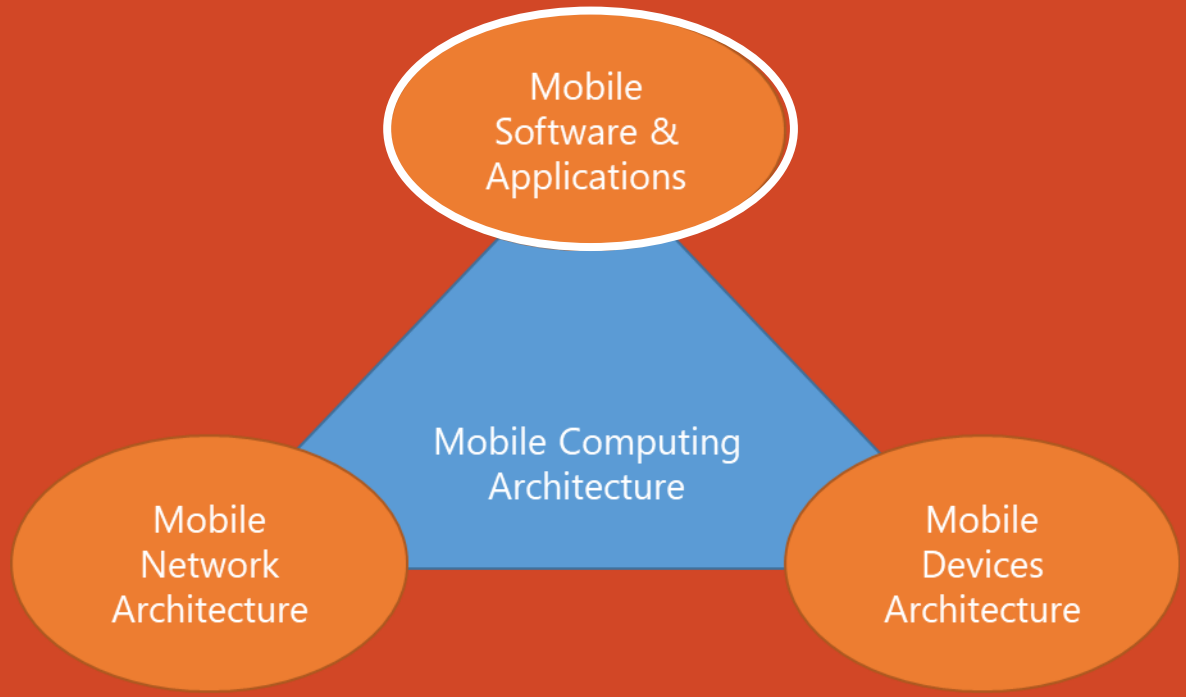
Mobile Computing Architecture

UW Bothell, WA

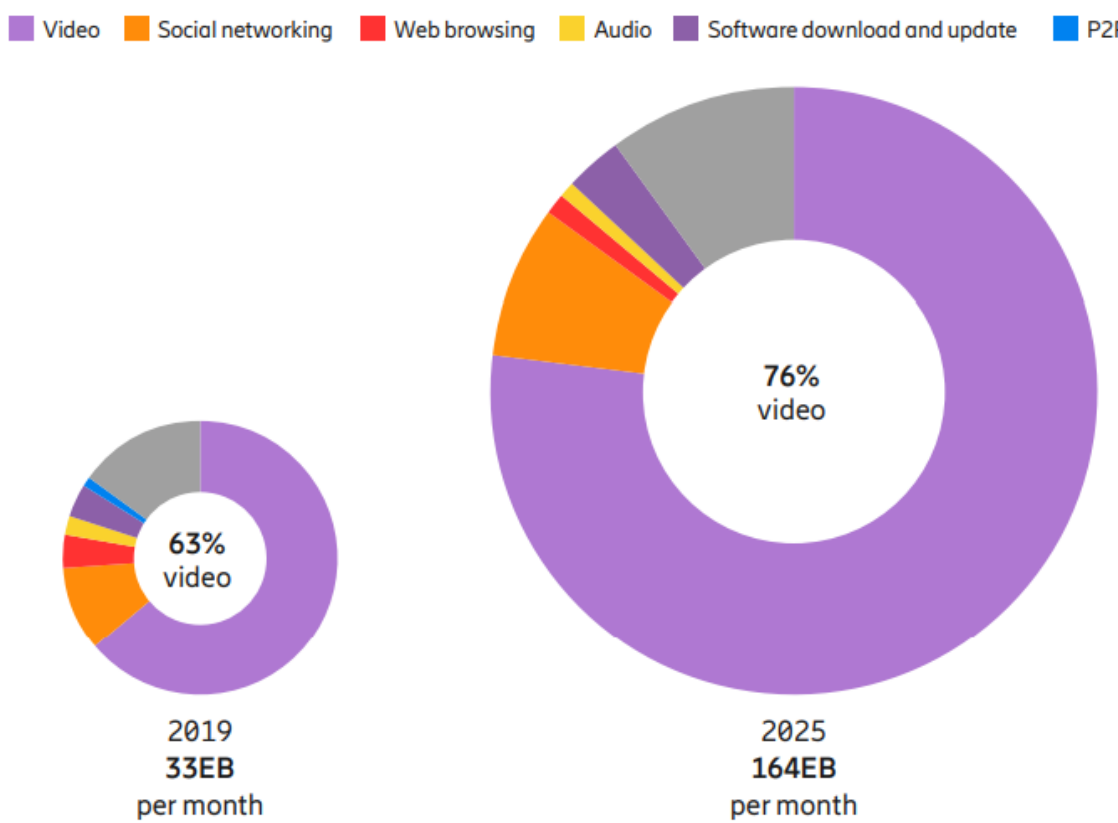
Augmented Reality (AR) over 5G



Sireen Malik. Mobile Computing Architecture, 2020

Mobile Traffic – June 2020 Ericsson Mobility Report

Video traffic in mobile networks is forecast to grow by around 30 percent annually up to 2025. It will account for nearly three-quarters of mobile data traffic, which is up from just over 60 percent in 2019. Mobile video traffic growth is driven by the increase of embedded video in many online applications, growth of video-on-demand (VoD) streaming services in terms of both subscribers and viewing time per subscriber, and the evolution towards higher screen resolutions on smart devices. All of these factors are influenced by the increasing penetration of video-capable smart devices. Social network traffic is also expected to rise by around 20 percent annually over the next 6 years. However, its relative share of traffic will decline from 10 percent in 2019 to around 8 percent in 2025, because of the stronger growth of video.[1]



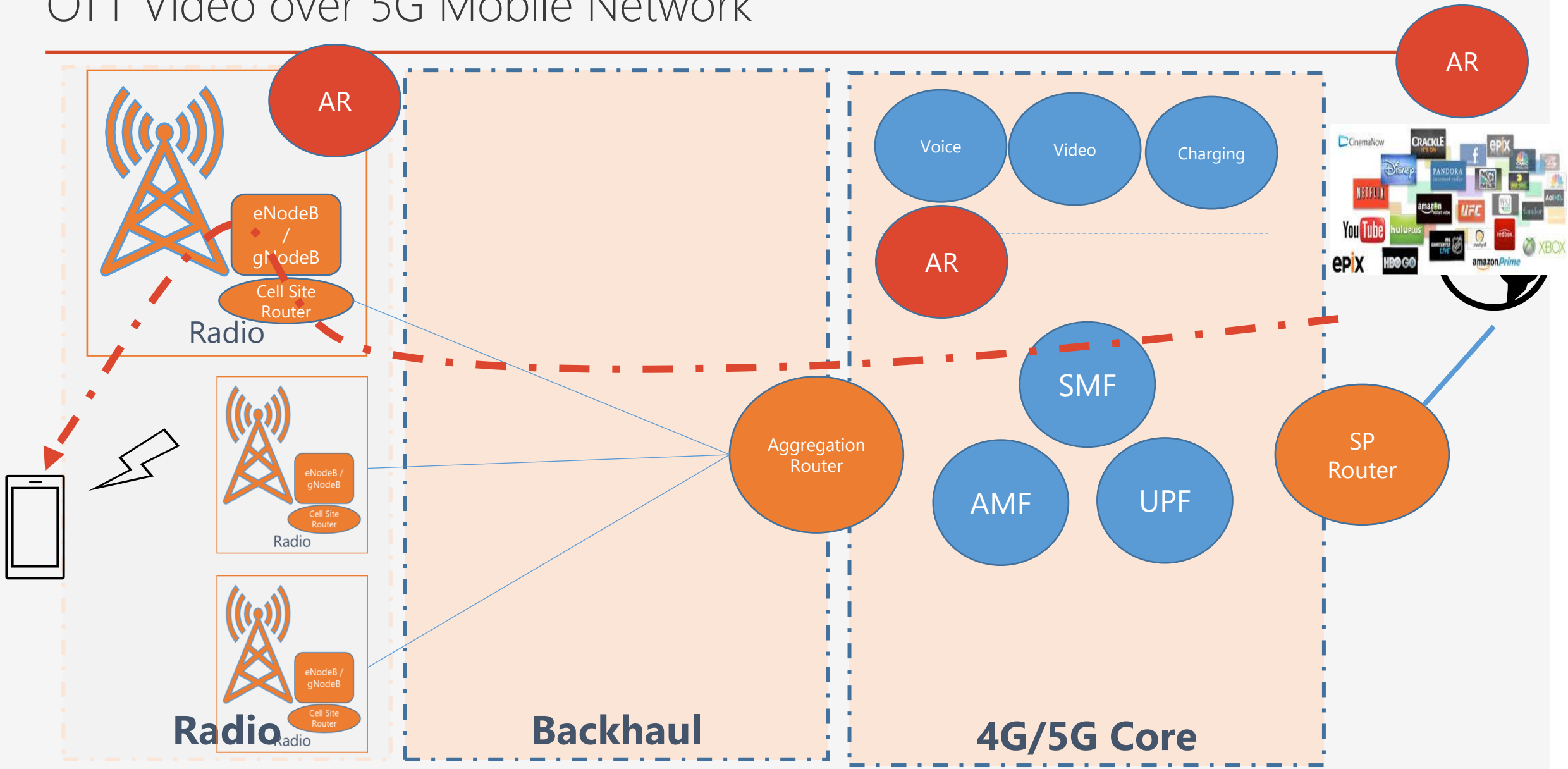
Main drivers for video traffic growth

- Video is part of most online content (news, ads, social media, etc.)
- Video sharing services
- Video streaming services
- Changing user behavior – video being consumed anywhere, any time
- Increased segment penetration, not just early adopters
- Evolving devices with larger screens and higher resolutions
- Increased network performance through evolved 4G deployments
- Emerging immersive media formats and applications (HD/UHD, 360-degree video, AR, VR)

[1] Traffic from embed… …plication category "Video"

AR Is Non-Existent

OTT Video over 5G Mobile Network

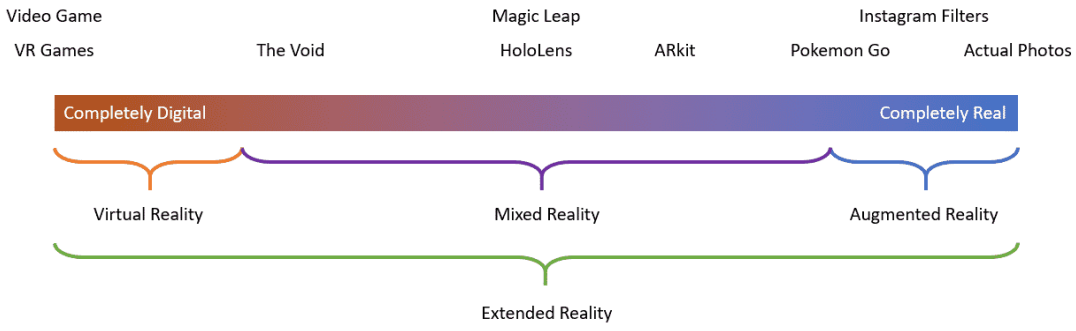


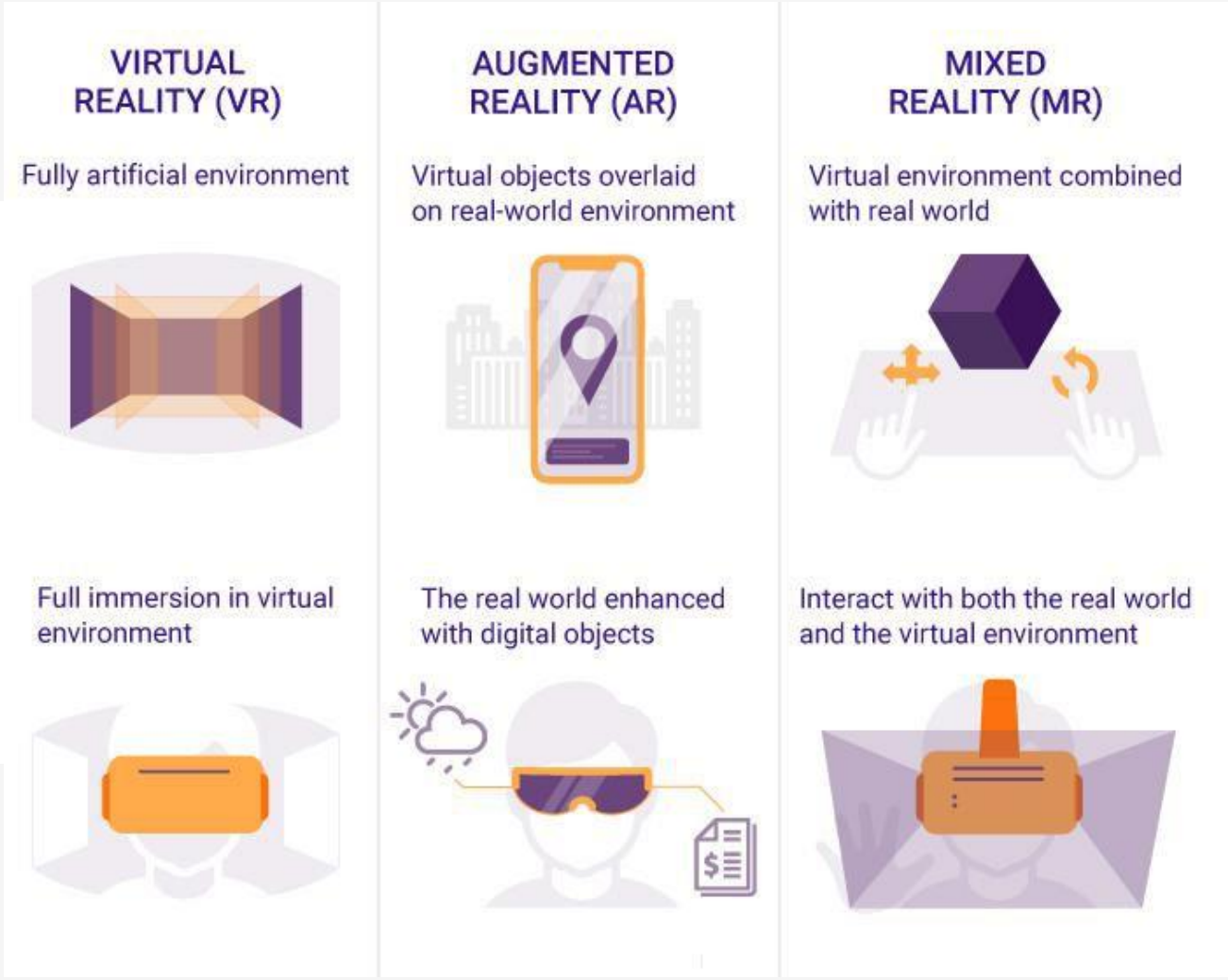
Applications

- **Augmented Reality**
  - **Ultra-Low Latency**
  - **High Thruput**
- **Throughput is easy**
- **Ultra-Low Latency is hard (and expensive!)**

AR, VR and Mixed Reality

Reality – Virtuality Spectrum





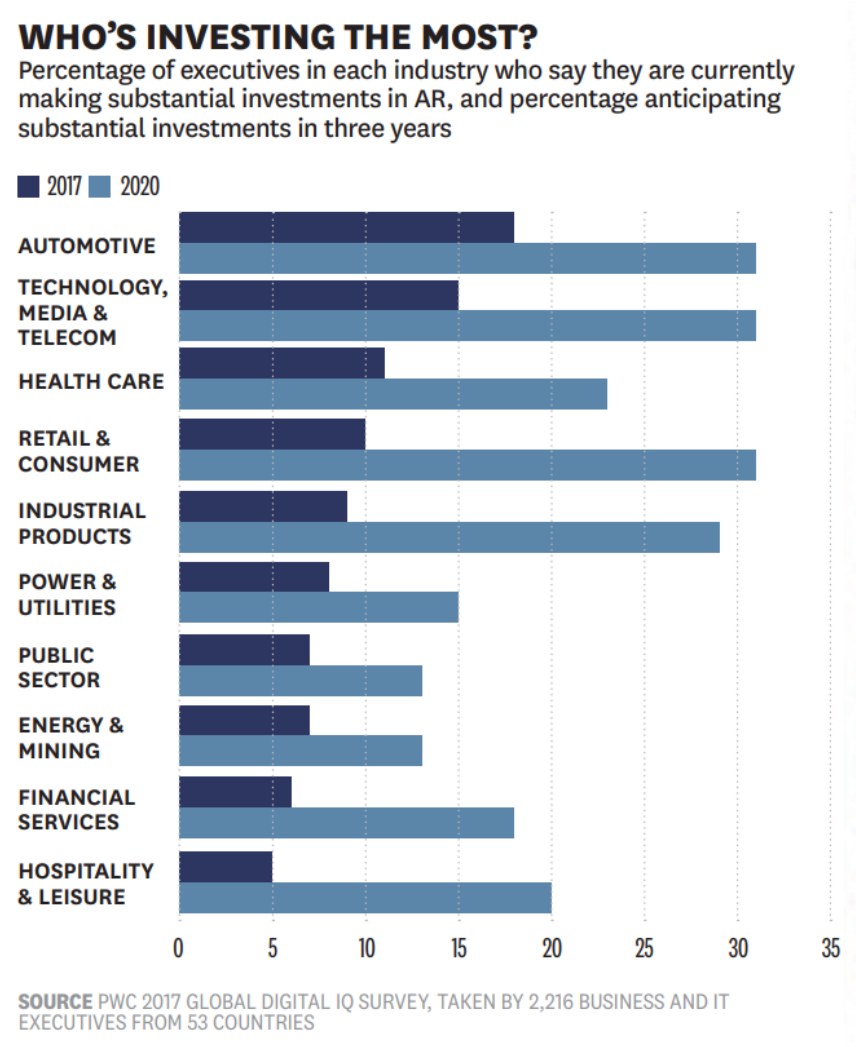
https://www.forbes.com/sites/quora/2018/02/02/the-difference-between-virtual-reality-augmented-reality-and-mixed-reality/#279c04c32d07

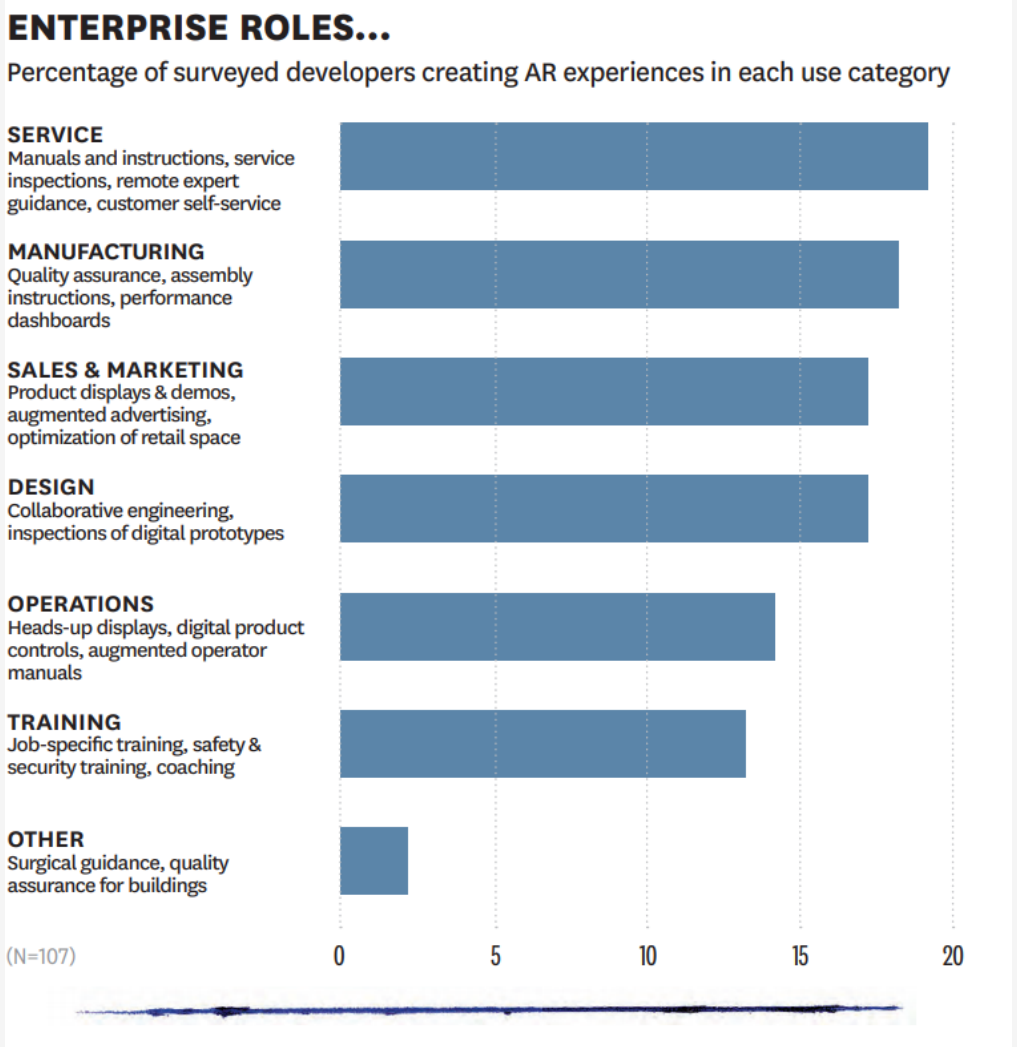
AR Market Forecasts

Augmented reality, a set of technologies that superimposes digital data and images on the physical world, promises to close this gap and release untapped and uniquely human capabilities.

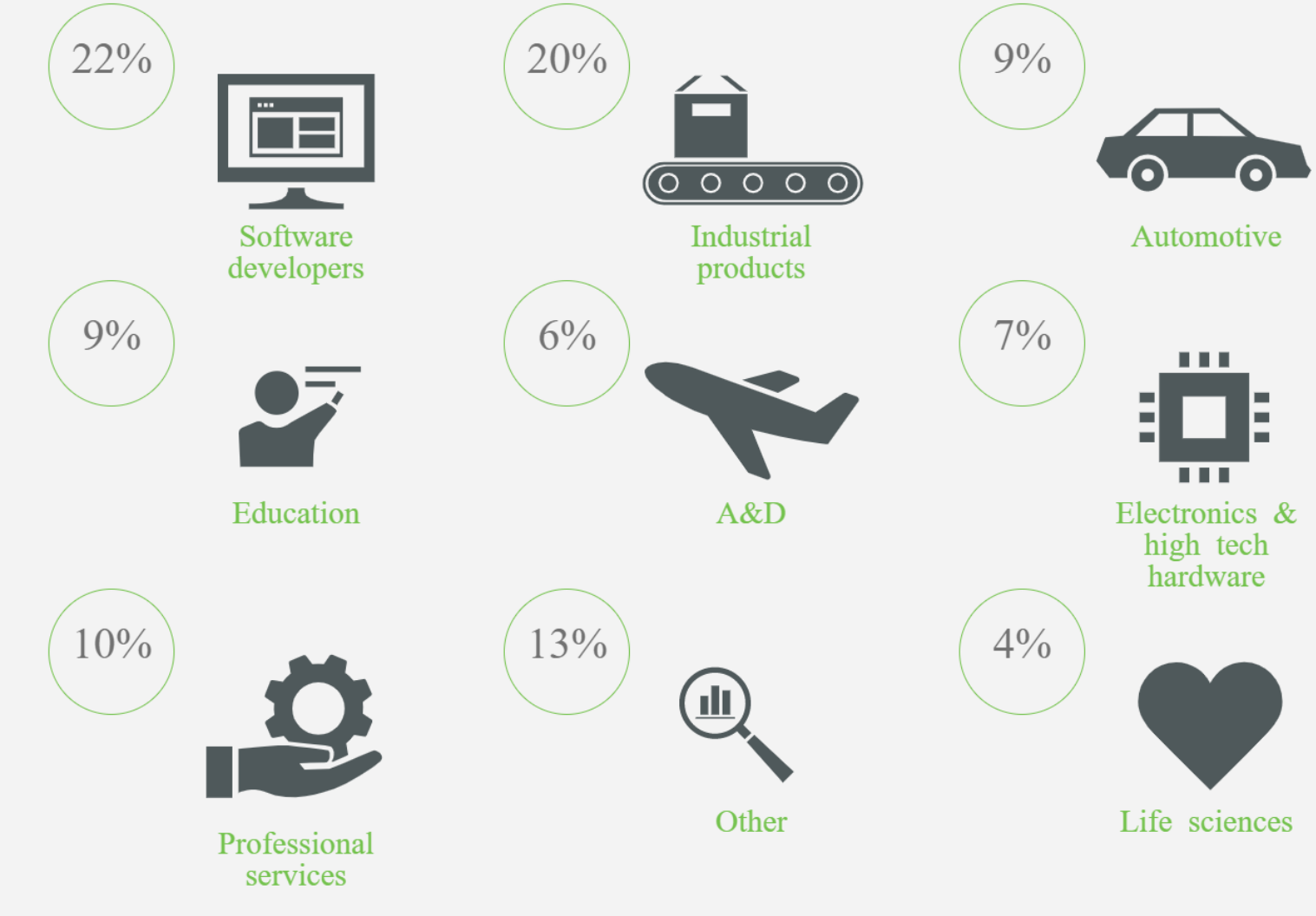
- Though still in its infancy, AR is poised to enter the mainstream; according to one estimate, spending on AR technology will hit $60 billion in 2020 [HBR]
- ABI Research has a more aggressive forecast: by 2021 the total AR market will be $96 billion (ABI Research, 2017) and total VR market of $64 billion (ABI Research, 2017).
- The Cloud giants are investing in AR/VR applications. Apple, Facebook, Google, Microsoft, Intel, etc. are have invested more billions of dollars into AR/VR in the last decade
- Facebook’s Oculus and Microsoft's Mojang accounted for more than $4.5 billion.
- Magic Leap - a mixed reality startup - has attracted more than billions of dollars of investment

AR Investments



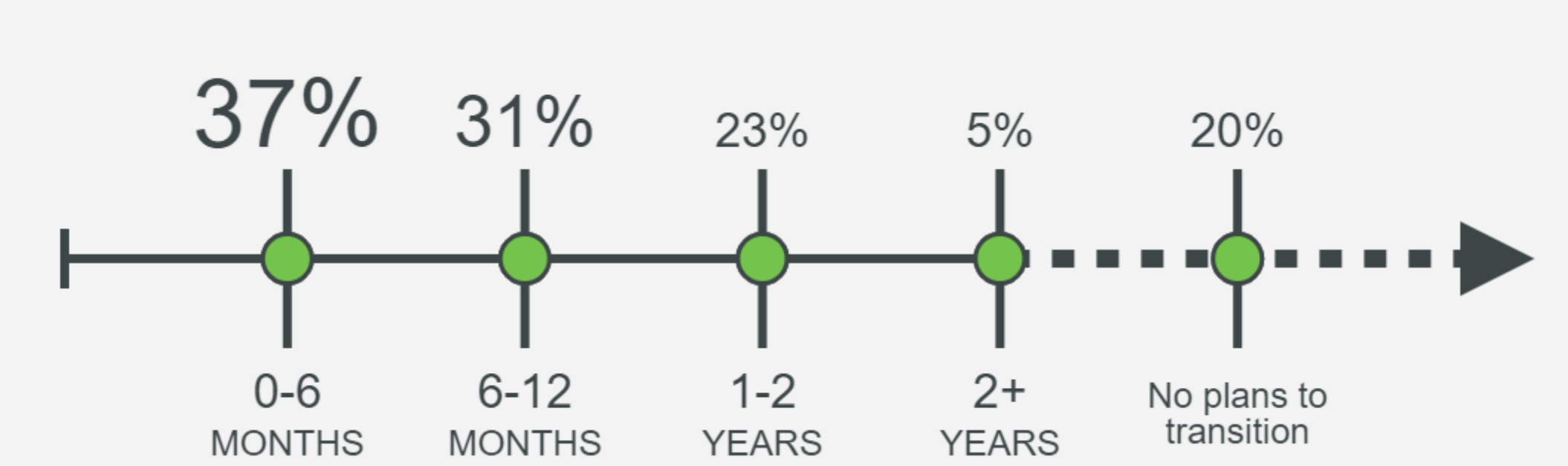


AR – Industry Adaption



https://www.ptc.com/en/resources/augmented-reality/white-paper/state-of-industrial-ar

AR – Expected To Go Live Forecast



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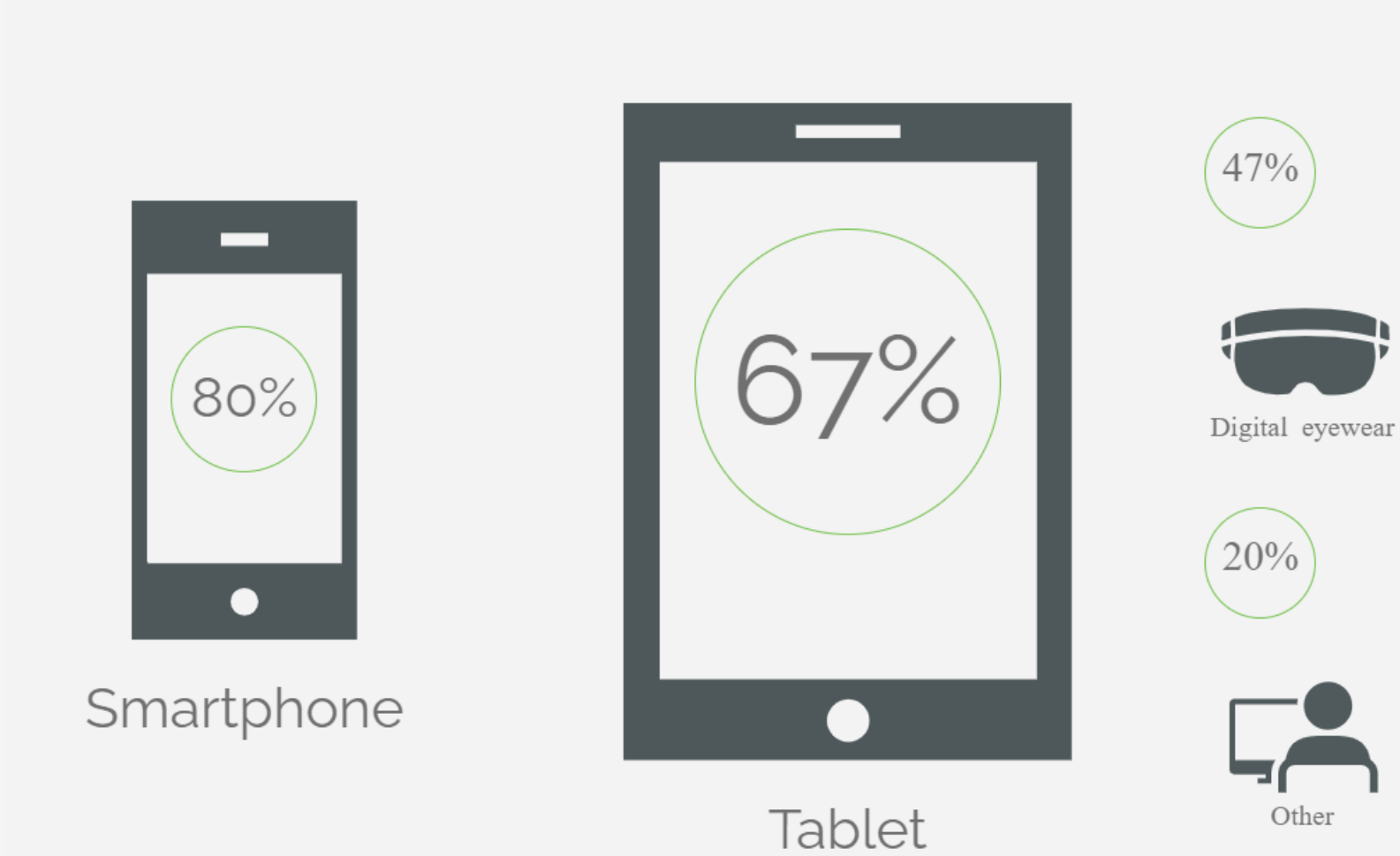
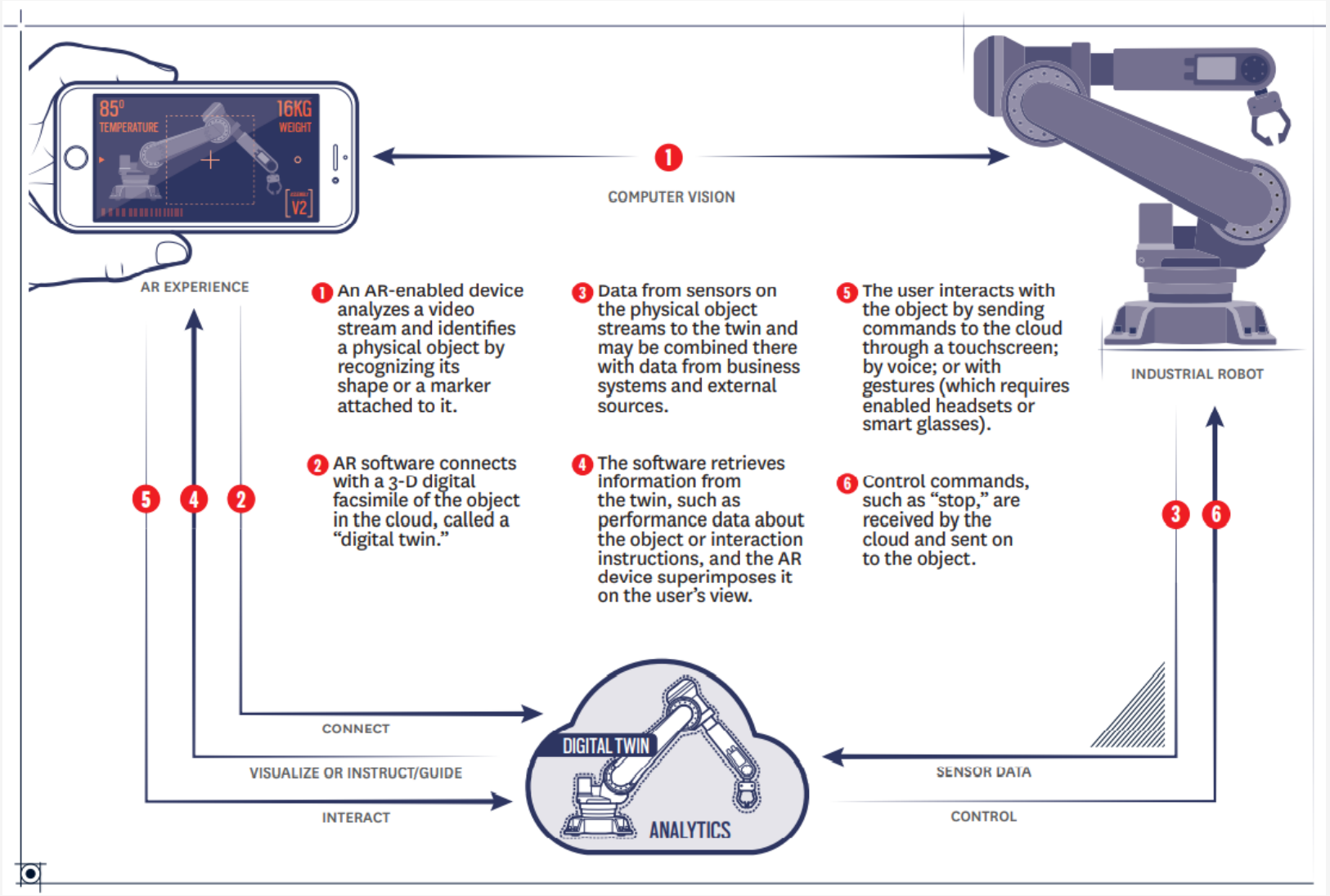
AR – Which Devices?



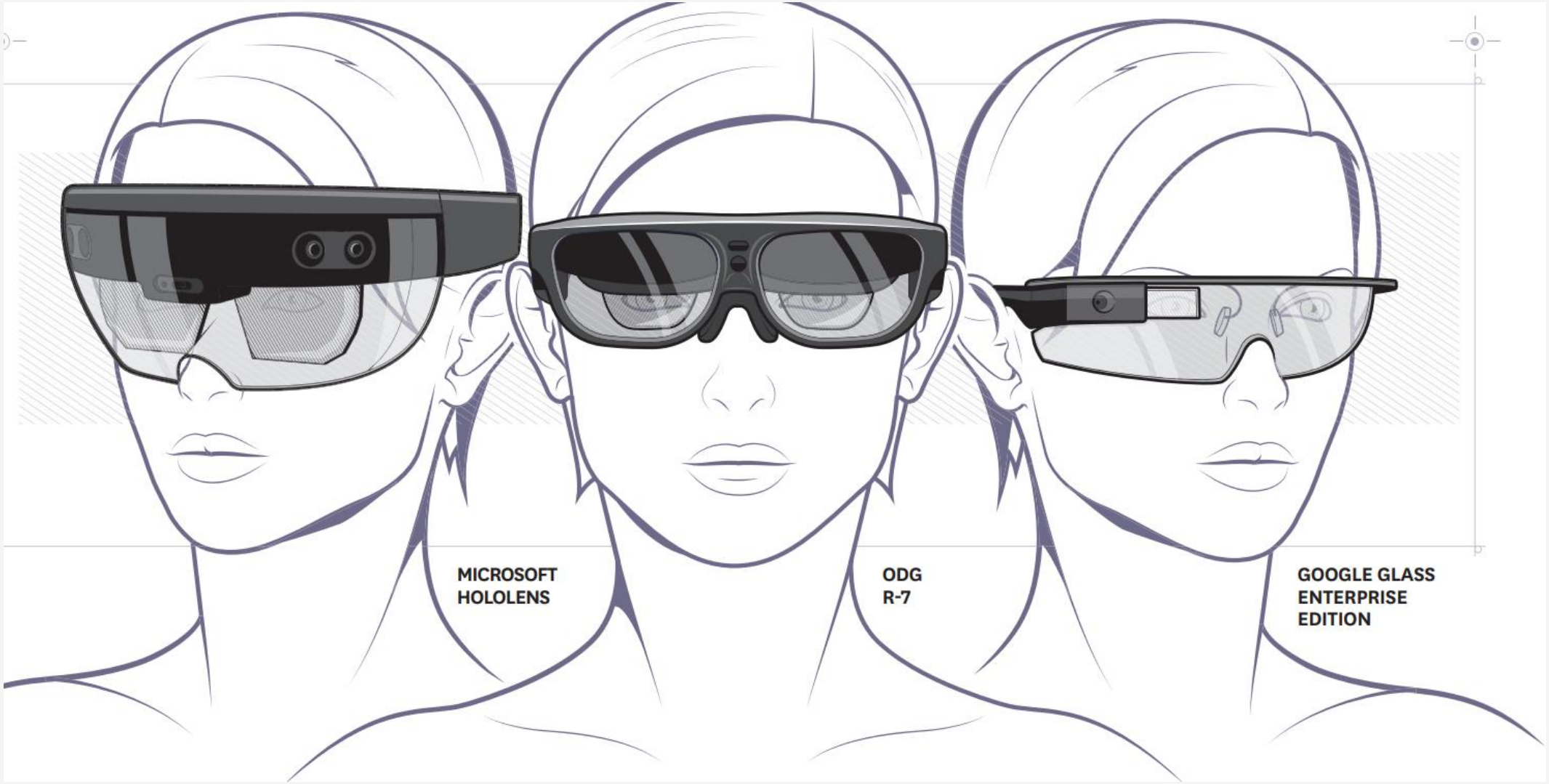
- Are you surprised by this insight?
- AR needs **Mobility**
- As you will see it needs **5G**!!!

https://www.ptc.com/en/resources/augmented-reality/white-paper/state-of-industrial-ar

AR – How Does it (Typically) Work?

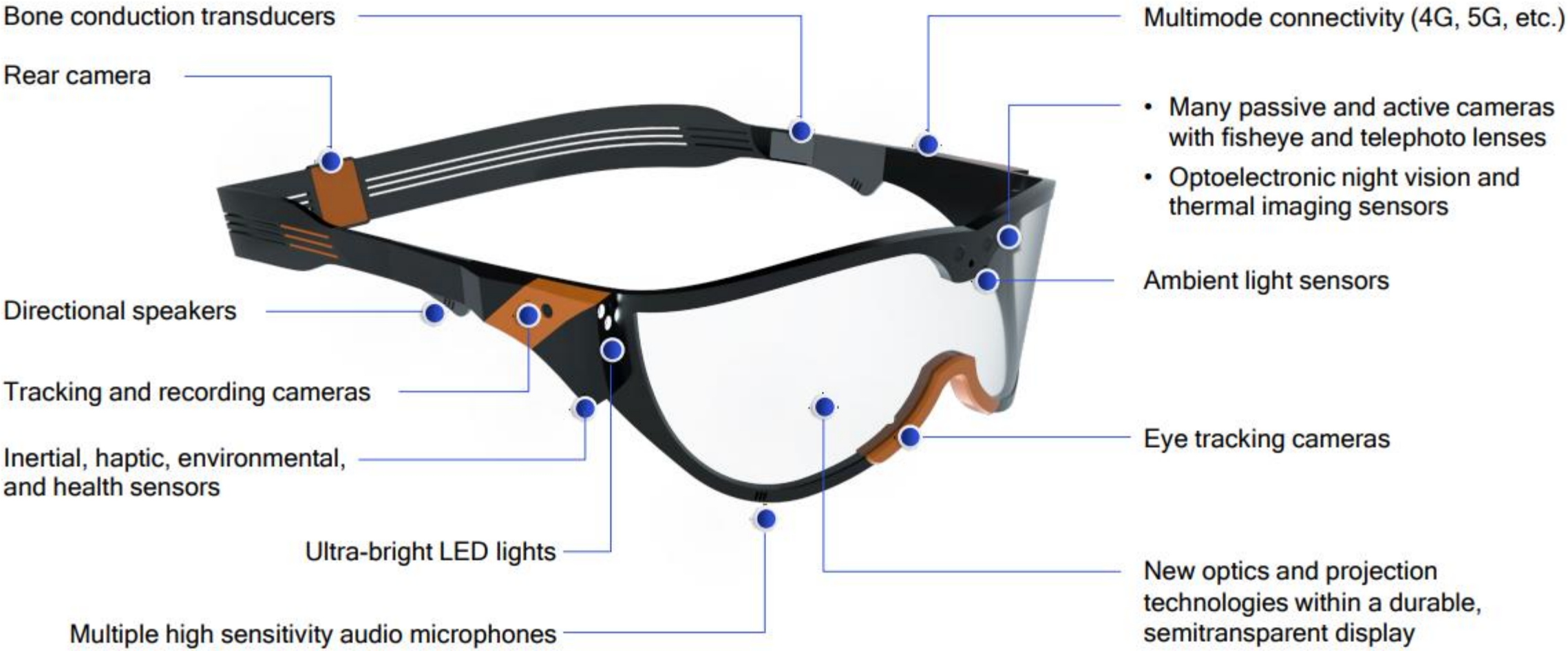


AR Smart Glasses



https://www.ptc.com/-/media/Files/PDFs/Augmented-Reality/HBR-Managers-Guide-to-AR.pdf

AR – Future Device Form Factors

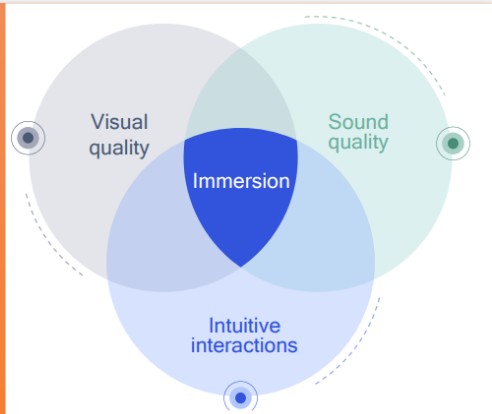


https://www.qualcomm.com/media/documents/files/the-mobile-future-of-augmented-reality.pdf

AR – Immersive Experience

There are three factors for an imperceptible immersion experience (Qualcomm, 2016) of AR/VR applications:

- Intuitive Interactions
- Visual Quality
- Audio Quality



Intuitive Interactions

The time between the detection of the movement, visual processing and the update on the display is captured by **Motion-to-Photon latency (MTP).** Motion-to-Photon (MTP) Latency: Studies have shown that achieving a MTP latency of less than 15 ms makes the delay imperceptible to nearly all users (Qualcomm and ABI Research, 2016).

Visual Quality

Each human eye has ~145° horizontal Field of View. The fovea can see ~60 pixels per degree (PPD) but comprises less than 1% of the retinal size (Qualcomm, 2016). To look anywhere in the virtual world, VR needs to provide full 360° spherical view and incorporate full Stereoscopic view. (Note: there are two streams, one for each eye). Codecs like HDR, 8K, MPE4, HEVC, 3D Mov, etc. generating from 10 to 1000 Mbps bitrates will be used for higher definition required for AR/VR applications. Avoid incorrect Occlusion. Lights and shadows as eye sees it naturally

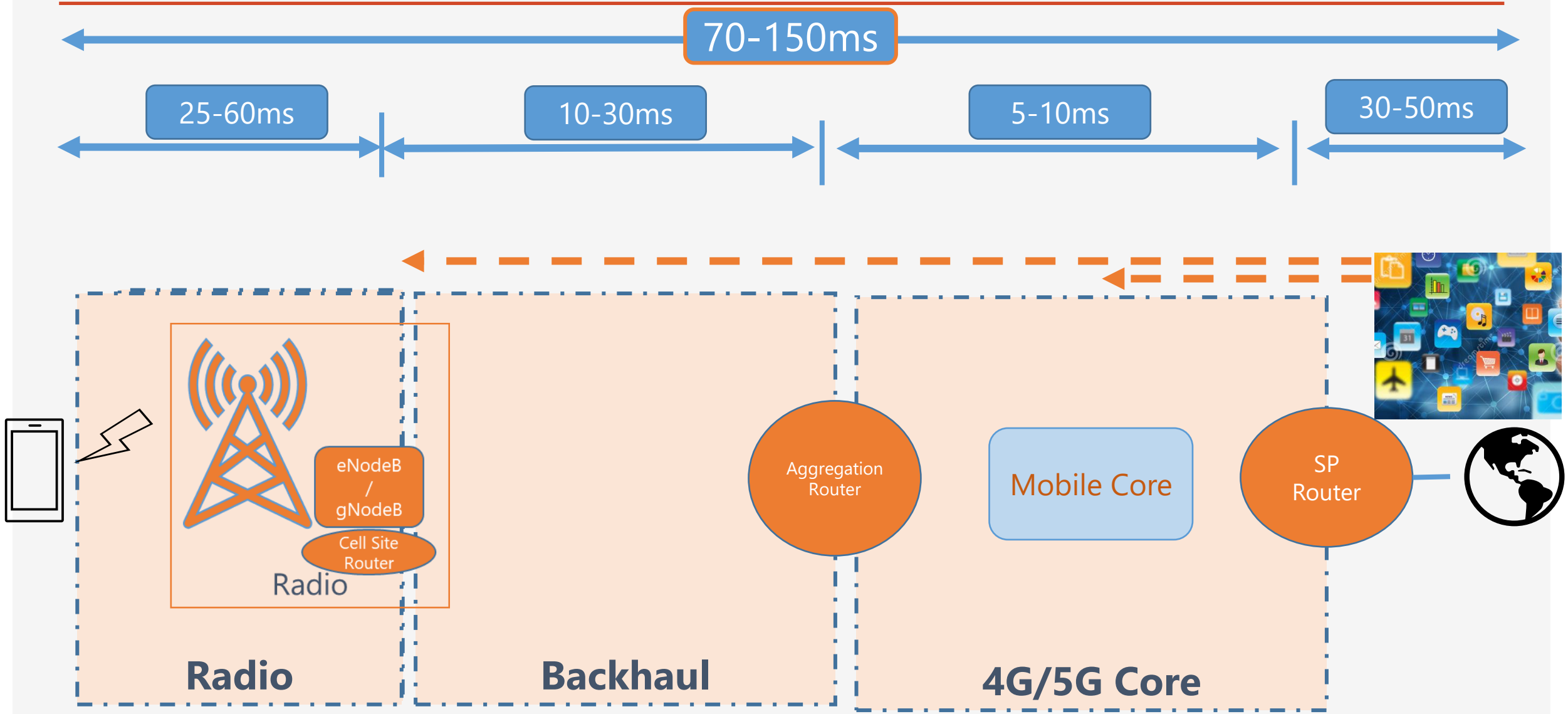
Audio Quality

3D sound, positional and stereo audio synced with visuals and intuitive interactions (Qualcomm, 2016)

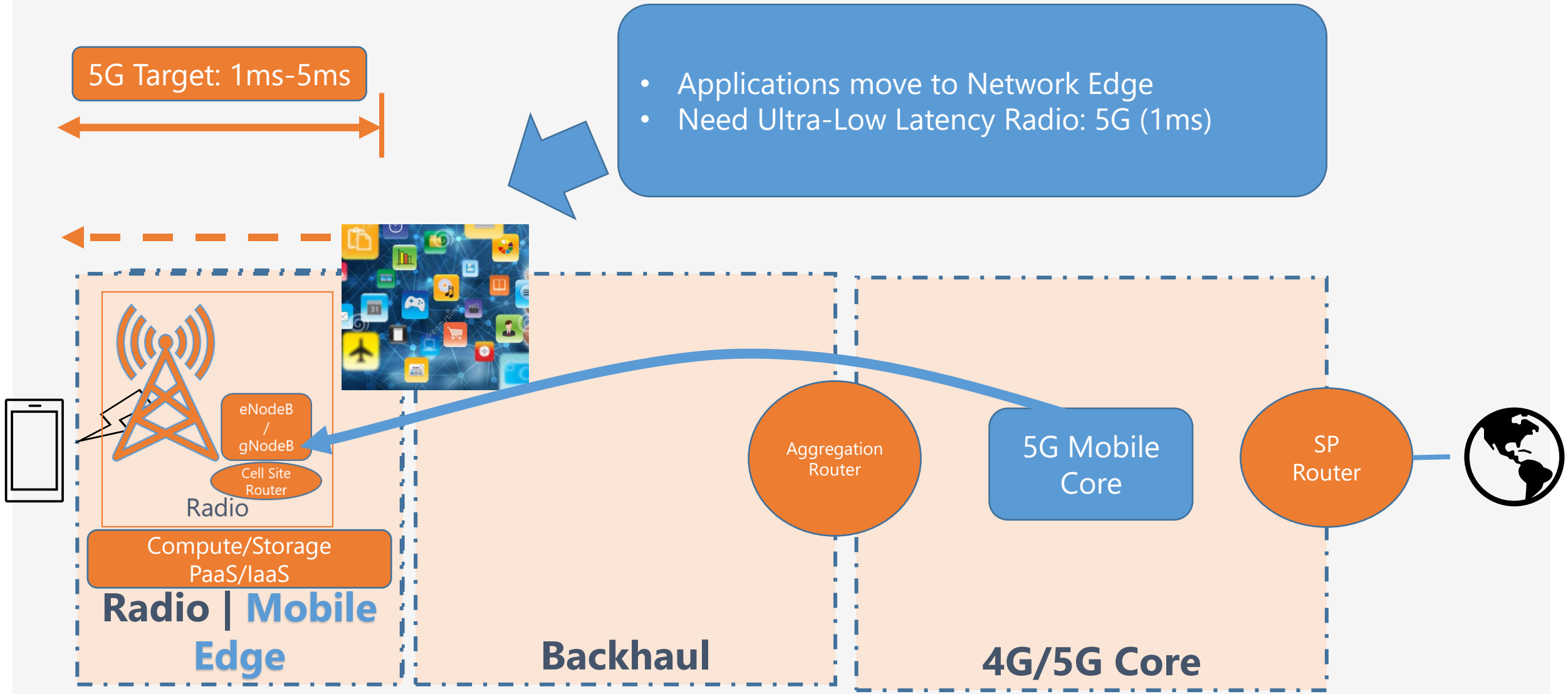
AR – Immersive Experience – Typical Use case : 6DoF

- Six degrees of freedom (6DoF) is the movement of an object in 3D space
- The body is free to change position surge, heave, sway, pitch, yaw, and roll
- The inside-out tracking applications track the body movement for tethered and un-tethered devices
- The 6DoF applications have trade-off between latency and bandwidth
  - For latency 1-5 ms: 6DoF content 100 -200 Mbps
  - For latency 5-20 ms, 6DoF content 400 Mbps to 600 Mbps
- Lower latency for the Live 6DoF relieves the demand on expensive radio spectrum.

From Lecture 9: How can we achieve 1 to 5ms for AR/VR, Driving,…?



Mobile Edge Computing (MEC)



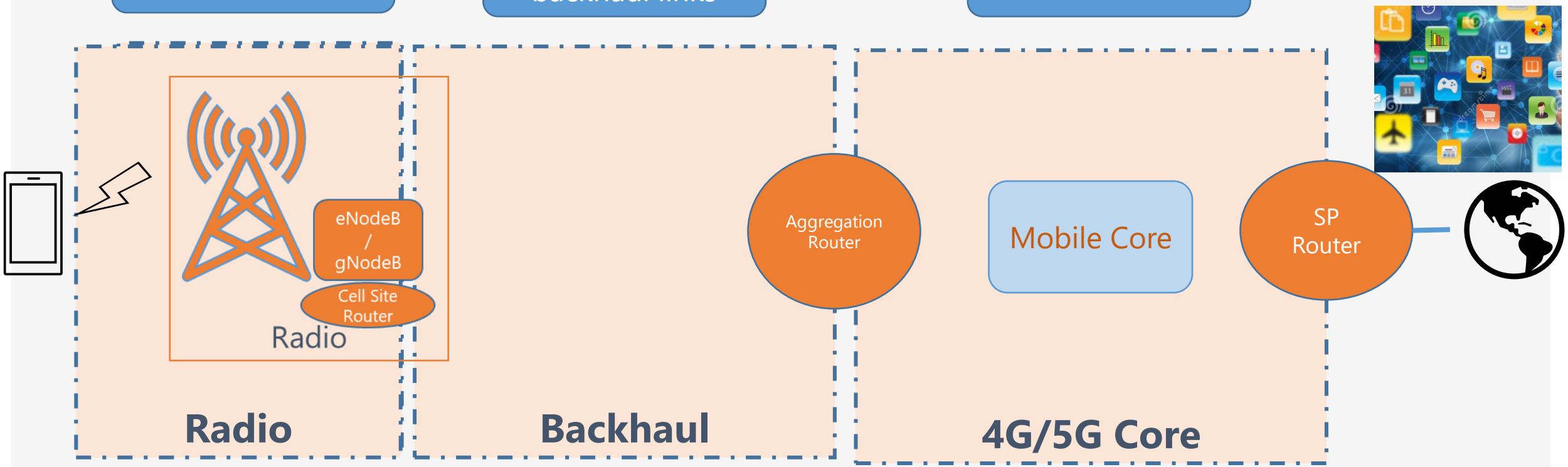
MEC Scale

Forecast: 500-5000 MEC sites

5000-100,000 radio sites

5000-100,000 backhaul links

20-200 sites



MEC Scale – Investment?

Forecast: 500-5000 MEC sites

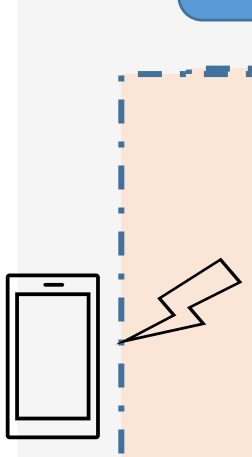
100k-250k/site
Total: $$$$$$

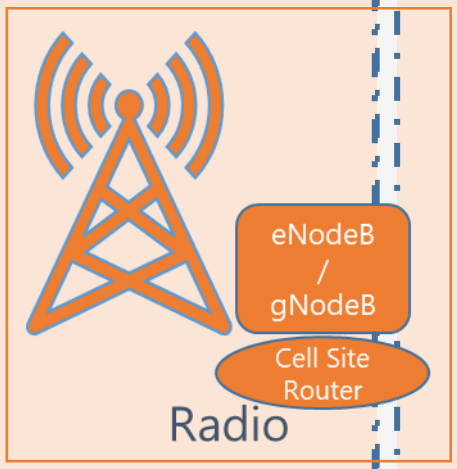
Latency is an expensive asset!

5000-100,000 radio sites

5000-100,000 backhaul links

20-200 sites





Aggregation Router

Mobile Core

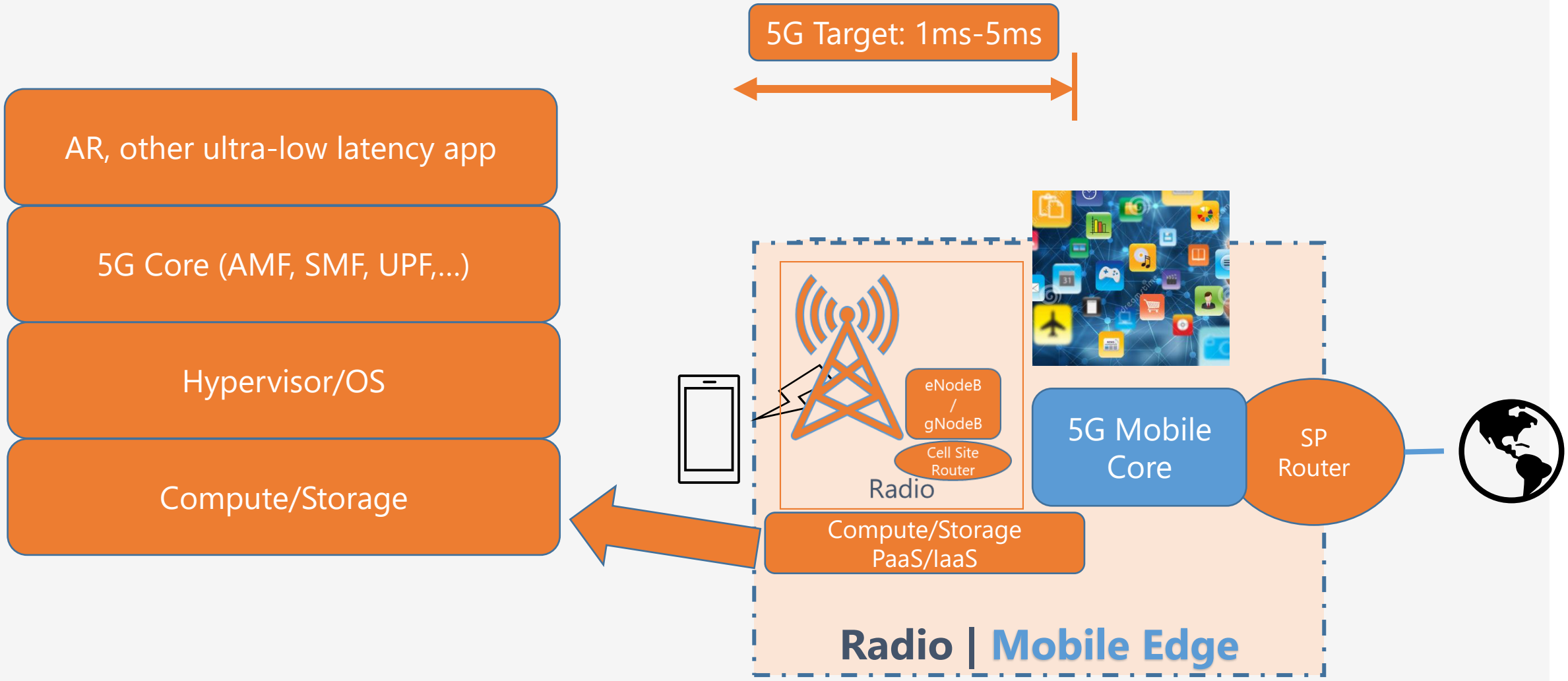
SP Router

Radio

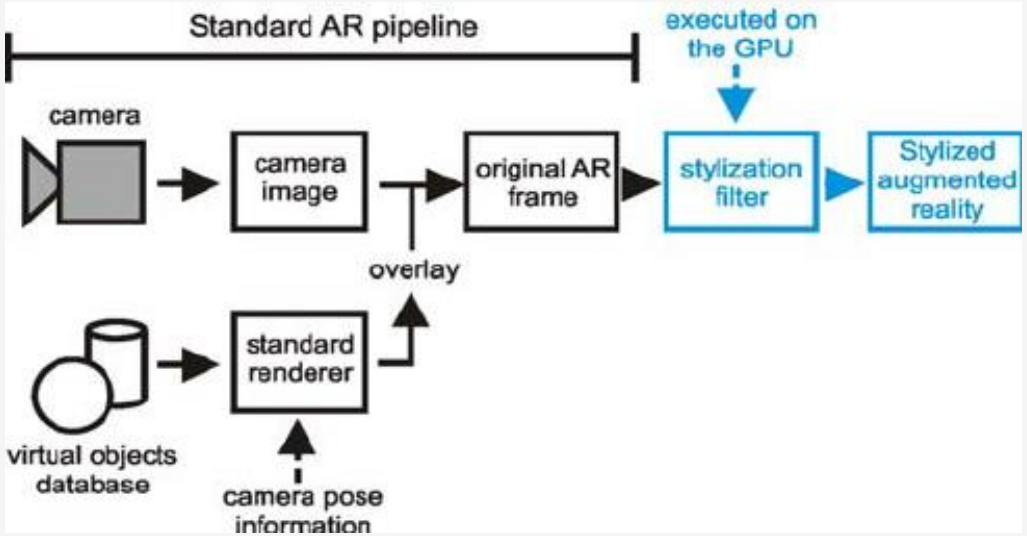
Backhaul

4G/5G Core

Mobile Edge Computing (MEC)



AR – Compute

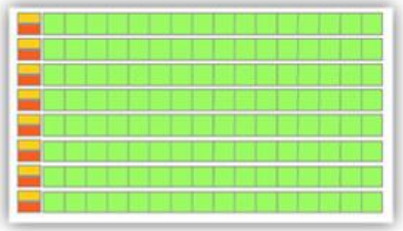


Instance Size	GPUs	GPU Peer to Peer	vCPUs	Memory (GiB)	Network Bandwidth*
p2.xlarge	1	-	4	61	1.25Gbps
p2.8xlarge	8	Y	32	488	10Gbps
p2.16xlarge	16	Y	64	768	20Gbps

CPU

- Low compute density
- Complex control logic
- Large caches (L1$/L2$, etc.)
- Optimized for serial operations
  - Fewer execution units (ALUs)
  - Higher clock speeds
- Shallow pipelines (<30 stages)
- Low Latency Tolerance
- Newer CPUs have more parallelism

GPU



- High compute density
- High Computations per Memory Access
- Built for parallel operations
  - Many parallel execution units (ALUs)
  - Graphics is the best known case of parallelism
- Deep pipelines (hundreds of stages)
- High Throughput
- High Latency Tolerance
- Newer GPUs:
  - Better flow control logic (becoming more CPU-like)
  - Scatter/Gather Memory Access
  - Don't have one-way pipelines anymore

AR – Development Kits

Development Tools

Xcode

Android Studio

Unity

Visual Studio

Exercise ? 15 minutes Activity

Think of use-cases:

Industry:

Reality? Digital Reality?

What kind of device?

What will do?

What kind of customers will use it?

Reading material

the-mobile-future-of-augmented-reality.pdf

state-of-ar-report-2019.pdf

HBR-Managers-Guide-to-AR.pdf