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COMMUNICATIONS

Edge Computing and the Evolution of AR/VR

Stanford University, 11/21/19

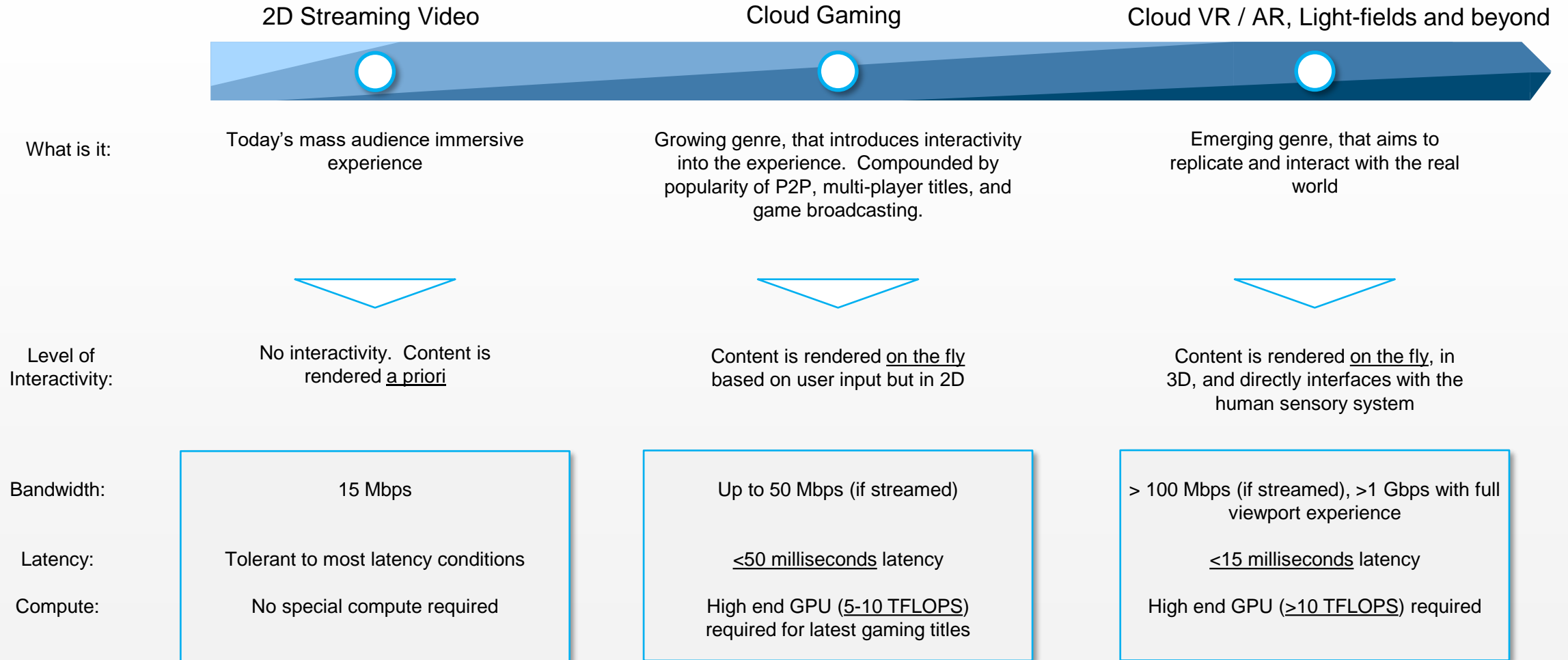
DJ Lal, Charter Communications

Key Points

- Immersive in its various forms is the next frontier for entertainment
- Its realization requires that technical challenges and the cost of compute be resolved
- Service providers can help by embedding “network compute”
- This is a hard problem, but it can be solved
- Bandwidth + Low Latency + Compute = Superior experiences enabled by the network

Immersive is the Next Evolution of Storytelling

The network will democratize compute



Current Barriers Make Mass Adoption Challenging

Extant industry challenges need to be solved to stimulate market adoption

Virtual Reality

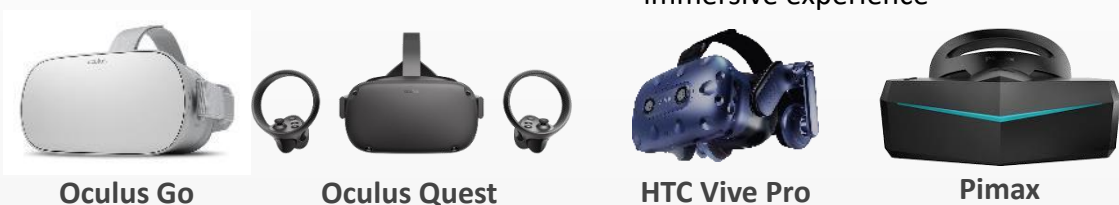
1 HMDs available at a wide variety of price points, but premium experiences require large investment in PC/console

Low cost HMDs

- ✓ Price encourages user adoption (~\$200)
- ✗ Lower res., frame rate experiences

Premium HMDs

- ✓ Provide great immersive experiences
- ✗ High TCO for HMD + PC/console to drive immersive experience





2 Vertically integrated, fragmented content stores create a barrier to consumer investment in VR HMDs



Augmented Reality

1 Smartphone based AR requires low latency and high intensity compute to enable good consumer experiences

 **Limited GPU power** prevents smartphones from being able to run high fidelity AR experiences

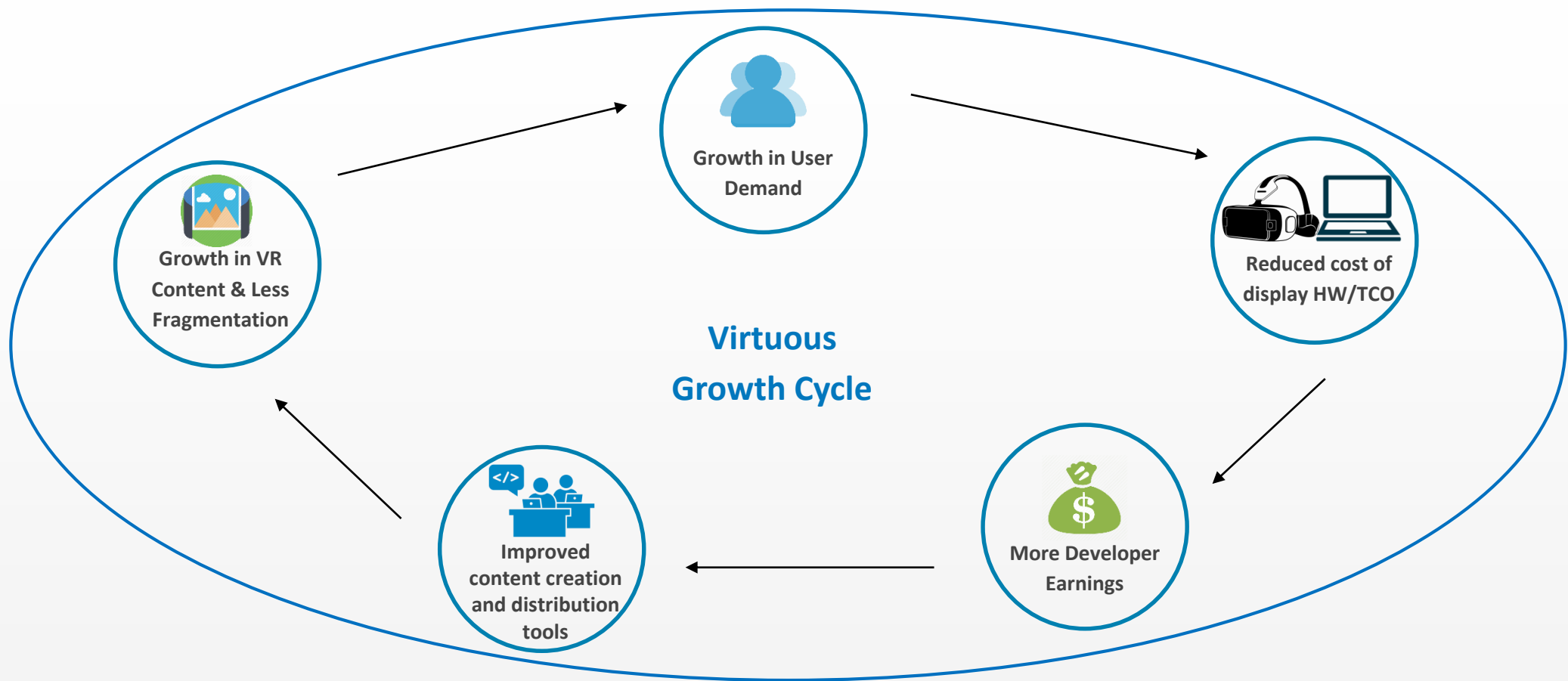
 **Battery limitations** in smartphones result in immersive experiences draining them very quickly

2 High price point of AR HMDs causes price friction and prevents mass adoption (\$1300 - \$3500)



Ramping the Growth Cycle will Stimulate the Market

Additional content availability and increased HMD penetration



A self-feeding sequence with **increasing user base** and **variety of content** provides a **Virtuous Growth Cycle** that **attracts more creators** and **encourages overall growth**

Ramping the Growth Cycle will Stimulate the Market

Additional content availability and increased HMD penetration

Use of network to reduce display hardware requirements

- Minimize latency perceived over cloud rendered experiences
- Reduce HW requirements in display HMD
- Encourage user demand



Reduced cost of display HW/TCO

Fragmentation

**Virtuous
Growth Cycle**



A self-feeding sequence with **increasing user base** and **variety of content** provides a **Virtuous Growth Cycle** that **attracts more creators** and **encourages overall growth**

The Network is the Computer (Again)

A \$2,000+ computer is migrated to a network datacenter to deliver immersive

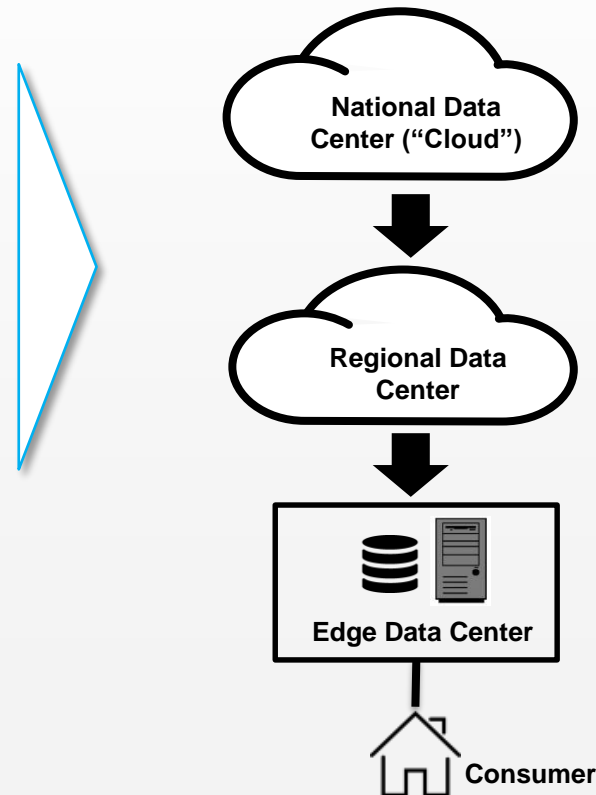
1. Modern day GPUs have been successfully migrated to the cloud to deliver high quality “PC grade” gaming



The gaming PC days are NUMBERED!

LINUS TECH TIPS

2. Streaming future immersive content from the network necessitates rendering closer to the consumer to deliver a low latency, high quality experience



3. Head-mounted and Light Field displays will continue to push the compute, bandwidth and latency envelop



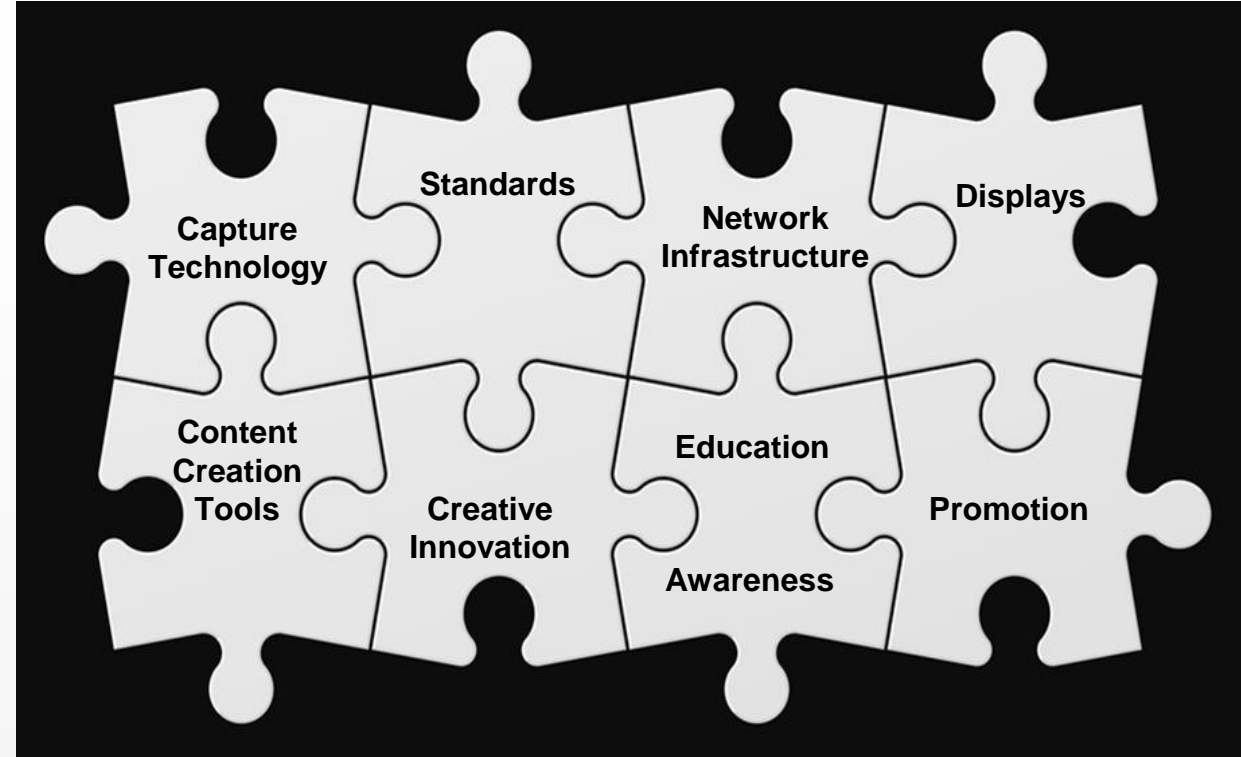
Light Field Lab concept art demonstrating Light field display

Immersive Digital Experiences Alliance (IDEA)

Created with the purpose of

- Developing a family of royalty-free technical specifications to support the end-to-end conveyance of immersive media
- Gathering marketplace and technical requirements to define and support the immersive media specifications
- Facilitating interoperability testing and demonstration of immersive technologies
- Producing educational events and materials
- Providing a forum for the exchange information and news relevant to the immersive media ecosystem

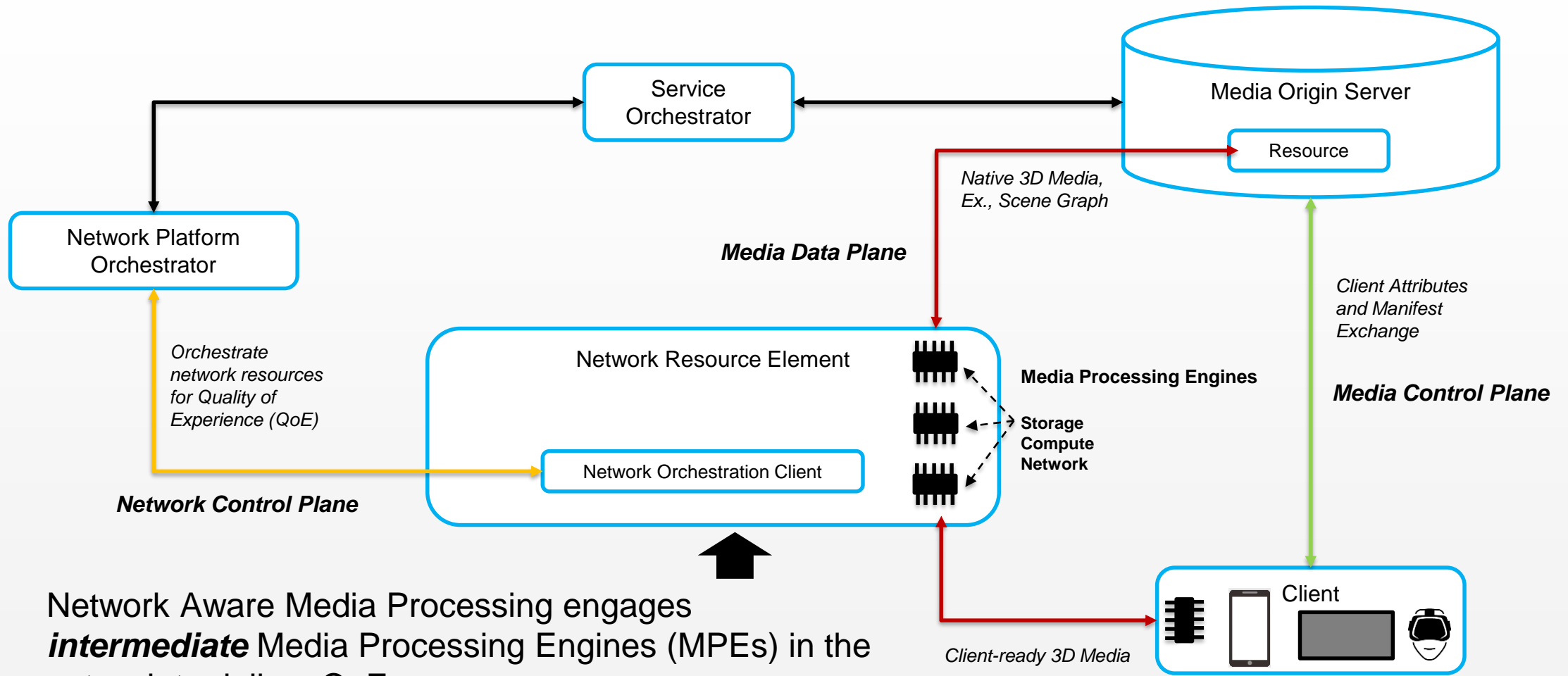
Initial Members



The Network Architecture Workgroup explores network aware 3D media delivery, including highly photorealistic rendering and interactivity supported from the edge

IDEA Network Aware Media Processing

Engaging service provider network, storage and compute resources for media delivery*



Network Aware Media Processing engages **intermediate** Media Processing Engines (MPEs) in the network to deliver QoE

*<https://www.immersivealliance.org>

Delivering Quality Immersive Experiences is a Balance

... of compute, latency, and bandwidth



Compute

Considerable computation power is required to synthetically render, encode and stream the virtual environment

Latency

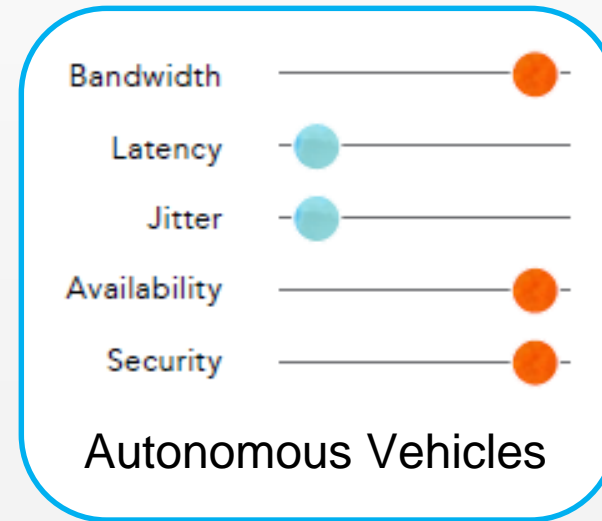
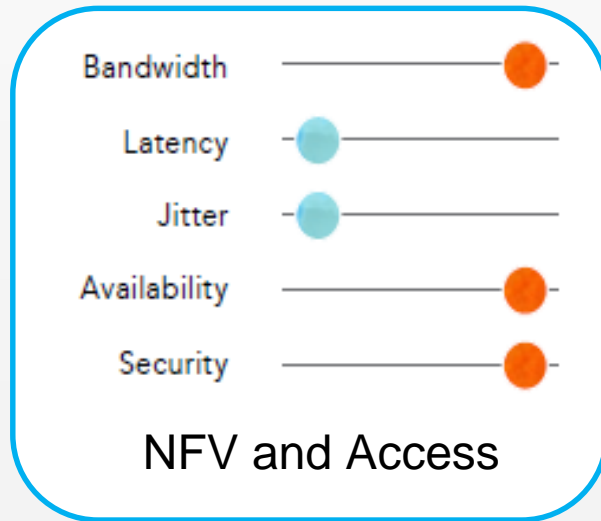
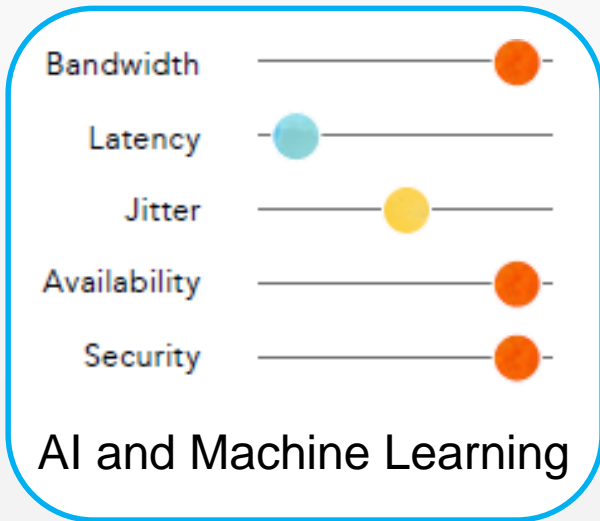
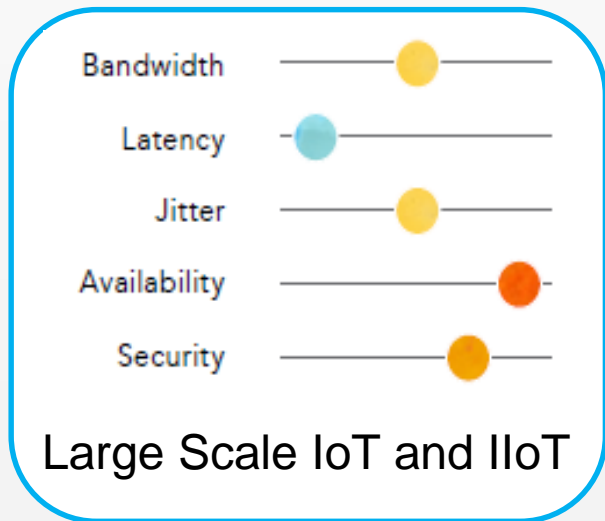
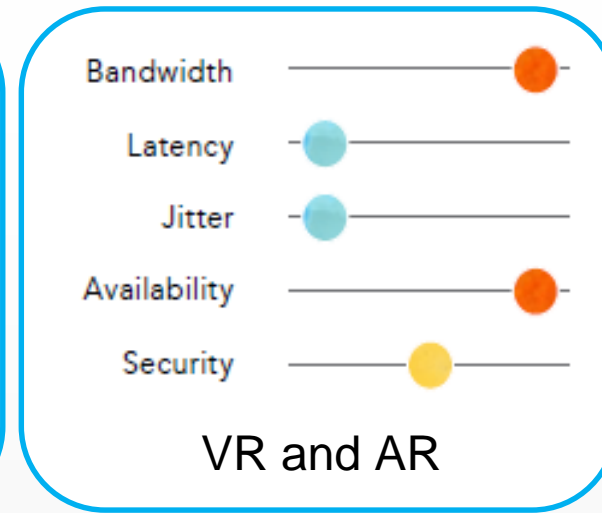
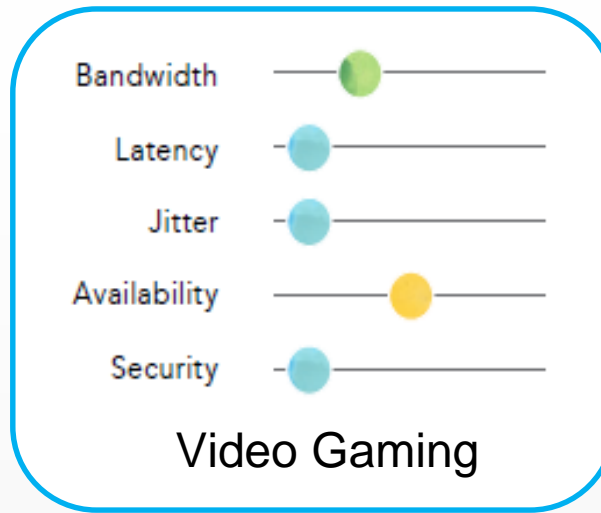
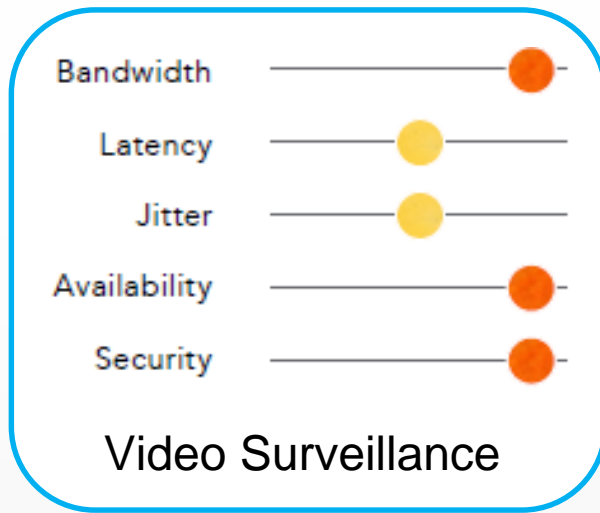
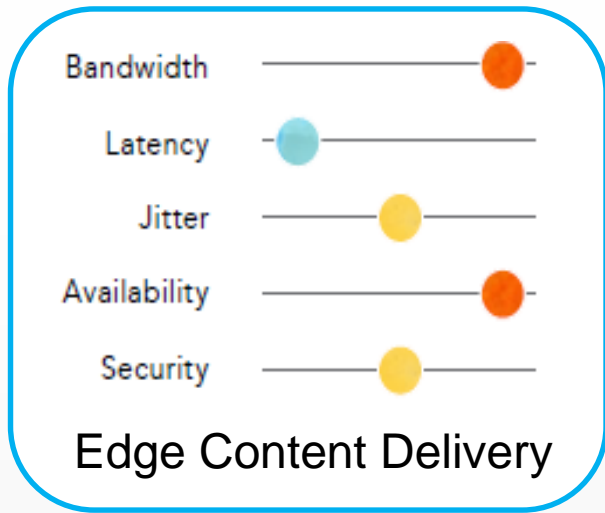
Experiences need to achieve the “motion to photon” experience of real life interactions

Bandwidth

Delivery of immersive over large pipes is required to democratize the technology

Edge Computing Sample Use Cases*

A variety of existing and emergent applications shall drive compute to the edge



*State of the Edge 2018: A Market and Ecosystem Report for Edge computing

In Conclusion...

- Network edge computing has the potential to democratize AR/VR and other immersive experiences
- Edge computing is agnostic of any one access network technology; albeit low latency / high bandwidth access is a prerequisite to reap the benefits of edge computing
- The edge internet economy has a potential to scale in value in a decade to the same level as the cloud or mobile economy of today*

