Transport Problem for AR&VR

draft-han-iccrg-arvr-transport-problem

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Goals of this draft

- **Quantify the network problems for network based AR&VR**
  - Bandwidth, Latency, Burst
  - Transport technology
- **Attract telnets from different organizations to study and give more solutions**
  - Ecosystem
  - SDO liaison
- **Technology ready for AR&VR integrated with Internet and cloud**
- **Make Internet able to support similar extreme applications (V2X, tactile network, etc)**

New Era is coming

4th time of tech waves

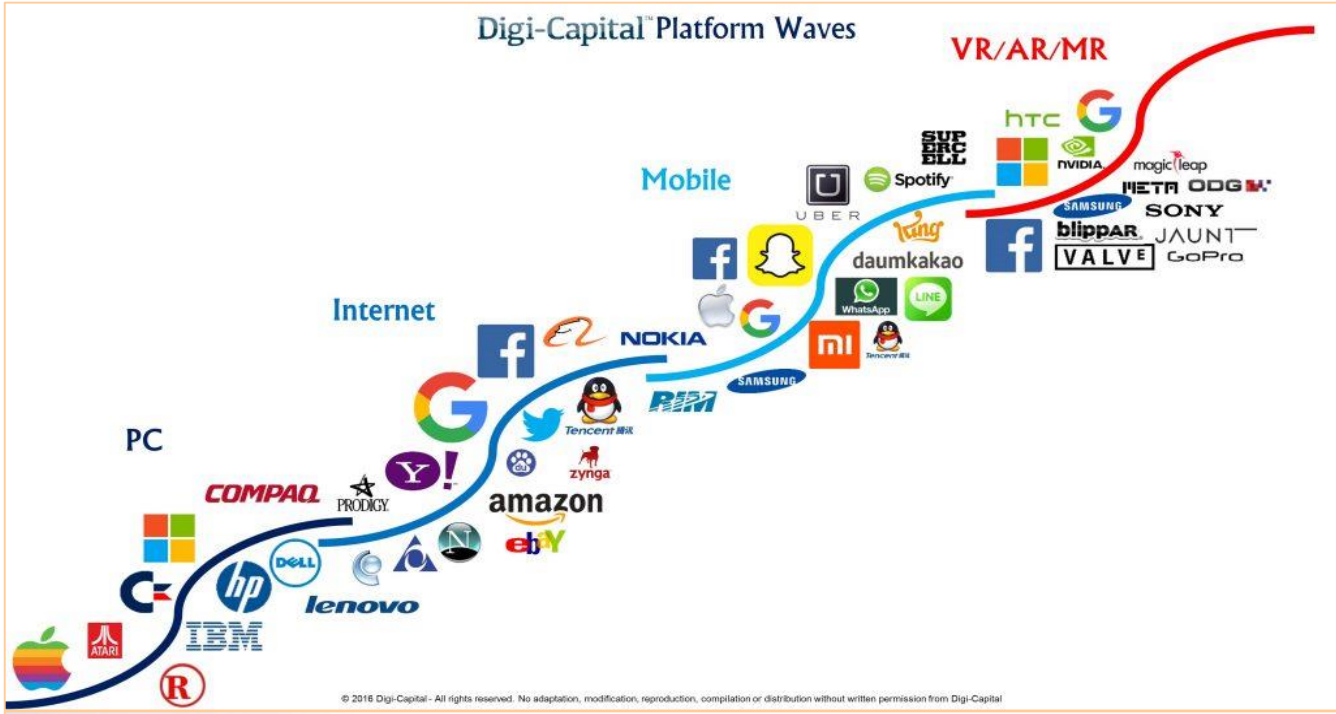
PC, Internet, Mobile, AR&VR

- Has attracted tremendous VC investment to a lot startup
- FB, Google, and many other companies also put a lot resource on it.
- Some old industry map may be dramatically changed, mobile, computer, TV, game, etc
- The market of software and hardware for AR&VR could reach $180bn by 2025 (*Goldman Sachs Global Investment Research 2016*)

4th generation of computing platform

Main frame, PC, Smart phone, AR&VR

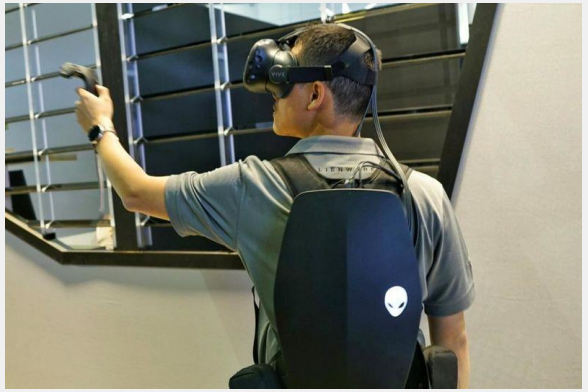
- What you see from AR&VR is your new desktop, and all applications and running results will be displayed on top of it as objects in virtual world.
- What you act to the virtual objects will be the input to the computer.



AR&VR integrated with Internet and Cloud

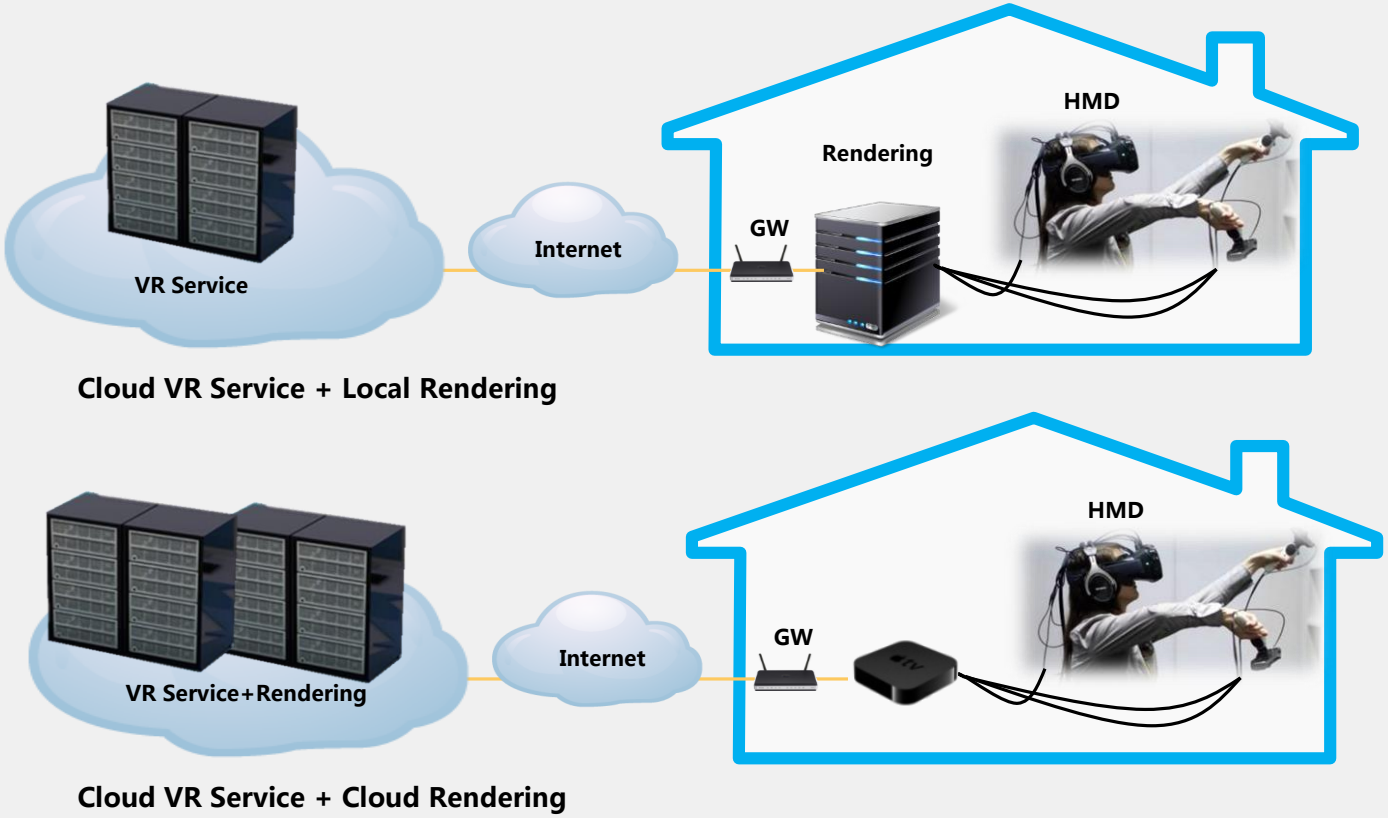
Localized VR

HDMI



http://www.trendhunter.com/trends/backpack-computer

Network based VR

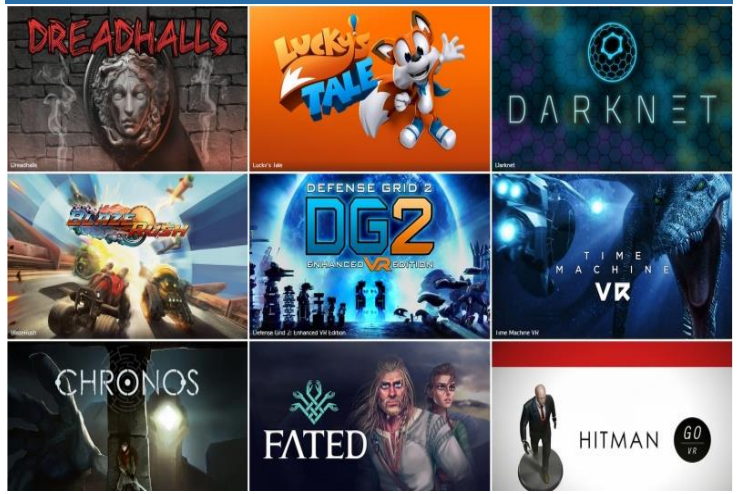


New Applications of Network Based AR&VR

VR live broadcast

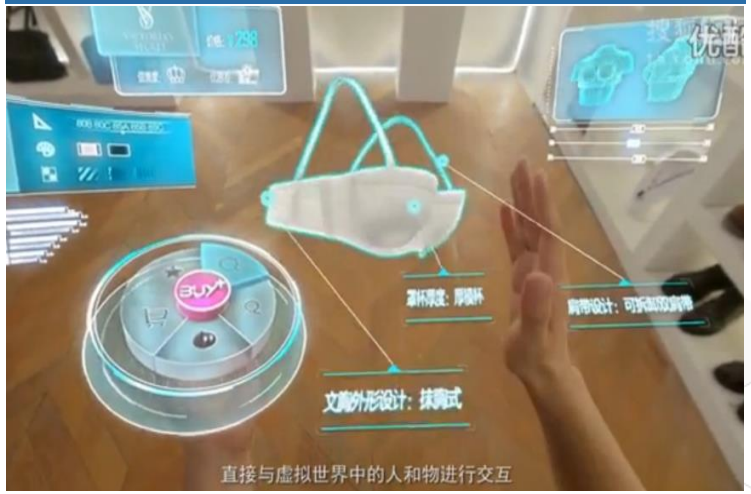
- **NextVR** focuses on **the VR live broadcast** operation (e.g. NBA, Boxing, presidential debate).
- **It gained $3.5 million investment from Comcast & Time Warner.**

VR online Games



- **Oculus focus on development of VR online game .**
- **It has been acquired by Facebook for $2 billion.**

VR online shopping



- **Alibaba is popularizing the concept of Buy+ , which adopts the VR technology to provide a interactive 3D online shopping environment for the customers.**

Technologies ready?

- **Sensor**
  - Action detection/capturing
  - Action simulation
- **Computing**
  - Rendering
  - Color sampling
  - Coding/decoding
  - …
- **Display**
  - Super high resolution
  - Super fast response time
- **Power Supplier**
  - Power consumption
  - Heat Dissipation
- **Network**
  - Transport technologies
  - Throughput, Latency, Packet Loss, etc

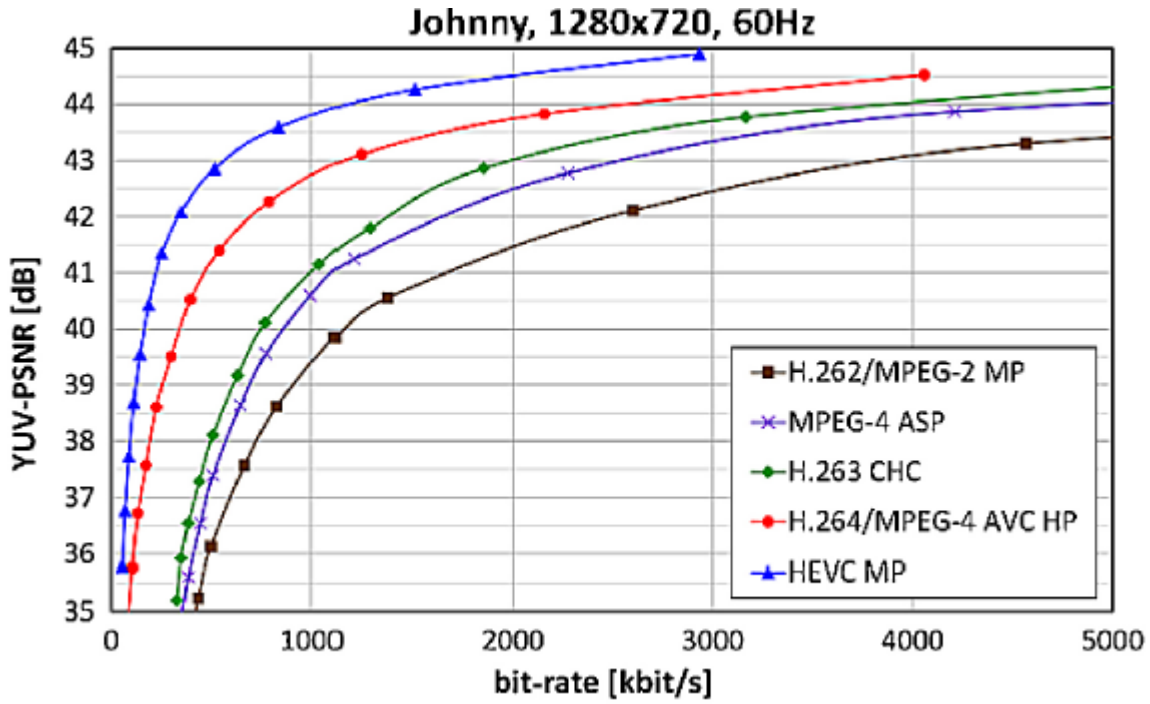
Video quality, Encoding and Bitrate

- **Normal Encoder setting**
  - Size
  - FPS
  - Color, sampling
  - Profile
  - Bitrate mode (CBR, VBR)
  - Pass number
  - Bitrate, maximum bitrate (VBR)
  - GOP distance
  - B-frame
  - ….

No exact formula for bitrate

$$PSNRY[\mathrm{dB}] = 10 \cdot \log_{10}\left(\frac{(2^b-1)^2}{\frac{1}{W \cdot H}\sum_{h=1}^{H}\sum_{w=1}^{W}(I_1(w,h)-I_2(w,h))^2}\right),$$

https://www.sri.com/sites/default/files/publications/3_07_h264_format_bitrate_quality_tradeoff_study.pdf



J.R.Ohm et al.,"Comparison of the Coding Efficiency of Video Coding Standards—Including High Efficiency Video Coding (HEVC)", IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY, VOL. 22, NO. 12, DECEMBER 2012

Math for Bit rate, Peak bit rate, Burst

Bit rate = W * H * FPS * Rank * 0.07 — Adobe, "H.264 Primer", 2016

W: Pixel number in horizontal direction
H: Pixel number in Vertical direction
FPS: Frame per second
Rank: Motion rank,
- it can be Low motion, Medium motion or High motion.
- Low motion = 1, Medium motion = 2, High motion = 4.
- Low motion: video that has minimal movement
- Medium motion: video that has some degree of movement
- High motion: video that has a lot movements and movement is unpredictable.

Average Bit rate = T * W * H * S * d * FPS / Cv
Bit rate for I-frame = T * W * H * S * d * FPS / Cj
Burst size = T * W * H * S * d / Cj
Burst time = 1/FPS

T: Type of video, 1 for 2D, 2 for 3D
W: Pixel number in horizontal direction
H: Pixel number in Vertical direction
S: scale factor,
1 for YUV400, 1.5 for YUV420, 2 for YUV422, 3 for YUV444
d: Color depth bits
FPS: Frame per second
Cv: Average Compression ratio for video.
Cj: Compression ratio for I-frame

	Entry-level VR	Advanced VR	Ultimate VR
Type	4K 2D Video	12K 2D Video	24K 3D Video
Resolution W*H 360 degree video	3840*1920	11520*5760	23040*11520
HMD Resolution/ view angle	960*960/ 90	3840*3840/ 120	7680*7680/ 120
PPD (Pix per degree)	11	32	64
d (bit)	8	10	12
Cv	120	150	200(2D), 350(3D)
FPS	30	60	120
Mean Bit rate	22Mbps	398Mbps	2.87Gbps(2D) 3.28Gbps(3D)
Cj	20	30	20(2D), 30(3D)
Peak bit rate	132Mbps	1.9Gbps	28.7Gbps(2D) 38.2Gbps(3D)
Burst size	553K byte	4.15M Byte	29.9M Byte(2D) 39.8M Byte(3D)
Burst time	33ms	17ms	8ms
Infor Ratio of HMD/Whole Video	0.125	0.222	0.222

MTP Latency – Motion-to-Photon Latency

【1】***Motion-to-Photon latency*** *is the time needed for a user movement to be fully reflected on a display screen.* **(http://www.chioka.in/what-is-motion-to-photon-latency/)**

【2】***Motion-to-photon latency*** *also known as the End-to-end latency is the delay between the movement of the user's head and the change of the VR device's display reflecting the user's movement. As soon as the user's head moves, the VR scenery should match the movement. The more delay (latency) between these 2 actions, the more unrealistic the VR world seems. To make the VR world realistic, VR systems want low latency of <20ms and even really low latency of <7ms* **(http://xinreality.com/wiki/Motion-to-photon_latency)**

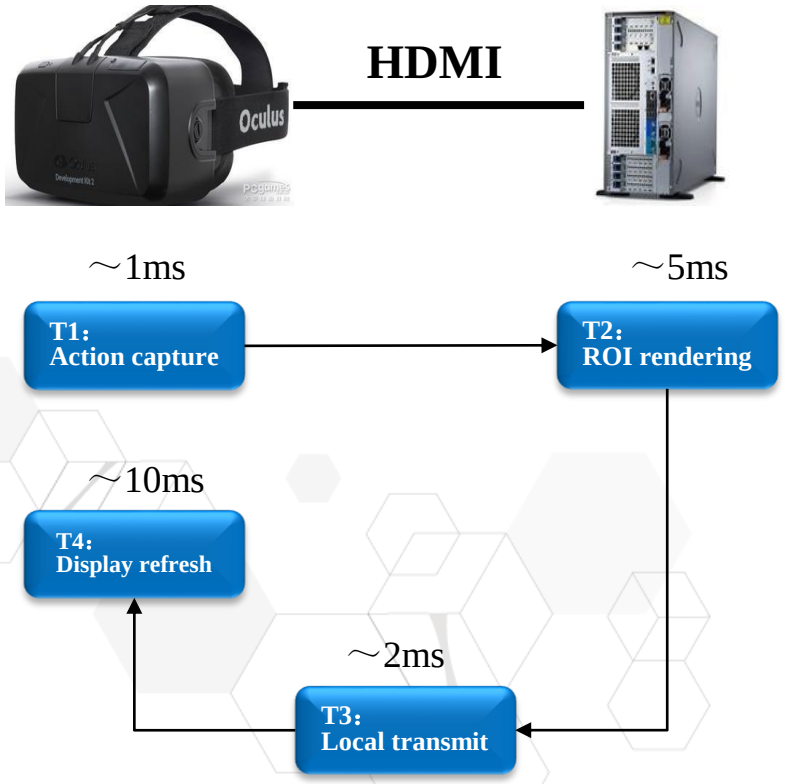
However, still some difference

	MTP (from the movement of user header to …	**Reference**
Oculus, Atman Binstock	the screen starts the display of new image	https://developer.oculus.com/blog/optimizing-vr-graphics-with-late-latching/
Oculus, John Carmack	the screen finishes the display of new image	https://www.twentymilliseconds.com/post/latency-mitigation-strategies
Valve, Alex Vlachos	the screen finishes the display of new image	Advanced VR Rendering，GDC 2015
Qualcomm	the screen center starts the display of new image	http://www.qualcomm.cn/news/blog-2016-07-20

Network Latency is Bigger Challenge
MTP < 20ms

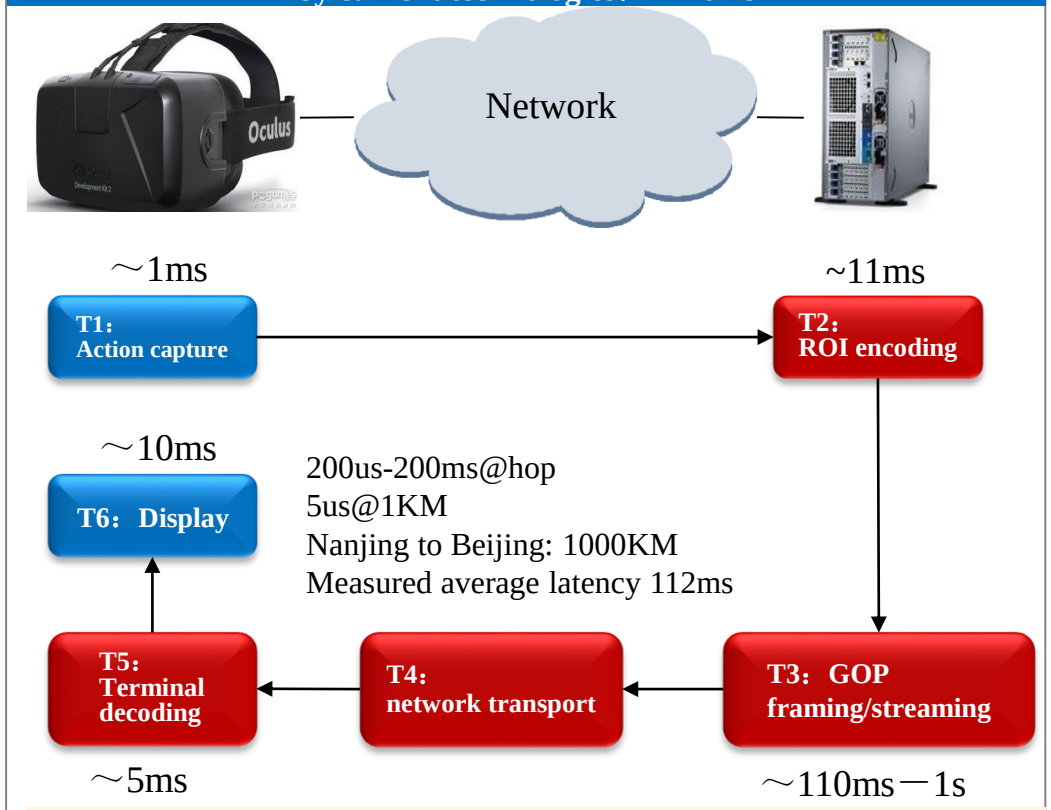
The maximum latency for network device = 5~7 ms – Propagation Delay(200km/ms)
User to server distance 500km (round propagation delay= 5ms),
The maximum queuing latency accumulated on all device (one direction) < 1ms

Latency of Localized VR APP：～18ms



Latency of Localized VR APP <20ms

Total latency of network based VR APP by current technologies：>>20ms



Network based AR/VR APP has 4 more processing than localized APP, Total Latency >> 20ms

Network latency must be < 5-7ms

HW parallel coding

Dynamic refreshing、TimeWap

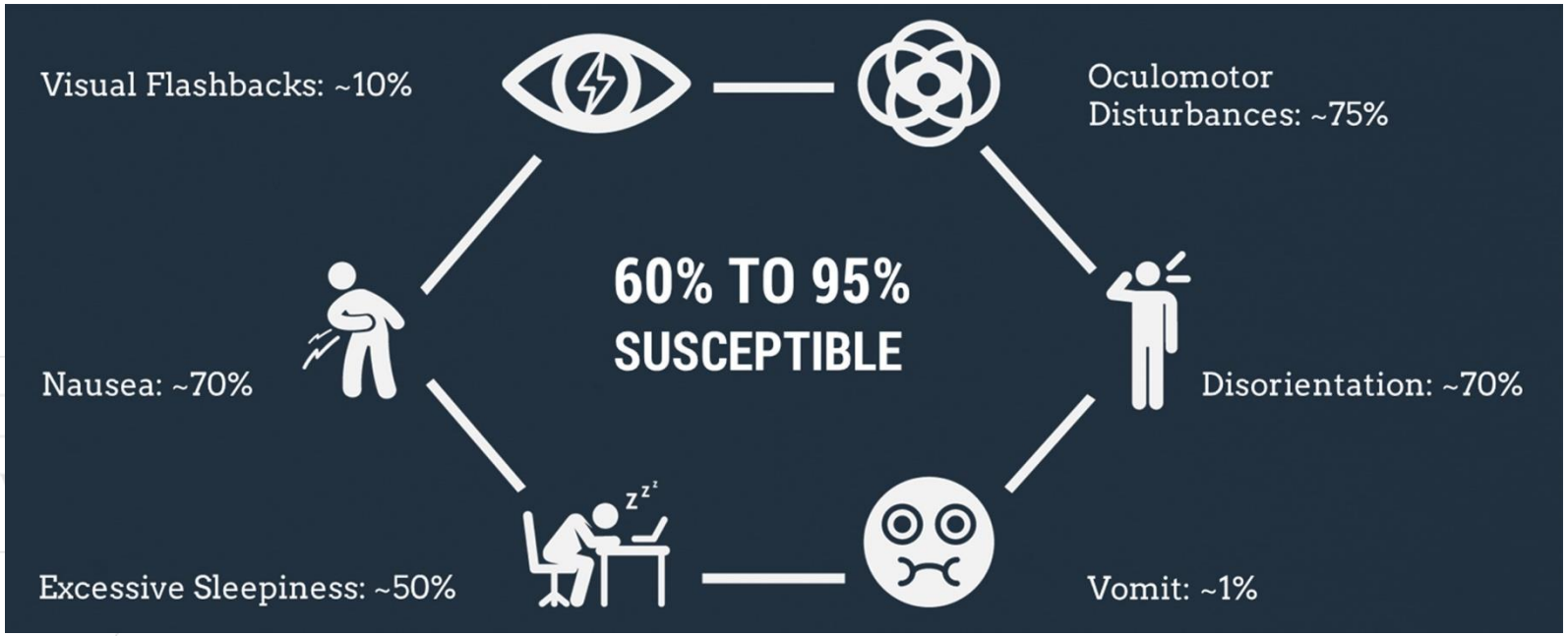
Major optimization for processing time in future VR：

- ➢Action capture ~= 1ms
- ➢Display refreshing ~= 0.01ms（AMOLED screen，dynamic refreshing、TimeWap）
- ➢Server coding ~= 2ms（HW parallel coding）
- ➢Streaming re-order ~= 5ms
- ➢Terminal decoding ~= 5ms
- ➢Network transport ~= 5ms－7ms

Latency in future networks must be about 5~7 ms, considering the technology advances in future

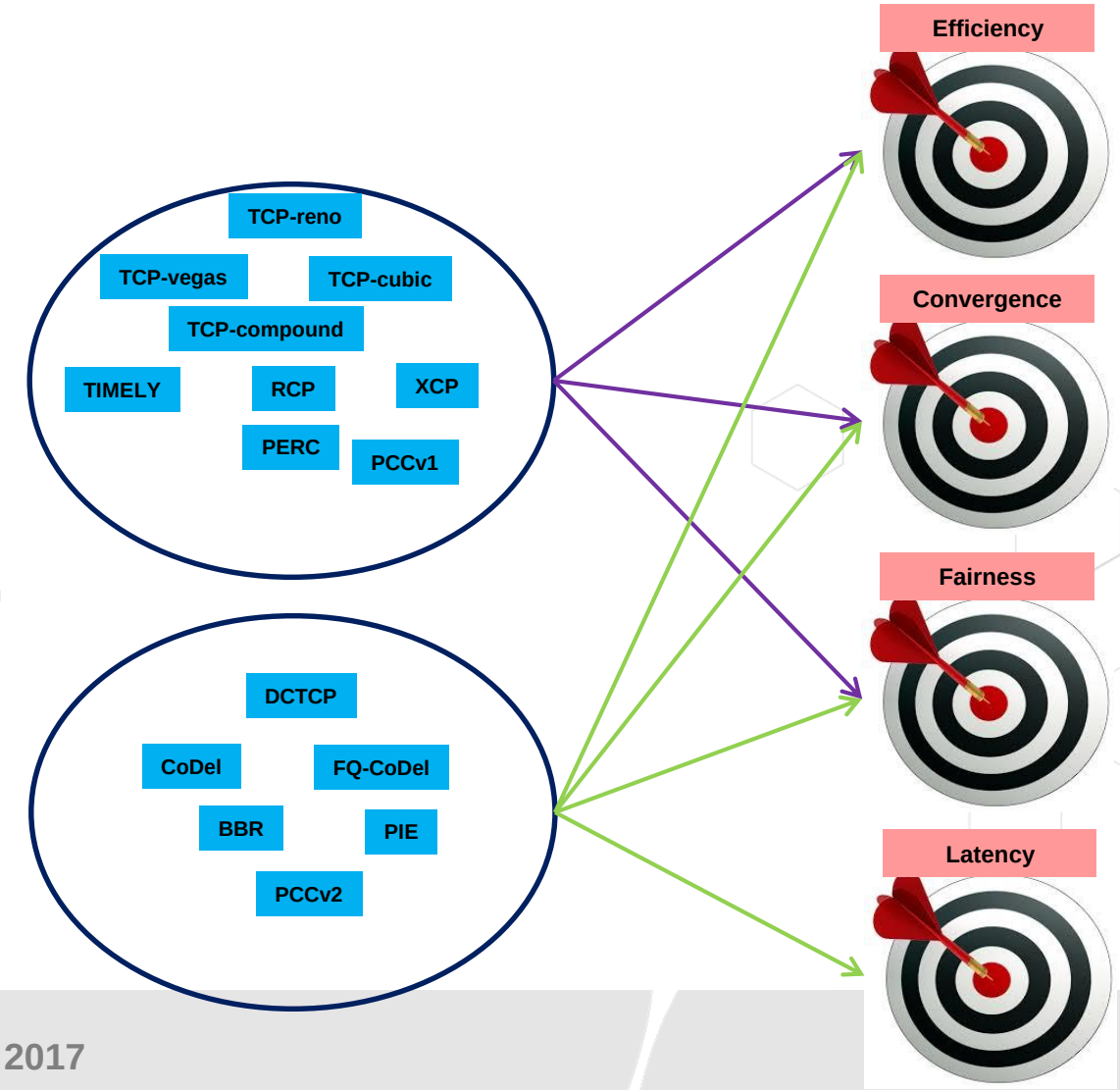
Summary

- **Network needs to support “High throughput + Ultra-short latency + High burst”**
- **Network quality greatly impacts AR&VR User Experience**
- **Much lower tolerance of packet loss or delay than watching HD TV.**
- **Compromise of network quality may cause CyberSickness**



TCP Overview

- **Many variations for TCP**
  - Place to change: Host only, Network only, or Host plus network
    - Host only: TCP-reno, TCP-vegas, TCP-cubic, TCP-compound, TIMELY, BBR, PCC
    - Network only: PIE(no ECN), CoDel(no ECN), FQ-CoDel(no ECN)
    - Host plus network: DCTCP, PIE(with ECN), CoDel(with ECN), FQ-CoDel(with ECN), XCP, RCP, PERC
  - Reactive or Proactive
    - Proactive: PERC
    - Reactive: Others
  - Allowed bandwidth detection: Congestion based, performance based, rate based, calculation based
    - Congestion based: TCP-reno, TCP-cubic, TCP-vegas, PIE, TIMELY, DCTCP, CoDel, FQ-Codel
    - Performance (rate, RTT, loss) based: PCC, BBR
    - Rate based: XCP, RCP,
    - Calculation based: PERC
  - Congestion detection: packet loss, RTT, packet loss+RTT, Delay on router, Q depth
    - Packet loss: TCP-reno, TCP-cubic
    - RTT: TCP-vegas, TIMELY
    - Packet loss+RTT: TCP-compound
    - Delay on router: PIE, CoDel, FQ-CoDel,
    - Q depth: DCTCP,
  - Rate detection: Implicit or Explicit rate
    - Explicit: XCP, RCP, PERC, BBR, PCC
    - Implicit: Others



Can Current Transport Support Extreme Applications?

- **Extreme applications**
  - AR&VR (High throughput + ultra-short latency + High burst)
  - Tactile Network (ultra-short latency)
- **Fundaments of transport technologies**
  - Network device: Fair queuing + buffer constraint
  - Host: Adaptive sending rate/gape based on different congestion control algorithm
- **Transport problems:**
  - Fairness
    - All flows/users share the bandwidth equally, it does not allow a flow to obtain more bandwidth or shorter latency than others instantaneously
    - If “bandwidth requirement > available bandwidth”, long flow has higher probability to loss packet.
  - Buffer and latency
    - Maximum throughput and Minimum Latency are conflicting targets
    - High burst needs big buffer
  - Control
    - Reactive, applications got impacted already
    - One RTT, slow to handle burst
  - No or weak service guaranteed
    - Bandwidth and latency are not deterministic

Prospective Solution

- **No Network Assistant**
  - Is it possible?
- **With Network Assistant, How?**
  - Allocate more resource to special app/users
  - Compatibility
  - Performance
  - Scalability
  - Net-neutrality

Q&A