecture shown in figure 5.19.3.1.1-1, the 5GMSd Application Provider makes the CMMF-encoded media objects, and possibly original source media (e.g., MPEG-DASH or HLS media segments), available at reference point M2d as well as to third-party CDNs.

2. Upon initialization, the 5GMSd-Aware Application obtains relevant Service Access Information from the 5GMSd Application Provider at reference point M8d. At a minimum, this includes details concerning the location of each service endpoint/location (CMMF endpoint) from which a stripe of CMMF-encoded and possibly original media (e.g., MPEG-DASH or HLS media segments) may be obtained, as well as appropriate signalling to indicate whether the media at each location is CMMF-encoded.

3. The 5GMSd Client connects to and downloads CMMF-encoded media objects, and possibly the original source media (e.g., MPEG-DASH or HLS media segments), from each service endpoint/location (CMMF endpoint) simultaneously via reference point CMMF‑1 (client architecture #1) or M4d (client architecture #2), terminating downloads early upon obtaining enough of the CMMF-encoded objects to recover the source media (e.g., MPEG‑DASH or HLS media segment). Successfully decoded source media is presented by the Media Player.

The procedure depicted below illustrates how CMMF can supplement downlink media delivery using MPEG-DASH as defined in clause 5.2.3 of TS 26.501 [15].

The following assumptions apply:

- The 5GMSd Application Provider prepares source media for distribution using CMMF and ensures that each service endpoint/location (CMMF endpoint) is provisioned with a uniquely encoded representation (or stripe) of all media.

- CMMF-encoded content hosted is treated within the 5GMS System as any other non-CMMF-encoded content is treated (i.e., hosting CMMF-encoded content within the 5GMS System is transparent to the 5GMS Content Hosting function).

- The 5GMSd Client is provisioned with the functionality to access and download from multiple CMMF endpoint in parallel. This includes the functionality to efficiently download partial CMMF objects and jointly decode these partially received CMMF objects to recover the original source media requested by the Media Player.

Differences from the baseline procedure in clause 5.2.1 of TS 26.501 [15] are highlighted in **boldface**.

NOTE:

Msc-generator~|version=8.6.1~|lang=signalling~|size=1006x1372~|text=# Over-the-top (OTT) multi-source delivery~n# High-level call flow~n# Procedures for downlink Media Streaming~n# General~nhscale=auto;~ndefstyle delta [text.color=blue, text.bold=yes, tag.text.color=blue, tag.text.bold=yes, tag.line.color=blue, line.color=blue, arrow.color=blue];~n~nApp: 5GMSd-Aware\nApplication;~nC: 5GMSd Client {~n~4MP [delta]: CMMF Client or\nCMMF-Enabled\nMedia Player;~n~4MSH: Media\nSession\nHandler;~n};~nAF: 5GMSd AF;~nAS: 5GMSd AS {~n~4AS_CD [delta]: Content\nDistribution\n(A);~n};~nTP [delta]: Third-Party Provider(s) {~n~4AP_CD [delta]: Content Service\nLocation/Endpoint\n(B);~n};~nAP_AP: 5GMSd\nApplication\nProvider;~n~n~nvspace 5;~n--: 1: Service Announcement and Content Discovery~n{~n~4App-~gAP_AP: Get media session information;~n~4AP_AP-~gApp: \bList of media session URLs and CMMF Configuration Information\n\-(List of Entry URLs with additional metadata);~n};~n~nApp-~gMP [delta]: \b1a: Configure\nCMMF Client or\nCMMF-Enabled\nMedia Player;~nApp--App: 2: Select\nMedia Content;~nApp-~gMSH: 3: Initiate Media Playback\n\-(Media Player Entry);~nhide App;~nMSH..AF [tag=~qopt~q]:~n{~n~4MSH~l-~gAF [arrow.type=dot]: 4: Service Access\nInformation acquisition;~n};~nMSH-~gMP: 5: Start media playback\n\-(Entry URL);~nMP~l-~gAS_CD [arrow.type=dot]: 6: Establish transport session for the manifest;~nMP-~gAS_CD: 7: Request MPD (Entry Point);~nAS_CD-~gMP: 8: OK\n\-(MPD);~nMP--MP [delta]: 9: Process\nMPD\n\-Combine CMMF endpoint base URLs\nand CMMF URL Template with\nURLs contained in MPD to obtain\nURLs of CMMF-encoded content;~nvspace 5;~nMP-~gMSH: 10: MPD Rx Notification;~n~nvspace 5;~nbox MP..AP_AP [tag=~qopt~q]:~n{~n~4MP~l~gAP_AP: 11: DRM License acquisition;~n};~nhide AP_AP;~n~nvspace 5;~nMP--MP: 12: Configure playback\npipeline;~n~nvspace 5;~nMP--AP_CD [tag=~qpar~q, delta]: 13: Establish transport sessions for content \-(optional Transport Session Parameters)~n{~n~4MP~l-~gAS_CD;~n}~n~2-- [tag=~q~q]:~n{~n~4MP~l-~gAP_CD;~n};~n~nMP-~gMSH: 14: Notification\n\-(Transport Session Parameters);~n~nvspace 5;~n-- [tag=~qloop~q]:~n{~n~4-- [tag=~qpar~q, delta]: 15: Request Initialization Information(s)~n~4{~n~8MP~l-~gAS_CD;~n~4}~n~6-- [tag=~q~q]:~n~4{~n~8MP~l-~gAP_CD;~n~4};~n~9~3~n~4-- [tag=~qpar~q, delta]: 16: OK \-(Initialization Informations(s))~n~4{~n~8MP~l-~gAS_CD;~n~4}~n~6-- [tag=~q~q]:~n~4{~n~8MP~l-~gAP_CD;~n~4};~n~9~9~2~n~4MP--MP [delta]: 16a: CMMF\nDecode;~n};~n~nvspace 15;~n-- [tag=~qloop~q]: 19: Repeat~n{~n~4-- [tag=~qpar~q, delta]: 17: Request Media Segment(s) \-(in parallel from multiple CMMF endpoints)~n~4{~n~8MP~l-~gAS_CD;~n~4}~n~6-- [tag=~q~q]:~n~4{~n~8MP~l-~gAP_CD;~n~4};~n~4~n~4-- [tag=~qpar~q, delta]: 18: Media Content~n~4{~n~8MP~l-~gAS_CD;~n~4}~n~6-- [tag=~q~q]:~n~4{~n~8MP~l-~gAP_CD;~n~4};~n~8~n~4MP--MP [delta]: 18a: CMMF\ndecode;~n};~n~n~|

Figure 5.19.4.1.2.6: High-level procedure for DASH content using CMMF delivery

Editor’s Note: Metadata required to modify the above procedure is included as alt-text within the figure. See <https://msc-generator.gitlab.io/msc-generator/Alt_002dtext-embedding.html> for more details.

The steps for this procedure are largely the same as that shown in clause 5.2.3 of TS 26.501 [15]. The only differences are:

1. The 5GMSd-Aware Application triggers the Service Announcement and Service and Content Discovery procedure. The Service and Content Discovery procedure only involves the App and the external Application Server. The Service Announcement includes either the whole Service Access Information (i.e. details for Media Session Handling (M5d) and for Media Streaming access (M4d)) or a reference to the service access information. **The Service Access Information includes relevant CMMF Client configuration information. This CMMF client configuration information may consist of URLs to each CMMF endpoint, a CMMF URL template allowing for translation of the URLs provided in content manifests (e.g., MPD) into URLs that can be used to access CMMF-encoded media within the 5GMS System, etc.**

**1a. The 5GMSd-Aware Application uses the CMMF client configuration information to set up and configure the CMMF object and decode functions within the CMMF Client or CMMF-Enabled Media Player.**

9. The Media Player processes the MPD. **Based on the information contained within the MPD as well as the relevant CMMF client configuration Information contained in the Service Access Information, the CMMF Client or CMMF-enabled Media Player determines, for example, the number of transport sessions needed for media acquisition, complete URLs to CMMF-encoded media, etc.** The Media Player should use the MPD information to initialize the media pipelines for each media stream. The MPD should also contain information to initialize the DRM client, when DRM is used.

NOTE: CMMF does not impede the use of DRM as long as DRM is applied to the original source media prior to creation of CMMF-encoded objects of that media.

14. The Media Player establishes the necessary transport sessions for the **CMMF-encoded** content. For example, the **CMMF Client or CMMF-enabled** Media Player may establish one transport session for each media component (audio, video, etc) and possibly additional transport sessions for other media representations **to each CMMF endpoint communicated by the CMMF client configuration information.**

15.The Media Player requests initialization information. **In the case where this initialization information has been encoded within CMMF objects, the CMMF Client or CMMF-enabled Media Player requests the CMMF-encoded initialization information objects from each CMMF endpoint in parallel.** **The URLs of the CMMF-encoded initialization information objects are determined using the MPD and information contained within the CMMF client configuration information (e.g., base URLs to each CMMF endpoint, CMMF URL Template, etc.).** The **CMMF Client of CMMF-enabled** Media Player repeats this step for each required initialization segment.

16. The **CMMF Client or CMMF-enabled** Media Player receives the initialization information. **In the case where this initialization information has been encoded within CMMF objects, the CMMF Client or CMMF-enabled** **Media Player downloads these multiple CMMF-encoded initialization information objects from each CMMF endpoint in parallel until such time as the CMMF decoder has received enough information to successfully decode, at which point the download of any incompletely acquired CMMF object is abandoned.**

16a. **In the case where the initialization information has been encoded within CMMF objects, the received information from the CMMF objects containing the initialization information is decoded by the CMMF decoder in the CMMF Client.**

17. The **CMMF Client or CMMF-enabled** Media Player requests media segments according to the MPD. **In the case where these media segments have been encoded within CMMF objects, the CMMF Client or CMMF-enabled** **Media Player requests the CMMF-encoded media segment objects from each CMMF endpoint in parallel. The URLs of the CMMF-encoded media segment objects are determined using the MPD and information contained within the CMMF Client configuration information (e.g., base URLs to each CMMF endpoint, CMMF URL template, etc.).**

18. The **CMMF Client or CMMF-enabled** Media Player receives media segments. **In the case where these media segments have been encoded within CMMF objects, the CMMF Client or CMMF-enabled Media Player downloads these multiple CMMF-encoded media segment objects from each CMMF endpoint in parallel until such time as the CMMF decoder has received enough information to successfully decode, at which point the download of any incompletely acquired CMMF object is abandoned.**

18a. **In the case where the media segments have been encoded within CMMF objects, the received information from the CMMF objects containing the media segment is decoded by the CMMF decoder in the CMMF Client** **and the decoded information is placed** into the appropriate media rendering pipeline.

#### 5.19.4.2 5GMS-integrated multi-source delivery

##### 5.19.4.2.1 General high-level call flows

The procedures defined in clause 5 of TS 26.501 [15] generally apply to the architecture described in clause 5.19.3.2. However, some procedure(s) for unicast downlink Media Streaming session establishment defined in clause 5.2 of TS 26.501 [15] and media preparation are dependent on the multi-source approach in use. Any differences are expanded upon further in subsequent clauses.

##### 5.19.4.2.2 Multi-source approach specific high-level call flows

###### 5.19.4.2.2.1 Overview

Depending on the approach used to implement multi-source functionality, the procedures for unicast downlink Media Streaming session establishment and content preparation may differ from those defined in clause5 of TS 26.501 [15].

###### 5.19.4.2.2.2 DNS-based switching

The call flow is similar to that contained in clause 5.19.4.1.2.2 with the following exceptions:

- The *Content Service Location/Endpoint* located within the Third-Party Provider(s) becomes a second *Content Distribution* within the 5GMSd AS.

- The Online Service Location/Endpoint Management subfunction located within the Third-Party Provider(s) is becomes a subfunction within the 5GMSd AS.

###### 5.19.4.2.2.3 MPEG-DASH client-side switching

The call flow is similar to that contained in clause 5.19.4.1.2.3 with the following exceptions:

- The *Content Service Location/Endpoint* located within the Third-Party Provider(s) becomes a second *Content Distribution* within the 5GMSd AS.

###### 5.19.4.2.2.4 Content Steering Server driven switching

The call flow is similar to that contained in clause 5.19.4.1.2.3 with the following exceptions:

- The *Content Service Location/Endpoint* located within the Third-Party Provider(s) becomes a second *Content Distribution* within the 5GMSd AS.

- The *Online Service Location/Endpoint Management* subfunction located within the Third-Party Provider(s) becomes a subfunction within the 5GMSd AS.

###### 5.19.4.2.2.5 SAND4M multi-source delivery

Editor’s Note: High-level call flows describing how SAND4M can be used to enable multi-source delivery requires further study.

###### 5.19.4.2.2.6 CMMF-based multi-source delivery

5.19.4.2.2.6.1 Overview

The intent of CMMF is to supplement existing downlink streaming procedures, rather than replace them entirely. As such, minimal changes to the procedures provided in clause 5 of TS 26.501 [15] are necessary. Enabling multi-source media delivery using CMMF within existing downlink media delivery workflows can generally be realised through the following:

1. CMMF-encoded media objects, and possibly original source media (e.g., MPEG-DASH or HLS media segments), are striped across multiple uniquely addressable 5GMSd AS Content Distributions. Each 5GMSd AS Content Distribution containing the same CMMF-encoded media object (or stripe) of the media (i.e., the CMMF-encoded media object is replicated across multiple 5GMSd AS instances with an identical Content Distribution) is considered a single CMMF endpoint. The 5GMSd Application Provider makes the CMMF-encoded media objects, and possibly original source media (e.g., MPEG-DASH or HLS media segments), available at reference point M2d or they may be created by the 5GMSd AS performing content preparation on either regular media objects (e.g., MPEG-DASH or HLS media segments) ingested at reference point M2d or already created CMMF-encoded media objects ingested at reference point M2d.

2. Upon initialization of a playback session, the 5GMSd Client’s Media Session Handler obtains relevant Service Access Information from the 5GMSd AF at reference point M5d. At a minimum, this includes details concerning the location of each 5GMSd AS Content Distribution (CMMF endpoint) from which a stripe of CMMF-encoded and possibly original media (e.g., MPEG-DASH or HLS media segments) may be obtained, as well as appropriate signalling to indicate whether the media at each location is CMMF-encoded.

3. The 5GMSd Client connects to and downloads CMMF-encoded media objects, and possibly the original source media (e.g., MPEG-DASH or HLS media segments), from each 5GMSd AS Content Distribution (CMMF endpoint) simultaneously via reference point CMMF‑1 (client architecture #1) or M4d (client architecture #2), terminating downloads early upon obtaining enough of the CMMF-encoded objects to recover the source media (e.g., MPEG‑DASH or HLS media segment). Successfully decoded source media is presented by the Media Player.

The procedures for enabling multi-source delivery using CMMF for MPEG-DASH streaming sessions and provisioning the 5GMS System as shown in figure 5.19.3.2.1-1 to deliver CMMF-encoded media objects are provided in the following clauses.

5.19.4.2.2.6.2 CMMF provisioning, hosting, and processing procedure

The workflow for provisioning network resources and/or hosting CMMF-encoded media is dependent on the 5GMSd Application Provider requirements and network configuration. Assuming the 5GMSd Application Provider creates CMMF-encoded media, provides that media over reference point M2d, provisions CMMF endpoints external to the 5GMS System, and manages the configuration of the 5GMSd Client over reference point M8d, the procedures as outlined in clause 5.19.4.1.2.6 are sufficient to host and deliver CMMF-encoded media. However, cases exist where the 5GMS System may take a more active role in delivering CMMF-encoded media. These cases are outlined in the procedure below. Differences from the baseline procedure in clause 7.2 of TS 26.501 [15] are highlighted in **boldface**.

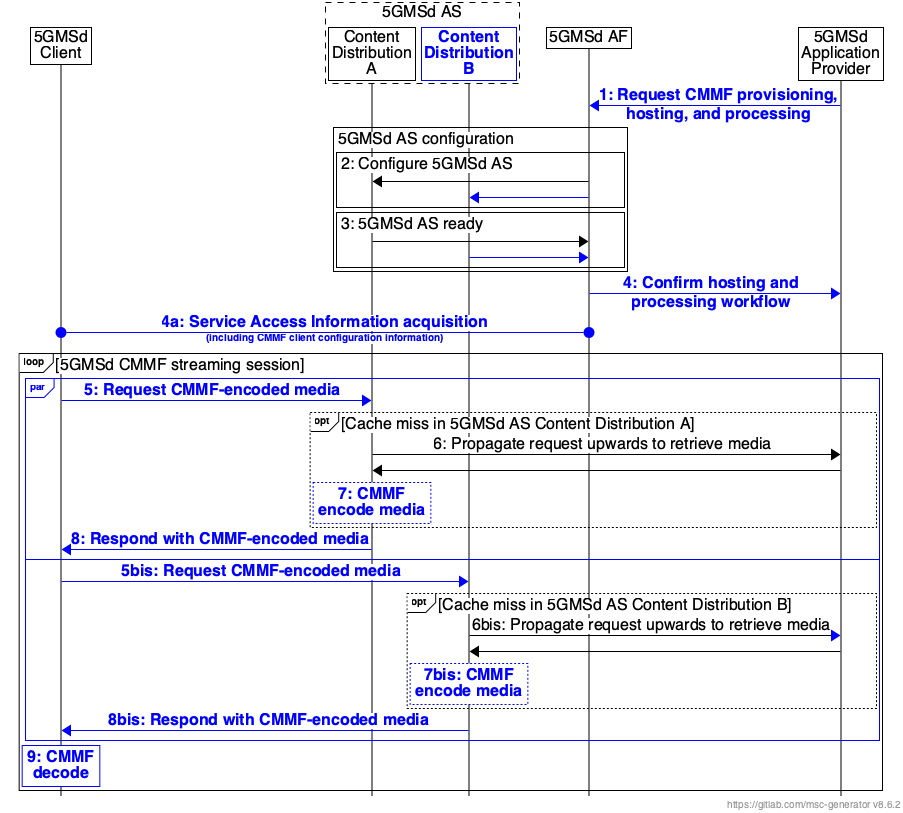


Figure 5.19.4.2.2.6.2-1: Media provisioning, hosting, and processing procedures for downlink media streaming using CMMF

Editor’s Note: Metadata required to modify the above procedure is included as alt-text within the figure. See <https://msc-generator.gitlab.io/msc-generator/Alt_002dtext-embedding.html> for more details.

Steps:

1. Upon setting up a **CMMF Provisioning and Content Hosting Configuration**, the 5GMSd Application Provider requests **CMMF** media processing and hosting to be set up. **The 5GMSd Application Provider provides a description of the type and placement of the processing used to encode CMMF objects, including the required number of CMMF endpoints to be exposed as addressable 5GMSd AS Content Distribution sets, and defines the flow of content through the 5GMS System.** The 5GMS System may only allow a shortlisted set of media processing functions to be used by the 5GMSd Application Provider.

4. The 5GMSd AF confirms the successful creation of the **CMMF Provisioning and Content Hosting Configuration** with the requested media processing to the 5GMSd Application Provider.

4a. The 5GMSd AF exchanges relevant **CMMF client configuration information** with the 5GMSd Client to enable the 5GMSd Client to access and download **both CMMF-encoded media and original source media**. **This CMMF client configuration information may consist of URLs to each CMMF endpoint established in step 2, a CMMF URL template allowing for translation of the URLs provided in content manifests (e.g., MPD) into URLs that can be used to access CMMF-encoded media within the 5GMS System, etc.**

5. A 5GMSd Client sends one or more requests for **CMMF-encoded media content** to one or more of the 5GMSd AS Content Distributions (established as CMMF endpoints) listed in the provisioned Content Hosting Configuration (see clause 5.4 of TS 26.501 [15]).

6. If it does not already have a copy of the requested media cached, the 5GMSd AS Content Distribution by the 5GMSd Client fetches the media **from a back-end 5GMSd AS Content Distribution** or from the 5GMSd Application Provider.

NOTE 1: Multiple options are available for distributing CMMF-encoded media to the addressed 5GMSd AS Content Distribution. These options are dependent on how the 5GMS System is provisioned and configured during steps 1-4. Options and details on the call flows involving cache misses are provided below.

7. Depending on the media content received **from a back-end 5GMSd AS Content Distribution** or from the 5GMSd Application Provider, **the addressed 5GMSd AS Content Distribution may be required to create a unique CMMF-encoded representation of the requested media using content processing provisioned in step 1 and referenced by the Content Hosting Configuration**.

NOTE 2: Additional details are provided below.

8. The addressed 5GMSd AS Content Distribution serves **the requested CMMF-encoded media or original source media** to the 5GMSd Client.

9. **In the case where CMMF-encoded media is obtained from one or more 5GMSd AS Content Distributions, the 5GMSd Client decodes this CMMF-encoded media and recovers the original source media.**

Different variants of these procedures (specifically steps 6 and 7) may be possible, depending on the placement of the processing, the placement of the CMMF endpoints, and the characteristics of the CMMF Content Provisioning and Hosting Configuration. Furthermore, the introduction of CMMF to supplement the download of media in other scenarios (e.g., downlink streaming to Media Players with different presentation manifests per clause 5.2.4 of TS 26.501 [15]) can be applied in a similar fashion to that shown below.

1. *Content preparation by 5GMSd Application Provider.* The procedure used when the 5GMSd Application Provider is responsible for encoding and packaging source media within CMMF bitstreams/objects prior to delivery of that content separately to each 5GMSd AS Content Distribution via reference point M2d, or to each externally deployed 5GMSd AS Content Distribution, is provided in figure 15.19.4.2.2.6.2-2. In these cases, the 5GMSd Application Provider provides a unique CMMF-encoded representation of the original source media to each 5GMSd AS Content Distribution configured as a CMMF endpoint.

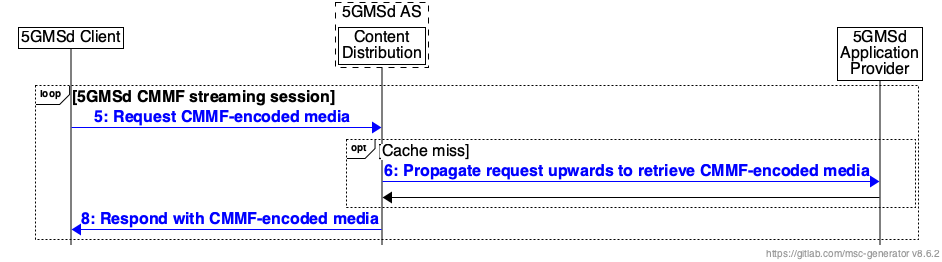


Figure 5.19.4.2.2.6.2-2: 5GMSd Application Provider CMMF Content Preparation and media processing procedures for downlink media streaming

Editor’s Note: Metadata required to modify the above procedure is included as alt-text within the figure. See <https://msc-generator.gitlab.io/msc-generator/Alt_002dtext-embedding.html> for more details.

Steps:

5. A 5GMSd Client sends one or more requests for **CMMF-encoded media content** to one or more of the 5GMSd AS Content Distributions (established as CMMF endpoints) listed in the provisioned Content Hosting Configuration (see clause 5.4 of TS 26.501 [15]).

6. **If the 5GMSd AS Content Distribution does not have the required CMMF-encoded media cached, it requests and fetches a unique CMMF-encoded representation of the requested media from the 5GMSd Application Provider. In this case, it is the responsibility of the 5GMSd Application Provider to ensure that the CMMF-encoded representations of the requested media provided to each CMMF endpoint are unique. Upon receipt of the requested unique CMMF-encoded representation of the requested media, the 5GMS AS Content Distribution may cache the CMMF object locally to support subsequent requests for that content.**

7. **Media processing is not required.**

8. The addressed 5GMSd AS Content Distribution serves **the requested CMMF-encoded media** to the 5GMSd Client.

2. *Centralized 5GMSd content preparation.*Figure 5.19.4.2.2.6.2-3 shows the procedure used when source content is ingested at reference point M2d by a single, primary 5GMSd AS Content Distribution that encodes and packages it into CMMF bitstreams/objects according to a configuration provided by a Content Preparation Template contained within a CMMF Provisioning and Hosting Configuration previously provisioned by the 5GMSd Application Provider.  
  
In these cases, the placement of 5GMSd AS Content Distribution is hierarchical, as shown in figure 5.19.3.2.2.6.3-1 and the client-addressable 5GMSd AS Content Distribution (CMMF endpoints) accessed at reference point M4d by 5GMSd Clients ingest, via reference point M10d, CMMF-encoded media from an upstream back-end 5GMSd AS Content Distribution that is configured to encode and package source media into CMMF bitstreams/objects. The 5GMSd AS Content Distribution performing CMMF content preparation is responsible for providing a unique CMMF-encoded representation of the original source media to each client-addressable 5GMSd AS Content Distribution configured as a CMMF endpoint.

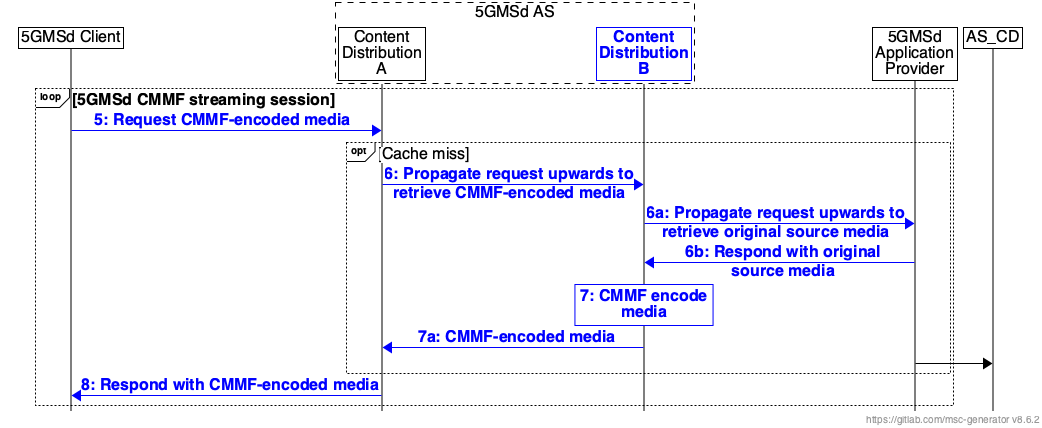


Figure 5.19.4.2.2.6.2-3: Centralized 5GMSd Content Preparation and media processing procedures for downlink media streaming

Editor’s Note: Metadata required to modify the above procedure is included as alt-text within the figure. See <https://msc-generator.gitlab.io/msc-generator/Alt_002dtext-embedding.html> for more details.

Steps:

5. The 5GMSd Client sends request(s) for **CMMF-encoded media** **to one or more addressable sets of 5GMSd AS Content Distributions where each set is configured as a different CMMF endpoint.**

6. **If the 5GMSd AS Content Distribution (A) does not have the required CMMF-encoded media cached, it requests a unique CMMF-encoded representation of the requested media from a back-end 5GMSd AS Content Distribution (B).**

6a. **If the 5GMSd AS Content Distribution (B) does not have the required CMMF-encoded media cached, it requests the original source media from the 5GMSd Application Provider.**

6b: **The 5GMSd Application Provider sends the requested original source media to the 5GMSd AS Content Distribution (B).**

7: **The 5GMSd AS Content Distribution (B) encodes the received original source media to create a CMMF-encoded representation unique to the requesting 5GMSd AS Content Distribution (A).**

7a: **The 5GMSd AS Content Distribution (B) sends the requested CMMF-encoded media to the 5GMSd AS Content Distribution (A).**

8. **The 5GMSd AS Content Distribution (A) responds to the 5GMSd Client’s request with a CMMF-encoded representation of the requested media that is unique to the CMMF endpoint to which the 5GMSd AS Content Distribution (A) belongs.**

3. *Decentralized 5GMSd content preparation.* The procedure shown in figure 5.19.4.2.2.6.2-4 is used when CMMF media processing and content preparation is distributed across 5GMSd AS Content Distributions where each 5GMSd AS Content Distribution is responsible for the creation of a single CMMF representation which it intends to cache and/or deliver via reference point CMMF-1 or M4d (depending on the assumed 5GMSd Client architecture described in clause 5.19.3.2.1. This case is illustrated in figure 5.19.3.2.2.6.3-2.

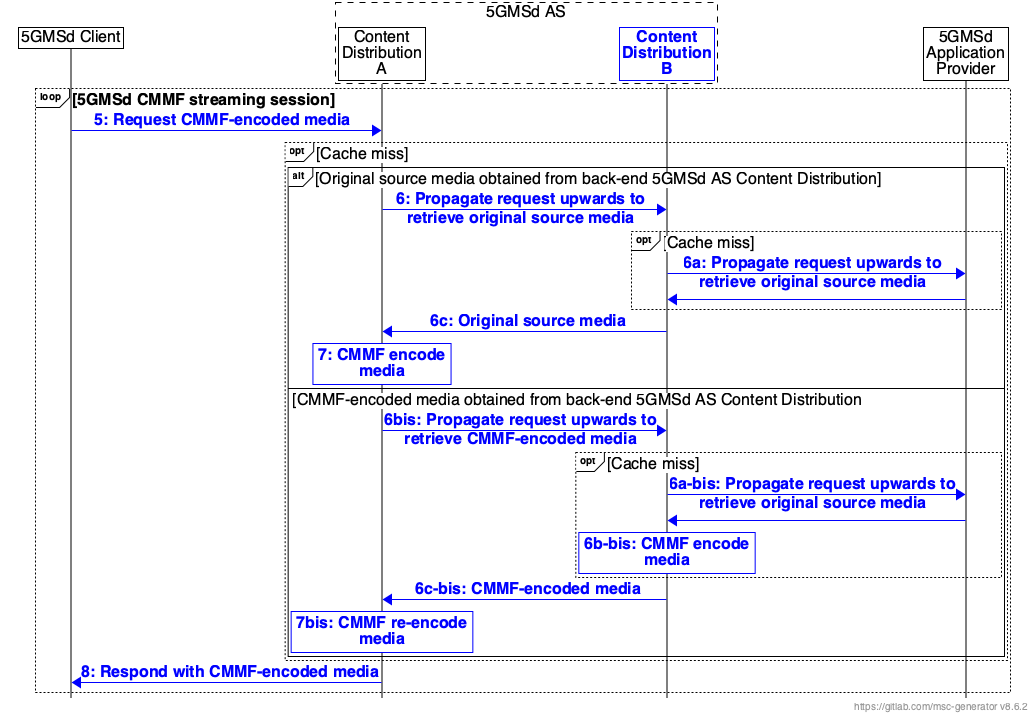


Figure 5.19.4.2.2.6.2-4: Decentralized 5GMSd Content Preparation and media processing procedures for downlink media streaming

Editor’s Note: Metadata required to modify the above procedure is included as alt-text within the figure. See <https://msc-generator.gitlab.io/msc-generator/Alt_002dtext-embedding.html> for more details.

Steps:

5. The 5GMSd Client sends request(s) for **CMMF-encoded media** **to one or more addressable sets of 5GMSd AS Content Distributions where each set is configured as a different CMMF endpoint.**

**6. If the 5GMSd AS Content Distribution (A) does not have the required CMMF-encoded media cached, it requests the media from a back-end 5GMSd AS Content Distribution (B). The 5GMSd AS Content Distribution (A) can explicitly request either the original source media or the CMMF representation unique to the back-end 5GMSd AS Content Distribution (B), or it can make a general request that may return one or the other.**

**6a. If the back-end 5GMSd AS Content Distribution (B) does not have a copy of the original source media or a CMMF-encoded representation cached, it may obtain it from the 5GMSd Application Provider.**

**6b. In the case where original source media is obtained in step 6, the 5GMSd AS Content Distribution (B) encodes it into a unique CMMF representation where it may also be cached for later retrieval.**

**6c. Either the original source media or a CMMF-encoded representation unique to the 5GMSd AS Content Distribution (B) is sent to 5GMSd AS Content Distribution (A).**

**7. In the case where original source content is obtained from the back-end 5GMSd AS Content Distribution (B), a CMMF-encoded representation unique to the 5GMSd AS Content Distribution (A) is created. In the case where a CMMF-encoded representation unique to the back-end 5GMSd AS Content Distribution (B) is obtained, the CMMF-encoded representation is decoded back to the original source content and re-encoded to create a CMMF-encoded representation unique to the 5GMSd AS Content Distribution (A).**

**8. The 5GMSd AS Content Distribution (A) responds to the 5GMSd Client’s request with a CMMF-encoded representation of the requested media that is unique to the CMMF endpoint to which the 5GMSd AS Content Distribution (A) belongs.**

Variations to the above content provisioning, preparation, and hosting procedures are possible to support different use cases, and 5GMS network configurations.

5.19.4.2.2.6.3 Procedures for CMMF downlink media streaming

The call flow is similar to that contained in clause 5.19.4.1.2.6 with the following exceptions:

- The *Content Service Location/Endpoint* located within the Third-Party Provider(s) becomes a second *Content Distribution* within the 5GMSd AS.

### 5.19.5 Gap analysis and requirements

#### 5.19.5.1 Over-the-Top (OTT) multi-source delivery

5GMS network support for delivering media from multiple locations using the architecture described in clause 5.19.3.1 is largely supported by the 5GMS System. Within this architecture, the 5GMS System is configured such that it can be considered a single service location (or endpoint), while Content Distributions provisioned within External DNs (e.g., commercial CDNs) are outside of the scope of 5GMS. Furthermore, signalling availability of multiple service locations and management of their selection is performed by the 5GMSd Application Provider via the 5GMSd-Aware Application which is also outside of the scope of 5GMS. However, 5GMSd Client multi-source/endpoint functionality is necessary for most multi-source delivery approaches considered. The required functionality includes:

1. 5GMSd Client that supports the multi-source/endpoint approach in use. This includes:

a. Functionality to switch between or simultaneously use multiple source/endpoints located within either the Trusted or External DNs. For MPEG-DASH client-side switching and Content Steering Server switching, this functionality includes the capability to switch the source/endpoint in use while accessing/downloading media. For CMMF-based delivery, this functionality includes the capability to efficiently access/download multiple CMMF-encoded media objects in parallel; as well as decode these received (or partially received) CMMF-encoded media objects to recover original source media objects required for playback.

b. Functionality necessary to support signalling of measurement and control messaging at reference point M4d’.

2. Exchange multi-source/endpoint configuration information over Media Session Handling (M6) and/or Media Stream Handler (M7/M11) APIs (clauses 12 and 13 of TS 26.512 [16]). In cases where multi-source delivery is configured and signalled by the 5GMSd Application Provider at reference point M8d rather than in-band (e.g., within the manifest), the Media Session Handling (M6) and/or Media Stream Handler (M7/M11) APIs are required to support signalling of parameters needed to configure a Media Player to execute multi-source/endpoint delivery. These parameters may include a list of source/endpoint base URLs, CMMF configuration information, remote multi-source/endpoint management information (e.g., Content Steering Server URL), etc.

#### 5.19.5.2 5GMS-integrated multi-source delivery

Fully integrating multi-source/endpoint delivery within the 5GMS System as described in clause 5.19.3.2 is generally supported with a several exceptions. Within this architecture, the 5GMS System is configured such that it natively supports multi-source/endpoint delivery. 5GMS currently supports establishment of multiple Content Distributions via the Content Hosting Configuration where each can be considered a distinct content endpoint within the network. Each Content Distribution can also be configured to perform Content Preparation as needed by the specific multi-source/endpoint approach in use. However, this Content Preparation subfunction or its configuration is not fully supported. Furthermore, signalling necessary multi-source/endpoint delivery parameters to both 5GMSd Clients and within each 5GMSd Client is also not fully supported. The following gaps in existing 5G Media Streaming specifications have not yet been addressed to support the capabilities discussed.

1. *Capability to configure and provision content endpoints within the 5GMS network to support multi-source/endpoint delivery.* 5GMS supports the configuration and establishment of multiple content endpoints with the 5GMS network via the Content Hosting Configuration (clause 8.8 of TS 26.510 [26510]). Each content endpoint can be established as a unique Distribution Configuration where each Distribution Configuration is provisioned with a Fully-Qualified Domain Name (FQDN) canonical domain name and base URL by the 5GMSd AF. Content in each Content Distribution is made available to 5GMSd Clients at reference point M4d. Furthermore, Content Preparation Templates can be linked to each Content Distribution to support use cases where either the manifest (i.e., MPD) or content requires modification/preparation prior to its delivery at reference point M4d. While most of the capabilities currently exist to configure and provision multiple content endpoints within the 5GMS network, the following capabilities are currently missing:

a. *Content Preparation and Content Preparation Templates to support multi-source/endpoint delivery.* Content Preparation Templates used during Content Distribution provisioning are not currently specified with 5GMS. These Content Preparation Templates should define the content preparation functions necessary to prepare content for delivery at reference point M4d. These functions should enable the following:

i. *Manifest (e.g., MPD) manipulation for cases where content endpoints (e.g., service locations) and/or content endpoint access management function (e.g., Content Steering Server) locations are communicated within the manifest.* The provisioned Content Preparation subfunction should accept content endpoint URLs and content endpoint access management function locations from the 5GMSd AF and make the appropriate changes to each manifest before delivery to a 5GMSd Client at reference point M4d.

ii. *CMMF encoding and packaging for cases where the content endpoints are provisioned to perform these operations.* These Content Preparation Templates and Content Preparation subfunctions should support the workflows described in clause 5.19.4.2.2.6.2.

b. *Capability to configure and provision Content Distribution ingest configurations.* As currently specified in clause 8.8.3.1 of TS 26.510 [26510], Content Distributions currently inherit the ingest configuration of the Content Hosting Configuration which they belong. As is currently the case, the ingest configuration specifies the parameters for ingesting media content into the 5GMSd AS at reference point M2d. Support for more complex Content Distribution deployments (e.g., the centralized and decentralized content preparation workflows described in clause 5.19.4.2.2.6.2) should be supported.

c. *Capability to configure Content Distribution deployment requirements.* Current specifications are unclear about where and how distinct Content Distributions are provisioned within the 5GMSd AS. As an example, the capability to configure each Content Distribution on a separate 5GMSd AS physical host may be desirable for cases where improved robustness to content endpoint degradation/failure is required.

2. *Capability to signal multi-source/endpoint configuration information to 5GMSd Clients at reference point M5d.* For use cases where multi-source/endpoint delivery configuration information is not signalled in-band at reference point M4d (e.g., via the manifest), out-of-band signalling of this information is necessary. The 5GMS System supports this via the Service Access Information provided by the 5GMSd AF at reference point M5d. However, the currently specified Service Access Information does not allow for the following:

a. *Capability to signal external content endpoint locations.* Use cases where the 5GMSd Application Provider provisions content endpoints externally to the 5GMS System are not currently supported since there are currently no methods to communicate content endpoints provisioned by the 5GMSd Application Provider in External DNs via the 5GMSd AF.

b. *Capability to signal a list of endpoint locations that can be used for multi-source/endpoint delivery.* The Service Access Information currently only supports the communication of a list of Media Entry Points (e.g., MPDs). The Service Access Information should also provide the capability to communicate the FQDN base URLs of the provisioned Content Distributions defined in the Content Hosting Configuration.

c. *Capability to signal 5GMSd AS Online Service Location/Endpoint Management subfunction configuration information.* For cases where an Online Service Location/Endpoint Management function (e.g., a Content Steering Server) is provisioned within the 5GMSd AS, information about the URL this function can be accessed at reference point M4d, the API in use, etc. should be made available to the 5GMSd Client at reference point M5d.

d. *Capability to signal URL path rewrite rules 5GMSd Clients should use when accessing media from different Content Distributions.* In some use cases, media may be assigned a unique URL based on the Content Distribution from which it is served, how it was packaged, etc. An example includes CMMF-encoded media where CMMF-encoded media objects containing different representations (or stripes) of the same original source media are accessible via unique URLs. Clause 5.19.3.2.2.6.4 provides examples of different URL path rewrite rules addressing CMMF-encoded content.

e. *Capability to signal CMMF-specific configuration information.* In some cases, additional information beyond what is discussed above may be required to support CMMF-based multi-source delivery. This additional information may include the CMMF code type used to encode media, the CMMF profile in use, etc.

3. *Capability to configure and provision Online Service Location/Endpoint Management subfunctions within the 5GMSd AS.* An example may include the configuration and deployment of a Content Steering Server [DIFCS] within the 5GMSd AS.

4. *5GMSd Client multi-source/endpoint functionality is necessary for most multi-source delivery approaches considered.* The required functionality includes:

a. *5GMSd Client that supports the multi-source/endpoint approach in use.* This includes:

i. *Functionality to switch between or simultaneously use multiple source/endpoints located within either the Trusted or External DNs.* See item 1.a in clause 5.19.5.1.

ii. *Functionality necessary to support signalling of measurement and control messaging between the 5GMSd Client and a 5GMSd AS Online Service Location/Endpoint subfunction at reference point M4d.* See item 1.b in clause 5.19.5.1.

b. *Exchange multi-source/endpoint configuration information over Media Session Handling (M6) and/or Media Stream Handler (M7/M11) APIs (clauses 12 and 13 of TS 26.512 [16]).* See item 2 in clause 5.19.5.1.

### 5.19.6 Candidate solutions

#### 5.19.6.1 Overview

TBD

#### 5.19.6.2 Content endpoint configuration and provisioning candidate solutions

##### 5.19.6.2.1 Content Preparation Templates and Content Preparation candidate solutions

###### 5.19.6.2.1.1 Overview

Examples of content preparation that might be needed to support different multi-source/endpoint use cases include:

* Repackaging ingested content (e.g., repackage content from MPEG-DASH to CMAF).
* Encoding content ingested at reference point M2d into multiple CMMF representations/stripes before distributing it at reference point M4d (e.g., CMMF delivery).
* Embellishing, or otherwise modifying, the Media Entry Point (e.g., MPEG-DASH MPD) ingested at reference point M2d before distributing it at reference point M4d to include references to content service locations/endpoints (e.g., *BaseURLs*), content steering service endpoints (e.g., *ContentSteering* URL), etc.

Before provisioning the Content Hosting Configuration and Distribution Configurations, the 5GMSd Application Provider first provisions one or more Content Preparation Templates at reference point M1d. If necessary, a Content Preparation Template is referenced by a Distribution Configuration using the Content Preparation Templates’ *contentPreparationTemplateId*.

The syntax and semantics of all Content Preparation Templates are opaque to the 5GMSd AF, but they are understood by the 5GMSd AS. Different 5GMSd AS content distributions may support different types of Content Preparation Template, or different subsets of functionality expressed in each Content Preparation Template type. The Content Protocols Discovery API specified in clause 8.3 of TS 26.510 [26510] should be extended to allow a 5GMSd Application Provider to determine which types of Content Preparation Template (and which sub-features of each) are supported in a particular 5GMS System.

The following options for the format of the Content Preparation Template should be considered:

###### 5.19.6.2.1.2 Option A: Multipurpose Content Preparation Template file format specified outside the scope of 3GPP

The Content Preparation Template follows a multi-purpose file format specified outside the scope of 3GPP (e.g. MPEG-I Part 8 (Network-Based Media Processing) as specified in ISO/IEC 23090-8 [ISO26098]). The MIME content type of the Content Preparation Template is as specified in ISO/IEC 23090-8. The usage of this generic Content Preparation Template is profiled in 3GPP TS 26.511 [96]. The generic MIME content type is listed in clause 4.3.5.2 of TS 26.512 [16] as valid for use with the 5GMS System along with a reference to the set of valid profiles specified in TS 26.511 [96].

###### 5.19.6.2.1.3 Option B: Bespoke Content Preparation Template file format specified outside the scope of 3GPP

The Content Preparation Template follows a file format specified outside the scope of 3GPP that is bespoke to the form of content preparation (e.g., a CMMF configuration file format specified in an annex to ETSI TS 103 973 [CMMF]). The MIME type of the bespoke Content Preparation Template document format is also specified outside the scope of 3GPP, but it is listed in clause 4.3.5.2 of TS 26.512 [16] as valid for use with the 5GMS System along with a reference to the relevant external specification.

###### 5.19.6.2.1.4 Option C: Bespoke Content Preparation Template file format specified by 3GPP

The Content Preparation Template follows file format specified by 3GPP that is bespoke to the form of content preparation (e.g. a CMMF configuration file format specified in an annex to 3GPP TS 26.511 [96]). The MIME type of the bespoke Content Preparation Template document format is also specified in 3GPP TS 26.511, and it is also listed in clause 4.3.5.2 of TS 26.512 [16] as valid for use with the 5GMS System along with a reference to TS 26.511.

##### 5.19.6.2.2 Content Hosting Configuration candidate solutions

###### 5.19.6.2.2.1 Overview

The 5GMS System allows for the establishment of multiple logical content endpoints that can be used for multi-source/endpoint delivery through the Content Hosting provisioning API specified in clause 8.8 of TS 26.510 [26510]. The Content Hosting Configuration data model as specified in clause 8.8.3.1 of TS 26.510 allows for the 5GMSd Application Provider to specify an ingest configuration at reference point M1d for media ingested at reference point M2d and one or more Distribution Configurations where media is made available to 5GMSd Clients at reference point M4d. Each distribution configuration is accessible through a Fully-Qualified Domain Name (FQDN), or *baseURL*, assigned by the 5GMSd AF. A distribution configuration may describe a single content item, or multiple content items. An entry point (e.g., MPD) is defined if the former, and it is omitted if the latter.

Several options exist for Content Hosting provisioning with the 5GMS System to support multi-source/endpoint media delivery. In some cases, the Content Hosting provisioning API should be extended to allow a 5GMSd Application Provider to define a Content Hosting Configuration that supports their multi-source/endpoint use case.

The following should be considered:

###### 5.19.6.2.2.2 Content distribution ingest configuration candidate solutions

5.19.6.2.2.2.1 Option D: 5GMSd AF managed content distribution ingest configuration

The 5GMSd AF may configure and provision individual 5GMSd AS content distributions at M3d with appropriate Content Preparation Template(s). Content preparation may be centralized or distributed among multiple 5GMSd AS content distributions at the discretion of the 5GMSd AF. Content prepared in one 5GMSd AS content distribution may be conveyed to another 5GMSd AS content distribution via reference point M10d on a hierarchical or peer-to-peer basis at the discretion of the 5GMSd AF. Clause 5.2.8 in TS 26.510 [26510] is updated appropriately.

5.19.6.2.2.2.2 Option E: 5GMSd Application Provider guided content distribution ingest configuration

In some use cases, the 5GMSd Application Provider may require specific deployment configurations where it dictates the structure of content distributions within the Content Hosting Configuration. In such cases, content distributions can be chained together to form flat, hierarchical, or peer-to-peer structures within the 5GMSd AS by adding a distribution ingest configuration property similar to that of the *ingestConfiguration* property in the ContentHostingConfiguration resource provided in clause 8.8.3 of TS 26-510 [26510]. Additional properties are added to the ContentHostingConfiguration resource, including:

- *distributionConfigurations.ingestConfiguration*

- *distributionConfiguration.ingestConfiguration.mode*

- *distributionConfiguration.ingestConfiguration.protocol*

- *distributionConfiguration.ingestConfiguration.baseURL*

In cases where these properties are defined by the 5GMSd Application Provider, the 5GMSd AF takes them into account when provisioning Content Hosting within the 5GMSd AS. If these properties are not defined, content distribution provisioning is left to the discretion of the 5GMSd AF.

###### 5.19.6.2.2.3 Content distribution 5GMSd AS instance deployment configuration candidate solutions

5.19.6.2.2.3.1 Option F: Require 5GMSd AF provisioning of content distributions on separate 5GMSd AS instance

Require in clause 5.2.8 and 8.8 of TS 26.510 [26510] that each content distribution defined within the Content Hosting Configuration to be provisioned by the 5GMSd AF on separate 5GMSd AS instances.

5.19.6.2.2.3.2 Option G: Content distribution affinity parameter

Define a new top-level Boolean *distributionAffinity* property within the ContentHostingConfiguration resource provided in clause 8.8.3 of TS 26-510 [26510]. This property specifies whether all distribution configurations are to be hosted on the same 5GMSd AS instance as each other, or whether they are all to be hosted on different 5GMSd AS instances.

- If TRUE:

- The 5GMSd AF configures a set of 5GMSd AS instances at reference point M3d where each content distribution defined by the Content Hosting Configuration are provisioned on different 5GMSd AS instances within the 5GMS System.

- The authority in both the *distributionConfiguration.canonicalDomainName* and *distributionConfiguration.baseURL* assigned by the 5GMSd AF for each content distribution are unique to the provisioned content distribution.

- If FALSE:

- Provisioning of content distributions across a set of 5GMSd AS instance is at the discretion of the 5GMSd AF. The 5GMSd AF may configure a set of 5GMSd AS instances at reference point M3d where each content distribution defined by the Content Hosting Configuration may or may not be provisioned on different 5GMSd AS instances.

- When two or more content distributions are provisioned on a single 5GMSd AS instance, the authority in both the *distributionConfiguration.canonicalDomainName* and *distributionConfiguration.baseURL* assigned by the 5GMSd AF for each content distribution may or may not be unique to the provisioned content distribution. In the latter case, the path should be unique to each provisioned content distribution.

Editor’s Note: This clause is a work in progress. The text included below comes from an email conversation but provides an idea for the direction(s) this clause is going to take.

#### 5.19.6.3 Multi-source/endpoint 5GMSd Client configuration candidate solutions

##### 5.19.6.3.1 Overview

##### 5.19.6.3.2 External content endpoint configuration signaling candidate solutions

###### 5.19.6.3.2.1 Option

Signaled via M8d

###### 5.19.6.3.2.2 Option

Signaled via M5d

##### 5.19.6.3.3

2. *Capability to signal multi-source/endpoint configuration information to 5GMSd Clients at reference point M5d.* For use cases where multi-source/endpoint delivery configuration information is not signalled in-band at reference point M4d (e.g., via the manifest), out-of-band signalling of this information is necessary. The 5GMS System supports this via the Service Access Information provided by the 5GMSd AF at reference point M5d. However, the currently specified Service Access Information does not allow for the following:

a. *Capability to signal external content endpoint locations.* Use cases where the 5GMSd Application Provider provisions content endpoints externally to the 5GMS System are not currently supported since there are currently no methods to communicate content endpoints provisioned by the 5GMSd Application Provider in External DNs via the 5GMSd AF.

b. *Capability to signal a list of endpoint locations that can be used for multi-source/endpoint delivery.* The Service Access Information currently only supports the communication of a list of Media Entry Points (e.g., MPDs). The Service Access Information should also provide the capability to communicate the FQDN base URLs of the provisioned Content Distributions defined in the Content Hosting Configuration.

c. *Capability to signal 5GMSd AS Online Service Location/Endpoint Management subfunction configuration information.* For cases where an Online Service Location/Endpoint Management function (e.g., a Content Steering Server) is provisioned within the 5GMSd AS, information about the URL this function can be accessed at reference point M4d, the API in use, etc. should be made available to the 5GMSd Client at reference point M5d.

d. *Capability to signal URL path rewrite rules 5GMSd Clients should use when accessing media from different Content Distributions.* In some use cases, media may be assigned a unique URL based on the Content Distribution from which it is served, how it was packaged, etc. An example includes CMMF-encoded media where CMMF-encoded media objects containing different representations (or stripes) of the same original source media are accessible via unique URLs. Clause 5.19.3.2.2.6.4 provides examples of different URL path rewrite rules addressing CMMF-encoded content.

e. *Capability to signal CMMF-specific configuration information.* In some cases, additional information beyond what is discussed above may be required to support CMMF-based multi-source delivery. This additional information may include the CMMF code type used to encode media, the CMMF profile in use, etc.

3. *Capability to configure and provision Online Service Location/Endpoint Management subfunctions within the 5GMSd AS.* An example may include the configuration and deployment of a Content Steering Server [DIFCS] within the 5GMSd AS.

4. *5GMSd Client multi-source/endpoint functionality is necessary for most multi-source delivery approaches considered.* The required functionality includes:

a. *5GMSd Client that supports the multi-source/endpoint approach in use.* This includes:

i. *Functionality to switch between or simultaneously use multiple source/endpoints located within either the Trusted or External DNs.* See item 1.a in clause 5.19.5.1.

ii. *Functionality necessary to support signalling of measurement and control messaging between the 5GMSd Client and a 5GMSd AS Online Service Location/Endpoint subfunction at reference point M4d.* See item 1.b in clause 5.19.5.1.

b. *Exchange multi-source/endpoint configuration information over Media Session Handling (M6) and/or Media Stream Handler (M7/M11) APIs (clauses 12 and 13 of TS 26.512 [16]).* See item 2 in clause 5.19.5.1.

1. Provision multiple **distribution configurations** in the same **Content Hosting Configuration**, one for each logical content endpoint, which may have **the same MIME content type**.
   * *(We already allow multiple distributions for different MIME content types, so this is just a simple extension of that concept.)*

[[JC]] From 26.510 clause 8.8.3.1, there does not appear to be any requirements on the MIME content type within *distributionConfigurations*. In fact, it explicitly states that one or more distributions can be configured to deliver the same ingested content.  We would have to add/change a few fields to the Content Hosting Configuration data model (clause 8.8.3.1). As an example, there currently is not a way to chain distribution configurations together to support some of the CMMF deployment options outlined in S4AL240185. Perhaps the addition of a field such as *distributionConfigurations*.*ingestConfiguration* would allow one to do this chaining.

1. Provision a **Content Preparation Template** for each logical distribution specifying how content ingested at reference point M2d is to be manipulated by the (logical) 5GMSd AS before distribution to the 5GMSd Client at reference point M4d.
   * *(This is another small delta on what is already specified.)*

[[JC]] This approach can work as well. One small change that would need to be made is to allow for the Content Hosting Configuration defined in each Content Preparation Template to ingest media content from outside Content Preparation/Content Hosting Configurations (via M10). At a minimum, a modification to the *ContentHostingConfiguration*.*ingestConfiguration* description would be necessary. From a Service Access Information perspective, this might be a little messy. The 5GMS Client would need to be aware of multiple *provisioningSessionId’s*.

1. Advertise the logical content endpoint URLs available at reference point M4d in the complete Service Access Information provided by the 5GMSd AF to the Media Session Handler at reference point M5d.
   * *(Reusing the entryPoints array in the streamingAccess* object.)

I have tried to specify the bare minimum modifications to the existing 5GMS System to make the known Use Cases work, based on my (imperfect) understanding of them. I leave it to others to judge if I have achieved that goal, and to point out any deficiencies.

Putting more flesh on these bones:

|  |  |
| --- | --- |
| **Requirement** | **Candidate solution** |
| 1. Ability to provision multiple logical content endpoints at reference point M4d for the same source media ingested at reference point M2d. | 5GMSd Application Provider provisions a Content Hosting Configuration at reference point M1d:   * One **ingest configuration** to ingest content into the 5GMSd AS at reference point **M2d**. * One **distribution configuration** per logical content endpoint to distribute the content at reference point **M4d**.   + The optional *entryPoint* object is present in every distribution configuration and is populated as follows:     - The *relativePath* is typically different for each logical content endpoint, but need not be unique if they can instead be discriminated based on host name (see later).       * This may be a full path to a Media Entry Point document (e.g. MPEG-DASH MPD) or media resource (e.g. MP4), in which case subsequent requests by the 5GMSd Client at M4d may be made relative to that resource.       * Alternatively, and in a change to TS 26.510, this may be just a path prefix, in which case all requests by the 5GMSd Client at M4d are relative to this path.   ***[[TS]] As mentioned, DASH-IF defines service location (a label attached to a BaseURL), and HLS defines pathways.***  [[JC]] I think the purpose of doing this is to offload the communication of the service locations to the 5GMS System so that the MPDs do not have to be updated each time a distribution configuration is changed. The Content Hosting provisioning API (26.510 clause 8.8) allows for paths to be rewritten via *pathRewriteRules*. However, a similar function is not available in the Service Access Information (clause 9.2.3). One possible change could be to add these rules/maps to the Service Access Information to help the 5GMS Client translate URLs appropriately.     * + - The *contentType* indicates the regular MIME content type (e.g. MPEG-DASH or HLS).   [[JC]] It appears that the MIME content type is only necessary to be defined if there is an *entryPoints* defined. If the distribution configuration contains multiple content items, these fields are omitted.     * + - The *protocol* controlled term optionally indicates additional encoding applied to the content (e.g. CMMF).   ***[[TS]] I am not sure we can consider CMMF as a protocol. For me, in case CMMF is used, you have a new entry point. But this is what I am still trying to understand.***  [[JC]] I agree with Thomas that we should avoid considering CMMF a protocol. As an alternative to using protocol to signal that CMMF is in use, could we use the profile field?     * + The *contentPreparationTemplateId* references a previously provisioned Content Preparation Template (see below) for the logical content endpoint corresponding to this distribution configuration.   + In principal, several distribution configurations can reference the same Content Preparation Template resource, but there would need to be a new optional *contentPreparationTemplateReference* property added in this case so that each distribution configuration can dereference a different sub-configuration in a shared Content Preparation Template, supporting the Use Case where each one needs to distribute different content at M4d. Otherwise, each distribution configurations needs to reference a different Content Preparation Template resource in such cases.   + A new *relativeWeighting* property indicates the relative weighting of this distribution configuration relative to the others.     - This drives client selection likelihood.     - This also informs the 5GMSd AF about the horizontal scaling requirements of 5GMSd AS instance(s) serving this distribution configuration.   ***[[TS]] weighting I am not sure. In what sense. For example if you operate content steering, you will monitor which of the networks work for which client and will steer the client.***   * A new top-level Boolean *distributionAffinity* property specifies whether all distribution configurations are to be hosted on the same 5GMSd AS instance as each other, or whether they are all to be hosted on different 5GMSd AS instances.   + The *baseURL* reflected back to the 5GMSd Application Provider in the provisioning response needs to have a different host name for each distribution configuration if they are hosted on different 5GMSd AS instances.   + When hosted on the same 5GMSd AS instance, the host name in the *baseURL* assigned by the 5GMSd AF may be the different (e.g. different virtual host) or the same for each distribution configuration. Only in the latter case do the values of *relativePath*need to be unique.   The 5GMSd AF configures a set of 5GMSd instances at M3d with Content Hosting Configurations that together completely provide the required set of logical content endpoints at reference point M4d.   * Depending on the value of the *distributionAffinity* property, each Content Hosting Configuration provided at reference point M3d may contain all distribution configurations provisioned at M1d or only one of them.   ***[[TS]] I am not sure why we need all of these details.***  [[JC]] In some cases, we want to ensure that content is available on different 5GMS AS physical hosts to provide resiliency to degraded service on any one of them. If I’m interpreting the *distributionAffinity* property definition correctly, this would signal the 5GMS AF to distribute distribution configurations across the 5GMS AS physical hosts correctly. There are also use cases where this isn’t necessary (e.g., multi-access using CMMF), so these distribution configurations could co-exist on a single physical host. |
| 1. Ability to configure the content preparation subfunction of the 5GMSd AS to make the intended content available from each provisioned logical content endpoint at reference point M4d. | Examples of content preparation that might be needed to support different multi-CDN Use Cases include:   * Repackaging ingested content (e.g. repackage from MPEG-DASH to CMAF). * Encoding content into multiple redundant objects/stripes (e.g. CMMF). * Embellishing or otherwise modifying the Media Entry Point document (e.g. MPEG-DASH MPD) ingested at reference point M2d before distributing it at reference point M4d. * Exposing a content steering service to 5GMSd Clients via reference point M4d?   ***[[TS]] You may also add multiple BaseURLs to Manifest/MPD***  Before provisioning the Content Hosting Configuration as above, the 5GMSd Application Provider first provisions a separate **Content Preparation Template** at reference point M1d for each distribution configuration specifying the unique content preparation requirements for logical media endpoint corresponding to that distribution.  The 5GMSd AF configures individual 5GMSd instances at M3d with appropriate Content Preparation Template(s). Content preparation may be **centralised** or **distributed** among multiple 5GMSd AS instances **at the discretion of the 5GMSd AF**. Content prepared in one 5GMSd AS instance may be conveyed to another 5GMSd AS instance via reference point **M10d** on a **hierarchical** or **peer-to-peer** basis **at the discretion of the 5GMSd AF**.  ***[[TS]] Why do we need this “instance” concept? For me this is unnecessarily confusing.***  [[JC]] We need some terminology to differentiate between physical locations. Otherwise, one might interpret things in a way that it is completely ok to deploy multiple distribution configurations to a single physical host (which would complete negate the purpose of doing “multi-CDN”). Furthermore, the term 5GMS AS instance already exists within the specifications so we are not creating it from scratch (e.g., it is used throughout 26.501).  The syntax and semantics of all Content Preparation Templates are opaque to the 5GMSd AF, but are understood by the 5GMSd AS. Different 5GMSd AS instances may support different types of Content Preparation Template, or different subsets of functionality that can be expressed in a given Content Preparation Template type. The Content Protocols Discovery API specified in clause 8.3 of TS 26.510 should be extended to allow a 5GMSd Application Provider to find out which types of Content Preparation Template (and which sub-features of each) are supported in a particular 5GMS System.  The following options for the format of the Content Preparation Template should be considered:  **Option A**  The Content Preparation Template follows a multipurpose file format specified outside the scope of 3GPP, e.g. MPEG-I Part 8 (Network-Based Media Processing) as specified in ISO/IEC 23090-8. The MIME content type of the Content Preparation Template is as specified in ISO/IEC 23090-8. The usage of this generic Content Preparation Template is profiled in 3GPP TS 26.511. The generic MIME content type is listed in clause 4.3.5.2 of TS 26.512 as valid for use with the 5GMS System along with a reference to the set of valid profiles specified in TS 26.511.  **Option B**  The Content Preparation Template follows file format specified outside the scope of 3GPP that is bespoke to the form of content preparation (e.g. a CMMF configuration file format specified in an annex to ETSI TS 103 973). The MIME type of the bespoke Content Preparation Template document format is also specified outside the scope of 3GPP, but is listed in clause 4.3.5.2 of TS 26.512 as valid for use with the 5GMS System along with a reference to the relevant external specification.  **Option C**  The Content Preparation Template follows file format specified by 3GPP that is bespoke to the form of content preparation (e.g. a CMMF configuration file format specified in an annex to 3GPP TS 26.511). The MIME type of the bespoke Content Preparation Template document format is also specified in 3GPP TS 26.511, and is also listed in clause 4.3.5.2 of TS 26.512 as valid for use with the 5GMS System along with a reference to TS 26.511. |
| 1. Ability to advertise the logical content endpoints available at reference point M4d to the 5GMSd Client. | Each distribution configuration in the Content Hosting Configuration is exposed as a different member of the *entryPoints* array in the *streamingAccess* object when the Service Access Information resource is retrieved by the Media Session Handler from the 5GMSd AF at reference point M5d. Clause 9.2.3.1 of TS 26.510 and clause 4.7.2.1 of TS 26.512 are modified to specify:   * The definition of the *locator* property is extended to allow URLs comprising bare paths (i.e., not a fully-qualified Media Entry Point document or media resource). * The value of the *contentType* property is copied verbatim from the distribution configuration and indicates the regular MIME content type (e.g. MPEG-DASH or HLS). * The value of the *protocol* property is copied verbatim from the distribution configuration and indicates additional encoding is applied to the content (e.g. CMMF). * An additional *relativeWeighting* property is copied verbatim from the distribution configuration.   To pass the information about the available logical content endpoint URLs to the Media Player in the 5GMSd Client, the media stream handling client API at reference point M6/M11 specified in clause 13 of TS 26.512 is extended:  **Option D**   * Additional input parameters to the ***attach()* method** in clause 13.2.3.3 listing the set of logical content endpoint URLs available at M4d along with their relative weightings.   **Option E**   * Additional object(s) in the **Configuration and settings API** in clause 13.2.4 listing the set of logical content endpoint URLs available at M4d along with their relative weightings.   In addition, the 3GPP Service URL for launching 5GMS is extended to add an endpoint-path query parameter (which may appear multiple times in the URL). The value of each such query parameter contains a relative weighting and (percent-encoded) URL duple, the two subfields being separated by a reserved delimiter character from the *sub-delims* production in RFC 3986 such as a comma or semicolon.  The above logical content endpoint paths are combined by the Media Player with the base URLs in the MPEG-DASH MPD supplied in the *attach()* method using a well-defined recipe. This allows retrieval of media resources from the different logical content endpoints available at reference point M4d. **Exact details of the well-defined recipe for combining URLs, and of Media Player operation with multiple logical content endpoints are outside the scope of 3GPP standardisation.** |

### 5.19.7 Summary and conclusions

## END OF CHANGES