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ATSC 3.0 ROUTE/DASH Signaling for Immersive Broadcasting: New Perspectives and Examples

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ABSTRACT In this paper, we mainly address ATSC3.0 ROUTE/DASH service signaling methodology to provide perspectives on realistic and immersive media broadcasting services and their platform architecture. In particular, we have considered and described ways to provide contents encoding/decoding using scalable HEVC (SHVC) and layered services for UHD stereoscopic 3D and 360 virtual reality (VR) contents under a band-limited transmission environment. In the era of COVID-19 pandemics, this kind of type, ATSC 3.0 realistic 3D media service method is expected to become an alternative to performance and media consumption in the future.

INDEX TERMS ATSC 3.0, ROUTE, MPEG-DASH, Immersive Media, 360-degree Video, Virtual Reality, Augmented Reality

I. INTRODUCTION

In recent decades, a large number of Internet Protocol Television (IPTV) providers have emerged and are expanding their markets thanks to the development of Internet networks and the high demand for Video-on-Demand (VoD) services. In addition, as the connection of the Internet using mobile devices becomes easy, the market for digital video streaming services is also expanding rapidly. However, these services are often incompatible with each other because the delivery protocol and the media player are different for each service provider. Users may feel uncomfortable depending on the capability of the devices and the network environments. Besides, network service providers also have a problem in terms of network operation because the bandwidth required by each service is different and difficult to control completely. These problems have forced software providers to develop their own solutions such as HTTP-based Dynamic Streaming (HDS) by Adobe, HTTP Live Streaming (HLS) by Apple, and Smooth Streaming by Microsoft. However, since they still require to use their dedicated media player and server solutions, there are many limitations to become a unified and integrated solution.

For that reason, many industrial companies have tried to solve this problem since 2010 and eventually released the first

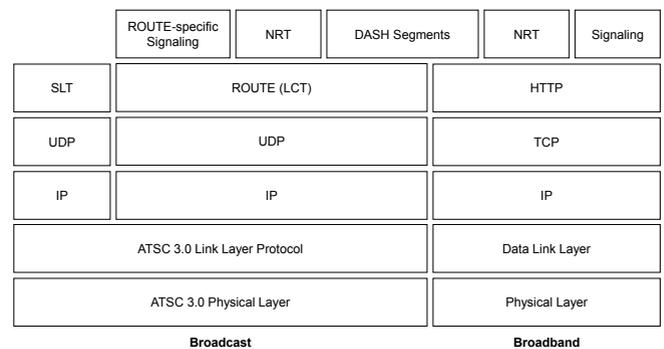


FIGURE 1: ATSC 3.0 ROUTE protocol stack

version of MPEG Dynamic Adaptive Streaming over HTTP (DASH) in 2012 [1]. The main feature of MPEG-DASH is to download or stream multimedia content in adaptable environments by Internet Protocol (IP). For that reason, MPEG-DASH has been widely spread and especially being used by well-known video streaming platforms such as YouTube and Netflix. Moreover, in recent years, MPEG-DASH has been also used for a next-generation broadcast standard such as Advanced Television Systems Committee (ATSC) 3.0 [2].

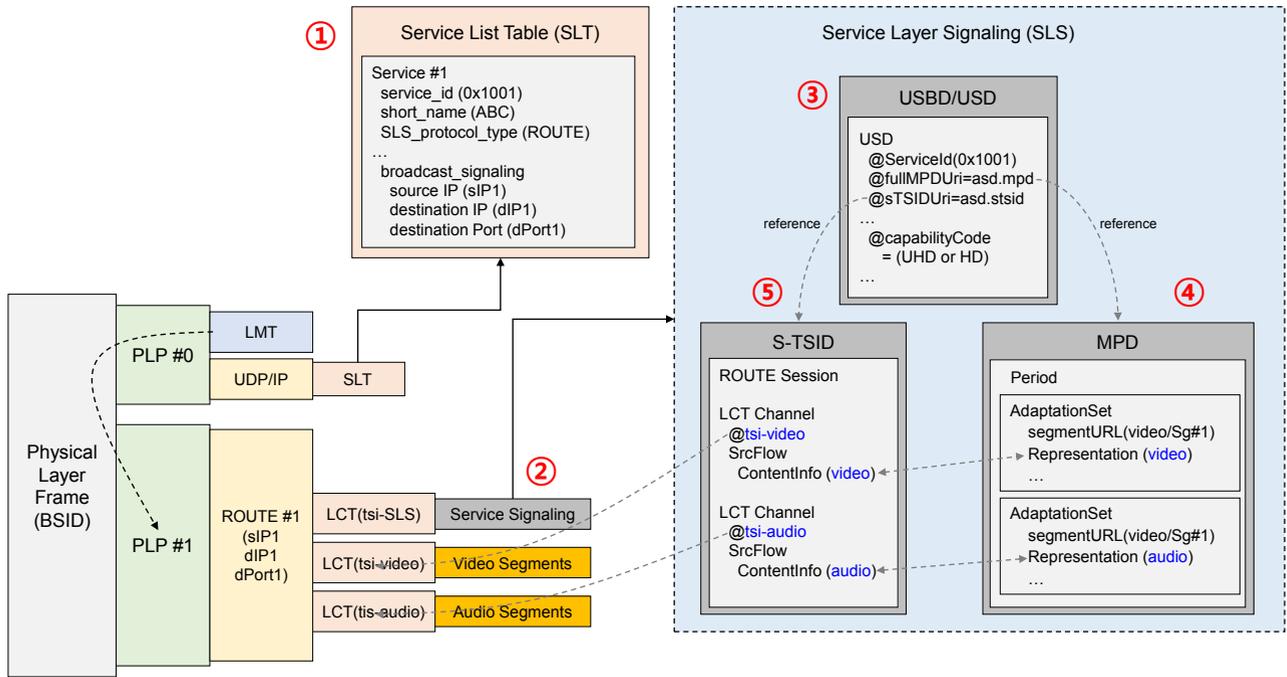


FIGURE 2: Example of ROUTE/DASH service signaling for the bootstrapping and service discovery.

ATSC 3.0 is a fully IP-based broadcasting standard to provide more flexible receptions on both fixed and mobile devices with higher quality and interactivity [3]. ATSC 3.0 adopts two transport protocols: i) MPEG Media Transport Protocol (MMTP) [4] and ii) real-time object delivery over unidirectional transport (ROUTE) protocol [5]. MMTP and ROUTE can be considered as extensions of MPEG Transport Stream (MPEG-TS) and File Delivery over Unidirectional Transport (FLUTE) [6], respectively. However, both protocols are designed to split content components into multiple segments (or chunks) according to ISO Base Media File Format (ISOBMFF) [7]. It allows discovering and accessing available services and their segmented contents by specific signaling, which describes essential characteristics that make up each service such as content type, video coding format, and so on. In the respect of exploiting the segmentation, these two protocols seem to be similar, but ROUTE uses MPEG-DASH supporting both broadcast (over UDP) and broadband (over HTTP/TCP) whereas MMTP does not. The details are discussed in the following chapters.

In this paper, therefore, we only deal with ATSC 3.0 ROUTE/DASH and its comprehensive perspective on the signaling methods, i.e. Low-Level Signaling (LLS) and Service Layer Signaling (SLS). The former is for the discovery of all services provided to users and the latter is for the access and presentation of a specific service. In particular, by concentrating on immersive broadcasting and its specific signaling methods, we provide new perspectives on upcoming broadcast services. Finally, since ROUTE/DASH uses a media presentation description (MPD) for the service presentation which varies according to the content formats, we also

present some examples of MPD signaling that enables the immersive service via ROUTE/DASH in ATSC 3.0. This is the extended version of our previous work in [8].

The remainder of this paper is organized as follows. Basic principle including LLS and SLS of ATSC 3.0 ROUTE protocol is described in Section II. Various perspectives and examples about immersive broadcasting and MPD signaling are discussed in Section III and IV, respectively. Finally, the conclusion is given in Section V.

II. BASIC PRINCIPLE OF ROUTE/DASH IN ATSC 3.0

Fig. 1 shows a conceptual ATSC 3.0 ROUTE protocol stack in which MPEG-DASH segments can be delivered through both ROUTE/UDP/IP and HTTP/TCP/IP. Native broadcasting services are generally delivered through ROUTE/UDP/IP and additional multimedia contents, such as secondary language audio and text, are delivered through HTTP/TCP/IP along with the native services. In addition, non-real-time (NRT) contents, such as the electronic service guide (ESG) and emergency alert (EA), can be also delivered through both ROUTE/UDP/IP and HTTP/TCP/IP. The ROUTE-specific SLS is delivered through ROUTE/UDP/IP, while bootstrap signaling information is provided by means of the service list table (SLT). The SLT is one of LLS and supports building a basic service list, as well as discovering the SLS and accessing each ATSC 3.0 service. The details are in [9]. The relationship between SLT and SLS is illustrated in Fig. 2, and the brief process is described as follows.

- 1) ATSC 3.0 users first receive SLT which provides the bootstrap information to discover the SLS for each service. The SLT includes the IP addresses/ports of each

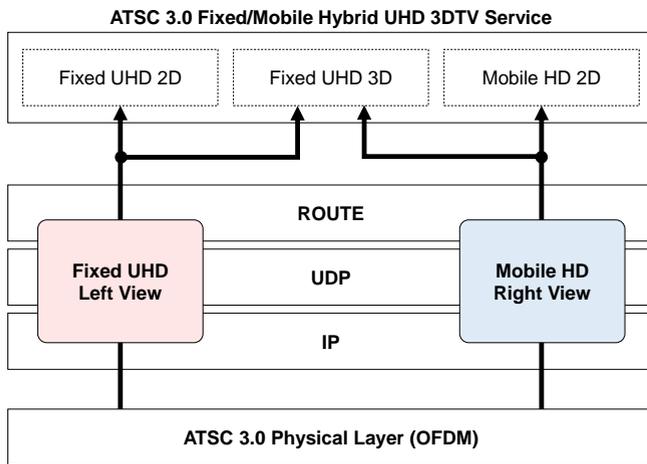


FIGURE 3: Concept of fixed/mobile hybrid UHD 3DTV service.

layered coding transport (LCT) channel that carries an SLS. In general, a ROUTE session may consist of one or more LCT channels and each LCT channel carries a content component, such as video, audio, and caption.

- 2) Before acquiring the delivered contents by broadcasters, ATSC 3.0 users have to parse the SLS that is comprised of XML-based fragments: the user service bundle description (USBD), the service-based transport session instance description (S-TSID), and the DASH media presentation description (MPD). These fragments organizationally provide information about the characteristics of the desired service.
- 3) The USBD fragment of the ATSC 3.0 is similar to that of the 3GPP MBMS [12]. It provides overall information on the service such as service identification (ID) and device capabilities (e.g. HD or UHD). Especially, the USBD refers to MPD and S-TSID fragments to access a chosen service and content components, respectively.
- 4) The MPD fragment provides identification information for the content components that make up the service, such as the content ID and type (e.g., video or audio), video coding format, etc. [13]. Therefore, user devices determine how to decode and play the contents according to the MPD.
- 5) The S-TSID fragment provides the information on where to acquire the DASH segments described in the MPD. In other words, the S-TSID tells users which LCT session delivers the DASH-formatted content components. Importantly, the ContentInfo of the S-TSID and the Representation ID of the MPD must be matched.

III. PERSPECTIVES ON IMMERSIVE BROADCASTING

In this section, we deal with hybrid immersive broadcasting services, in which various qualities of the immersive media can be provided via only one physical transmission simultaneously. Firstly, we address a hybrid stereoscopic 3D service, in which low-quality 2D video, and high-quality 2D and 3D

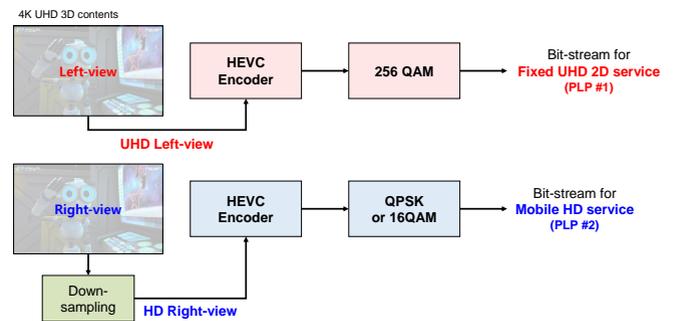


FIGURE 4: HEVC-based simulcast 3D service.

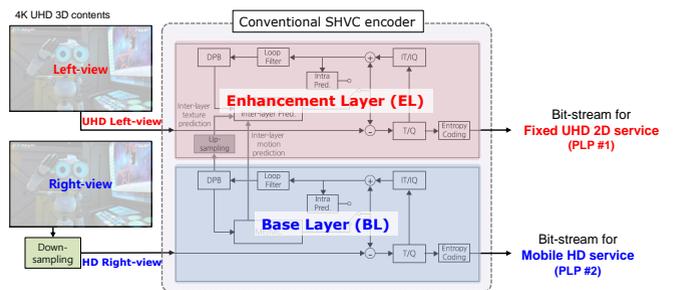


FIGURE 5: SHVC-based layered service.

videos can be provided simultaneously for both mobile and fixed TV users. Secondly, we address a tile-based hybrid stereoscopic 360 VR service, in which low-quality mono video, high-quality mono video, and stereoscopic 360 VR video can be provided simultaneously for both mobile and fixed VR users. This can be considered as an extension of the first one that enables an adaptive delivery of 360 VR videos.

A. FIXED/MOBILE HYBRID 3D SERVICE

Fig. 3 shows a concept of a hybrid 3D service for fixed and mobile users in which the UHD left-view and the HD right-view videos are provided. Since mobile users generally experience worse channels than fixed users, low-quality HD right-view (mono) video is only decoded. Conversely, fixed users decode both HD right and UHD left-view videos because of better channel condition, so high-quality UHD right-view (mono) and stereoscopic 3D services can be provided in accordance with the device's capabilities. In addition, the fixed/mobile hybrid UHD 3D service can be divided into two cases according to the video coding formats that are used as follows: the HEVC-based simulcast and the SHVC-based layered services. The H.265/HEVC is a video compression standard that is an extension of the H.264/MPEG-4 AVC [10]. The HEVC supports resolutions up to 8192×4320 , including 8K UHD. The SHVC supports scalability in spatial, SNR, and color terms, and thus it can reduce the average data rate by up to approximately 15% for a 4K UHD video [11]. The details by video coding methods are as follows:

1) HEVC-based Simulcast Service

The HEVC-based simulcast 3D system is illustrated in Fig. 4, in which the UHD left-view and the HD right-view of a stereoscopic 3D video are encoded independently by two HEVC encoders. The HD right-view for mobile users is modulated by the low-order modulation, such as the QPSK and 16QAM for high reliability, whereas the UHD left-view is modulated by the high-order modulation 256QAM due to its large amount of data. The two modulated video streams are delivered by different physical layer pipes (PLPs) and provide UHD and HD 2D services for the fixed and mobile devices, respectively. The number of PLPs used can vary depending on the ATSC 3.0 physical layer multiplexing schemes. In addition, if the fixed user devices have the capabilities to display stereoscopic 3D video, the devices can get the UHD right-view and the HD left-view videos through two independent PLPs.

2) SHVC-based Layered Service

Fig. 5 shows that the HD right-view and the UHD-left view videos are encoded into a base layer (BL) and an enhancement layer (EL), respectively. The UHD right-view is first scaled down into HD quality and encoded into a BL. Next, the down-scaled HD right-view is again scaled up into the original UHD quality, compared with the UHD left-view to obtain the inter-layer prediction value, and re-encoded into an EL. The EL is independently undecodable without the BL because it is encoded on top of the BL. Hence, the BL needs to be modulated by the low-order modulation for the purpose of its high reliability, while the UHD EL is modulated by the high-order modulation due to its large amount of data. The BL and EL are also delivered through different PLPs, respectively. For example, PLP #1 is for the BL and PLP #2 is for the EL. For the mobile HD service, the BL is sufficient, whereas the fixed devices require both the BL and EL to reconstruct the UHD 2D content. Furthermore, if user devices have the capabilities to display stereoscopic 3D video, the devices can also combine the two video views to display stereoscopic 3D. This is unlike the HEVC-based simulcast 3D service in which one video encoder/decoder, such as SHVC encoder/decoder, is only required to provide users with three services simultaneously, including HD 2D service, and UHD 2D/3D services.

B. TILE-BASED HYBRID 360 VR SERVICE

As the demand for immersive media grows, various types of VR services such as 360 VR media are emerging. According to [14], providing the stereoscopic 360 VR is very important for making the VR experience more immersive. To this end, the left 360 and right 360 videos must be separately projected and displayed to each eye. However, because poorly implemented stereoscopic 360 VR service can cause major discomforts, such as headaches, eye strain, and nausea, many studies have been widely conducted to reduce this problem.

Fig. 6 shows an overview of the tile-based hybrid stereoscopic 360 VR service, in which both the left 360 and right

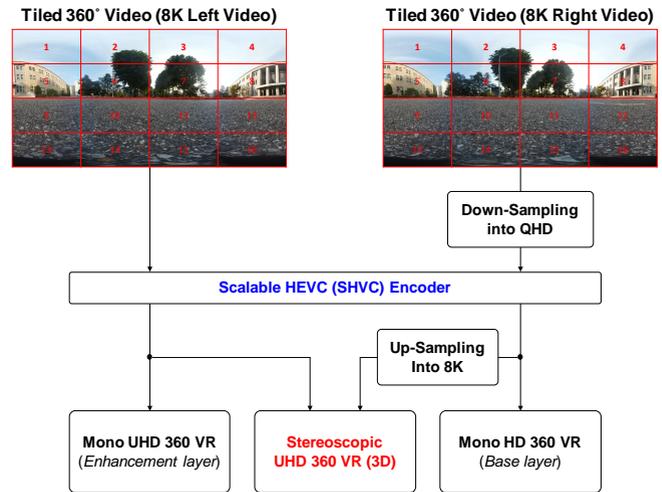


FIGURE 6: Tile-based hybrid stereoscopic 360° VR service.

360 VR videos are equirectangularly projected and separated into independent 16 tiles (4×4). The number of tiles can vary sufficiently depending on the purpose. These tiles are used for parallel processing. Similar to the SHVC-based layered service, the 8K (7680×4320) 360 right video is first scaled down into low resolution 360 video (e.g., QHD, 2560×1440), and encoded by a single SHVC encoder along with the original 8K 360 left video. This encoding process is identical to the conventional SHVC encoder shown in Fig 5. The encoded low-quality (360 right) and high-quality (360 left) streams are also called BL and EL, respectively. The BL is for VR users within a bad channel environment (e.g., mobile VR), whereas the EL is for VR users within a good channel environment (e.g., fixed VR). In addition, if VR users are capable of displaying stereoscopic 3D within a good network environment, both the BL and EL are combined to provide stereoscopic 360 VR videos for the user.

IV. MDP SIGNALING EXAMPLES

As we described in Section II, ROUTE/DASH-specific signaling includes three fragments: USBD/USD, S-TSID, and MPD. However, for the immersive broadcasting and its signaling considered in this paper, it is sufficient to redefine the MPD fragment only. This is because USBD/USD and S-TSID are not interested in content-related information such as codec, frame rate, resolution, view position, dependency, etc. In this section, therefore, we present some examples of MPD signaling for hybrid immersive broadcasting.

A. HEVC-BASED SIMULCAST SERVICE

As mentioned in Section III-A1, the HD right-view and the UHD left-view videos are independently encoded. The view position information must be described in the MPD fragment so that the ATSC 3.0 users identify which view is left or right. The MPD signaling for the HEVC-based simulcast service is described in Fig. 7(a), in which some elements and attributes are omitted for simplicity. There are two AdaptationSet ele-

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<MPD availabilityStartTime="2016-10-04T07:55:30Z" profiles="urn:mpeg:dash:profile:isoff-live:2011" maxSegmentDuration="PT0H0M2.000S" minBufferTime="PT1.5S"
timeShiftBufferDepth="PT1M" minimumUpdatePeriod="PT1H" type="dynamic" xmlns="urn:mpeg:dash:schema:mpd:2011">
  <Period start="PT0S">
    <!--1st Adaptation Set: HD right video for 3D service -->
    <AdaptationSet id="right" lang="eng" segmentAlignment="true" maxWidth="3840" maxHeight="2160" maxFrameRate="60000/1001" par="16:9">
      <Representation id="rv1" mimeType="video/mp4" codecs="hev1.2.4.L153.B0" width="1920" height="1080" frameRate="60000/1001" sar="1:1" startWithSAP="1" bandwidth="4000000">
        <SegmentTemplate initialization="video_100_init.mp4" duration="96096" startNumber="3" media="video_100_$.mp4" timescale="90000"/>
      </Representation>
    </AdaptationSet>
    <!--2nd Adaptation Set: UHD left video for 3D service -->
    <AdaptationSet id="left" lang="eng" segmentAlignment="true" maxWidth="3840" maxHeight="2160" maxFrameRate="60000/1001" par="16:9">
      <EssentialProperty value="right" schemeIdUri="http://dashif.org/guidelines/dash-atsc-videoposition"/>
      <Representation id="lv1" mimeType="video/mp4" codecs="hev1.2.4.L153.B0" width="3840" height="2160" frameRate="60000/1001" sar="1:1" startWithSAP="1" bandwidth="19000000">
        <SegmentTemplate initialization="video_102_init.mp4" duration="96096" startNumber="3" media="video_102_$.mp4" timescale="90000"/>
      </Representation>
    </AdaptationSet>
  </Period>
</MPD>

```

(a) The MPD signaling for HEVC-based simulcast service.

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<MPD availabilityStartTime="2016-10-04T07:55:30Z" profiles="urn:mpeg:dash:profile:isoff-live:2011" maxSegmentDuration="PT0H0M2.000S" minBufferTime="PT1.5S"
timeShiftBufferDepth="PT1M" minimumUpdatePeriod="PT1H" type="dynamic" xmlns="urn:mpeg:dash:schema:mpd:2011">
  <Period start="PT0S">
    <!--1st Adaptation Set: HD right video for 3D service -->
    <AdaptationSet id="right" lang="eng" segmentAlignment="true" maxWidth="3840" maxHeight="2160" maxFrameRate="60000/1001" par="16:9">
      <Representation id="rv1" mimeType="video/mp4" codecs="hev1.2.4.L153.B0" width="1920" height="1080" frameRate="60000/1001" sar="1:1" startWithSAP="1" bandwidth="4000000">
        <SegmentTemplate initialization="video_100_init.mp4" duration="96096" startNumber="3" media="video_100_$.mp4" timescale="90000"/>
      </Representation>
    </AdaptationSet>
    <!--2nd Adaptation Set: enhancement layer of SHVC for UHD left video (for 3D service) -->
    <AdaptationSet id="left" lang="eng" segmentAlignment="true" maxWidth="3840" maxHeight="2160" maxFrameRate="60000/1001" par="16:9">
      <EssentialProperty value="right" schemeIdUri="http://dashif.org/guidelines/dash-atsc-videoposition"/>
      <Representation id="lv1" mimeType="video/mp4" codecs="lhe1" width="3840" height="2160" frameRate="60000/1001" sar="1:1" startWithSAP="1" bandwidth="19000000"
        dependencyID="rv1" |>hevcp1=0, 1.0.7.80.L153.BD.88">
        <SegmentTemplate initialization="video_102_init.mp4" duration="96096" startNumber="3" media="video_102_$.mp4" timescale="90000"/>
      </Representation>
    </AdaptationSet>
  </Period>
</MPD>

```

(b) The MPD signaling for SHVC-based layered service.

FIGURE 7: Examples of MPD signaling for (a) HEVC-based simulcast service and (b) SHVC-based layered service.

ments that separately have a different Representation element corresponding to the HD right-view and the UHD left-view, respectively. By using this information, the ATSC 3.0 users can select either one of the two in accordance with their respective capabilities (e.g., HD or UHD). The combination of the first and second AdaptationSets is for the 3D service. To indicate the 3D service, an EssentialProperty element should be included in the AdaptationSet for the UHD left-view video [1]. The @schemeIdUri and @value attributes should be matched with 'http://dashif.org/guidelines/dash-atsc-videoposition' [13] and the first AdaptationSet ID "right", respectively. This is to indicate that the second AdaptationSet for the UHD left-view video is a stereo pair with the first AdaptationSet for the HD right-view video.

B. SHVC-BASED LAYERED SERVICE

In the case of the SHVC-based layered service, the HD right-view and the UHD left-view are encoded into the BL and EL, respectively. Because the EL is encoded on top of the BL, EL is independently undecodable without the BL. In other words, there is a dependency between the BL and EL, so the MPD signaling must indicate the dependency along with the stereo view position. The example of the MPD signaling for the SHVC-based layered service is described in Fig. 7(b). Like the case of the HEVC-based 3D service, there are two video components (i.e., AdaptationSets) with their own qualities (i.e., Representations). The first AdaptationSet contains the BL and indicates the HD right-view video stream. It is for mobile devices that are experiencing bad channel conditions. On the other hand, the second AdaptationSet contains the EL, and it is decoded into the UHD left-view video with

```

01 <MPD>
02 <Period>
03 <!-- Adaptation Sets for Down-sampled Right QHD 360 Video Separated into 16 (4x4) Tiles -->
04 <AdaptationSet id="right_tile_1">
05 <SupplementalProperty schemeIdUri="urn:mpeg:dash:srd:2014" value="1,0,0,640,360,2560,1440" <!--1st Tile of Right Video-->
06 <Representation id="right_nHD_1" mimeType="video/mp4" width="640" height="360"...>
07 <BaseURL>right_nHD_1.mp4 </BaseURL>
08 </Representation>
09 </AdaptationSet>
10 <AdaptationSet id="right_tile_2">
11 <SupplementalProperty schemeIdUri="urn:mpeg:dash:srd:2014" value="1,640,0,640,360,2560,1440" <!--2nd Tile of Right Video-->
12 <Representation id="right_nHD_2" mimeType="video/mp4" width="640" height="360"...>
13 <BaseURL>right_nHD_2.mp4 </BaseURL>
14 </Representation>
15 </AdaptationSet>
16 :
17 <!-- Adaptation Sets for Left 8K 360 Video Separated into 16 (4x4) Tiles -->
18 <AdaptationSet id="left_tile_1">
19 <SupplementalProperty schemeIdUri="urn:mpeg:dash:srd:2014" value="2,0,0,1920,1080,7680,4320" <!--1st Tile of Left Video-->
20 <EssentialProperty value="right_tile_1" schemeIdUri="http://dashif.org/guidelines/dash-atsc-video-position/" <!--Stereoscopic Paring-->
21 <Representation id="left_FHD_1" mimeType="video/mp4" width="1920" height="1080" dependencyID="right_nHD_1">
22 <BaseURL>left_FHD_1.mp4 </BaseURL>
23 </Representation>
24 </AdaptationSet>
25 <AdaptationSet id="left_tile_2">
26 <SupplementalProperty schemeIdUri="urn:mpeg:dash:srd:2014" value="2,1920,0,1920,1080,7680,4320" <!-- For 2nd Tile of Left Video-->
27 <EssentialProperty value="right_tile_2" schemeIdUri="http://dashif.org/guidelines/dash-atsc-video-position/" <!--Stereoscopic Paring-->
28 <Representation id="left_FHD_2" mimeType="video/mp4" width="1920" height="1080" dependencyID="right_nHD_2">
29 <BaseURL>left_FHD_2.mp4 </BaseURL>
30 </Representation>
31 </AdaptationSet>
32 :
33 </Period>
34 </MPD>

```

FIGURE 8: Examples of MPD signaling for tile-based hybrid stereoscopic 360 VR service.

reference to the BL that is contained the first AdaptationSet. To indicate the dependency (or layering), the Representation ID “rv1” of the first AdaptationSet must be indicated in @dependencyId attribute in the Representation of the second AdaptationSet. In other words, for the decoding of the UHD left-view video, both AdaptationSets must be chosen. The combination of the first and second AdaptationSets is for the 3D service, and the stereoscopic mapping is indicated by EssentialProperty, such as in the case of the HEVC-based 3D service.

C. TILE-BASED HYBRID 360 VR SERVICE

Fig. 8 shows the example of MPD signaling that enables the tile-based hybrid stereoscopic 360 VR service. In general, spatial relationship description (SRD) is used to indicate the tile position in MPD fragment. Accord-

ing to [15], the position shall be signaled by using a @schemeIdUri with urn:mpeg:dsh:srd:2014 and a @value of SupplementalProperty at an AdaptationSet. Especially, the @value must include following parameters in order: source_id, object_x, object_y, object_width, object_height, total_width, total_height and spatial_set_id. These denote an identifier for the original video, the horizontal and vertical positions of the top-left corner of the associated tile, the width and height of the associated tile, the width and height of the original video, and an identifier for a group of tiles, respectively. All parameters are non-negative integer in the decimal representation, and the last spatial_set_id is optional.

In Fig. 8, MPD of the tile-based hybrid stereoscopic 360 VR service is described. We consider an original 8K left

360° video that is separated into 16 tiles (i.e., the resolution of each tile is 1920×1080) and the @value of the first tile of left video is described as (2, 0, 0, 1920, 1080, 7680, 4320), in which assuming that the source_id of left video is “2”. Similarly, the @value of the second tile of left video can also be described as (2, 1920, 0, 1920, 1080, 7680, 4320). In addition to the spatial relationship of tiles, we should describe the stereoscopic relationship between the left and right videos, as well as the dependency between the BL and EL. However, these descriptions are omitted because these are already detailed in Section IV-A and IV-B.

V. CONCLUSION

This paper dealt with ATSC 3.0 ROUTE/DASH protocol and its specific signaling for immersive broadcasting. First, we presented service structures categorized in accordance with the video coding formats HEVC and SHVC. Especially in the case of using SHVC, three services, i.e. low-quality 2D, high-quality 2D/3D services, can be provided simultaneously through one physical channel. In addition, we presented MPD signaling examples that enable the aforementioned immersive broadcasting. We believe that the presented structures and signaling examples may give readers new perspectives on immersive broadcasting via ATSC 3.0 ROUTE/DASH protocol.

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