To QoE or not to QoE

Towards QoE-aware Resource Allocation for Real-time Media

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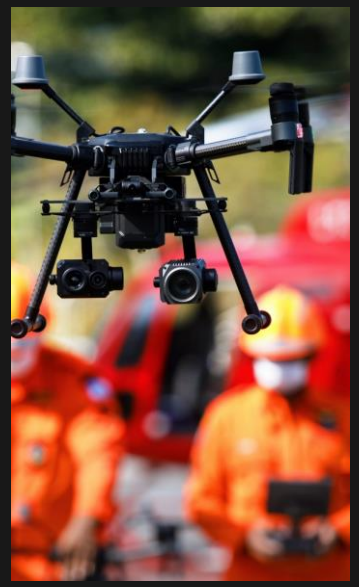
Mobile Video Use cases

Realtime: interactive, human (or AI) in the loop

~30 – 110ms "finger to photon" latency

Remote-rendered XR

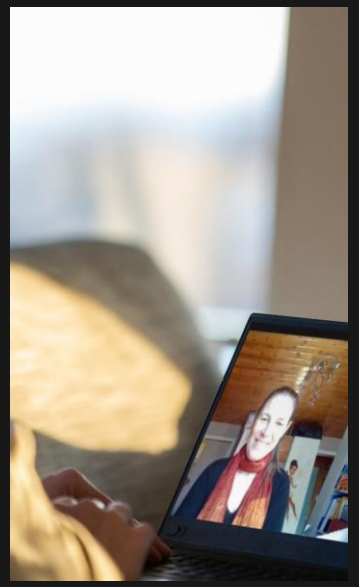
Cloud gaming



Remote control (drones / cars / heavy equipment)

Near-Realtime

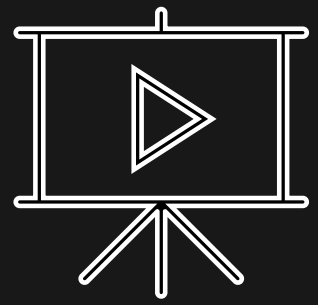
100 – 500ms



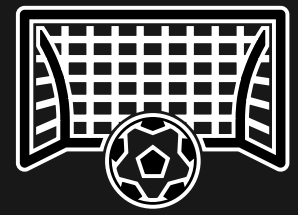
Video Conferencing

Non-Realtime / Video on Demand

>1000ms. Typically 10 – 90 seconds (buffering)



DASH / HLS video (short form)

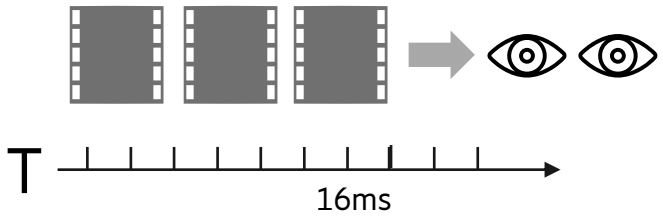


DASH / HLS video (regular)

QoE Components (Realtime)

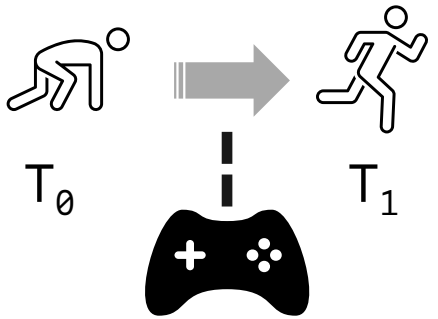
Spatial Quality
(Q_S)

- Visual picture quality vs. perfect
- Not simply the resolution
- Dependent on bitrate, encoder and content
- Metrics: VMAF, P.1204.3, PSNR, SSIM
- **Our focus in this talk**



Temporal Quality
(Q_T)

- High and consistent frame rate
- No visible freezing (i.e. due to drops)



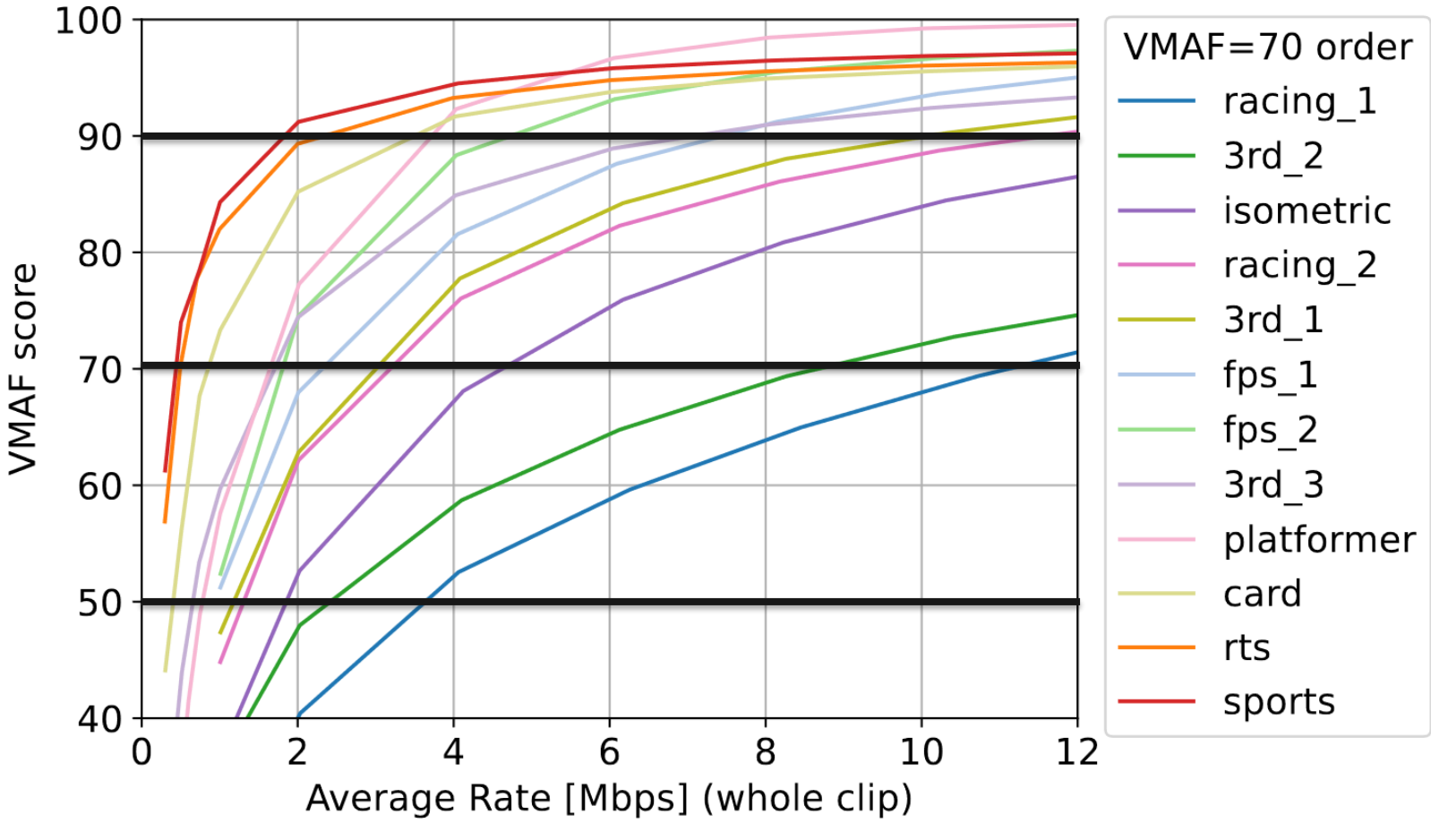
InputLag Quality
(Q_I)

- "finger to photon" – button press until resulting action is visible

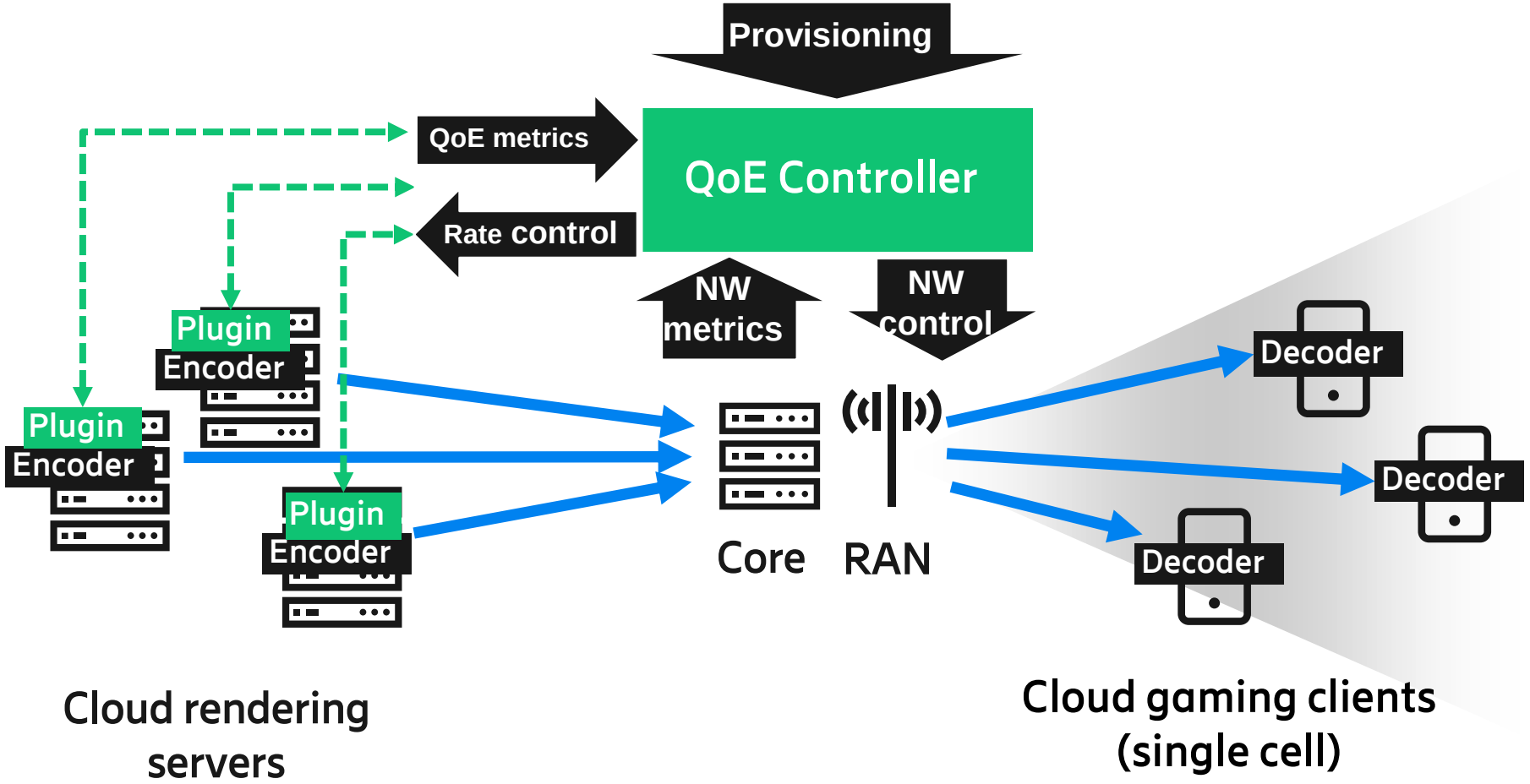
- Frames must be transmitted fast, in a few frame times
- No long-time averaging like for DASH

Spatial complexity curves example
Spatial QoE measure (VMAF) as a function of Average Rate

- 10 s long homogenous HD video game clips
  - Encoded with different target rate settings
- VMAF: Spatial QoE measure
  - By Netflix, for movies
  - 50: minimum acceptable, 70: good, 90: excellent QoE
- The two extremes are:
  - racing_1 (most demanding)
  - sports (least demanding)

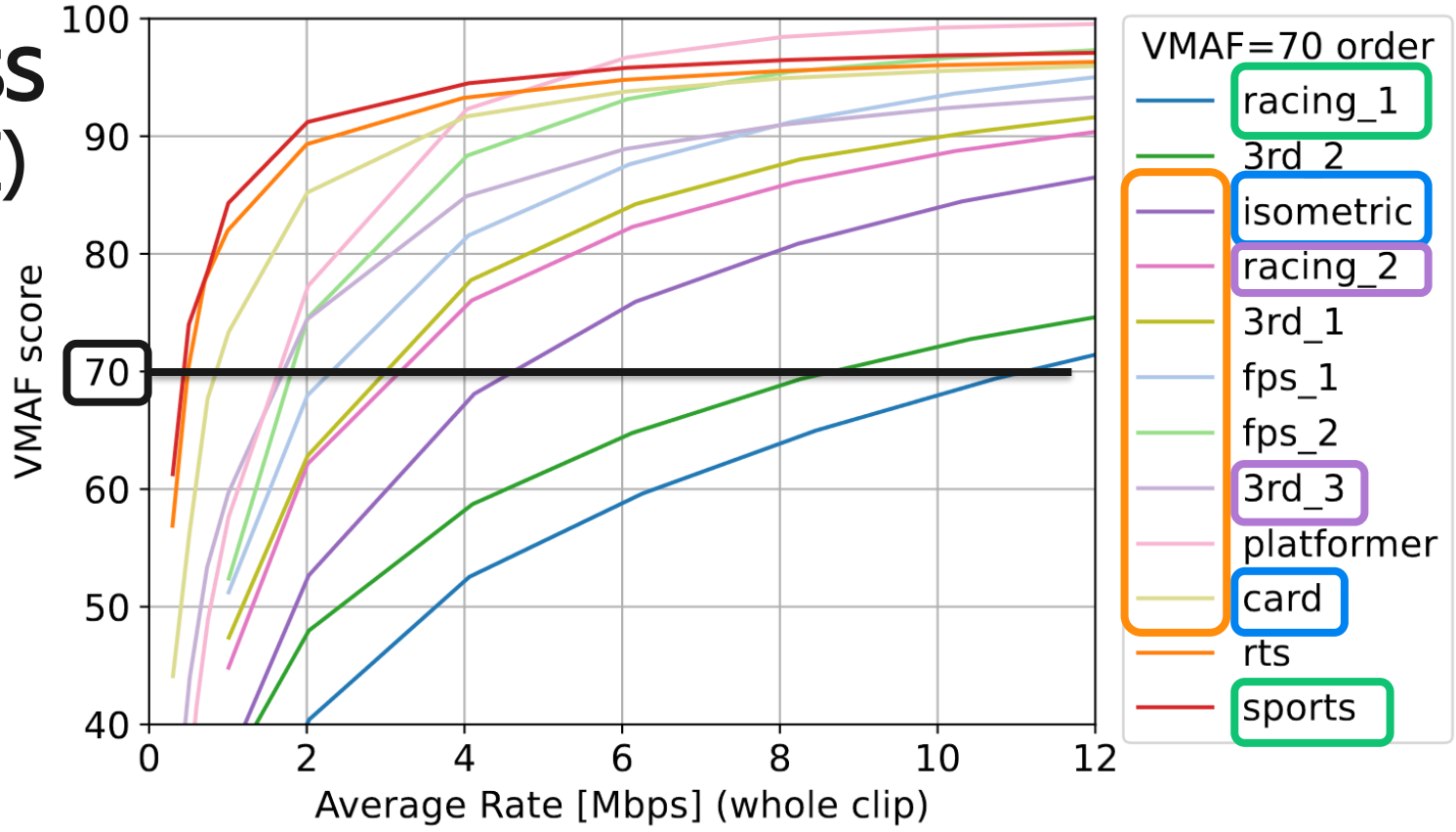


Architecture



Gain of QoE-awareness
VMAF target = 70 (good QoE)

Scenario	N_{ER}	N_{QoE}	Gain factor
sports vs. racing_1	13	26	2
card vs. isometric	32	55	1.72
all 12 games	13	47	3.62
8 games	32	66	2.06
3rd_3 vs. racing_2	49	65	1.33



We determine the max number of flows (N_{ER} and N_{QoE}) for two strategies

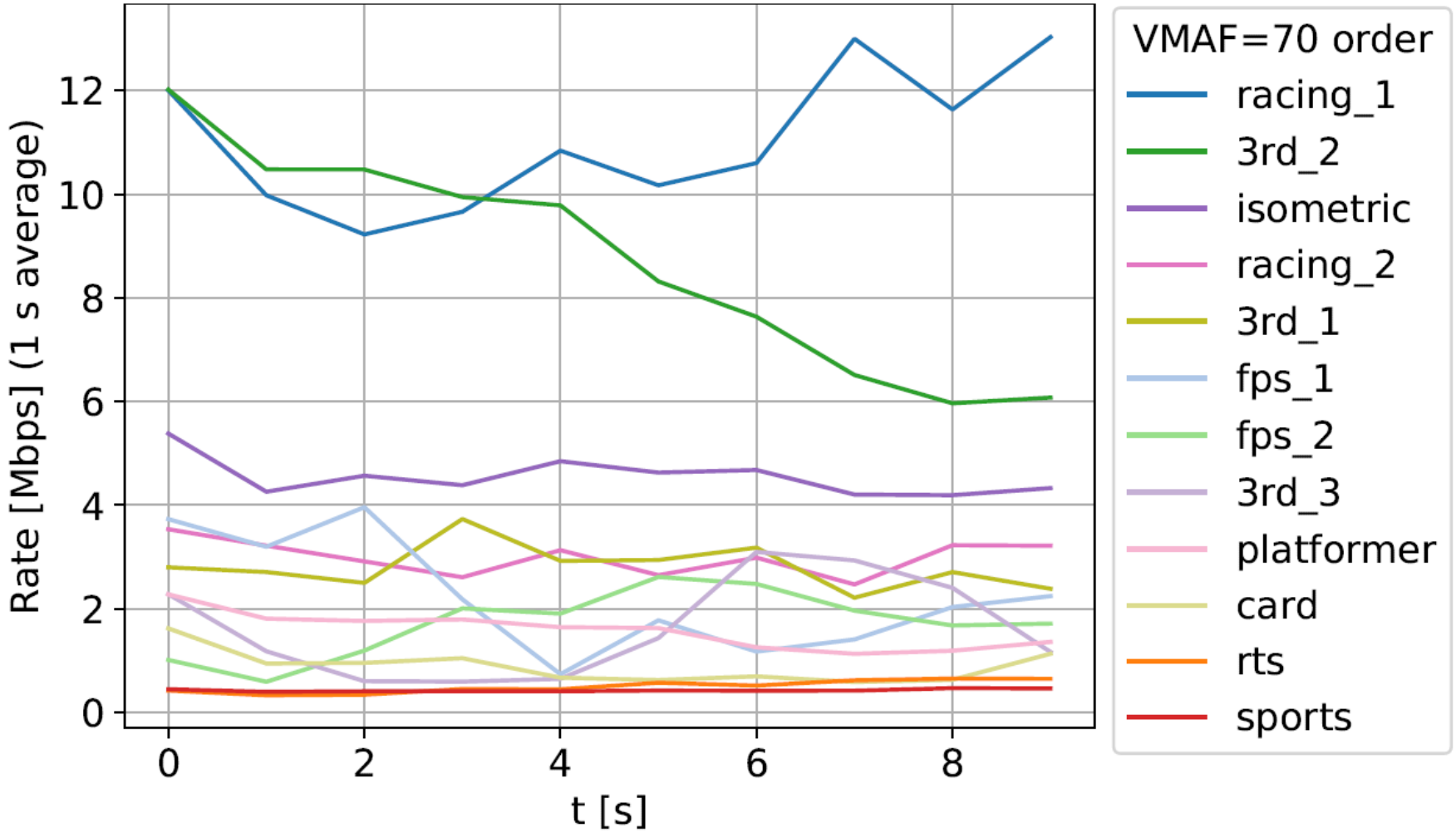
- N_{ER}: for the "Equal bitrate" strategy: all flows get the most demanding game's rate requirement
- N_{QoE}: for the "Equal QoE" strategy: all flows get just enough rate to reach VMAF=70

Gain factor = N_{QoE}/N_{ER} (Scalability gain, 150 Mbps bottleneck)

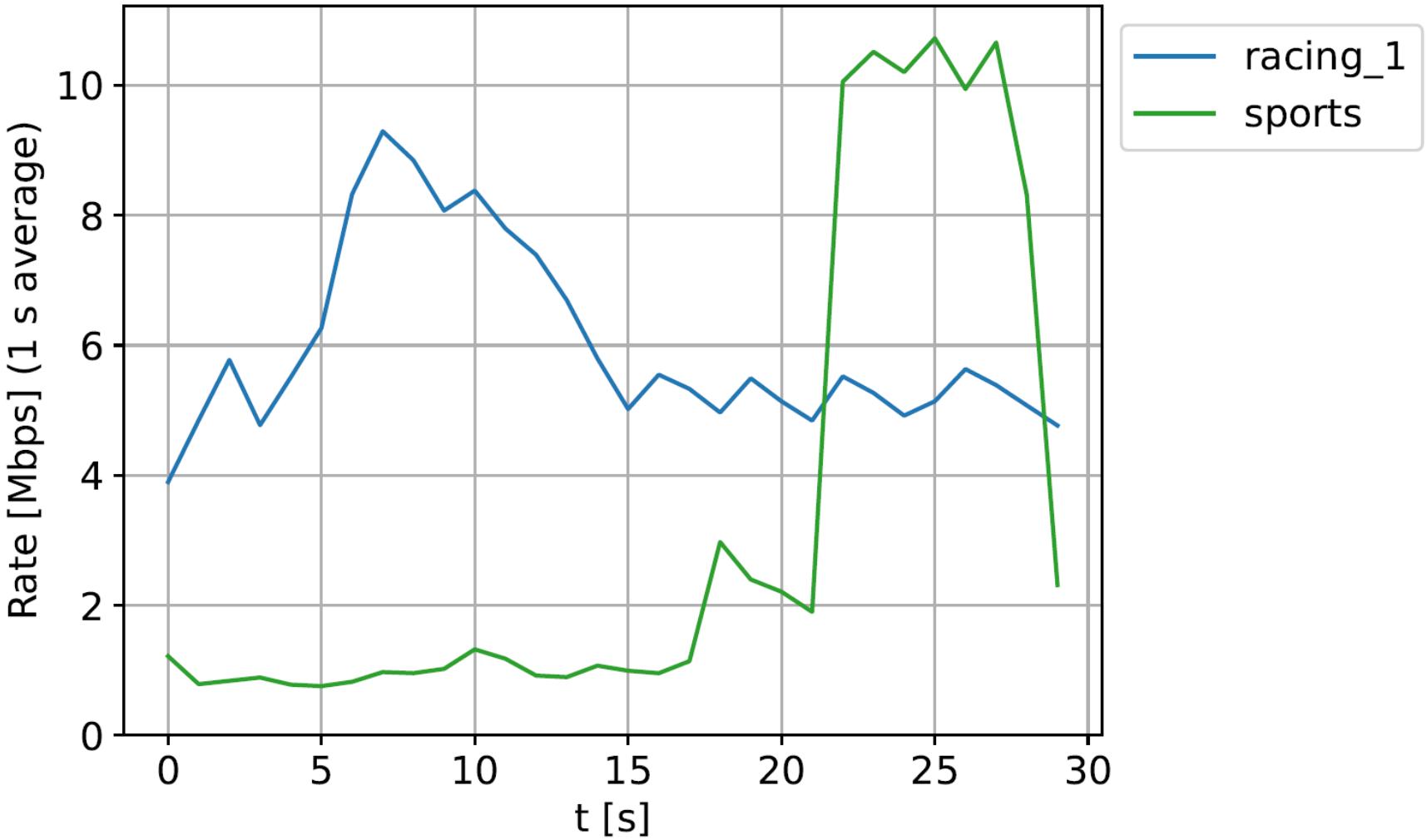
Cellular Network Characteristics

- A Base Station have a given amount of Radio Resources
- Spectral Efficiency determines the bitrate achievable with given amount of Radio Resources
  - It varies as radio channel quality varies due to mobility, noise and interference
  - In this analysis we assumed constant Spectral Efficiency
  - More on dynamic Spectral Efficiency in the paper
- The resource sharing over the air is determined by the air interface scheduler
  - Packets queued into per user queues (potentially multiple queues per user)
  - This overrides any fairness achieved by end-to-end algorithms over shared bottlenecks

Spatial Complexity Variation
1 s average rate required to reach VMAF 70 each second



Spatial Complexity Variation
30 s long, non-homogenous clips



QoE controller design

- Simplest algorithm is to provide equal QoE to all flows,
  - send rate guidance to encoder in servers
  - have full knowledge of spatial complexity curves
  - give resources to the flow with the smallest QoE
    - among equals the one with the highest spectral efficiency
  - potentially, have a minimum QoE requirement and admission control
- Handle spatial complexity variation
- Potential improvements
  - QoE guidance
  - partial knowledge about spatial complexity
  - take into account the resources needed to reach a QoE, e.g. by using utility functions
  - service differentiation, Gold having higher QoE than Silver

Conclusion

- We demonstrated high potential for scalability gains
  - by moving traffic management from the bitrate domain to the QoE domain
- An interface for application-network collaboration is needed to be able to achieve this gain
  - there is a trust issue, which is not trivial to solve
- Benefits
  - end users: increased QoE
  - carriers: lower contention, cost savings
  - service providers: more consistent QoE
- Cooperation among players is needed. We are active in this area and welcome discussions.