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Title: Application Level Bandwidth Requirements for 3DoF+/6DoF Virtual Reality Services (Simply HEVC-encoded Bitrates)

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Abstract: The purpose of this document is LAB data for 3DOF+/6DOF VR Services.

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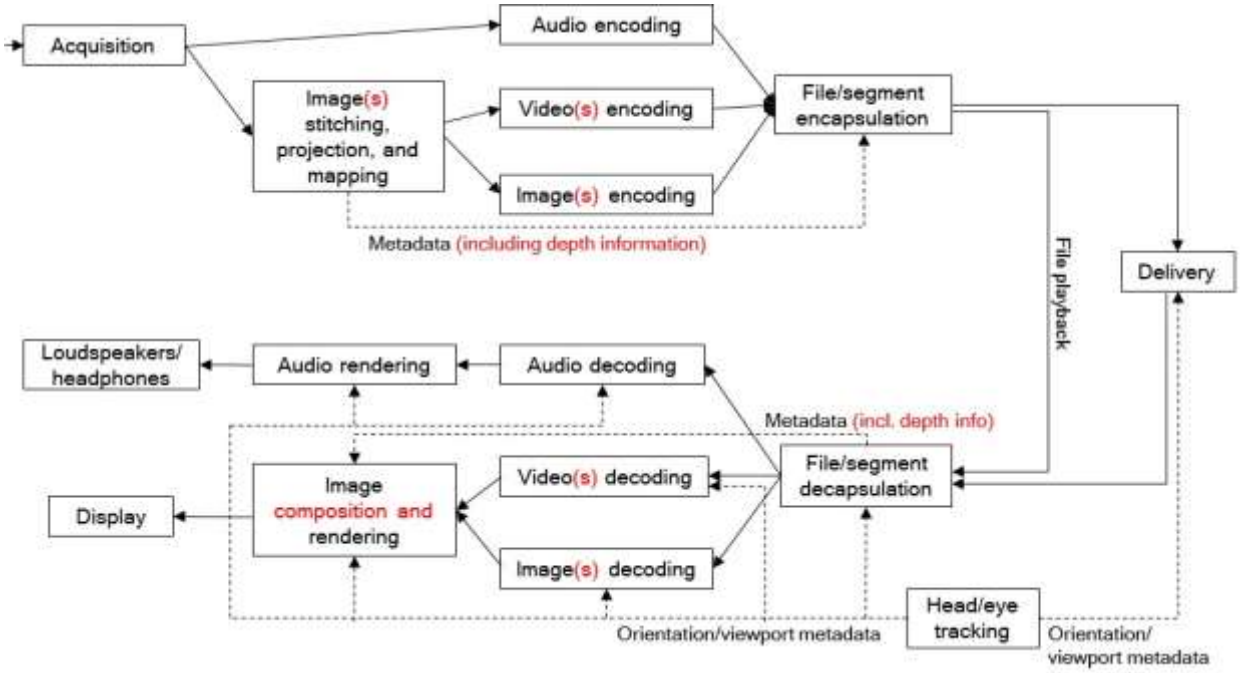
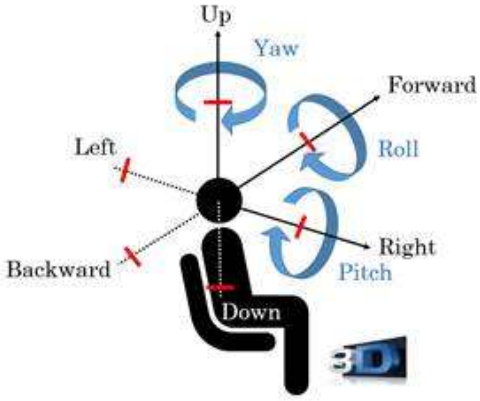
3 Degree of Freedom+ (3DoF+)

- Background
  - MPEG defined degree of freedom of VR as 3DoF, 3DoF+, and 6DoF
  - Limited movements for user sitting in a chair is available for 3DoF+
- Requirements
  - Solution will be built on HEVC with 3DoF+ metadata(included in MPEG-I part 7)
  - Both objective and subjective quality evaluation will be performed





Use case for 3DoF+

3DoF+ Common Test Condition (Defined by MPEG-I Standard)

❖ Test Sequences

ClassroomVideo

TechnicolorMuseum

TechnicolorHijack

TechnicolorPainter

IntelKermit

Sequence	Class	Resolution	No. of views	Frame count	Frame rate	Source FoV
ClassroomVideo	A	4096x2048	15	120	30	360° x 180°
TechnicolorMuseum	B	2048x2048	24	300	30	180° x 180°
TechnicolorHijack	C	4096x4096	10	300	30	180° x 180°
TechnicolorPainter	D	2048x1088	16	300	30	46° x 25°
IntelKermit	E	1920x1080	13	300	30	77.8° x 77.8°

Test Condition

- Test Sequences
  - ClassroomVideo
    - 15 Views (15 texture views, 15 depth views)
  - TechnicolorMusium
    - 24 Views (24 texture views, 24 depth views)
- Quantization Parameters
  - Texture: 20, 22, 24
  - Depth: 15, 17, 19
- FPS : 30
- Encoder/Decoder: HEVC/H.265 Reference SW

Test Results: Needed App-level BW for MPEG 3DoF+ (Simply encoded by HEVC)

❖ ClassroomVideo

Bitrate (Kbps)
Y-PSNR (dB)

Quantization Parameter: 20 (texture) / 15 (depth)

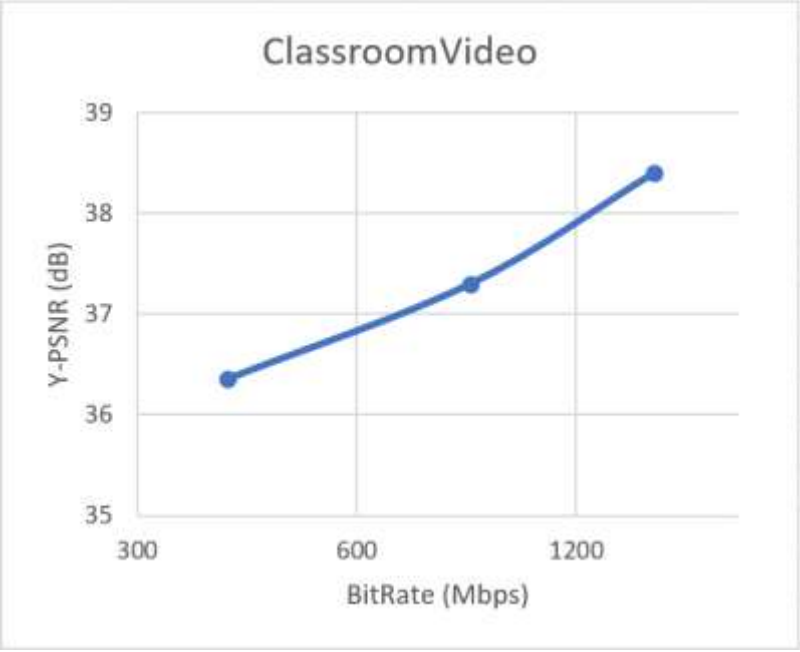
	View Number	v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	Sum
Classroom Video	Bitrate	123804.31	78540.76	89108.78	104979.48	108331.32	105593.24	107231.57	107295.30	105868.23	107016.50	103289.94	109515.16	104011.35	108973.46	106246.77	**1569806.16**
	Y-PSNR	38.19	38.78	38.64	38.38	38.34	38.37	38.35	38.36	38.36	38.36	38.41	38.33	38.39	38.33	38.36	

Quantization Parameter: 22 (texture) / 17 (depth)

	View Number	v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	Sum
Classroom Video	Bitrate	69974.80	43359.65	49557.52	58707.68	60769.33	58968.30	60068.07	59425.47	59165.21	59991.79	57896.38	61570.66	58113.91	61223.86	59477.61	**878270.23**
	Y-PSNR	36.96	37.86	37.66	37.28	37.21	37.26	37.23	37.24	37.25	37.24	37.32	37.20	37.29	37.20	37.24	

Quantization Parameter: 24 (texture) / 19 (depth)

	View Number	v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	Sum
Classroom Video	Bitrate	32557.76	20111.78	22783.72	27335.23	28292.41	27447.04	27958.97	28028.63	27504.70	28086.86	27102.26	28727.24	27020.59	28439.11	27651.08	**409047.33**
	Y-PSNR	35.92	37.04	36.79	36.33	36.26	36.32	36.28	36.28	36.31	36.29	36.39	36.23	36.35	36.24	36.30	



Test Results: Needed App-level BW for MPEG 3DoF+ (Simply encoded by HEVC)

❖ TechnicolorMuseum

Bitrate (Kbps)
Y-PSNR (dB)

Quantization Parameter: 20 (texture) / 15 (depth)

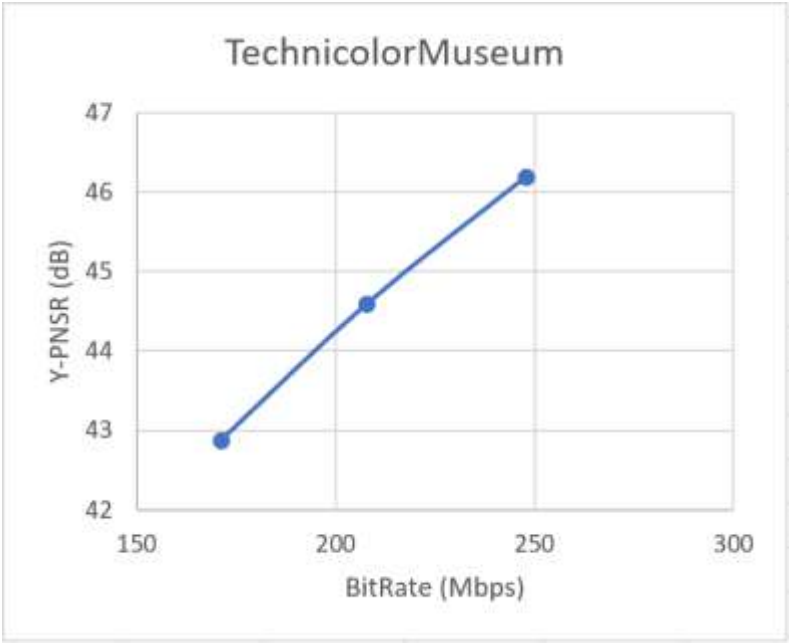
	View Number	v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	
Technicolor Museum	Bitrate	13174.82	10135.52	11063.30	12080.60	8956.87	13713.36	13424.78	11384.72	12379.98	11028.56	10109.51	11691.59	8334.93	8081.27	9540.86	
	Y-PSNR	45.63	46.23	45.76	45.79	46.42	45.41	45.55	46.08	45.65	45.69	46.07	45.59	46.83	46.76	46.41	
	View Number	V15	v16	v17	v18	v19	v20	v21	v22	v23							Total
	Bitrate	10946.60	10250.81	9980.81	8700.74	10157.93	10961.91	8691.04	7571.21	11309.82							**253674.53**
	Y-PSNR	46.32	46.49	46.50	46.75	46.50	46.21	46.81	47.00	46.07							

Quantization Parameter: 22 (texture) / 17 (depth)

	View Number	v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	
Technicolor Museum	Bitrate	11018.63	8481.74	9037.91	10104.11	7400.06	11392.20	11213.69	9607.66	10307.19	8895.48	8357.27	9571.51	7046.12	6740.48	8015.21	
	Y-PSNR	44.04	44.64	44.24	44.22	44.88	43.86	44.00	44.50	44.12	44.23	44.50	44.09	45.11	45.13	44.75	
	View Number	v15	v16	v17	v18	v19	v20	v21	v22	v23							Total
	Bitrate	9368.55	8813.16	8532.99	7357.01	8719.14	9382.02	7403.66	6390.32	9546.20							**212702.31**
	Y-PSNR	44.69	44.82	44.89	45.11	44.83	44.54	45.12	45.34	44.44							

Quantization Parameter: 24 (texture) / 19 (depth)

	View Number	v0	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14	
Technicolor Museum	Bitrate	9064.16	6977.36	7232.31	8292.22	6013.42	9282.80	9183.43	7981.35	8424.79	6979.59	6754.68	7683.67	5867.93	5519.08	6623.04	
	Y-PSNR	42.32	42.95	42.63	42.52	43.25	42.17	42.29	42.79	42.46	42.63	42.83	42.46	43.33	43.42	42.99	
	View Number	v15	v16	v17	v18	v19	v20	v21	v22	v23							Total
	Bitrate	7892.36	7478.71	7187.95	6121.22	7374.17	7918.01	6222.73	5311.53	7926.65							**175313.04**
	Y-PSNR	42.92	43.04	43.14	43.37	43.05	42.76	43.35	43.62	42.71							



Conclusion

- Bitrates with good video quality vary from 150Mbps to 1.5Gbps according to video content features.
- Required application layer bandwidth is too high, even the target bitrate proposed by MPEG-Immersive standardization is as shown in the following table.
- Because of the bandwidth problem, better solutions are needed.

	Target bitrates [Mbit/s]					
Sequence	Rate 1	Rate 2	Rate 3	Rate 4	Rate 5	Rate 6
ClassroomVideo	6.5	10	15	25	40	65
TechnicolorMuseum	10	15	25	40	65	100
TechnicolorHijack	6.5	10	15	25	40	65
TechnicolorPainter	6.5	10	15	25	40	65
IntelKermit	4	6.5	10	15	25	40

MPEG-I 3DoF+ Call for Proposal Objective Evaluation