UNIVERSITY OF ZAGREB
Faculty of Electrical Engineering and Computing

Social XR in 5G and Beyond

Requirements, use cases, and standardization efforts

MUEXlab

Lea Skorin-Kapov

Spring School on Social XR, March 8 2024, CWI, Amsterdam

Outline

- Evolution of the telecom industry – is XR the next mass market mobile computing platform?
- Emerging XR applications: implications on future network requirements
- Technology enablers for XR in 5G
- Standardization efforts and use cases
- Beyond 5G

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- **Evolution of the telecom industry – is XR the next mass market mobile computing platform?**
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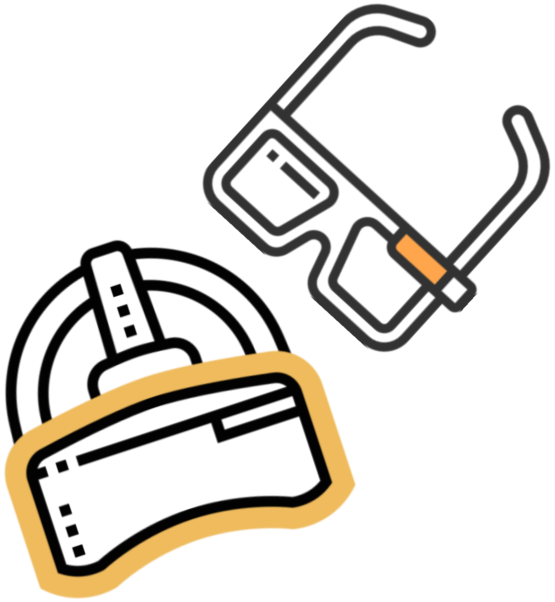
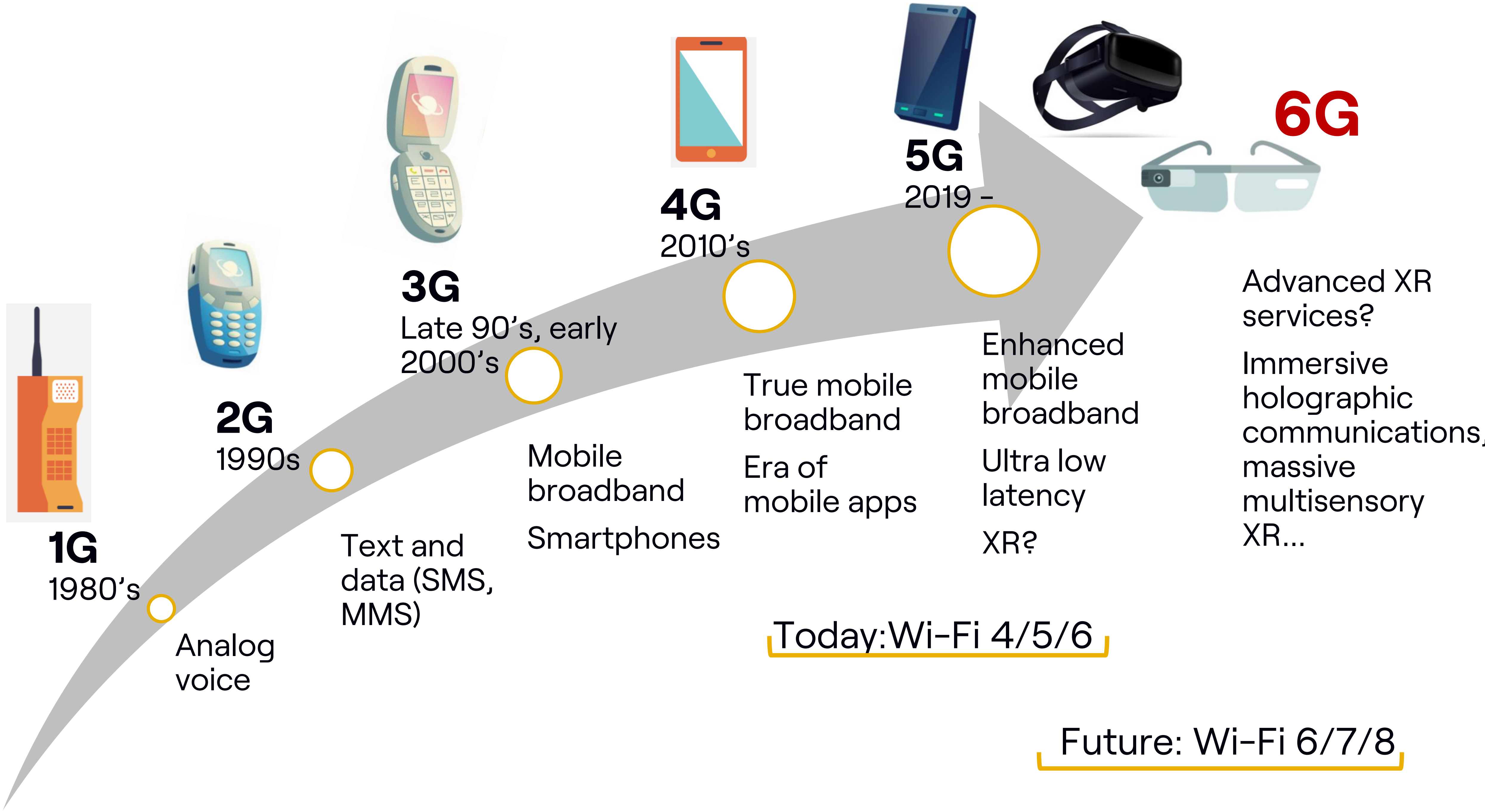
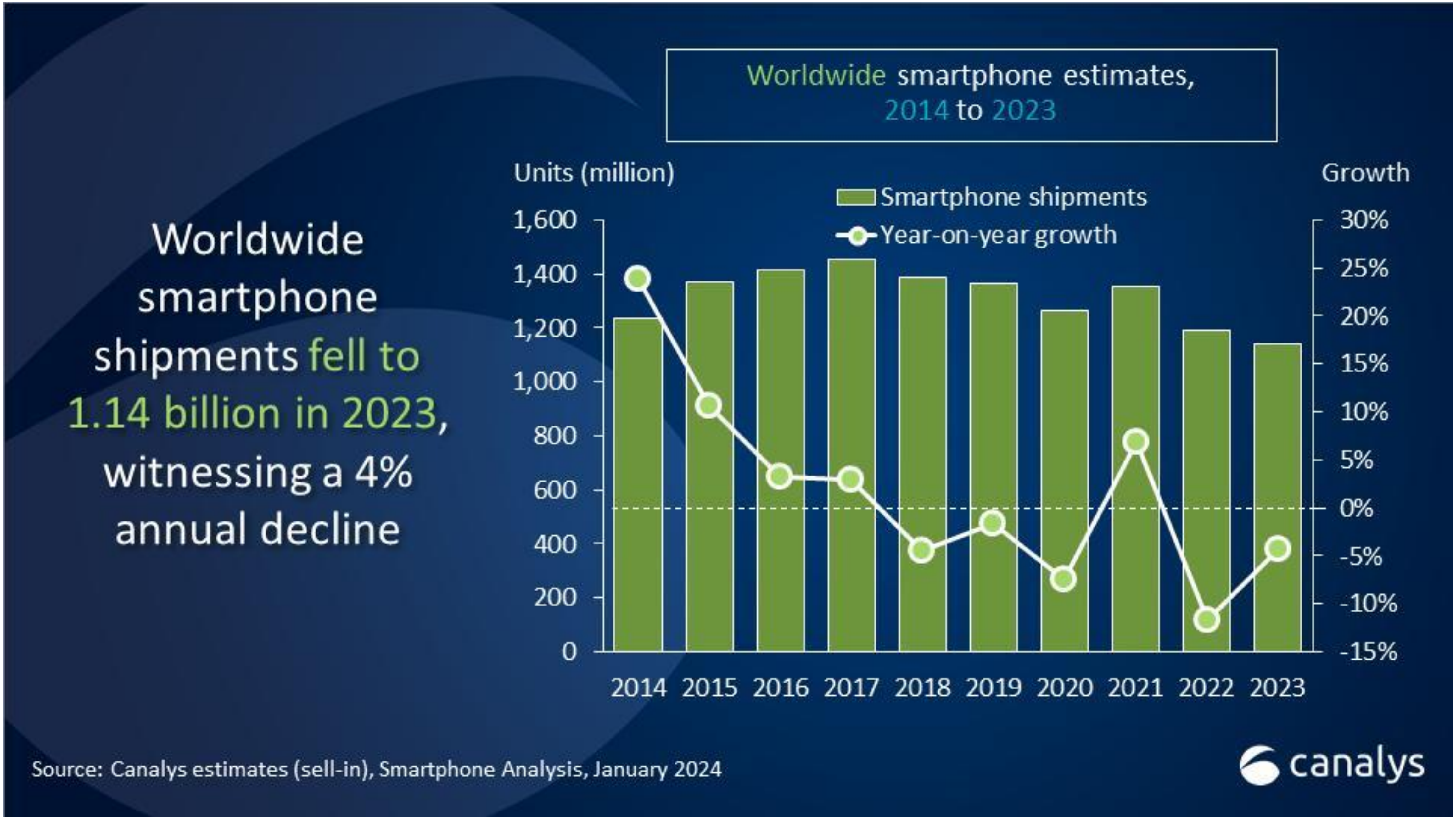
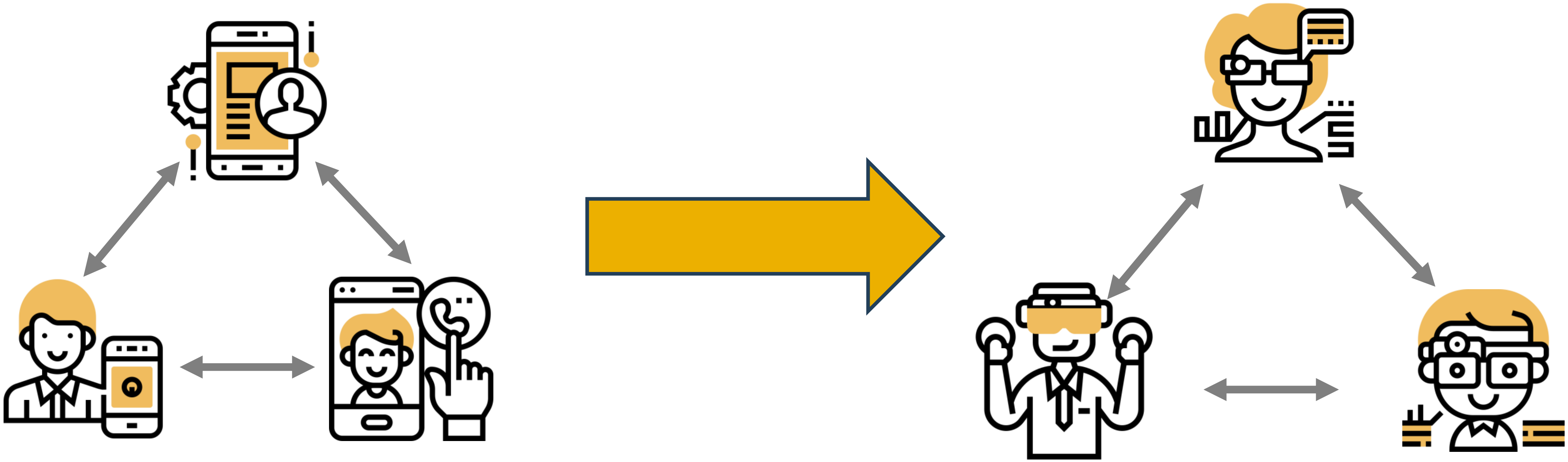



1G
1980's
Analog voice
2G
1990s
Text and data (SMS, MMS)
3G
Late 90's, early 2000's
Mobile broadband
Smartphones
4G
2010's
True mobile broadband
Era of mobile apps
5G
2019 –
Enhanced mobile broadband
Ultra low latency
XR?
6G
Advanced XR services?
Immersive holographic communications, massive multisensory XR...
Today:Wi-Fi 4/5/6
Future: Wi-Fi 6/7/8



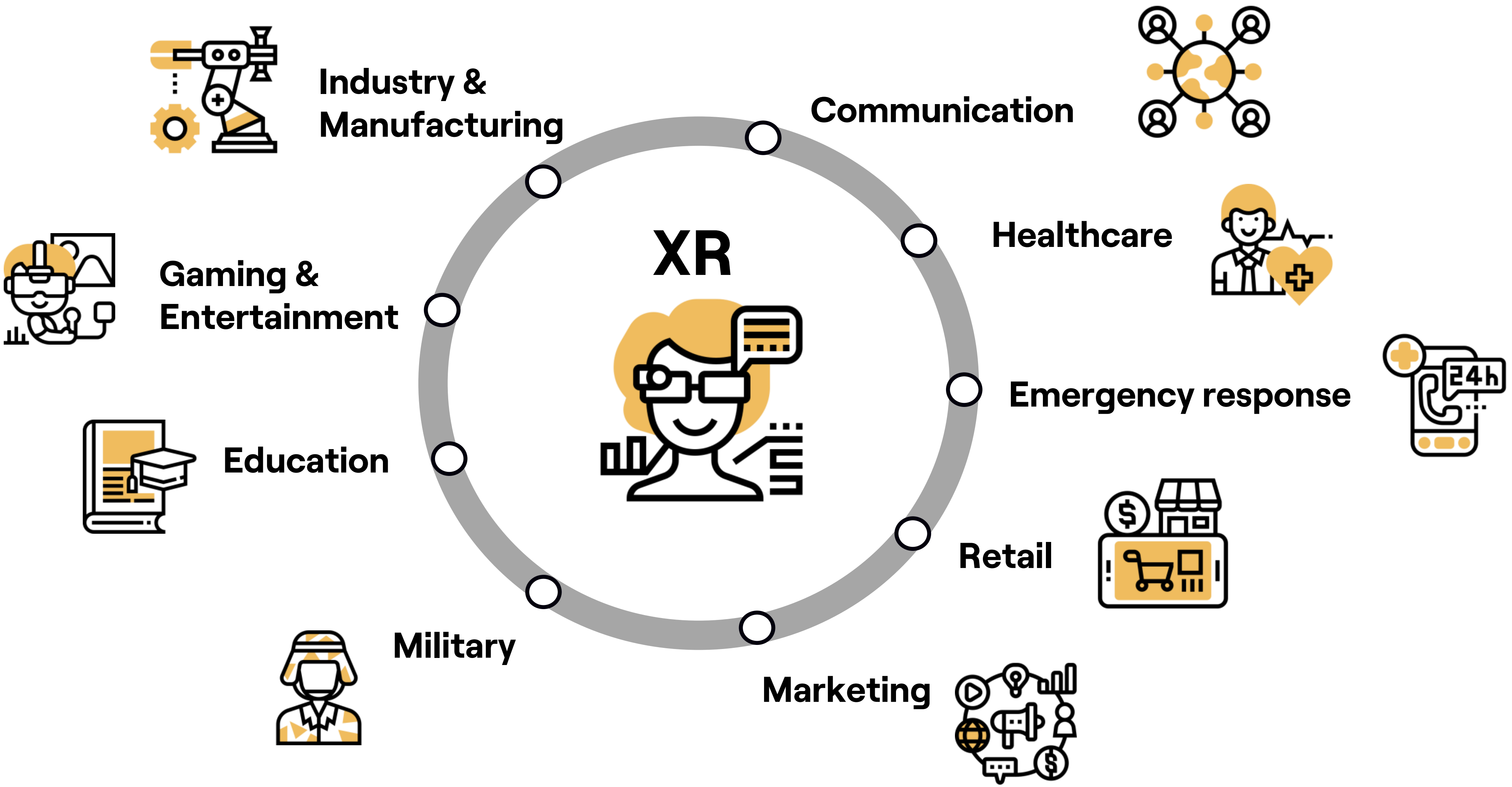
Worldwide smartphone shipments fell to 1.14 billion in 2023, witnessing a 4% annual decline
Worldwide smartphone estimates, 2014 to 2023
Units (million)
Growth
Smartphone shipments
Year-on-year growth
1,600
1,400
1,200
1,000
800
600
400
200
0
30%
25%
20%
15%
10%
5%
0%
-5%
-10%
-15%
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Source: Canalys estimates (sell-in), Smartphone Analysis, January 2024
canalys

A paradigm shift in the telecom industry?



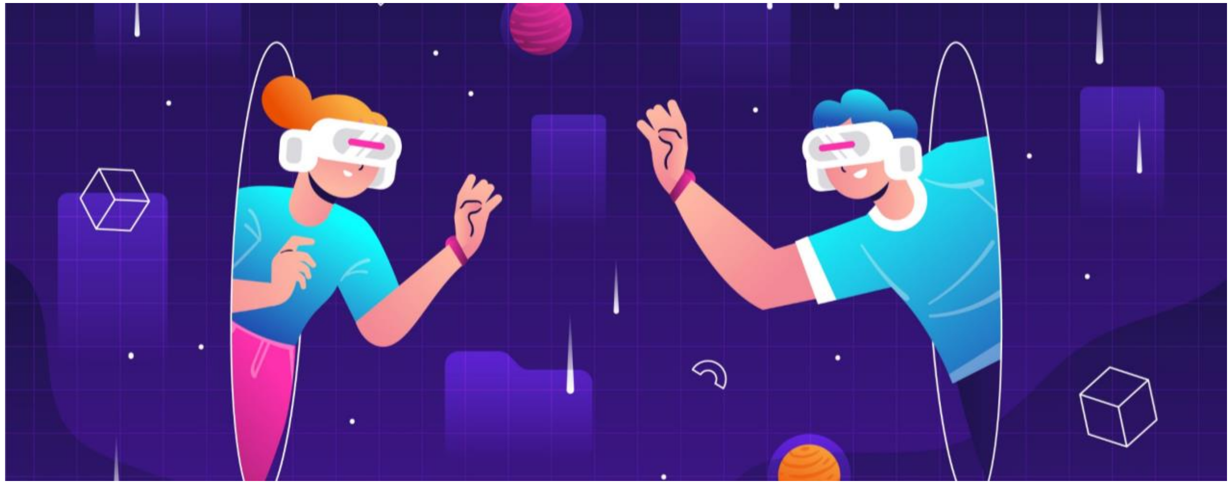
Beyond flat screens and connectivity towards intuitive interfaces and richer immersive communication

XR: considered by many to be the next Mobile Computing Platform



According to 3GPP: the "**mobile metaverse**" is defined as the user experience enabled by the 5G (and beyond) system of interactive and/or immersive eXtended Reality (XR) media, including haptic media.

3GPP Tech Trends, 2024



From a telco perspective

- XR is seen as a huge opportunity for the (currently flattening) mobile broadband market
- Current investments planned to meet mobile broadband traffic requirements → will XR require additional investments?
- Still consider early days of XR – need to prepare for new and advanced XR applications and devices, moving toward immersive communications
- Insufficient network capabilities, no mass market mobile XR

Example XR devices on the market

VR Passthrough

High-end

Apple Vision Pro
- indoors, WiFi
- weight: 600-650 g

Mass-Market

Meta Quest 3
- indoors, WiFi
- weight: 515 g

AR/MR

High-end

Magic Leap 2
- indoors, WiFi & cabled
- weight: 260 g

Mass-Market

Xreal Air
- anywhere, cabled
- weight: 79 g

High-end

Microsoft Hololens 2
- indoors, WiFi
- weight: 566 g

Example XR devices on the market

VR Passthrough

High-end

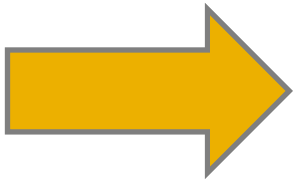
Mass-Market

AR/MR

High-end

Mass-Market

High-end



Slim, lightweight form factor

?

Spatial compute and rendering **on the device**

Spatial compute and rendering **in the cloud**

Today
(VR/AR/MR)

Mid term
(MR/AR more widepsread)

Long term
(extended XR use)

- local area
- best effort MBB

- local → wide area
- increased sharing (e.g., shared spatial maps)

- wide area
- rich capacity, low latency (downlink and uplink)





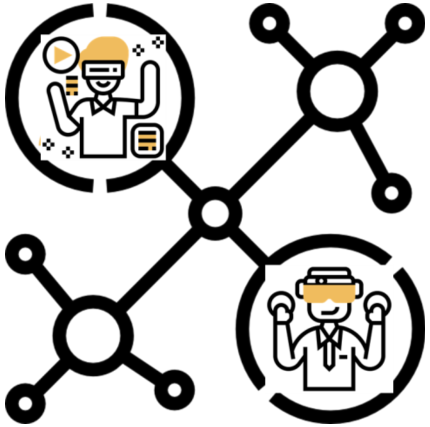
Mass-market adoption of mobile XR → calls for **evolution of devices** from bulky HMDs to lightweight glasses/headsets

Lightweight glasses /headsets → require **compute offload**

Compute offload → drives **network requirements**

When do we need 5G?

- Many concurrent users – high graphical fidelity experience
- Wide area coverage
- Truly mobile experience → immersive XR anywhere, anytime



Motorola and Verizon develop "5G collar" for VR and AR

Apr 16 2023 Jan Wöbbeking


Wireless Private Wireless 5G Tech

BREAKING NEWS: Keep current with MWC Barcelona cover

TECH

Motorola pairs with Verizon to create 5G XR neckband

By Bevin Fletcher · Feb 14, 2022 5:31pm

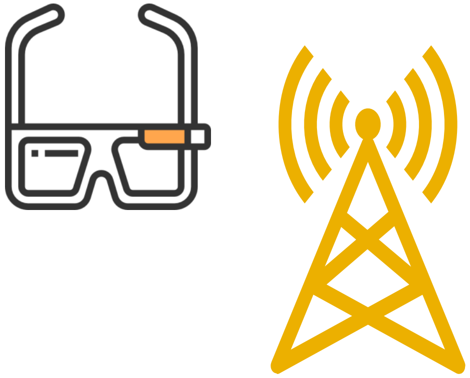
Motorola Verizon Qualcomm XR

Image: Trigger XR

https://mixed-news.com/en/motorola-and-verizon-develop-5g-collar-for-vr-and-ar/

Vodafone's HyperRealityHub to pave the way for lightweight extended reality glasses at MWC24

Today: NO commercially available XR headsets that support embedded cellular technology

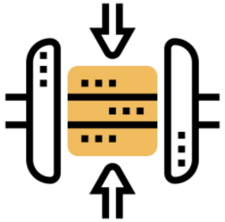


Building blocks needed to deliver mass-market mobile XR

5G-connected XR devices

- mobility
- new interfaces
- lower power consumption

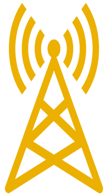
+



Compression algorithms

- high quality real-time video
- encoding and transmission of immersive media

+



Optimized mobile network

- connectivity
- capacity
- low latency

+

Edge cloud

- low latency
- compute offloading

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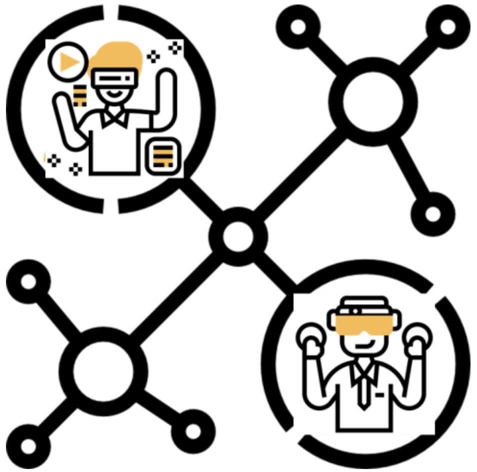


Understanding XR service requirements

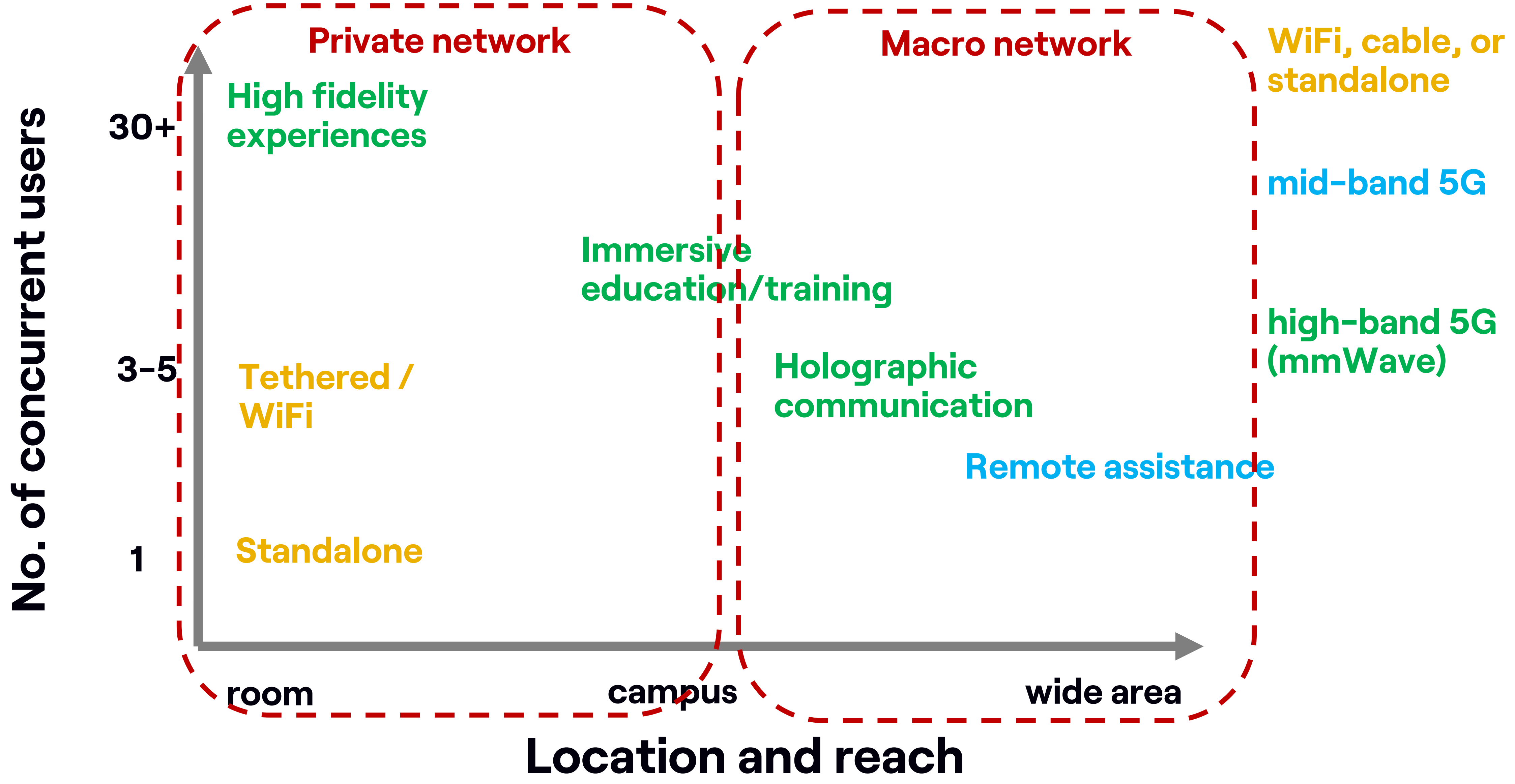
QoS perspective

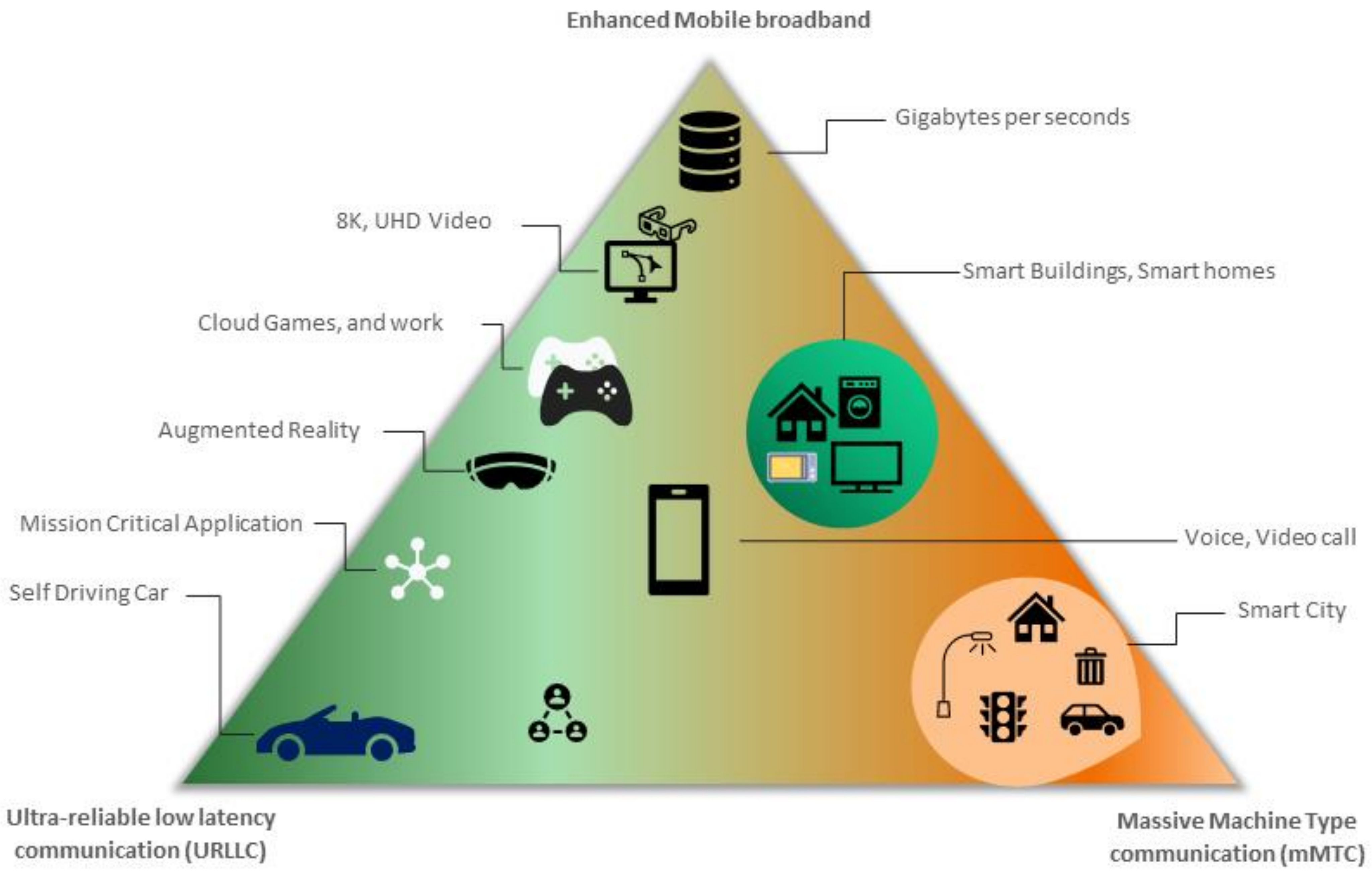
- future requirements are **heterogeneous** and **uncertain**
- **dynamic traffic** due to 6DoF movements, gestures, and real-time user control feedback
- different degrees of **offloading** drive different requirements

QoE perspective

- need to **develop QoE metrics** for new XR services → e.g., for designing compression algorithms, which **drive network requirements**
- network operator – needs to know **what to optimize for** (also key in lowering production costs)

When do we need 5G?





https://www.emnify.com/blog/5g-spectrum-service-grades

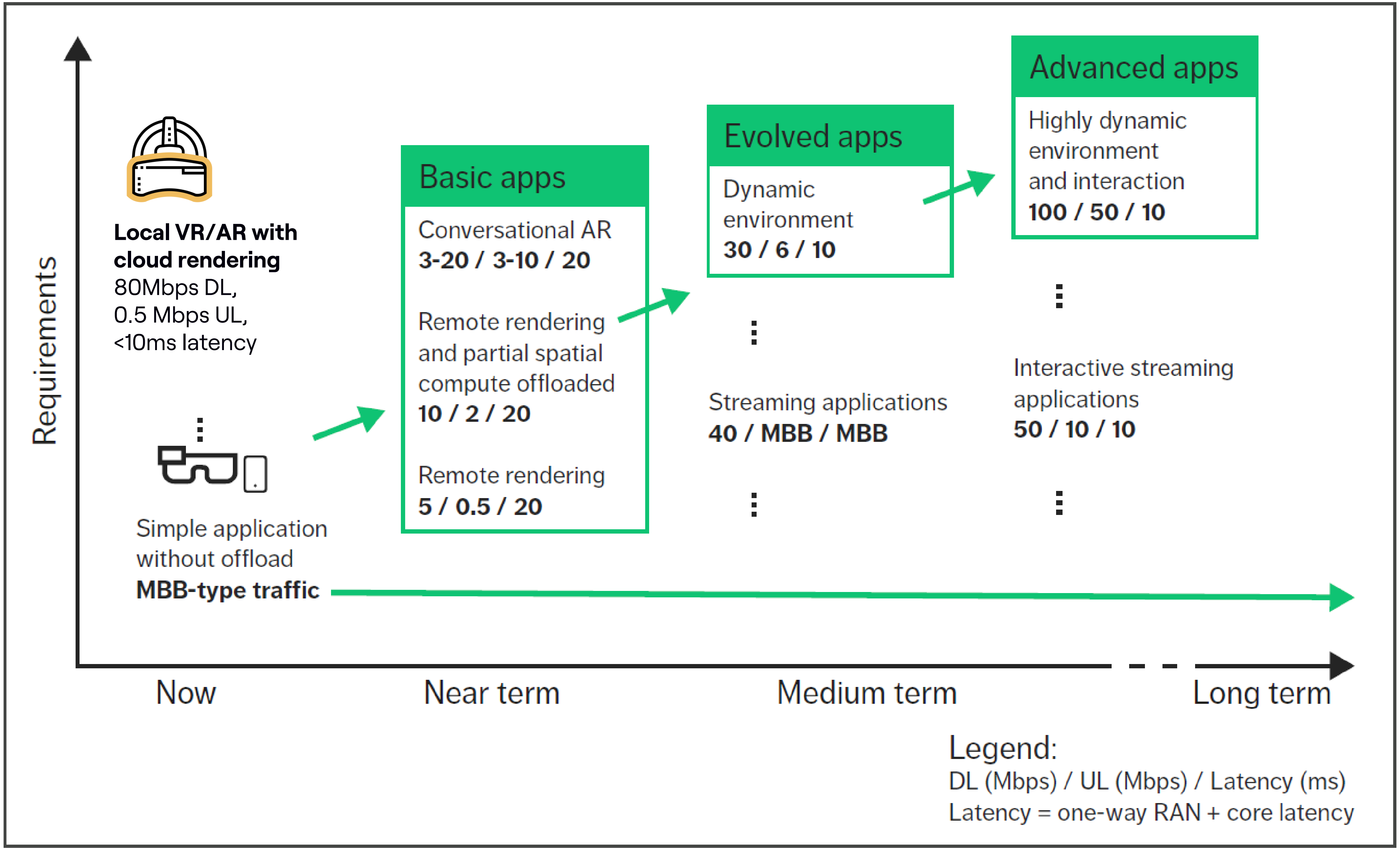
Understanding XR service requirements

XR applications differ, e.g., in terms of:

- AR/MR/VR
- single-user vs multi-user communication scenarios
- complexity and graphics
- need for alignement with the real environment
- multiple data streams (e.g., video, audio, haptics, UE pose/control)
- traffic characteristics (periodicity, packet sizes)

advanced applications with high degree of computation offloading → high impact on network requirements

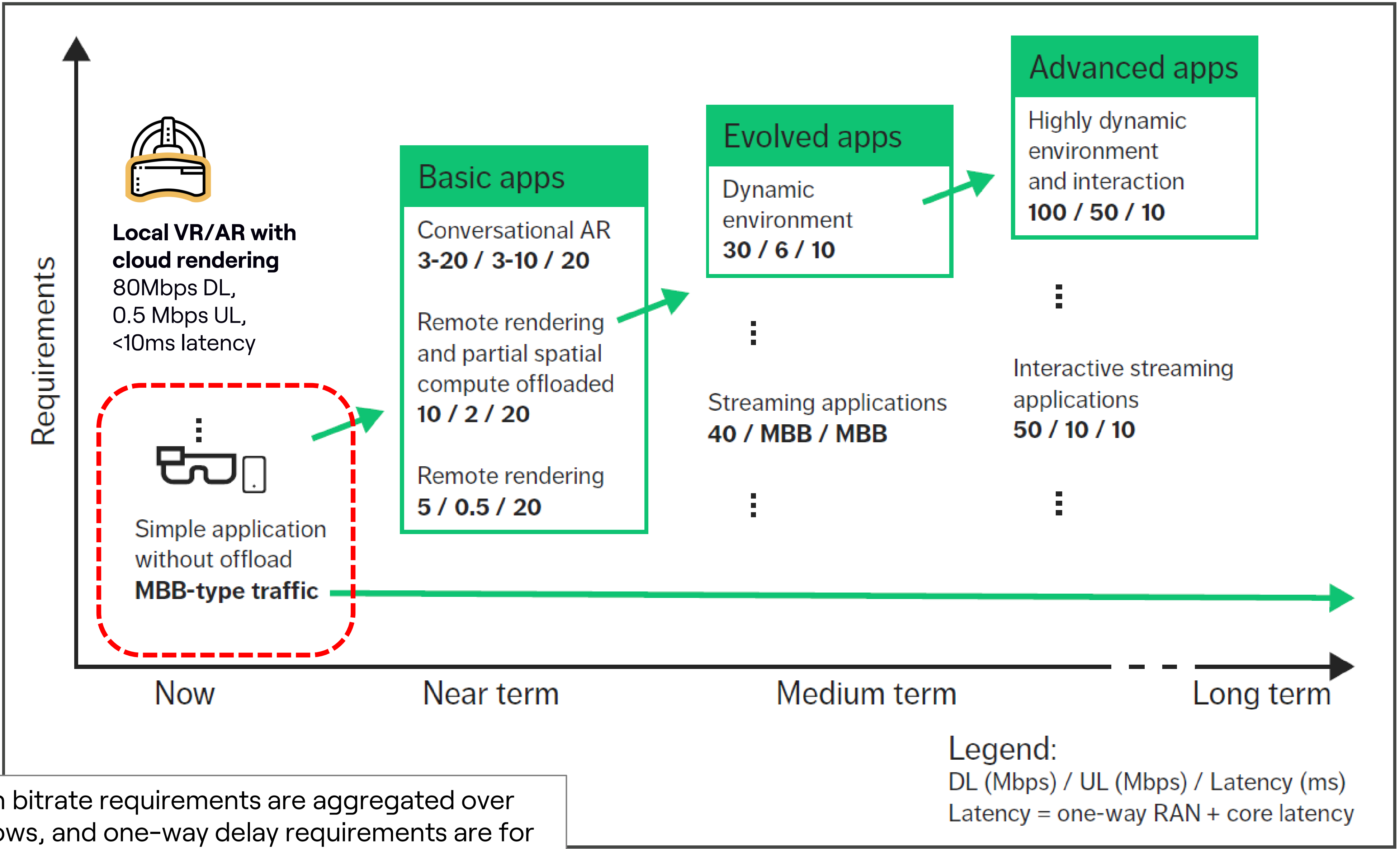
Dimensioning future networks



Indicated examples and numbers are simplified and represent a limited selection of samples in a wide range !

source: Ericsson Technology Review, 04/2023

Dimensioning future networks



all processing locally or on tethered device

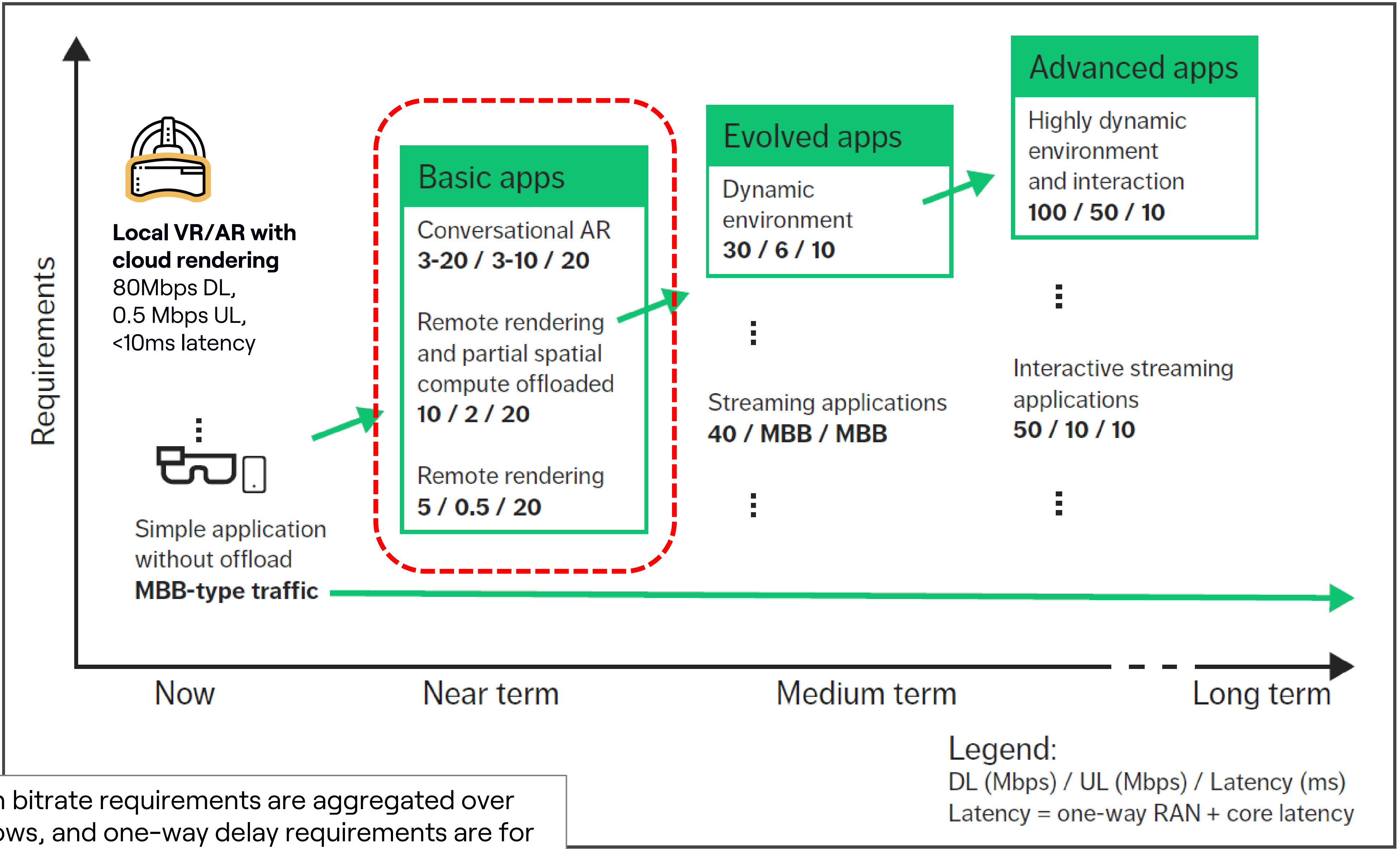
e.g., simple navigation; virtual screens controlled by hand gestures

global representations of virtual world downloaded non-real-time

shown bitrate requirements are aggregated over the flows, and one-way delay requirements are for the most sensitive flow.

source: Ericsson Technology Review, 04/2023

Dimensioning future networks



shown bitrate requirements are aggregated over the flows, and one-way delay requirements are for the most sensitive flow.

remote rendering, (partial) SLAM on HMD

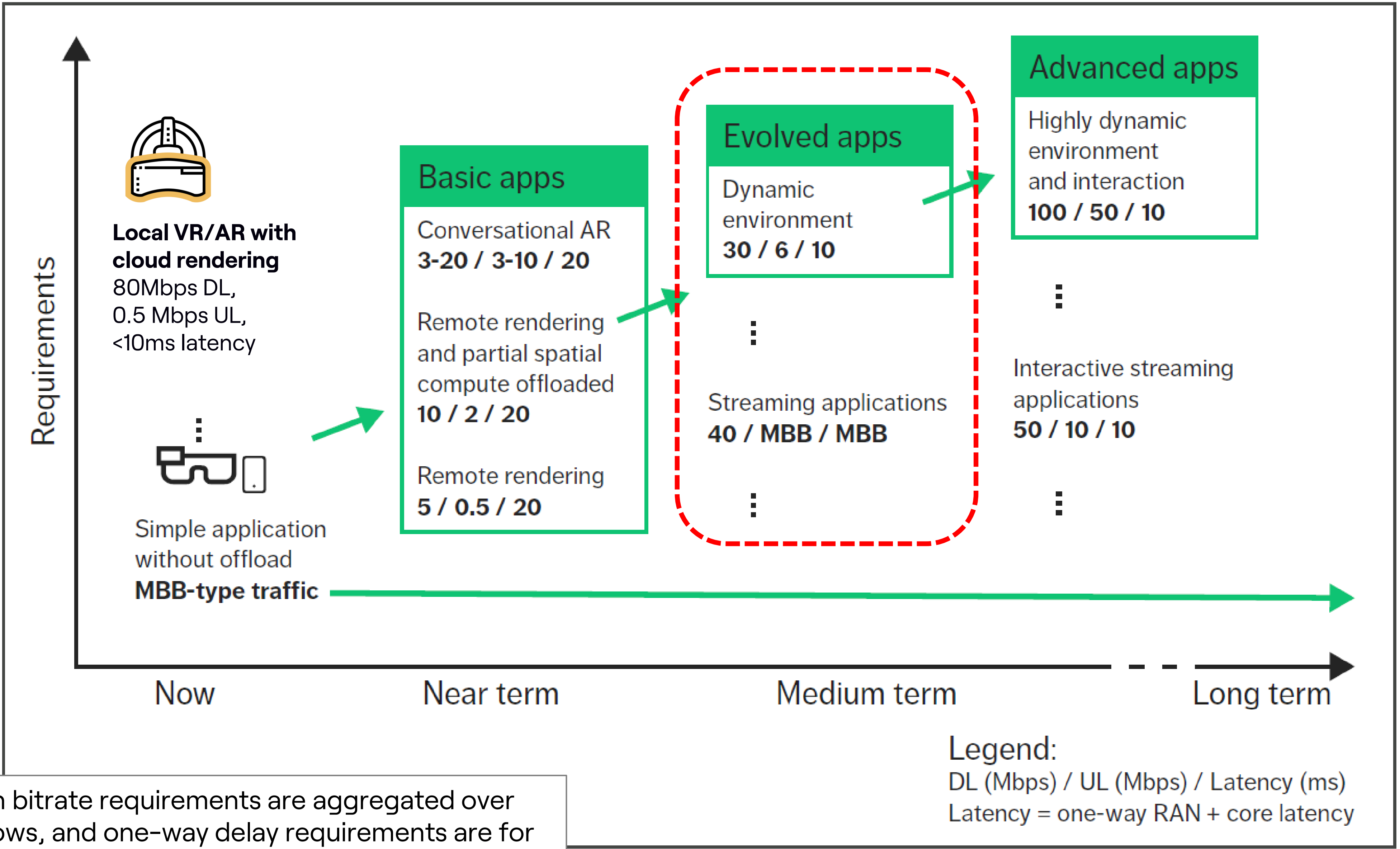
DL remote rendered content: 2D video or simple volumetric content

UL: HMD pose, user input, sensor data

Conversational AR: no offloading

source: Ericsson Technology Review, 04/2023

Dimensioning future networks



AR objects adapt to changes in the physical world in real time

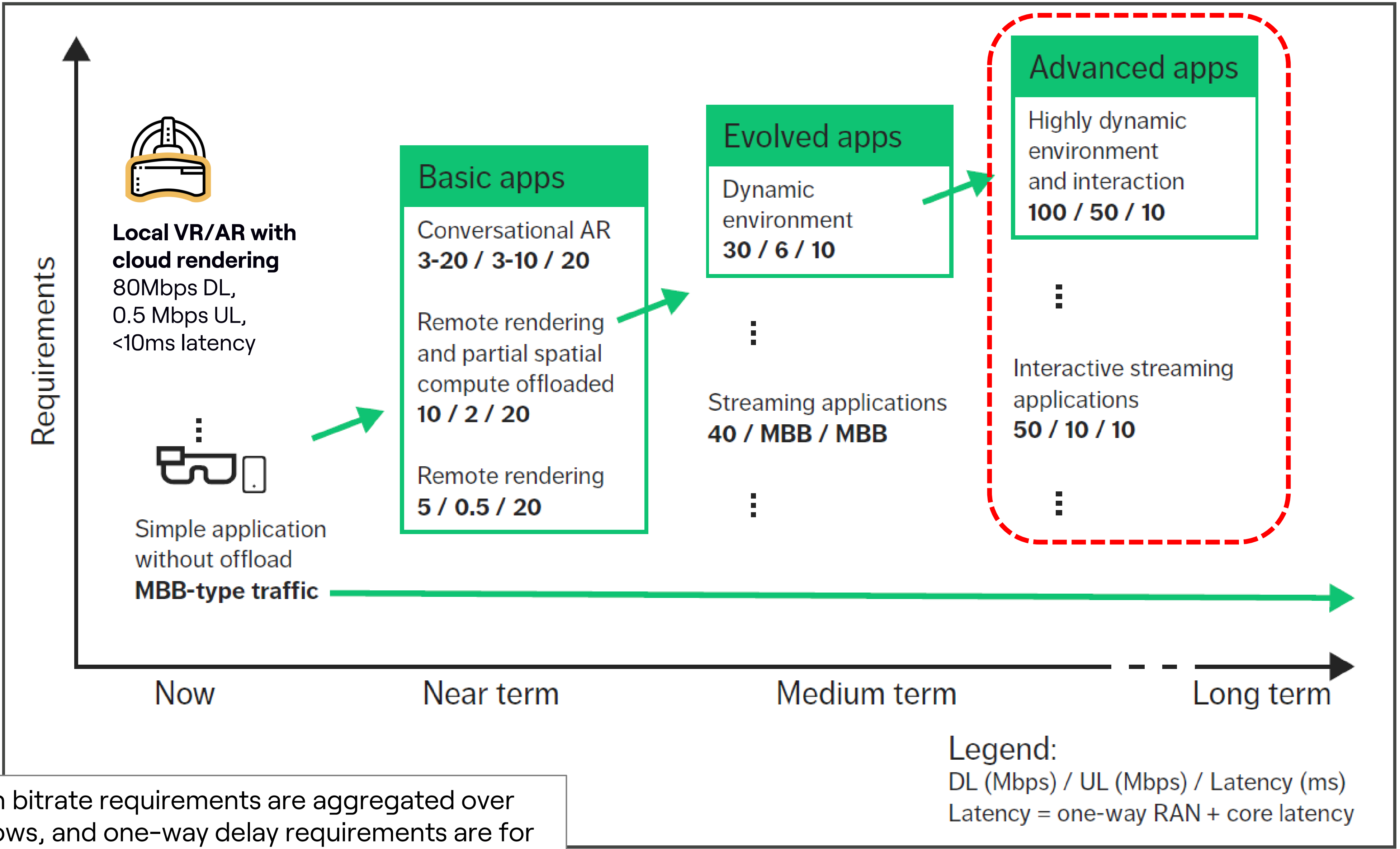
remote rendering and offload of spatial mapping

streaming of volumetric content

shown bitrate requirements are aggregated over the flows, and one-way delay requirements are for the most sensitive flow.

source: Ericsson Technology Review, 04/2023

Dimensioning future networks



user's behavior will affect content streamed from a server

SLAM offloaded

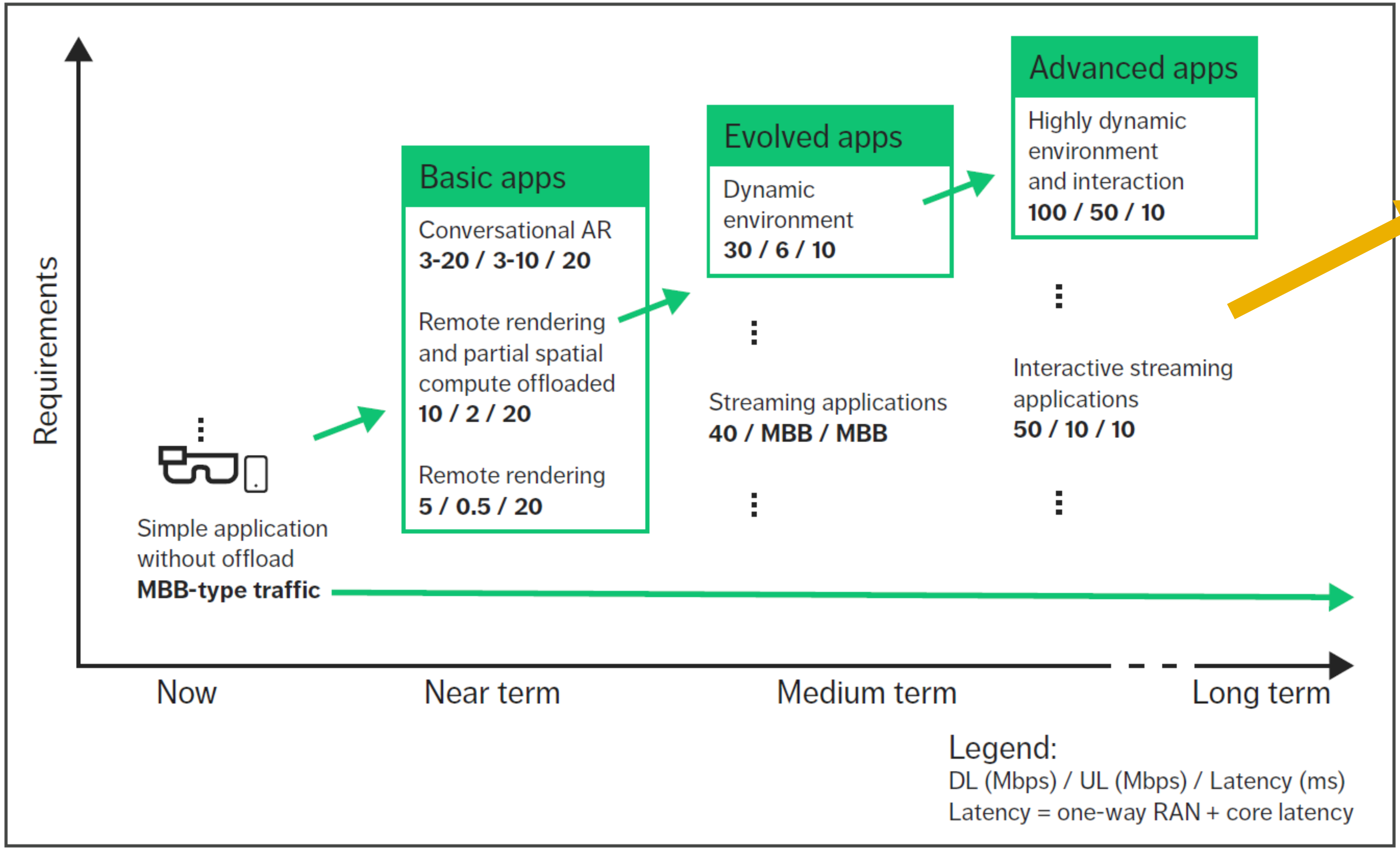
remote rendering of volumetric video

multiple users interacting with AR objects simultaneously

shown bitrate requirements are aggregated over the flows, and one-way delay requirements are for the most sensitive flow.

source: Ericsson Technology Review, 04/2023

Dimensioning future networks

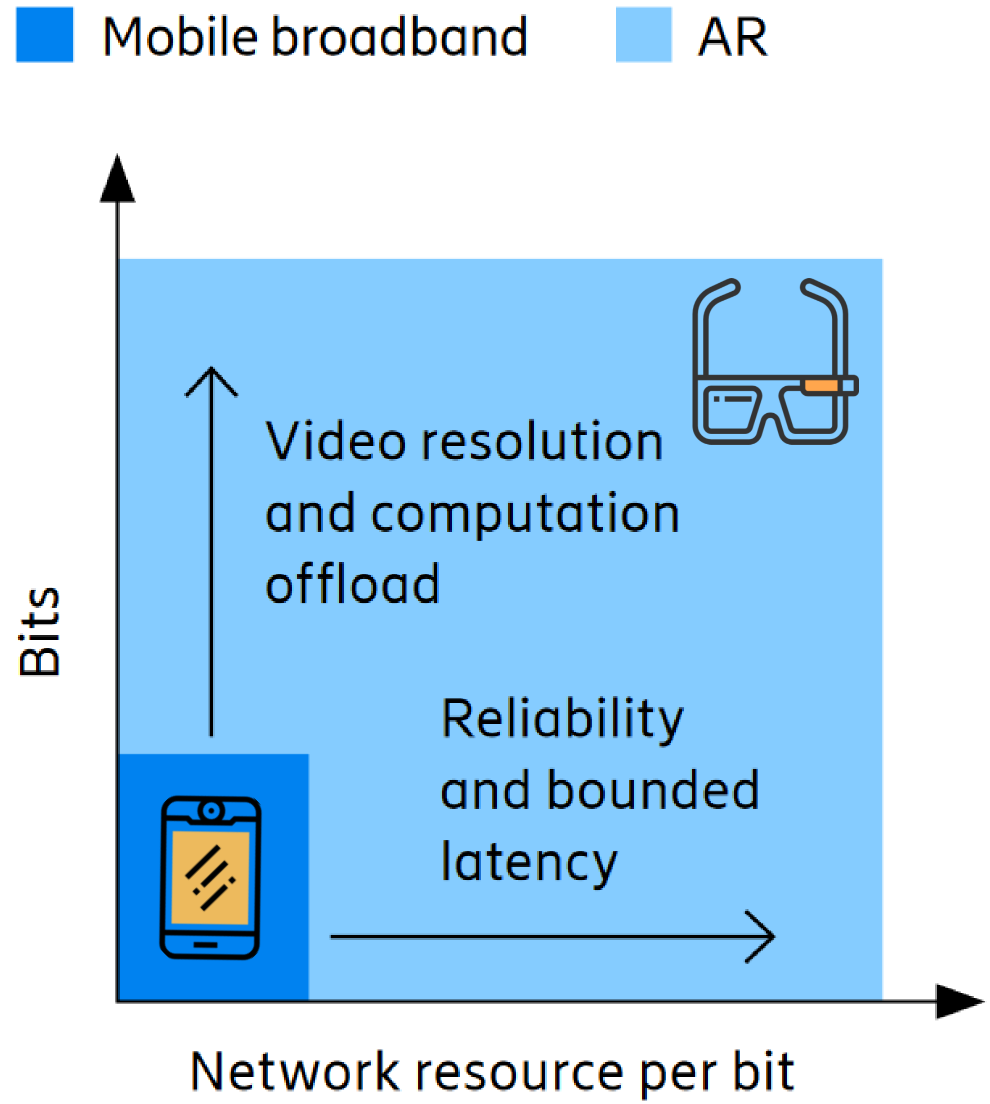


Immersive communication
(multisensory XR,
holographic communication)

<u>Examples:</u>
1–10 Gbps DL
5 Gbps UL
1–5 ms latency

source: Ericsson Technology Review, 04/2023

Simulation for a 2030 uplink scenario



AR with cloud offloading could require ~12x more radio resources than a MBB use during peak hrs

source: Ericsson Mobility Report, June 2023

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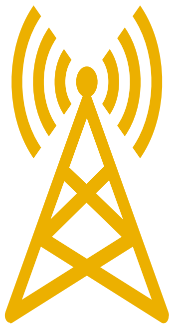
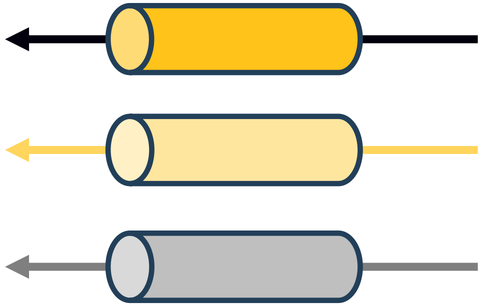


Cloud/Edge computing

compute offloading

QoS management



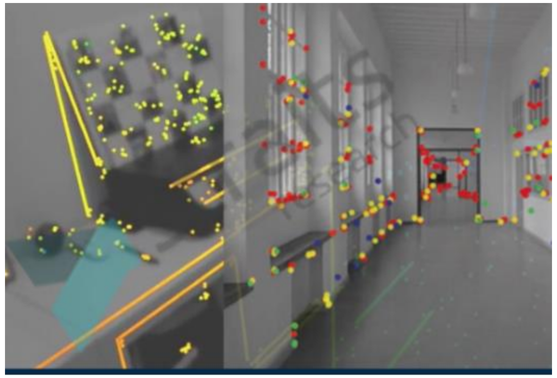
service differentiation, tight delay bounds

Network slicing

traffic separation into multiple logical (virtual) networks

Computationally heavy functions needed to realize XR experiences

SLAM
input: sensor data
output: environment map + localization


img source: NXP Community

Object detection & tracking
input: sensor data
output: object location + semantics (image recognition and tracking)

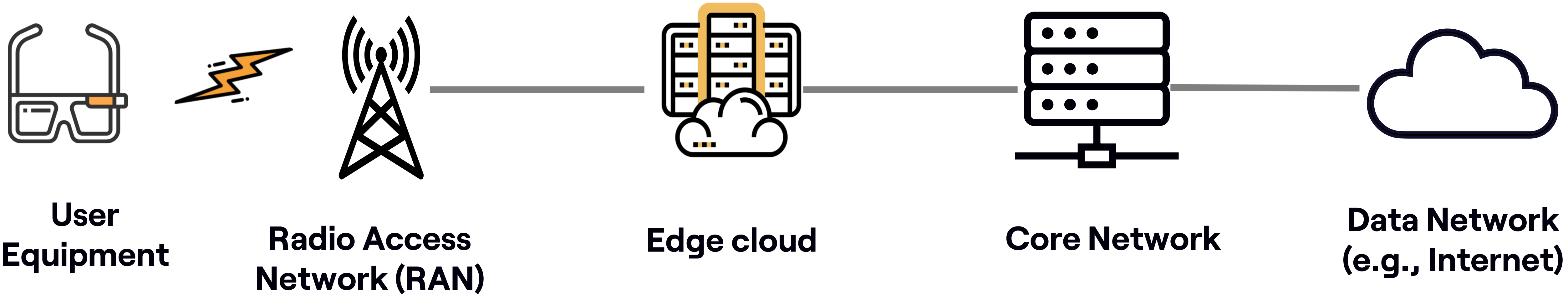

img source: Unity

Rendering
input: models
output: graphics (video)


img source: Twinmotion

Edge computing

- Moves the computing of traffic and services from a centralized cloud to the edge of the network and closer to the customer
- Necessary to keep latency at target low values. Otherwise, no chance.



Remote rendering

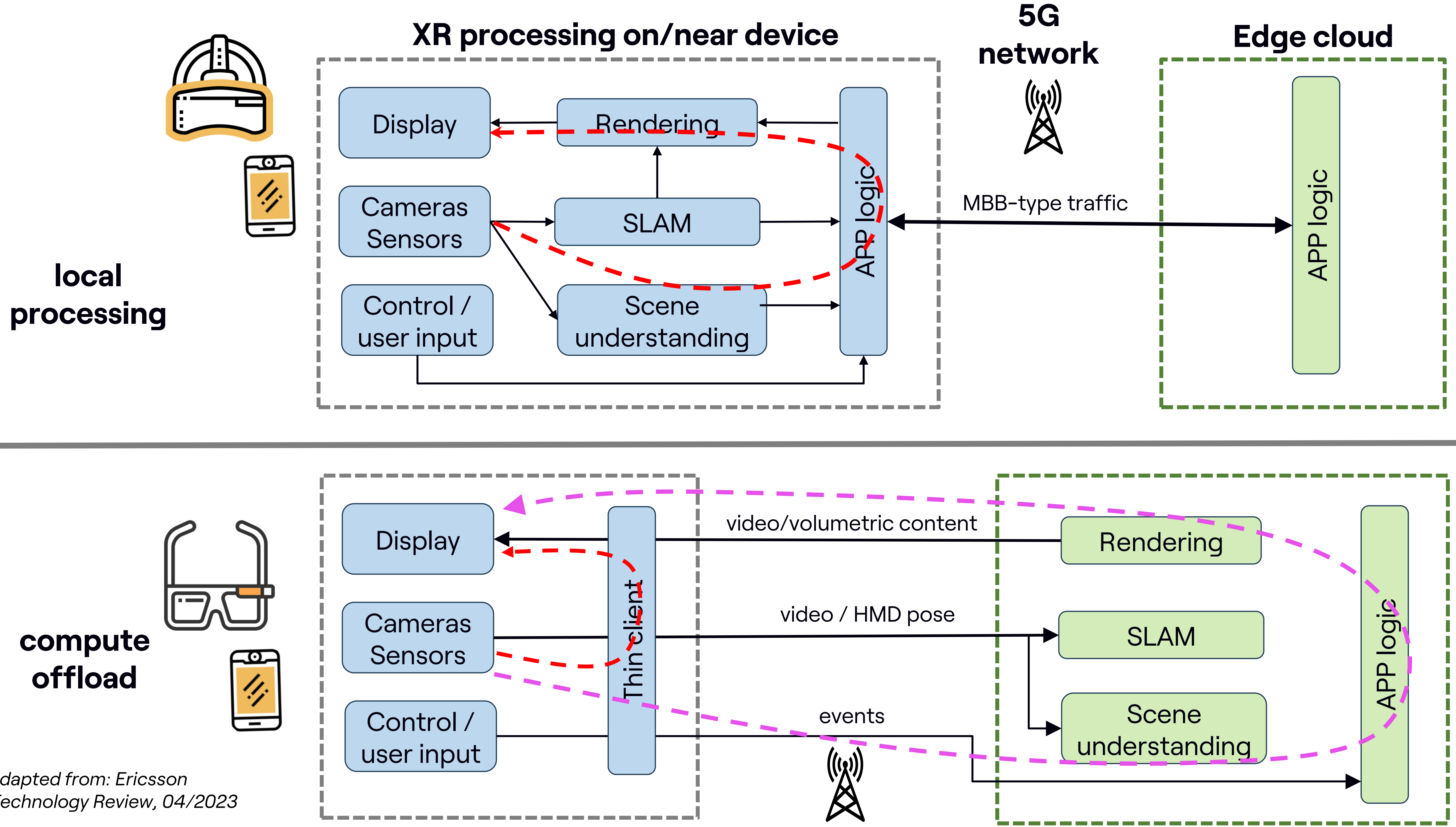
- Application graphics rendered at a remote (edge) server and sent to the HMD through a 5G (or other) network.
- Requires high downlink bitrate + low latency
- Typically, two or more 2D video streams are sent in the DL
  - Case of foveated rendering: four 2D streams of different resolutions
- Remote rendering of volumetric content while final 2D rendering is performed on the HMD based on real-time pose data

Spatial computation offloading

- HMD uploads compressed sensor data (video, lidar, etc.) or detected objects to a server that builds a map of the environment and positions the HMD within it.
- Various offloading options → complete offload results in stringent latency requirements

Offloading will likely be progressive as networks evolve and become more capable of meeting heterogenous and emerging XR service requirements

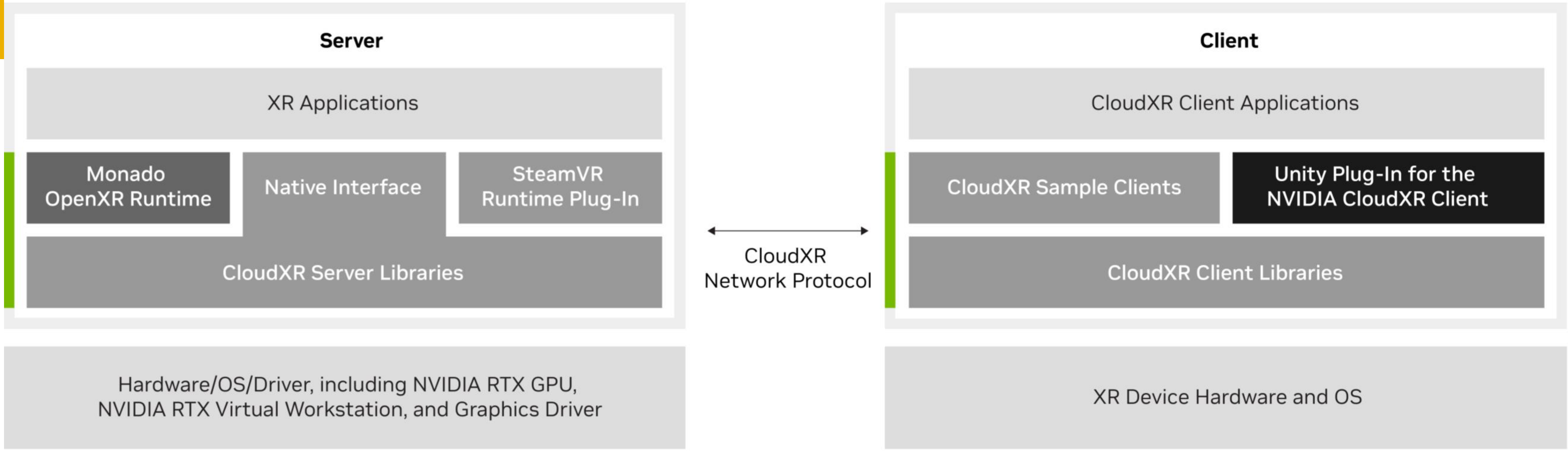
source: Ericsson Technology Review, 04/2023



adapted from: Ericsson Technology Review, 04/2023

Example: Nvidia Cloud XR

- streaming of VR/AR content via WiFi or 5G directly to the VR/AR device.
- high fidelity visuals without the need for restrictive wires or a high-end gaming PC
- dynamical adaptation to network conditions

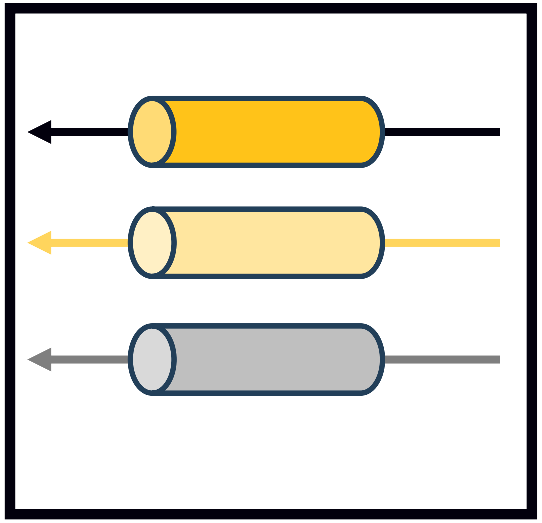


https://developer.nvidia.com/cloudxr-sdk#manufacturing

Cloud/Edge computing

compute offloading

QoS management



service differentiation, tight delay bounds

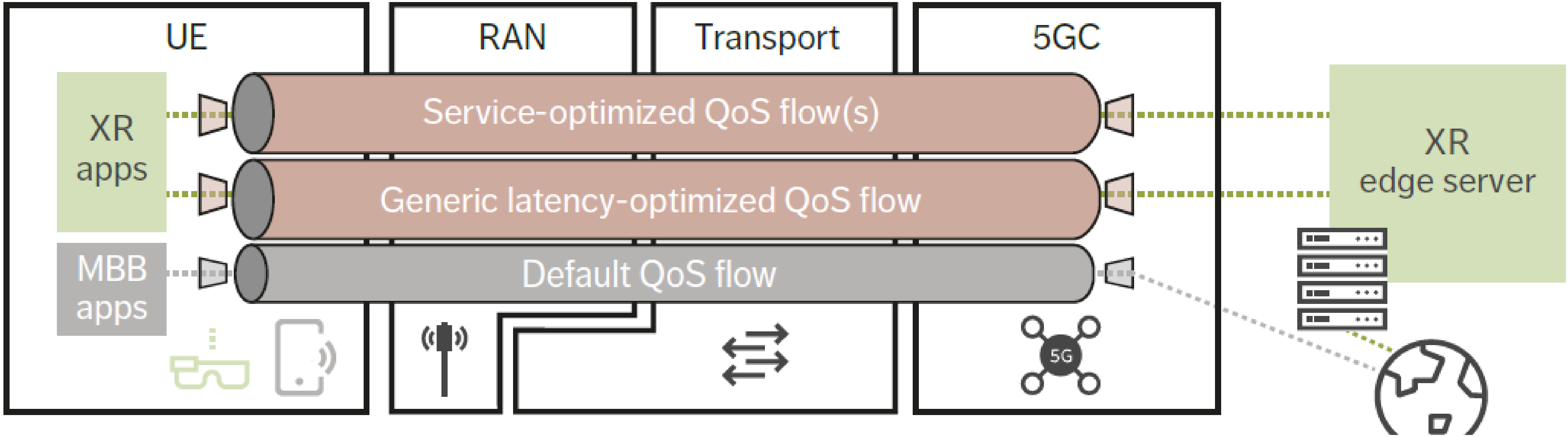
Network slicing

traffic separation into multiple logical (virtual) networks

Why do we need QoS management?

- Different services require differentiated QoS treatments.
- Operators want the ability to provide a differentiated packet forwarding treatment of data which may belong to different users, different applications or even different services or media within the same applications.
    - For example: provide low latency for a voice flow; allocate high bandwidth to a video streaming flow; provide high reliability for sensor data

Service differentiation



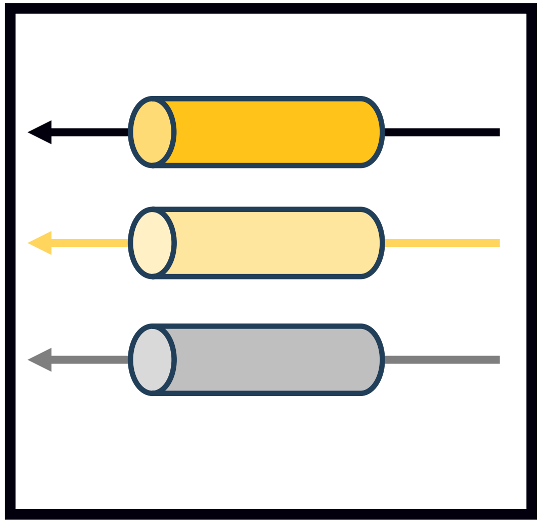
Separate best-effort MBB from XR traffic to allow for special measures needed for XR

source: Ericsson Tech Review 8/2021

Cloud/Edge computing

compute offloading

QoS management



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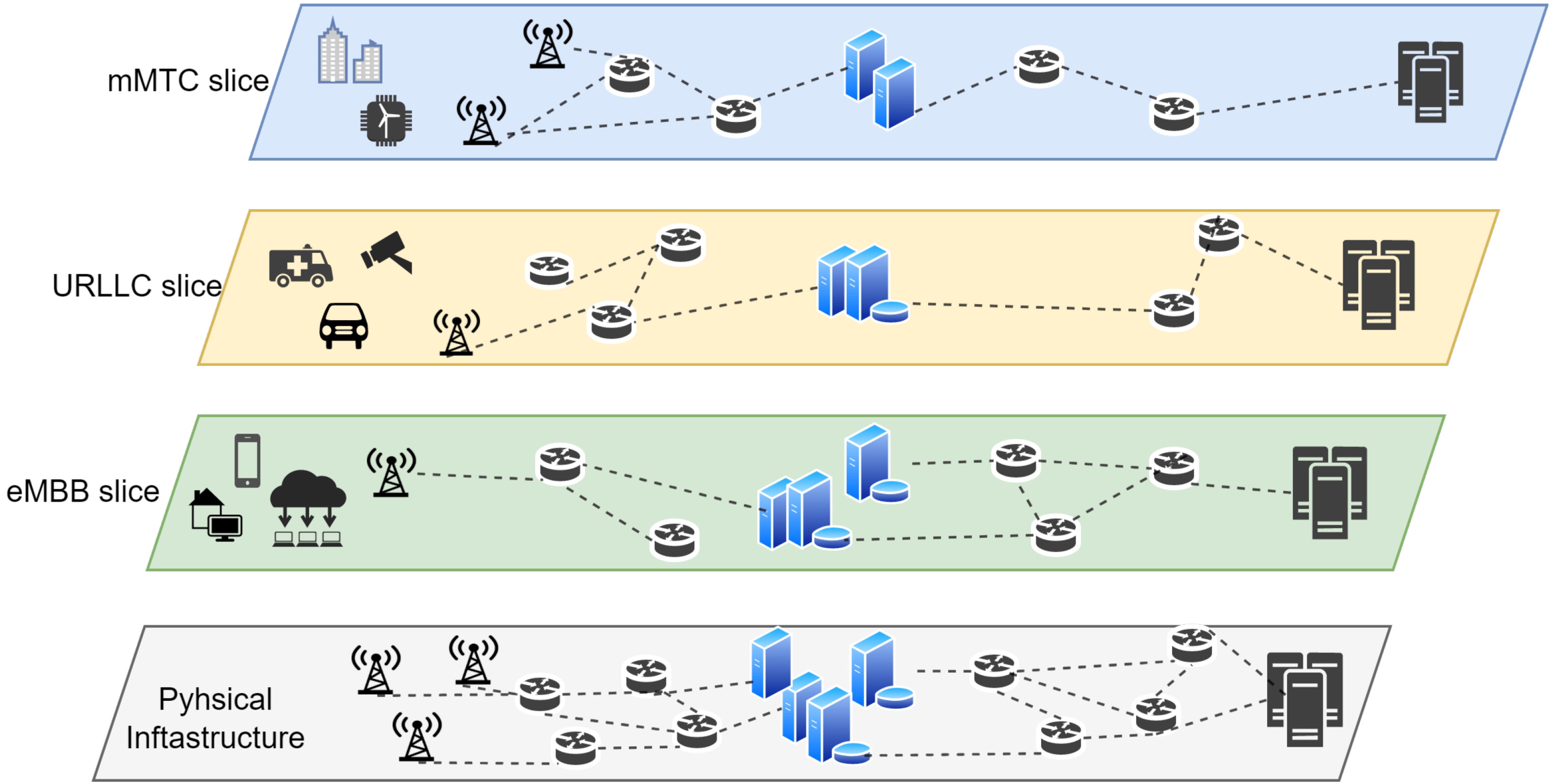
traffic separation into multiple logical (virtual) networks

Network slicing

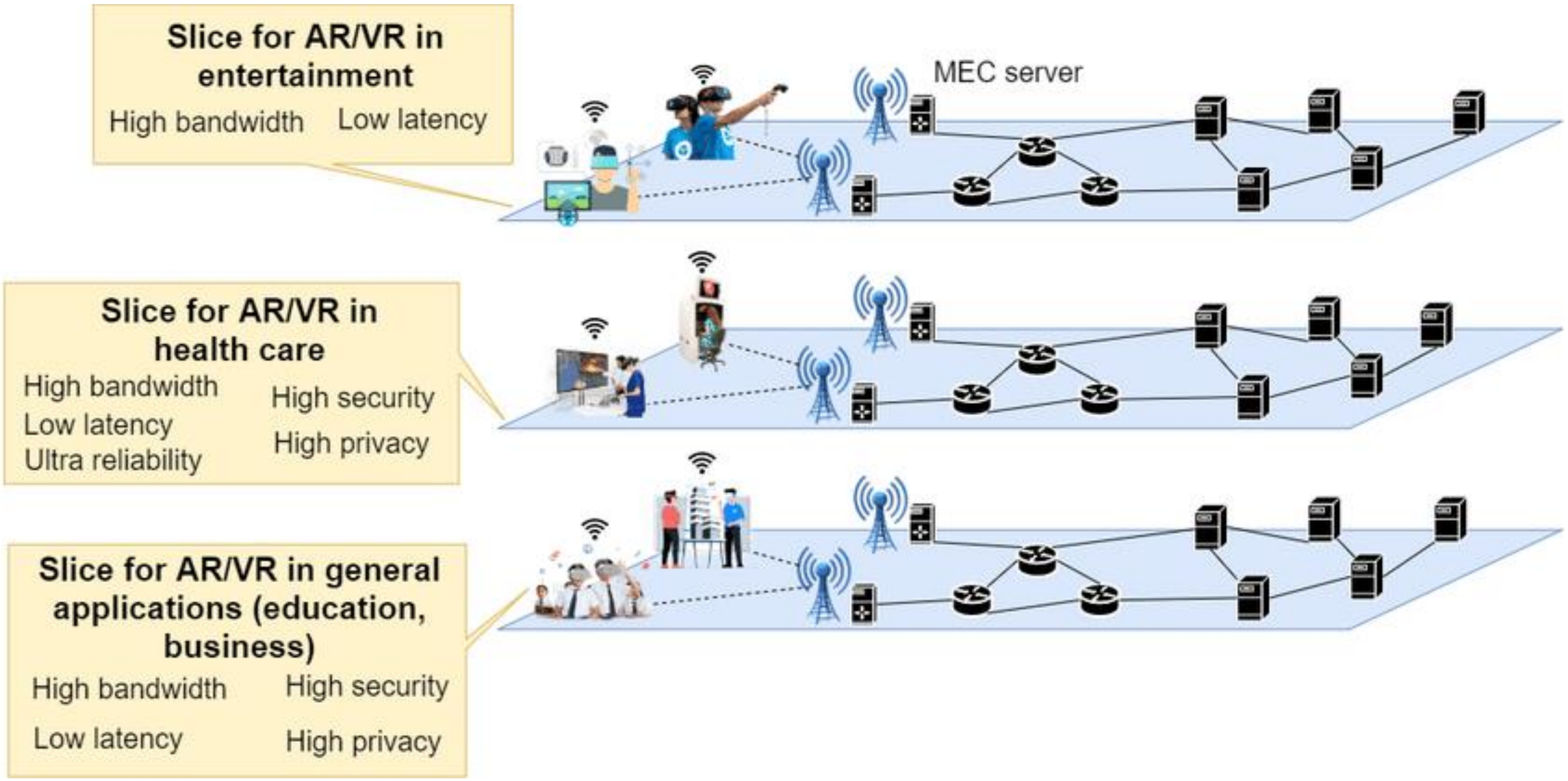
- **Virtualization** enables building logical networks on top of a common and shared network infrastructure

Goal: separate traffic into multiple logical (virtual) networks that all execute on and share a common physical infrastructure

Network slicing: partitioning of a physical network into multiple independent logical networks → each slice designed to meet specific requirements.



source: Domeke A, Cimoli B, Monroy IT. Integration of Network Slicing and Machine Learning into Edge Networks for Low-Latency Services in 5G and beyond Systems. Applied Sciences. 2022 Jun 29;12(13):6617.



source: Wijethilaka S, Liyanage M. Survey on network slicing for Internet of Things realization in 5G networks. IEEE Communications Surveys & Tutorials. 2021

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XR in 5G and beyond

3GPP
A GLOBAL INITIATIVE

ITU

VQEG

KHRONOS
GROUP

OpenXR

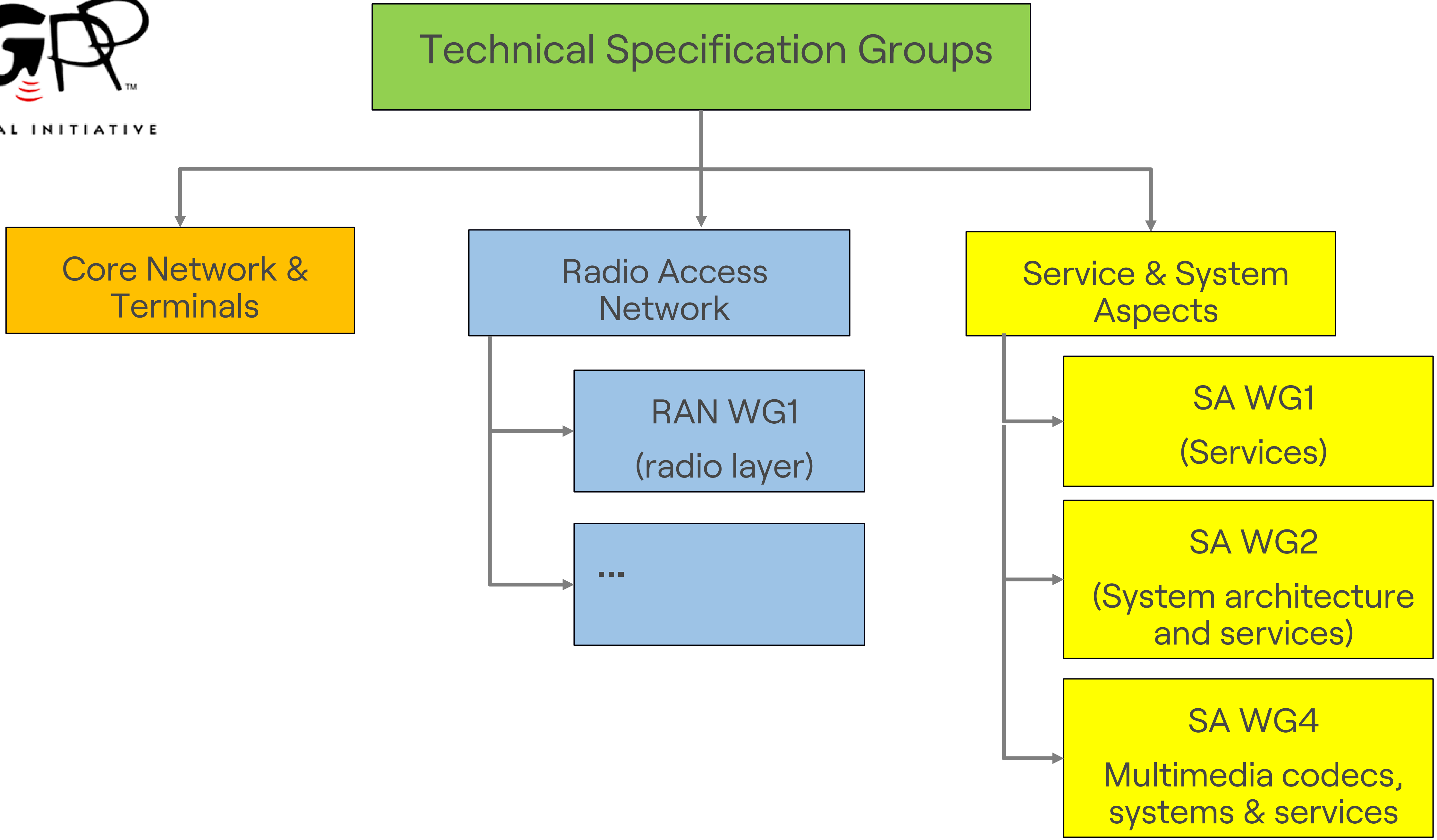
GSMA

Metaverse
STANDARDS FORUM

IETF

IEEE
Advancing Technology for Humanity

MPEG


Technical Specification Groups
Core Network & Terminals
Radio Access Network
Service & System Aspects
RAN WG1
(radio layer)
...
SA WG1
(Services)
SA WG2
(System architecture and services)
SA WG4
Multimedia codecs, systems & services

RAN WG1 (radio layer)	3GPP TR 38.838: "Study on XR (Extended Reality) evaluations for NR", 2022
SA WG1 (Services)	3GPP TS 22.261: "Service requirements for 5G services", 2021.
SA WG2 (System architecture and services)	3GPP TR 23.700-70 "Study on architecture enhancement for Extended Reality and Media service (XRM); Phase 2", 2024
SA WG4 Multimedia codecs, systems & services	3GPP TR 26.998: "LTE; 5G; Support of 5G Glass-type Augmented Reality / Mixed Reality (AR/MR) devices", 2022.
	3GPP TR 26.928: "Extended Reality (XR) in 5G", 2022.
	3GPP TR 26.926: "Traffic Models and Quality Evaluation Methods for Media and XR Services in 5G Systems", 2023.

Core use cases

- Offline sharing of 3D objects
- Real-time XR sharing
- XR multimedia streaming
- XR conference
- XR mission critical
- Online XR gaming
- Spatial audio multiparty call

Example specific use cases

- 360-degree conference meeting
- 3D shared experience
- 6DOF VR conferencing
- XR meeting
- Convention / poster session

Example: AR conferencing (1:1)

3GPP TR 26.998: “LTE; 5G; Support of 5G Glass-type Augmented Reality / Mixed Reality (AR/MR) devices”, 2022.

Preconditions

Cameras capture each participant (including depth)

AR glasses: allow 3D volumetric representation of other participants

QoS/QoE req.

Support different volumetric user representation formats

bitrates and latencies sufficient to stream volumetric data in real-time

Exampe values and transmission formats

2D+/RGB Depth Camera: >2.7 Mbps (single camera), >5.4 Mbps (double cameras) (1080p@30 FPS)

3D Mesh: ~ 30Mbps @ 20-25 FPS

3D Geometry based Point Cloud Compression (GPCC): 5-50Mbps; MPEG V-PCC 8 Mbps

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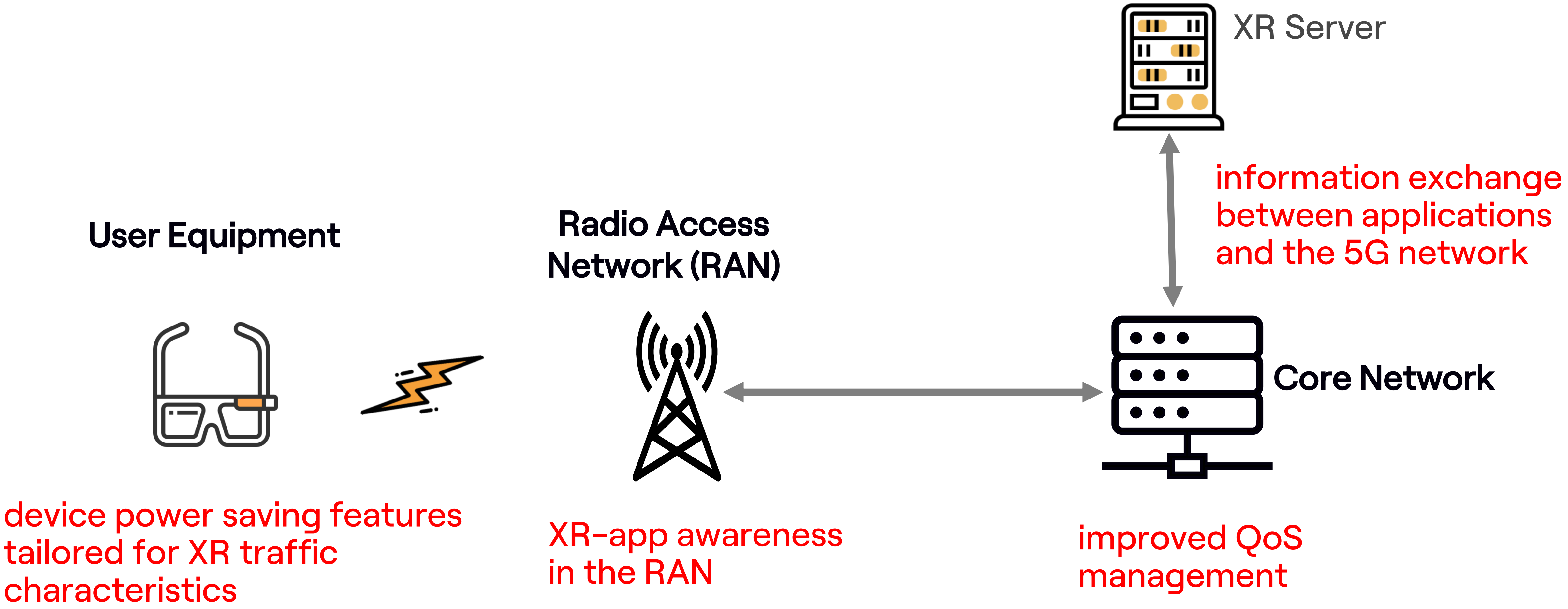
5G-Advanced technology improvements / challenges



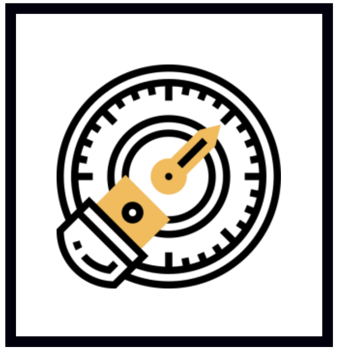
balancing QoE and power savings

Towards 6G

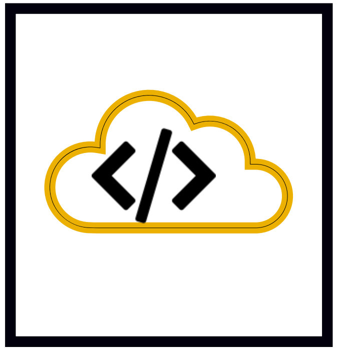
6G expected to be "the first generation of data-driven mobile networks."

[3GPP Tech. Trends, 2024]

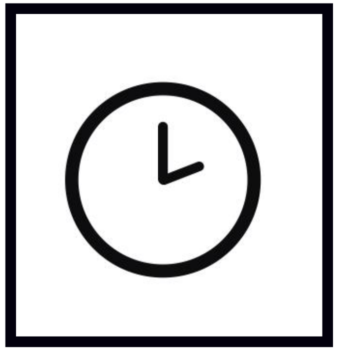
faster data rates (potentially Tbps)



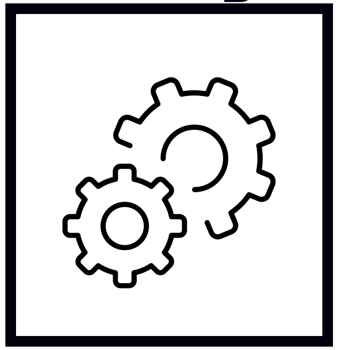
progammable networks



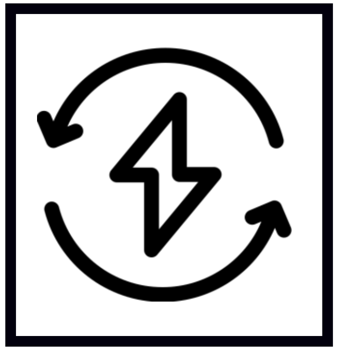
sub-millisecond latency



AI-driven orchestration and management



sustainable



Take-aways

- 5G-based mobile XR: a promising use case for future mobile networks
- Simple XR use cases work across today's mobile broadband networks, but as devices and services evolve, high performance wireless networks will be required (e.g., due to cloud/edge compute offload; conversational use cases…)
- Standardization work on improved network support for XR in 5G and beyond networks is still in its early stages
- Collaboration needed: telecom venders and network operators; device, content, and platform providers; standardization organizations (in addition to developing the tech, consideration of societal impact necessary!)

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Thank you!

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