

**hulu**

# **Scaling Live OTT with DASH**

**Techniques and Lessons Learned**

Scaling Live OTT with DASH

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Video Platform Architect



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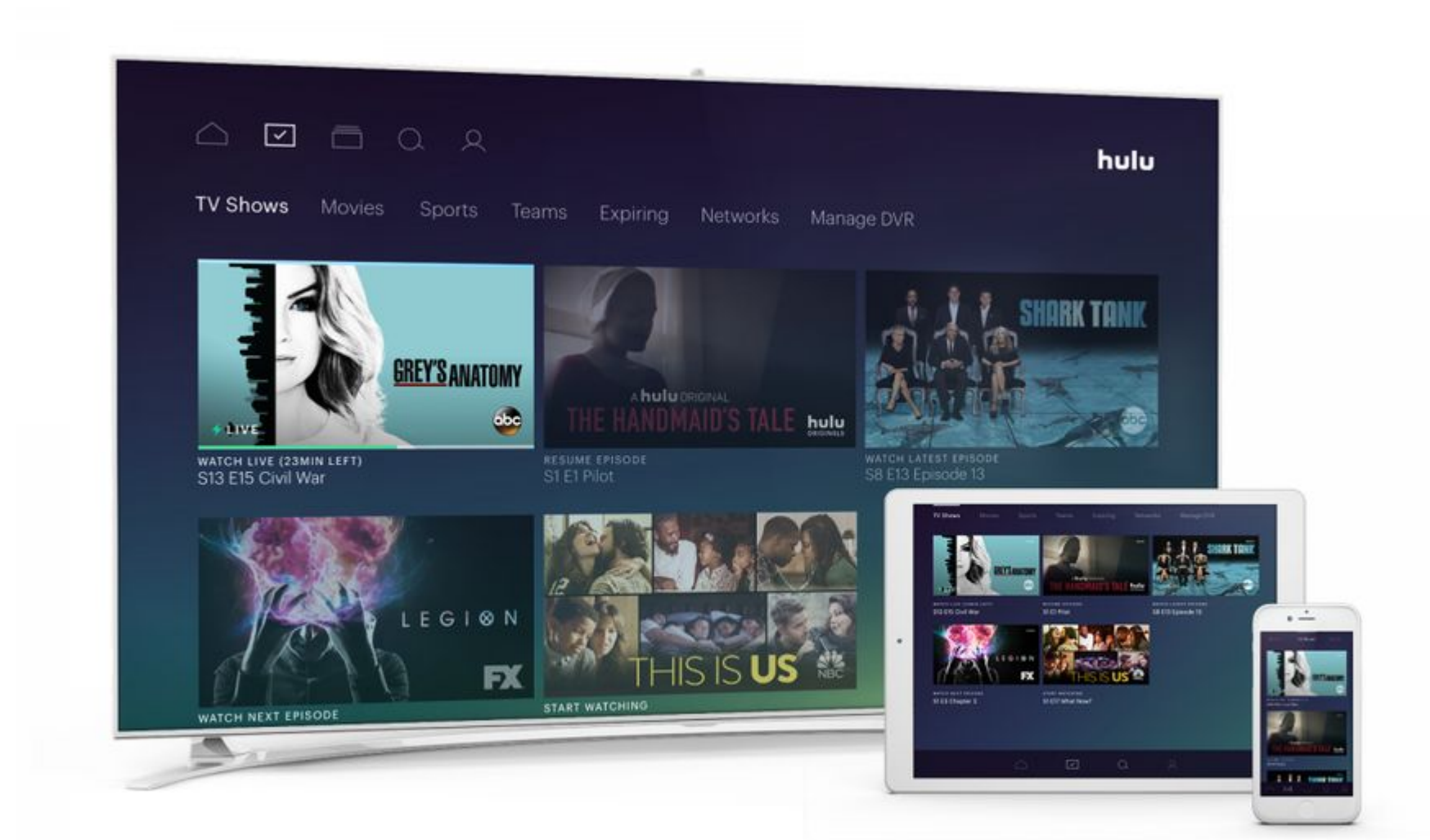
Scaling Live OTT with DASH

# Background

## BACKGROUND

# Hulu + Live TV

- Launched May 3rd 2017
  - Local Live Channels
  - Personal DVR
  - Includes Full Hulu Library
- Technical Points
  - 1000+ Live Streams Ingested
  - 3 Signal Acquisition / Encoding Vendors
  - In-House Packaging and Origin



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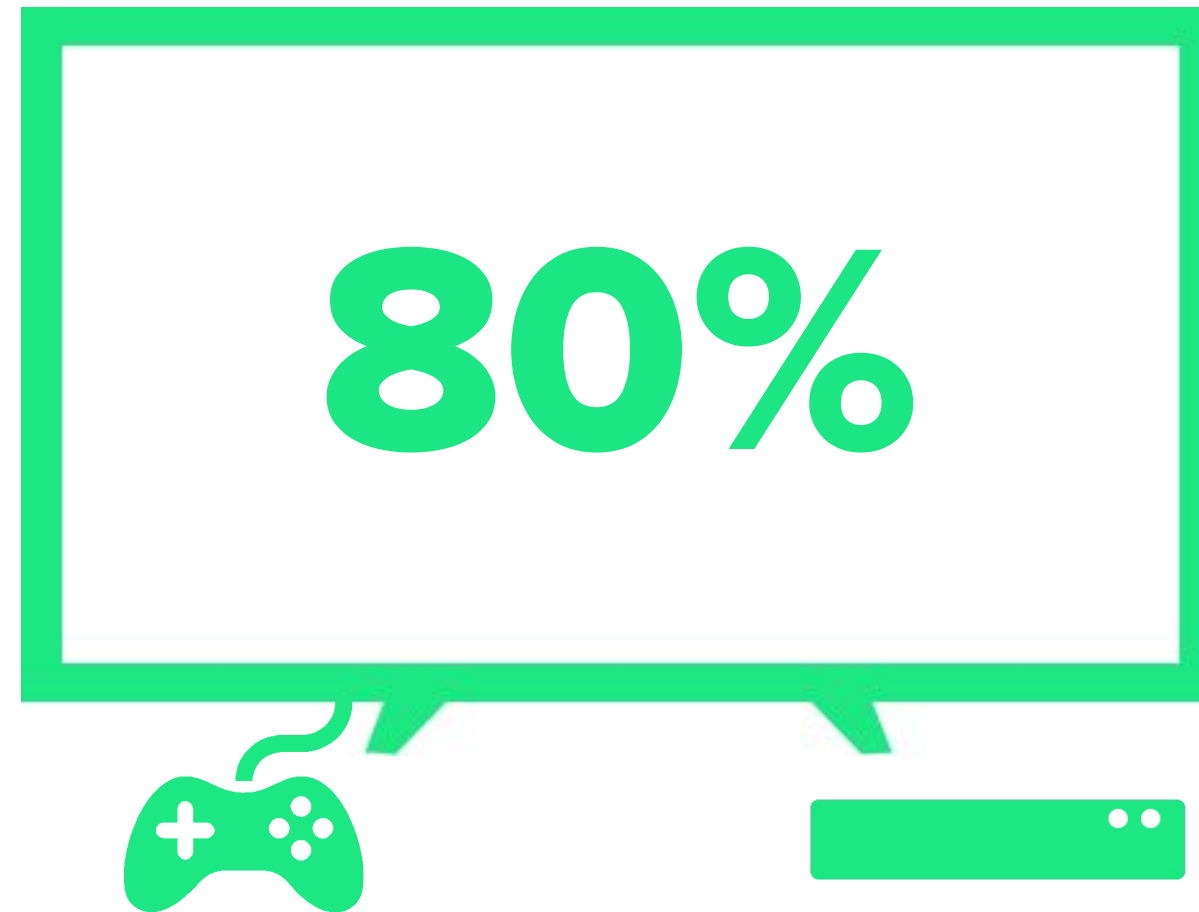
# Device Landscape

---

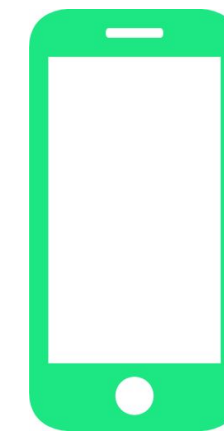
**WEB**



**LIVING ROOM**



**MOBILE**



**hulu**

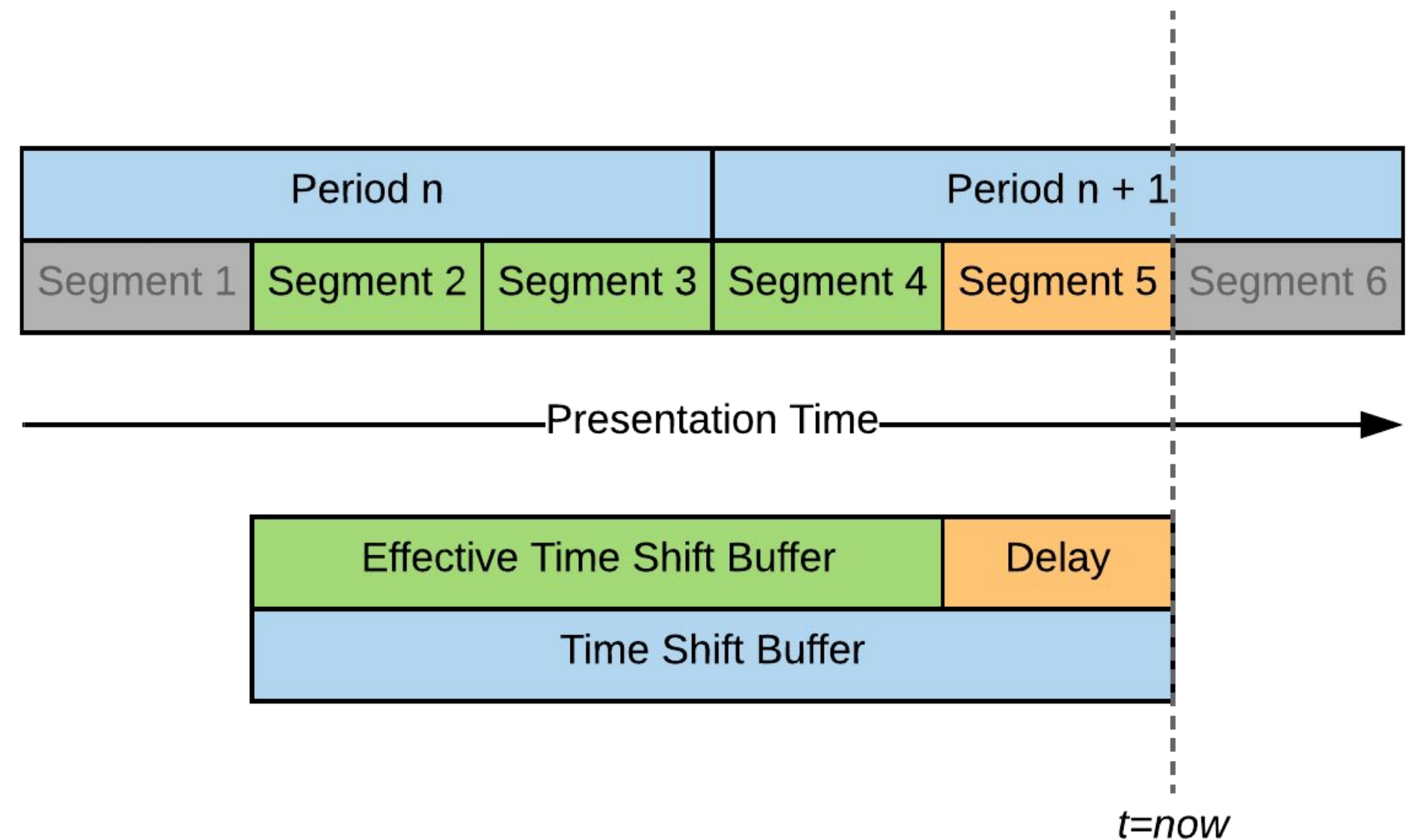
Scaling Live OTT with DASH

# LIVE Streaming with DASH

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# The Timing Model

- Well Defined Timing Model
  - Synchronized to Real Time Clock
  - Explicit Segment Availability
- Declarative Timing Control
  - DVR Buffering Window
  - Presentation Delay
- Presentation Updates
  - Basic Simple Polling
  - Advanced In-Segment Signalling



# Segment Addressing

- Templated Segment Addressing
  - \$Number\$ or \$Time\$
- Optional Explicit Addressing
  - Individual segment entries
  - Fully represents missing segments
- Deployed \$Time\$ with Timeline
  - Artifact of stateless ingest system
  - Re-evaluating for Low Latency

```
<SegmentTemplate timescale="90000"  
  presentationTimeOffset="3054136803"  
  media="STREAM/video/$Time$.m4s"  
  initialization="STREAM/init/video.mp4">  
  <SegmentTimeline>  
    <S t="3054139806" d="360360" />  
    <S t="3054500166" d="360360" />  
    <S t="3054860526" d="360360" />  
    <S t="3055220886" d="360360" />  
    <S t="3055581246" d="360360" />  
    <S t="3055941606" d="360360" />  
    <S t="3056301966" d="360360" />  
    <S t="3056662326" d="360360" />  
    <S t="3057022686" d="360360" />  
    <S t="3057383046" d="360360" />  
    <S t="3057743406" d="360360" />  
  </SegmentTimeline>  
</SegmentTemplate>
```

# Multi-CDN Enablement

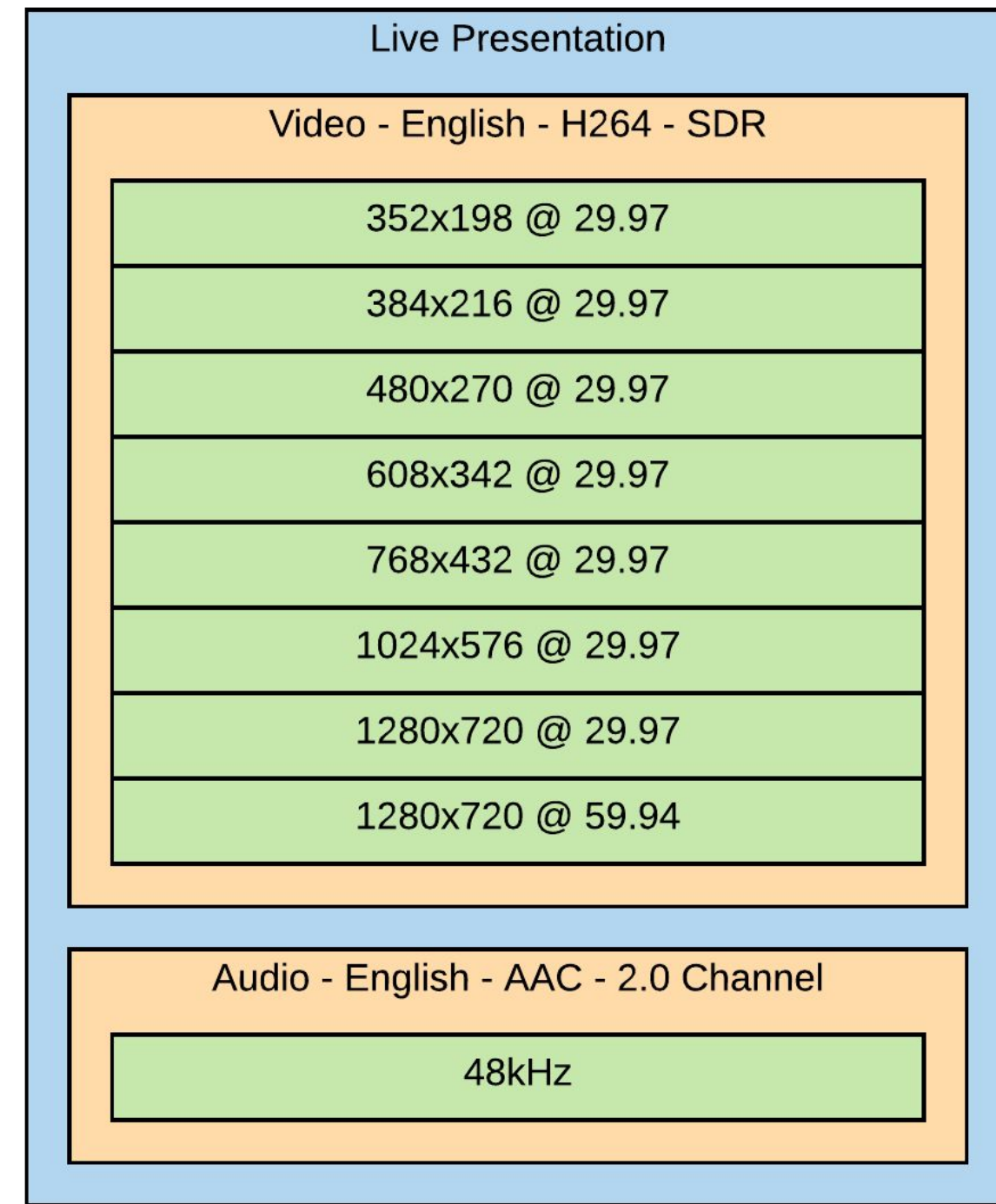
---

- Multiple BaseURL Elements
  - One per CDN
  - Client has ability to choose source
  - Switching enabled by ABR
- Segment Authentication Complicated
  - No common auth scheme
  - Must add token per CDN
  - ExtUrlQueryInfo used to abstract manifest from tokens

```
<Period id="1" start="...">  
  <BaseURL serviceLocation="cdn-1">...</BaseURL>  
  <BaseURL serviceLocation="cdn-2">...</BaseURL>  
  <BaseURL serviceLocation="cdn-3">...</BaseURL>  
  ...  
</Period>
```

# Basic Manifest Example

- Let's look at a 5 minute manifest
- Live Streaming Details
  - Multi-Period
  - 8 Video Representations
  - 1 Audio Representation
  - CEA-608/708 Captions
  - 3 Segment CDNs



## 5 Minute Manifest (1 of ?)

```
<?xml version="1.0" encoding="UTF-8"?>
<MPD type="dynamic" minimumUpdatePeriod="PT3.0S" suggestedPresentationDelay="PT8S"
  availabilityStartTime="2017-05-01T07:00:00+00:00" ...>
  <Period id="1" start="PT70406325.063S">
    <BaseURL serviceLocation="cdn-1">https://cdn-1.net/CNN/</BaseURL>
    <BaseURL serviceLocation="cdn-2">https://cdn-2.net/CNN/</BaseURL>
    <BaseURL serviceLocation="cdn-3">https://cdn-3.net/CNN/</BaseURL>
    <AdaptationSet id="2" mimeType="video/mp4" segmentAlignment="true"
      bitstreamSwitching="true" maxWidth="1280" maxHeight="720" maxFrameRate="60000/1001">
      <Accessibility schemeIdUri="urn:scte:dash:cc:cea-608:2015" value="CC1=eng" />
      <ContentProtection schemeIdUri="urn:mpeg:dash:mp4protection:2011"
        value="cenc" cenc:default_KID="..." />
      <ContentProtection schemeIdUri="urn:uuid:9a04f079-9840-4286-ab92-e65be0885f95" />
      <ContentProtection schemeIdUri="urn:uuid:edef8ba9-79d6-4ace-a3c8-27dcd51d21ed" />
      <Representation id="VIDEO_7" codecs="avc1.4d400d" width="352" height="198"
        startWithSAP="1" bandwidth="474092" frameRate="30000/1001">
        <SegmentTemplate timescale="90000" presentationTimeOffset="3054136803"
          media="CNN/VIDEO_7/$Time$.m4s"
          initialization="CNN/init/VIDEO_7.mp4">
          <SegmentTimeline>
            <S t="3054139806" d="360360" />
          </SegmentTimeline>
        </Representation>
      </AdaptationSet>
    </Period>
  </MPD>
```

## 5 Minute Manifest (2 of ?)

```
<S t="3054500166" d="360360" />  
<S t="3054860526" d="360360" />  
<S t="3055220886" d="360360" />  
<S t="3055581246" d="360360" />  
<S t="3055941606" d="360360" />  
<S t="3056301966" d="360360" />  
<S t="3056662326" d="360360" />  
<S t="3057022686" d="360360" />  
<S t="3057383046" d="360360" />  
<S t="3057743406" d="360360" />  
<S t="3058103766" d="360360" />  
<S t="3058464126" d="360360" />  
<S t="3058824486" d="360360" />  
<S t="3059184846" d="360360" />  
<S t="3059545206" d="360360" />  
<S t="3059905566" d="360360" />  
<S t="3060265926" d="360360" />  
<S t="3060626286" d="360360" />  
<S t="3060986646" d="360360" />  
<S t="3061347006" d="360360" />  
<S t="3061707366" d="360360" />
```

## 5 Minute Manifest (3 of ?)

```
<S t="3062067726" d="360360" />  
<S t="3062428086" d="360360" />  
<S t="3062788446" d="360360" />  
<S t="3063148806" d="360360" />  
<S t="3063509166" d="360360" />  
<S t="3063869526" d="360360" />  
<S t="3064229886" d="360360" />  
<S t="3064590246" d="360360" />  
<S t="3064950606" d="360360" />  
<S t="3065310966" d="360360" />  
<S t="3065671326" d="360360" />  
<S t="3066031686" d="360360" />  
<S t="3066392046" d="360360" />  
<S t="3066752406" d="360360" />  
<S t="3067112766" d="360360" />  
<S t="3067473126" d="360360" />  
<S t="3067833486" d="360360" />  
<S t="3068193846" d="360360" />  
<S t="3068554206" d="360360" />  
<S t="3068914566" d="360360" />  
<S t="3069274926" d="360360" />
```

## 5 Minute Manifest (4 of ?)

```
<S t="3069635286" d="360360" />  
<S t="3069995646" d="360360" />  
<S t="3070356006" d="360360" />  
<S t="3070716366" d="360360" />  
<S t="3071076726" d="360360" />  
<S t="3071437086" d="360360" />  
<S t="3071797446" d="360360" />  
<S t="3072157806" d="360360" />  
<S t="3072518166" d="360360" />  
<S t="3072878526" d="360360" />  
<S t="3073238886" d="360360" />  
<S t="3073599246" d="360360" />  
<S t="3073959606" d="360360" />  
<S t="3074319966" d="360360" />  
<S t="3074680326" d="360360" />  
<S t="3075040686" d="360360" />  
<S t="3075401046" d="360360" />  
<S t="3075761406" d="360360" />  
<S t="3076121766" d="360360" />  
<S t="3076482126" d="360360" />  
<S t="3076842486" d="360360" />
```

## 5 Minute Manifest (5 of ?)

```
<S t="3077202846" d="360360" />
<S t="3077563206" d="360360" />
<S t="3077923566" d="360360" />
<S t="3078283926" d="360360" />
<S t="3078644286" d="360360" />
<S t="3079004646" d="360360" />
<S t="3079365006" d="360360" />
<S t="3079725366" d="360360" />
</SegmentTimeline>
</SegmentTemplate>
</Representation>
<Representation id="VIDEO_6" codecs="avc1.4d400d" width="384" height="216"
startWithSAP="1" bandwidth="741797" frameRate="30000/1001">
<SegmentTemplate timescale="90000" presentationTimeOffset="3054136803"
media="CNN/VIDEO_6/$Time$.m4s"
initialization="CNN/init/VIDEO_6.mp4">
<SegmentTimeline>
<S t="3054139806" d="360360" />
<S t="3054500166" d="360360" />
<S t="3054860526" d="360360" />
<S t="3055220886" d="360360" />
```



MOMENTS

LATER

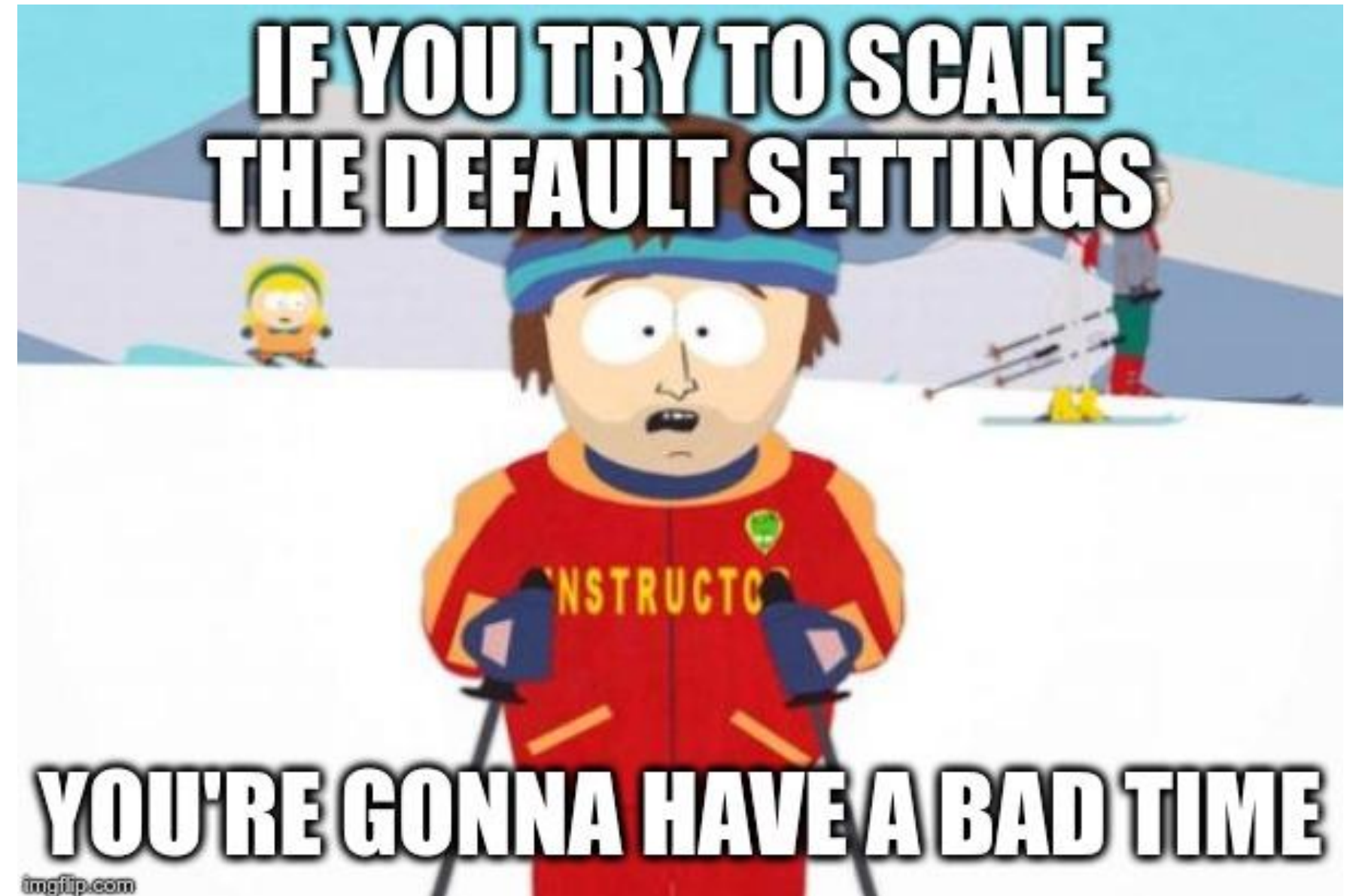
## 5 Minute Manifest (36 of 36)

```
<S t="3074681608" d="360960" />
<S t="3075042568" d="359040" />
<S t="3075401608" d="360960" />
<S t="3075762568" d="360960" />
<S t="3076123528" d="359040" />
<S t="3076482568" d="360960" />
<S t="3076843528" d="360960" />
<S t="3077204488" d="359040" />
<S t="3077563528" d="360960" />
<S t="3077924488" d="360960" />
<S t="3078285448" d="359040" />
<S t="3078644488" d="360960" />
<S t="3079005448" d="360960" />
<S t="3079366408" d="359040" />
<S t="3079725448" d="360960" />
  </SegmentTimeline>
  </SegmentTemplate>
</Representation>
</AdaptationSet>
</Period>
</MPD>
```

## Only 5 Minutes of Content

---

- By The Numbers
  - 694 XML Nodes
  - 46KB Uncompressed Size
  - ~30ms Parse Time
- Simply Does Not Scale
  - 1 hour => 8665 Nodes, 573KB
  - 3 hours => 26512 Nodes, 1.9MB
- What Makes The Manifest So Big?
  - Explicit segment addressing
  - Usage of multiple periods



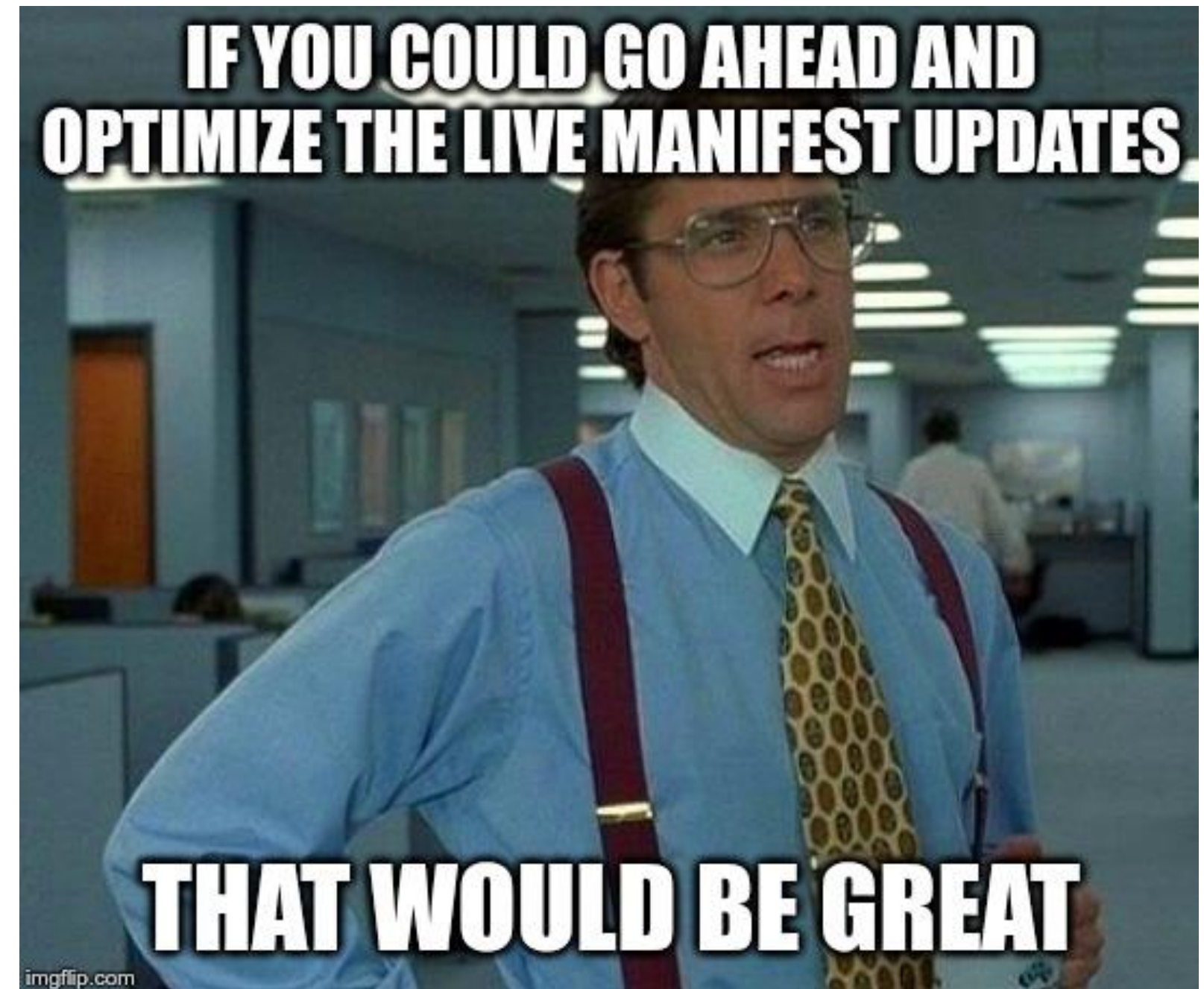
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# Optimizing for Scale

## Focusing Optimizations

---

- Concurrency Is The Challenge
  - Clients constantly polling
  - Need highly cacheable responses
  - Avoid sacrificing quality for scale
- Optimize For Network and Clients
  - Ensure high cache hit ratio
  - Minimize cost of updates for clients
  - Service resources aren't endless
- Important To Optimize Wholistically



# Compress the Timelines

- Utilize S@r Attribute
  - Collapse repeated durations
  - Not effective on “patterned” durations
- Omit S@t for Consecutive Segments
  - Only necessary for start and gaps
- One Timeline per AdaptationSet
  - Segments are time aligned anyways
  - \$RepresentationID\$ template
  - Representation timescales must match

```
<SegmentTemplate timescale="90000"  
  media="CNN/$RepresentationID$/Time$.m4s"  
  initialization="CNN/init/$RepresentationID$.m4s"  
  ...>  
  <SegmentTimeline>  
    <S t="3054860526" d="360360" r="71" />  
    <S d="270270" />  
  </SegmentTimeline>  
  <Representation id="VIDEO_7" .../>  
  <Representation id="VIDEO_6" .../>  
  <Representation id="VIDEO_5" .../>  
  <Representation id="VIDEO_4" .../>  
  <Representation id="VIDEO_3" .../>  
  <Representation id="VIDEO_2" .../>  
  <Representation id="VIDEO_1" .../>  
  <Representation id="VIDEO_0" .../>  
</SegmentTemplate>
```

# 5 Minute Manifest with Compressed Timeline

- By The Numbers
  - 78 XML Nodes
  - 8.1KB Uncompressed Size
  - ~20ms Parse Time
- Smaller Magnitude, Scales The Same
  - 1 hour => 986 Nodes, 100KB
  - 3 hour => 3351 Nodes, 373KB
- Cost Accumulates Over Time
  - Updates increase in cost over time
  - Parsing during playback is expensive
  - What is really changing in updates?

```
<?xml version="1.0" encoding="UTF-8"?>
<MPD type="dynamic" minBufferTime="PT1.0S" minimumUpdatePeriod="PT3.0S" suggestedPresentationDelay="PT8S" ...>
  <Period id="1" start="PT70406333.088S">
    <BaseURL serviceLocation="cdn-1">https://cdn-1.net/CNN/</BaseURL>
    <BaseURL serviceLocation="cdn-2">https://cdn-2.net/CNN/</BaseURL>
    <BaseURL serviceLocation="cdn-3">https://cdn-3.net/CNN/</BaseURL>
    <AdaptationSet id="2" mimeType="video/mp4" segmentAlignment="true" bitstreamSwitching="true" ...>
      <Accessibility schemeIdUri="urn:scte:dash:cc:cea-608:2015" value="CC1=eng"/>
      <ContentProtection schemeIdUri="urn:mpeg:dash:mp4protection:2011" value="cenc" cenc:default_KID="..." />
      <ContentProtection schemeIdUri="urn:uuid:edef8ba9-79d6-4ace-a3c8-27dcd51d21ed" />
      <ContentProtection schemeIdUri="urn:uuid:9a04f079-9840-4286-ab92-e65be0885f95" />
      <SegmentTemplate timescale="90000" presentationTimeOffset="3054857523"
        media="CNN/$RepresentationID$/Time$.m4s"
        initialization="CNN/init/$RepresentationID$.mp4">
        <SegmentTimeline>
          <S t="3054860526" d="360360" r="71"/>
        </SegmentTimeline>
      </SegmentTemplate>
      <Representation id="VIDEO_7" width="352" height="198" .../>
      <Representation id="VIDEO_6" width="384" height="216" .../>
      <Representation id="VIDEO_5" width="480" height="270" .../>
      <Representation id="VIDEO_4" width="608" height="342" .../>
      <Representation id="VIDEO_3" width="768" height="432" .../>
      <Representation id="VIDEO_2" width="1024" height="576" .../>
      <Representation id="VIDEO_1" width="1280" height="720" .../>
      <Representation id="VIDEO_0" width="1280" height="720" .../>
    </AdaptationSet>
    <AdaptationSet id="1" mimeType="audio/mp4" segmentAlignment="true" bitstreamSwitching="true">
      <ContentProtection schemeIdUri="urn:mpeg:dash:mp4protection:2011" value="cenc" cenc:default_KID="..." />
      <ContentProtection schemeIdUri="urn:uuid:edef8ba9-79d6-4ace-a3c8-27dcd51d21ed" />
      <ContentProtection schemeIdUri="urn:uuid:9a04f079-9840-4286-ab92-e65be0885f95" />
      <InbandEventStream schemeIdUri="www.nielsen.com:id3:v1" value="1" />
      <SegmentTemplate timescale="90000" presentationTimeOffset="3054857523"
        media="CNN/$RepresentationID$/Time$.m4s"
        initialization="CNN/init/$RepresentationID$.mp4">
        <SegmentTimeline>
          <S t="3054861448" d="360960" />
          <S d="359040" />
          <S d="360960" r="1" />
          <S d="359040" />
          <S d="360960" r="2" />
          <S d="359040" />
          <S d="360960" r="1" />
          <S d="359040" />
          <S d="360960" r="1" />
          <S d="359040" />
          <S d="360960" r="1" />
          <S d="359040" />
          <S d="360960" r="1" />
          <S d="359040" />
          <S d="360960" r="2" />
        </SegmentTimeline>
      </SegmentTemplate>
      <Representation id="AUDIO" codecs="mp4a.40.2" audioSamplingRate="48000" startWithSAP="1" bandwidth="96000">
        <AudioChannelConfiguration schemeIdUri="urn:mpeg:dash:23003:3:audio_channel_configuration:2011" value="2" />
      </Representation>
    </AdaptationSet>
  </Period>
</MPD>
```

# Changes Across Updates

```
<?xml version="1.0" encoding="UTF-8"?>
<MPD type="dynamic" minBufferTime="PT1.0S" minimumUpdatePeriod="PT3.0S" suggestedPresentationDelay="PT8S" ...>
  <Period id="1" start="PT70406333.088S">
    <BaseURL serviceLocation="cdn-1">https://cdn-1.net/CNN/</BaseURL>
    <BaseURL serviceLocation="cdn-2">https://cdn-2.net/CNN/</BaseURL>
    <BaseURL serviceLocation="cdn-3">https://cdn-3.net/CNN/</BaseURL>
    <AdaptationSet id="2" mimeType="video/mp4" segmentAlignment="true" bitstreamSwitching="true" ...>
      <Accessibility schemeIdUri="urn:scte:dash:cc:cea-608:2015" value="CC1=eng"/>
      <ContentProtection schemeIdUri="urn:mpeg:dash:mp4protection:2011" value="cenc" cenc:default_KID="..." />
      <ContentProtection schemeIdUri="urn:uuid:edef8ba9-79d6-4ace-a3c8-27dcd51d21ed" />
      <ContentProtection schemeIdUri="urn:uuid:9a04f079-9840-4286-ab92-e65be0885f95" />
      <SegmentTemplate timescale="90000" presentationTimeOffset="3054857523"
        media="CNN/$RepresentationID$/Time$.m4s"
        initialization="CNN/init/$RepresentationID$.mp4">
        <SegmentTimeline>
          <S t="3054860526" d="360360" r="1" />
        </SegmentTimeline>
      </SegmentTemplate>
      <Representation id="VIDEO_7" width="352" height="198" .../>
      <Representation id="VIDEO_6" width="384" height="216" .../>
      <Representation id="VIDEO_5" width="480" height="270" .../>
      <Representation id="VIDEO_4" width="608" height="342" .../>
      <Representation id="VIDEO_3" width="768" height="432" .../>
      <Representation id="VIDEO_2" width="1024" height="576" .../>
      <Representation id="VIDEO_1" width="1280" height="720" .../>
      <Representation id="VIDEO_0" width="1280" height="720" .../>
    </AdaptationSet>
    <AdaptationSet id="1" mimeType="audio/mp4" segmentAlignment="true" bitstreamSwitching="true">
      <ContentProtection schemeIdUri="urn:mpeg:dash:mp4protection:2011" value="cenc" cenc:default_KID="..." />
      <ContentProtection schemeIdUri="urn:uuid:edef8ba9-79d6-4ace-a3c8-27dcd51d21ed" />
      <ContentProtection schemeIdUri="urn:uuid:9a04f079-9840-4286-ab92-e65be0885f95" />
      <InbandEventStream schemeIdUri="www.nielsen.com:id3:v1" value="1" />
      <SegmentTemplate timescale="90000" presentationTimeOffset="3054857523"
        media="CNN/$RepresentationID$/Time$.m4s"
        initialization="CNN/init/$RepresentationID$.mp4">
        <SegmentTimeline>
          <S t="3054861448" d="360960" />
          <S d="359040" />
        </SegmentTimeline>
      </SegmentTemplate>
      <Representation id="AUDIO" codecs="mp4a.40.2" audioSamplingRate="48000" startWithSAP="1" bandwidth="96000">
        <AudioChannelConfiguration schemeIdUri="urn:mpeg:dash:23003:3:audio_channel_configuration:2011" value="2" />
      </Representation>
    </AdaptationSet>
  </Period>
</MPD>
```

```
<?xml version="1.0" encoding="UTF-8"?>
<MPD type="dynamic" minBufferTime="PT1.0S" minimumUpdatePeriod="PT3.0S" suggestedPresentationDelay="PT8S" ...>
  <Period id="1" start="PT70406333.088S">
    <BaseURL serviceLocation="cdn-1">https://cdn-1.net/CNN/</BaseURL>
    <BaseURL serviceLocation="cdn-2">https://cdn-2.net/CNN/</BaseURL>
    <BaseURL serviceLocation="cdn-3">https://cdn-3.net/CNN/</BaseURL>
    <AdaptationSet id="2" mimeType="video/mp4" segmentAlignment="true" bitstreamSwitching="true" ...>
      <Accessibility schemeIdUri="urn:scte:dash:cc:cea-608:2015" value="CC1=eng"/>
      <ContentProtection schemeIdUri="urn:mpeg:dash:mp4protection:2011" value="cenc" cenc:default_KID="..." />
      <ContentProtection schemeIdUri="urn:uuid:edef8ba9-79d6-4ace-a3c8-27dcd51d21ed" />
      <ContentProtection schemeIdUri="urn:uuid:9a04f079-9840-4286-ab92-e65be0885f95" />
      <SegmentTemplate timescale="90000" presentationTimeOffset="3054857523"
        media="CNN/$RepresentationID$/Time$.m4s"
        initialization="CNN/init/$RepresentationID$.mp4">
        <SegmentTimeline>
          <S t="3054860526" d="360360" r="2" />
        </SegmentTimeline>
      </SegmentTemplate>
      <Representation id="VIDEO_7" width="352" height="198" .../>
      <Representation id="VIDEO_6" width="384" height="216" .../>
      <Representation id="VIDEO_5" width="480" height="270" .../>
      <Representation id="VIDEO_4" width="608" height="342" .../>
      <Representation id="VIDEO_3" width="768" height="432" .../>
      <Representation id="VIDEO_2" width="1024" height="576" .../>
      <Representation id="VIDEO_1" width="1280" height="720" .../>
      <Representation id="VIDEO_0" width="1280" height="720" .../>
    </AdaptationSet>
    <AdaptationSet id="1" mimeType="audio/mp4" segmentAlignment="true" bitstreamSwitching="true">
      <ContentProtection schemeIdUri="urn:mpeg:dash:mp4protection:2011" value="cenc" cenc:default_KID="..." />
      <ContentProtection schemeIdUri="urn:uuid:edef8ba9-79d6-4ace-a3c8-27dcd51d21ed" />
      <ContentProtection schemeIdUri="urn:uuid:9a04f079-9840-4286-ab92-e65be0885f95" />
      <InbandEventStream schemeIdUri="www.nielsen.com:id3:v1" value="1" />
      <SegmentTemplate timescale="90000" presentationTimeOffset="3054857523"
        media="CNN/$RepresentationID$/Time$.m4s"
        initialization="CNN/init/$RepresentationID$.mp4">
        <SegmentTimeline>
          <S t="3054861448" d="360960" />
          <S d="359040" />
          <S d="360960" />
        </SegmentTimeline>
      </SegmentTemplate>
      <Representation id="AUDIO" codecs="mp4a.40.2" audioSamplingRate="48000" startWithSAP="1" bandwidth="96000">
        <AudioChannelConfiguration schemeIdUri="urn:mpeg:dash:23003:3:audio_channel_configuration:2011" value="2" />
      </Representation>
    </AdaptationSet>
  </Period>
</MPD>
```

# Changes Across Updates

```
<?xml version="1.0" encoding="UTF-8"?>
<MPD type="dynamic" minBufferTime="PT1.0S" minimumUpdatePeriod="PT3.0S" suggestedPresentationDelay="PT8S" ...>
  <Period id="1" start="PT70406333.088S">
    <BaseURL serviceLocation="cdn-1">https://cdn-1.net/CNN/</BaseURL>
    <BaseURL serviceLocation="cdn-2">https://cdn-2.net/CNN/</BaseURL>
    <BaseURL serviceLocation="cdn-3">https://cdn-3.net/CNN/</BaseURL>
    <AdaptationSet id="2" mimeType="video/mp4" segmentAlignment="true" bitstreamSwitching="true" ...>
      <Accessibility schemeIdUri="urn:scte:dash:cc:cea-608:2015" value="CC1=eng"/>
      <ContentProtection schemeIdUri="urn:mpeg:dash:mp4protection:2011" value="cenc" cenc:default_KID="..." />
      <ContentProtection schemeIdUri="urn:uuid:edef8ba9-79d6-4ace-a3c8-27dcd51d21ed" />
      <ContentProtection schemeIdUri="urn:uuid:9a04f079-9840-4286-ab92-e65be0885f95" />
      <SegmentTemplate timescale="90000" presentationTimeOffset="3054857523"
        media="CNN/$RepresentationID$/Time$.m4s"
        initialization="CNN/init/$RepresentationID$.mp4">
        <SegmentTimeline>
          <S t="3054860526" d="360360" r="1" />
        </SegmentTimeline>
      </SegmentTemplate>
      <Representation id="VIDEO_7" width="352" height="198" .../>
      <Representation id="VIDEO_6" width="384" height="216" .../>
      <Representation id="VIDEO_5" width="480" height="270" .../>
      <Representation id="VIDEO_4" width="608" height="342" .../>
      <Representation id="VIDEO_3" width="768" height="432" .../>
      <Representation id="VIDEO_2" width="1024" height="576" .../>
      <Representation id="VIDEO_1" width="1280" height="720" .../>
      <Representation id="VIDEO_0" width="1280" height="720" .../>
    </AdaptationSet>
    <AdaptationSet id="1" mimeType="audio/mp4" segmentAlignment="true" bitstreamSwitching="true">
      <ContentProtection schemeIdUri="urn:mpeg:dash:mp4protection:2011" value="cenc" cenc:default_KID="..." />
      <ContentProtection schemeIdUri="urn:uuid:edef8ba9-79d6-4ace-a3c8-27dcd51d21ed" />
      <ContentProtection schemeIdUri="urn:uuid:9a04f079-9840-4286-ab92-e65be0885f95" />
      <InbandEventStream schemeIdUri="www.nielsen.com:id3:v1" value="1" />
      <SegmentTemplate timescale="90000" presentationTimeOffset="3054857523"
        media="CNN/$RepresentationID$/Time$.m4s"
        initialization="CNN/init/$RepresentationID$.mp4">
        <SegmentTimeline>
          <S t="3054861448" d="360960" />
          <S d="359040" />
        </SegmentTimeline>
      <Representation id="AUDIO" codecs="mp4a.40.2" audioSamplingRate="48000" startWithSAP="1" bandwidth="96000">
        <AudioChannelConfiguration schemeIdUri="urn:mpeg:dash:23003:3:audio_channel_configuration:2011" value="2" />
      </Representation>
    </AdaptationSet>
  </Period>
</MPD>
```

```
<?xml version="1.0" encoding="UTF-8"?>
<MPD type="dynamic" minBufferTime="PT1.0S" minimumUpdatePeriod="PT3.0S" suggestedPresentationDelay="PT8S" ...>
  <Period id="1" start="PT70406333.088S">
    <BaseURL serviceLocation="cdn-1">https://cdn-1.net/CNN/</BaseURL>
    <BaseURL serviceLocation="cdn-2">https://cdn-2.net/CNN/</BaseURL>
    <BaseURL serviceLocation="cdn-3">https://cdn-3.net/CNN/</BaseURL>
    <AdaptationSet id="2" mimeType="video/mp4" segmentAlignment="true" bitstreamSwitching="true" ...>
      <Accessibility schemeIdUri="urn:scte:dash:cc:cea-608:2015" value="CC1=eng"/>
      <ContentProtection schemeIdUri="urn:mpeg:dash:mp4protection:2011" value="cenc" cenc:default_KID="..." />
      <ContentProtection schemeIdUri="urn:uuid:edef8ba9-79d6-4ace-a3c8-27dcd51d21ed" />
      <ContentProtection schemeIdUri="urn:uuid:9a04f079-9840-4286-ab92-e65be0885f95" />
      <SegmentTemplate timescale="90000" presentationTimeOffset="3054857523"
        media="CNN/$RepresentationID$/Time$.m4s"
        initialization="CNN/init/$RepresentationID$.mp4">
        <SegmentTimeline>
          <S t="3054860526" d="360360" r="2" />
        </SegmentTimeline>
      </SegmentTemplate>
      <Representation id="VIDEO_7" width="352" height="198" .../>
      <Representation id="VIDEO_6" width="384" height="216" .../>
      <Representation id="VIDEO_5" width="480" height="270" .../>
      <Representation id="VIDEO_4" width="608" height="342" .../>
      <Representation id="VIDEO_3" width="768" height="432" .../>
      <Representation id="VIDEO_2" width="1024" height="576" .../>
      <Representation id="VIDEO_1" width="1280" height="720" .../>
      <Representation id="VIDEO_0" width="1280" height="720" .../>
    </AdaptationSet>
    <AdaptationSet id="1" mimeType="audio/mp4" segmentAlignment="true" bitstreamSwitching="true">
      <ContentProtection schemeIdUri="urn:mpeg:dash:mp4protection:2011" value="cenc" cenc:default_KID="..." />
      <ContentProtection schemeIdUri="urn:uuid:edef8ba9-79d6-4ace-a3c8-27dcd51d21ed" />
      <ContentProtection schemeIdUri="urn:uuid:9a04f079-9840-4286-ab92-e65be0885f95" />
      <InbandEventStream schemeIdUri="www.nielsen.com:id3:v1" value="1" />
      <SegmentTemplate timescale="90000" presentationTimeOffset="3054857523"
        media="CNN/$RepresentationID$/Time$.m4s"
        initialization="CNN/init/$RepresentationID$.mp4">
        <SegmentTimeline>
          <S t="3054861448" d="360960" />
          <S d="359040" />
          <S d="360960" />
        </SegmentTimeline>
      <Representation id="AUDIO" codecs="mp4a.40.2" audioSamplingRate="48000" startWithSAP="1" bandwidth="96000">
        <AudioChannelConfiguration schemeIdUri="urn:mpeg:dash:23003:3:audio_channel_configuration:2011" value="2" />
      </Representation>
    </AdaptationSet>
  </Period>
</MPD>
```

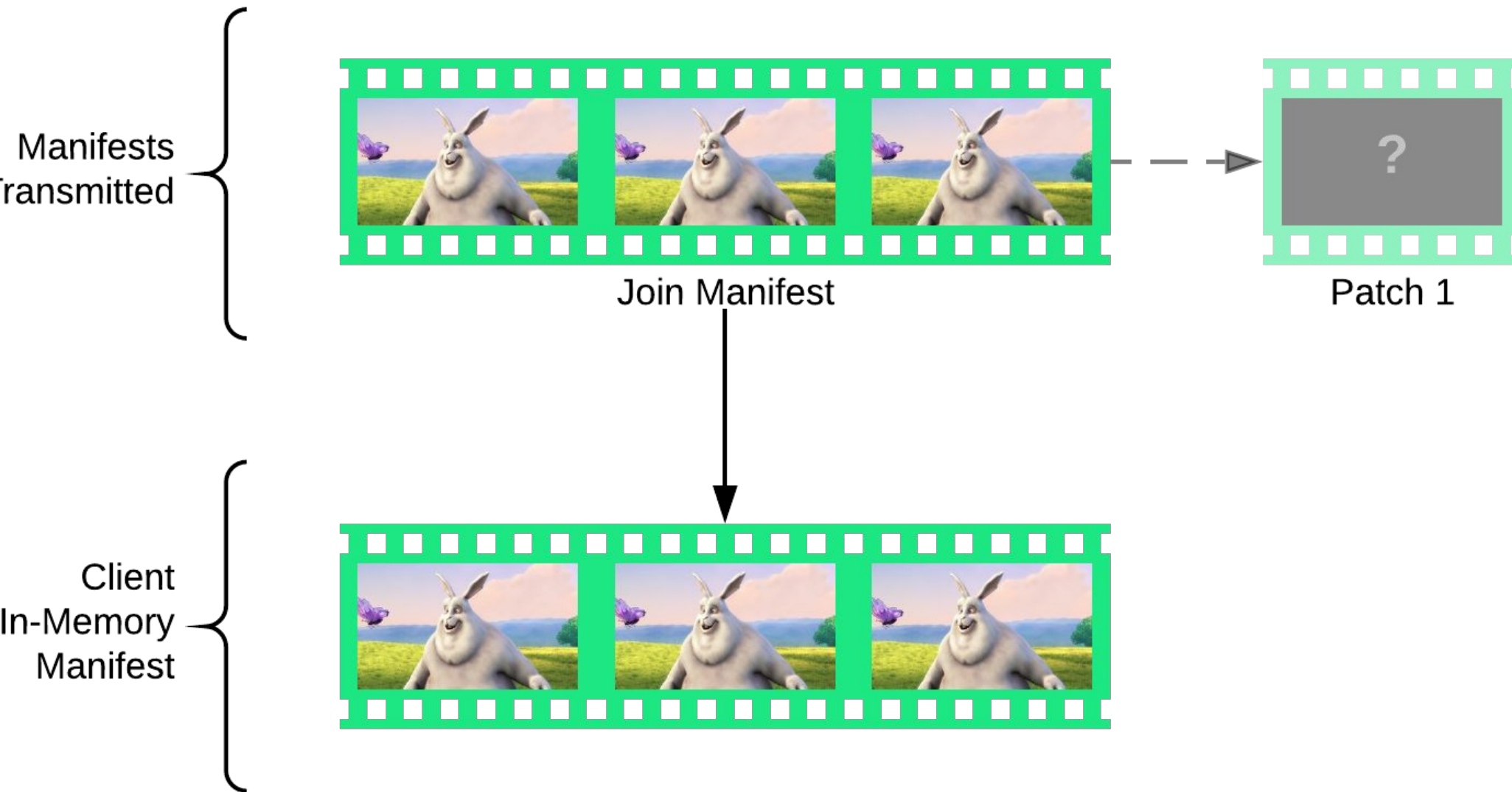
## Optimizing Update Requests

---

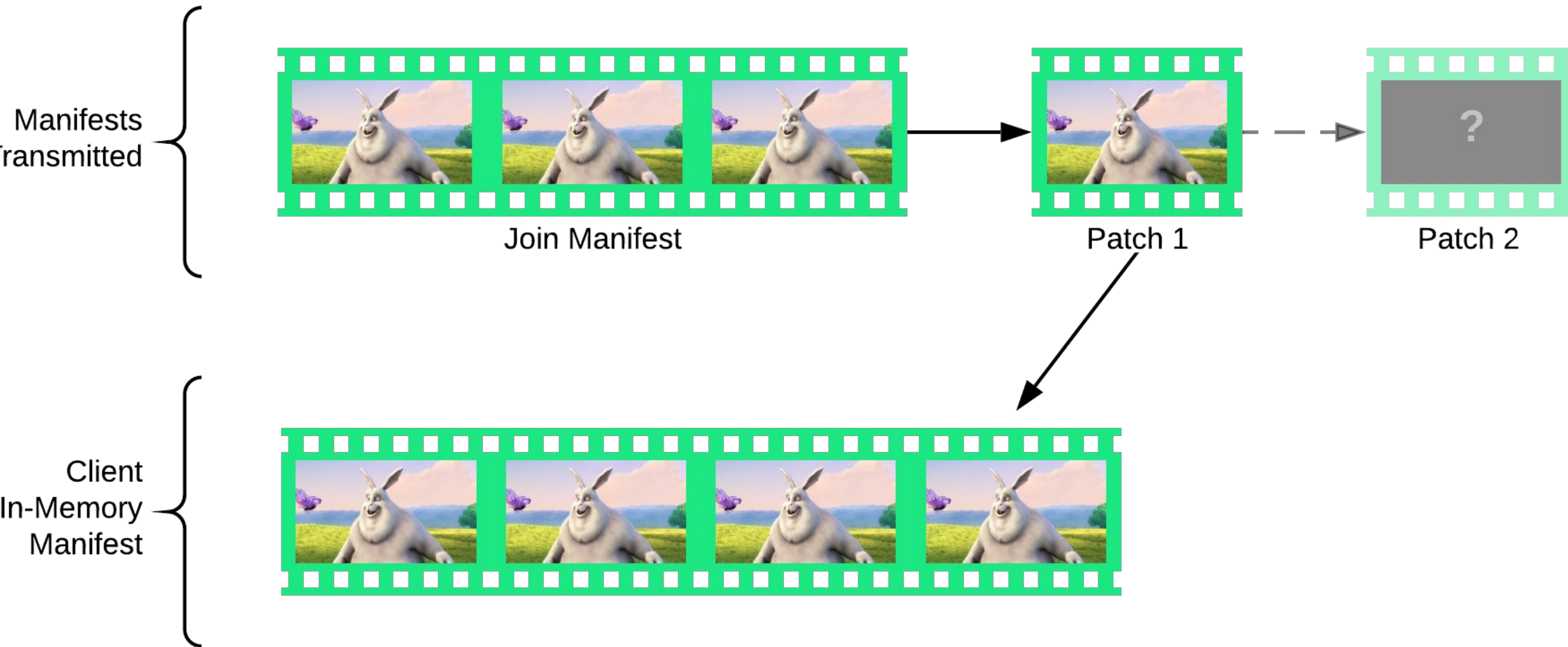
- Solution Constraints
  - Send only new information to clients
  - Maintain response caching
  - Minimize request client processing
  - Keep server in control of playout
- Created the Patch Manifest concept
  - Special server update response
  - Leverages MPD structure semantics
  - Uses client persisted breadcrumbing
  - Relies on client timeline persistence



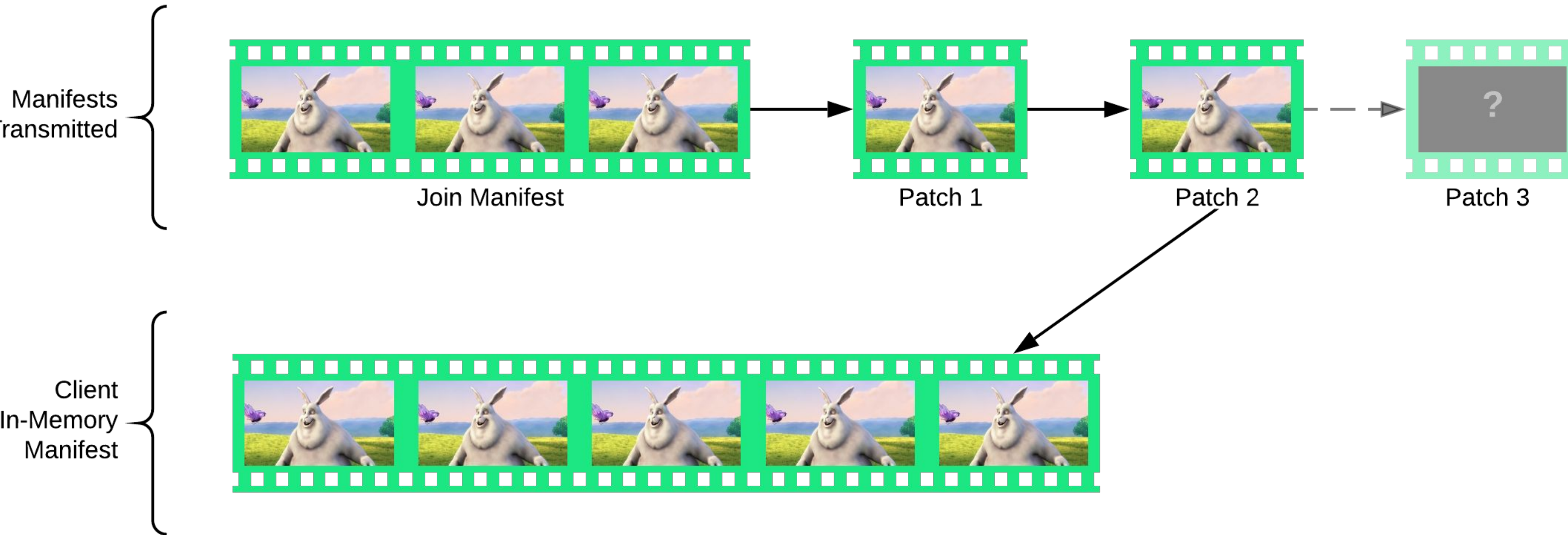
# Patch Manifest Playout



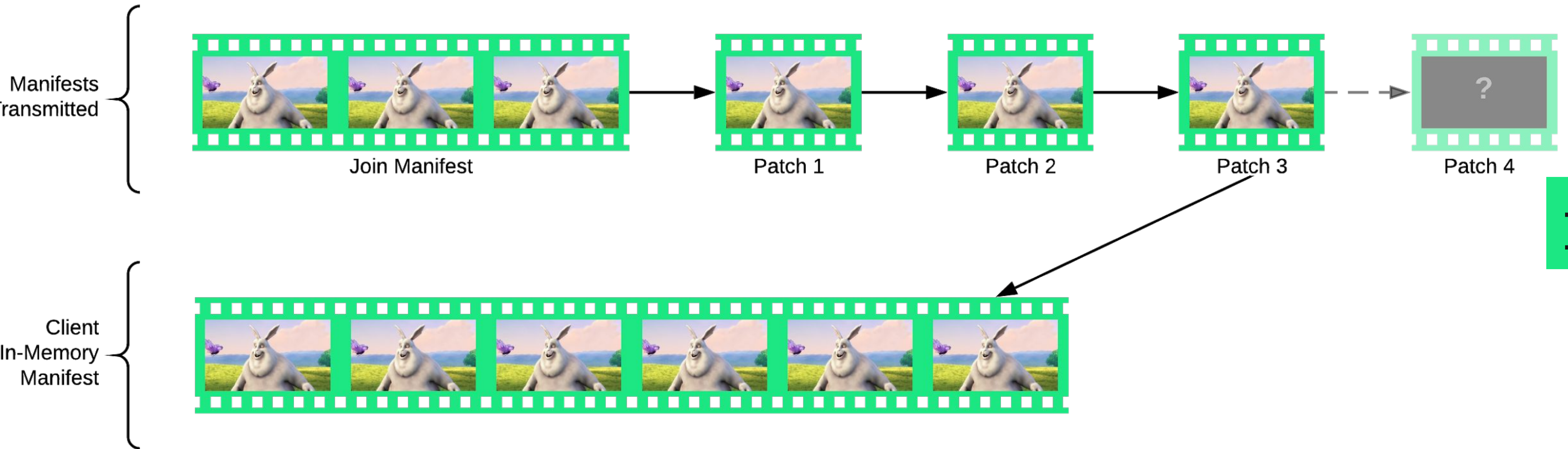
# Patch Manifest Playout



# Patch Manifest Playout



# Patch Manifest Playout



# Anatomy of a Join Manifest

```
<?xml version="1.0" encoding="UTF-8"?>
<MPD type="dynamic" minBufferTime="PT1.0S" minimumUpdatePeriod="PT3.0S" suggestedPresentationDelay="PT8S" ...>
  <SupplementalProperty schemeIdUri="urn:com:hulu:schema:mpd:2017:patch">
    <Location>/patch_playlist/CNN.mpd?period=1&video=5095823234&audio=5095823752</Location>
  </SupplementalProperty>
  <Period id="1" start="PT70715052.772S">
    <BaseURL serviceLocation="cdn-1">https://cdn-1.net/CNN/</BaseURL>
    <BaseURL serviceLocation="cdn-2">https://cdn-2.net/CNN/</BaseURL>
    <BaseURL serviceLocation="cdn-3">https://cdn-3.net/CNN/</BaseURL>
    <AdaptationSet id="2" mimeType="video/mp4" segmentAlignment="true" bitstreamSwitching="true" ...>
      <Accessibility schemeIdUri="urn:scte:dash:cc:cea-608:2015" value="CC1=eng"/>
      <ContentProtection schemeIdUri="urn:mpeg:dash:mp4protection:2011" value="cenc" cenc:default_KID="..." />
      <ContentProtection schemeIdUri="urn:uuid:9a04f079-9840-4286-ab92-e65be0885f95" />
      <ContentProtection schemeIdUri="urn:uuid:edef8ba9-79d6-4ace-a3c8-27dcd51d21ed" />
      <SegmentTemplate timescale="90000" presentationTimeOffset="5069874311"
        media="CNN/$RepresentationID$/Time$.m4s"
        initialization="CNN/init/$RepresentationID$.mp4">
        <SegmentTimeline>
          <S t="5069877314" d="360360" r="71" />
        </SegmentTimeline>
      </SegmentTemplate>
      <Representation id="VIDEO_7" width="352" height="198" .../>
      <Representation id="VIDEO_6" width="384" height="216" .../>
      <Representation id="VIDEO_5" width="480" height="270" .../>
      ...
    </AdaptationSet>
  </Period>
</MPD>
```

# Anatomy of a Join Manifest

```

<?xml version="1.0" encoding="UTF-8"?>
<MPD type="dynamic" minBufferTime="PT1.0S" minimumUpdatePeriod="PT3.0S" suggestedPresentationDelay="PT8S" ...>
  <SupplementalProperty schemeIdUri="urn:com:hulu:schema:mpd:2017:patch">
    <Location>/patch_playlist/CNN.mpd?period=1&video=5095823234&audio=5095823752</Location>
  </SupplementalProperty>
  <Period id="1" start="PT0/15052.772S">
    <BaseURL serviceLocation="cdn-1">https://cdn-1.net/CNN/</BaseURL>
    <BaseURL serviceLocation="cdn-2">https://cdn-2.net/CNN/</BaseURL>
    <BaseURL serviceLocation="cdn-3">https://cdn-3.net/CNN/</BaseURL>
    <AdaptationSet id="2" mimeType="video/mp4" segmentAlignment="true" bitstreamSwitching="true" ...>
      <Accessibility schemeIdUri="urn:scte:dash:cc:cea-608:2015" value="CC1=eng"/>
      <ContentProtection schemeIdUri="urn:mpeg:dash:mp4protection:2011" value="cenc" cenc:default_KID="..." />
      <ContentProtection schemeIdUri="urn:uuid:9a04f079-9840-4286-ab92-e65be0885f95" />
      <ContentProtection schemeIdUri="urn:uuid:edef8ba9-79d6-4ace-a3c8-27dcd51d21ed" />
      <SegmentTemplate timescale="90000" presentationTimeOffset="5069874311"
        media="CNN/$RepresentationID$/Time$.m4s"
        initialization="CNN/init/$RepresentationID$.mp4">
        <SegmentTimeline>
          <S t="5069877314" d="360360" r="71" />
        </SegmentTimeline>
      </SegmentTemplate>
      <Representation id="VIDEO_7" width="352" height="198" .../>
      <Representation id="VIDEO_6" width="384" height="216" .../>
      <Representation id="VIDEO_5" width="480" height="270" .../>
      ...
    </AdaptationSet>
  </Period>
</MPD>

```

# Anatomy of a Patch Manifest

```
<?xml version="1.0" encoding="UTF-8"?>
<MPD ...>
  <EssentialProperty schemeIdUri="urn:com:hulu:schema:mpd:2017:patch" />
  <Location>/patch_playlist/CNN.mpd?period=1&video=5096183594&audio=5096184712</Location>
  <Period id="1">
    <AdaptationSet id="2">
      <SegmentTemplate>
        <SegmentTimeline>
          <S t="5095823234" d="360360" />
        </SegmentTimeline>
      </SegmentTemplate>
    </AdaptationSet>
    <AdaptationSet id="1">
      <SegmentTemplate>
        <SegmentTimeline>
          <S t="5095823752" d="360960" />
        </SegmentTimeline>
      </SegmentTemplate>
    </AdaptationSet>
  </Period>
</MPD>
```

## Patch Manifests

---

- By The Numbers
  - 15 XML Nodes
  - 1KB Uncompressed Size
  - ~3ms Parse Time
- Successfully Deployed Solution
  - Constant cost addition over time
  - Efficient for network and client
  - No reduction in cache efficiency
  - Server fully in control of timeline
- Proposed back to MPEG-DASH



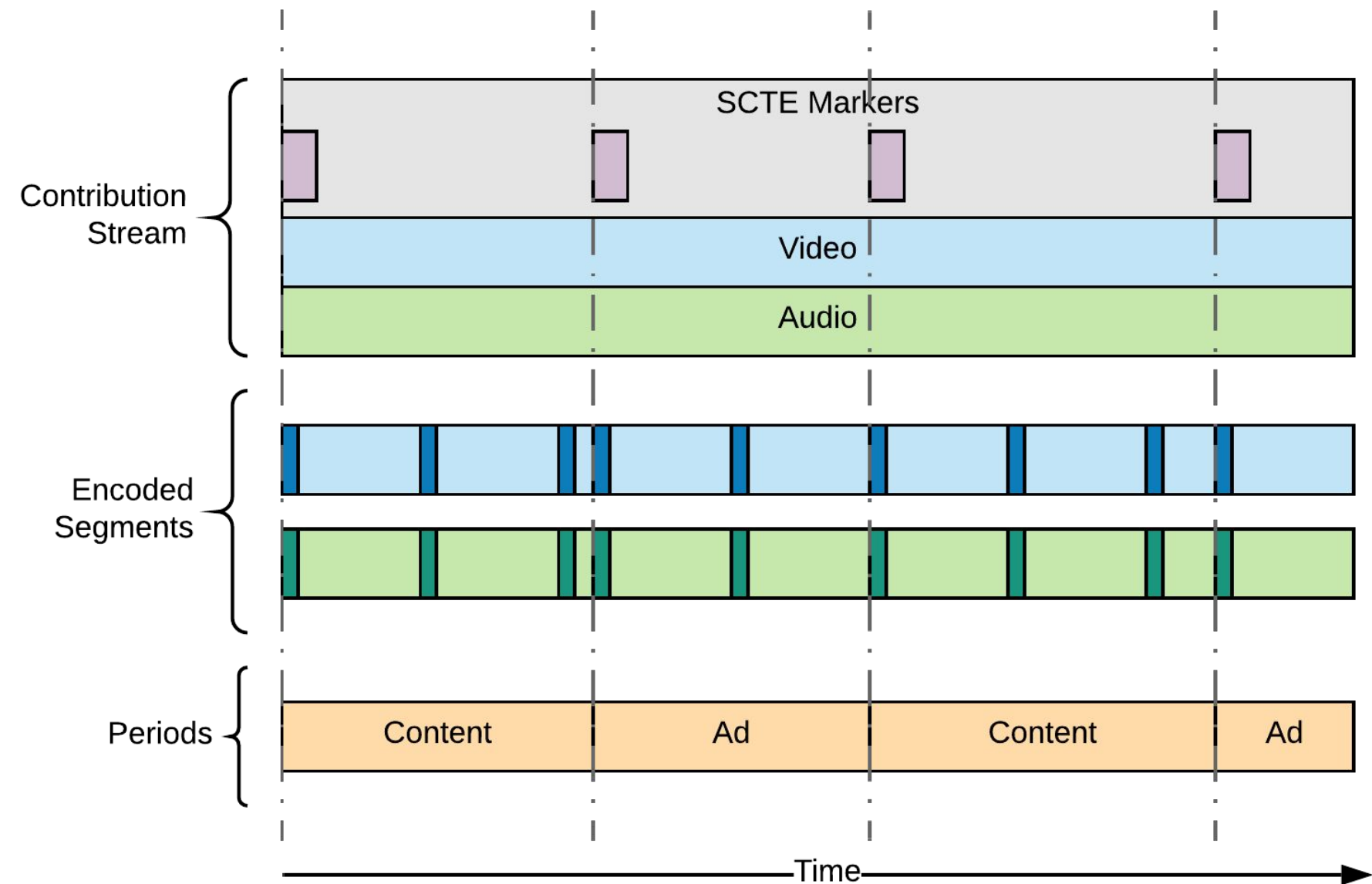
Scaling Live OTT with DASH

# Dynamic Ad Replacement

hulu

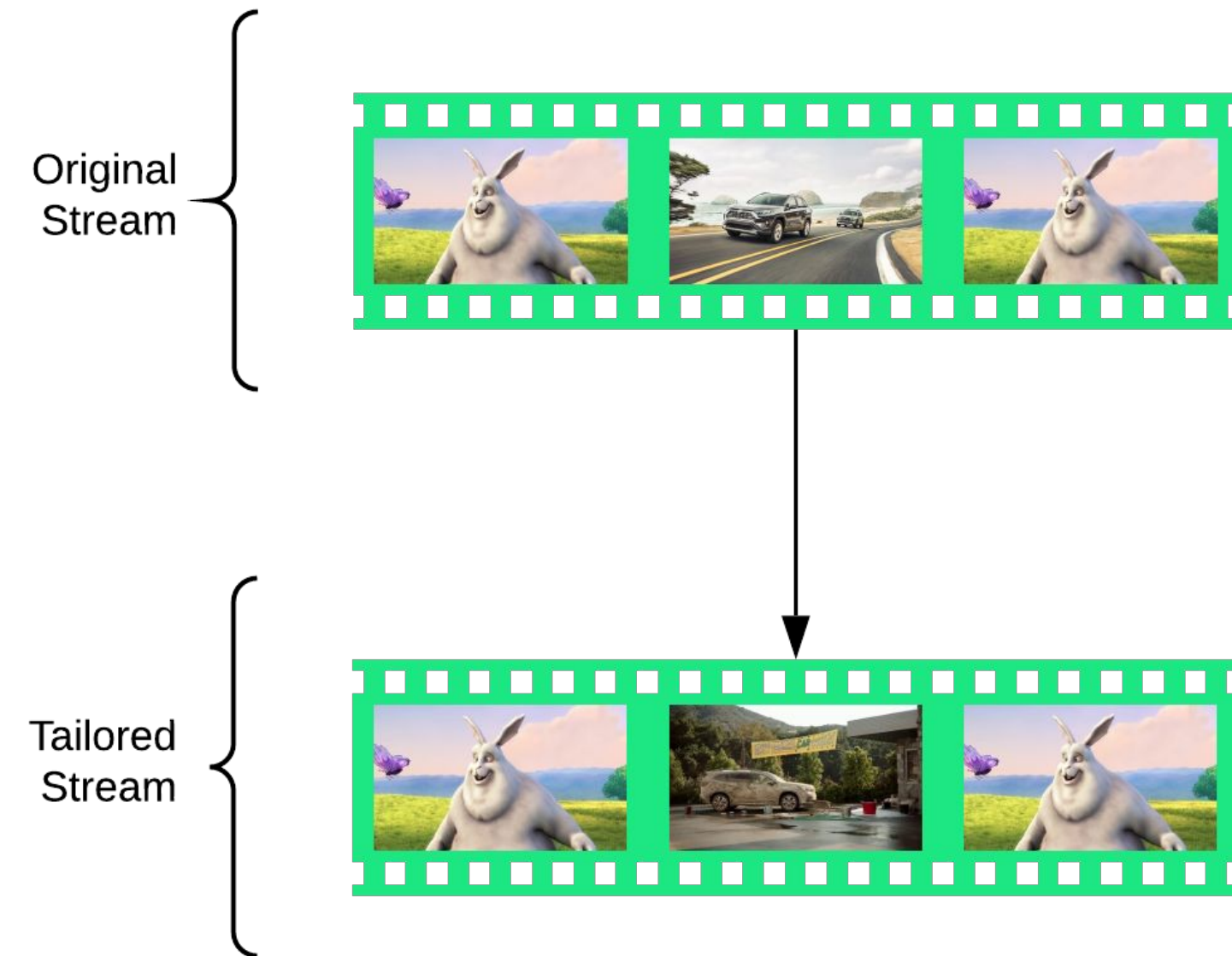
# Preparing Streams for Ad Replacement

- SCTE-35 Identifies Opportunities
  - Ingest stream contains markers
  - Encoders force segment boundaries at markers
- Opportunities Translated to Periods
  - Consistency with VOD model
  - SCTE signals too inconsistent for client processing

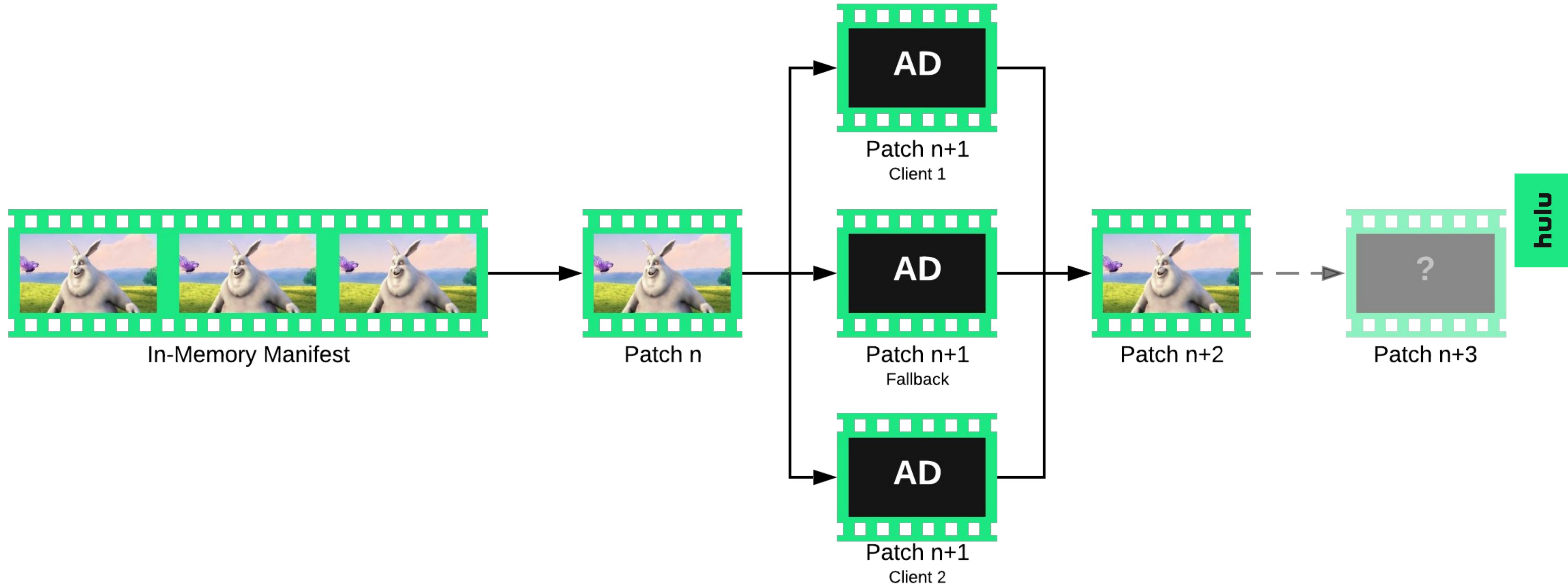


# Replacing In Stream Ads

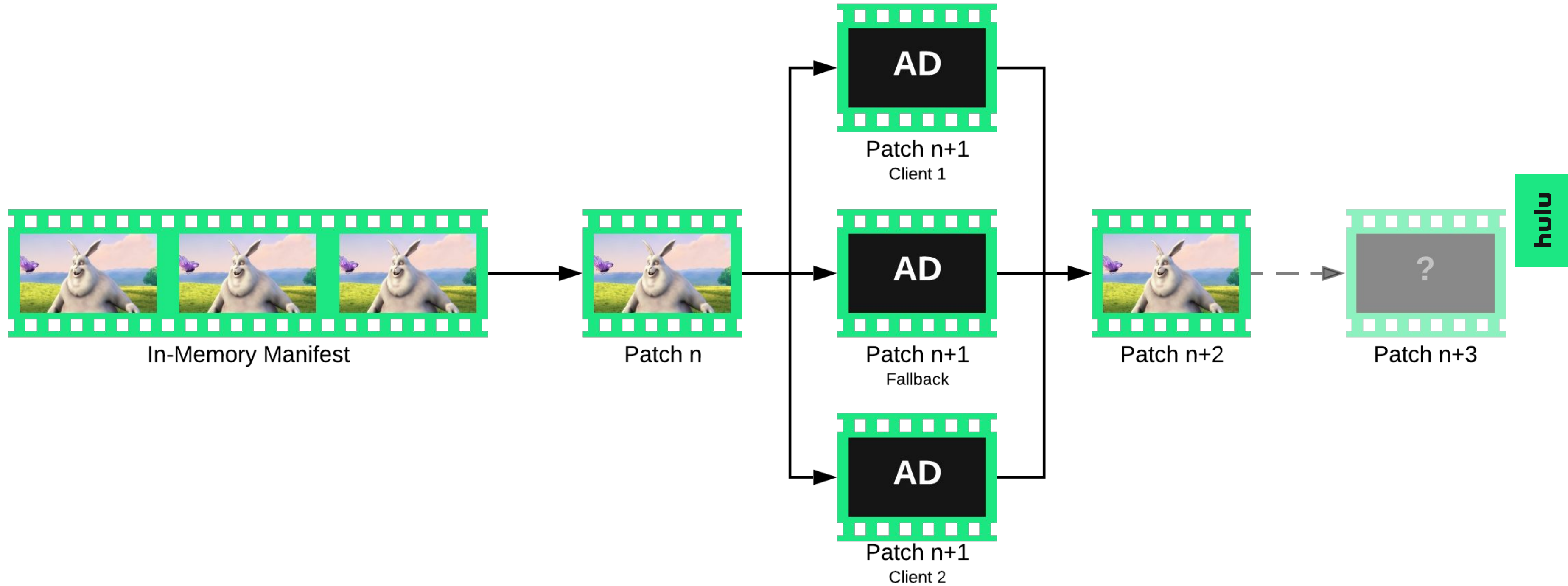
- Simple Period Replacement
  - Use SCTE-35 signalled duration
  - Frame accurate replacement
  - Advertisement Data contained in Period EventStream
- Ad Targeting Impacts Cacheability
  - Caching granularity tied to targeting
  - OTT wants per user targeting



# Supporting Per User Targeting with Patch Manifests



# Supporting Per User Targeting with Patch Manifests



Find out how this works at Demuxed 2019!

**hulu**

**THANK YOU**

**hulu**

**Q&A**