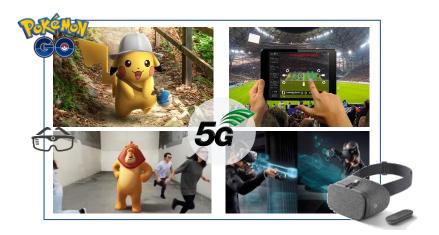Bell Labs Consulting

AR/VR and 5G QoMEX paper overview

Video Quality Experts Group (VQEG) presentation December 2020

NOKIA

Key concerns/questions telecom operators are asking

- Operators looking to monetize their assets – to create value for their 5G (or LTE network)

- What is required to make VR/AR work on LTE and 5G/Edge Cloud?

- Value creation comes from creating a great user experience (high QoE)

  - How to measure QoE for AR/VR/XR?

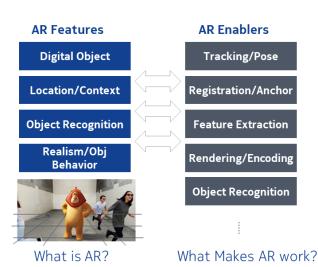 - How to engineer their network to ensure a good user experience?

Paper proposes a methodology

XR Features	XR Enablers	XR KQI	Network KPIs	Tracking QOE
Decompose	QoE measure		NW measure	Score

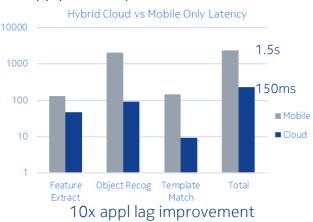**Network operators need to create a demand for 5G by showcasing its abilities**

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Cloud delivered AR/VR – market and technology readiness

- **AR/VR are computationally complex (CPU limited)**
- **XR operates locally (HMD)**

AR Features

Digital Object	
Location/Context	
Object Recognition	
Realism/Obj Behavior	

AR Enablers

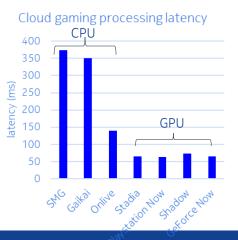| |
|---|
| Tracking/Pose |
| Registration/Anchor |
| Feature Extraction |
| Rendering/Encoding |
| Object Recognition |

What is AR?   What Makes AR work?

- **Why move XR to Cloud?**
  - Battery life and Heat reduce
  - Scalability of app (e.g. obj recog)
  - Device ergonomics and portability, app portability and feature adds

Hybrid Cloud vs Mobile Only Latency

1.5s
150ms

Mobile
Cloud

Feature Extract   Object Recog   Template Match   Total

10x appl lag improvement

- **GPU have brought possibility of remote AR/VR**
  - Cloud gaming has similar performance requirements of AR/VR/XR (complex, real time, etc)

Cloud gaming processing latency

CPU

GPU

latency (ms)

SMG   Gaikai   Onlive   Stadia   Playstation Now   Shadow   GeForce Now

Market evolutions towards 5G, Edge Cloud and GPU have enabled AR/VR cloud

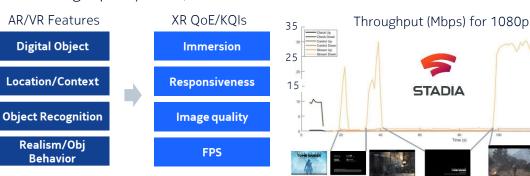Bell Labs Consulting Confidential   Bell Labs Consulting
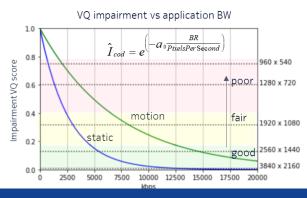
How to define QoE for AR/VR

- Each AR/VR application is characterized by features tied to enablers (KQIs)
  - Responsiveness - appl lag
  - Immersion is related to content resolution
  - Image quality – PLR, etc

- Relating KQIs to network KPIs (1080p to throughput)

- Leveraging internal and external research and existing ITU-T standards when possible

- Impairment models were used to characterize degradation

- Combining impairment models using multiplicative model

$$Q_{XR} = \alpha \times \hat{I}_x \times \hat{I}_y \times \hat{I}_z + \beta$$

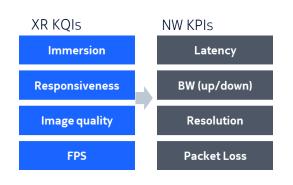**AR/VR Features**

| Digital Object |
| Location/Context |
| Object Recognition |
| Realism/Obj Behavior |

XR QoE/KQIs

| Immersion |
| Responsiveness |
| Image quality |
| FPS |

Throughput (Mbps) for 1080p

STADIA

VQ impairment vs application BW

$$\hat{I}_{cod} = e^{\left(-a_0 \frac{BR}{PixelsPerSecond}\right)}$$

Leveraging best practices and existing research to create a method for measuring AR/VR QoE
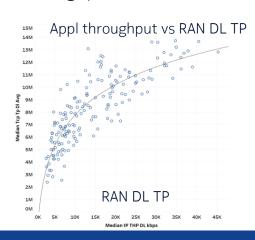
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Engineering the network to meet a desired QoE level

- Correlating NW KPIs to XR KQIs is achieved through customer data analysis (analytics)

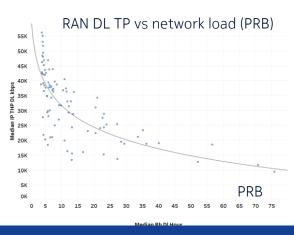- NW operators track KPIs which can be engineered through capacity planning

- Network KPIs like RAN DL throughput can be measured against application throughput

- Network RTT also impacts appl throughput

- LTE network load (PRB) or volume (GB/hour) impacts user throughput

- Using traffic growth we can predict future throughput

XR KQIs

Immersion
Responsiveness
Image quality
FPS

NW KPIs

Latency
BW (up/down)
Resolution
Packet Loss

Appl throughput vs RAN DL TP

RAN DL TP

Median Tcp Tp Dl Avg

Median IP THP DL kbps

RAN DL TP vs network load (PRB)

PRB

Median IP THP DL kbps

Median Rb Dl Hour

Engineering for QOE can be achieved by correlating application KQI targets to KPI performance
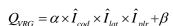
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Evaluating LTE and 5G QoE based on developed models

VR Gaming

Capacity increase is not sufficient for 4K VR Gaming
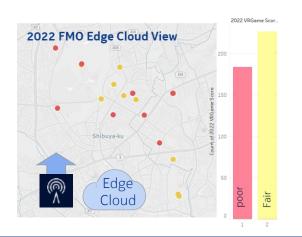- Assumption: Cloud latency 190ms, 4G 70ms

$$Q_{VRG} = \alpha \times \hat{I}_{cod} \times \hat{I}_{lat} \times \hat{I}_{plr} + \beta$$

2022 FMO NODE View

LTE Capacity Increase

2022 VRGame Sc..

600
550
500
450
400
350
300
250
200
150
100
50
0

Count of 2022 VRGame Score

550

150

poor   fair
1   2

Cloud performance GPU and far edge based
- Assumption: Edge Cloud latency 70ms

2022 FMO Edge Cloud View

Edge Cloud

2022 VRGame Scor..

200

150

100

50

0

Count of 2022 VRGame Score

poor   Fair
1   2

Cloud performance GPU and far edge based
- Assumption: 5G Latency 10ms

2022 FMO 5G Edge Cloud View

5G
Spectrum (HZ)
Spectral Efficiency (bps/hz)
Space (bps/m²)

Edge Cloud

2022 VRGame Scor..

400

350

300

250

200

150

100

50

0

Count of 2022 VRGame Score

fair   good
2   3

VR gaming QoE is enabled by the reduced latency in the edge cloud and 5G network

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