



Beyond 5G

Paul Crane

Director

Converged Network Research

BT Applied research

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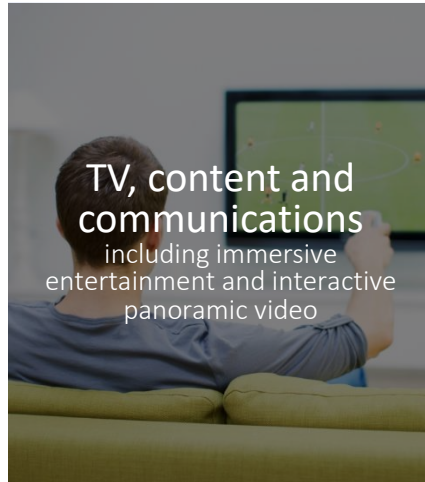
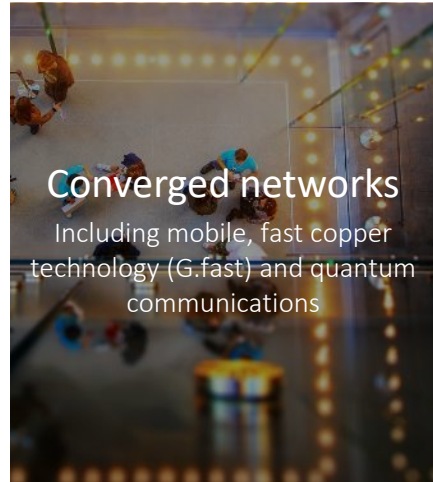


(1) Background

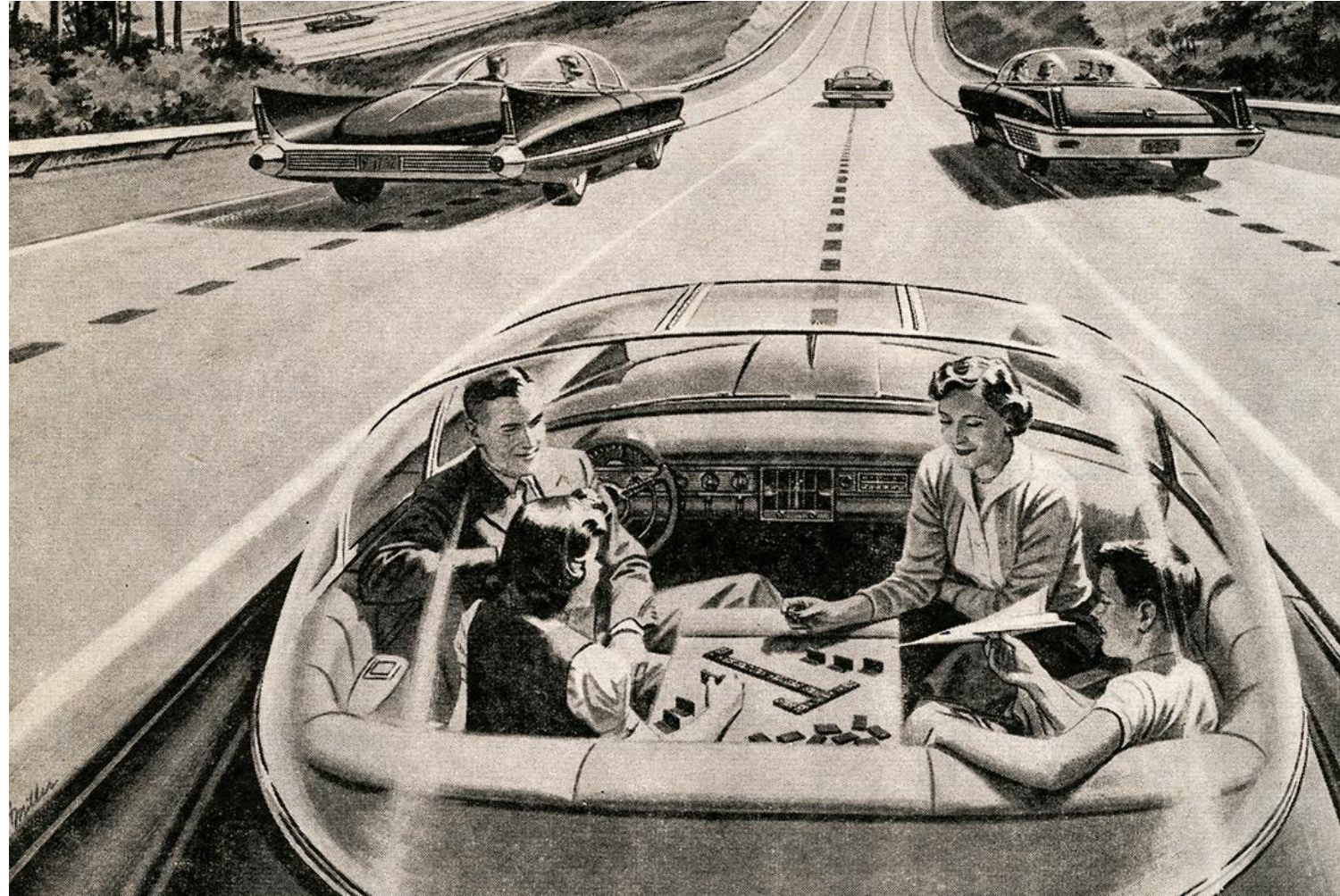
(2) Industry Landscape

(3) Network requirements

BT Applied Research Priorities



From 1957

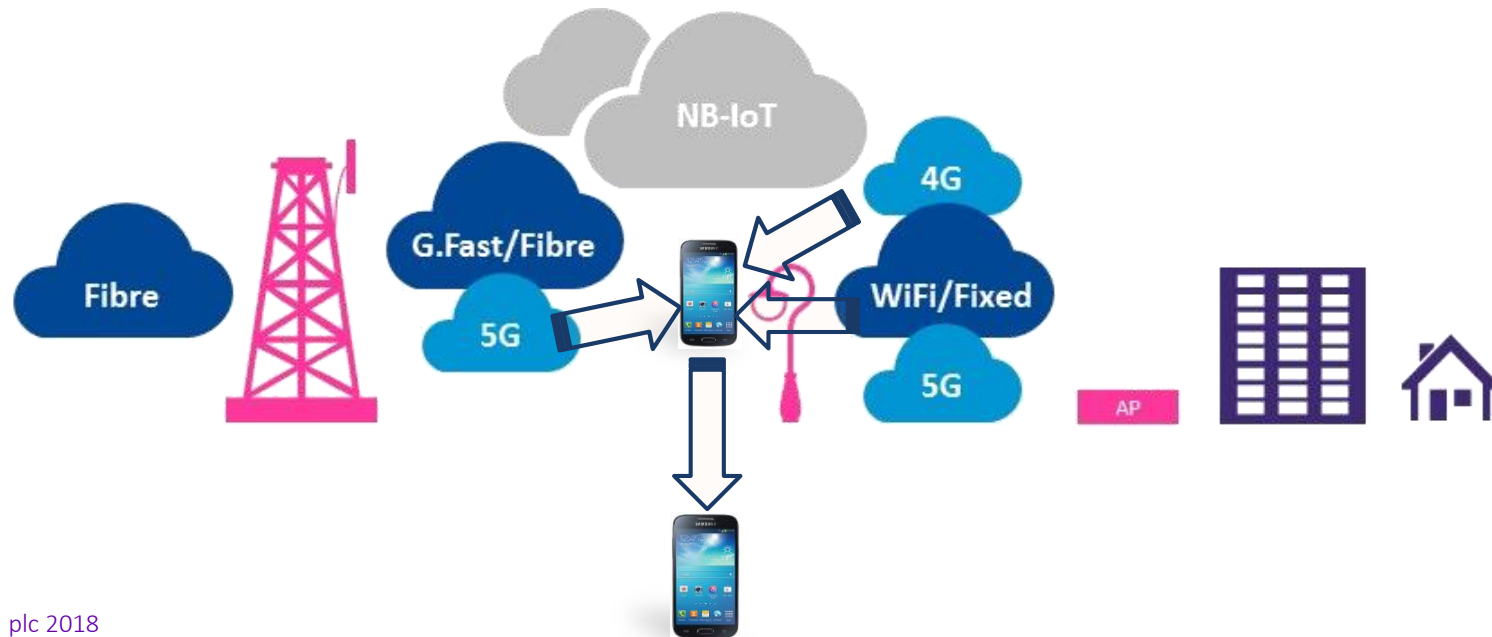
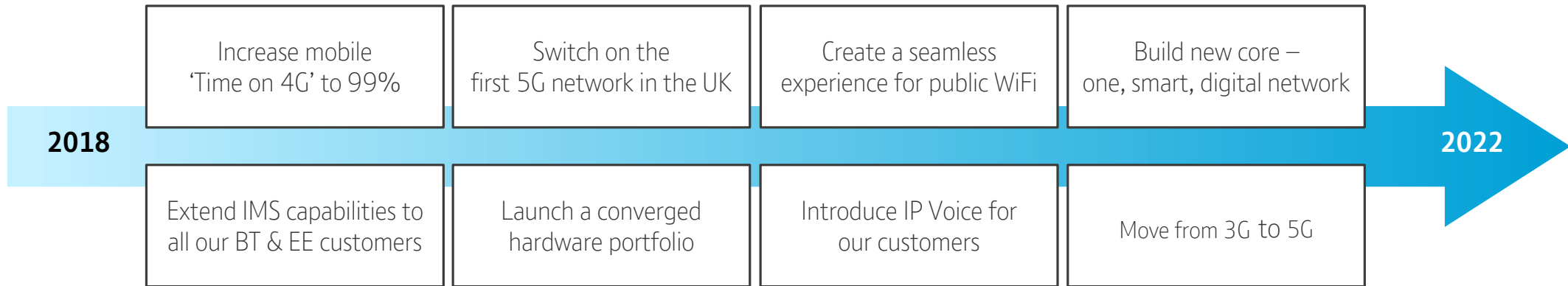


Source: <https://becominghuman.ai/part-i-dont-fasten-your-seatbelts-your-car-is-driverless-aeae86d5b8>



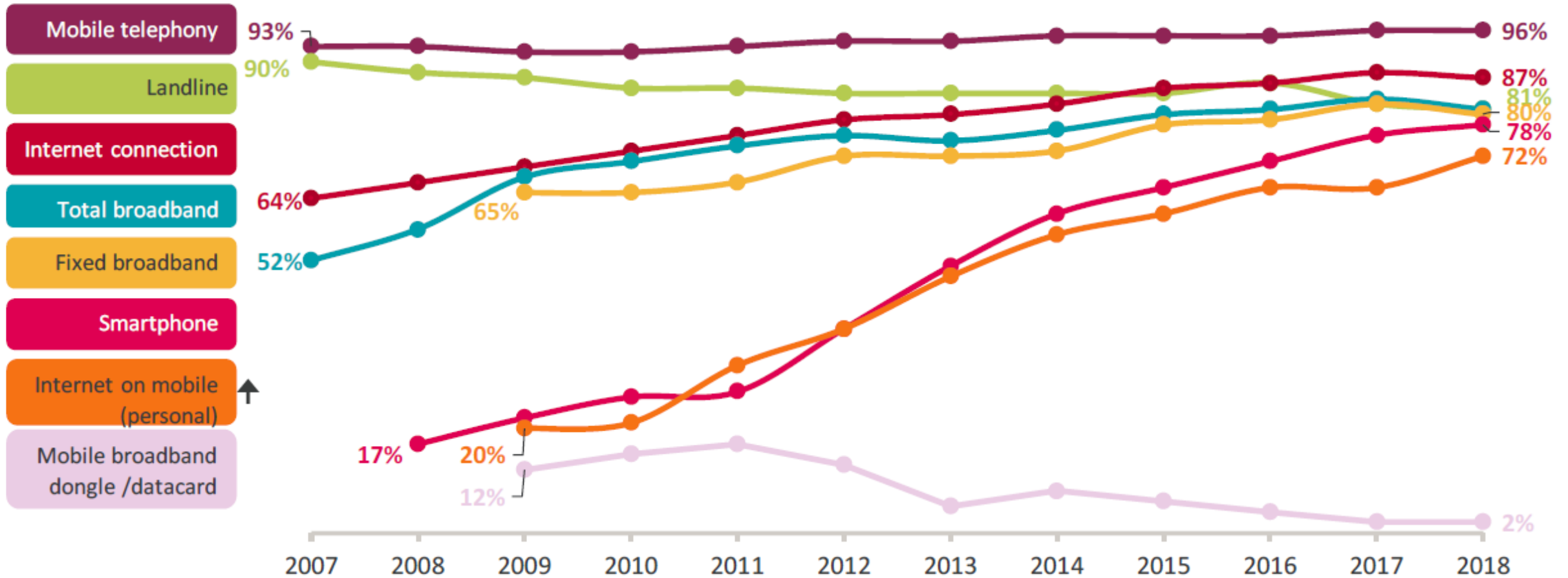
Industry Landscape

Baseline: The journey towards 5G



Industry Economics: A look back at the communications market

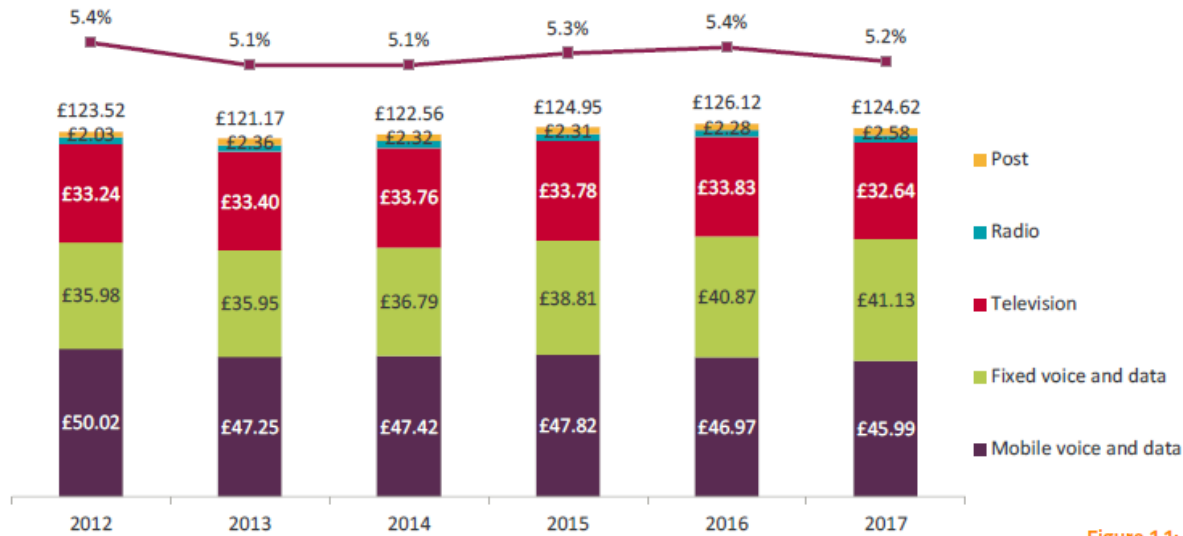
Figure 1.3: Take-up of communications services



Source: Ofcom Technology Tracker. Data from Quarter 1 of each year 2007-2014, then Half 1 2015-2018.

Industry Economics: Very competitive market

Figure 1.2: Average household spend on communications services

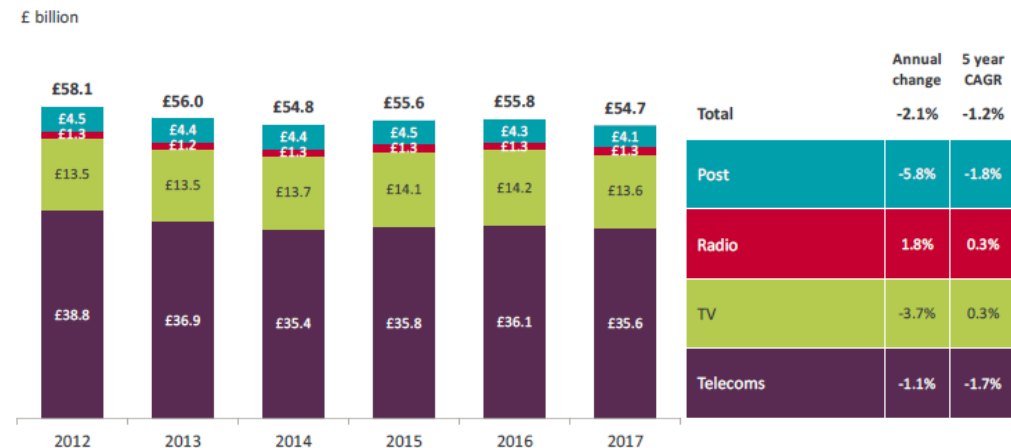


Source: Ofcom / operators / ONS

Total UK communications revenue last year declined to £54.7bn, the lowest level in the last five years

In the UK market, average monthly spend on communications services fell 1.2% in 2016/17

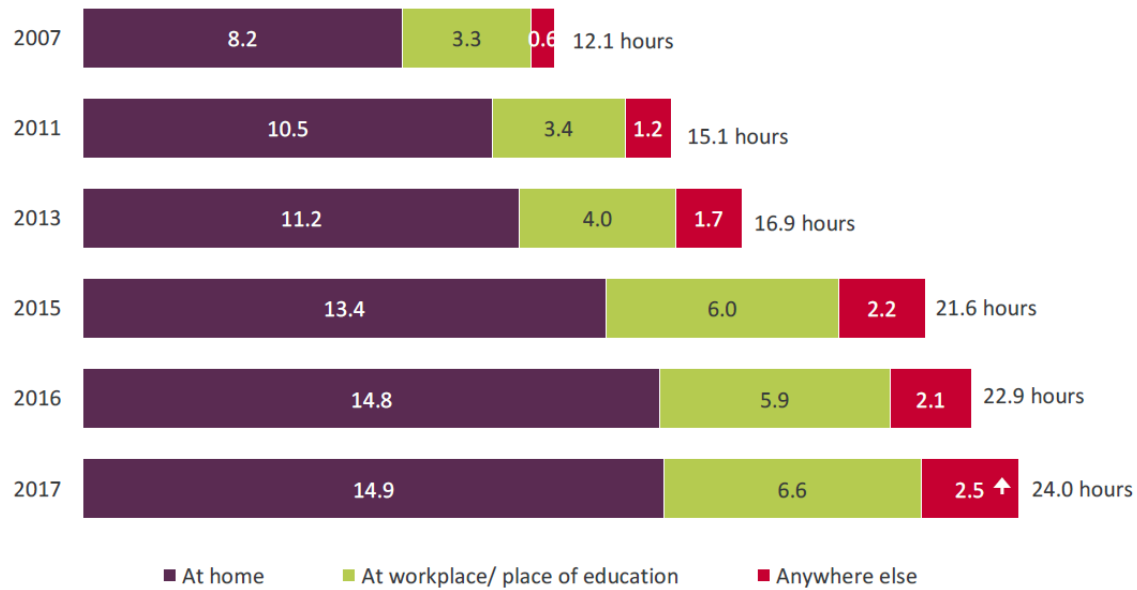
Figure 1.1: Communications industry revenue: telecoms, TV, radio and post (£bn)



Source: Ofcom/ operators.

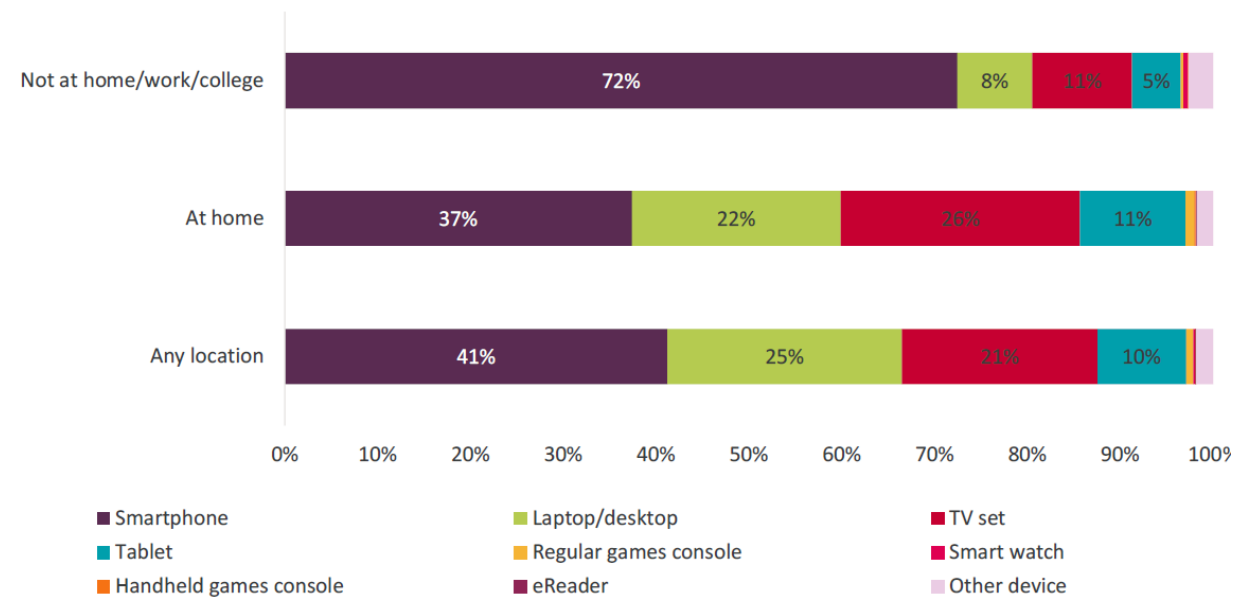
Industry Economics: essential for today's society

Figure 1.6: Claimed time spent going online each week, by location



Source: [Ofcom Adult Media Literacy Tracker 2017](#)

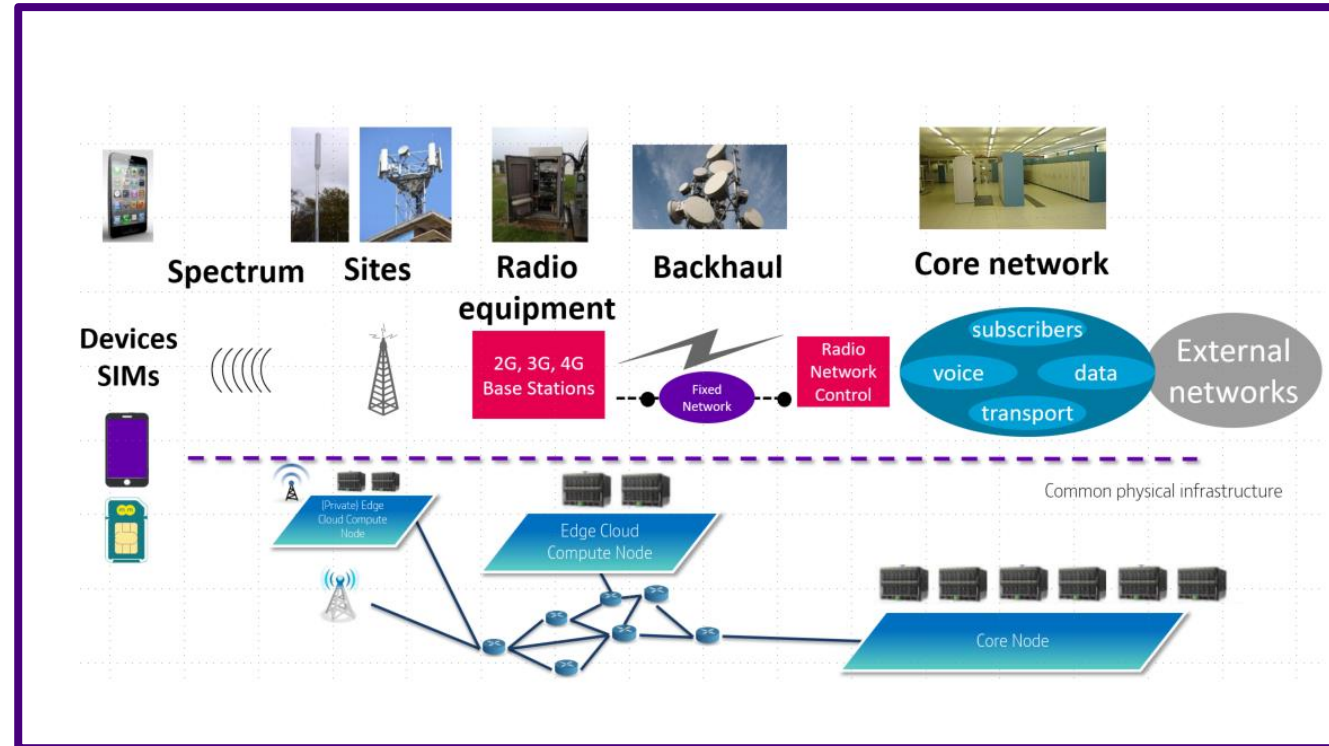
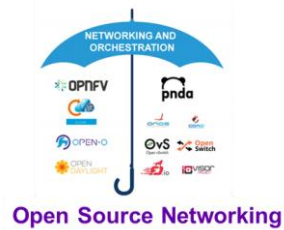
Figure 1.7: Proportion of time spent online, by device and location



Source: TouchPoints 2017

Evolving supply chain

Virtualisation is a very radical change to the way we build networks



What will customers want towards 2030?

5G requirements have so far stood the test of time, except coverage.

Expect to see mission critical becoming more prominent

Expect Ultra low latency to enable new forms of collaboration and entertainment

Towards the 'hyper connected society'?

Enhanced Mobile Broadband – UHD Video, Virtual/Assisted Reality, Interactive gaming, Tactile Internet, Fixed Wireless Access



Mission Critical Machine Type Comms – self/assisted driving, traffic safety and control, industry automation, remote surgery



Massive Machine Type Comms – IoT, Smart Home/Building/Factory/Energy, Smart Agriculture, Logistics, Asset Tracking





Network Requirements

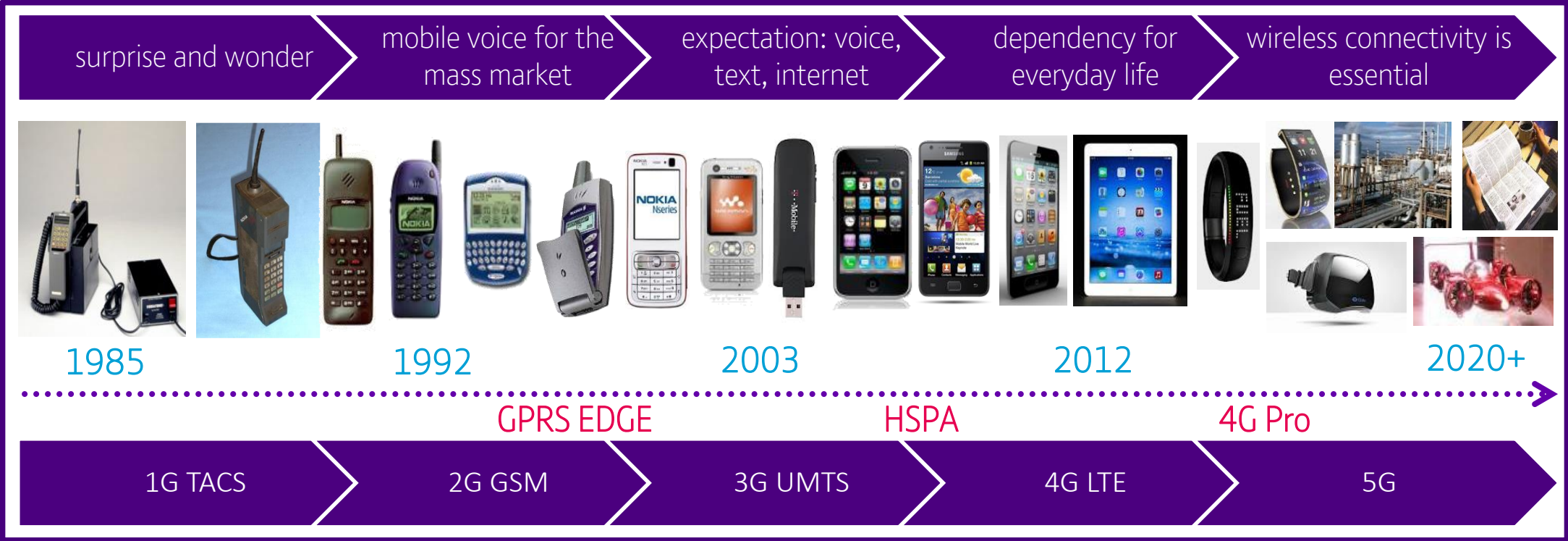
Evolution not generation
Simplification
Capacity
Coverage
Security

Evolution not generation

Standardisation has been core to the success of telecoms and especially mobile

A generational technology change may no longer be sustainable

Industry should focus on enabling an evolutionary change



Wi-Fi Evolution with Backwards Compatibility

Wi-Fi avoids spectrum re-farming by ensuring that all generations of Wi-Fi technology can co-exist with each other in the same spectrum.

This means that as new Wi-Fi technologies are introduced, the proportion of traffic of the legacy generation will gradually decline as the prevalence of new devices increases.

In the transition period, however, any client of any generation can still communicate with any access point of any generation.

There is no switch-over day, nor any requirement to reserve greenfield spectrum for the new technology.

Requiring that all new devices can send and receive transmissions from all previous generations.

Standard	Channel	Modulation	Channel BW (MHz)	MIMO
802.11b	2.4GHz only	DSSS	22	No
802.11g	2.4GHz only	OFDM 64 QAM	20	No
802.11n (Wi-Fi 4)	2.4GHz and 5GHz	OFDM 64 QAM	20, 40	4 SU
802.11ac (Wi-Fi 5)	5GHz only	OFDM 256 QAM	20, 40, 80, 160	8 MU
802.11ax (Wi-Fi 6)	2.4GHz and 5GHz	OFDMA 1024 QAM	20, 40, 80, 160	8 MU

Evolution will not be challenge free

Wi-Fi Backwards Compatibility – Pros and Cons

Pros	Cons
<ul style="list-style-type: none">• Old devices do not become obsolete – the earliest Wi-Fi device can talk to the latest.• No need to allocate greenfield spectrum to the latest deployment, nor to “refarm” old allocations.	<ul style="list-style-type: none">• Greater complexity in transceiver design – new transceivers are supersets of older ones.• Can result in lower efficiency use of spectrum than would be possible with a greenfield approach.• Does not promote the replacement of out-of-date, inefficient equipment.

How do we make future mobile networks backwardly compatible?

Coverage

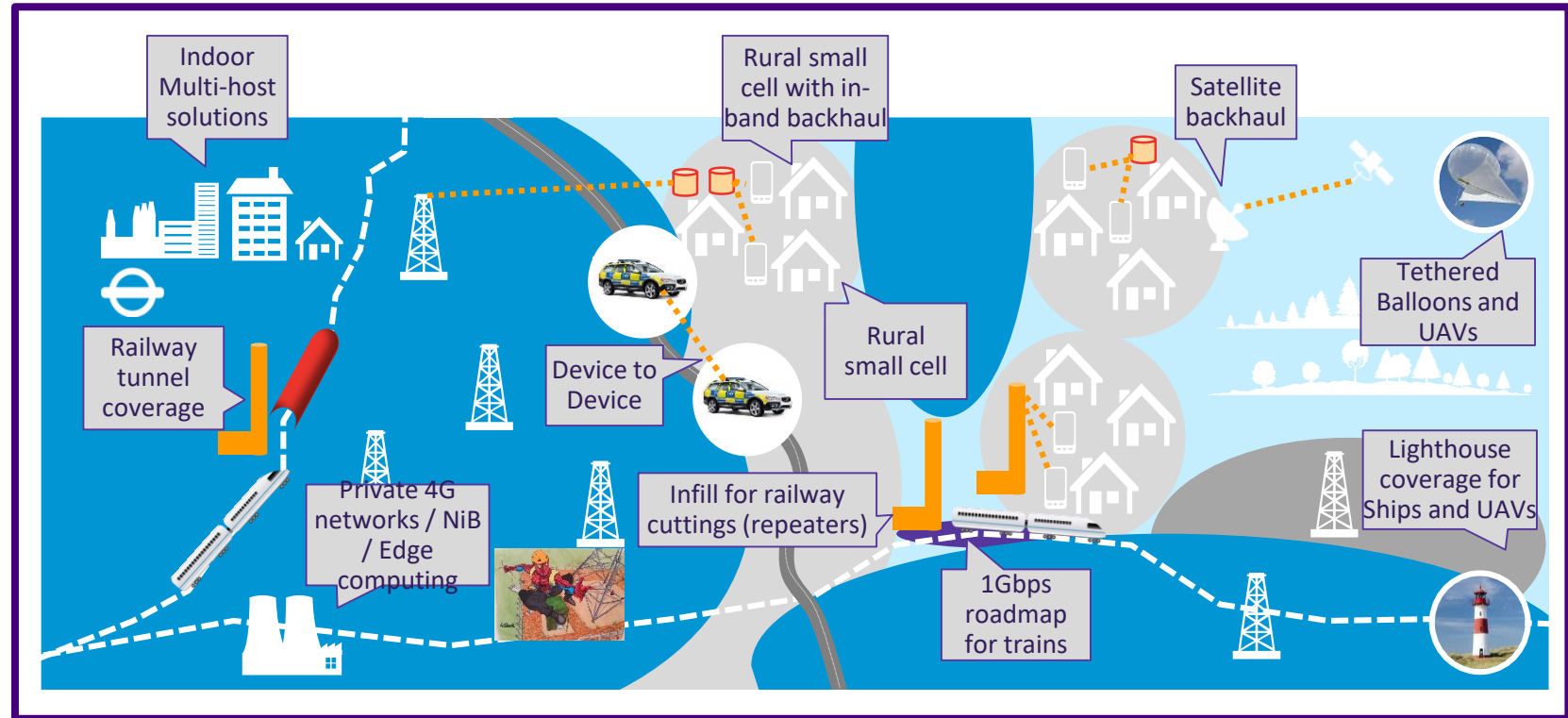
Missing driver for 5G, we must void future rural / urban digital divide

Some industry activity innovating economic solutions

What else can be done?



TELECOM INFRA PROJECT



Achieving capacity growth

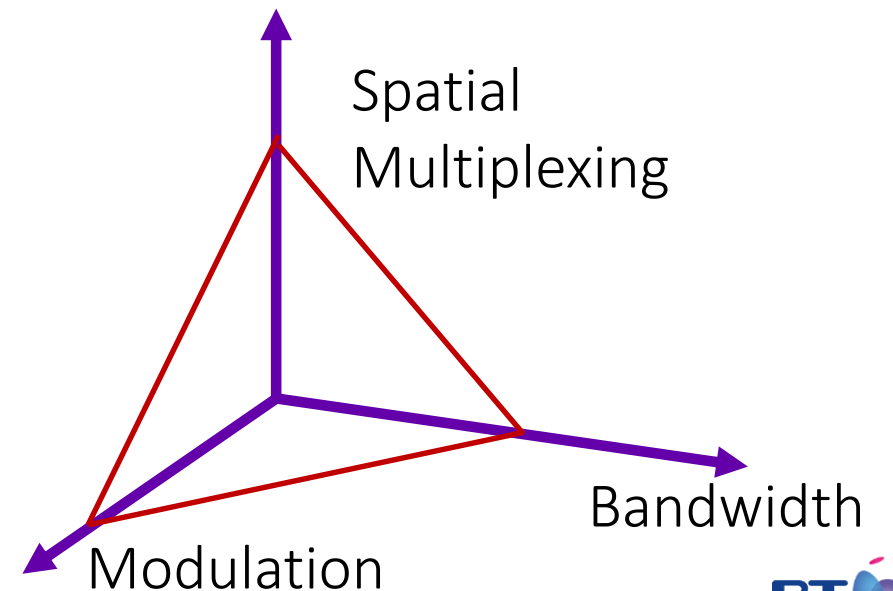
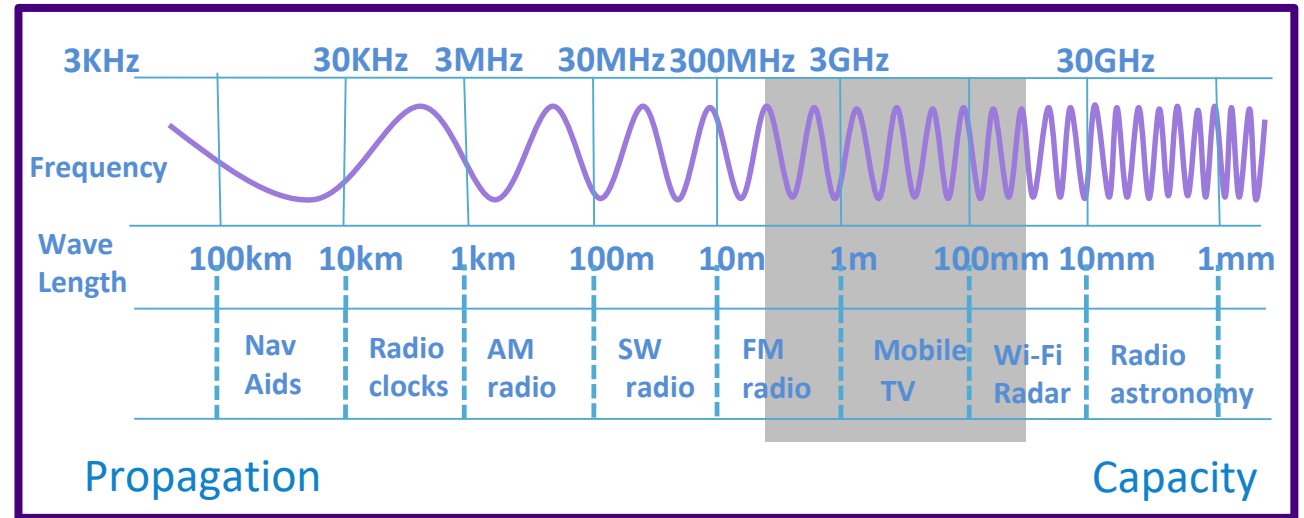
Use more spectrum – expensive or difficult to use in a mobile system

Building more sites - expensive

Increase modulation rates
– near Shannon limit for current technology?

Spatial multiplexing – M-MIMO demonstrates massive potential

How much capacity can we achieve in sub 6GHz mobile spectrum?



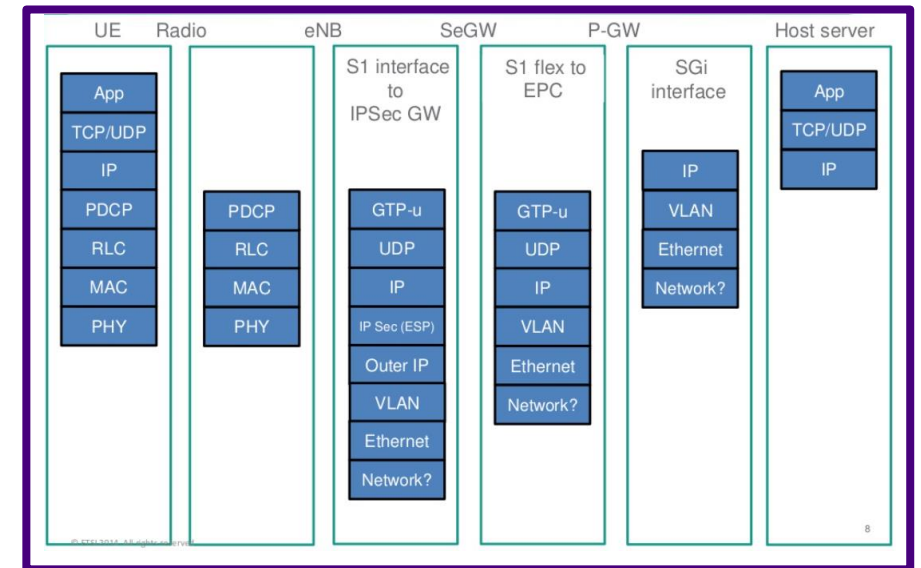
Simplification

Networks today are highly structured to make them understandable, predictable and manageable by people.

Complexity introduced to solve specific problems.

Self Organising Networks, AI/ML, web scale technologies and autonomies will remove the constraints of human understanding and structure, resulting in a network that is paradoxically simpler, more efficient & agile.

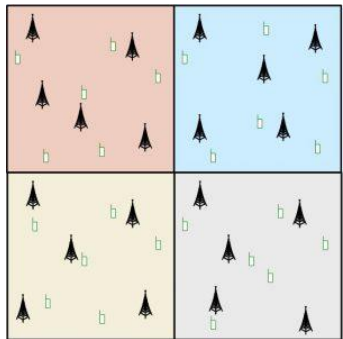
Can AI transform how we construct networks?



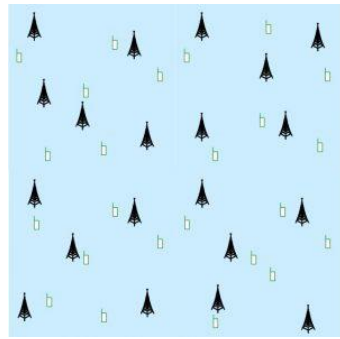
Physical Simplification

Advances in electronics, signal processing and compute infrastructure gives us the opportunity to revisit some basic assumptions about how networks are built

Cell-less mobile

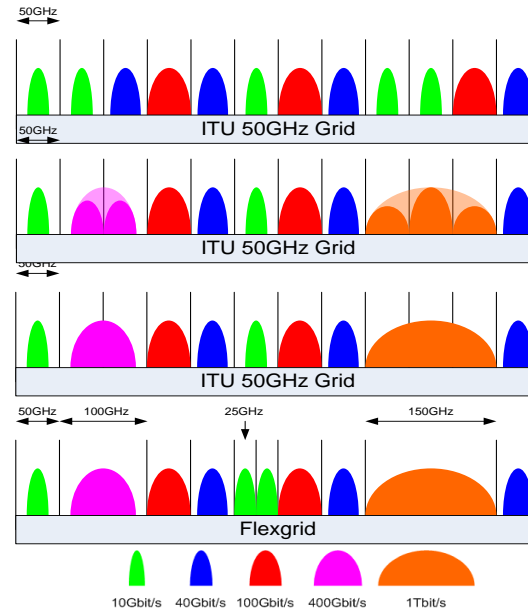


Distributed Massive MIMO



Cell-Free Massive MIMO

Grid-less Optical



Server-less networks



Security & Trust

Wireless systems are increasingly critical and new threats are inevitable

Security by design:

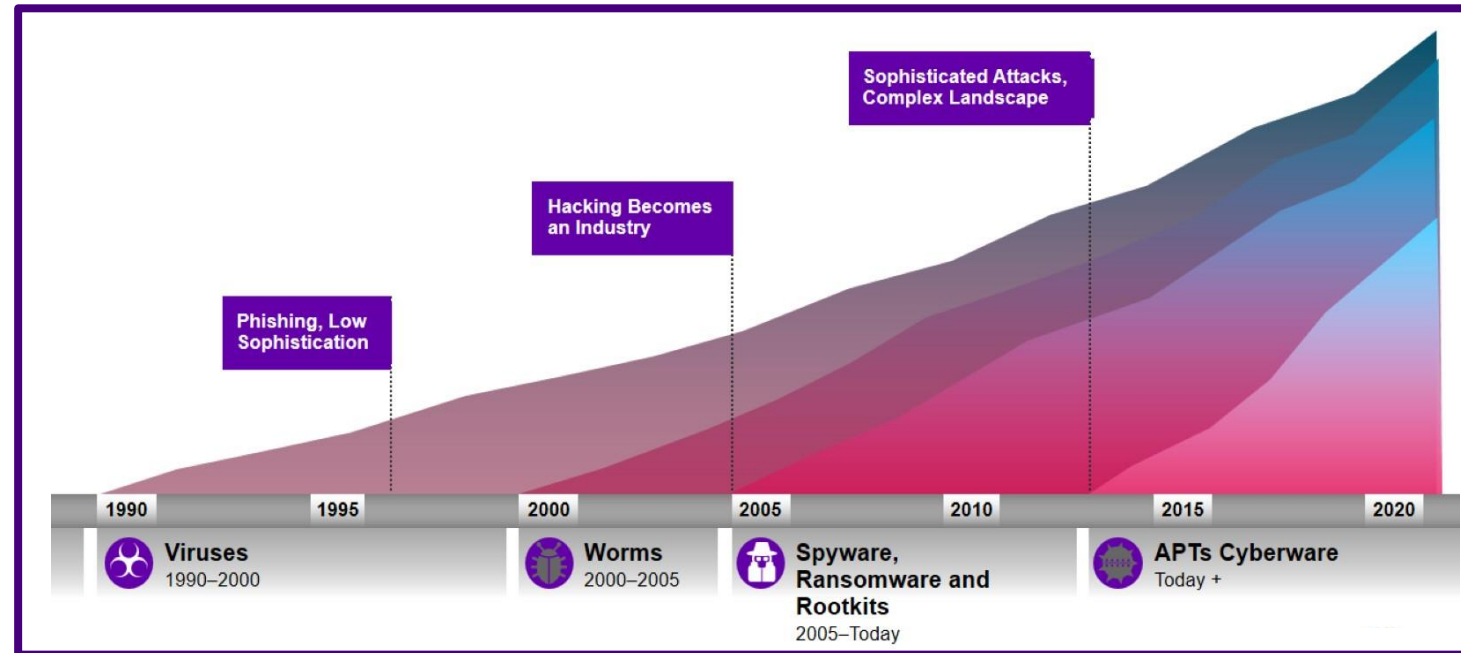
Wireless denial of service resilience

Protocol Attack

Spoofing

Eavesdropping

Prepare for Quantum Computing?



Summary

Evolution not generation

Simplification

Coverage

Security

Capacity

