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DASH Live Streaming at Scale

Portland Video Meetup, December 2019

DASH Live Streaming at Scale

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Video Platform Architect


DASH Live Streaming at Scale
Hulu is TV
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Content Catalog

Device Ecosystem

In-House Ad Services

Topics Today

- **Basics of a Live Stream**
  - Live Streaming with DASH
  - Optimizing for Scale
  - MPD Patch Updates
- **Dynamic Ad Replacement**
  - Requirements of Ad Targeting
  - Server-Guided Ad Insertion
  - Returning from a Replacement
- **Q&A**

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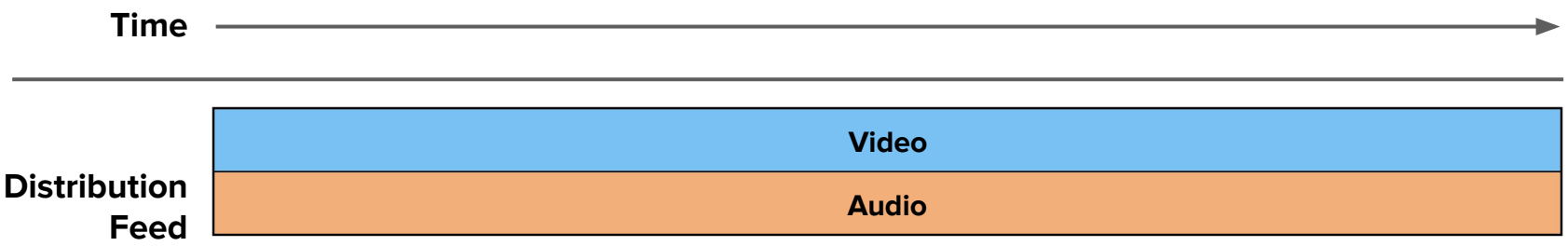
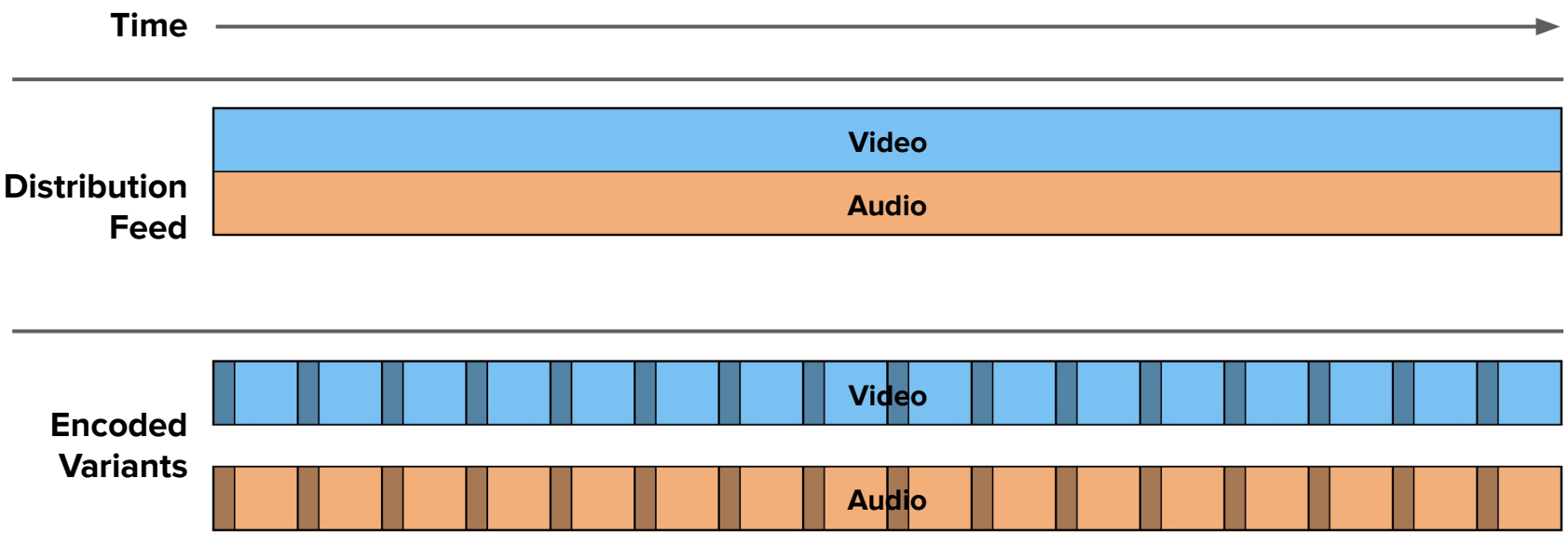
Basics of a Live Stream

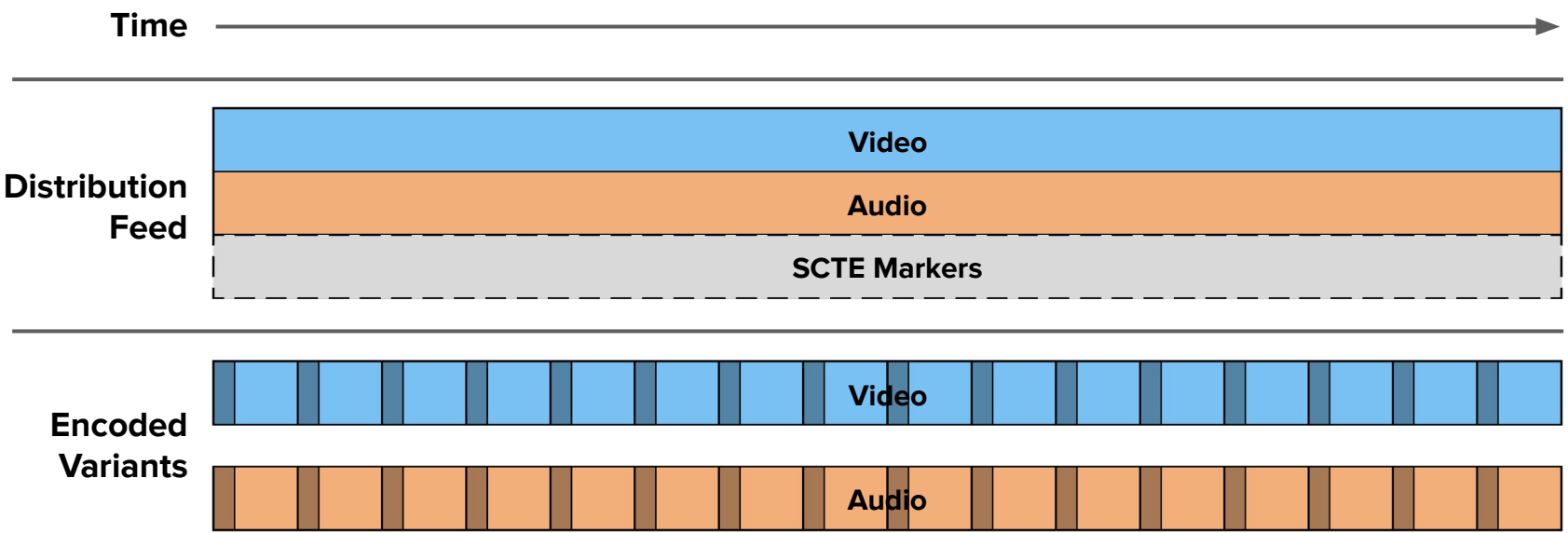
Basics of a Live Stream



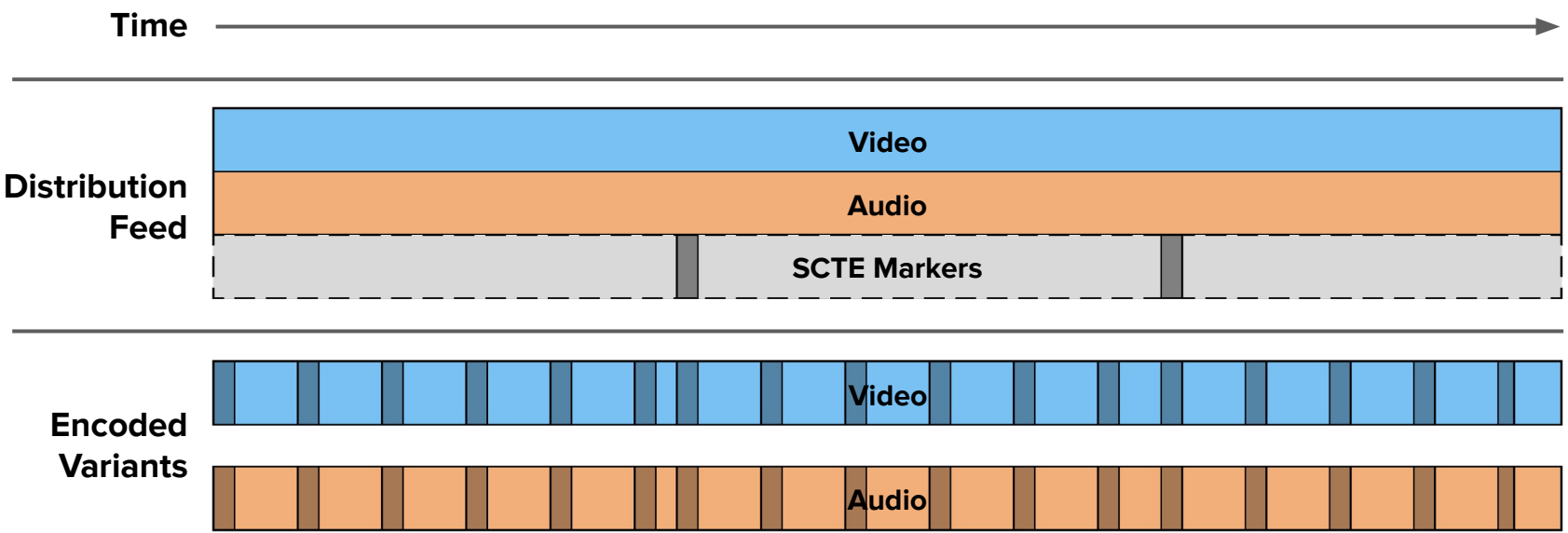
Basics of a Live Stream



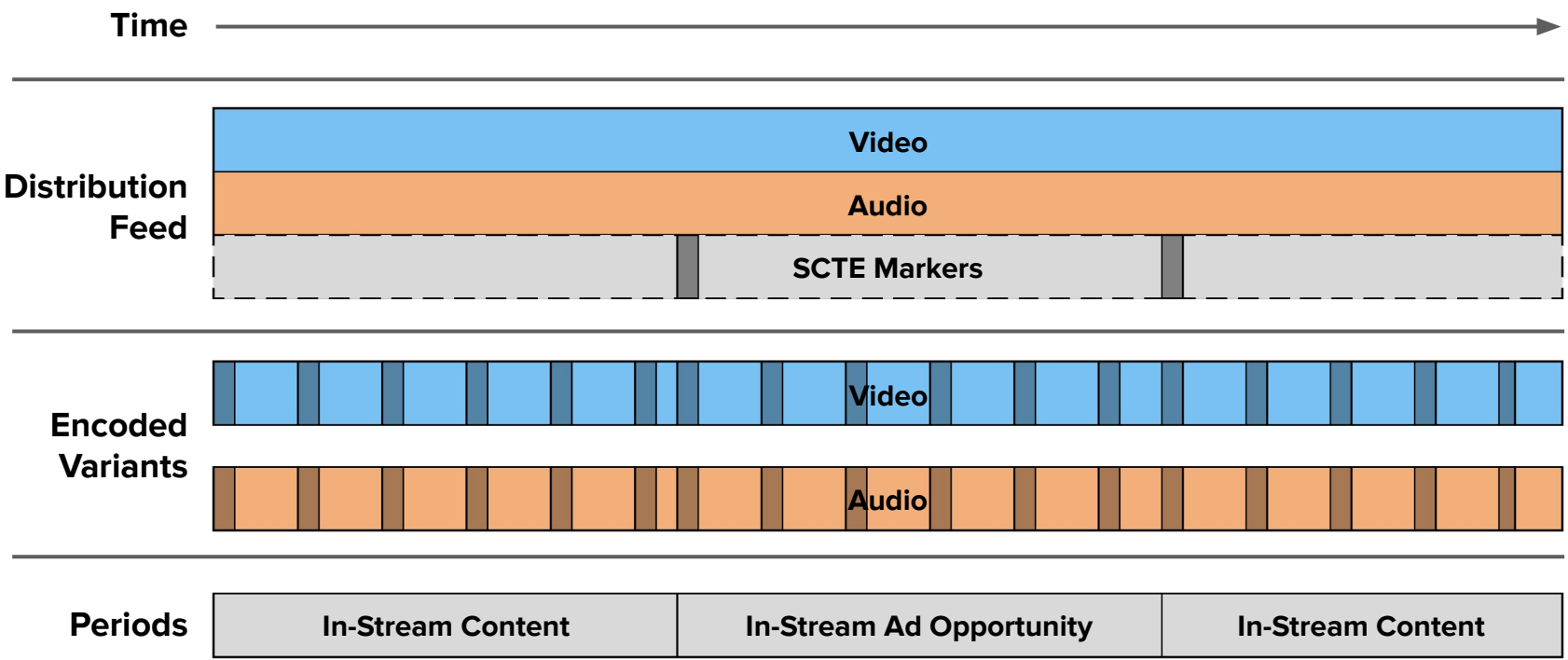
Basics of a Live Stream



Basics of a Live Stream

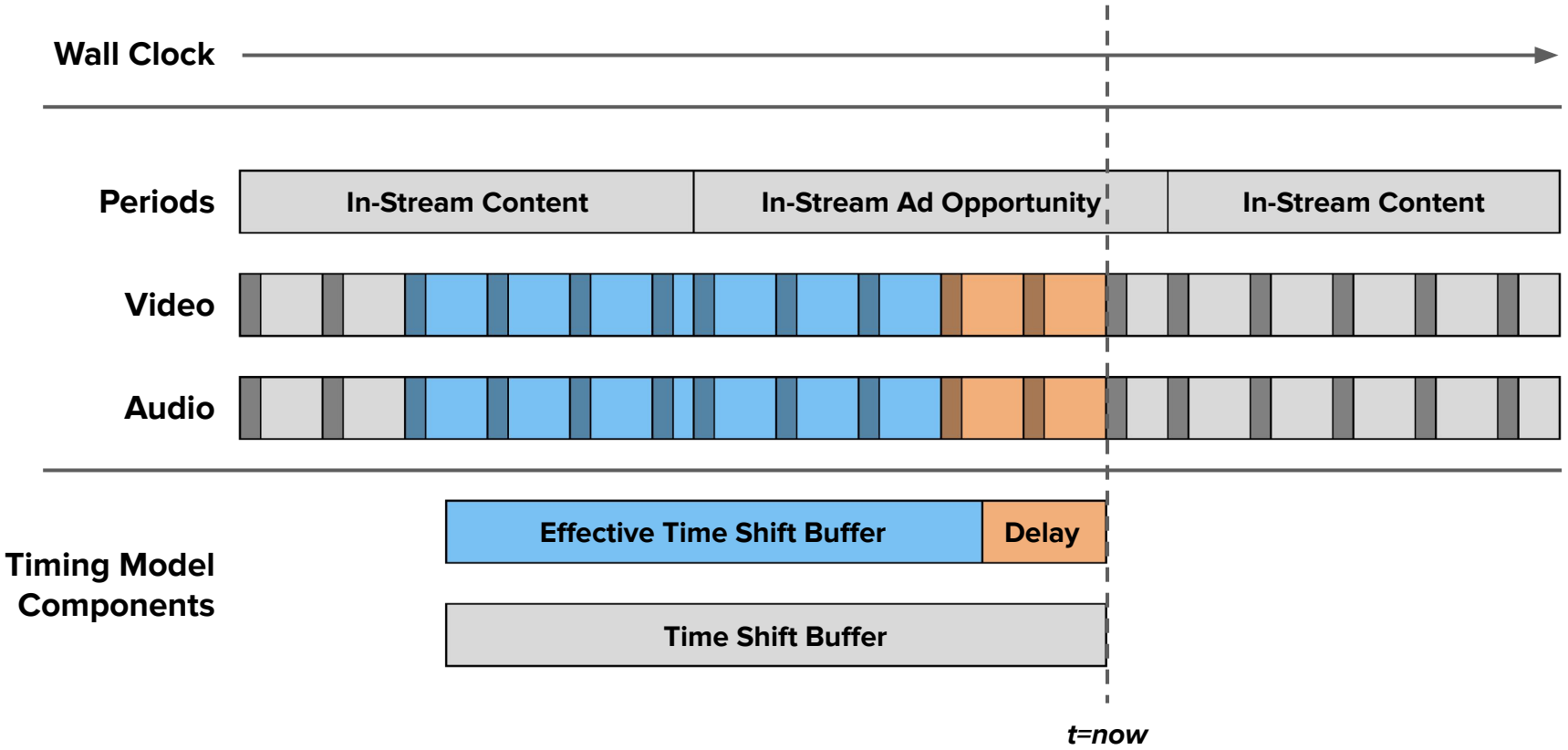


Basics of a Live Stream

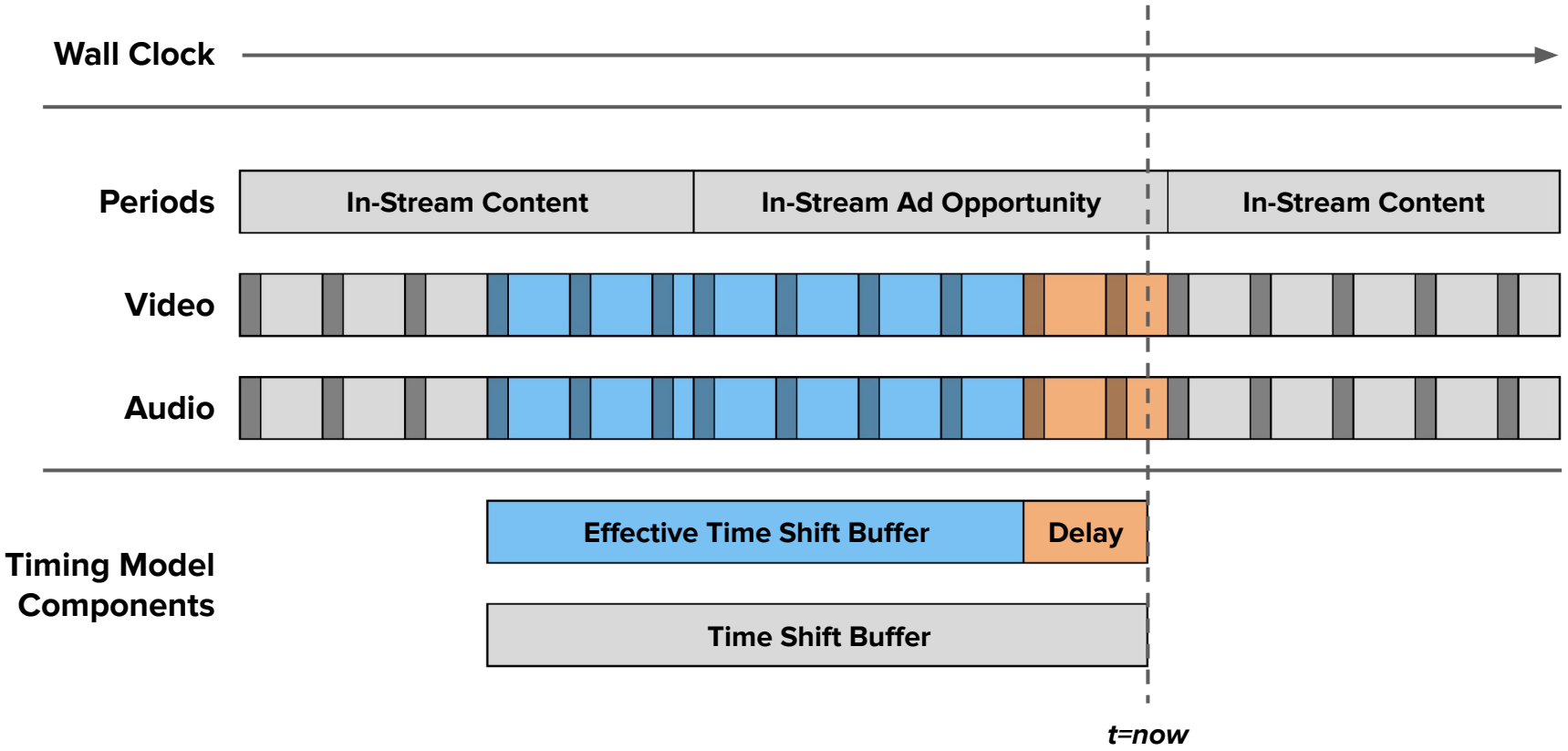


Live Streaming with DASH

The Timing Model



The Timing Model



Segment Addressing

```
channel/init/video.mp4
channel/video/1.m4s
channel/video/2.m4s
channel/video/3.m4s
channel/video/4.m4s
channel/video/5.m4s
channel/video/6.m4s
channel/video/7.m4s
channel/video/8.m4s
channel/video/9.m4s
```

Segment Addressing: HLS

```
channel/init/video.mp4
channel/video/1.m4s
channel/video/2.m4s
channel/video/3.m4s
channel/video/4.m4s
channel/video/5.m4s
channel/video/6.m4s
channel/video/7.m4s
channel/video/8.m4s
channel/video/9.m4s
```

```
#EXTM3U
#EXT-X-TARGETDURATION:4
#EXT-X-VERSION:4
#EXT-X-MEDIA-SEQUENCE:1
#EXT-X-MAP:URI="channel/init/video.mp4"
#EXTINF:4.004
channel/video/1.m4s
#EXTINF:4.004
channel/video/2.m4s
#EXTINF:4.004
channel/video/3.m4s
#EXTINF:4.004
channel/video/4.m4s
#EXTINF:4.004
channel/video/5.m4s
#EXTINF:4.004
...
```

Segment Addressing: SegmentList

```
channel/init/video.mp4
channel/video/1.m4s
channel/video/2.m4s
channel/video/3.m4s
channel/video/4.m4s
channel/video/5.m4s
channel/video/6.m4s
channel/video/7.m4s
channel/video/8.m4s
channel/video/9.m4s
```

Segment Addressing: SegmentTemplate with $Number$

```
channel/init/video.mp4
channel/video/1.m4s
channel/video/2.m4s
channel/video/3.m4s
channel/video/4.m4s
channel/video/5.m4s
channel/video/6.m4s
channel/video/7.m4s
channel/video/8.m4s
channel/video/9.m4s
```

```
<SegmentTemplate timescale="90000"
    duration="360360"
    startNumber="1"
    media="channel/video/$Number$.m4s"
    initialization="channel/init/video.mp4">
</SegmentTemplate>
```

Segment Addressing: SegmentTemplate with $Time$

```
channel/init/video.mp4
channel/video/1.m4s
channel/video/2.m4s
channel/video/3.m4s
channel/video/4.m4s
channel/video/5.m4s
channel/video/6.m4s
channel/video/7.m4s
channel/video/8.m4s
channel/video/9.m4s
```

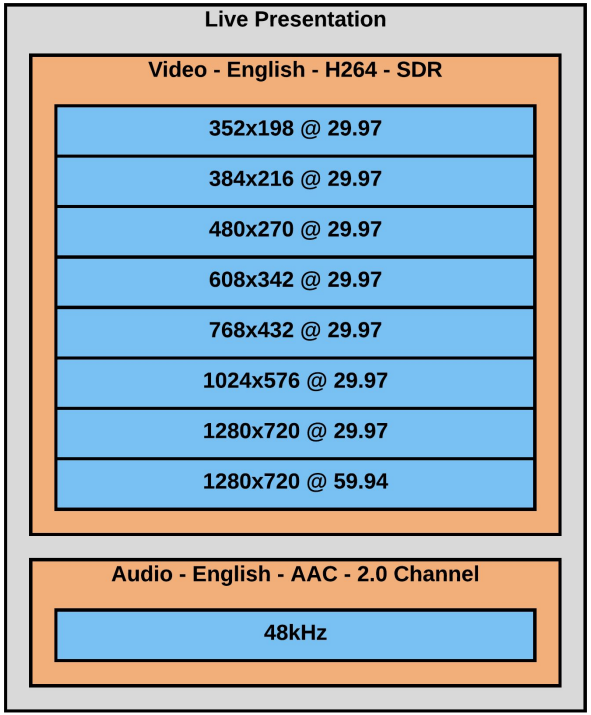
```
<SegmentTemplate timescale="90000"
    presentationTimeOffset="3054136803"
    media="channel/video/$Time$.m4s"
    initialization="channel/init/video.mp4">
    <SegmentTimeline>
        <S t="3054139806" d="360360"/>
        <S t="3054500166" d="360360"/>
        <S t="3054860526" d="360360"/>
        <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

```
<Period id="1" start="...">
    <BaseURL serviceLocation="cdn-1">https://www.cdn1.com/</BaseURL>
    <BaseURL serviceLocation="cdn-2">https://www.cdn2.com/</BaseURL>
    <BaseURL serviceLocation="cdn-3">https://www.cdn3.com/</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/channel/</BaseURL>
    <BaseURL serviceLocation="cdn-2">https://cdn-2.net/channel/</BaseURL>
    <BaseURL serviceLocation="cdn-3">https://cdn-3.net/channel/</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="channel/VIDEO_7/$Time$.m4s"
          initialization="channel/init/VIDEO_7.mp4">
          <SegmentTimeline>
            <S t="3054139806" d="360360"/>
```

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="channel/VIDEO_6/$Time$.m4s"
      initialization="channel/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"/>
```

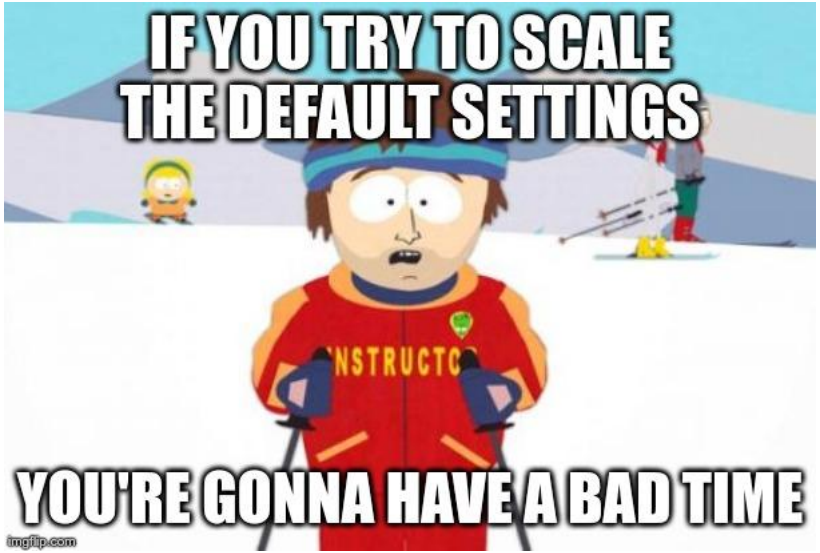

MOMENTS
LATER...

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

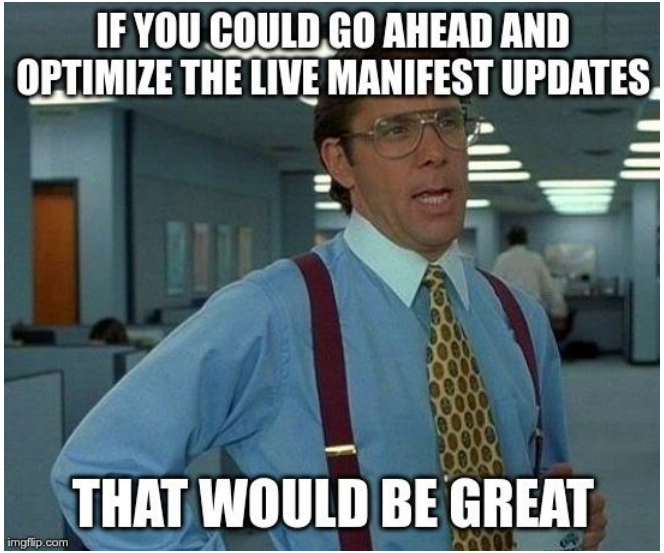
- By The Numbers
  - 694 XML Nodes
  - 46KB Uncompressed Size
  - ~30ms Parse Time
- Simply Does Not Scale
  - 1 hour => 8665 Nodes, 573KB
  - 3 hours => 26512 Nodes, 1.9MB
- What Makes The Manifest So Big?
  - Explicit segment addressing
  - Usage of multiple periods



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 Holistically



Compress the Timelines: Omit S@t for Consecutive Segments

```
<SegmentTemplate timescale="90000"
    presentationTimeOffset="3054136803"
    media="channel/video/$Time$.m4s"
    initialization="channel/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>
```

```
<SegmentTemplate timescale="90000"
    presentationTimeOffset="3054136803"
    media="channel/video/$Time$.m4s"
    initialization="channel/init/video.mp4">
    <SegmentTimeline>
        <S t="3054139806" d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
    </SegmentTimeline>
</SegmentTemplate>
```

Compress the Timelines: Utilize S@r Attribute

```
<SegmentTemplate timescale="90000"
    presentationTimeOffset="3054136803"
    media="channel/video/$Time$.m4s"
    initialization="channel/init/video.mp4">
    <SegmentTimeline>
        <S t="3054139806" d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
        <S d="360360"/>
    </SegmentTimeline>
</SegmentTemplate>
```

```
<SegmentTemplate timescale="90000"
    presentationTimeOffset="3054136803"
    media="channel/video/$Time$.m4s"
    initialization="channel/init/video.mp4">
    <SegmentTimeline>
        <S t="3054139806" d="360360" r="10"/>
    </SegmentTimeline>
</SegmentTemplate>
```

Compress the Timelines: Amazon Pattern Proposal

```
<SegmentTemplate timescale="90000"
    presentationTimeOffset="3054857523"
    media="channel/audio/$Time$.m4s"
    initialization="channel/init/audio.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"/>
        ....many lines...
        <S d="360960" r="1"/>
    </SegmentTimeline>
</SegmentTemplate>
```

```
<SegmentTemplate timescale="90000"
    presentationTimeOffset="3054857523"
    media="channel/audio/$Time$.m4s"
    initialization="channel/init/audio.mp4">
    <SegmentTimeline>
        <Pattern t="3054861448"
            pattern_repeat="12">
            <P d="360960"/>
            <P d="359040"/>
            <P d="360960" r="1"/>
            <P d="359040"/>
            <P d="360960" r="2"/>
        </Pattern>
        <S d="359040"/>
        <S d="360960" r="1"/>
    </SegmentTimeline>
</SegmentTemplate>
```

Compress the Timelines: One Timeline per AdaptationSet

```
<AdaptationSet id="1" mimeType="video/mp4" segmentAlignment="true"
    bitstreamSwitching="true" ...>
    <SegmentTemplate timescale="90000" presentationTimeOffset="3054136803"
        media="channel/$RepresentationID$/$Time$.m4s"
        initialization="channel/$RepresentationID$/video.mp4">
        <SegmentTimeline>
            <S t="3054139806" d="360360" r="10"/>
        </SegmentTimeline>
    </SegmentTemplate>
    <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" .../>
</AdaptationSet>
```

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/channel/</BaseURL>
    <BaseURL serviceLocation="cdn-2">https://cdn-2.net/channel/</BaseURL>
    <BaseURL serviceLocation="cdn-3">https://cdn-3.net/channel/</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="channel/$RepresentationID$/$Time$.m4s"
        initialization="channel/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="channel/$RepresentationID$/$Time$.m4s"
        initialization="channel/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="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>
```

Change 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/channel/</BaseURL>
    <BaseURL serviceLocation="cdn-2">https://cdn-2.net/channel/</BaseURL>
    <BaseURL serviceLocation="cdn-3">https://cdn-3.net/channel/</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="channel/$RepresentationID$/$Time$.m4s"
        initialization="channel/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="channel/$RepresentationID$/$Time$.m4s"
        initialization="channel/init/$RepresentationID$.mp4">
        <SegmentTimeline>
          <S t="3054861448" d="360960"/>
          <S d="359040"/>
      </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/channel/</BaseURL>
    <BaseURL serviceLocation="cdn-2">https://cdn-2.net/channel/</BaseURL>
    <BaseURL serviceLocation="cdn-3">https://cdn-3.net/channel/</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="channel/$RepresentationID$/$Time$.m4s"
        initialization="channel/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="channel/$RepresentationID$/$Time$.m4s"
        initialization="channel/init/$RepresentationID$.mp4">
        <SegmentTimeline>
          <S t="3054861448" d="360960"/>
          <S d="359040"/>
          <S d="360960"/>
      </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>
```

Optimizing Update Requests

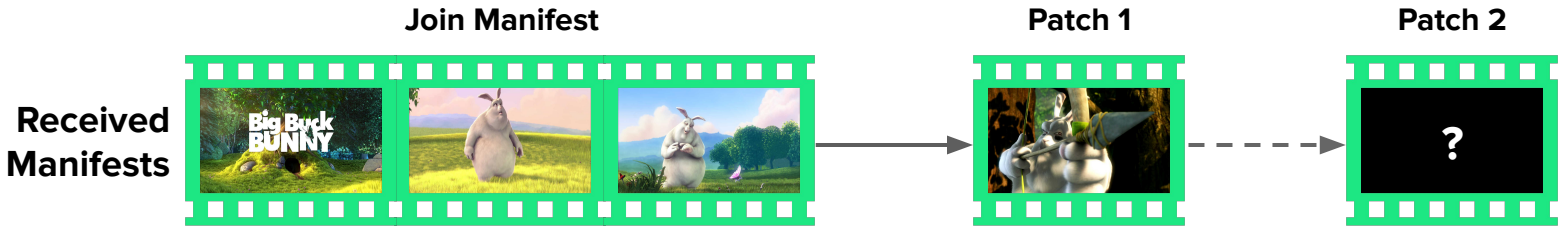
- Solution Constraints
  - Send only new information to clients
  - Maintain response caching
  - Minimize request client processing
  - Keep server in control of playout
- Created the Patch Manifest concept
  - Special server update response
  - Leverages MPD structure semantics
  - Uses client persisted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

MPD Patch Updates

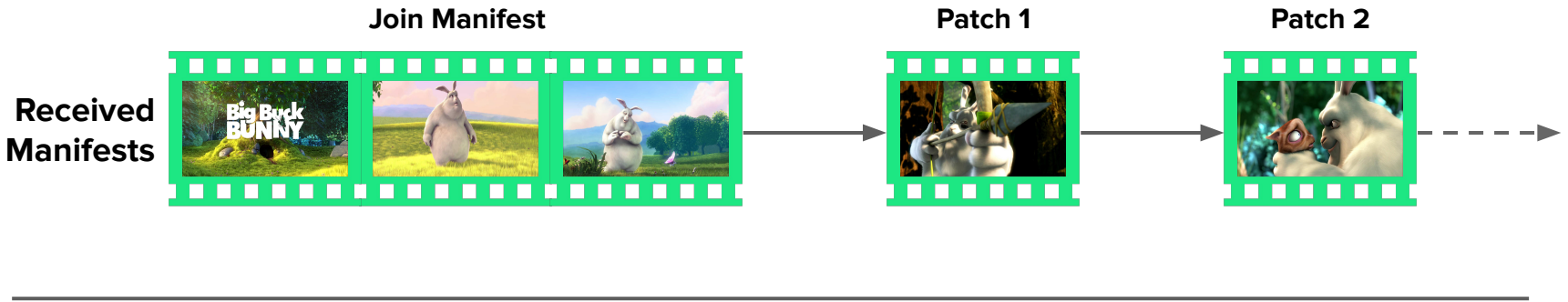
Patch Manifest Playout

Patch Manifest Playout

Patch Manifest Playout



Patch Manifest Playout



Anatomy of a Join Manifest

```
<?xml version="1.0" encoding="UTF-8"?>
<MPD type="dynamic" id="channel" minimumUpdatePeriod="PT3.0S" publishTime="2019-10-18T22:06:14" ...>
  <PatchLocation ttl="60">/patch/channel.mpd?publishTime=2019-10-18T22:06:14&s=5095823234</PatchLocation>
  <Period id="1" start="PT0.7723S">
    <BaseURL serviceLocation="cdn-1">https://cdn-1.net/channel/</BaseURL>
    <BaseURL serviceLocation="cdn-2">https://cdn-2.net/channel/</BaseURL>
    <BaseURL serviceLocation="cdn-3">https://cdn-3.net/channel/</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="channel/$RepresentationID$/$Time$.m4s"
        initialization="channel/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" .../>
      ...
```

Anatomy of a Patch Manifest

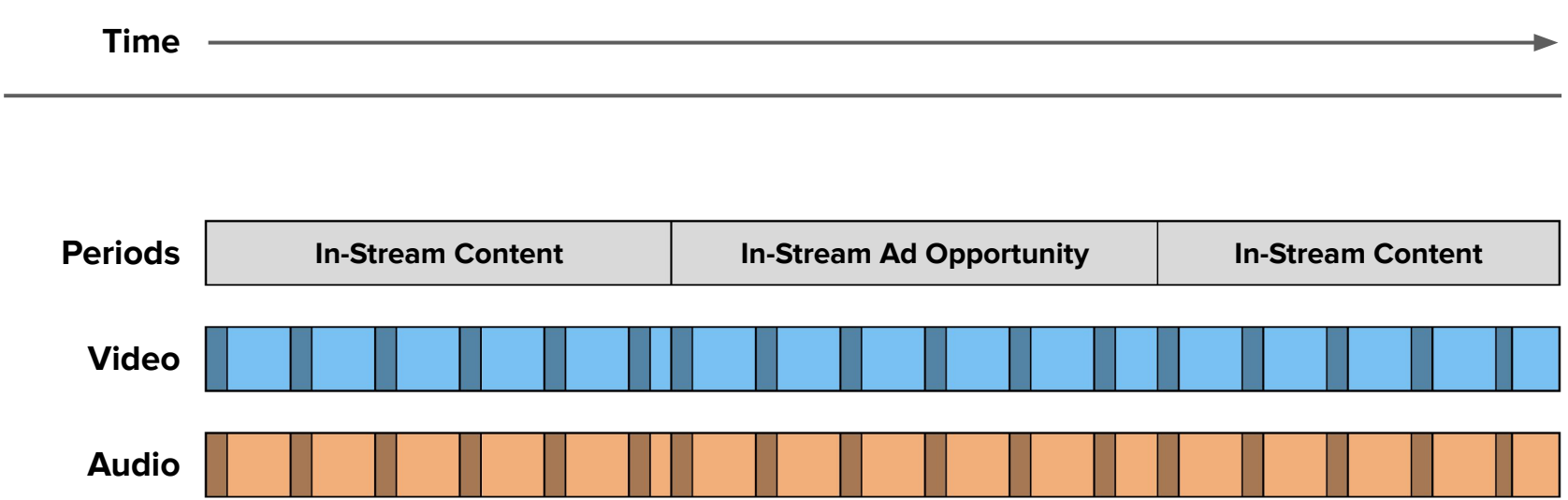
```
<?xml version="1.0" encoding="UTF-8"?>
<Patch mpdId="channel" originalPublishTime="2019-10-18T22:06:14" publishTime="2019-10-18T22:06:17"
  xmlns="urn:mpeg:dash:schema:mpd-patch:2020" xmlns:p="urn:ietf:params:xml:schema:patch-ops" ...>
  <p:replace sel="/MPD/@publishTime">2019-10-18T22:06:17</p:replace>
  <p:replace sel="/MPD/PatchLocation[0]">
    <PatchLocation ttl="60">/patch/channel.mpd?publishTime=2019-10-18T22:06:17&s=5095823234</PatchLocation>
  </p:replace>
  <p:add sel="/MPD/Period[@id='1']/AdaptationSet[@id='1']/SegmentTemplate/SegmentTimeline">
    <S t="5095823752" d="360960" />
  </p:add>
  <p:add sel="/MPD/Period[@id='1']/AdaptationSet[@id='2']/SegmentTemplate/SegmentTimeline">
    <S t="5095823234" d="360360" />
  </p:add>
</Patch>
```

Patch Manifests

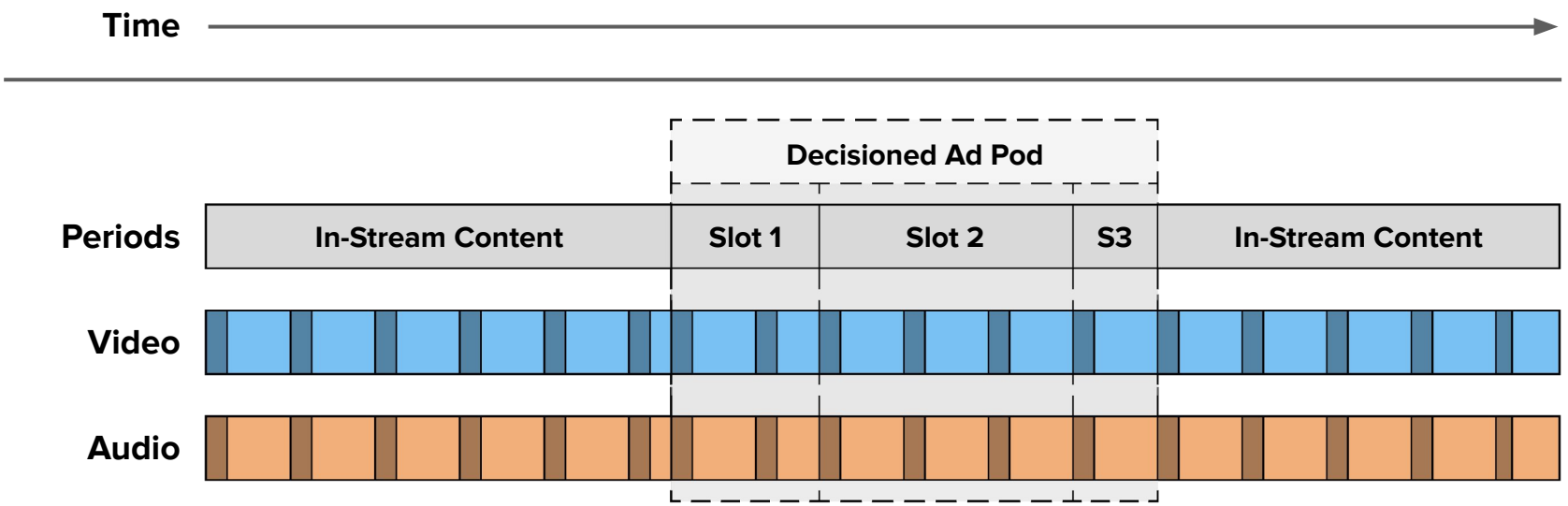
- By The Numbers
  - 9 XML Nodes
  - ~1KB Uncompressed Size
  - ~2ms Parse Time
- Successfully Deployed Solution
  - Constant cost addition over time
  - Efficient for network and client
  - No reduction in cache efficiency
  - Server fully in control of timeline

Dynamic Ad Replacement

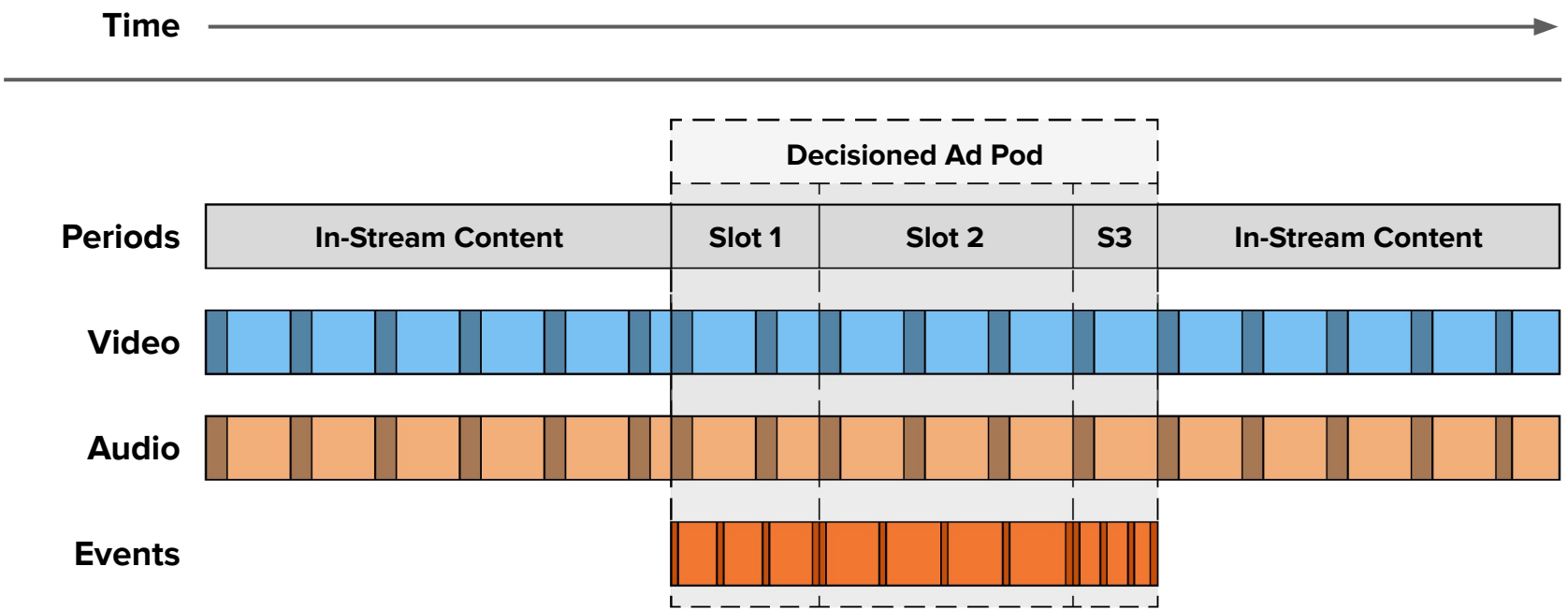
Performing Ad Replacement



Performing Ad Replacement

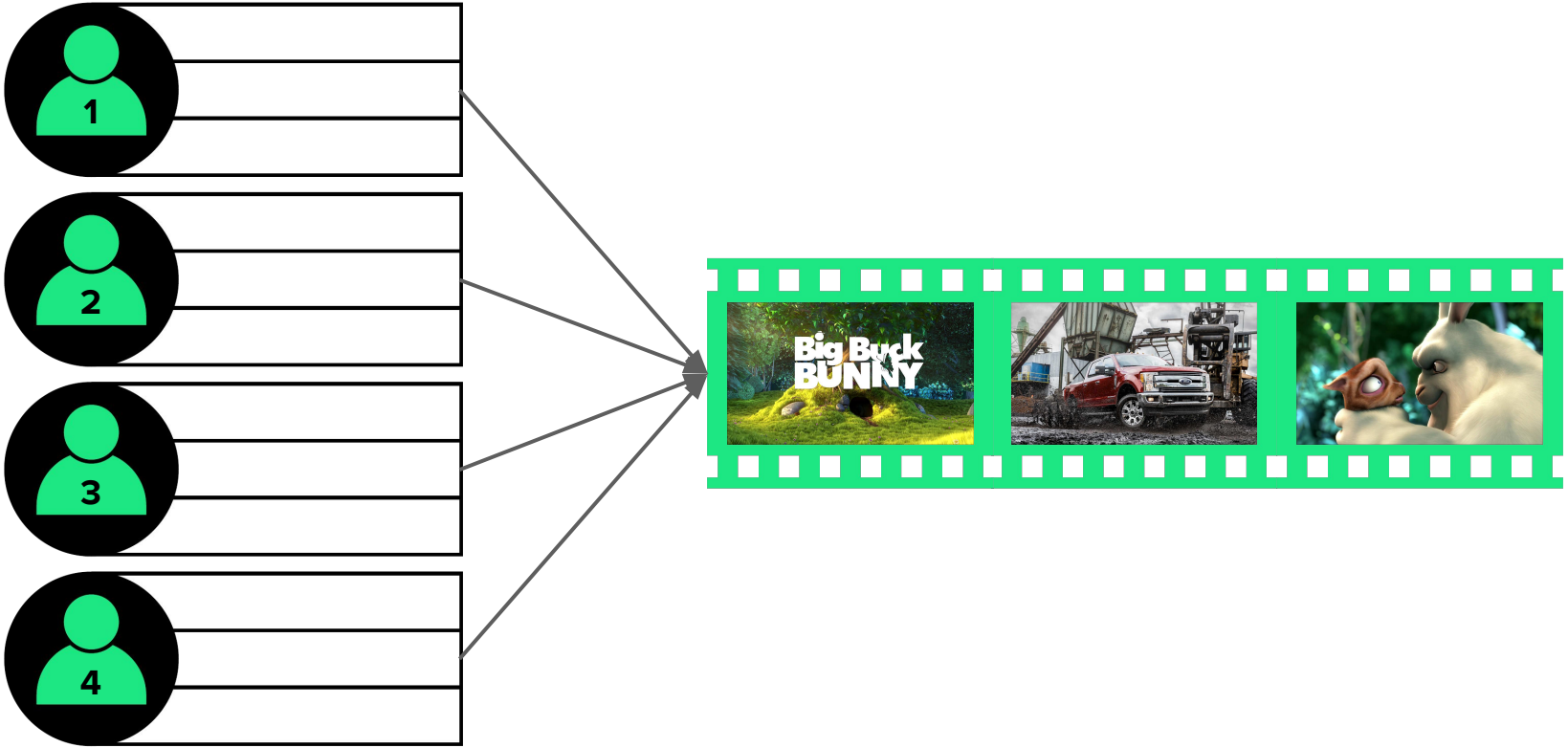


Performing Ad Replacement

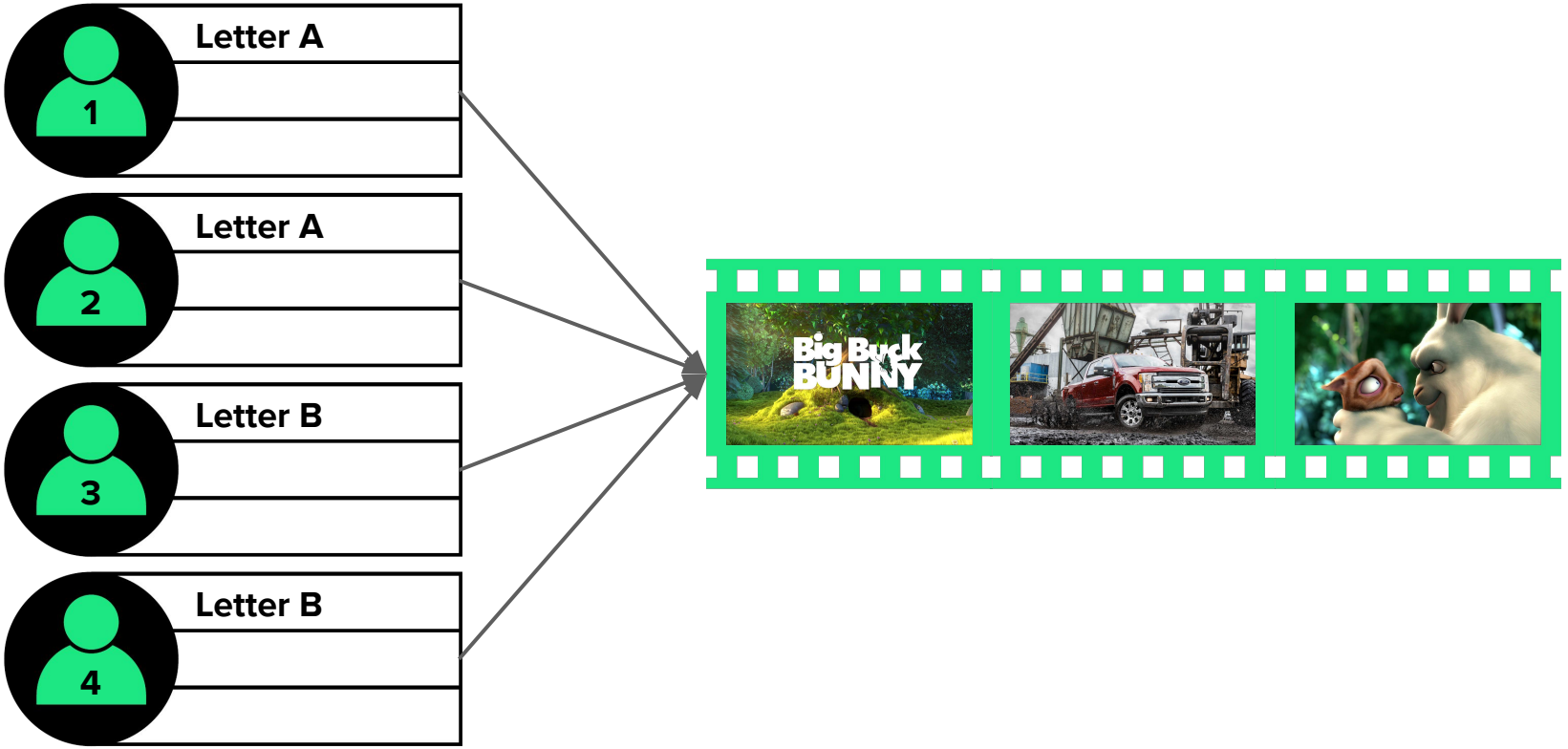


Requirements of Ad Targeting

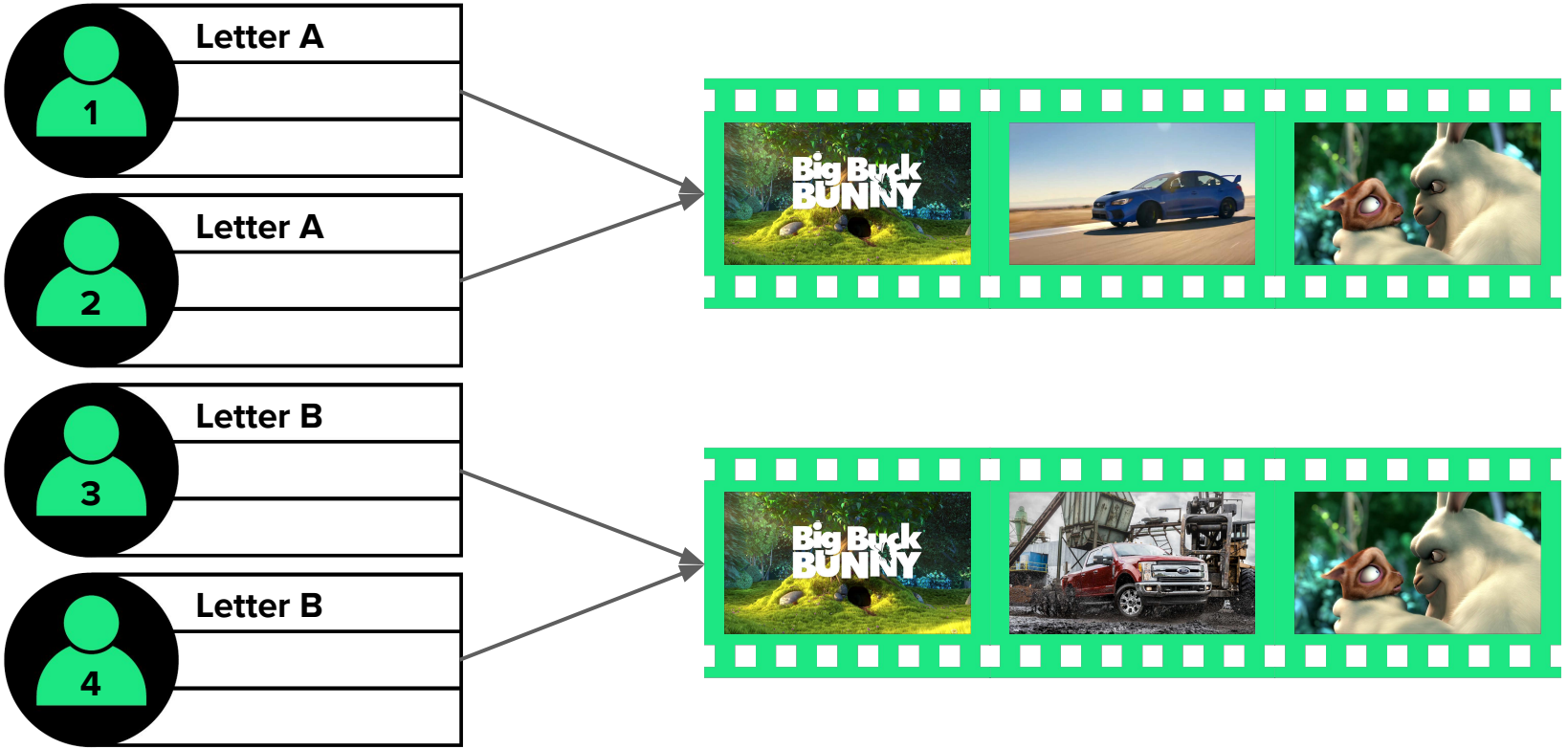
Targeting Drives Stream Uniqueness



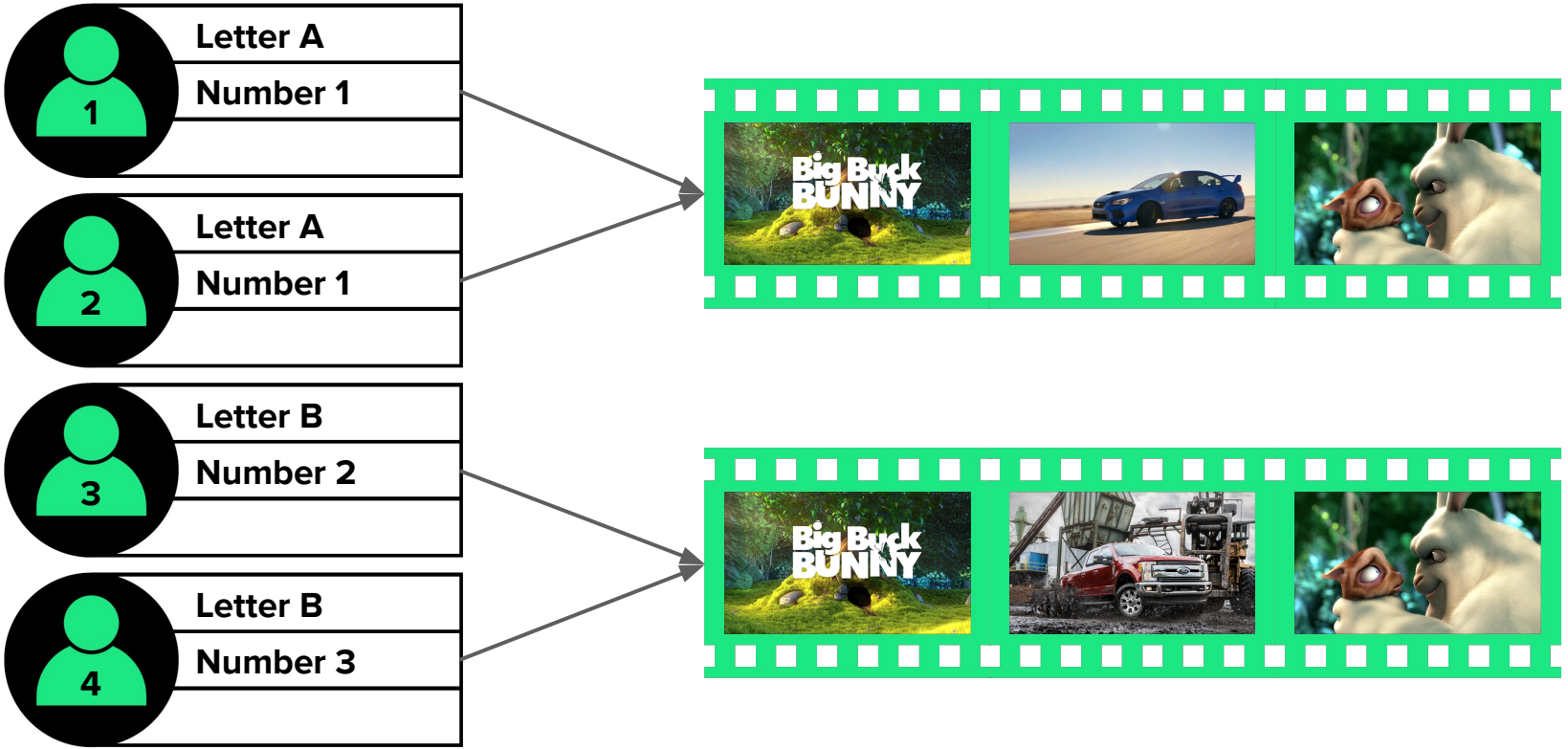
Targeting Drives Stream Uniqueness



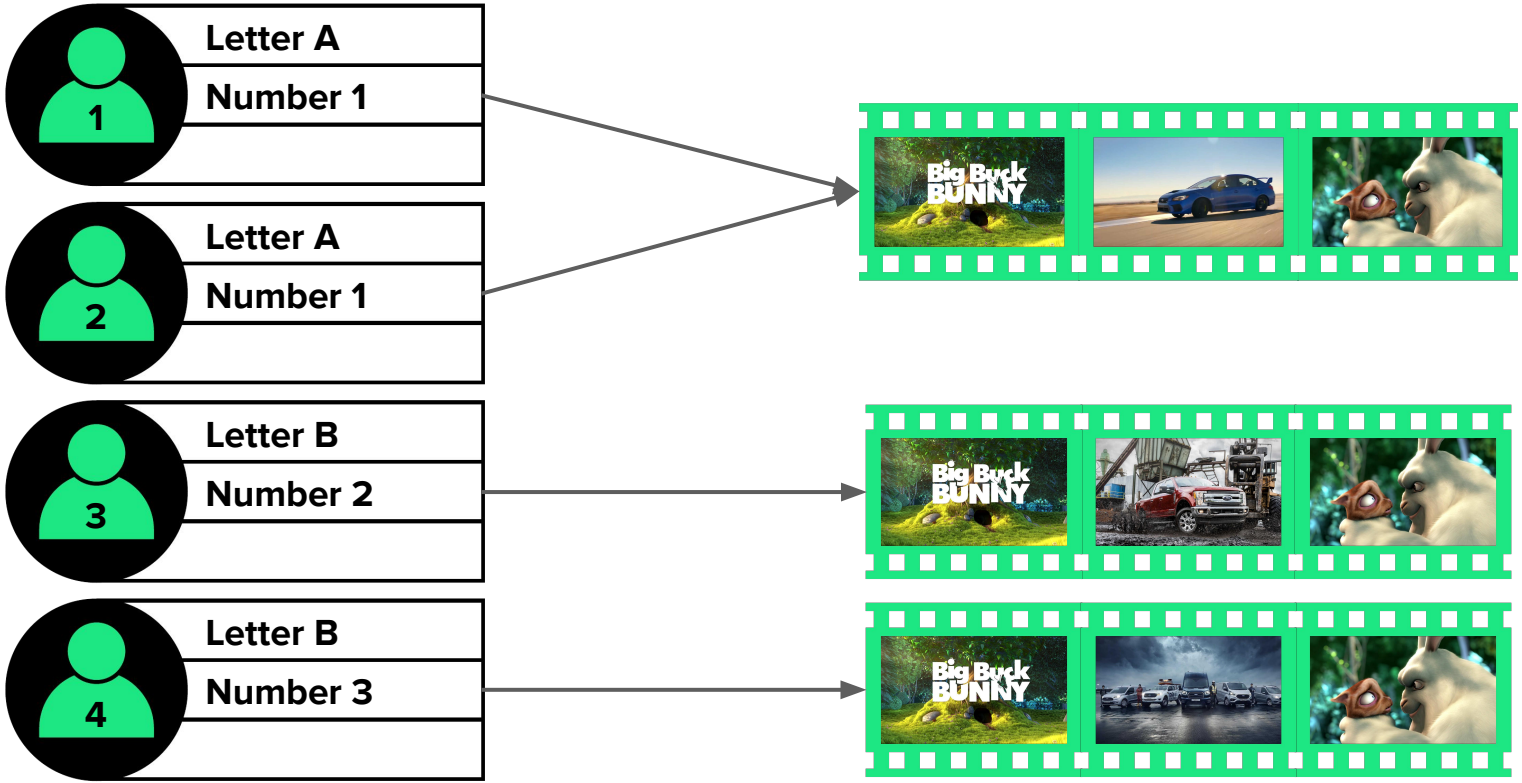
Targeting Drives Stream Uniqueness



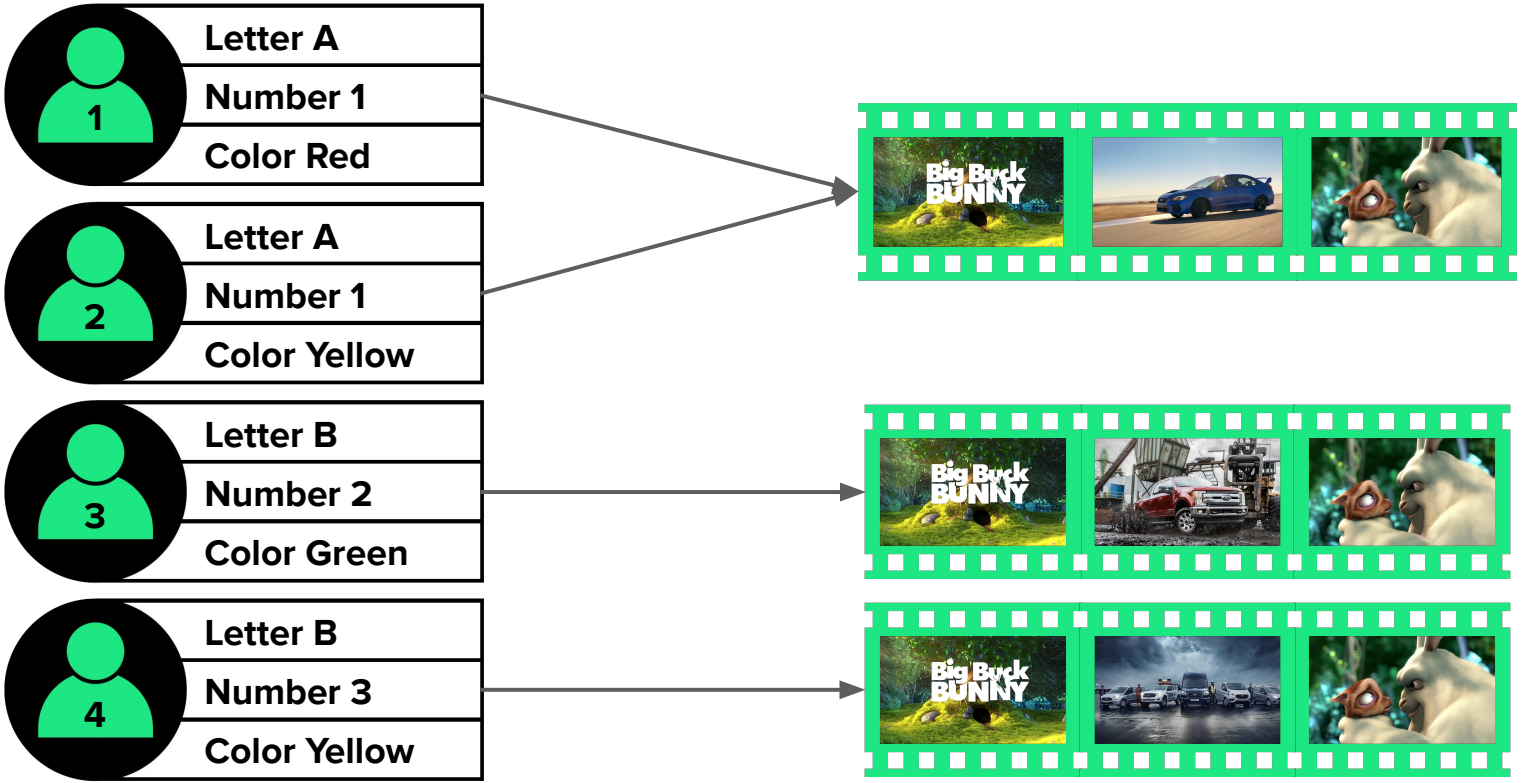
Targeting Drives Stream Uniqueness



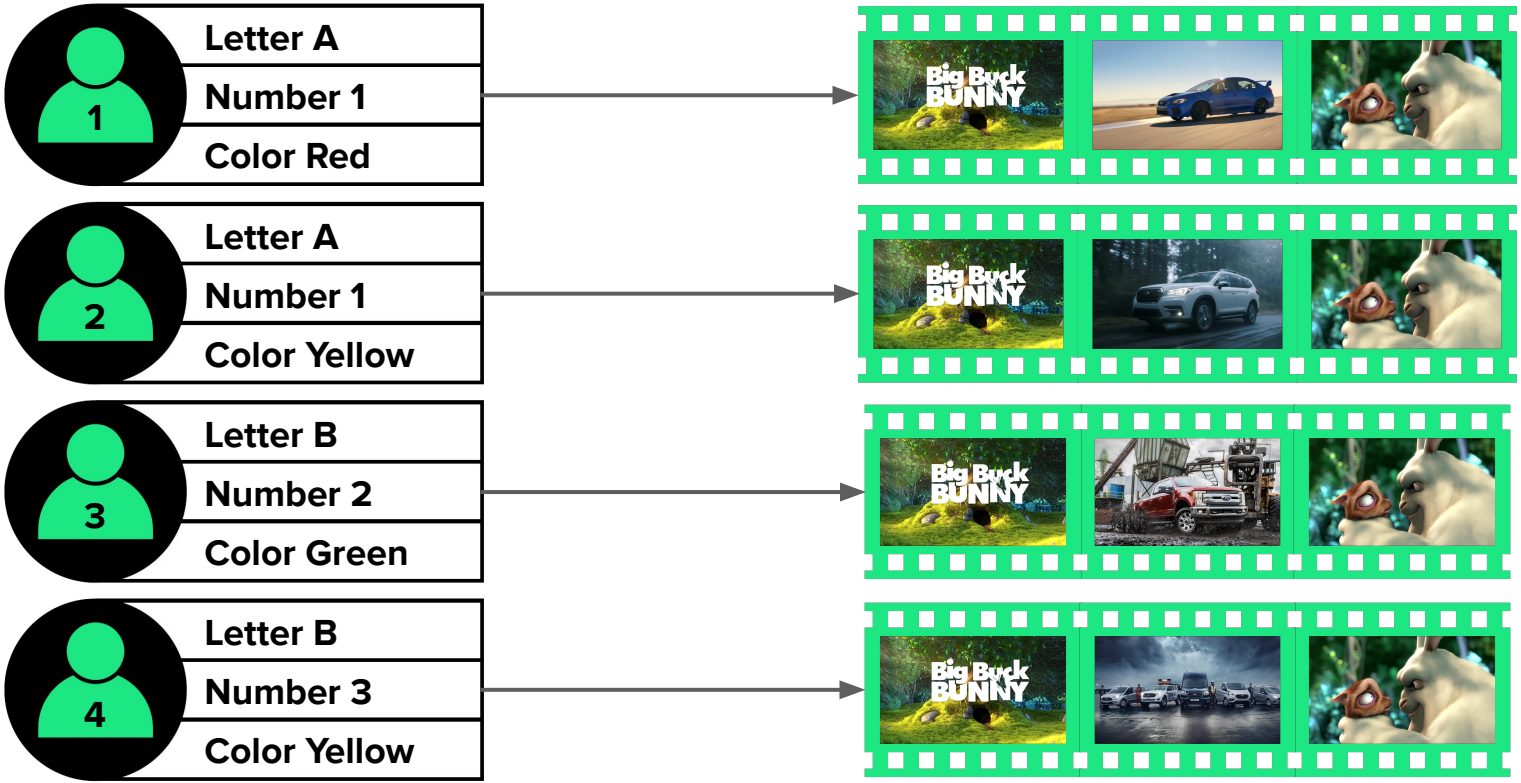
Targeting Drives Stream Uniqueness



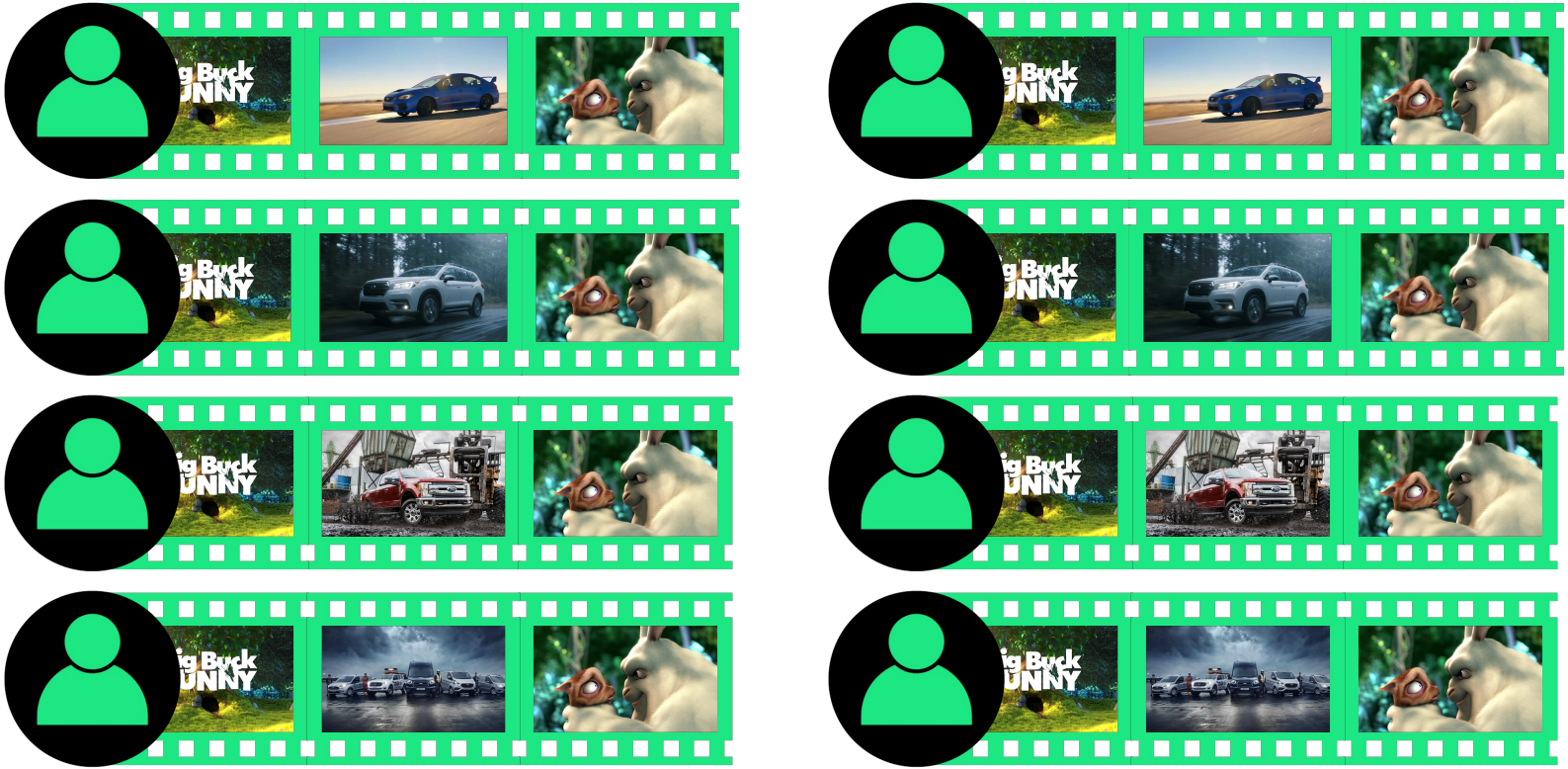
Targeting Drives Stream Uniqueness



Targeting Drives Stream Uniqueness

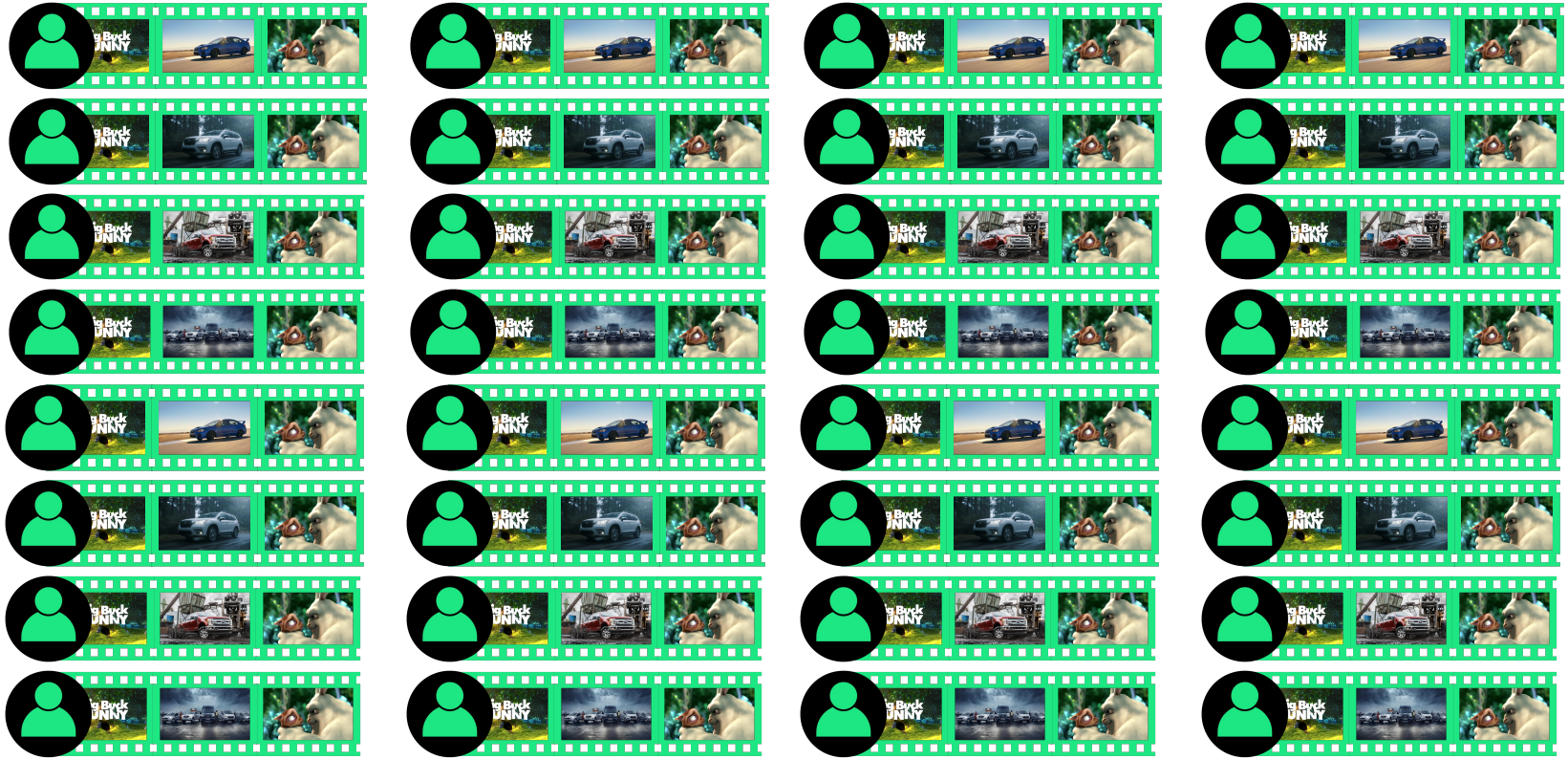


More Granularity, Greater Uniqueness



Requirements of Ad Targeting

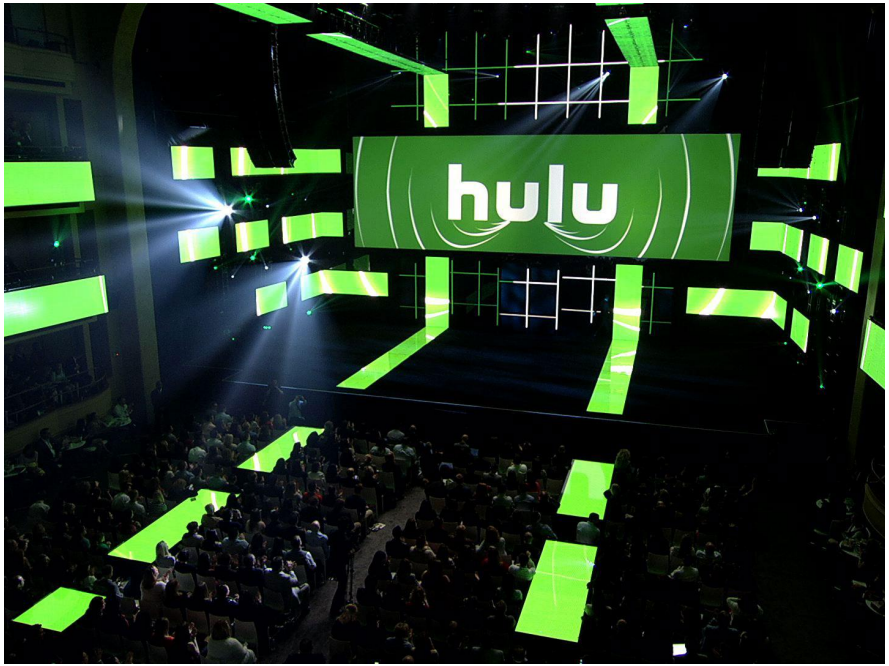
More Granularity, Greater Uniqueness



More Granularity, Greater Uniqueness

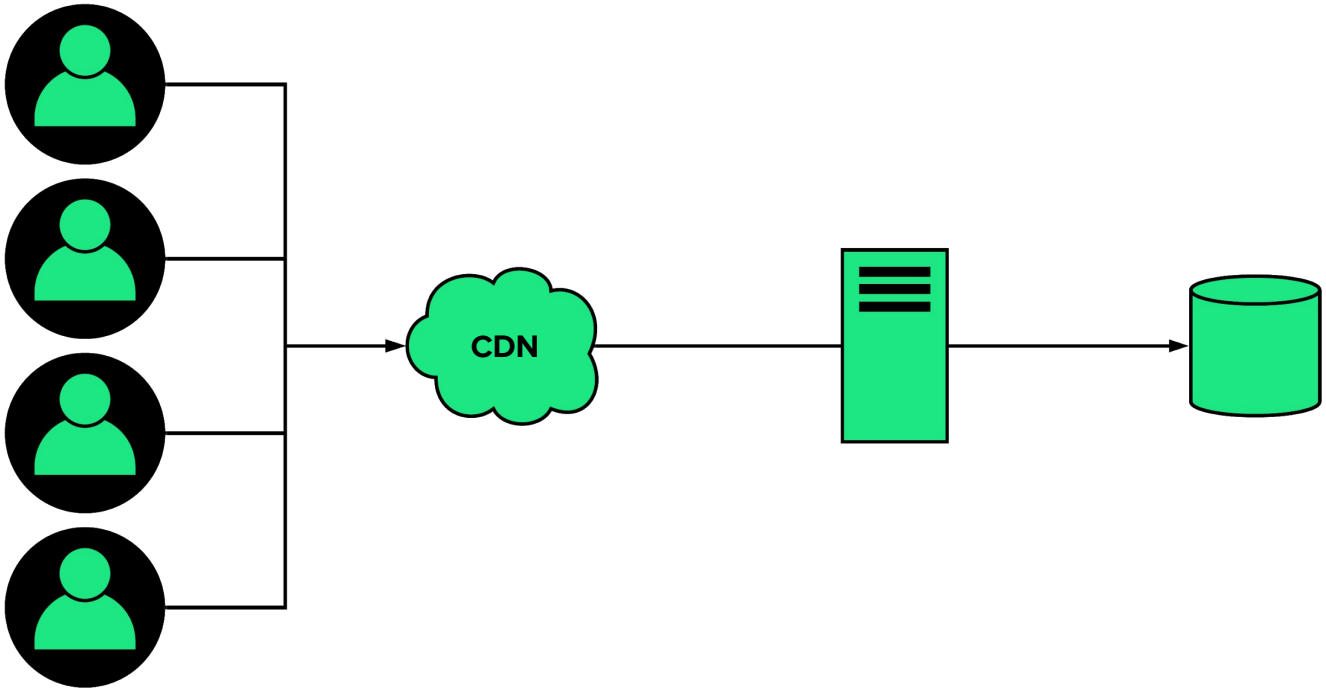
User Based Targeting

- Individualized Ad Targeting
  - Simplifies Ad Sales Flow
  - Keeps Ad Experience Consistent
  - Requires Stream Unique Decisions
- Common Live Streaming Requirements
  - Polling for Changes
  - Stream Update Consistency

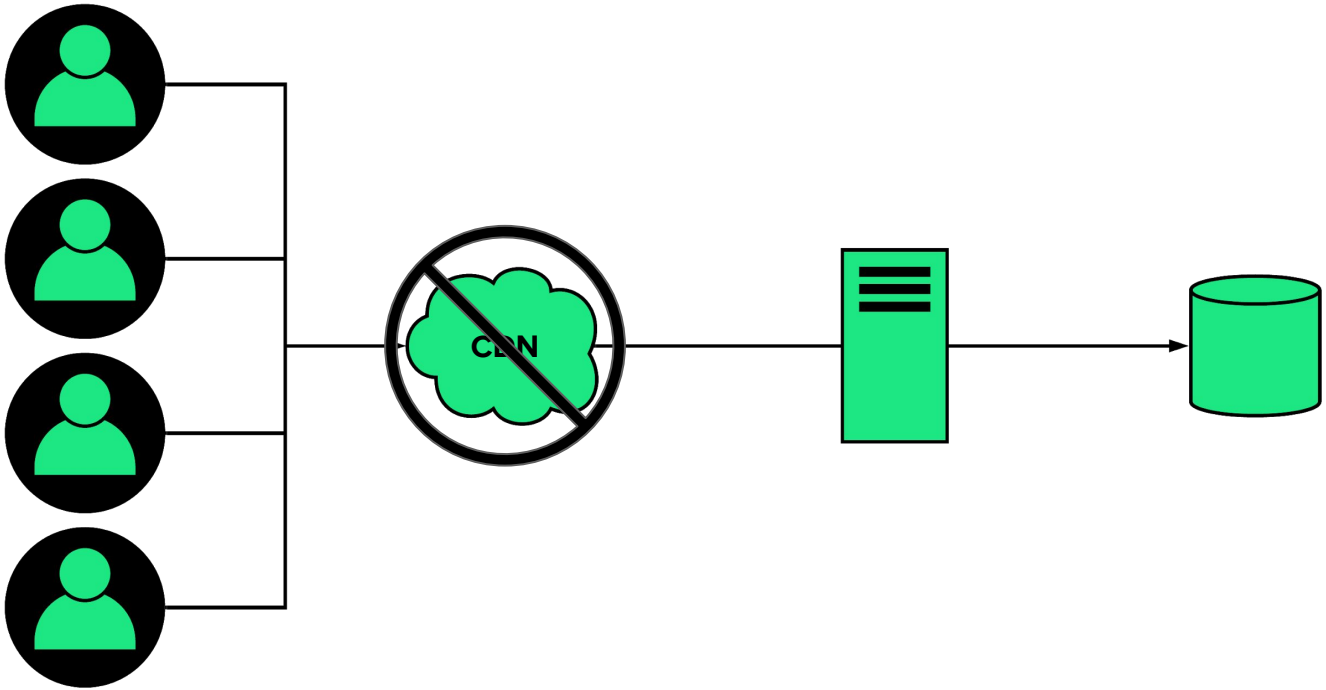


Players Requesting Unique Updates

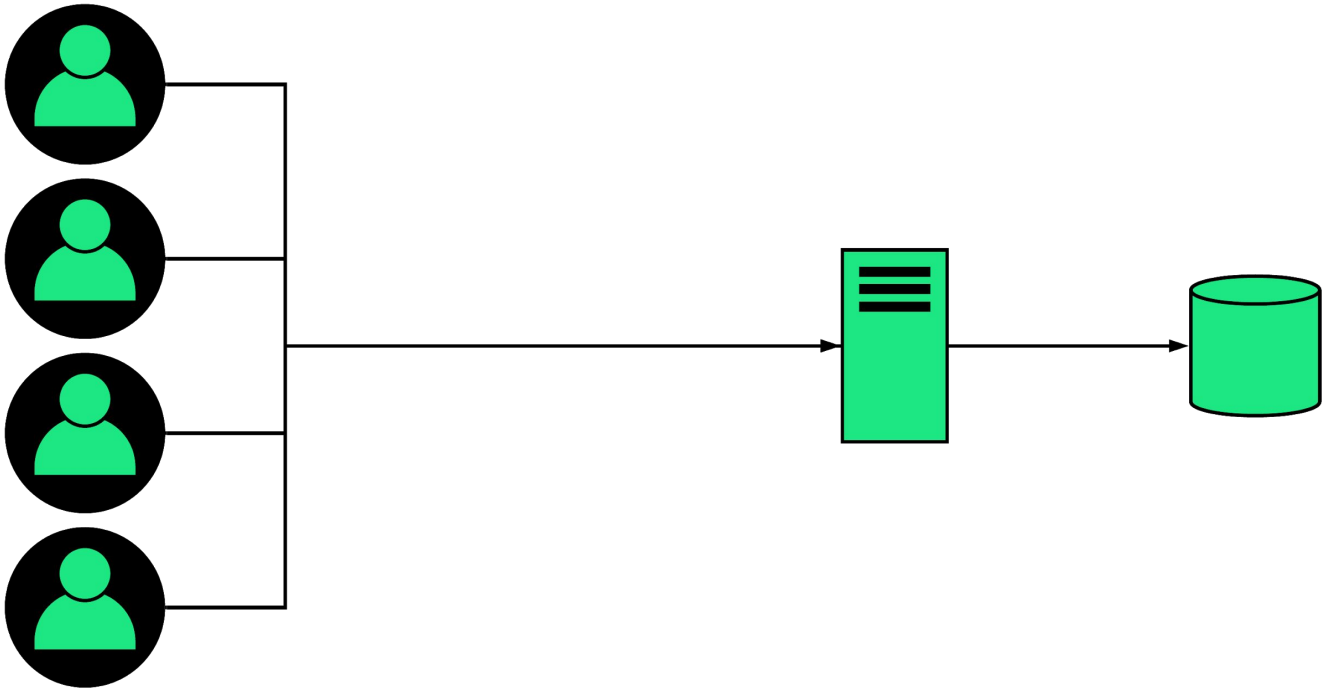
Per User Stream Updates



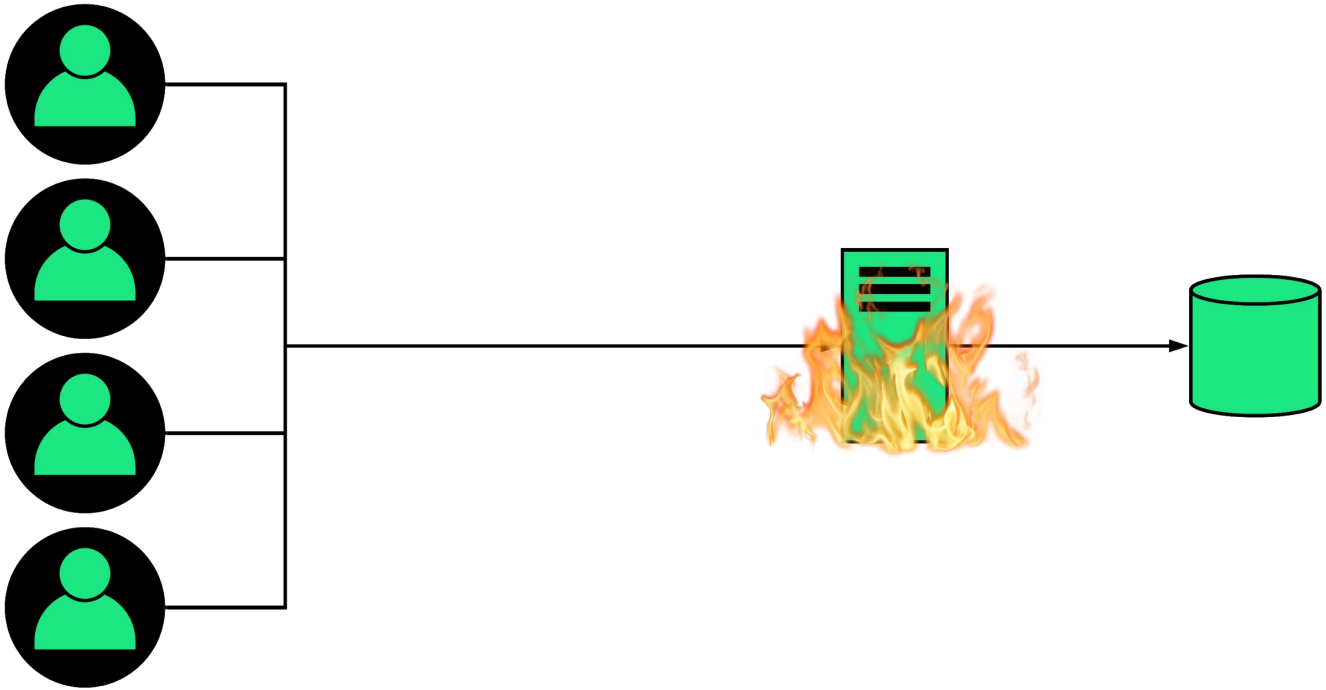
Per User Stream Updates



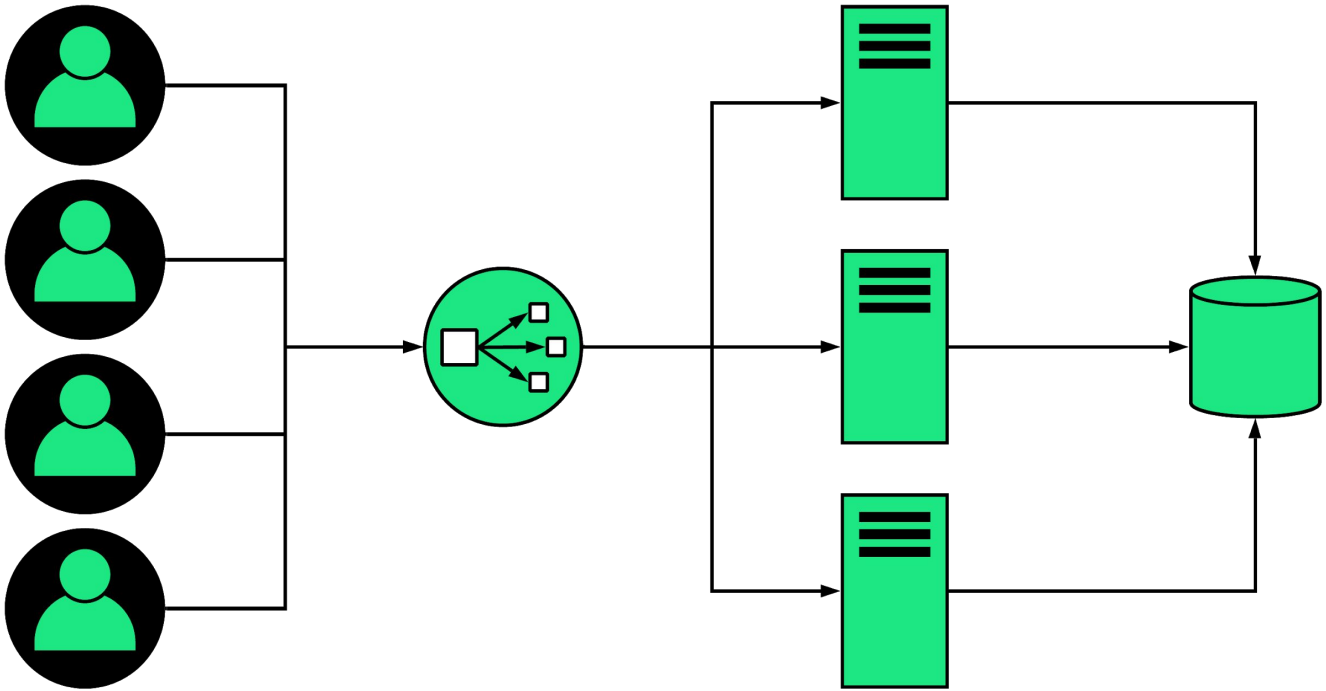
Per User Stream Updates



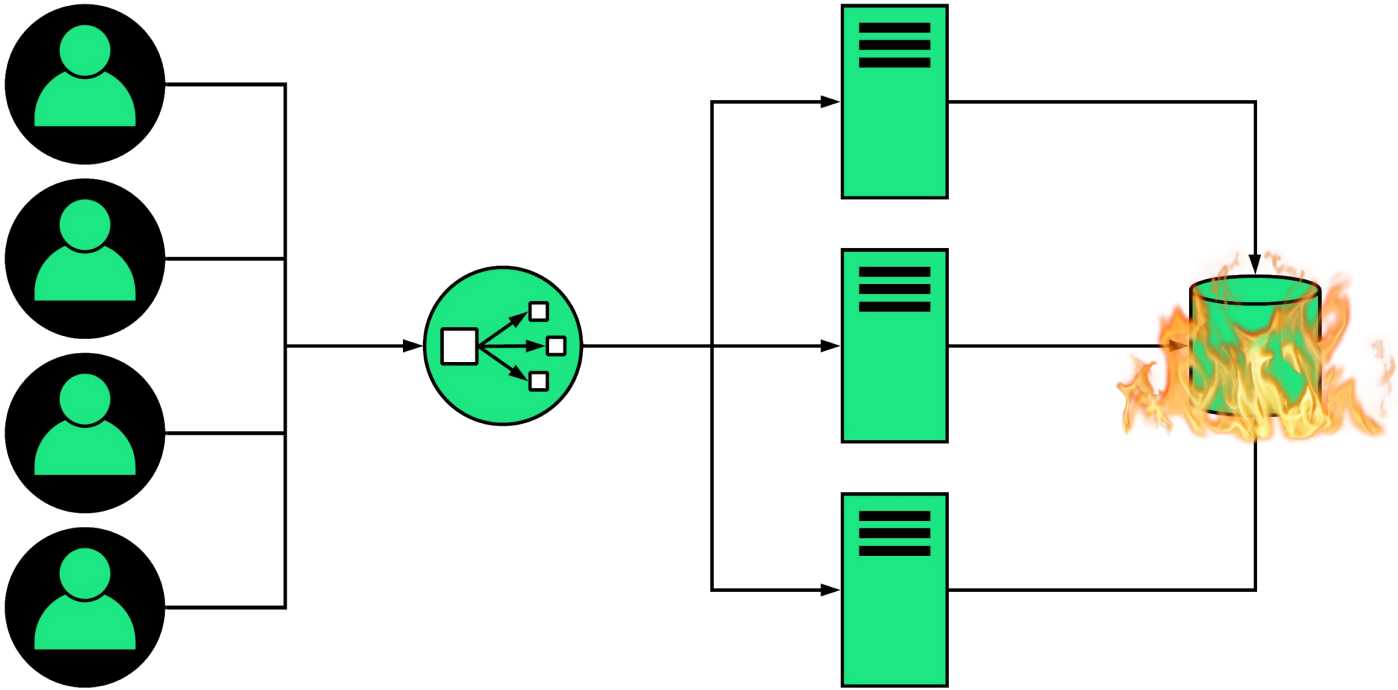
Per User Stream Updates



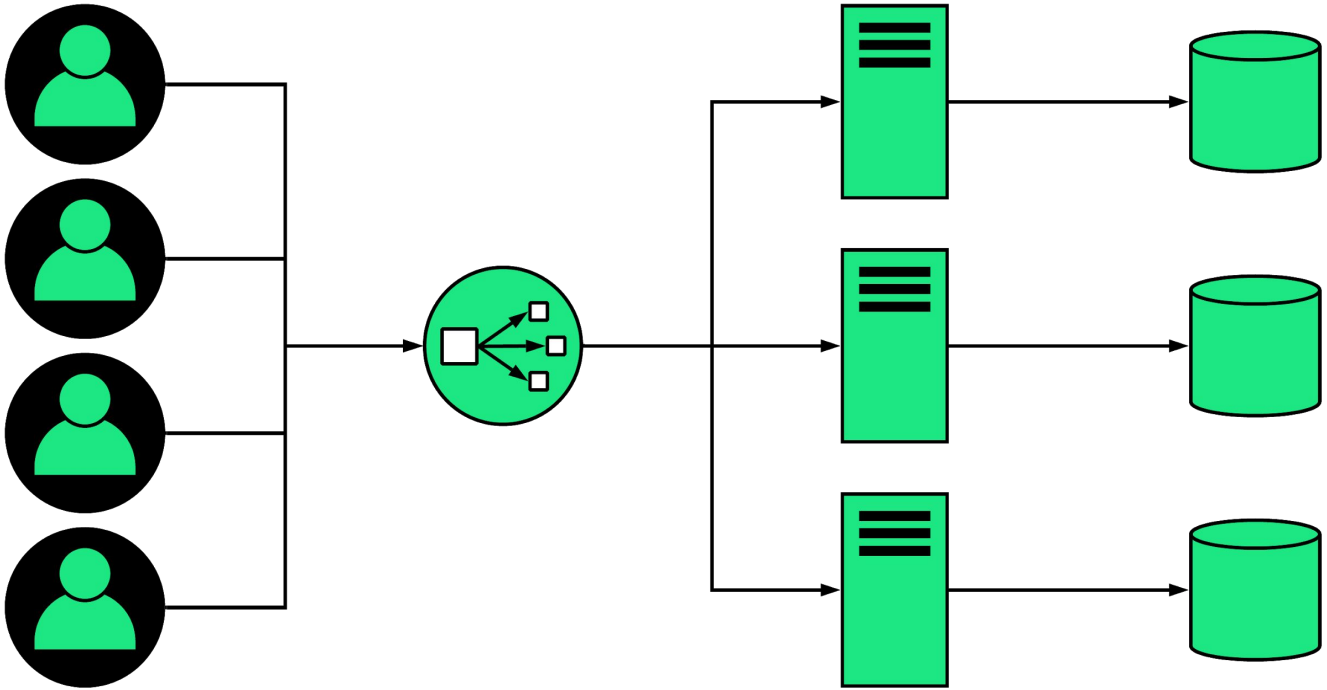
Per User Stream Updates



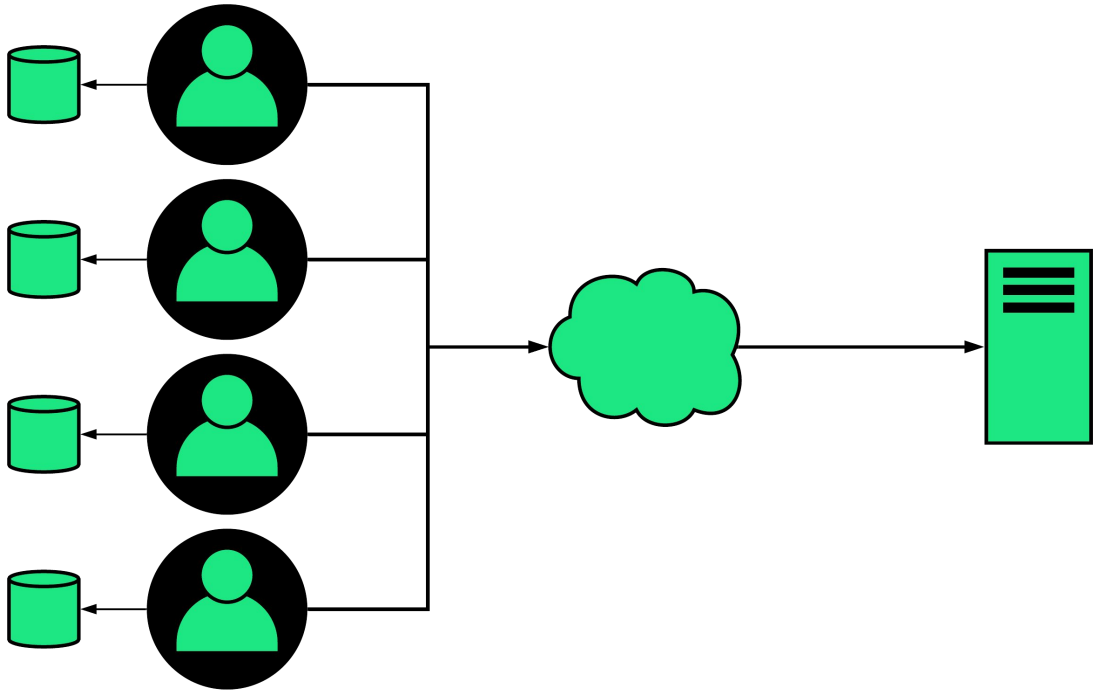
Per User Stream Updates



Per User Stream Updates

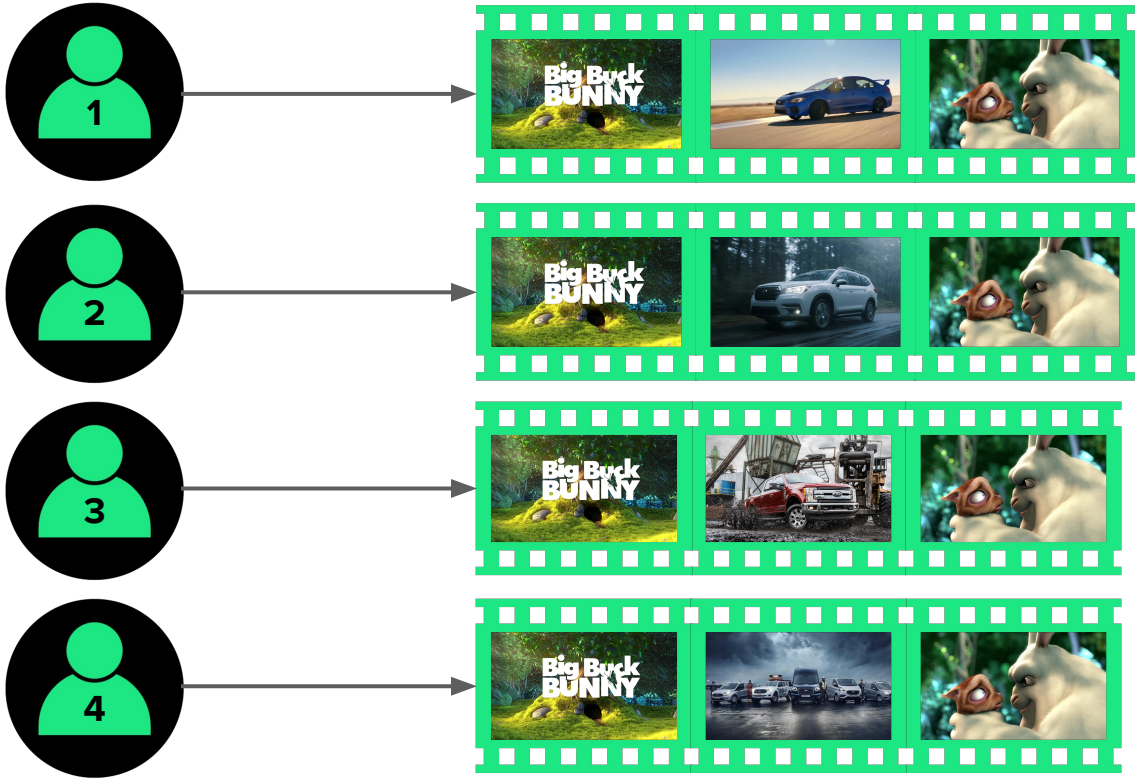


Per User Stream Updates

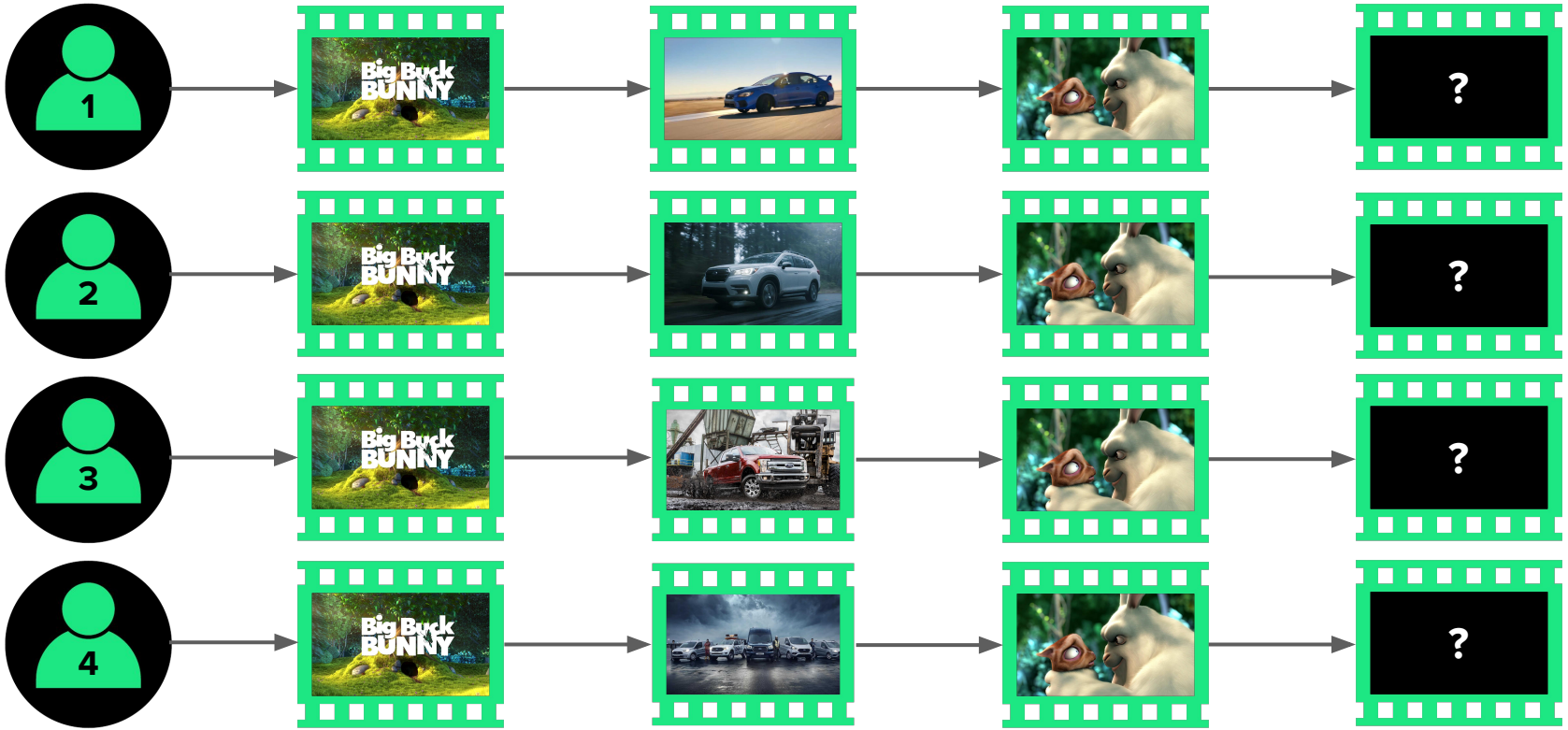


Server-Guided Ad Insertion

Revisiting Targeted Streams



Revisiting Targeted Streams



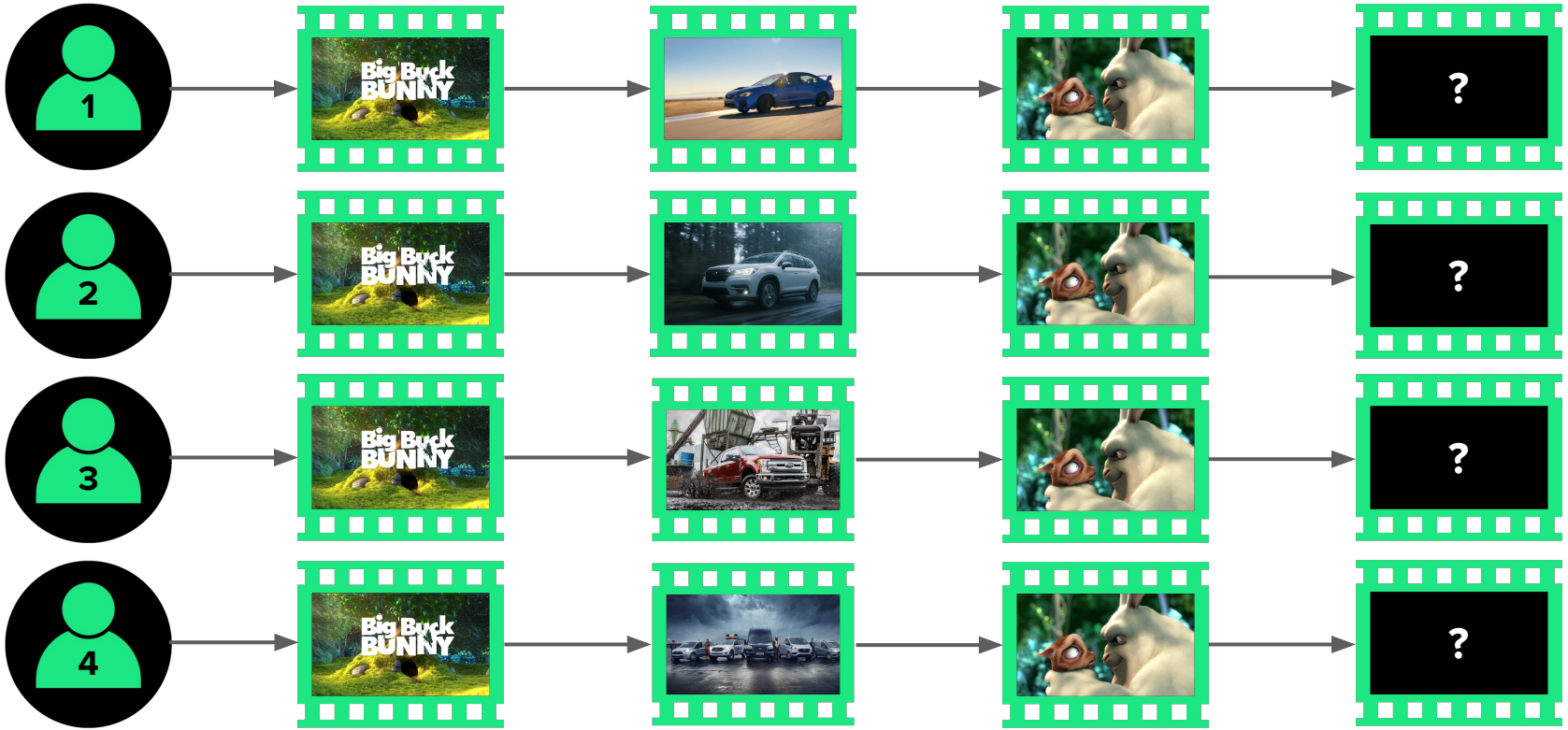
Keeping Responses Generic

Element or Attribute Name	Use	Description
`UrlQueryInfo`		Provides URL query string information
`@queryTemplate`	O (string)	Provides URL parameters template information
`@useMPDUrlQuery`	O (bool)	Indicates the URL parameters of the MPD URL are used
`ExtendedUrlInfoType`		Provides information for derivation of parameter string. This is an extension of **`UrlQueryInfo`**
`@includeInRequests`	OD (`"segment"`)	Specifies which HTTP GET requests shall carry parameters. White-spaced concatenated list of these keys: `"segment", "xlink", "mpd", "callback", "chaining", "fallback"`

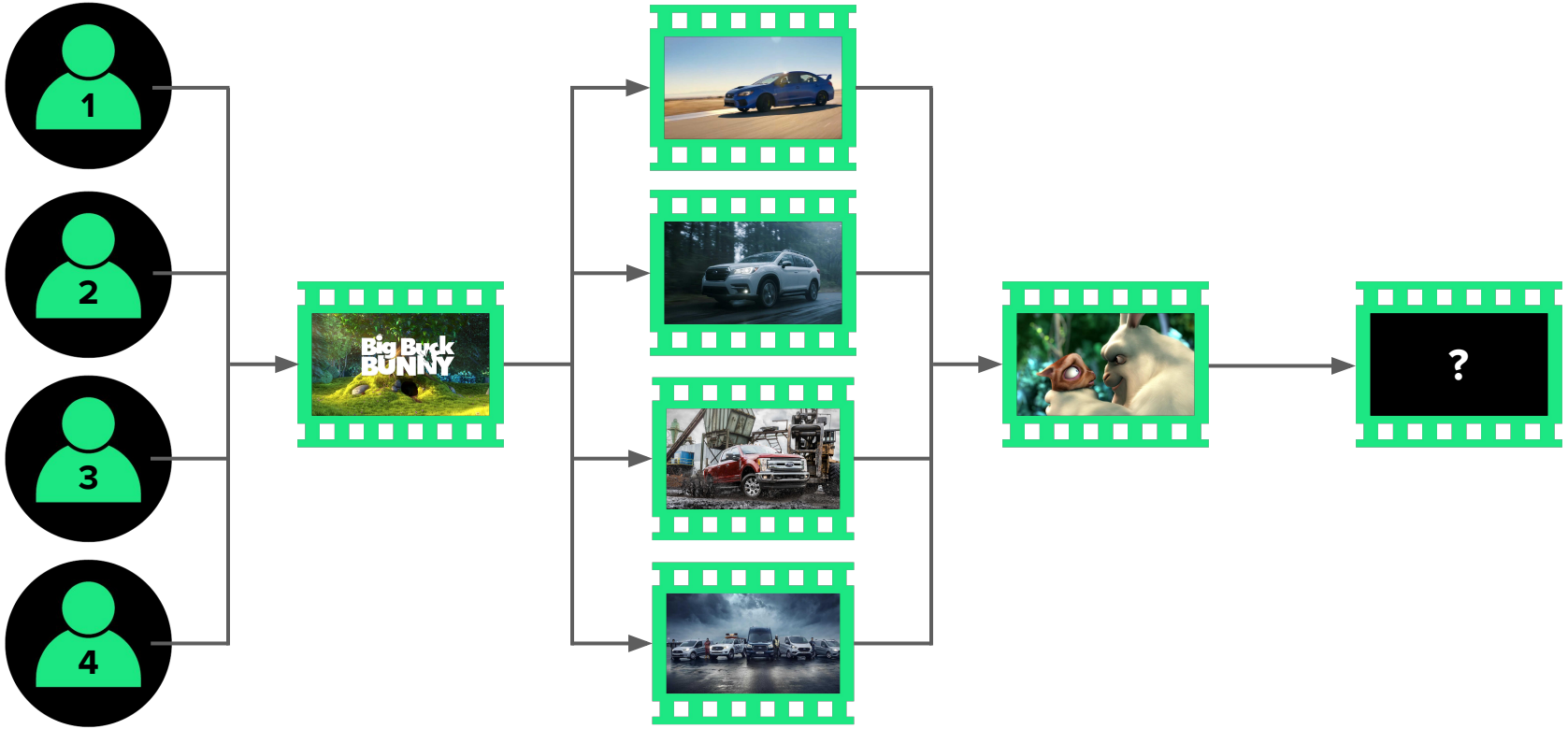
Keeping Responses Generic

```
<EssentialProperty schemeIdUri="urn:mpeg:dash:urlparam:2016">
    <up:ExtUrlQueryInfo useMPDUrlQuery="true" includeInRequests="mpd"
        queryTemplate="target_params=$query:target_params$" />
</EssentialProperty>
```

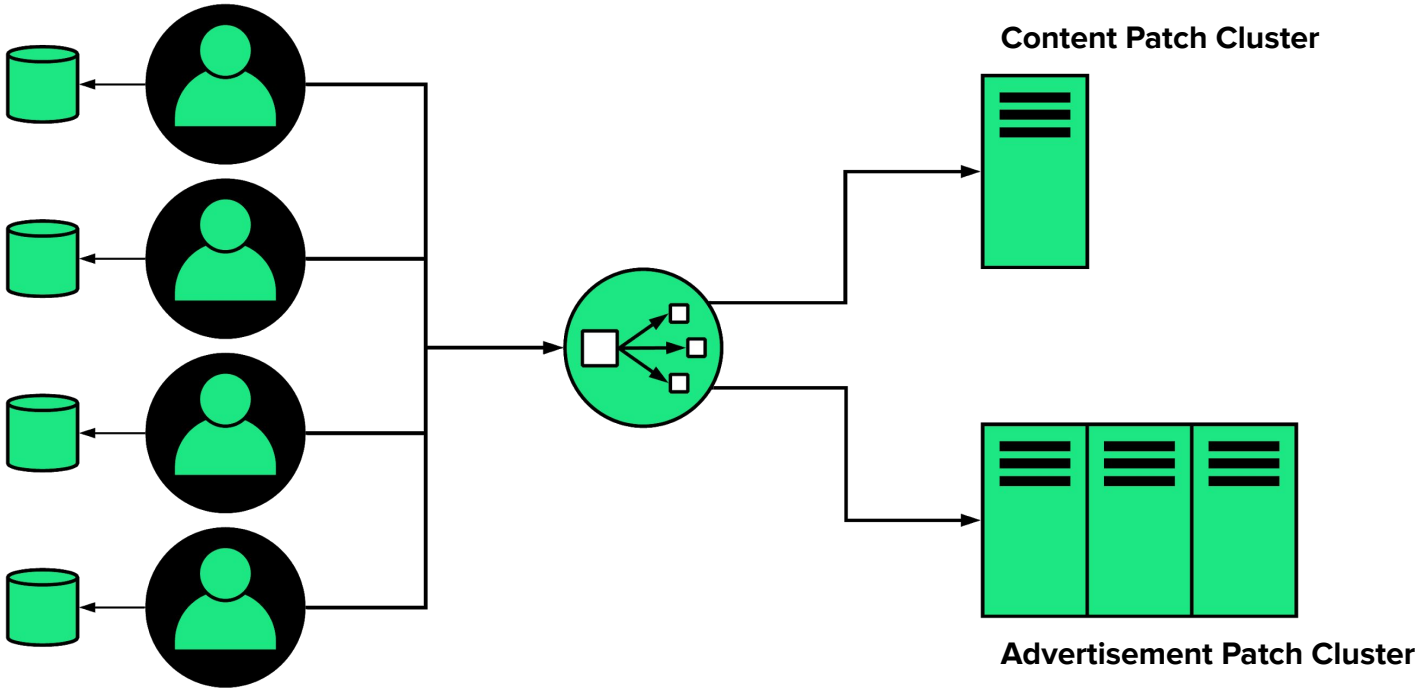
Shared Responses



Shared Responses

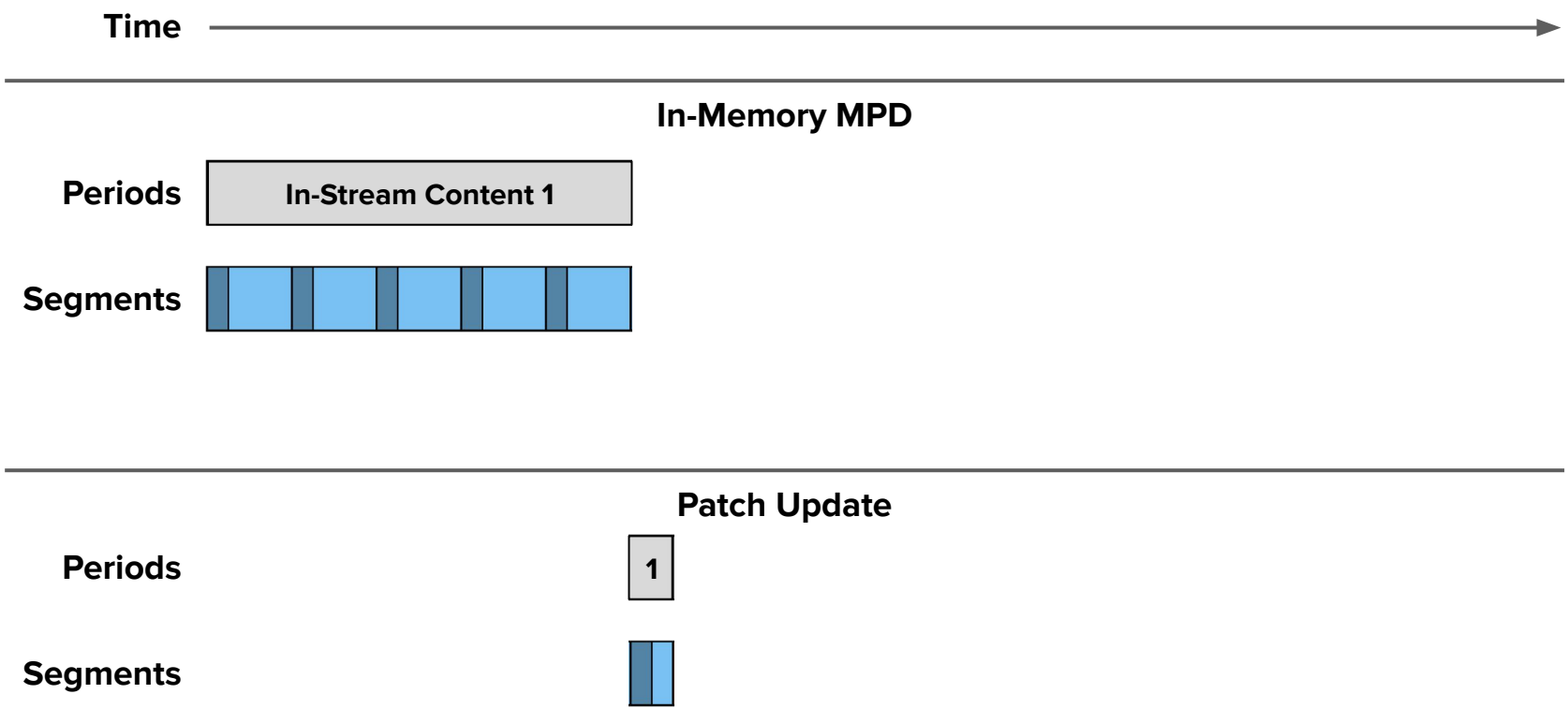


Separation of Scale Concerns

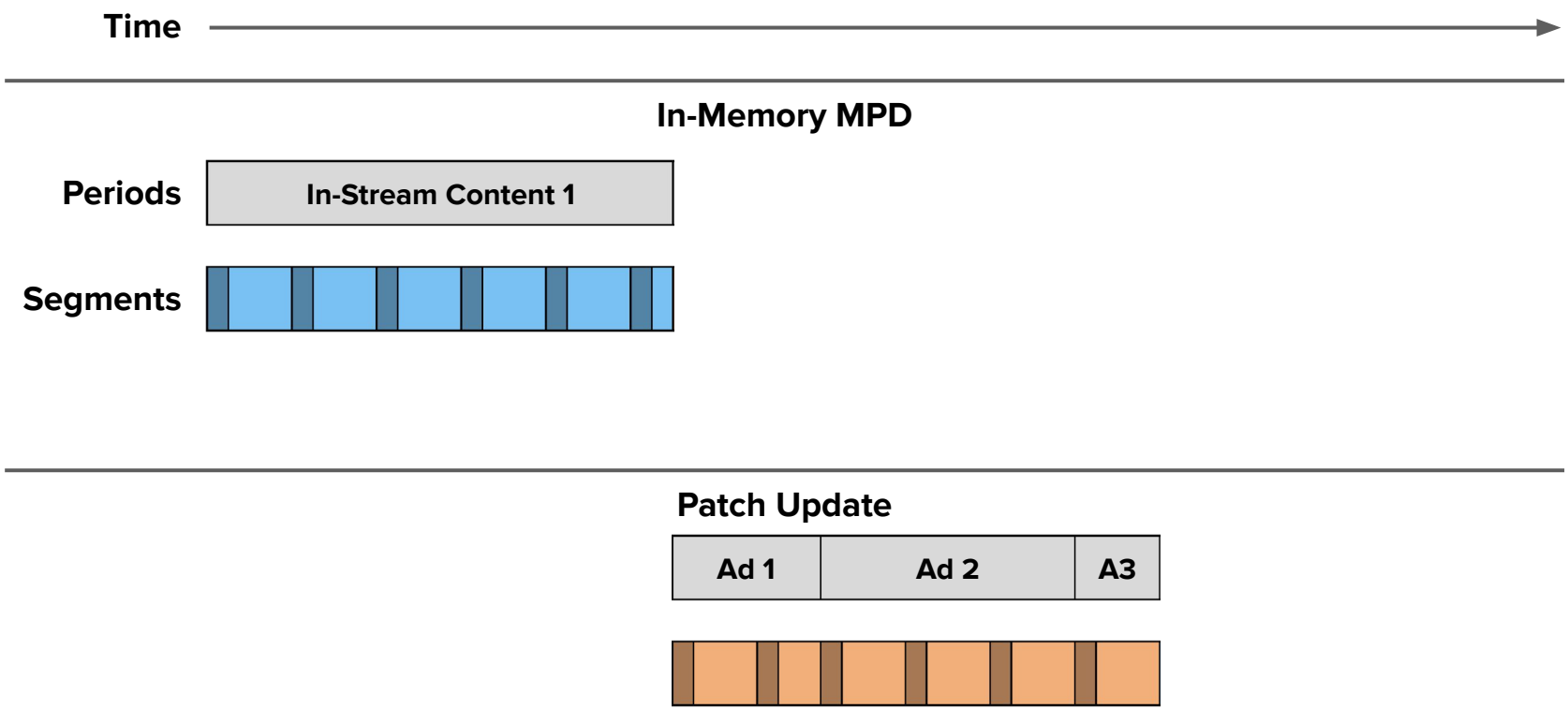


Returning from a Replacement

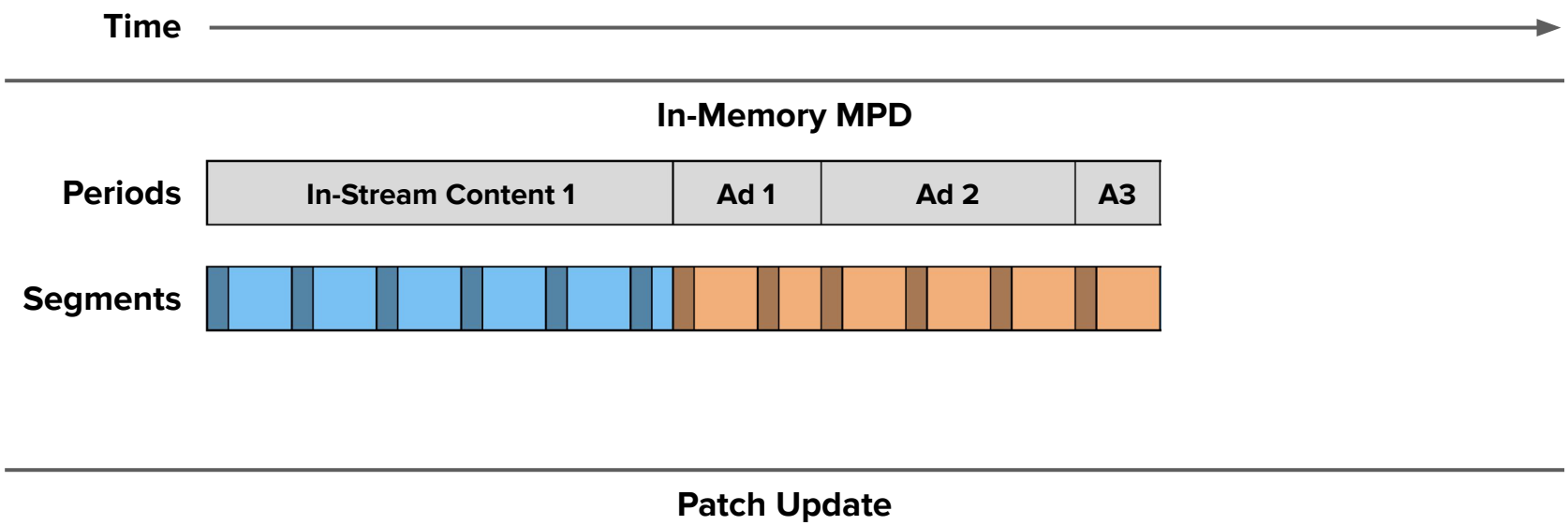
Normal Patch Playout



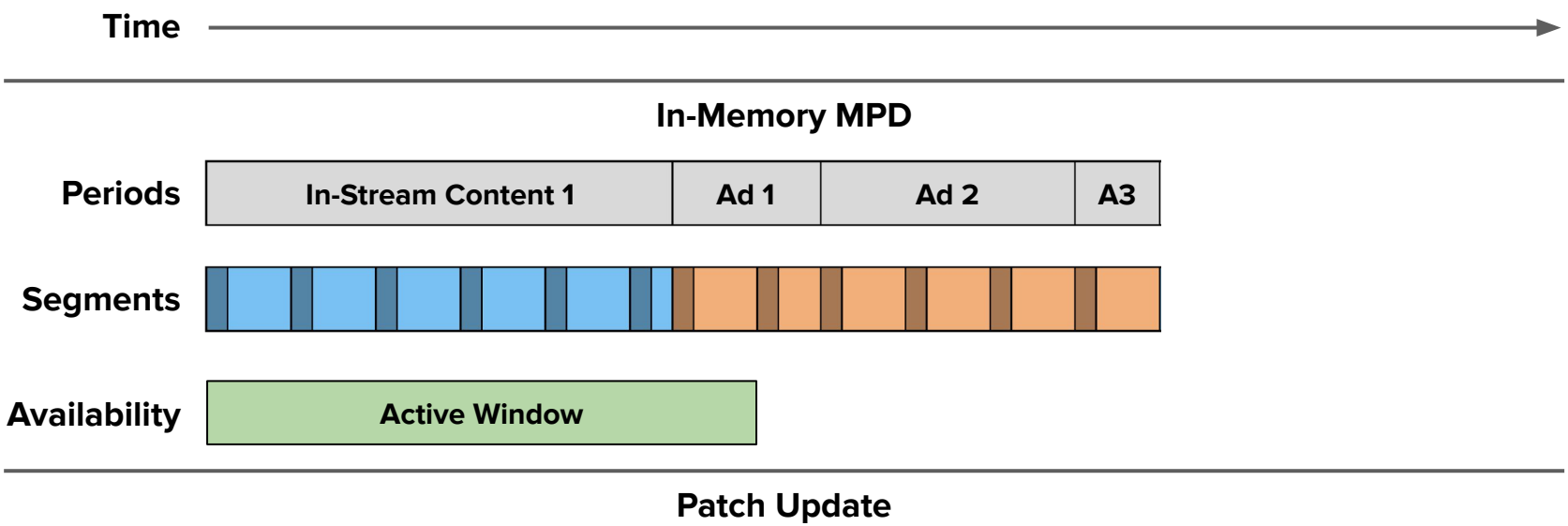
Advertisement Patch Occurs



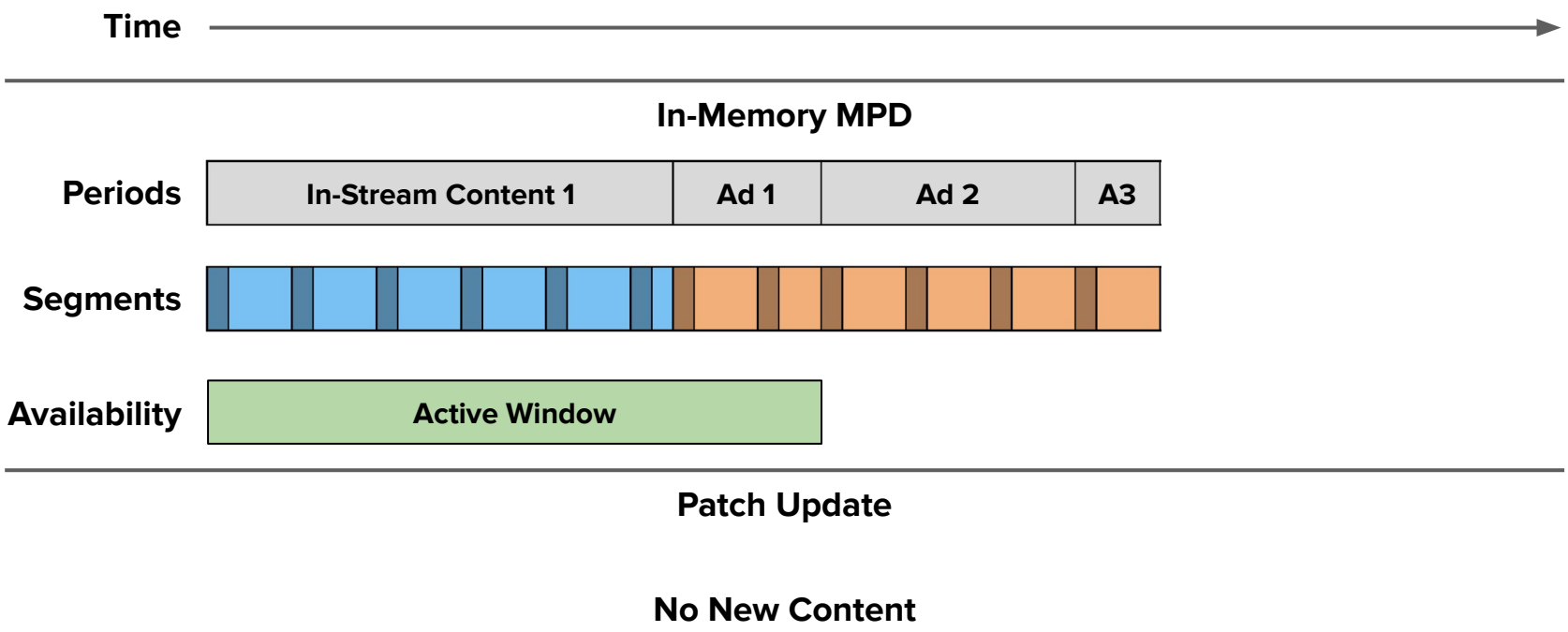
Early Segment Announcement



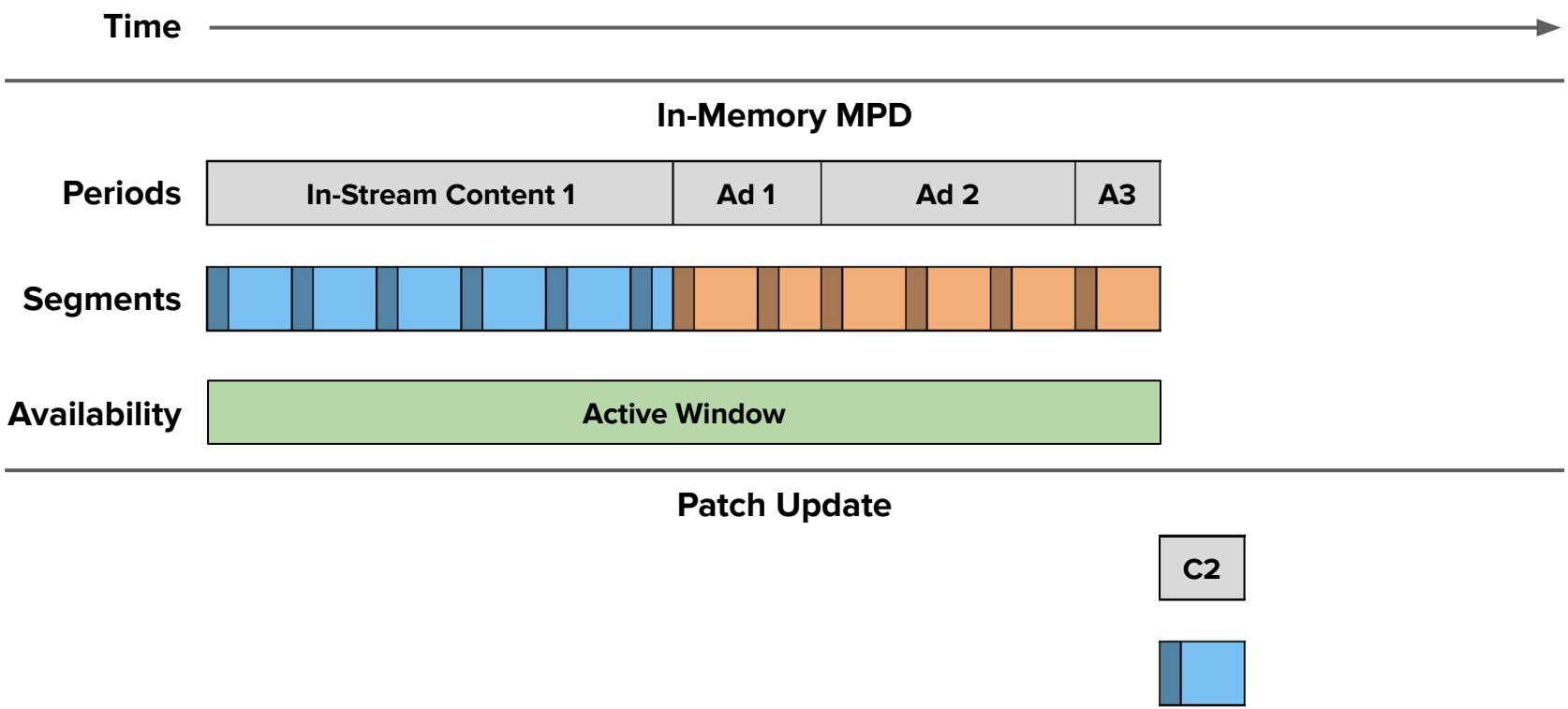
Early Segment Announcement



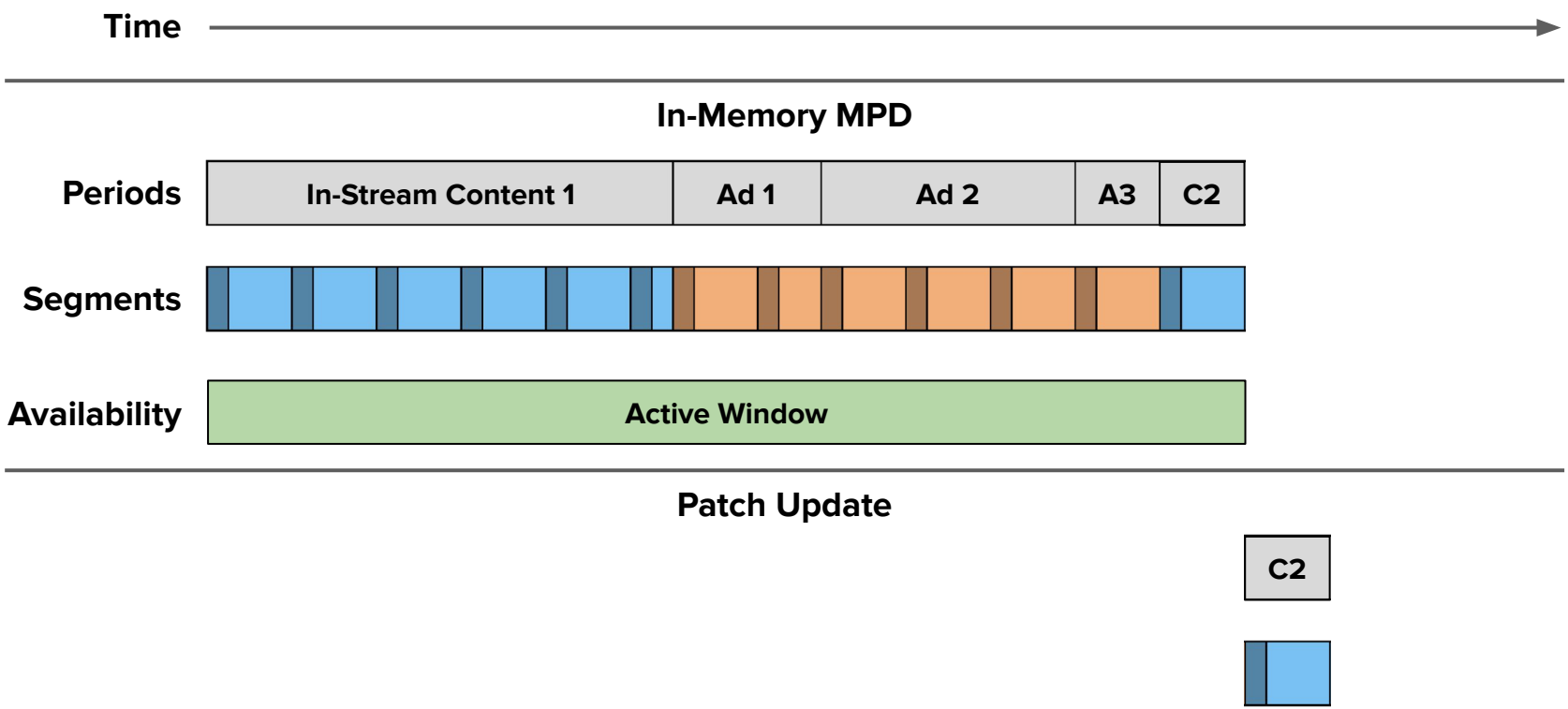
Early Segment Announcement



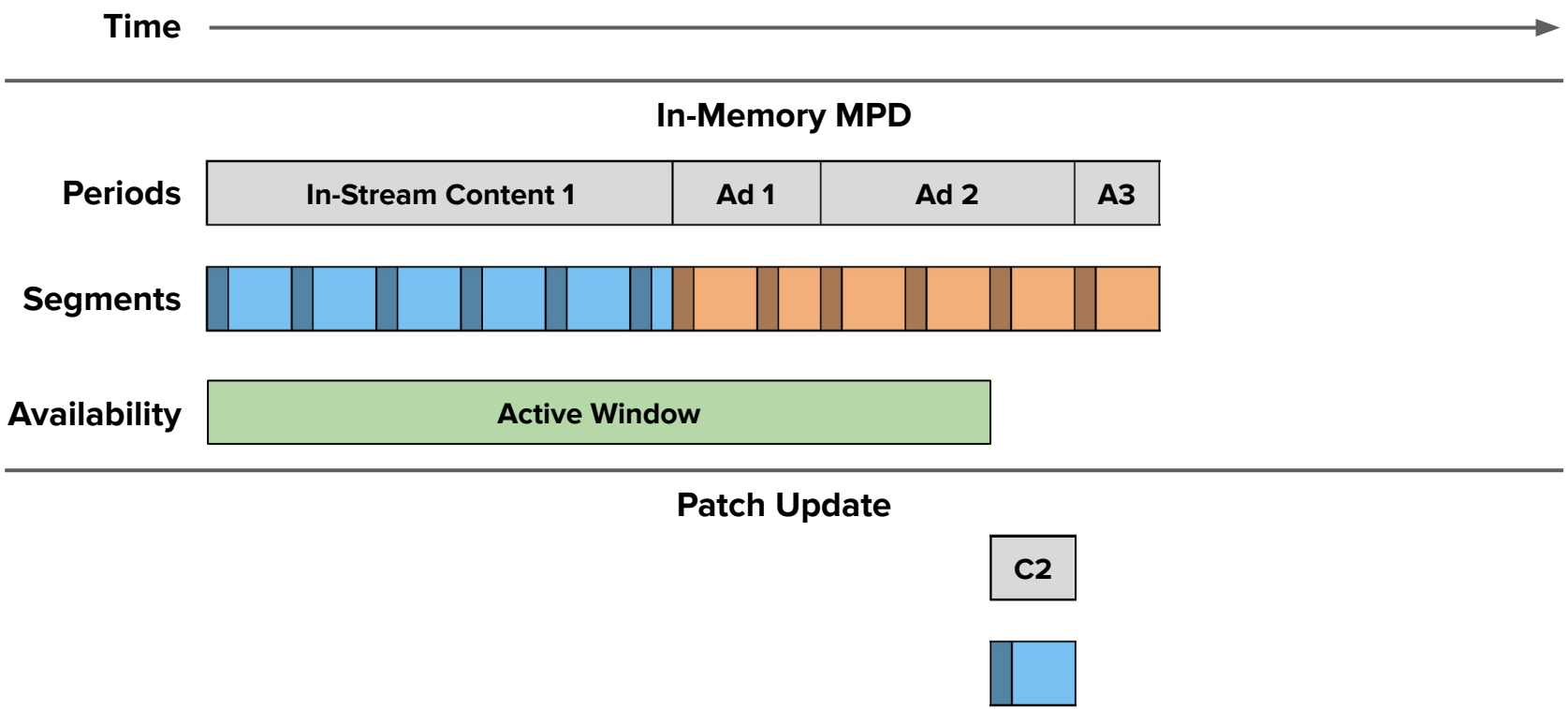
Return to Main Stream



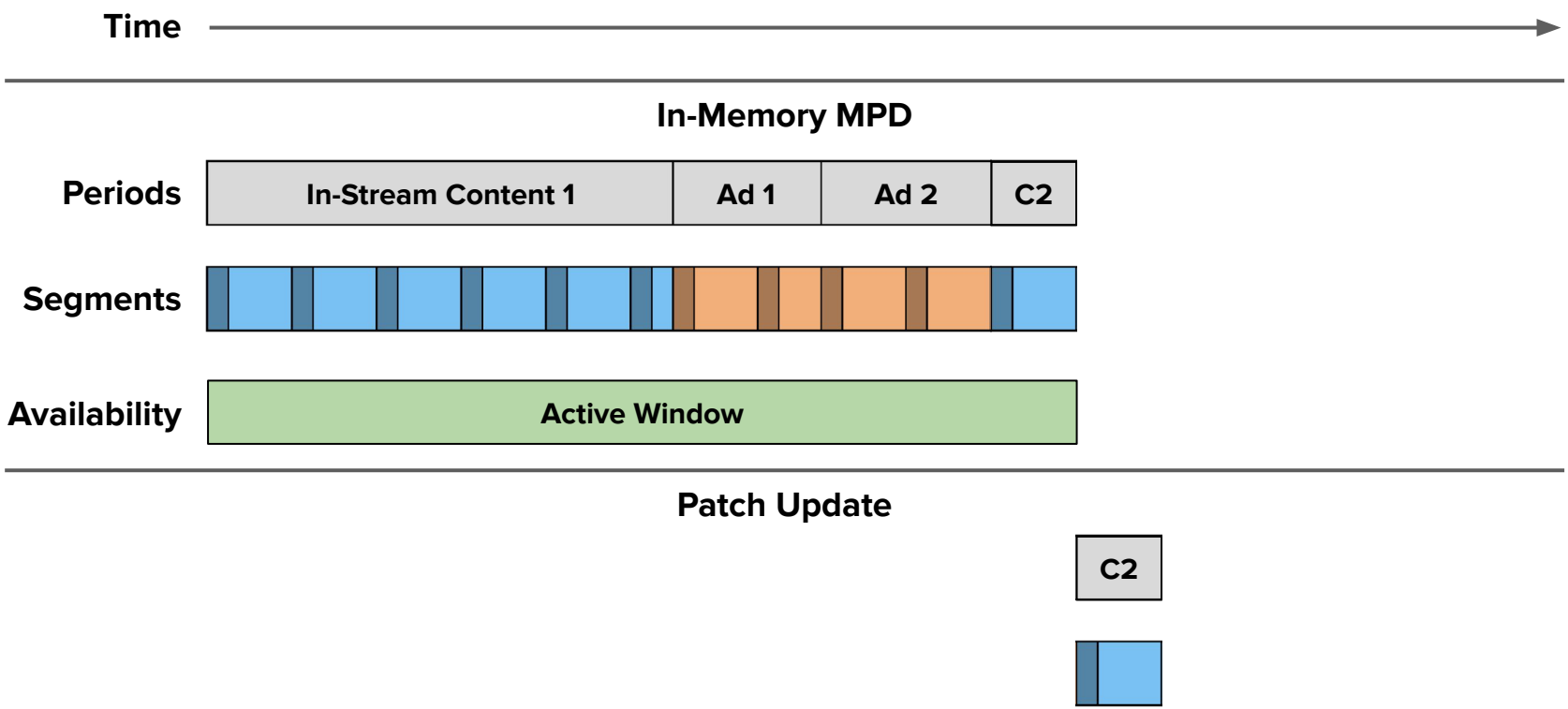
Return to Main Stream



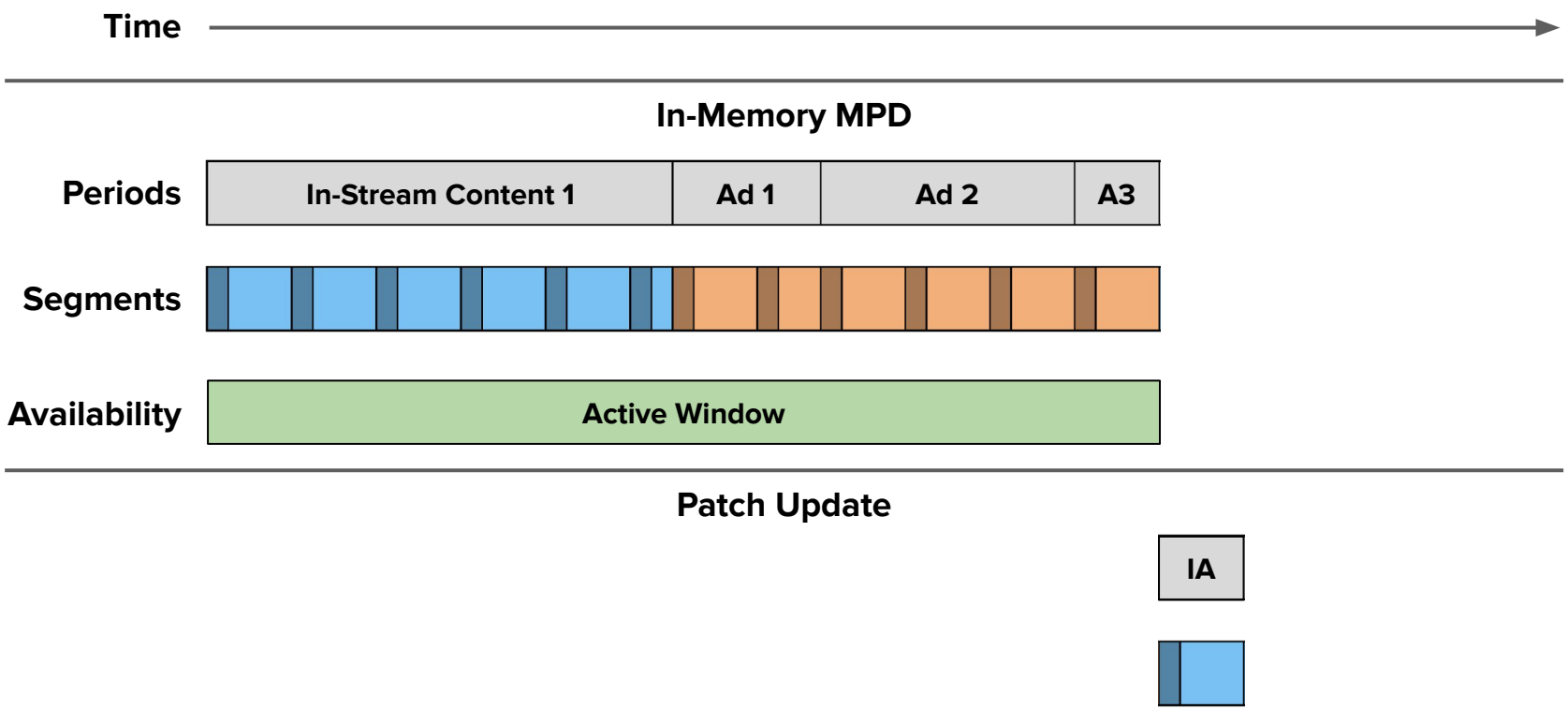
Early Cutback Scenario



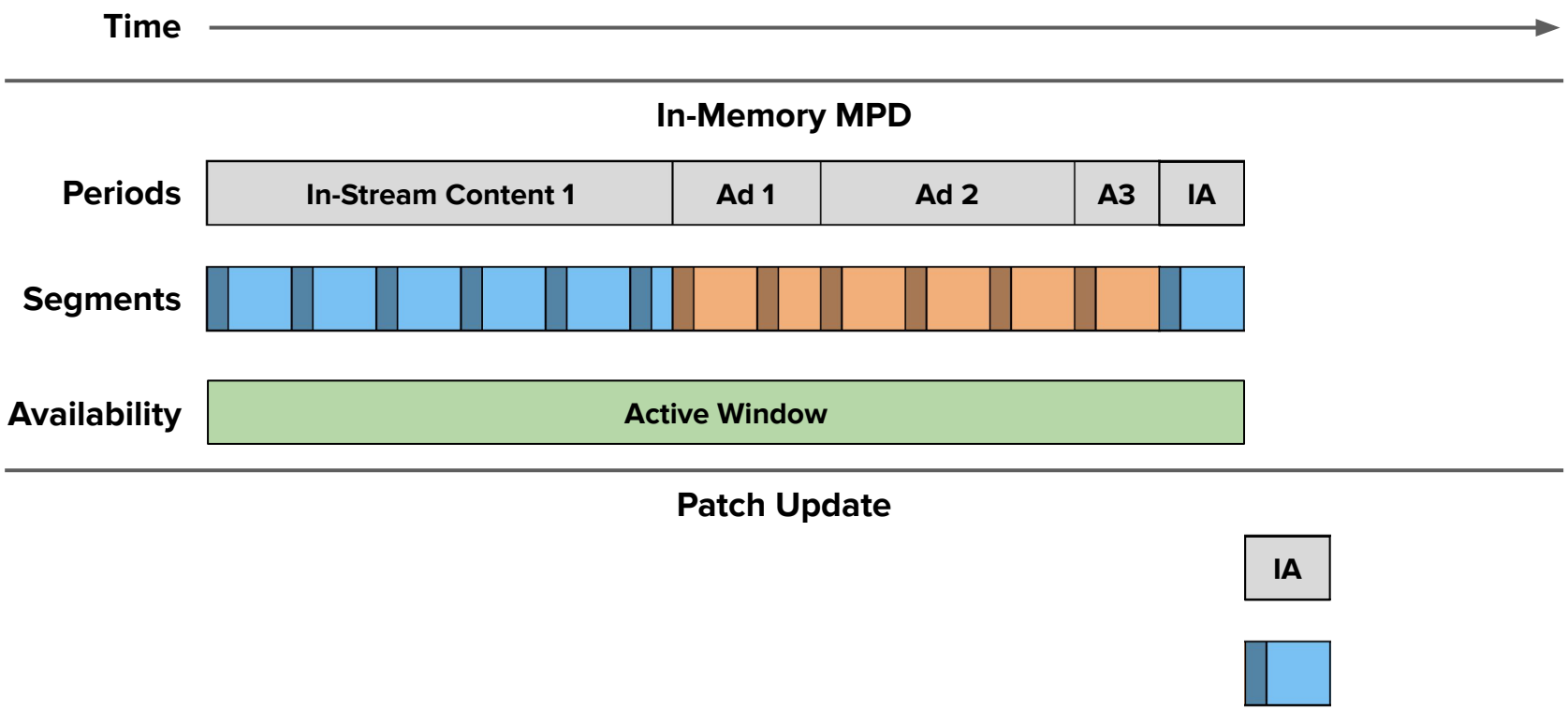
Early Cutback Scenario



Late Cutback Scenario



Late Cutback Scenario



The Best of Both Worlds

- Not quite client side or server side
  - Client only uses manifest concepts
  - Server doesn’t perform stitching
- Exists in both LIVE and VOD
  - LIVE handled as described here
  - VOD handled with X-Link
- Strongly separates content and ads
  - Enables robust scalability
  - Requires a structured timing model

Today / Forward Looking

- Active in production today
  - Enabled across variety of channels
  - Internal and partner player support
- Biggest setback is SCTE-35 quality
  - Each broadcaster has own flavor
  - Working with partners to correct
- DASH Industry Forum Updates
  - Ad Insertion Interoperability Points
  - Reference Implementations

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Q&A

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THANK YOU