DISTRIBUTING AR & VR COMPUTE IN A 5G WORLD

- Expectations are high that 5G will deliver interactive, immersive experiences
- Engaging immersive content will be required to drive adoption
- 5G brings many technical benefits to AR/VR experiences
- Many barriers to AR/VR adoption can be addressed by 5G
- AR/VR usages put unique requirements on 5G networks
- Different approaches to delivering immersive experiences are being pursued, taking advantage of new HMDs, clients, edge & cloud
5G SMART MEDIA: CONSUMERS WANT MULTI-SENSORY EXPERIENCES

ONE SEAMLESS 5G HOME
71% interested in 5G for all connected-home needs, including bundled internet and TV

FULLY IMMERSIVE SURROUND VIDEO
60% interested in a lifelike 360-degree documentary or movie using a VR headset

3D VIDEO THAT COMES TO LIFE
64% interested in AR-enabled virtual objects and characters that move about the real world

LIVING THE ACTION AT LIVE EVENTS
57% interested in app-driven sports and concerts that deliver up-close vantage points

AUGMENTED INSTRUCTION
60% interested in real-time insight from smart equipment with information overlays

ENHANCED SENSORY IMMERSION
57% interested in touch-enabled internet and gaming delivered via haptic suits

PASSENGER ENTERTAINMENT
57% interested in high-definition TV or video conferencing during travel in self-driving cars

ULTIMATE MOVIE CONTROL
60% interested in choose-your-own-adventure functionality for storylines and camera angles

3D HOLOGRAPHIC SHOWS
59% interested in multi-angle 3D-character images that don’t require assistive gear

Source: Intel, Ovum, “5G Economics of Entertainment Report” August 2018
<table>
<thead>
<tr>
<th></th>
<th>VR</th>
<th>AR</th>
</tr>
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<tbody>
<tr>
<td><strong>Consumer</strong></td>
<td>• Games</td>
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<td>• Immersive Video</td>
<td>• Education &amp; Training</td>
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<td><strong>Commercial</strong></td>
<td>• Film Production &amp; Amusement</td>
<td>• Retail Showcasing</td>
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<td>• Virtual Property Tours</td>
<td>• Industrial Maintenance</td>
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<td>• Product Development</td>
<td>• Onsite Assembly &amp; Safety</td>
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*IDC Worldwide Semiannual Augmented and Virtual Reality Spending Guide, Dec 2018*
INTEL AT THE FOREFRONT OF CREATING VR CONTENT

Intel® TrueVR: Live streaming VR content
- Broadcasted March Madness 2019
- Agreements with MLB, NCAA, NFL
- Announced multi-year engagement with Olympics

Intel® True View: watch the biggest moments in sports from every angle
- Intel Studios here in LA is the world’s largest stage for volumetric video capture
WIRELESS VR ENABLED BY INTEL WIGIG

Now Available

System Requirements:
- Desktops: PCIe add-in card + external antenna (available now)

"[WiGig] seems to provide exactly what VR fans have wanted for years: a high-performance, reliable wireless VR solution."
– GameCrate

"The sheer sense of liberating freedom achieved from cutting the cord... cannot be overstated."
– Upload

*Other brands and names may be claimed as the property of others
WHAT DOES 5G BRING TO AR/VR?

- Order of magnitude increase in data rates, up to 10Gbits/s
  - 60x **Faster than current cable** internet (~150Mbps)
  - 100x faster than 4G LTE
- Increase in bandwidth in both directions
- Lower network latency – below 1ms compared with 30-70ms for 4G
  - End-to-end AR/VR solutions likely to be ~10-20ms, just within typical VR motion-to-photon target of <20ms
- Support for greater density of connections
- Providers use the Edge to bring compute closer to the home/business
- All delivered **wirelessly**
5G BENEFITS FOR AR/VR USERS

User Benefits:
• Wireless experiences throughout the home/business
• AR experiences delivered while mobile and outdoors (in urban environments)
• Thinner clients due to distributed compute (Client, Edge, Cloud)
• Central services in the cloud & edge
  • Distributed security – better? Or easier to hack?
• Better streaming and sharing with lower latency
• More opportunities for streaming real-time content (e.g. sports)
• Share compute with/from your neighbor?
## 5G AND CLOUD REDUCE USER BARRIERS TO AR/VR ADOPTION

<table>
<thead>
<tr>
<th>Opportunity</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce “Time to fun”. It takes too long to download and update.</td>
<td>5G increases bandwidth for download</td>
</tr>
<tr>
<td>I want to play VR with my existing device, don't want to have to upgrade my PC/HMD</td>
<td>Cloud and Edge compute reduces requirements on client</td>
</tr>
<tr>
<td>I want to play where and when on device I want</td>
<td>5G enables high bandwidth wireless connection, allows free-range use within the home and mobile AR use when outdoors</td>
</tr>
<tr>
<td>I want to have a social/competitive experience, share my experience without impacting my game</td>
<td>Keep more compute in the cloud and in the edge, better quality streaming</td>
</tr>
<tr>
<td>My AR/VR Headset/glasses are too bulky and heavy on my head</td>
<td>Shifting compute to the cloud/edge means HMD/glasses can be lighter but need to make trade-offs between battery life and comfort</td>
</tr>
<tr>
<td>I want my AR/VR experience to be secure. I want my privacy</td>
<td>Could be harder to hack/cheat, but if hack is successful, impact would be greater</td>
</tr>
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</table>
VR OVER 5G SOLUTIONS ARE IN PROGRESS

Intel, Sony Pictures Virtual Reality & Nokia
demo “Spider-man Far From Home, the world’s first
multi-player virtual reality environment over 5G” at MWC.

ATT & HTC
Show PoC delivering 2880x1600 @75Hz VR with 5ms
latency.

SK Telecom
Offers Okusu VR experiences with no data limits
-Social VR experience
-Immersive videos
-Niantic's Harry Potter: Wizards Unite
AR/VR REQUIREMENTS FOR 5G NETWORKS

- **High Resolution Stereo Displays**
  - Support transmission of stereo video at resolutions of 1440x1600 per eye @90fps and moving towards 4K per eye by 2023

- **3DoF, 3DoF+, 6DoF Video Streaming**
  - Support back-channel transmission of stereo cameras and IMU data for 6DoF calculations and video pass-through
  - Encoding at the edge and/or cloud for viewpoint
  - End-to-end latency of 10-20ms with a 90fps refresh rate
  - Fast file app download rates.
  - Storage of files in the cloud, edge and client
  - All day battery life for client/HMD/Glasses
NEXT STEPS TO DELIVER THE 5G IMMERSIVE EXPERIENCES

Hardware:
- Develop lighter, wireless, and safe AR/VR display devices

Software:
- Design for 2-way interactivity
- Design for distributed compute
- Open SDKs for greatest HW compatibility

Network
- Edge introduces opportunity to reduce latencies at the last mile

Solutions:
- Build open, end-to-end solutions that optimize at all data points.