5G & The Future Mobile Network

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5G & The Future Mobile Network – Introduction

Overview

5G has been in the news a lot recently, but what is it all about? Do we need another "G" (Generation) of mobile technology? Is it true that 5G will enable Augmented Reality, Remote Surgery, Factory Automation and Self-Driving Cars? What is the engineering and commercial reality behind current UK deployments of 5G and what can we expect in the future?

Topics

History of Mobile Generations
4G Benchmarking
5G Performance Objectives
5G Use Cases
5G Innovation
BT/EE 5G Launch
Early 5G Benchmarking
5G Technology Components
5G Radio / 5G Spectrum
5G Architecture
5G Core Networks
5G Future Evolution

Brief History of Mobile Generations (1G to 5G)

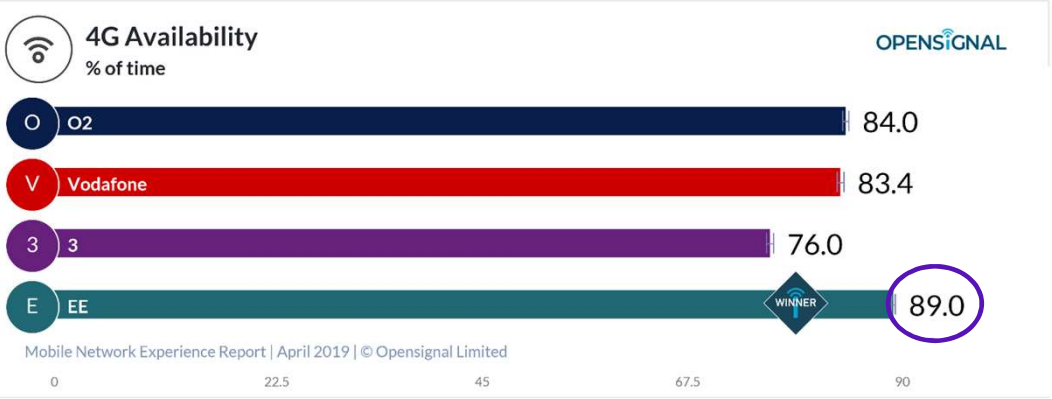
Surprise and wonder → Mobile voice for the mass market → Expectation: voice, text, internet → Dependency for everyday life → Wireless connectivity is essential

1985	1992			2003			2012			2019	2025
voice	sms	96 kbps	240 kbps	2 Mbps	14 Mbps		150 Mbps		600 Mbps	2 Gbps	10+ Gbps
			GPRS	EDGE		HSPA			LTE-A	NSA	SA
1G - TACS	2G - GSM			3G - UMTS			4G - LTE			5G - NR	

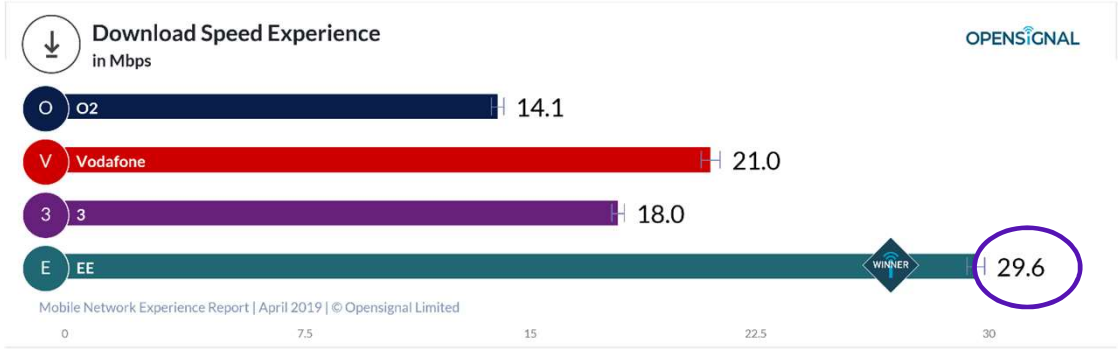
Source: OpenSignal UK Mobile Network Experience Report, April 2019

4G Benchmarking in the UK

4G Availability (%)

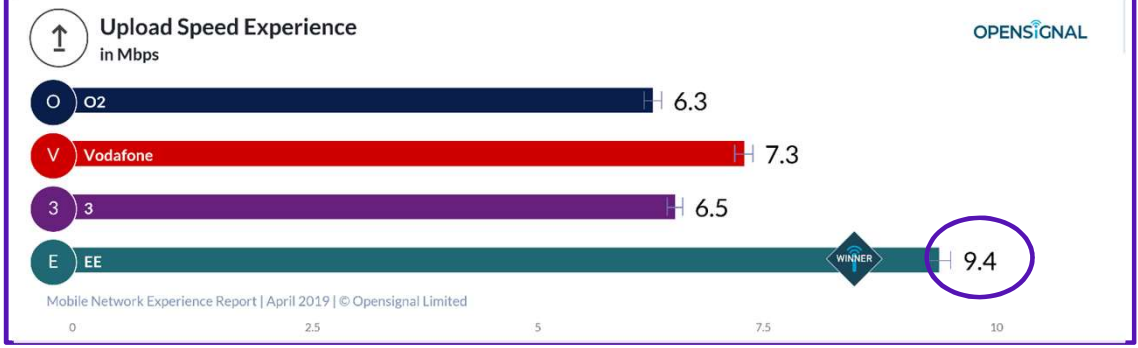


4G Download Speeds (Mbps)



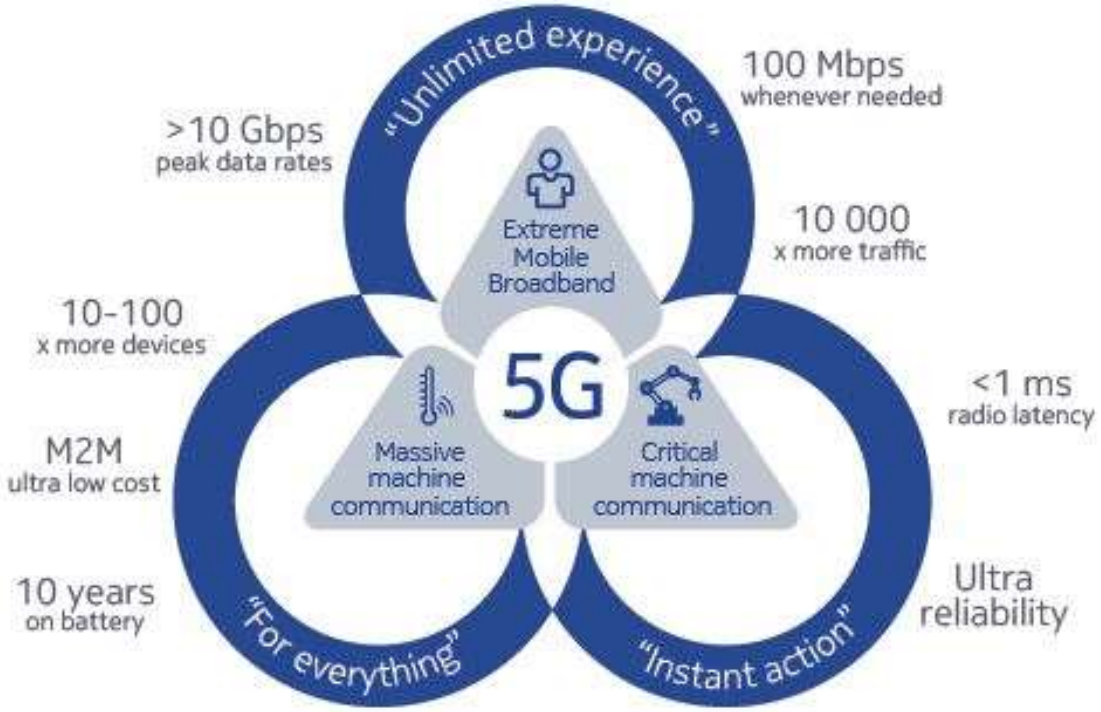
4G Latency (ms)

4G Upload Speeds (Mbps)



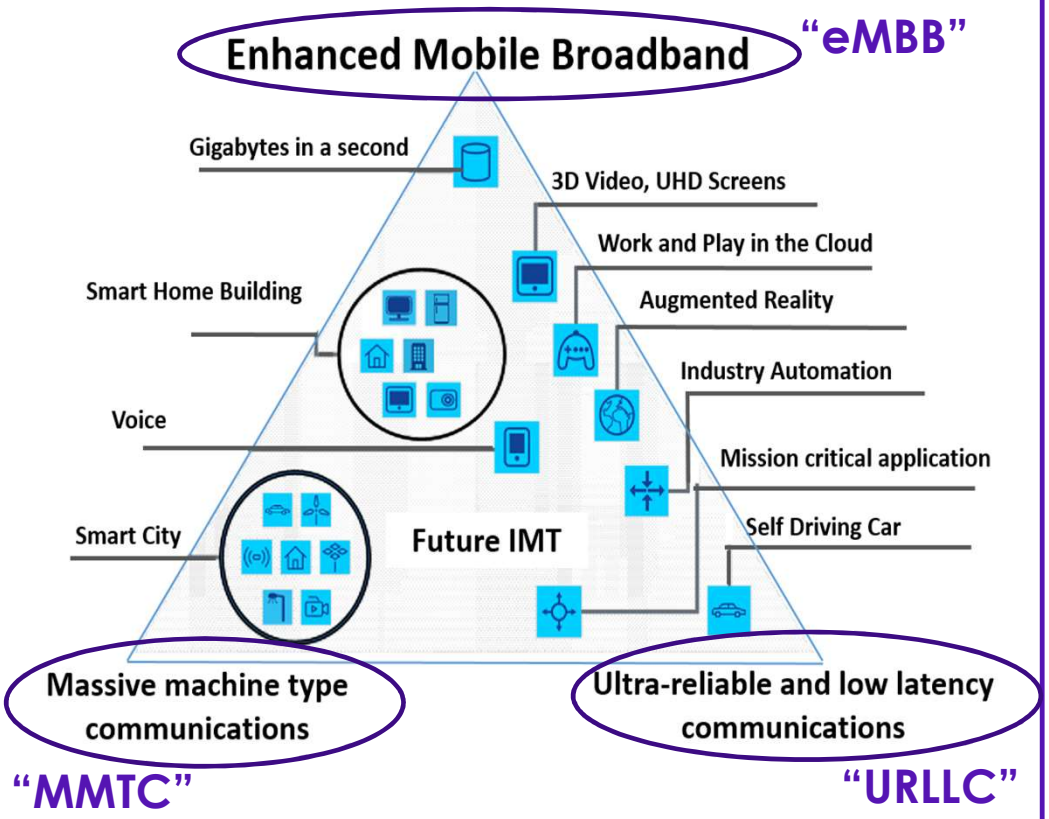
5G Performance Objectives

- 5G performance requirements have been defined by the ITU (IMT-2020) and developed by 3GPP.
- A step change (improvement of 10x-100x compared to 4G) in bandwidth, latency, density, battery life and reliability is demanded.
- **These requirements may not all be required or met at the same time.**
- 5G is expected to meet a wide variety of use-cases in different ways, e.g. via specialized devices, priority services, and a mix of public and private networks.



Source: Nokia – 5G For Mission Critical Communications

5G Use Cases



ITU – "IMT2020" Use Cases

4G unleashed tremendous innovation and disruption over the last decade, e.g.

Mostly Consumer and Smartphone oriented.

5G is expected to enable even greater innovation and disruption during the next decade, e.g.

- Augmented Reality
- Remote Healthcare
- Factory & Port Automation
- Autonomous Vehicles
- Drone Control

Mostly Enterprise and IOT oriented.

BT 5G Innovation

BT is playing a leading role in 5G Innovation, developing new use cases including:

- **Sports / Entertainment** – 5G AR/VR at Wembley Stadium
- **Mass Events** – first 5G Music Festival at Glastonbury
- **Healthcare** – first remote ultrasound over public 5G
- **Smart Ports** – pioneering AR over 5G in UK ports.
- **Media & Broadcast** – first TV broadcast over public 5G.
- **Connected Transport** – 5G autonomous vehicles at the Royal Welsh Agricultural Show.

Connected Ambulance Demo (Remote Healthcare)

Successful demonstration of remote ultrasound scan via haptic channel over 5G (low latency required).

BT KING'S College LONDON ERICSSON

High Quality IMS Bearer

Ambulance

Voice
Video
Haptic Communication

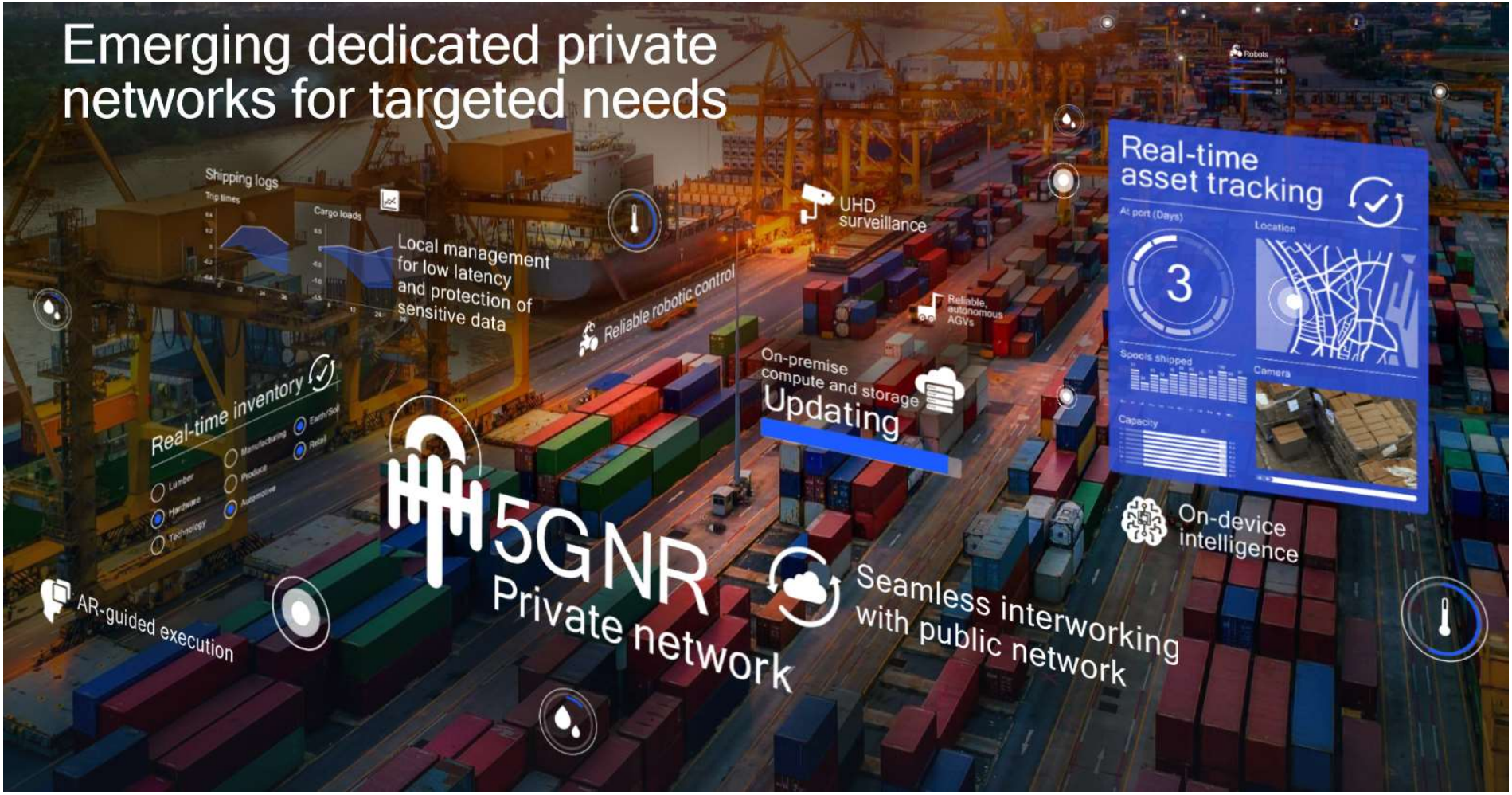
Hospital

5G Mobile Connection

5G Mobile Connection

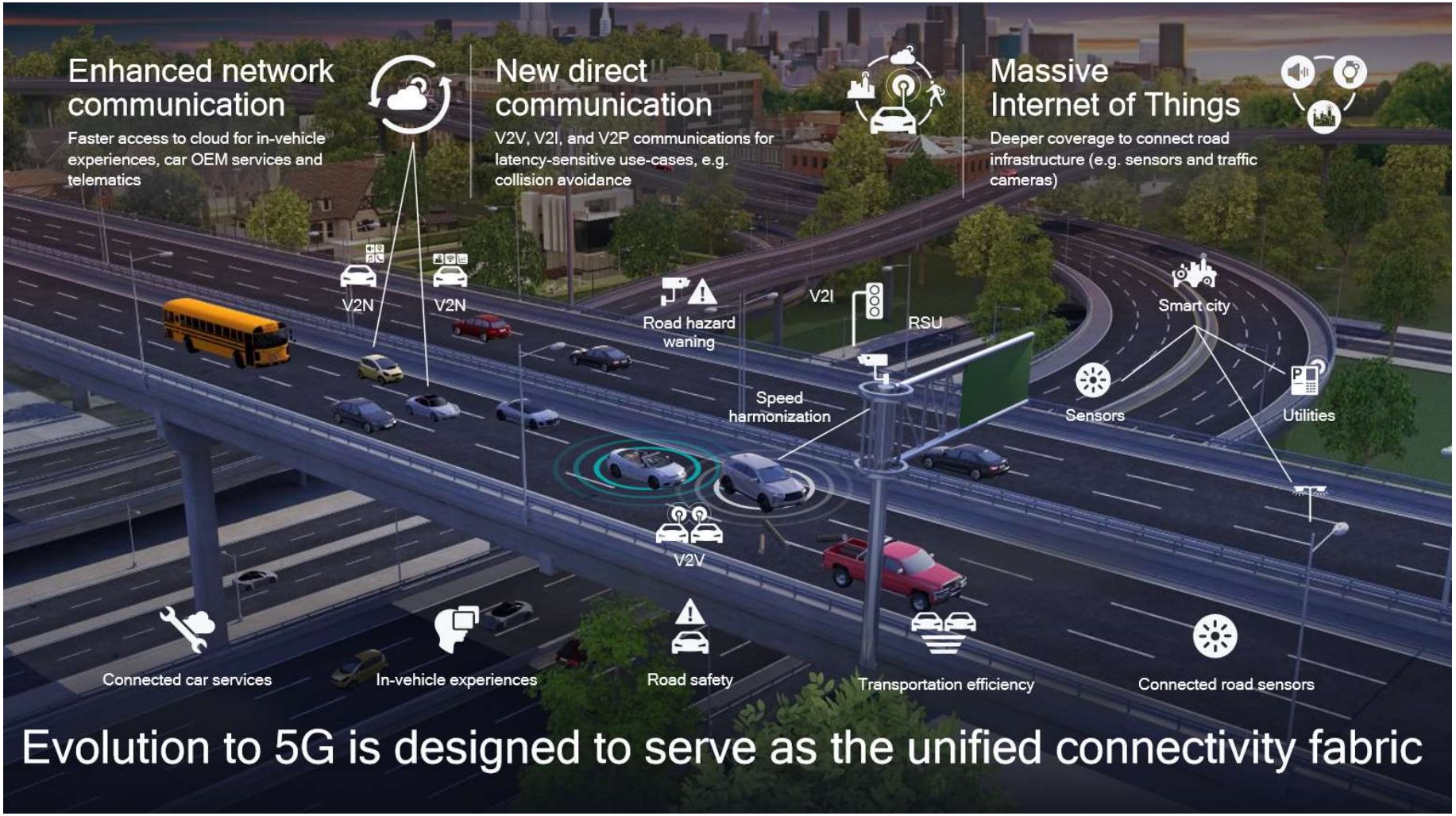
Factory/Port Automation

Source:
https://www.qualcomm.com/media/documents/files/future-of-5g.pdf



5G V2X Use Cases

Source:
https://www.qualcomm.com/media/documents/files/future-of-5g.pdf



BT/EE 5G Launch – Leading the UK

BT launched 5G in May 2019 under the EE brand – the first in the UK and one of the first in Europe.

BT/EE 5G is now available in **50 cities and towns across the UK** (as of Dec 2019).

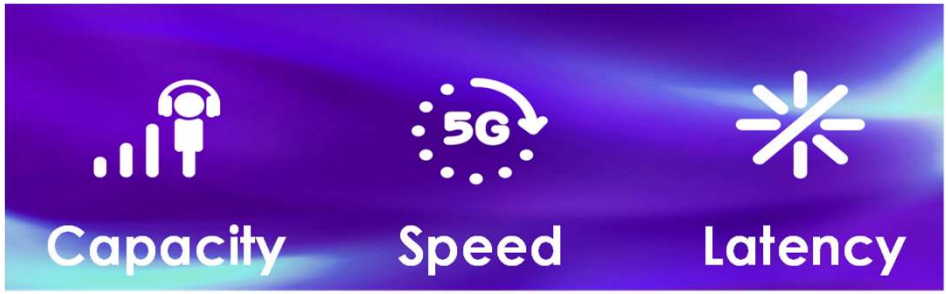
BT/EE have the **best 5G coverage** and the **fastest 5G speeds** in the UK:

- 5G peak download speeds up to **1 Gbps**
- 5G average download speeds around **150-200 Mbps**

Vodafone launched 5G in **July 2019**

Three launched 5G in **August 2019** (but currently limited to a 5G Home Broadband service in London only)

O2 launched 5G in **October 2019**



BT/EE 5G Rollout – Available in 50 Towns & Cities (as of Dec 19)

Early 5G Benchmarking in the UK

- Download speeds 5-6 times higher than 4G.
- Upload speeds 2 times higher than 4G.
- Some reduction in latency compared to 4G.
- Further improvements expected over time.

Ookla SpeedTest – "State of Mobile 5G in the UK" (Dec, 2019)

EE leads 5G speeds at the country level

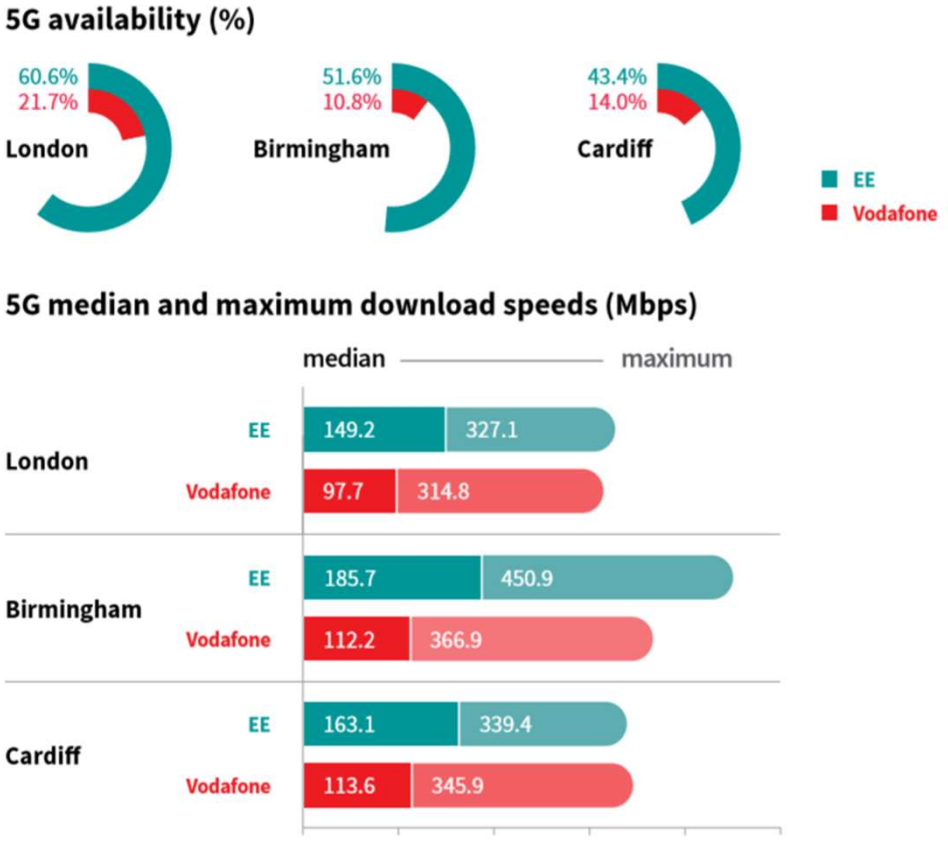
5G Speeds by Operator in the United Kingdom

Speedtest® Results | Q3 2019

Operator	5G Download (Mbps)	5G Upload (Mbps)	5G latency (ms)	5G Top 10% Download (Mbps)	5G Top 10% Upload (Mbps)
EE	205.02	19.17	25	359.66	34.85
O2	159.48	17.28	26	261.32	27.55
Vodafone	140.15	19.36	21	230.57	32.97

https://www.speedtest.net/insights/blog/5g-united-kingdom-2019/

RootMetrics – "5G First Look" (Oct/Nov 19)



http://www.rootmetrics.com/en-GB/home

5G Technology Components

5G Architecture

- Non-Standalone (5G New Radio + 4G Evolved Packet Core)
- Standalone (5G Radio + 5G Next Gen Core)

5G New Radio

- New Spectrum
- M-MIMO / Beamforming
- 10G Backhaul
- Phase Sync

5G Next Gen Core

- Core Network Virtualization
- Distributed Core / Edge Compute
- Network Slicing
- Private Networks

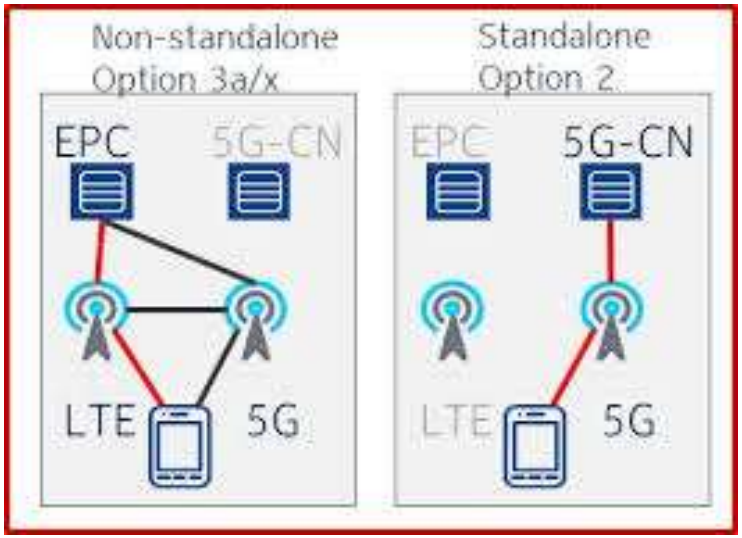
5G NSA (Non-Standalone) vs 5G SA (Standalone)

Almost all operators globally are launching 5G in **NSA (Non-Standalone)** mode, also called Option 3 or Dual Connectivity.

4G & 5G radio bearers are combined.

An upgraded version of the existing 4G Core Network (EPC) is used.

Higher bandwidth is achieved, but latency improvements over 4G are modest and 5G-CN based services are not yet possible.



5G SA (Standalone) mode will come later. Also called Option 2.

5G radio is combined with a new 5G Core Network (5G-CN, also called NGC – Next-Gen Core).

There is no dependency on 4G radio or 4G core (EPC) within 5G coverage areas.

Further reductions in latency are achieved. New services based on 5G-CN are possible.

Other 5G architecture options (Option 4, Option 5, Option 7) have been defined, but their adoption is uncertain at this time.

UK Spectrum Allocations (2G/3G/4G/5G – and WiFi)

Frequency	Primary Technology	Comments
57-71 GHz	Unlicensed	WiGig (802.11ad/ay) + other ISM use
26 GHz	5G (TDD)	Under study by Ofcom, potential auction in 2021 or later.
		Part of this spectrum set aside by Ofcom for Indoor Use Only.
6 GHz	Unlicensed	Future extension of 5 GHz WiFi/ISM band.
5 GHz	Unlicensed	Wireless LAN (WiFi) + other ISM use + 4G LAA
3.8-4.2 GHz	5G (TDD)	Set aside by Ofcom as Locally Licensed Spectrum (where not already used for Satellite, Fixed Links etc).
3.6-3.8 GHz	5G (TDD)	120 MHz to be auctioned by Ofcom in 2020
3.4-3.6 GHz	5G (TDD)	150 MHz auctioned by Ofcom in 2018, basis for UK 5G launch.
2600 MHz	4G (FDD/TDD)	High-band spectrum – used for capacity
2400 MHz	Unlicensed	Wireless LAN (WiFi) + Bluetooth + other ISM (Industrial/Scientific/Medical) use
2300 MHz	4G (TDD)	Includes 10 MHz set aside by Ofcom as Locally Licensed Spectrum
2100 MHz	3G/4G (FDD)	Mid-band spectrum – provides coverage & capacity
1800 MHz	2G/3G/4G (FDD)	Mid-band spectrum – provides coverage & capacity
1400 MHz	SDL	Used for 4G Supplementary Downlink (SDL)
900 MHz	2G/3G/4G (FDD)	Low-band spectrum – used for coverage
800 MHz	4G (FDD)	Low-band spectrum – used for coverage
700 MHz	4G/5G (FDD) + SDL	80 MHz to be auctioned by Ofcom in 2020 (includes 20 MHz of SDL)

Potential future use for 5G (NR-U)

Potential future use for 5G (NR-U)

Eventually re-farmed as 5G ?

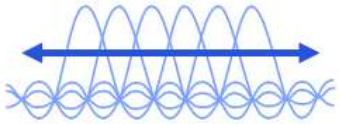
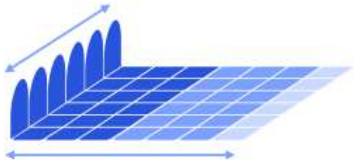
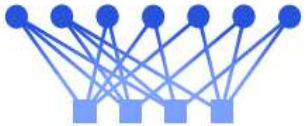
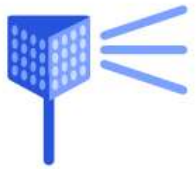
Likely to be re-farmed eventually as 5G

Capacity

Coverage

5G New Radio – Technology Components

Source:
https://www.qualcomm.com/media/documents/files/future-of-5g.pdf

Scalable OFDM-based air interface	Flexible slot-based framework	Advanced channel coding	Massive MIMO	Mobile mmWave
				
Scalable OFDM numerology	Self-contained slot structure	Multi-Edge LDPC and CRC-Aided Polar	Reciprocity-based MU-MIMO	Beamforming and beam-tracking
Address diverse services, spectrum, deployments	Low latency, URLLC, forward compatibility	Support large data blocks, reliable control channel	Large # of antennas to increase coverage/capacity	For extreme capacity and throughput

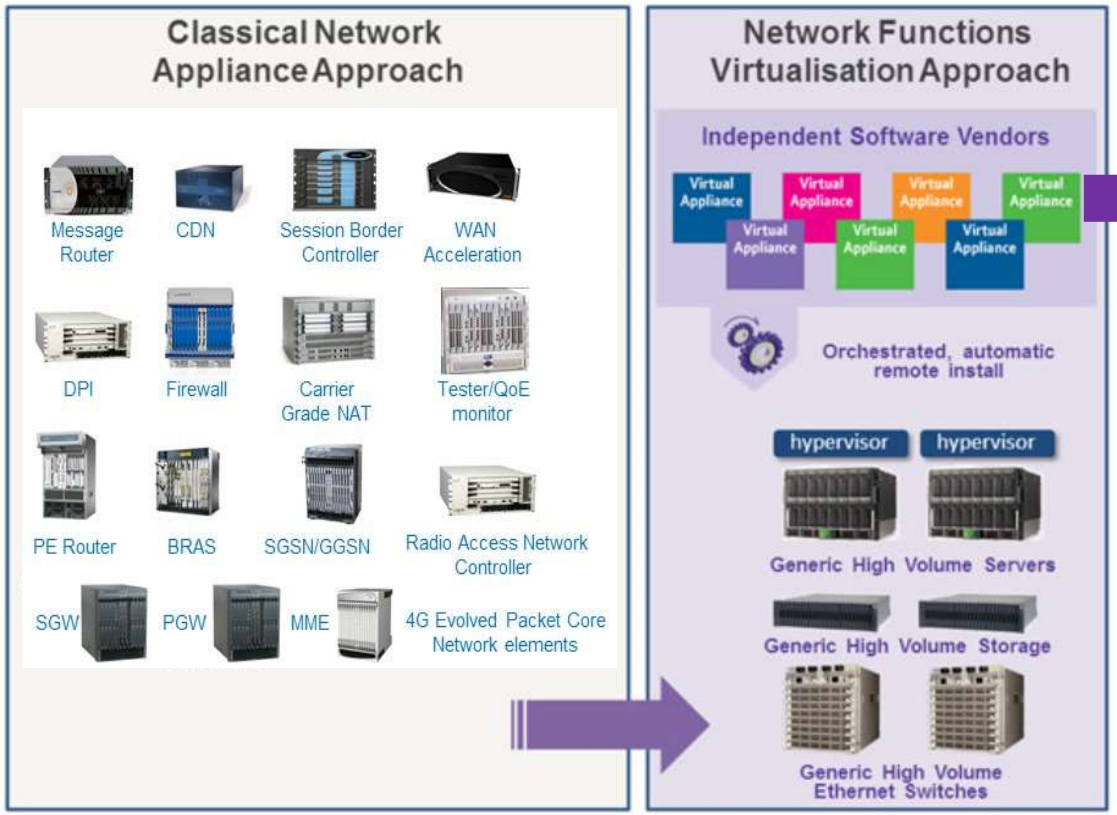
Spatial diversity / spatial multiplexing (e.g. 64T64R "Massive MIMO" antennas) will significantly increase cell capacity in 5G.

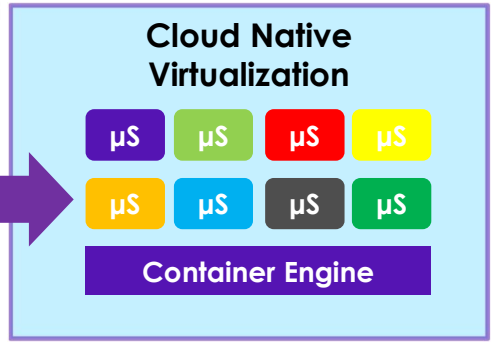
May require tower upgrades due to larger/heavier antennas).

Core Network Virtualization

Increasingly, operators are moving away from appliance-based network functions to "Network Functions Virtualization" (NFV).

5G Core Networks have been designed as "Cloud Native" from day one (this is a further evolution of the NFV concept).





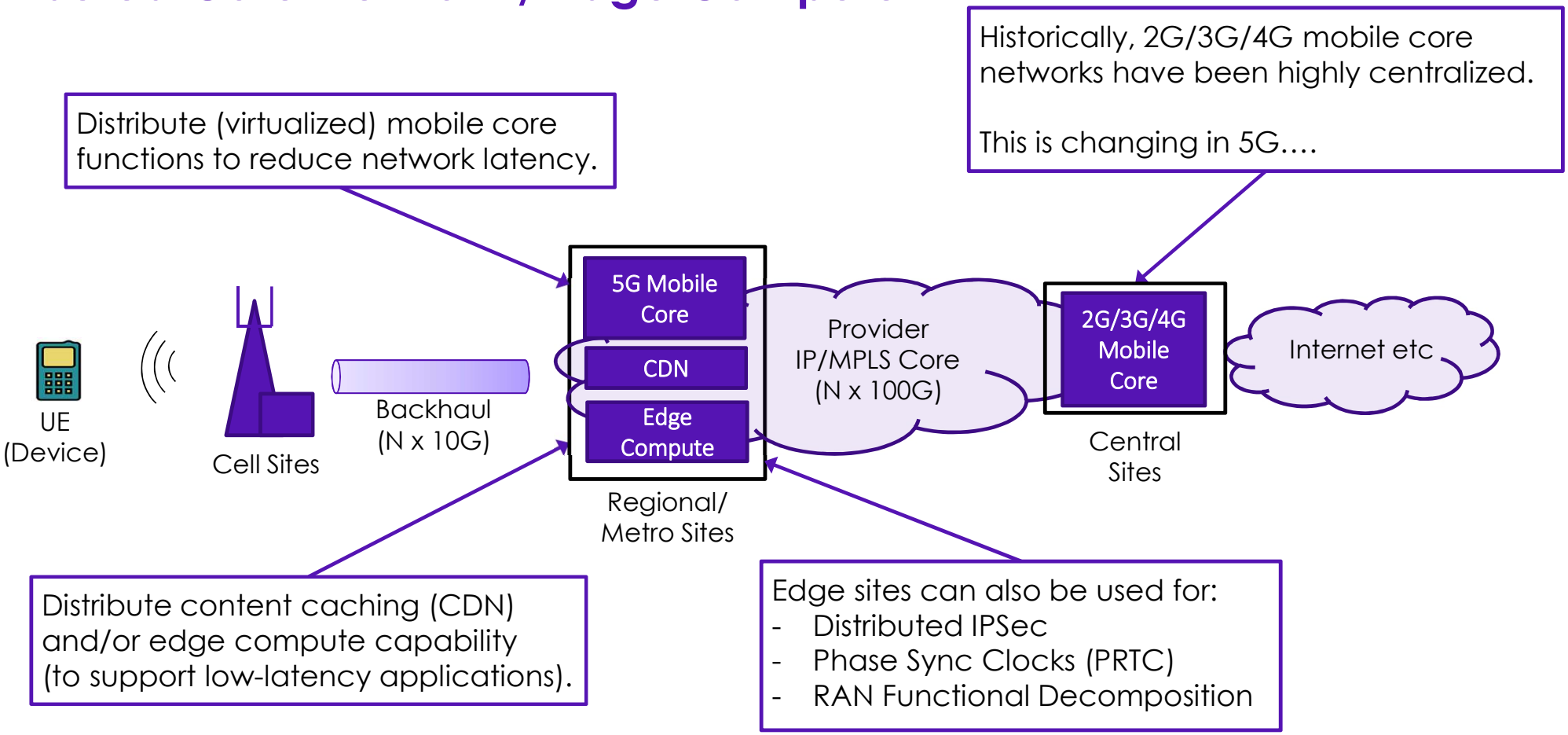
Why Virtualization?

- Lower cost & improved scalability.
- Increased automation, easier to upgrade.
- Easier to distribute network functions.

Why Cloud Native?

- Smaller/re-usable blocks of code in "containers".
- Separately scalable, separately upgradeable.
- Increased agility and resilience.

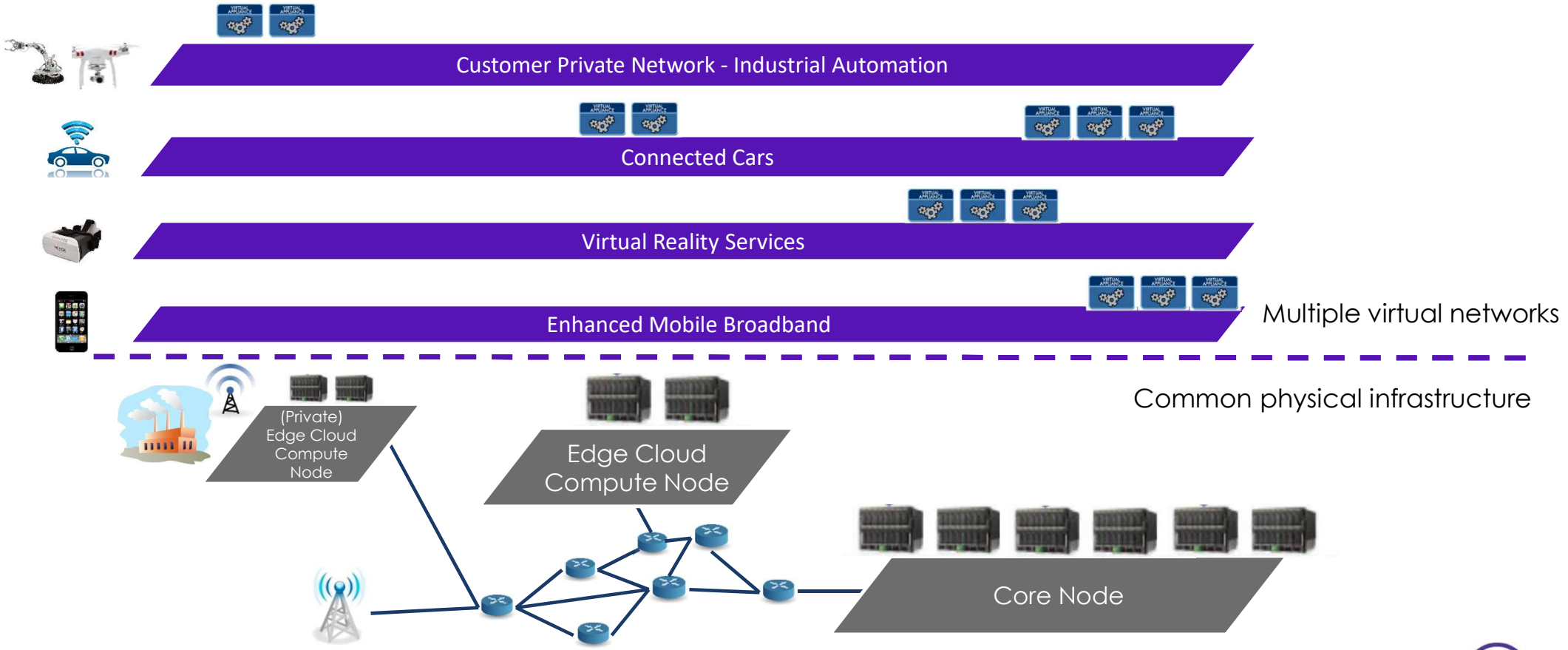
Distributed Core Network / Edge Compute



5G Network Slicing & 5G Private Networks

What are the drivers ?

- Support for different operational models
- Support for conflicting functional requirements
- Traffic Isolation & Data Sovereignty



5G Future Evolution

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https://www.qualcomm.com/media/documents/files/future-of-5g.pdf