ENTER THE NEW Digital Ecosystem

As media, entertainment and technology converge, the result is a connected network that is redefining business models and revenue streams.
Streaming UHD-Quality VR at Realistic Bitrates: Mission Impossible?

Raoul Monnier, Harmonic
Rob Koenen, Tiledmedia
Overview

- Challenges in Virtual Reality Video
- State of the art in VR video streaming
- Basics of Tiled VR streaming
- Quality and bitrate trade-offs
CHALLENGES IN VIRTUAL REALITY VIDEO
Why is VR Relevant Now?

Wave of New Head Mounted Display (HMD) Launches in 2016

Technology Available for Good QoE
Three Main Challenges for VR

- Low Display Resolution
- Screen-door effect
- 15-20 Mbps

Motion sickness
Motion to photon latency
Video quality & bitrate
STATE OF THE ART IN VR VIDEO STREAMING
Virtual Reality Revenue by Industry

Video streaming: $570M in 2020

Video streaming: $3.9B in 2025

Source: Piper Jaffray report "Next MegaTech Theme is Virtual Reality (May 2015)
VR Ecosystem

Prepare

Capture

2D
3D

Stitch

Live
Offline

Map

Equirectangular
Cubic

Encode

“Brute Force”
Tiling

Package
Transmit or Store

Distribute

Decode

Play

Enjoy

Use of the HW decoder of the smartphone
Legacy / Brute Force Approach

12% - 15% of picture

15 – 20 Mbps
# Commercially Deployed VR Video Services

<table>
<thead>
<tr>
<th>Function</th>
<th>Resolution</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capture Stitch Map Encode</td>
<td>4K x 2K</td>
<td>Easy to implement</td>
</tr>
<tr>
<td>Transmit Store</td>
<td>4K x 2K</td>
<td>Not sensitive to network delay</td>
</tr>
<tr>
<td>Display</td>
<td>1K x 1K per eye</td>
<td>Poor video quality</td>
</tr>
</tbody>
</table>
Are People Happy with VR 360 Video Today?

No!

Consumers
- Video quality is poor

Operators
- Bitrate is high
- Difficult to reach sufficient customers:
  - ~25% of households
  - <15% in some countries (e.g. France, Italy)
TiledVR STREAMING
Take a 360 Panorama
You Only See About $\frac{1}{8}$th
Cut Everything Up In Tiles
Determine Which Tiles Are In View

Covered by Tiles

VIEWPORT
Stream Only Those Tiles
Also Send Low-Resolution Background
Compatible with Adaptive Streaming
Cubic Works Better With Tiles
Efficient Use of Decoder Buffer

Tiles in viewport

Cancelled tiles

Newly requested tiles
Good Fit With Existing Chains

Capture, encode and tile 360 VR
Stitch → Encode → Tile

Transport only relevant tiles
Any CDN → Client Library

Combine & decode
Client Library → HMD

HEVC Decode

#NABShow
## The Numbers

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motion-to-photon latency</td>
<td>&quot;Instantaneous (limited by refresh rate of HMD)&quot;</td>
</tr>
<tr>
<td>Motion-to-high-resolution latency</td>
<td>20-40ms using typical CDN (Akamai, Cloudfront, etc.)</td>
</tr>
<tr>
<td># of required decoders</td>
<td>1 single decoder (Hardware or software)</td>
</tr>
<tr>
<td>Bandwidth reduction</td>
<td>Factor of ~5</td>
</tr>
</tbody>
</table>

### Typical Bandwidth Use

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Bandwidth Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>4K panorama</td>
<td>~ 4 – 6 Mbps</td>
</tr>
<tr>
<td>8K panorama</td>
<td>~ 12 – 16 Mbps</td>
</tr>
<tr>
<td>12K panorama</td>
<td>~ 16 – 20 Mbps</td>
</tr>
</tbody>
</table>
The Benefits

- Bandwidth under control
- Extend reach
- Use existing HTTP delivery chains
- Use standard encoders and decoders
- Use only one single decoder

- Use 8K panoramas on existing devices that can’t decode 8K (e.g. Gear VR)
- Zero Motion-to-Photon Latency: No motion sickness
- Low Motion-to-High-Resolution Latency (24 – 40 msec.)
- On-demand and Live
QUALITY OF EXPERIENCE AND BITRATE TRADE-OFFS
Benefits of Tiled VR

Twofold: Today and Tomorrow

Today

• Allows to reduce bandwidth by optimizing it to HMD resolution
  \( \Rightarrow \) \textit{Reach increased} from 5-25% to 55-85%

Tomorrow

• Will \textit{increase video quality} when HMD resolution increases
What About Connection Speed?
QoE is Not Only Video Resolution

Low latency, especially when moving the head, is key
Round-Trip-Delay on CDNs

CEDEXIS, January 2017

Poor QoE

Europe

USA

#NABShow
Tile Switching Latency (@30p)

TILE SWITCHING LATENCY

San Jose (LAN) vs The Hague (WIFI)

% Of Tile Switches Completed After x Frames

# Of Frames After Tile Switch

Poor QoE
CONCLUSION
Tiled VR is the Right Technology...

...to balance:

• Video quality for the end-user
• Bitrate for the operator
Thank You

Raoul Monnier - raoul.monnier@harmonicinc.com
Rob Koenen - rob@tiledmedia.com