

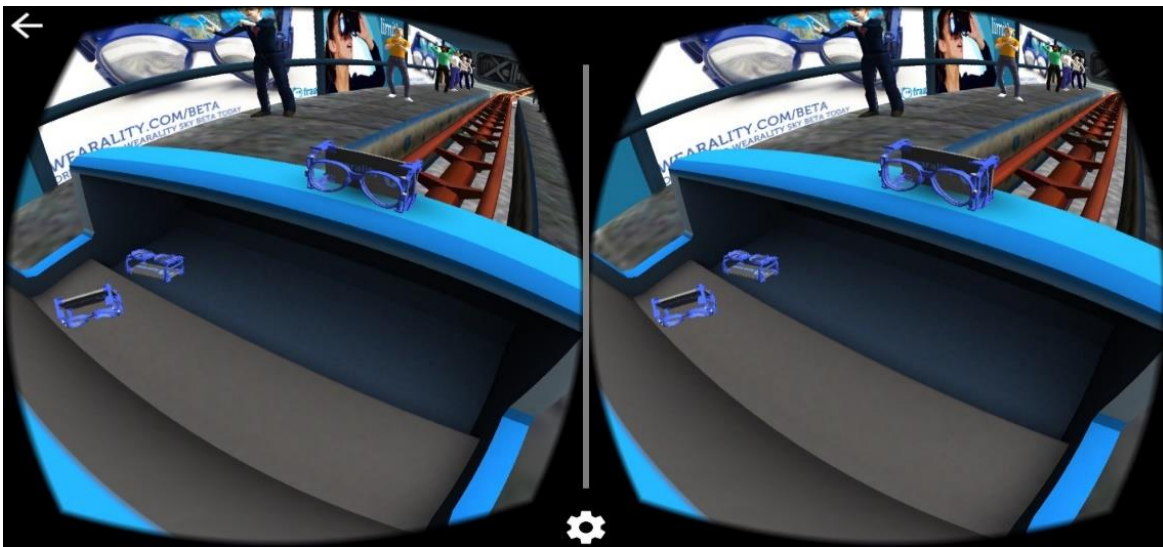
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Project	<b>HMD based 3D Content Motion Sickness Reducing Technology</b> < <a href="http://sites.ieee.org/sagroups-3333-3/">http://sites.ieee.org/sagroups-3333-3/</a> >
Title	<b>Bandwidth and Latency Requirements for Virtual Reality</b>
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Re:	Session #2, NY, USA
Abstract	Determining bandwidth and latency requirements for Virtual Reality using the LAB data.
Purpose	Provide specific network requirements for VR service and reflect these technical requirements to IEEE P3333.3 standards.
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## 1. VR HMD Characteristics

VR HMD (Virtual Reality Head Mounted Display) display two separate but identical images for left and right eye respectively in order to create stereoscopic image. Also, it uses a pair of fish eye lenses to maximize the field of view so that the user does not see the display edges and believes that he is seeing the virtual world with his own eyes, not through a display. This usage of fish eye lenses distorts the images displayed on the screen like Figure 1 and enlarges field of view, we are only perceiving 45% of the actual screen resolution. This is the reason why the VR HMD manufacturers are suggesting to use 4K UHD display to provide the visual fidelity we are commonly seeing from most popular TV sets, which is 1080p FHD display.



**Figure 1. Stereoscopic image for VR HMD**

4K UHD resolution offers 3840 x 2160 pixels. It means that an image requires 1G size and the VR content service which requires 90 FPS would require 18 Gbps data transfer rate.

$$\text{Equation: resolution} \times 24\text{bit (color)} \times \text{frame rate} = \text{data capacity}$$

Even if the movie clip data is compressed, 1 Gbps data transfer rate needs to be guaranteed.

Table 1. IMT-2020 vs WLAN vs IMT-Advanced

	IMT-Advanced	WLAN(802.11ac)	IMT-2020
Peak data rate	1 Gbps	7Gbps	20 Gbps
User experienced data rate	10 Mbps (urban/suburban)	300Mbps (urban/suburban)	100 Mbps (urban/suburban), 1Gbps (hotspots)
Mobility	350 Km/h	N/A	500 Km/h
Area traffic capacity	0.1 Mbps/ m2	N/A	10 Mbps/ m2

Refer to Table 1, minimal data transfer rate for VR service would require at least IMT-Advanced wireless network; and 802.11ac or above WLAN or IMT-2020 wireless network will be necessary to create smooth VR service environment.

However, only IMT-2020 specifications are available and its technological implementation standards are not yet ready whereas VR already has commercial services ready. Hence, we are currently facing a situation where content is ready to be served but the network infrastructure is not ready to accommodate the needs. Therefore, it would be great if IEEE 802 can examine the industry requirements and provide standards for a secured and stable wireless network infrastructure that the industry can use to provide VR content services.

Especially, IEEE 802.21 is working on network handover issues and it would be worthwhile to examine different cases where VR service may leverage its standards on network handover.

## 2. Video Coding Standard for VR and Its Bandwidth Requirements

### 2.1. Quality requirements for VR to reduce nausea

There have been joint collaborations between ISO/IEC SC29 MPEG (Moving Picture Experts Group) and ITU-T VCEG (Video Coding Experts Group) to compress raw video sequences efficiently. For example, AVC (Advanced Video Coding), HEVC (High Efficiency Video Coding) were standardized in 2001 and 2013, respectively, and FVT (Future Video Coding) are under standardizing by the Joint Video Exploration Team (JVET) of MPEG and VCEG now. Because ISO/IEC SC29 MPEG standard covers the system and the file format area, MPEG-I actively standardizes the immersive media technology for 360 video VR service as well.

In 116<sup>th</sup> MPEG meeting (Oct. 2016), Technicolor, Qualcomm, Harmonic, and TNO announced the quality requirements for VR [1], which indicated 12K video with 90 frames per second are desirable

to reduce the user nausea. The document addresses the visible viewport is about 12~14% of the total environment. Thus, if the resolution of target HMD is a 4K, the desirable resolution for 360 video VR service is 3 times of 4K resolution (11520x6480). Table 2 addresses that the VR video with 12K resolution, 90 fps, and 20ms delays reduces VR users' nausea.

Table 2. Quality Requirements for VR Presented in MPEG 116<sup>th</sup> Meeting

Requirement	Details
Pixels/degree	- 40 pix/deg - No HMD is capable of displaying 40pix/degree today
Video Resolution	- 3 times 4K(3840x1920) vertical resolution = 11520x6480
Framerate	- 90 fps - 90fps framerate offers a latency low enough to prevent nausea
Stitching Errors	- Delivery and rendering processes shall not introduce additional stitching errors
3D Audio	- Support of scene-based and/or environmental audio - 360 surround sound, object-based audio, Ambisonics
Motion-to-photon latency & motion-to-audio latency	- How much time there is between the user interacts and an image / audio - Maximum 20 ms
Foreground & Parallax	- Objects in the foreground shall be far enough to prevent nausea - If objects are too close it is likely they can become an important cause of nausea - Interactive parallax with background shall be present for such objects

Thus, we measured the bandwidth requirement to meet the quality requirements. Experiments were conducted with the common test condition (CTC) defined in JVET.

The picture coding structure RA (Random Access) and LDB (Low-delay B), and QP (Quantization parameter) 22, 27, 32, and 37 were used. Test sequence were prepared by cropping and merging JVET's 8K (5760x3240) test sequences (Gaslamp, Harbor, KiteFlite, Trolley) because there are no 12K test sequences defined in JVET yet.

For the pilot tests, the video standard reference software HM (ver. 16.6) encoded first 10 frames of the sequence because of its complexity (3 hours per 1 test set, total 8 sets.)

Experimental results in Table 3 shows **maximum 360 Mbps are needed for 12K 90fps VR service.**

Table 3. Measured Bandwidth Requirement for 12K VR under the CTC of JVET

Coding Structure	Quantization Parameter	12K Bitrate (@90fps)
RA	37	60 Mbps
	32	107 Mbps
	27	191 Mbps
	22	<b>353 Mbps</b>
LDB	37	58 Mbps
	32	106 Mbps
	27	192 Mbps
	22	<b>357 Mbps</b>

※ HM: HEVC test Model (reference software of the H.265 Standard)

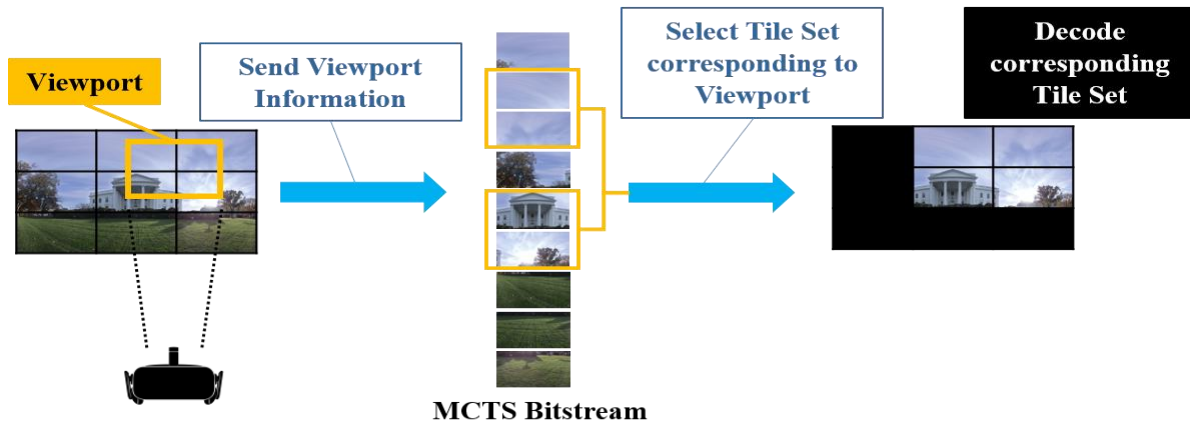
## 2.2. Bandwidth requirements with viewport-based adaptive tile streaming

Due to the high bandwidth requirement for VR streaming service, there have been some researches to reduce the bandwidth using viewport-based adaptive tile streaming.

Figure 2 shows the conceptual sequences of the technology to reduce bandwidth: (1) HMD signals the viewport information of user to a VR server, (2) VR server extracts and transmits the tiles including the viewport area, (3) Corresponding tiles are decoded and rendered.

To simulate the bandwidth savings with the independent tile decoding, MCTS (Motion-Constrained Tile Set) method to prevent PU (Prediction Unit) referencing over tiles were implemented by Gachon University.

The maximum number of viewport tiles is four while the minimum number of it is one when the resolution of each tile is around 4K. Table 4 shows the bandwidth savings with the two cases: (1) four tiles streaming and (2) only one tile streaming. The results **indicate that maximum 165 Mbps bandwidth is still required** even the bandwidth saving technologies are applied for the VR service. This experiment did not use the projection technologies using partial down-sampling such as CMP (Cube-Map Projection). Thus, further studies are needed to investigate the bandwidth saving and the efficient VR video streaming.



**Figure 2. Viewport-based Adaptive Tile Streaming**

Table 4. Bandwidth Requirements for Viewport Tile Streaming

Coding Structure	Quantization Parameter	Original Bitrate (9 Tiles/@90fps)	Proposed Bitrate (4 Tiles/@90fps)	Proposed Bitrate (1 Tiles/@90fps)
RA	37	60 Mbps	28 Mbps(-53%)	7 Mbps(-88%)
	32	107 Mbps	50 Mbps(-53%)	12 Mbps(-88%)
	27	191 Mbps	88 Mbps(-53%)	22 Mbps(-88%)
	22	353 Mbps	<b>162 Mbps(-54%)</b>	<b>40 Mbps(-88%)</b>
LDB	37	58 Mbps	28 Mbps(-51%)	7 Mbps(-87%)
	32	106 Mbps	50 Mbps(-52%)	12 Mbps(-88%)
	27	192 Mbps	90 Mbps(-53%)	22 Mbps(-88%)
	22	357 Mbps	<b>165 Mbps(-53%)</b>	<b>41 Mbps(-88%)</b>

## References

1. ISO/IEC JTC1/SC29/WG11 MPEG 116/m39532, "Quality Requirements for VR", Oct. 2016.