DASH-IF Live Media Ingest Protocol

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#Specification: Live Media Ingest # {#IngestSpec}

Abstract

This document presents the DASH-IF Live Media Ingest Protocol Specification. Two protocol interfaces are defined. The first, interface 1, CMAF ingest, is based on fragmented MPEG-4 as defined in the common media application track format (CMAF). The second interface is based on MPEG DASH and HLS as defined by ISO SC29 WG 11 and IETF. Both Interfaces use the HTTP POST Method to transmit media objects from the ingest source to the receiving entity. Examples of live streaming workflows using these protocol interfaces are also presented. The protocol interfaces also support carriage of timed metadata and timed text. Guidelines for redundancy and failover are also included.

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1. Introduction (informative)§

The main goal of this specification is to define the interoperability point between an Ingest Source and a Receiving entity that typically reside in the cloud or the network. This specification does not impose any new constraints or requirements to clients that consume streams using any defined streaming protocol, with a preference for [MPEGDASH]

Live media ingest happens between an Ingest source, such as a Live encoder and a Receiving entity. Examples of such a Receiving entity could be a media packager, streaming origin or a Content Delivery Network. The combination of ingest sources and receiving entities is common in practical video streaming deployments. In such deployments, media processing functionality is distributed between the ingest source and receiving entities.

Nevertheless, in such deployments, interoperability between ingest sources and downstream processing entities can sometimes be challenging. This challenge comes from the fact that there are multiple levels of interoperability to be considered. This challenge also comes from the fact that each vendor has a different view of what is expected/preferred as well as how various technical specifications apply.

For example, the network protocol for transmission of data and the setup of the connectivity are important. This includes schemes for establishing the ingest connection, handling disconnects and failures, providing procedures for reliably sending and receiving the data, and timely resolution of hostnames.

A second level of interoperability lies with the media container and coded media formats. The Moving Picture Experts Group defines several media container formats such as [ISOBMFF] and [MPEG2TS] which are widely adopted and well supported. However, these are general purpose formats, targeting several different application areas. To do so, they provide many different profiles and options. Detailed interoperability is often achieved through other application standards such as those for broadcast, storage, or video on demand. For interoperable live media ingest, this document provides guidance on how to use [ISOBMFF] and [MPEGCMAF] for formatting the media content.

In addition, the codec and profile used, e.g. [MPEGHEVC] are important interoperability points that themselves also have different profiles and different configurations. This specification provides some guidance on how encoded media should be represented and transmitted.

A third level of interoperability, lies in the way metadata is inserted in streams. Live content often needs such metadata to signal opportunities for ad insertion, program information, or other attributes like timed graphics or general information relating to the broadcast. Examples of such metadata formats include [SCTE35] markers which are often found in broadcast streams and other metadata such as ID3 tags [ID3v2] containing information relating to the media presentation.

In fact, many more types of metadata relating to the live event might be ingested and passed on to an over-the-top (OTT) streaming workflow.

Fourth, for live media, handling the timeline of the presentation consistently is important. This includes sampling of the media, avoiding timeline discontinuities and synchronizing timestamps attached by different ingest sources such as audio and video. In addition, media timeline discontinuities must be avoided as much as possible during normal operation. Further, when using redundant ingest sources, the ingested streams must be accurately synchronized in a sample accurate manner. Last, streams may need to be started at the same time so as to avoid misalignment between audio and video tracks.

Fifth, in streaming workflows it is important to have support for failovers of both the ingest sources and Receiving entities. This is important to avoid interruptions of 24/7 live services such as Internet television where components may fail occasionally.

In practical deployments, multiple ingest sources and Receiving entities are often used. This requires that multiple ingest sources and receiving processing entities work together in a redundant workflow where some of the components might fail. Well defined failover behavior will help interoperability.

This document provides a specification for establishing these interoperability points. The approaches are based on known standardized technologies that have been tested and deployed in several large-scale streaming deployments.

To address this interoperability point, two key interfaces and their protocol specification have been identified. The first, CMAF Ingest, mainly functions as an ingest format to a packager or active media processor, while the second works mainly to ingest media streaming presentations to origin servers, cloud storage or Content Deliery Networks.

The section on interfaces and profiles provides more background and motivation around these two interfaces that both use HTTP POST.

We further motivate the specification in this document supporting HTTP/1.1 [RFC7235] and [ISOBMFF]. We believe that Smooth streaming MS-SSTR and HLS [RFC8216] have shown that HTTP usage can survive the Internet ecosystem for media delivery. In addition, HTTP-based ingest fits well with current HTTP based streaming protocols including [MPEGDASH]. In addition, there is good support for HTTP middle-boxes and HTTP routing available making it easy to debug and trace errors. The HTTP POST provides a push-based method for delivering the live content when it becomes available.

Regarding the transport protocol, in future versions, alternative transport protocols could be considered advancing over HTTP/1.1 or TCP. We believe the proposed media format and protocol interfaces will provide the same benefits with other transport protocols. Our view is that for current and near future deployments, using [RFC7235] is still a good approach.

The document is structured as follows, section 3 presents the conventions and terminology used throughout this document. Section 4 presents use cases and workflows related to media ingest and the two profiles/interfaces presented. Sections 5-9 will detail the two different protocol interfaces defined.

2. Conventions and Terminology§

The following terminology is used in the rest of this document.

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14, RFC 2119 [RFC2119].

ABR : Adaptive Bit-Rate

CMAF Header : CMAF track header defined in [MPEGCMAF] clause 7.3.2.1

CMAF Media object : CMAF media object defined in [MPEGCMAF], a cmaf chunk, segment, fragment or track

CMAF fragment : CMAF fragment defined in [MPEGCMAF] clause 7.3.2.4

CMAF chunk : CMAF chunk defined in [MPEGCMAF] clause 7.3.2.3

CMAF Presentation logical grouping of CMAF tracks corresponding to a media presentation as defined in [MPEGCMAF] clause 6

CMAFstream : byte-stream that follows the CMAF track format structure format defined in [MPEGCMAF] between ingest source and receiving entity. Due to error control behavior such as retransmission of CMAF fragments and Headers a cmaf stream may not fully conforming CMAF track file. The receiving entity can filter out retransmitted fragments and headers and restore a valid CMAF track file from the cmaf stream.

CMAF Track CMAF Track defined in [MPEGCMAF] clause 7.3.2.2

CMAF Ingest: Ingest interface defined in this specification for push based [MPEGCMAF]

Connection: A connection setup between two hosts, typically the media Ingest source and Receiving entity.

DASH Ingest: Ingest interface defined in this specification for push based [MPEGDASH]

HLS Ingest: Ingest interface defined in this specification for push based [RFC8216]

HTTP POST : Command used in the Hyper Text Transfer Protocol for sending data from a source to a destination [RFC7235]

Ingest source: A media source ingesting live media content to a receiving entity , it is typically a live encoder but not restricted to this, e.g. it could be a stored media resource.

Ingest Stream: The stream of media pushed from the ingest source to the Receiving entity

ISOBMFF:

the ISO Base Media File Format specified in [ISOBMFF]

Live stream session: The total live stream for the ingest relating to a broadcast event.

Live encoder: Entity performing live encoding of a high quality Ingest stream, can serve as ingest source

Manifest objects Objects ingested that represent streaming manifest e.g. .mpd in MPEG DASH, .m3u8 in HLS

Media objects Objects ingested that represent the media, and or timed text, or other non manifest objects, typically these are CMAF addressable media objects such as CMAF chunks, fragments or segments.

Media fragment Media fragment, combination of "moof" and "mdat" in ISOBMFF structure (MovieFragmentBox and mediaDataBox), could be a CMAF fragment or chunk. A media fragment may include top level boxes defined in CMAF fragments such as emsg, prft and styp. Used for backward compatibility with fragmented mp4

Objects [=Manifest objects] or Media objects

Publishing point: Entry point used to receive an ingest stream, consumes/receives the incoming media ingest stream, typically via a publishing URL setup to receive the stream

POST_URL : Target URL of a POST command in the HTTP protocol for posting data from a source to a destination. The POST_URL is known by both the ingest source and receiving entity. The POST_URL basepath is setup by the receiving entity. The ingest source may add extended paths to signal track names, fragment names or segment names.

Receiving entity: Entity used to receive the media content, receives/consumes an [=Ingest stream].

Streaming presentation set of Objects composing a Streaming presentation based on a streaming protocol such as for example [MPEGDASH]

Switching set: Group of tracks corresponding to a switching set defined in [MPEGCMAF] or an adaptation-set in [MPEGDASH]

Switching Set ID Identifier generated by a live ingest source to group CMAF tracks in a switchingset. The Switching Set ID is unique for each switchingset in a live streaming session.

TCP: Transmission Control Protocol (TCP) as defined in [RFC793]

RTP : Real Time Protocol

OTT : Over the top transmission, i.e. HTTP based video streaming

moof: The MovieFragmentBox "moof" box as defined in the ISOBMFF base media file format [ISOBMFF] that defines the index information of samples in a fragment.

ftyp: The FileTypeBox "ftyp" box as defined in the ISOBMFF [ISOBMFF]

mdat : The mediaDataBox "mdat" box defined in ISOBMFF [ISOBMFF].

mfra: The movieFragmentRandomAccessBox "mfra" box defined in the ISOBMFF [ISOBMFF] to signal random access samples (these are samples that require no prior or other samples for decoding) [ISOBMFF].

tfdt : The TrackFragmentBaseMediaDecodeTimeBox box "tfdt" defined in [ISOBMFF] used to signal the decode time of the media fragment signalled in the moof box.

basemediadecodetime : Decode time of first sample as signalled in the tfdt box

mdhd : The MediaHeaderBox "mdhd" as defined in [ISOBMFF], this box contains information about the media such as timescale, duration, language using ISO 639-2/T [iso-639-2] codes [ISOBMFF]

elng : Extended language tag box "elng" defined in [ISOBMFF] that can override the language information

nmhd : The nullMediaHeaderBox "nmhd" as defined in [ISOBMFF] to signal a track for which no specific media header is defined, used for metadata tracks

3. Media Ingest Workflows and Interfaces (informative)§

Two workflows have been identified mapping to the two protocol interfaces.

The first workflow uses a separate live encoder as Ingest source and packager as Receiving entity. In this case, interface 1, [MPEGCMAF] (CMAF) Ingest may be used. This interface uses [MPEGCMAF] to ingest a live encoded stream to the packager. The Receiving entity in this case may do the packaging, encryption, or other active media processing. This interface is defined in a way that it will be possible to generate streaming presentation based on [MPEGDASH] or HLS [RFC8216] based on information in the ingested stream.

The second workflow, constitutes ingest to a passive delivery system such as a cloud storage or a Content Deliery Network. In this case the stream needs to be formatted as closely as possible to the final stream for consumption by an end client. This interface is defined in the second part, interface 2 DASH Ingest or HLS Ingest. It enables a HTTP POST based version of these commonly used streaming protocols. In this case, besides the media objects, also manifest objects are ingested by the Receiving entity.

Figure 1: Example with CMAF Ingest

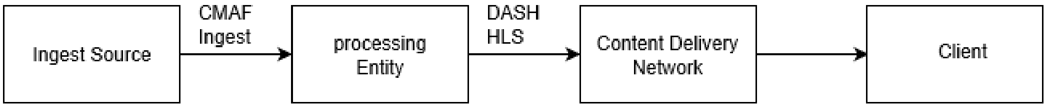


Figure 2: Example with DASH Ingest

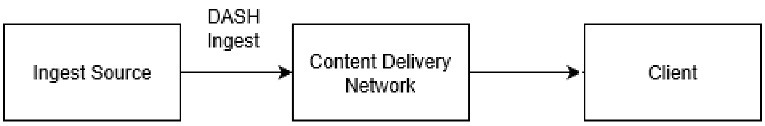


Figure 1 shows an example workflow with live media ingest from an ingest source towards a Receiving entity. In the example, the Receiving entity prepares the final media presentation for the client . The Receiving entity could be a live packager for DASH or HLS streams. The segments of the stream may be requested via a CDN that acts as an intermediate proxy.

Figure 2 shows an example in workflow where content is ingested directly by a Content Delivery Network. The Content Delivery Network enables the delivery to the client, but does not generate the manifests.

A legacy example of a media ingest protocol for the first workflow is the ingest part of the Microsoft Smooth

Streaming protocol MS-SSTR. This protocol connects live encoders/ingest sources to the Microsoft Smooth Streaming server and to the Microsoft Azure cloud. This protocol has shown to be robust, flexible and easy to implement in live encoders. In addition, it provided features for high availability and server side redundancy.

The DASH-IF CMAF Ingest protocol, interface 1, defined in Section 5, advances over the Smooth ingest protocol including lessons learned over the last ten years after the initial deployment of Smooth Streaming in 2009 and several advances on signaling metadata and timed text.

In addition, the current specification incorporates the latest media formats and protocols, making it ready for current and next generation media codecs such as [MPEGHEVC] and protocols like MPEG-DASH [MPEGDASH].

The second interface referred as DASH and HLS ingest is included for ingest of media streaming presentations to entities where the media is not altered actively (the second workflow).

A key idea of this part of the specification is to re-use the similarities of MPEG-DASH [MPEGDASH] and HLS [RFC 8216] protocols to enable a simultaneous ingest of media presentations of these two formats using common media fragments such as based on [ISOBMFF] and [MPEGCMAF] formats. In this interface, naming and content type identification via MIME types is important to enable direct processing and storage of the presentation.

The two interfaces are presented separately. This reduces the overhead of the information that needs to be signalled compared to having both interfaces combined into one, as was the case in a draft version of this document. Nevertheless, some instantiations, may still consider combining the two interfaces. An example of this is given at the end of the document in the examples section.

Table 1 highlights some of the key differences and practical considerations of the interfaces. In CMAF Ingest Interface 1, the ingest source can be simple as the Receiving entity can do many of the operations related to the delivery such as encryption or generating the streaming manifests. In addition, the distribution of functionalities can make it easier to scale a deployment with many live media sources and Receiving entities.

In some cases, an encoder has sufficient capabilities to prepare the final presentation for the client. In that case, content can be ingested directly by a more passive Receiving entity that provides a pass-through functionality. In this case also Manifest objects and other client-specific information needs to be ingested. Besides these factors, choosing a workflow for a video streaming platform depends on many other factors. Note that interface 2 could also be used as an output format of a packager.

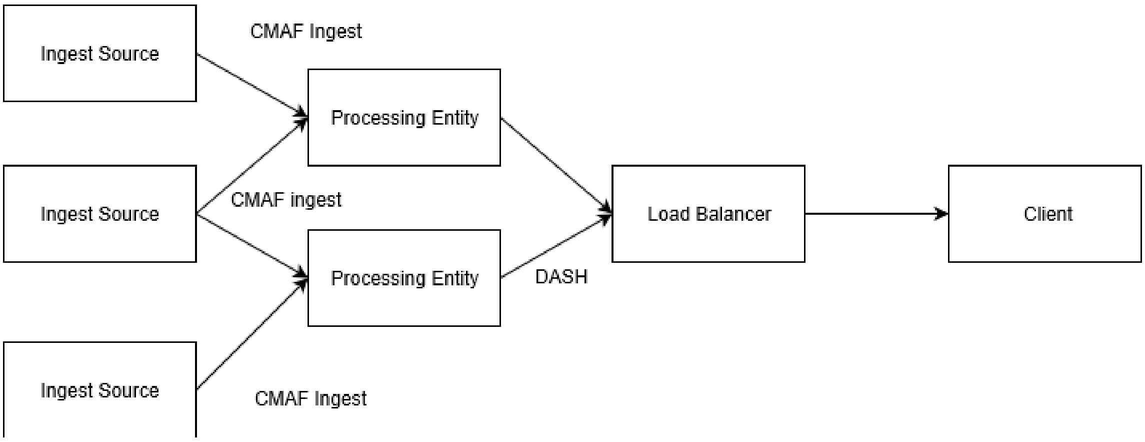
This specification does not provide guidance on which workflow is best to use in a given scenario. However, the live ingest specification covers the two interfaces most suitable for workflow ingest.

The best choice for a specific platform depends on many of the use case specific requirements, circumstances and the available technologies.

Table 1: different ingest use cases

Profile	*Ingest source*	*Receiving Entity*
CMAF Ingest	Limited overview, simpler encoder, multiple sources	re-encryption, transcoding, stitching, watermarking, packaging
DASH/HLS Ingest	Global overview, targets duplicate presentations, limited flexibility no redundancy	manifest manipulation, transmission, storage

Figure 3: workflow with redundant Ingest sources and receiving entities



Finally, Figure 3 highlights another aspect that was taken into consideration for large scale systems with many users. Often content owners would like to run multiple ingest sources, multiple receiving entities and make them available to the clients in a seamless fashion. This approach is already common when serving web pages, and this architecture also applies to video streaming over HTTP. In Figure 3 it is highlighted how one or more Ingest Sources can be sending data to one or more receiving entities. In such a workflow it is important to handle the case when one ingest source or Receiving entity fails. Both the system and client behavior is an important consideration in practical video streaming systems that need to run 24/7 such as Internet Television. Failovers must be handled robustly and without causing service interruption. This specification details how this failover and redundancy support can be achieved.

4. General Ingest Protocol Behavior§

The media ingest follows the following general requirements for both targetted interfaces. The ingest interface uses existing media formats in combination with the HTTP POST method.

1. The Ingest source SHALL communicate using the HTTP POST method as defined in the HTTP protocol, version 1.1 [RFC7235]
2. The Ingest source SHOULD use HTTP over TLS, if TLS is used it SHALL support atleast TLS version 1.2, higher version may also be supported additionally [RFC2818]
3. The Ingest source SHOULD us a domain name system for resolving hostnames to IP addresses such as DNS [RFC1035] or any other system that is in place. If this is not the case, the domain names the IP adress mapping must be known and static, such as configured in the operating system.
4. In the case of 3, Ingest source MUST update the IP to hostname resolution respecting the TTL (time to live) from DNS query responses. This will enable better resilience to changes of the IP address in large scale deployments where the IP address of the media processing entities may change frequently.
5. In case HTTP over TLS [RFC2818] is used, at least one of basic authentication HTTP AUTH [RFC7617], TLS client certificates, and HTTP Digest authentication [RFC7616] MUST be supported.
6. Mutual authentication SHALL be supported. TLS Client certificates SHALL chain to a trusted CA, or be self signed. Self signed certificates MAY be used, for example, when the ingest source and receiving entity fall under common administration.
7. As compatibility profile for the TLS encryption the ingest source SHOULD support the Mozilla intermediate compatibility profile MozillaTLS.
8. In case of an authentication error confirmed by an HTTP 403 response, the ingest source SHALL retry to establish the Connection within a fixed time period with updated authentication credentials. When that also results in error the ingest source can retry N times, after this the ingest source SHOULD stop and log an error. The number of retries N MAY be configurable in the Ingest Source.
9. The Ingest source SHOULD terminate the HTTP POST request if data is not being sent at a rate commensurate with the MP4 fragment duration. An HTTP POST request that does not send data can prevent the Receiving entity from quickly disconnecting from the ingest source in the event of a service update.

10. The HTTP POST for sparse data SHOULD be short-lived, terminating as soon as the data of a fragment is sent.
11. The POST request uses a POST_URL to the basepath of the publishing point at the Receiving entity and SHOULD use an additional relative path when posting different streams and fragments, for example, to signal the stream or fragment name.
12. Both the Ingest source and Receiving entity MUST support IPv4 and IPv6 transport.
13. The Ingest source SHOULD use a timeout in order of segment duration (1-6 seconds) for establishing the TCP connection. If an attempt to establish the connection takes longer than the timeout, abort the operation and try again.
14. The Ingest source SHOULD resend Objects for which a connection was terminated early, or when an error response was received such as HTTP 400 or 403 if the connection was down for less than 3 average segments durations. For connections that were down longer, ingest source can resume sending Objects at the live edge of the live media presentation instead.
15. The Ingest source MAY limit N, the number of retries, to establish a new connection or resume streaming after a TCP error occurs. This number N MAY be configurable.
16. After a TCP error, the Ingest source should perform the following: a. The current connection MUST be closed, and a new connection MUST be created for a new HTTP POST request. b. The new HTTP POST URL MUST be the same as the initial POST URL for the object to be ingested.
17. In case the Receiving entity cannot process the POST request due to authentication or permission problems, or incorrect path, then it SHALL return a permission denied HTTP 403 with error reason
18. In case the Receiving entity can process the fragment in the POST request body but finds the media type cannot be supported it MAY return an HTTP 415 unsupported media type, otherwise 400 bad request MUST be returned.
19. In case an unknown error happened during the processing of the HTTP POST request a HTTP 400 Bad request SHALL be returned by the Receiving entity
20. In case the receiving entity cannot process a fragment posted due to missing or incorrect init fragment, an HTTP 412 unfulfilled condition MAY be returned, otherwise, in case this is not supported by the system, a HTTP 400 bad request response MUST be returned.
21. The Receiving entity MAY return 50x HTTP response in case of other errors at the server, not particularly relating to the request from the Ingest Source, but due to an error at the receiving entity.
22. In case the receiving entity or publishing point receiving the HTTP POST body is not setup or available an HTTP 404 not found SHOULD be returned to the ingest source.
23. The ingest source SHOULD support the handling of 30x redirect responses.
24. The ingest source and receiving entity SHOULD support gzip based content encoding

5. Ingest Interface 1: CMAF Ingest Protocol Behavior§

This section describes the protocol behavior specific to interface 1: CMAF Ingest. Operation of this profile MUST also adhere to the general requirements specified in Section 4 § 4 General Ingest Protocol Behavior.

5.1. CMAF Ingest General Considerations (informative)§

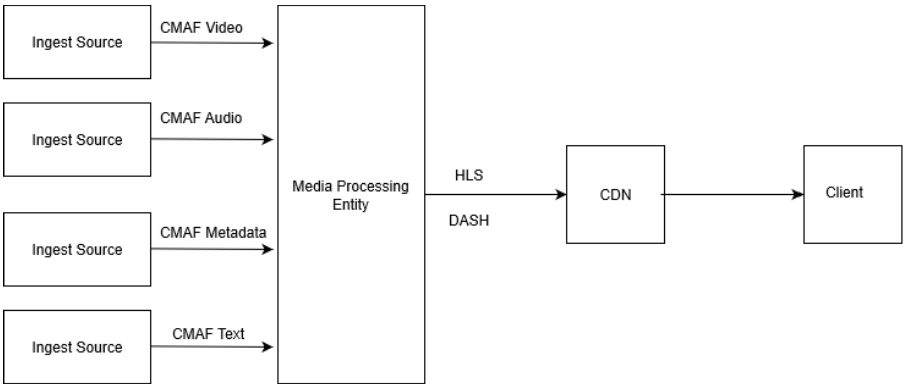
The media format is based on CMAF, conforming to track constraints as specified in [MPEGCMAF] clause 7. A key benefit of this format is that it allows easy identification of stream boundaries, enabling switching, redundancy, re-transmission resulting in a good fit with current Internet infrastructures. We believe that the CMAF track format will make things easier and that the industry is already heading in this direction following recent specifications like [MPEGCMAF] and HLS [RFC8216].

CMAF Ingest assumes ingest to an active Receiving entity, such as a packager or active origin server. However, it can also be used for simple transport of media to an archive, as the combination of CMAF header and CMAF fragments will result in a valid archived CMAF track file when an ingest is stored on disk by a receiving entity.

CMAF Ingest advances over the ingest part of the Smooth ingest protocol MS-SSTR by only using standardized media container formats and boxes based on [ISOBMFF] and [MPEGCMAF].

Many new techologies like MPEG HEVC, AV1, HDR have CMAF bindings. Using CMAF will make it easier to adopt such technogies. This project started as multi vendor interop project, some discussions on the early development of the specification have been documentedin fmp4git.

Figure 4: CMAF ingest with multiple ingest sources



Figures 5-7 detail some of the concepts and structures defined in [MPEGCMAF]. Figure 5 shows the data format structure of the CMAF Track. In this format media samples and media indexes are interleaved. The MovieFragmentBox moof box as specified in [ISOBMFF] is used to signal the information to playback and decode properties of the samples stored in the mdat box. The CMAF Header contains the track specific information and is referred to as a CMAF Header in [MPEGCMAF]. The combination of moof mdat can be referred as a CMAF fragment or CMAF chunk depending on the structure content and the number of moof mdat structures in the addressable object.

Figure 5: CMAF Track stream:

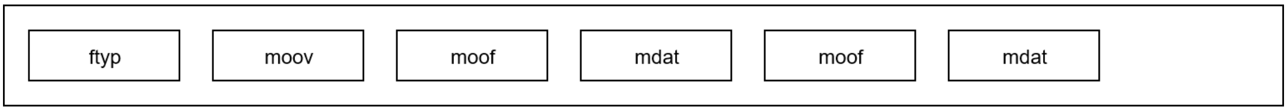


Figure 6 illustrates the presentation timing model, defined in [MPEGCMAF] clause 6.6. Different bit-rate tracks and/or media streams are conveyed in separate CMAF tracks. By having fragment boundaries time aligned for tracks and applying constraints on tracks, seamless switching can be achieved. By using a common timeline different streams can be synchronized at the receiver, while they are in a separate CMAF Track, send over a separate connection, possibly from a different Ingest source.

For more information on the synchronization model we refer to section 6 of [MPEGCMAF]. For synchronization of tracks coming from different encoders, sample time accuracy is required. i.e. samples with identical timestamp contain identical content.

In Figure 7 another advantage of this synchronization model is illustrated, i.e. the concept of late binding. In the case of late binding, streams are combined on playout/streaming in a presentation (see [MPEGCMAF] 7.3.6).

Note that it is important, as defined in MPEG CMAF, that different CMAF Tracks have the same starting time sharing an implicit timeline. A stream becoming available from a different source needs to be synchronized and time-aligned with other streams.

Figure 6: CMAF Track synchronization:

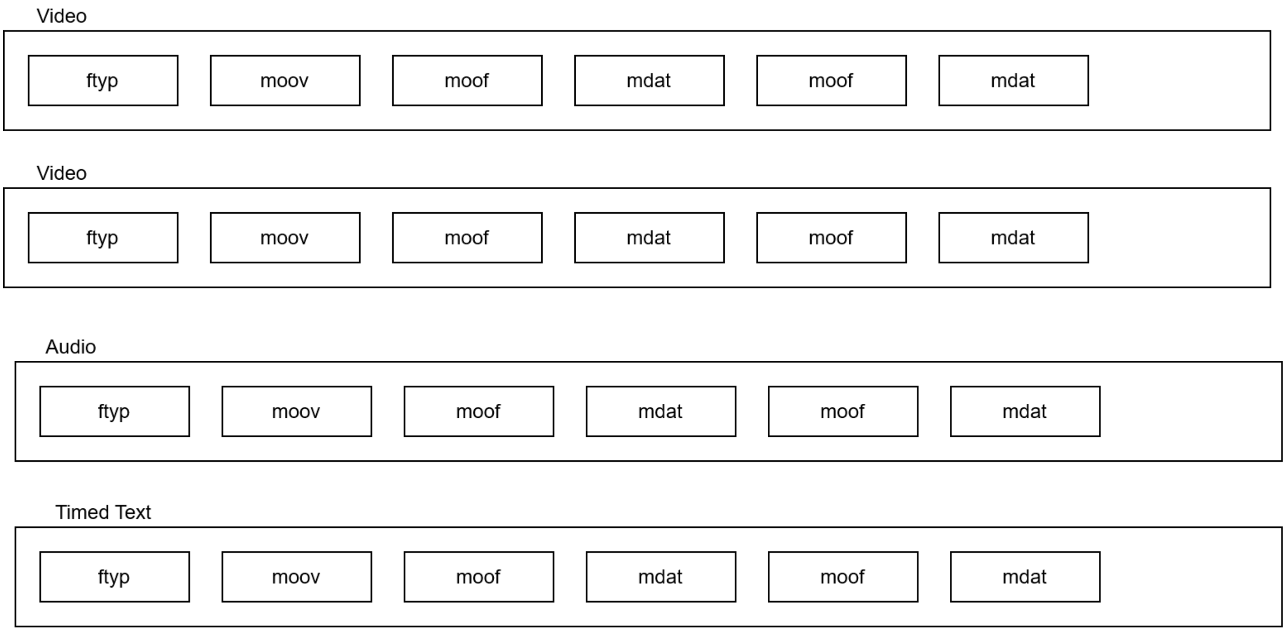


Diagram 7: CMAF late binding:

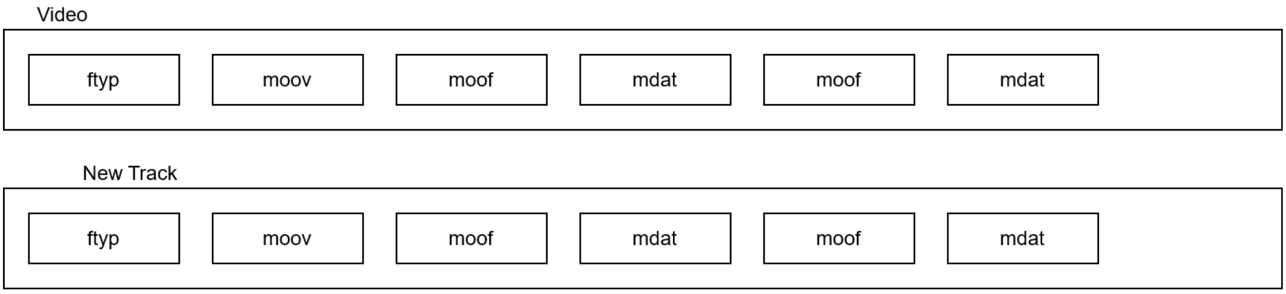


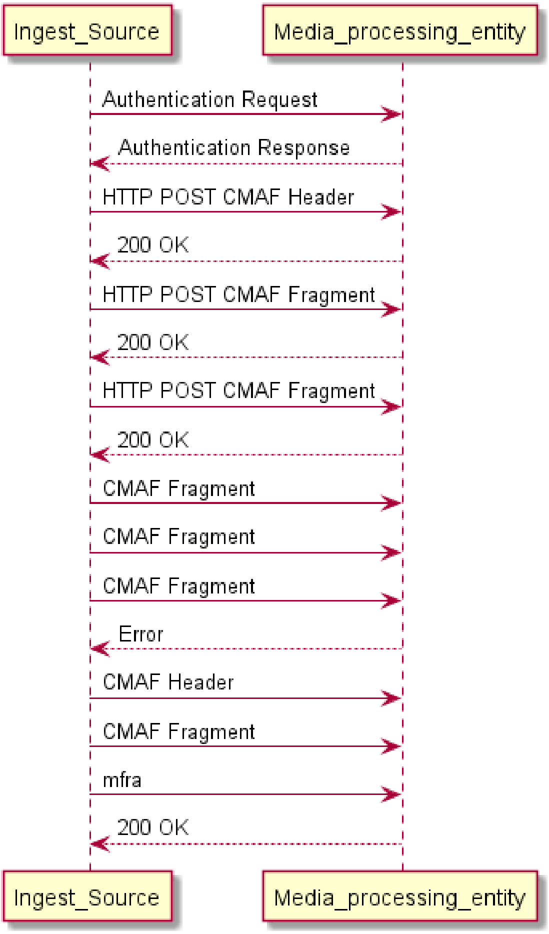
Figure 8 shows the sequence Figure of the protocol. It starts with a DNS resolution (if needed) and an authentication step (using Authy, or TLS certificates or HTTP Digest Authentication) to establish a secure TCP connection.

In some private datacenter deployments where nodes are not reachable from outside, a non authenticated connection may also be used. The ingest source then issues a POST to test that the Receiving entity is listening. This POST sends the CMAF Header or could be empty. In case this is successful this is followed by a CMAF Header and the fragments comprising the CMAFstream. At the end of the session, for tear down the source may send an empty mfra box to close the connection and Publishing point.

This is then followed with a zero length chunk, allowing the receiver to send a response, the encoder can follow up by closing the TCP connection using a FIN command as defined in HTTP RFC7235.

This last step is especially important in long runing posts using chunked transfer encoding, as in this case the receiver may not know that the connection needs to be closed or that the HTTP POST command is over. Note that CMAF ingest may use either long running or short running post commands.

Figure 8: CMAF ingest flow



5.2. General Protocol and Track Format Requirements§

The ingest source transmits media content to the receiving entity using HTTP POST or HTTP PUT. The receiving entity listens for content on a POST_URL that is known by both the ingest source and receiving entity. The POST_URL may contain a basepath corresponding to a domain name and a relative path, as setup by the receiving entity and a domain name system. An extended path to identify the stream name, switching set or fragment may be added by the ingest source. It is assumed that the ingest source can retrieve these paths and und use them. The POST_URL setup by a receiving entity can be referred to as a Publishing point and is used during a live stream session to receive the live content.

1. The Ingest source SHALL start by sending an HTTP POST request with the CMAF Header, or an empty request, to the POST_URL. This can help the ingest source to quickly detect whether the publishing point is valid, and if there are any authentication or other conditions required.
2. The Ingest source MUST initiate a media ingest connection by posting at least one CMAF header after step 1
3. The Ingest source SHALL transmit the one or more CMAF fragments comprising the track to the Receiving Entity once they become available. In this case, a single POST request message body MUST contain at least one or more CMAF fragments in the body of that request.
4. The Ingest source SHOULD use the chunked transfer encoding option of the HTTP POST command [RFC7235] when the content length is unknown at the start of transmission or to support use cases that require low latency.
5. If the HTTP POST request terminates or times out with a TCP error, the Ingest source MUST establish a new connection, and follow the preceding requirements. Additionally, the Ingest source MAY resend the fragment in which the timeout or TCP error occurred.
6. The Ingest source MUST handle any error responses received from the Receiving entity, as described in general requirements, and by retransmitting the CMAF Header.
7. In case the Live stream session is over the ingest source MAY signal the stop by transmitting an empty mfra box towards the Receiving entity. After that it SHALL send an empty HTTP chunk, Wait for the HTTP response

before closing TCP session RFC7235 when this response is received.

8. The Ingest source SHOULD use a separate, parallel TCP connection for ingest of each different CMAF track
9. The Ingest source MAY use a separate relative path in the POST_URL for ingesting each different track or track segment by appending it to the POST_URL. This can make it easy to detect redundant streams from different ingest sources. The Streams(stream_name) keyword may be used to signal the name of a stream.
10. The baseMediaDecodeTime timestamps basemediadecodetime in tfdt of fragments in the CMAFstream SHOULD arrive in increasing order for each of the fragments in the different tracks/streams that are ingested.
11. The fragment sequence numbers in the CMAFstream signalled in the mfhd SHOULD arrive in increasing order for each of the different tracks/streams that are ingested. Using both timestamp baseMediaDecodeTime and sequence number based indexing will help the Receiving entities identify discontinuities. In this case sequence numbers SHOULD increase by one.
12. The average and maximum bitrate of each track SHOULD be signalled in the "btrt" box in the sample entry of the CMAF header. These can be used to signal the bit-rate later on, such as in the manifest.
13. In case a track is part of a Switching set, all properties section 6.4 and 7.3.4 of [MPEGCMAF] MUST be satisfied, enabling the receiver to group the tracks in the respective switching sets.
14. Ingested tracks MUST conform to CMAF track structure defined in [MPEGCMAF]. Additional constraints on the CMAF track structure are defined in later sections.
15. CMAF Tracks MAY use segmentTypeBox to signal CMAF Media object brands like chunk, fragment, segment. Such signalling may also be inserted in a later stage by the receiving entity. A smart receiving entity can detect what type of media object is received from the information in the MovieFragmentBox.

> Note, in case a Receiving entity cannot process a request from an ingest source correctly, it can send a HTTP error code. Please see the section for the usage of these codes in Failover and error handling] or in general.

5.3. Requirements for Formatting Media Tracks§

[MPEGCMAF] has the notion of CMAF Track which are composed of CMAF fragment and CMAF chunks. A fragment can be composed of one or more chunks. The Media fragment defined in ISOBMFF predates the definition in CMAF. It is assumed that the ingest source uses HTTP POST to transmit a CMAF fragments to the receiving entity. The following are additional requirements imposed to the formatting of CMAF media tracks.

1. Media tracks SHALL be formatted using boxes according to section 7 of [MPEGCMAF]. Boxes defined in section 7.4. which dictate boxes that are not compliant to [ISOBMFF] relating to encryption and DRM systems are not supported. Common encryption is not supported.
2. The CMAF fragment durations SHOULD be constant, the duration MAY fluctuate to compensate for non-integer frame rates. By choosing an appropriate timescale (a multiple of the frame rate is recommended) this issue should be avoided.
3. The CMAF fragment durations SHOULD be between approximately 1 and 6 seconds.
4. Media Tracks SHOULD use a timescale for video streams based on the framerate and 44.1 KHz or 48 KHz for audio streams or any another timescale that enables integer increments of the decode times of fragments signalled in the "tfdt" box based on this scale. If necessary, integer multiples of these timescales could be used.
5. The language of the CMAF Track SHOULD be signalled in the mdhd box or elng boxes in the CMAF Header
6. Media tracks SHOULD contain the bitrate btrt box specifying the target average and maximum bitrate of the CMAF fragments in the sample entry container in the CMAF Header.
7. Media tracks MAY comprise CMAF chunks [MPEGCMAF] 7.3.2.3. , in this case they SHOULD be signalled using SegmentTypeBox styp to make it easy for the Receiving Entity to differentiate them from CMAF fragments. The brand type of a chunk is cmfl. CMAF chunks should only be signalled if they are not co-inciding with the start of a CMAF fragment.

8. In Video tracks, profiles like avc1 and hvc1 SHOULD be used that signal the sequence parameter set in the CMAF Header. In this case these codec parameters do not change dynamically during the live session in the media track.
9. Alternatively, video tracks MAY use profiles like avc3 or hev1 that signal the parameter sets (PPS, SPS, VPS) in in the media samples. This allows inband signalling of parameter changes.
10. In case the language of a track changes, a new CMAF Header with updated mdhd and or elng SHOULD be send. The CMAF Header MUST be identical, except the elng tag.
11. Track roles SHOULD be signalled in the ingest by using a kind box in userData udta box. The kind box MUST contain a schemeIdUri urn:mpeg:dash:role:2011 and a value containing a Role as defined in [MPEGDASH]. In case this signalling does not occur processing entity can define the role for the track independently.

5.4. Requirements for Signalling Switching Sets§

In live streaming a CMAF presentation of streams corresponding to a channel is ingested by posting to a Publishing point at the Receiving entity. CMAF has the notion of Switching Sets [MPEGCMAF] that map to similar streaming protocol concepts like Adaptation Set in [MPEGDASH]. To signal a switching set in a CMAF Presentation, CMAF media tracks MUST correspond to the constraints defined in [MPEGCMAF] clause 7.3.4 .

In addition, optional explicit signalling are defined in this clause. This would mean the following steps could be implemented by the Live ingest source.

1. A Live ingest source MAY generate a Switching Set ID that is unique for each switching set in a live streaming session. Tracks with the same Switching Set ID belong to the same switching set. The switching set ID can be a string or (small) integer number. Characters in switching set shall be unreserved i.e. A-Za-z0-9_.-~ in order to avoid introducing delimiters.
2. The Switching Set ID MAY be added in a relative path to the POST_URL using the Switching() keyword. In this case, a CMAF chunk is send from the live ingest source as POST chunk.cmfv POST_URL/Switching(Switching Set ID)/Streams(stream_id).
3. The live ingest source MAY add a kind box in the udta box in each track to signal the switching set it belongs to. The schemeIdUri of this kind box SHALL be urn:dashif:ingest:switchingset_id and the value field of the kind box SHALL be the Switching Set ID.

Table 2: Switching set signalling options

Signalling option	*Requirement*
Implicit signalling, based on Switchingset constraints [MPEGCMAF] clause 7.3.4	Mandatory
Signalling using Switching Set ID in post URI path using Switching() keyword and	Optional
Signalling using Switching Set ID in the track using kind box with schemeIdUri urn:dashif:ingest:switchingset_id and value set to Switching Set ID	Optional

5.5. Requirements for Timed Text, Captions and Subtitle Tracks§

The live media ingest specification follows requirements for ingesting a track with timed text, captions and/or subtitle streams. The recommendations for formatting subtitle and timed text tracks are defined in [MPEGCMAF] and [MPEG4-30].

We provide a few additional guidelines and best practices for formatting timed text and subtitle tracks.

1. CMAF Tracks carrying WebVTT signalled by cwvt brand or TTML Text signalled by *im1t* brand are preferred. [MPEG4-30] defines the track format selected in [MPEGCMAF]
2. Based on this [ISOBMFF], the trackhandler "hdlr" SHALL be set to "text" for WebVTT and "subt" for TTML following [MPEG4-30]
3. The ftyp box in the CMAF Header for the track containing timed text, images, captions and sub-titles MAY use signalling using CMAF profiles based on [MPEGCMAF]

   3a. WebVTT Specified in 11.2 ISO/IEC 14496-30 [MPEG4-30] *cwvt*

   3b.TTML IMSC1 Text Specified in 11.3.3 [MPEG4-30] IMSC1 Text Profile *im1t*

   3c.TTML IMSC1 Image Specified in 11.3.4 [MPEG4-30] IMSC1 Image Profile *im1i*
4. The BitRateBox btrt SHOULD be used to signal the average and maximum bitrate in the sample entry box, this is most relevant for bitmap or xml based timed text subtitles that may consume significant bandwidths (e.g. im1i im1t)
5. In case the language of a track changes, a new CMAF Header with updated mdhd and/or elng SHOULD be send from the ingest source to the Receiving entity.
6. Track roles can be signalled in the ingest, by using a kind box in udta box. The kind box MUST contain a schemeIdUri MPEG urn:mpeg:dash:role:2011 and a value containing a Role as defined in [MPEGDASH]

Note: [MPEGCMAF] allows multiple kind boxes, hence multiple roles can be signalled. By default one should signal the DASH role urn:mpeg:dash:role:2011. A receiver may derive corresponding configuration for other streaming protocols such as HLS [RFC8216]. In case this is not desired, additional kind boxes with corresponding schemeIdUri and values can be used to explicitly signal this information for other protocol schemes is allowed. Subschemes can be signalled in the schemeIdURI as schemeIdURI@value.

An informative scheme of defined roles in MPEG DASH and respective corresponding roles in HLS [RFC8216] can be found below, additionally the forced subtitle in HLS might be derived from a DASH forced subtitle role aswell by a Receiving Entity

Table 3: Roles for subtitle and Audio tracks and HLS Characteristics

Characteristic [RFC8216]	*urn:mpeg:dash:role:2011*
transcribes-spoken-dialog	subtitle
easy-to-read	easyreader
describes-video	describtion
describes-music-and-sound	caption

MPEG DASH roles are defined in urn:mpeg:dash:role:2011 [MPEGDASH]. Additionally, another example for explicitly signalling roles could be DVB DASH [DVB-DASH]. One could use schemeiduri@value and role as defined there. e.g. `kind.schemeIdUri="urn:tva:metadata:cs:AudioPurposeCS:2007@1" kind.value="Alternate"`.

5.6. Requirements for Timed Metadata Tracks§

This section discusses the specific formatting requirements for CMAF Ingest of timed metadata. Examples of timed metadata are opportunities for splice points and program information signalled by SCTE-35 markers. Such event signalling is different from regular audio/video information because of its sparse nature. In this case, the signalling data usually does not happen continuously, and the intervals may be hard to predict.

Other examples of timed metadata are ID3 tags [ID3v2], SCTE-35 markers [SCTE35] and

DASHEventMessageBoxes defined in section 5.10.3.3 of [MPEGDASH].

Table 4 provides some example urn schemes to be signalled Table 5 illustrates an example of a SCTE-35 marker stored in a DASHEventMessageBox, that is in turn stored as a metadata sample in a metadata track.

The presented approach enables ingest of timed metadata from different sources, because data are not interleaved with the media.

By using CMAF timed metadata tack, the same track and presentation formatting are applied for metadata as for other tracks ingested, and the metadata is part of the CMAF Presentation.

By embedding the DashEventMessageBox structure in timed metadata samples some of the benefits of its usages in DASH and CMAF are kept. In addition it enables signalling of gaps, overlapping events and multiple events starting at the same time in a single timed metadata track for this scheme. In addition, the parsing and processing of DashEventMessageBoxes is supported in many players. The support for this DashEventMessageBox embedded timed metadata track instantiation is described in clause 9.

Table 4 illustrates some example URN schemes to be carried in timed metadata tracks. Table 5 illustrates examples of metadata embedded in a DASHEventMessageBox.

An example of adding an id3 tag in a DashEventMessageBox can be found in aomid3

Table 4: Example URN schemes for timed metadata tracks

SchemeIdURI	*Reference*
urn:mpeg:dash:event:2012	[MPEGDASH], 5.10.4 subtitle
urn:dvb:iptv:cpm:2014	[DVB-DASH], 9.1.2.1
urn:scte:scte35:2013:bin	[SCTE214-1]] SCTE-35
www.nielsen.com:id3:v1	Nielsen ID3 in MPEG-DASH [ID3v2]

Table 5: Example of a SCTE-35 marker embedded in a DASH eventmessagebox

Tag	*Value*
scheme_uri_id	urn:scte:scte35:2013:bin
Value	value used to signal subscheme
Timescale	positive number, ticks per second, similar to track timescale
presentation_time_delta	non-negative number
event_duration	duration of event "0xFFFFFFFF" if unknown
id	unique identifier for message
message_data	splice info section including CRC

The following are requirements and recommendations that apply to timed metadata ingest of information related to events, tags, ad markers and program information and others:

1. Metadata SHALL be conveyed in a CMAF track, where the media handler (hdlr) is "meta", the track handler box is a null media header box nmhd as defined for timed metadata tracks in [ISOBMFF] clause 12.3

2. The CMAF timed metadata track applies to the CMAF Presentation ingested to a Publishing point at the Receiving Entity.
3. The URIMetaSampleEntry entry SHALL contain, in a URIbox, the URI following the URI syntax in [RFC3986] defining the scheme of the metadata (see the [ISOBMFF] clause 12.3).
4. All Timed Metadata samples SHALL be sync samples [ISOBMFF].
5. The CMAF fragments in the timed metadata track MAY NOT be of a constant duration. The fragments should be of durations that allow effective and in advance delivery of metadata to the receiving entity.
6. CMAF fragments carrying timed metadata MAY contain a single sample.
7. To fullfill CMAF track requirements [MPEGCMAF] in clause 7.3, such as not having gaps on the media timeline, filler data may needed. Such filler data SHALL be defined by the metadata scheme signalled in URIMetaSampleEntry. For example, webvtt tracks define a VTTEmptyCueBox in [MPEG4-30] clause 6.6. this cue is to be carried in samples in which no active cue occurs. Other schemes could define empty fillers amongst similar lines.
8. CMAF track files do not support overlapping, multiple concurrently active or zero duration samples. In case metadata or events are concurrent, overlapping or of zero duration, such semantics MUST be defined by the scheme signalled in the URIMetasampleEntry. The timed metadata track MUST still conform to [MPEGCMAF] clause 7.3.
9. CMAF Timed metadata tracks MAY carry DashEventMessageBoxes as defined in [MPEGDASH] clause 5.10.3.3 in the metadata samples.

   9a. In the case of 9, version 1 SHOULD be used, in case version 0 is used, the presentation_time_delta refers to the BaseMediaDecodeTime signalled in the tfdt of the CMAF fragment enclosing the timed metadata sample.

   9b. In the case of 9, the URIMetaSampleEntry SHOULD contain the URN "urn:mpeg:dash:event:2012" or an equivalent urn to signal the presence of DashEventMessageBoxes.

   9c. In the case of 9, the timescale of the DashEventMessageBox SHOULD match the value specified in the media header box "mdhd" of the timed metadata track.

   9d. In the case of 9, the sample composition time and the presentation time of the enclosed DashEventMessageBox SHOULD correspond by being equal. Earlier DashEventMesssageBoxes may be enclosed in the sample aswell, if they are still active during the composition time of that sample. In this case, the presentation time may not be equal. For each sample, at least one of the enclosed DashEventMessageBoxes has a presentation time that corresponds to the sample composition time.

   9e. In the case of 9, a single metadata sample MAY contain multiple DASHEventMessageBoxes. This happens if multiple DashEventMessageBoxes have the same Presentation Time or if an an earlier event is still active in a sample containing a newly started overlapping event.

   9f. In the case of 9, the duration of the metadata sample SHOULD correspond to the duration signalled in the DashEventMessageBox. If this is not possible due to CMAF or ISOBMFF track constraints, the duration of the sample MUST be the duration upto the next metadata sample. If the duration of a DashEventMessageBox is unknown, the metadata sample MAY have a duration of zero. Once the duration becomes known, it SHALL be updated in the track file to the correct non zero duration value. This behavior is only allowed for the last available sample in a timed metadata track.

   9g. In the case of 9, the schemeIdUri in the DASHEventMessageBox can be used to signal the scheme of the data carried in the message data field. This enables carriage of multiple metadata schemes in a track.

   9h. In the case of 9, For SCTE-35 ingest the schemeIdURI in the DASHEventMessageBox MUST be urn:scte:scte35:2013:bin as defined in [SCTE214-1]. A binary scte-35 payload is carried in the message_data field of a DASHEventMessageBox. The DASHEventMessageBox must conform to [SCTE214-1]. If a splice point is signalled, the SCTE-35 SpliceInsert command SHALL be used. In this case, media tracks MUST insert an IDR frame at the time corresponding to the event presentation time.

9i. In case of 9, it may be necessary to add filler samples to avoid gaps in the CMAF track timeline, a DashEventMessageBox with schemeIdUri urn:dash:event:2019:empty_cue SHOULD be used. The duration and timescale of this DashEventMessageBox MUST correspond to the duration and timescale of the sample to fill the timeline.

9j. In the case of 9, if ID3 tags are carried, the DashEventMessageBox MUST be formatted as defined in aomid3

9k. In the case of 9, the value and id field of the DashEventMessageBox can be used by the Receiving Entity to detect duplicate events.

10. The Ingest source SHOULD not embed inband top level DashEventMessage Boxes emsg in the timed metadata track or media tracks, however it is not strictly prohibited when conforming to this specification. In some setups, inband event messages may be used in media tracks, but it may result in a loss of performance for just-in-time packaging.

> Note: [MPEGCMAF] has the notion of an inband DashEventMessageBox to convey metadata and event messages. In the current specification a separate track is used instead to convey timed metadata and event messages. Advantages include avoiding sending duplicate information in multiple tracks, and avoiding a strong dependency between media and metadata by not interleaving them. The Ingest source SHOULD NOT send inband emsg box and the receiver SHOULD ignore it. Instead DashEventMessageBox can be carried in samples of the timed metadata track as described in clause 9.

5.7. Requirements for signalling and conditioning splice points§

Splicing is important to use cases like ad insertion or clipping of content. The requirements for signalling splice points and content conditioning at respective splice points are as follows.

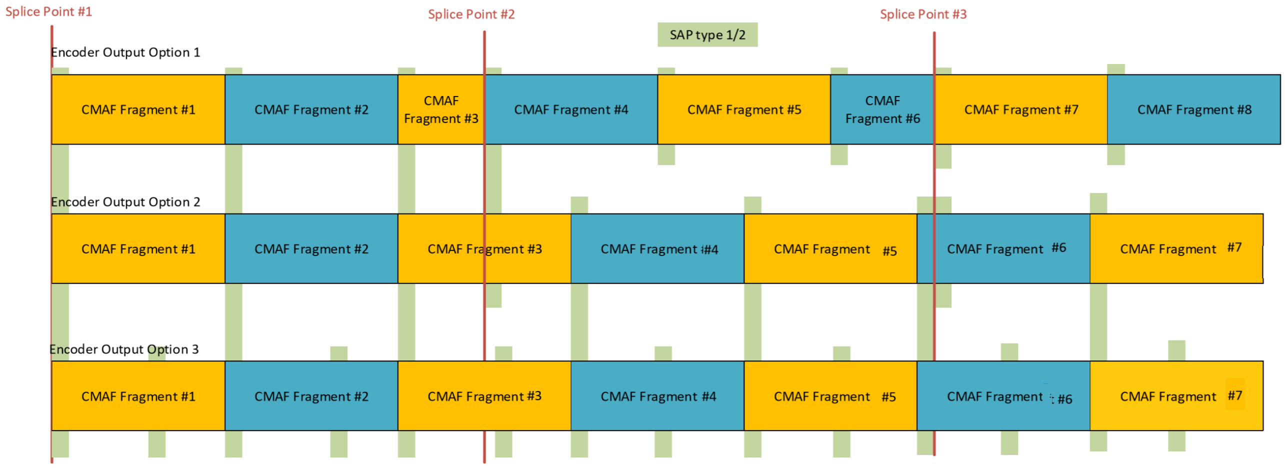
1. The preferred method for signalling splice point uses the timed metadata track sample with a presentation time corresponding to the splice point. The timed metadata track sample is carrying a DASHEventMessageBox carrying binary SCTE-35 based on the scheme urn:scte:scte35:2013:bin. The command carried in the binary SCTE-35 shall carry a spliceInsert command with out of network indicator set to 1.

> NOTE: this corresponds to clause 9h in § 5.6 Requirements for Timed Metadata Tracks

2. The media tracks in the CMAF presentation shall contain a sync sample at the presentation time signalled by the metadata sample / event message box in 1)
3. Sync samples shall be signalled according to the semantics of a Movie Fragment (i.e. using per sample flags in track run box instead of default flags if needed)

The conditioning follows DASH-IFad shown in Figure 9:

Figure 9: splice point conditioning



The splice point conditioning in DASH-IFad are defined as follows:

1. option 1: splice conditioned packaging: both a fragment boundary and a SAP 1 or SAP 2 (stream access point) at the splice point
2. option 2: splice conditioned encoding: a SAP 1 or SAP 2 stream access point at the frame at the boundary
3. option 3: splice point signalling: specific content conditioning at the splice point

This specification requires option 1 or 2 to be applied.

5.8. Requirements for Receiving and ingest source Entity Failover and Connection Error Handling

Given the nature of live streaming, good failover support is critical for ensuring the availability of the service. Typically, media services are designed to handle various types of failures, including network errors, server errors, and storage issues. When used in conjunction with proper failover logic from the ingest sources side, highly reliable live streaming setups can be build. In this section, we discuss requirements for failover scenarios. The following steps are required for an Ingest source to deal with a failing Receiving entity.

The CMAF ingest source and Receiving entity should implement the following recommendation to achieve failover support of the receiving entity.

1. In case the receiving entity failed, a new instance SHOULD be created, listening on the same Publishing point for the ingest stream.

Live encoder or Ingest source failover is the second type of failover. In this scenario, the error condition occurs on the Ingest source side. The following recommendations apply:

2. A new Ingest source instance SHOULD be instantiated to continue the ingest for the live streaming session
3. The Ingest source MUST use the same URL for HTTP POST requests as the failed instance.
4. The new Ingest source POST request MUST include the same CMAF Header or CMAF Header as the failed instance
5. The Ingest source MUST be properly synced with all other running ingest sources for the same live presentation to generate synced audio/video samples with aligned fragment boundaries in the track. This implies that UTC timestamps for fragments in the "tfdt" match between decoders, and encoders.
6. The new stream MUST be semantically equivalent with the previous stream, and interchangeable at the header and media fragment levels.
7. The new instance of Ingest source SHOULD try to minimize data loss. The basemediadecodetime tfdt of media fragments SHOULD increase from the point where the encoder last stopped. The basemediadecodetime in the

tfdt box SHOULD increase in a continuous manner, but it is permissible to introduce a discontinuity, if necessary. Receiving entities can ignore fragments that it has already received and processed, so it is better to error on the side of resending fragments than to introduce discontinuities in the media timeline.

6. Ingest Interface 2: DASH and HLS Ingest Protocol Behavior§

Interface 2 defines the protocol specific behavior required to ingest a Streaming presentation composed of Manifest objects and Media objects to receiving entities. In this mode, the Ingest source prepares and delivers to the receiving entity all the Objects intended for consumption by a client. These are a complete Streaming presentation including all manifest and media objects.

This interface is intended to be used by workflows which do not require active media processing after encoding. It leverages the fact that many encoders provide HLS and DASH packaging capabilities and that the resulting packaged content can easily be transferred via HTTP to standard web servers. However, neither HLS nor DASH has specified how such a workflow is intended to work leaving the industry to self specify key decisions such as how to secure and authenticate ingest sources, who is responsible for managing the content life cycle, the order of operations, failover, robustness, etc. In most cases a working solution can be had using a readily available web server such as Nginx or Varnish and the standard compliment of HTTP Methods. In many cases Interface 2 simply documents what is considered industry best practice while attempting to provide guidance to areas less commonly considered.

The requirements below encapsulate all needed functionality to support Interface 2. The requirements listed for Interface 1 (CMAF Ingest) in section § 5.2 General Protocol and Track Format Requirements do not apply to Interface 2. General shared requirements are covered in section general. In case [MPEGCMAF] media is used, the media track and segment formatting will be similar as defined in Interface 1.

6.1. General requirements§

6.1.1. Industry Compliance§

1. The Ingest source MUST be able to create a compliant Streaming presentation for MPEG-DASH [MPEGDASH] and/or HTTP Live Streaming [RFC8216]. The Ingest Source MAY create both MPEG-DASH and HLS Streaming Presentations using common Media objects (e.g., CMAF), but the Ingest Source MUST generate format-specific Manifest Objects which describe the common Media objects as a Streaming presentation.
2. The Ingest source MUST support the configuration and use of Fully Qualified Domain Names (per RFC8499) to identify the Receiving entity.
3. The Ingest source MUST support the configuration of the path which it will POST or PUT all the Objects to.
4. The Ingest source SHOULD support the configuration of the delivery path which clients will use to retrieve the content. When provided, the Ingest source MUST use this path to build absolute URLs in the Manifest Files it generates. When absent, relative pathing is assumed and the Ingest Source MUST build the Manifest Files accordingly.

These capabilities are further illustrated in the Examples sections, and may be defined outside the scope of this specification.

6.1.2. HTTP sessions§

1. The Ingest Source MUST transfer Manifest objects and Media objects to the Receiving entity via individual HTTP/1.1 [RFC7235] PUT or POST operations to the configured path. This specification does not imply any functional differentiation between a PUT or a POST operation. Either may be used to transfer content to the Receiving entity. Unless indicated otherwise, the use of the term POST can be interpreted as PUT or POST.

2. The Ingest Source SHOULD remove Media objects from the Receiving entity which are no longer referenced in the corresponding Manifest objects via an HTTP DELETE operation. How long the Ingest Source waits to remove unreferenced content MAY be configurable. Upon receipt of a DELETE request, the Receiving entity should:

   2a. delete the referenced content and return a 200 OK HTTP Response code

   2b. delete the corresponding folder if the last file in the folder is deleted and it is not a root folder but not necessarily recursively deleting empty folders.
3. To avoid delay associated with the TCP handshake, the Ingest Source SHOULD use Persistent TCP connections.
4. To avoid head of line blocking, the Ingest Source SHOULD use Multiple Parallel TCP connections to transfer the streaming presentation that it is generating. For example, the Ingest Source SHOULD POST each representation in a Media Presentation over a different TCP connection.
5. The Ingest source SHOULD use the chunked transfer encoding option of the HTTP POST command [RFC7235] when the content length of the request is unknown at the start of transmission or to support use cases that require low latency.

6.1.3. Unique segment and manifest naming§

1. The Ingest Source MUST ensure all Media objects (video segments, audio segments, initialization segments and caption segments) have unique paths. This uniqueness applies across all ingested content in previous sessions, as well as the current session. This requirement ensures previously cached content (i.e., by a CDN) is not inadvertently served instead of newer content of the same name.
2. The Ingest Source MUST ensure all objects in a Live stream session are contained within the configured path. Should the Receiving entity receive Media objects outside of the allowed path, it SHOULD return an HTTP 403 Forbidden response.
3. For each live stream session, the Ingest Source MUST provide unique paths for the Manifest objects. One suggested method of achieving this is to introduce a timestamp of the start of the live stream session into the manifest path. A session is defined by the explicit start and stop of the encoding process.
4. When receiving objects with the same path as an existing object, the Receiving entity MUST over-write the existing objects with the newer objects of the same path.
5. To support unique naming and support consistency, the Ingest Source SHOULD include a number which is monotonically increasing with each new Media Object at the end of Media object’s name, separated by a non-numeric character. This way it will be possible to retrieve this numeric suffix via a regular expression.
6. The Ingest Source MUST identify Media objects containing initialization fragments by using the .init file extension
7. The Ingest source MUST include a file extension and a MIME-type for all Media objects. The following file extensions and MIME-types are the ONLY permissible combinations to be used:

Table 6 outlines the formats that media and manifest objects are expected to follow based on their file extension.

Segments may be formatted as MPEG-4 [ISOBMFF] .mp4, .m4v, m4a, CMAF [MPEGCMAF] .cmf[v.a.m.t], or [MPEG2TS] .ts (HLS only). Manifests may be formatted as [MPEGDASH] .mpd or HLS [RFC8216] .m3u8.

NOTE: using MPEG-2 TS will break consistency with interface 1 which uses a CMAF container format structure

Table 6:

File Extension	*MIME Type*
.m3u8 [RFC8216]	*application/x-mpegURL or vnd.apple.mpegURL*

.mpd [MPEGDASH]	*application/dash+xml*
.cmfv [MPEGCMAF]	*video/mp4*
.cmfa [MPEGCMAF]	*audio/mp4*
.cmft [MPEGCMAF]	*application/mp4*
.cmfm [MPEGCMAF]	*application/mp4*
.mp4 [ISOBMFF]	*video/mp4 or application/mp4*
.m4v [ISOBMFF]	*video/mp4*
.m4a [ISOBMFF]	*audio/mp4*
.m4s [ISOBMFF]	*video/iso.segment*
.init	*video/mp4*
.header [ISOBMFF]	*video/mp4*
.key	*TBD*

6.1.4. DNS lookups§

DNS lookup requirements are defined in the general protocol requirements section § 4 General Ingest Protocol Behavior.

6.1.5. Ingest source identification§

1. The Ingest source SHOULD include a User-Agent header (which provides information about brand name, version number, and build number in a readable format) in all allowed HTTP messages. The Receiving entity MAY log the received User-Agent, along with other relevant HTTP Header data to facilitate troubleshooting.

6.1.6. Additional Failure behaviors§

The following items defines additional behavior of an ingest source when encountering certain error responses from the receiving entity.

1. When the ingest source receives a TCP connection attempt timeout, abort midstream, response timeout, TCP send/receive timeout or 5xx response when attempting to POST content to the Receiving entity, it MUST

   1a. For manifest objects: re-resolve DNS on each retry (per the DNS TTL) and retry as defined in general.

   1b. For media objects: re-resolve DNS on each retry (per the DNS TTL) and continue uploading for n seconds, where n is the segment duration. After it reaches the media object duration value, the Ingest source MUST continue with the next media object, and update the manifest object with a discontinuity marker appropriate for the protocol format. To maintain continuity of the time-line, the ingest source SHOULD continue to upload the missing media object with a lower priority. The reason for this is to maintain an archive without discontinuity in case the stream is played back at a later time. Once a media object is successfully uploaded, the ingest source SHOULD update the corresponding manifest object to reflect the now available media object. Note that many HLS clients do not like changes to manifest files, such as removing a previously present discontinuity, so this should only be applied for MPEG DASH manifests.
2. Upon receipt of an HTTP 403 or 400 error, the ingest source MAY be configured to NOT retry sending the

fragments, hence N will be 0, as descrbed in general.

6.2. HLS specific requirements§

6.2.1. File extensions and mime-types§

When ingesting prepared HLS content, the Ingest Source MUST:

1. MUST use a .m3u8 file extension for master and variant playlists.
2. SHOULD use a .key file extension for any keyfiles posted to the receiving entity for client delivery.
3. MUST use a ".ts" file extension for segments encapsulated in a MPEG Transport Stream (TS) File Format.
4. MUST use one of the allowed file extensions (per the table above) appropriate for the mime-type of the content encapsulated using [MPEGCMAF], it MUST NOT use a ".ts" file extension.

6.2.2. Upload order§

In accordance with the HTTP live Streaming [RFC8216] recommendation, ingest sources MUST upload all required files for a specific bitrate and segment before proceeding to the next segment. For example, for a bitrate that has segments and a playlist that updates every segment and key files, ingest sources upload the segment file followed by a key file (optional) and the playlist file in serial fashion. The encoder MUST only move to the next segment after the previous segment has been successfully uploaded or after the segment duration time has elapsed. The order of operation should be:

1. Upload media segment,
2. Optionally upload key file, if required,
3. Upload the .m3u8.

If there is a problem with any of the Steps, retry them. Do not proceed to Step 3 until Step 1 succeeds or times out as described in common failure behaviors above. Failed uploads MUST result in a stream manifest Discontinuity per [RFC8216].

6.2.3. Encryption§

1. The ingest source MAY choose to encrypt the media segments and publish the corresponding keyfile to the Receiving entity.

6.2.4. Relative paths§

1. The ingest source SHOULD use Relative URL paths to address each segment within the stream level manifest.
2. The ingest source SHOULD use Relative URL paths to address each variant playlist within the master playlist.

6.2.5. Resiliency§

1. When ingesting media objects to multiple receiving entities, the ingest source MUST send identical media objects with identical names.
2. When multiple ingest sources are used, they MUST use consistent media object names including when reconnecting due to any application or transport error. A common approach is to use (epoch time)/(segment duration) as the object name.

6.3. DASH-specific requirements§

6.3.1. File extensions and MIME-types§

When ingesting prepared DASH content, the Ingest Source MUST:

1. use an ".mpd" file extension for manifest objects.
2. use one of the allowed file extensions (see table 6 above) for Media objects. It MUST NOT use a ".ts" file extension.

6.3.2. Relative paths§

1. The ingest source SHOULD use Relative URL paths to address each segment within the manifest object.

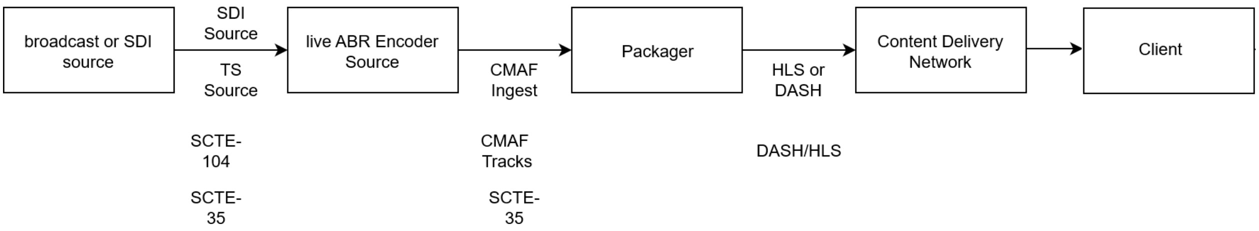
7. Illustrative Example of using CMAF and DASH ingest specification (informative)§

In this section we provide some example deployments for live streaming, mapping to the architecture defined in DASH-IF live Task Force using the emerging MPEG DASH CMAF profile.

7.1. Example 1 with CMAF ingest and a just-in-time packager§

Figure 10 shows an example where a separate packager and origin server are used.

Figure 10: Example setup schema with CMAF ingest and DASH/HLS ingest



The broadcast source is used as input to the live ABR encoder. The broadcast sources can be original SDI signals from a broadcast facility or MPEG-2 TS streams intercepted from a broadcast that need to be re-used in an OTT distribution workflow. The live ABR encoder source performs the ABR encoding of the tracks into CMAF tracks and functions as the ingest source in the CMAF ingest interface. Multiple live ABR encoder sources can be used, providing redundant inputs to the packager, which is the Receiving entity consuming the CMAF ingest. The ingest follows the CMAF Ingest specification in this document, allowing for failover, redundancy and many of the other features related to the content tracks. The live encoder source performs the following tasks:

- It demuxes and receives the MPEG-2 Transport Stream and/or SDI signal.
- It formats the metadata in these streams such as SCTE-35 or SCTE-104 to timed metadata tracks.
- It performs a high quality ABR encoding in different bit-rates with aligned switching points.
- It packages all media and timed text tracks as CMAF-compliant tracks and signals track roles in kind boxes.
- It POSTs the addressable media objects composing the tracks to the live packager according to the CMAF ingest specification interface defined in Section 5 of this document.
- The CMAF ingest allows multiple live encoder sources and packagers to be deployed benefiting. from redundant stream creation, avoiding timeline discontinuities due to failures as much as possible.
- In case the receiver entity fails, it will reconnect and resend as defined in § 4 General Ingest Protocol Behavior and § 5.8 Requirements for Receiving and ingest source Entity Failover and Connection Error Handling.

- In case the live encoder ingest source fails it will restart and perform the steps as in § 5.8 Requirements for Receiving and ingest source Entity Failover and Connection Error Handling.

The live encoder ingest source can be deployed in the cloud or on a bare metal server or even as a dedicated hardware. The live encoder source may have some tools or configuration APIs to author the CMAF tracks and feed instruction/properties from the original SDI or broadcast into the CMAF tracks. The packager receives the ingested streams, and performs the following tasks.

- It receives the CMAF tracks, grouping switching sets based on switching set constraints.
- When packaging to MPEG-DASH, an adaptation set is created for each switchingset ingested.
- The near constant fragment duration is used to generate segment template based presentation using either $Number$ or $Time$.
- In case changes happen, the packager can update the manifest and embed in-band events to trigger manifest updates in the fragments.
- The DASH Packager encrypts media segments according to key information available. This key information is typically exchanged by protocols defined in Content Protection Interchange Format (CPIX). This allows configuration of the content keys, initialization vectors and embedding encryption information in the manifest
- The DASH packager signals subtitles in the manifest based on received CMAF streams and roles signalled in kind box
- In case a fragment is missing and SegmentTimeline is used, the packager may signal a discontinuity in the Media Presentation Description.
- In case a low latency mode is used, the packager may make output available before the entire fragment is received using HTTP chunked transfer encoding.
- The packager may also have a proprietary API similar to the live source, for configuration of aspects like the segmentTimeBuffer, DVR window, encryption modes enabled etc.
- The packager uses DASH or HLS ingest (as specified in Section 6) to push content to the origin server of a Content Deliery Network. Alternatively, it could also make content directly available as an origin server. In this case DASH/HLS ingest is avoided, and the packager also serves as the origin server.
- The packager converts the timed metadata track and uses it to convert to either MPD Events or in-band events. signalled in the manifest.
- The packager may also generate HLS or other streaming media presentations based on the input.
- In case the packager crashes or fails, it will restart itself and wait for the ingest. source to perform the actions as detailed in the section on failover.

The Content Delivery Network (CDN) consumes a DASH/HLS ingest, or serves as a proxy for content delivered to a client. The CDN, in case it is consuming the POST based DASH/HLS ingest performs the following tasks

- it stores all posted content and makes them available for HTTP GET requests from locations corresponding to the paths signalled in the manifest
- it occasionally deletes content based on instructions from the ingest source, in this setup the packager
- in case low latency mode is used, content could be made available before the entire pieces of content are available
- It updates the manifest accordingly when a manifest update is received
- It serves as a cache proxy for HTTP get requests forwarded to the packager

In case the CDN serves as a proxy, it only forwards requests for content to the packager to receive the content,and caches relevant segments for a duration N until it expires.

The client receives DASH or HLS streams, and is not affected by the specification of this work. Nevertheless, it is expected that by using a common media application format, less caching and less overhead in the network will result in a better user experience. The client still needs to retrieve license and key information by steps defined outside of this specification. Information on how to retrieve this information will typically be signalled in the manifest prepared by the packager.

This example aims to illustrate how the specification defined in this document can be used to provide a live streaming presentation to clients, this example does not preclude other ways of using the specification and protocols defined in this document.

7.2. Example 2 low latency dash with an open source encoder and packager and a combination of interface 1 and 2§

A second example can be seen in Figure 11. It constitutes the reference workflow for chunked DASH CMAF under development by DASH-IF and DVB. In this workflow a contribution encoder produces an RTP mezzanine stream that is transmitted to FFmpeg, an example open source encoder/packager running on a server. Alternatively, a file resource may be used. In this workflow the open source encoder functions as the ingest source. FFmpeg produces the ingest stream with different ABR encoded CMAF tracks. In addition, it also sends a manifest that complies with DASH-IF and DVB low latency CMAF specification and MPD updates. The CMAF tracks also contain respective timing information (prft etc.). In this case the ingest source implements interface 2 DASH ingest. But as in this case the DASH presentation uses CMAF, the media and track constraints of interface 1 are also satisfied. By also resending CMAF Headers in case of failures both interfaces may be satisfied.

The origin server is used to pass the streams to the client, and may in some cases also perform a re-encryption or re-packaging of the streaming presentation as needed by the client (in case encryption is needed for example). The target example client is DASH.js and an end-to-end latency of maximum 3500 ms is targeted.

This example DASH reference workflow uses DASH Ingest that does not employ encryption and timed metadata and uses CMAF formatting. This exploits the synergies between the two interfaces defined in this document hence the ingest between FFmpeg and the origin server may implement both interfaces simultaneously, or only interface 2.

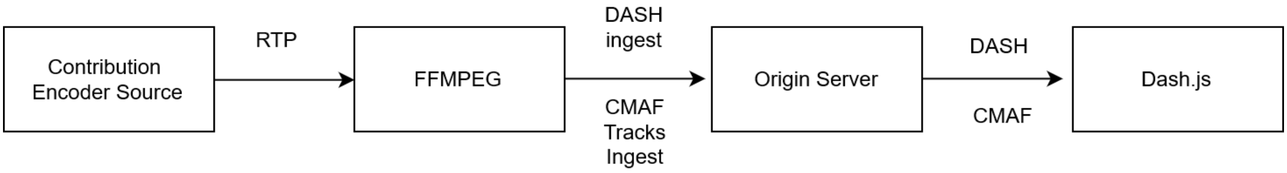
To receive the stream as a CMAF ingest for re-packaging at the origin the following steps can be applied. This is the case where interface 1 and interface 2 are used interchangeably, hence the live encoder can either ingest to an origin that supports interface 2 with CMAF formatting, including the requirements from interface 1.

1. Ignore the DASH Manifest
2. Ignore the segment names, only look at the relative path to identify the stream names
3. Ignore the HTTP Delete commands

The approaches for authentication and DNS resolution are similar for the two profiles/interfaces, as are the track formatting in case CMAF based media are used. This example does not use timed metadata. The ingest source may resend the CMAF header or init fragment in case of connection failures to conform to the CMAF ingest specification. The origin server can then be used to repackage or re-encrypt the streams. This might be useful approach when additional functionality is needed.

To receive the stream as a DASH Ingest in this workflow, the steps described in DASH Ingest may be applied.

Figure 11: DASH-IF Reference DASH-IF Live Chunked CMAF Production Workflow



8. Acknowledgements§

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CenturyLink, Microsoft, Unified Streaming, Facebook, Hulu, Comcast, ITV, Qualcomm, Tencent, Samsung, MediaExcel, Harmonic, Sony, Arris, BitMovin, DSR and AWS Elemental

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9.1. URL References§

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Conformance§

Conformance requirements are expressed with a combination of descriptive assertions and RFC 2119 terminology. The key words “MUST”, “MUST NOT”, “REQUIRED”, “SHALL”, “SHALL NOT”, “SHOULD”, “SHOULD NOT”, “RECOMMENDED”, “MAY”, and “OPTIONAL” in the normative parts of this document are to be interpreted as described in RFC 2119. However, for readability, these words do not appear in all uppercase letters in this specification.

All of the text of this specification is normative except sections explicitly marked as non-normative, examples, and notes. [RFC2119]

Examples in this specification are introduced with the words “for example” or are set apart from the normative text with `class="example"`, like this:

> ¶EXAMPLE 1
> This is an example of an informative example.

Informative notes begin with the word “Note” and are set apart from the normative text with `class="note"`, like this:

> Note, this is an informative note.

Index§

Terms defined by this specification§

References§

Normative References§

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