5G

and

Immersive Technologies

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Overview

- 5G is more than just next generation cellular technology
- A look at requirements to support AR/VR in 5G
- A call to collaborate at the interface of 5G service layer

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- Applied R&D to accelerate economic growth and productivity for the UK
- Combines tech and business expertise
- A not-for-profit, private limited company
- Completely neutral

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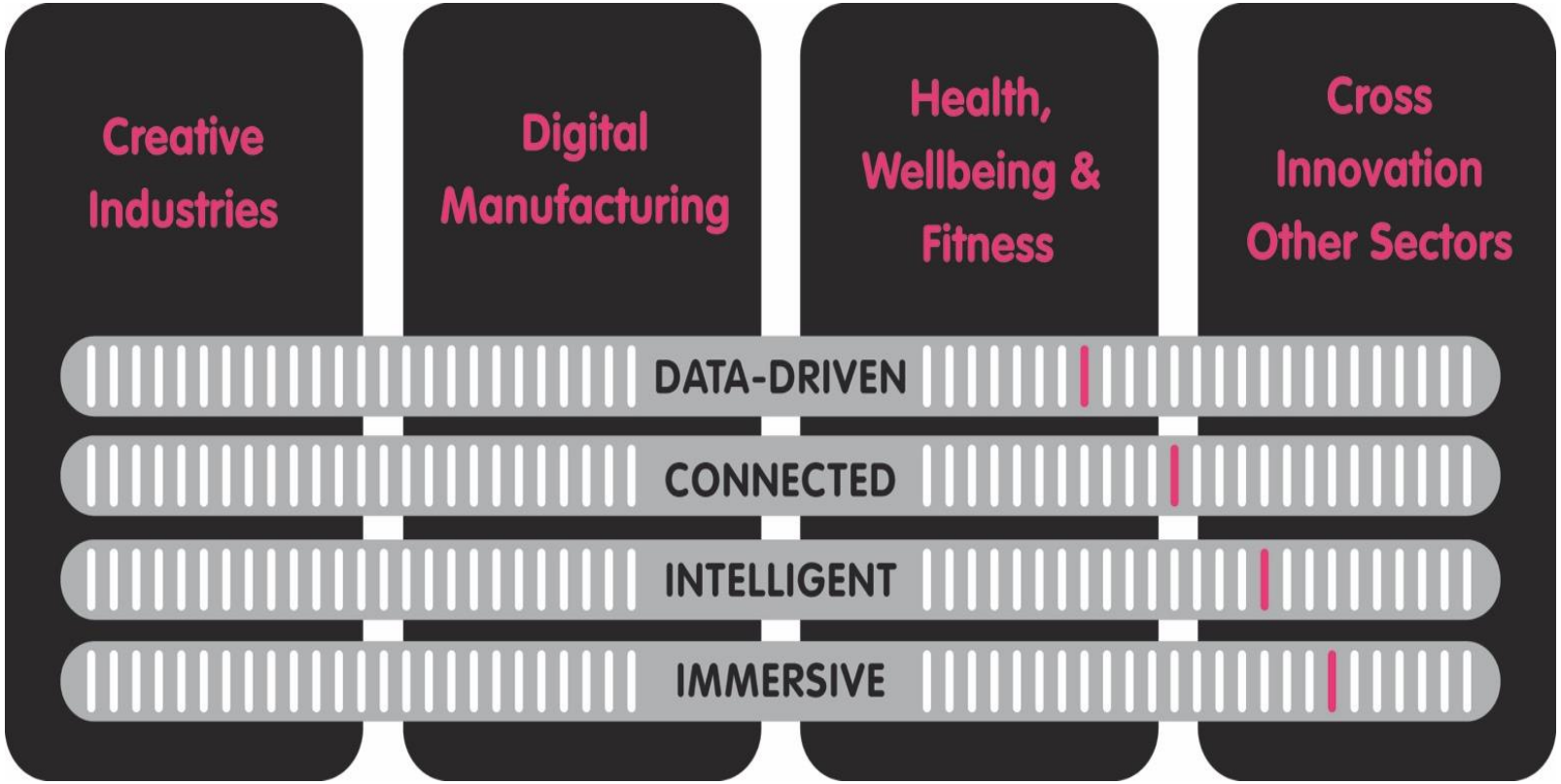
OUR AREAS OF STRATEGIC FOCUS



- We focus on key **technology layers** – which can make a commercial difference
- We work at the **intersections of emerging technologies and target markets**
- **Working with** startups and scaleups, academics and corporates

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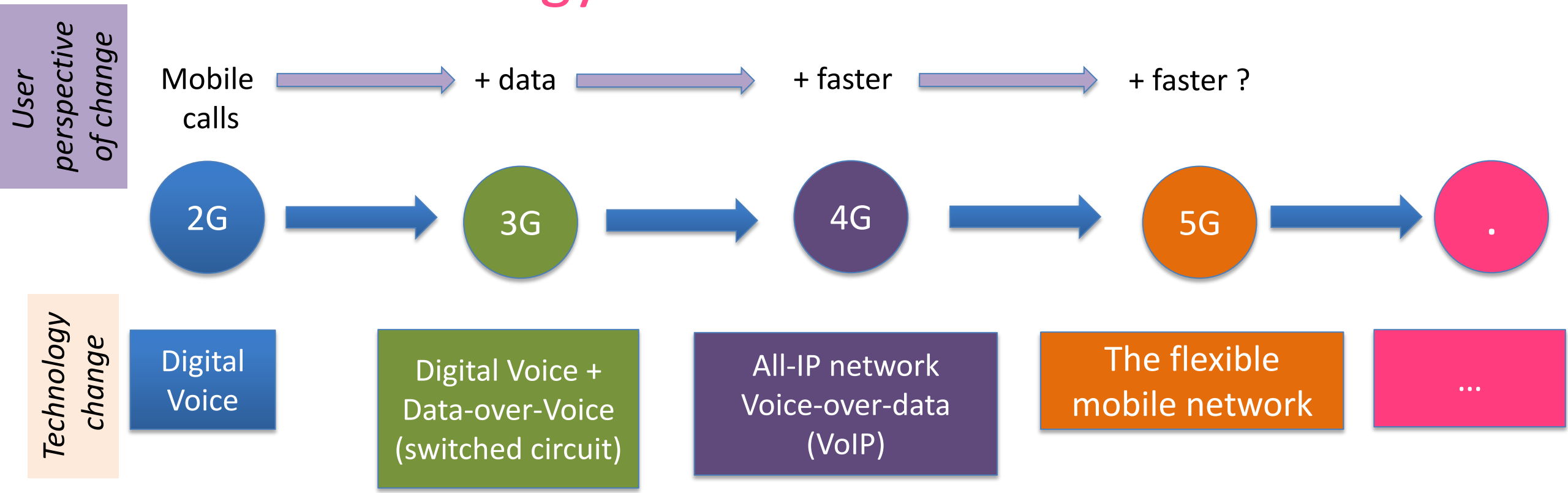
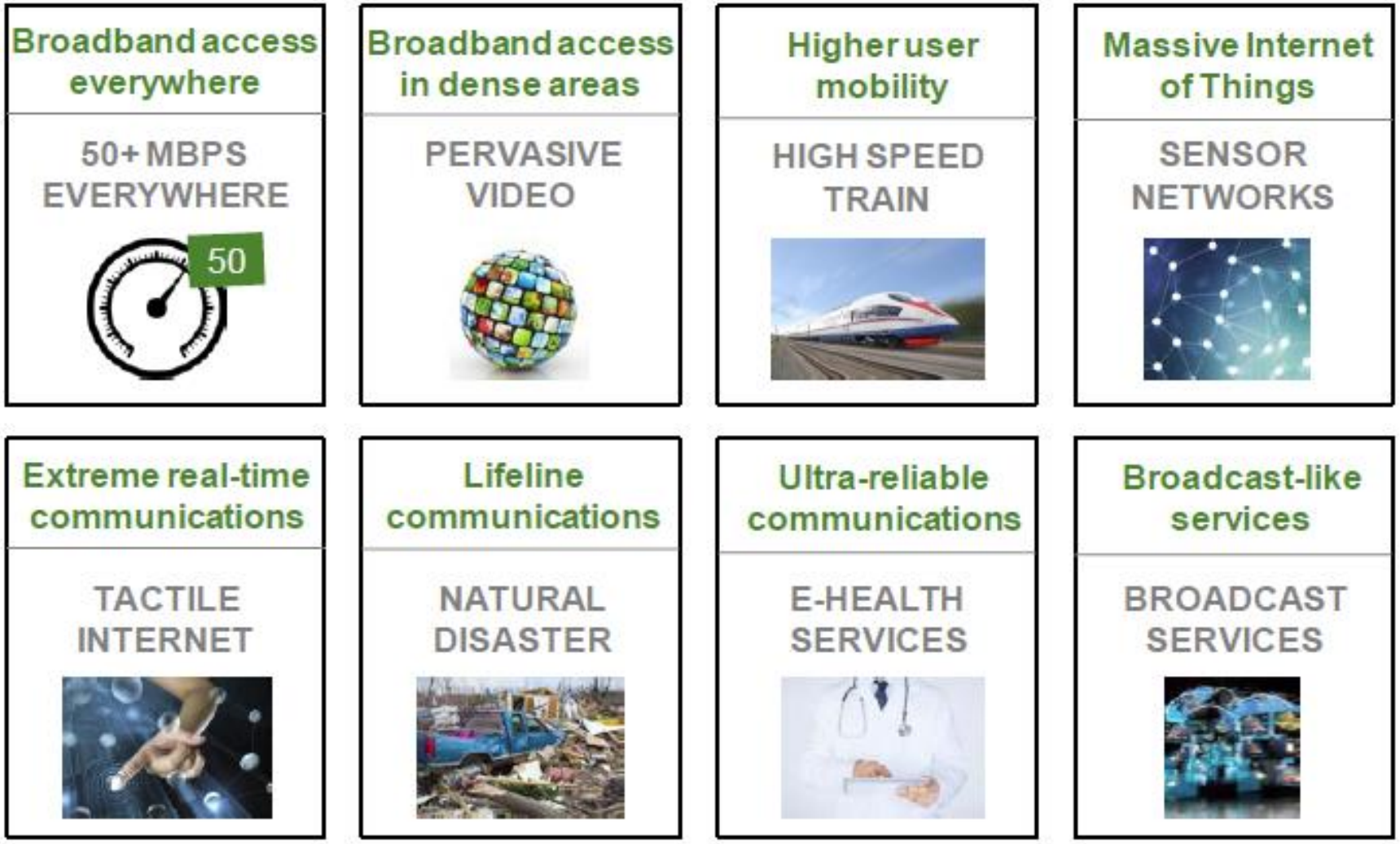
Mobile technology evolution



- This evolution has underpinned fundamental socio-economical change.
- Alongside a business that generates 4.2% of global GDP.

  (The Mobile Economy 2016, GSMA)

5G Vision (*NGMN, February 2015*)



- **1-10Gbps** to end points
- **1ms** end-to-end delay (*50x decrease*)
- **1000x** capacity per cell
- **10-100x** connected devices
- **99.999%** availability (reliability)
- **100%** coverage (perception)
- **90%** reduction in energy usage

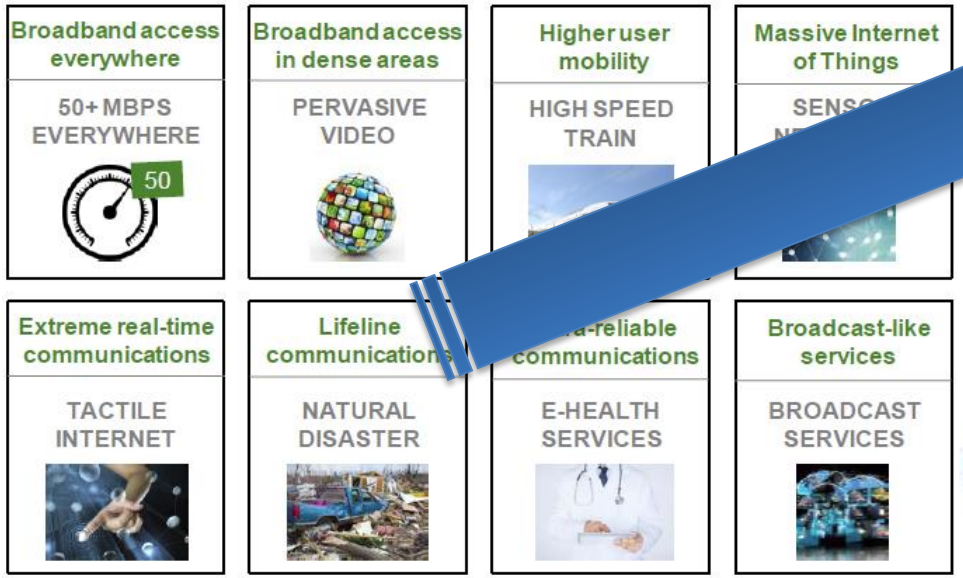
However, much of this vision has been aspirational.

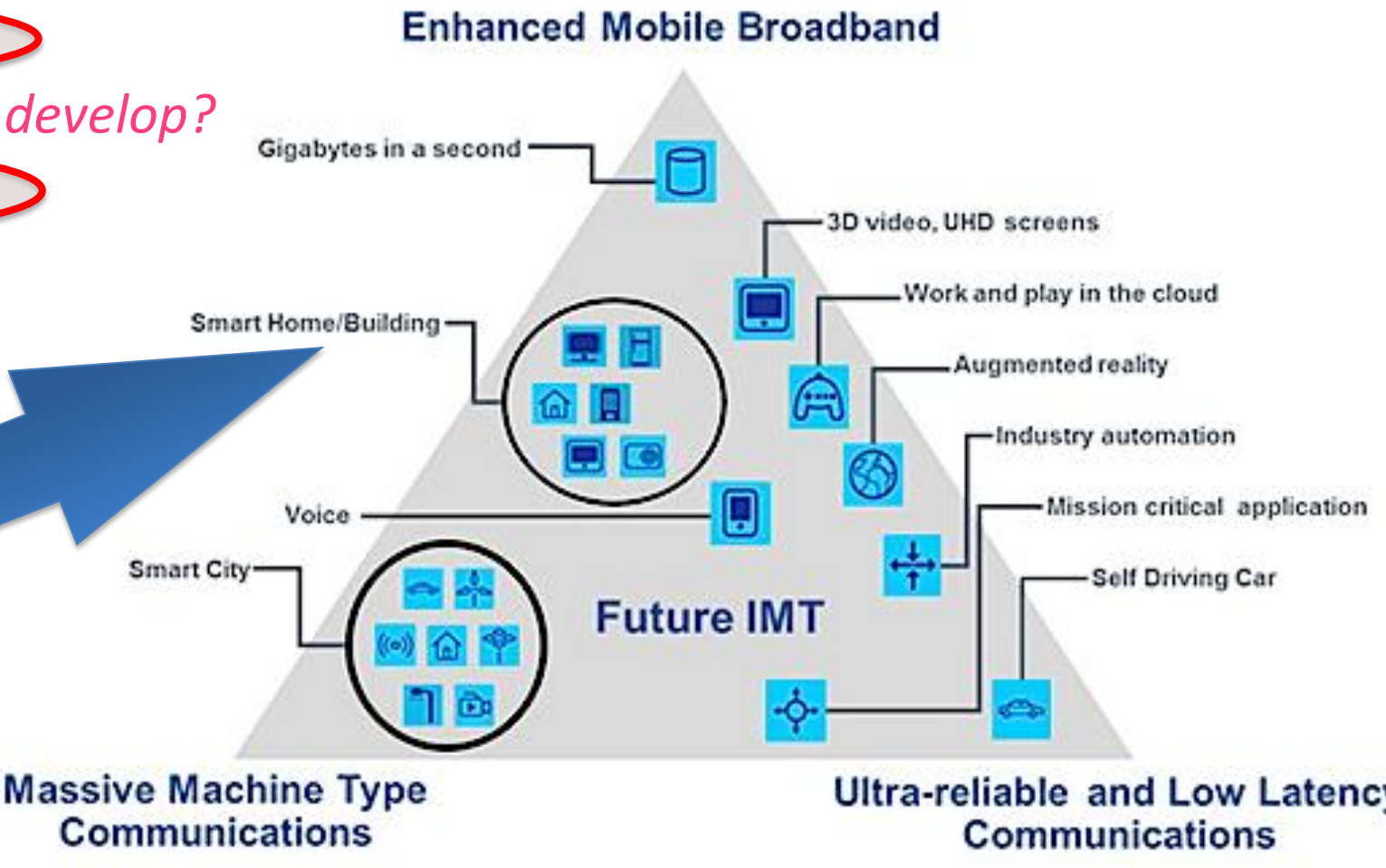
Now aspiration must translate to the real world.

What do we really want?

What could we conceivably develop?

And for whom, specifically?





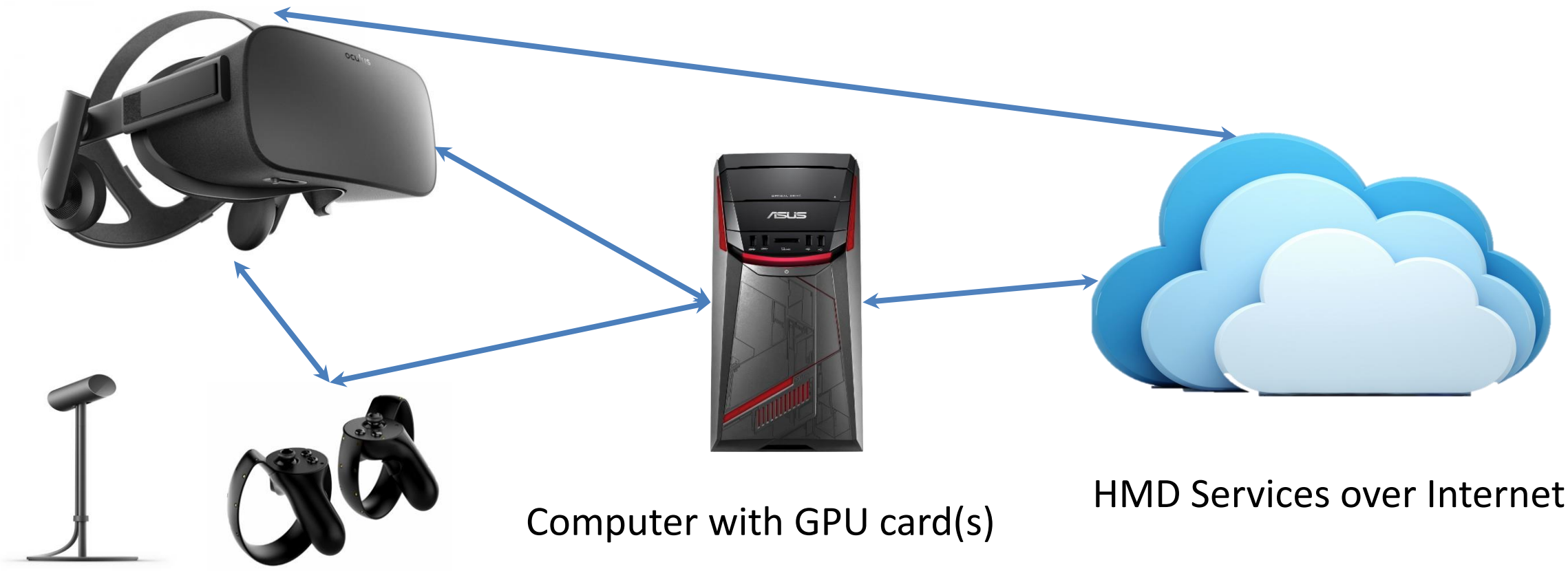
What is 5G? Two views – not quite the same!

- The hyper-connected vision (e.g. 5GPPP, NetWorld 2020)
  - 5G will lead to new network systems that properly integrate communication, computing and storage technologies for better data services anywhere, anytime.
  - Supporting IoT through new network technology.
  - Enabling development of advanced applications is key aspiration
  - Network fabric convergence becomes crucial aim for digital services.

- Traditional evolution to next generation cellular access technology
  - Evolutionary approach through existing cellular roadmaps - just another generation of connectivity technology.
  - Data takes care of itself - *more or less as today!*

Main Components of Different HMD Systems

Head-Mounted Display

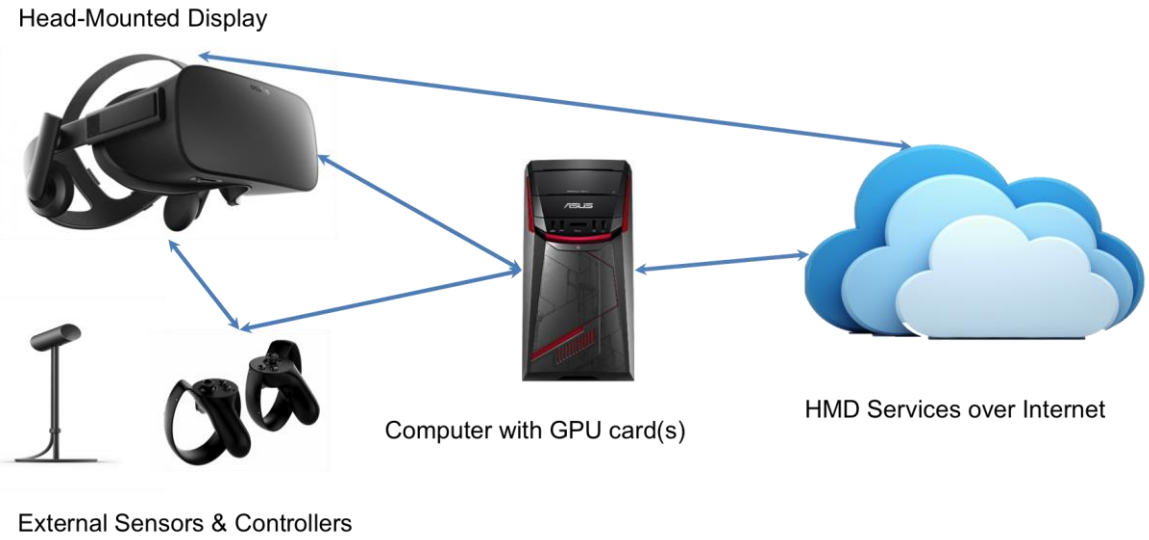


Computer with GPU card(s)

HMD Services over Internet

External Sensors & Controllers

Factors Affecting Connectivity Requirements



- System Architecture and Function Placements
  - Processing: onboard HMD *vs*. computer with dedicated GPU cards tethered to HMD *vs*. in-network processing *vs*. combination
  - Types of sensors involved and location: e.g. depth camera, microphone array
- Types of Application and environment:
  - gaming, video streaming, social interaction, remote operation, cultural informatics, …

Raw Bandwidth Requirements: HMD + External Controllers

Display (downstream to display)

Platform	Codec	Resolution	Fps	Avg. bitrate
Gear VR	H.265	3840×2160	30	10 – 20Mbps[1]
Oculus Rift	H.265 / H.264	4096×4096	60	40 – **60Mbps** [1]
Youtube	H.264	2560 x 1440	60	9 – 18Mbps [2]
Pixvana	HMD-compatible	10K * 1/6	60	1 – **6Mbps** [3]

Note: These are 360º ~4K video encoding but HMD resolution may be lower. e.g. Oculus Rift is 2160x1200

Speakers (downstream to speakers) [4]

Configuration	Quality	Channel Layout	Bit Rate
Stereo	3	L+R	96kps
Stereo	5	L+R	192kps
Surround 5.1	3	C, L+R, LS+RS, LFE	304kbps
Surround 5.1	5	C, L+R, LS+RS, LFE	**608kbps**

Controllers (external)

Range from 4.2kbps (basic) to **296kbps** (advanced, e.g. Leap Motion)

Sensors (upstream)

A similar sensing system such as Microsoft Kinect 2 produces **~1Gbps raw data** (has 1 RGB camera (1280x960 resolution, 30Hz), depth camera (512x424 resolution, 30 Hz), 4-array microphone and 3-axis accelerometer)

Towards wireless HMDs

- Virtual Reality HMDs are mostly tethered to a computing unit.
  - But this is changing very fast towards wireless offerings! (e.g. HTC Vive + TPCAST Wireless Upgrade Accessory)
- Augmented Reality HMDs (e.g. Microsoft HoloLens) are already wireless – but more WiFi than cellular.
- Reducing communication reqs through onboard processing is obvious
  - But but there are weight, power and heat obstacles due to the current performance of hardware.
  - Finding acceptable compromises on performance will be necessary. How do we find out which are acceptable?

5G projections for immersive relevant use cases

User Performance Requirements

Use case category	User Experienced Data Rate	E2E Latency
Broadband Access in dense areas	300 Mbps DL, 50Mbps UL	10ms
Broadband - Indoor	1Gbps DL, 500Mbps UL	10ms
Broadband – Crowd (30K stadium)	25 Mbps DL, 50MMbps UL	10ms
50Mbps+ everywhere	50 Mbps DL, 25Mbps UL	10ms
Ultra-low latency	50Mbps DL, 25Mbps UL	<1ms

System Performance KPIs

Use case category	Connection Density	Traffic Density
Broadband Access in dense areas	200-2500/km^2	750Gbps/km^2
Broadband - Indoor	75,000/km^2	15Tbps/km^2
Broadband – Crowd (30K stadium)	150,000/km^2	3.5Tbps/km^2
50Mbps+ everywhere	400/km^2	20Gbps/km^2
Ultra-low latency	***Not critical***	***Potentially high***

- KPIs can be derived for known applications
- Work is under way for others. E.g. early work from H2020 mmMagic project estimates that in high density/small cell environments, the mean aggregate traffic will be **12.75Gbps**, requiring **28-39Gbps/cell** (95-99% users)

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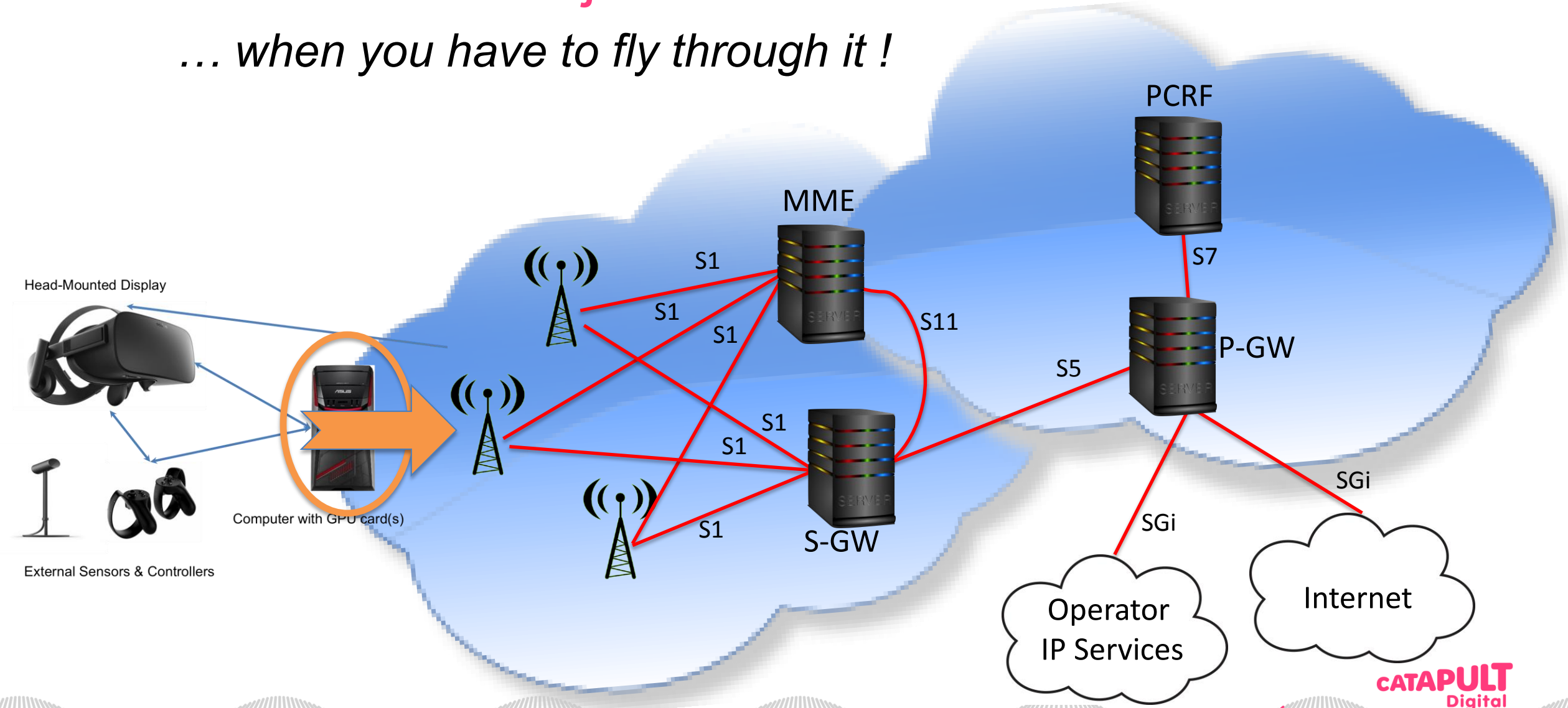
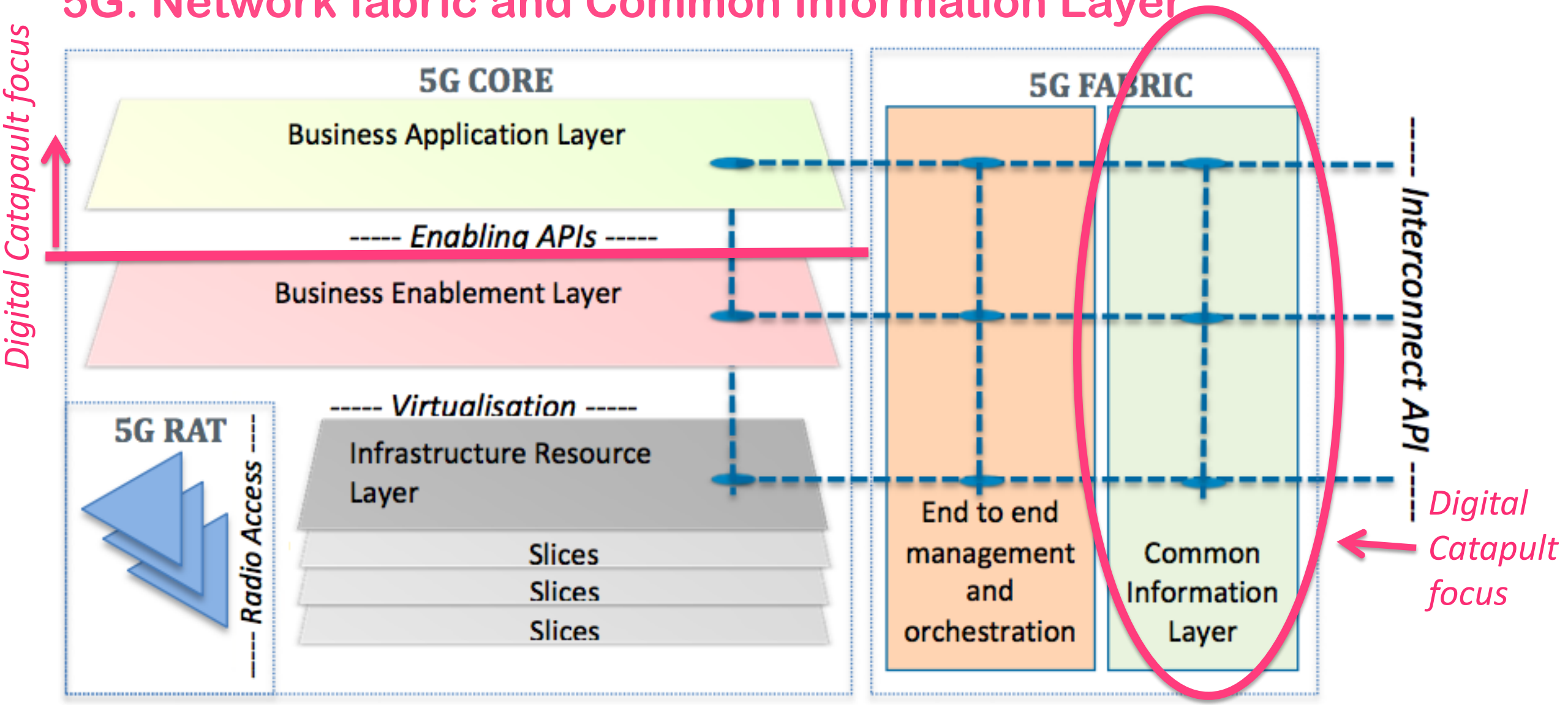
“The Cloud” is not just a cloud …

… when you have to fly through it !



5G: Network fabric and Common Information Layer



Source: WTIC, 2016

Summary

- 5G is not just another cellular solution.
  - Virtualisation and softwarisation (SDN + NFV) are changing the network service provisioning – dramatically!
- The raise of the flexible network:
  - It should be seen as a single infrastructure fabric that can/will be "instantiated" for different verticals.
- Developing this requires closer cooperation between the communication and vertical industries than currently exists.
- Learning, jointly, from real-life testbeds is crucial.

Questions ?

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