Future Communications Challenge Group (FCCG)

UK strategy and plan for 5G & Digitisation - driving economic growth and productivity

January 2017 Interim report

Report abstract

5G will provide revolutionary new technologies to manage a seamless evolution in network, mobile and wireless services to deliver significant opportunities for new business models, enhanced lifestyles and increased productivity. It is intended to support an exponential increase in mobile data demand and expectations, significant video communications growth, the full realisation of the IoT (internet of things) and the varying needs of different vertical industries, such as Creative Industries, Retail, Transport and Health as part of a much broader UK digital economy.

5G needs to be a collaborative effort in order to enable development of seamless services using common approaches to benefit all of industry, academia and society. So an unprecedented degree of collaboration across industries, government departments and independent bodies will be required. The UK has a strong track record and 'DNA' in collaborative working across diverse teams and has a real chance to show leadership in this space.

This report, generated by the FCCG, requests Government to use the funding announced in the Autumn Statement to fund 5G activities to provide the catalyst for the UK to improve our national infrastructure and services from transport to healthcare, from education to entertainment - with improved broadband to help local businesses grow and create more jobs and opportunities and the large scale, low delay, highly reliable services to deliver the IoT. It will ensure that the UK seizes the real chance to be a world leader in the development of 5G, playing a key role in defining industry standards to support an estimated 5 to 6% of UK GDP per annum.

Contents

1 Executive summary

The FCCG is a group, comprising academia, industry and independent advisors (Appendix 7.4), that was asked by DCMS to provide advice to Government on what the UK should do to maximise its chance to be a world leader in the development of 5G.

Although still not fully developed, it is likely that 5G will provide revolutionary new technologies to manage a seamless evolution in network, mobile and wireless services. This will deliver significant opportunities for new business models, enhanced lifestyles and increased productivity. 5G is being designed to deliver: enhanced mobile broadband; ultra-reliable and low latency services; large scale machine-to-machine communications; and the full realisation of the Internet of Things (IoT). It will provide new access technologies, core network architectures and interoperable interfaces to allow the development of seamless services. In essence, 5G should be viewed as a 'system of systems', bringing together Mobile (existing 3G, 4G and its next advances), Fixed (e.g. WiFi) and Broadcast networks. It is therefore something more than mobile, with an aim of bringing together all communications assets into a seamless connectivity experience, giving the impression of ubiquitous coverage and unlimited capacity. This will support an exponential increase in mobile data demand, significant video communications growth, and the varying needs of different vertical industries, such as Creative Industries, Retail, Transport and Health as part of a much broader UK digital economy.

Delivering ubiquitous, reliable connectivity across the UK will bring social and economic benefits - our communications infrastructure is critical for businesses and individuals across the UK. Although it is likely that market forces will eventually deliver this infrastructure for the UK, there is an opportunity to accelerate this deployment and realise the many benefits years sooner. Being at the forefront of the development of 5G also offers opportunities for the UK in terms of attracting inward investment as well as export opportunities for UK companies. Other territories such as China and Korea are investing heavily in their 5G programmes. Even the US, which has tended to allow the market to drive the infrastructure, is also investing to increase the pace of change. In Europe, Commissioner Oettinger has stated that he believes Europe needs to invest $800bn[1] in its digital infrastructure to catch up with US and China. Whilst this investment would be much wider than just 5G, it is indicative of the sense of urgency and opportunity worldwide. This report is proposing that the Government should fund a major programme of 5G development and deployment activities to ensure that the UK can remain a key player on the global communications stage as well as bringing significant benefits to society and the economy from education to transport, from healthcare to entertainment.

However, it is important to note that 5G does not yet exist. It is still in the research and early standardisation phase. There is significant opportunity for the UK to drive research and development activity through early implementation and beyond. The UK can leverage its proven track record in security, creative industries and eCommerce - all critical to the success of both 5G and the IoT. The UK also has strengths in end to end systems implementation including innovative, cross sector solutions. The UK is therefore well placed to show leadership in this space where so much collaboration, innovation, joined-up working is needed.

[1] EU: Europe needs to invest $800bn in digital infrastructure to catch up with US https://www.theguardian.com/technology/2016/sep/01/eu-europe-800-billion-digital-infrastructure-investment

There are a large number of use cases that are possible for 5G across many verticals – bringing these to reality in the short, medium or long term will require R&D, tests and trials to generate demand, collaboration across industries and internationally and the right regulatory and skills environment. This is partly due to the international and scale nature of 5G. The Government and policy-makers should focus on creating the very best conditions for research, development and infrastructure investment and allow the innovative applications that will run off 5G to develop and flourish. In turn, industry, SMEs and academia need to work collaboratively to focus research in the right areas and drive forward innovation.

The potential positive economic impact from 5G to the Mobile industry alone is considerable. However, the larger opportunity is for the wider UK economy through productivity and efficiency improvements across all sectors. The GSMA estimates Mobile's contribution to the global economy will be worth $3.9tn[2], 4.2% of global GDP by 2020, of which only 1% is attributed to the Mobile sector. 3.2% of this benefit will to the general economy, in particular from productivity improvements. Based on this analysis the UK GDP impact of Mobile would be £112bn in 2020, growing to £198bn per annum by 2030 (extrapolated to 2030 using trends forecasted from 2014 to 2020), see sections 3.4 and 7.3 for further details of model and assumptions. While this figure assumes that the UK is leading technology development and deployment of 5G, our current trajectory suggests that the economic impact could be reduced to around £112bn in 2020, growing to £164bn in 2030. Therefore not acting to ensure UK leadership in 5G would result in losing opportunity to create £173bn of incremental GDP over 10 years, 2020 to 2030.

Mobile impact to UK economy opportunity, £198bn per annum by 2030, 5.7% of UK GDP

UK leadership, enabled through report recommendations, estimated to generate £173bn of incremental GDP over 10 year period from 2020 to 2030

At Autumn Statement 2016, the Government announced £1bn of new funding to boost the UK's digital infrastructure, including funding for a new programme of 5G and fibre trials. The Government has committed to set out more detail on this programme at Budget 2017, alongside a new 5G strategy. The FCCG believes that this funding, as well as the 5G strategy, should develop and support UK ICT leadership potential, skills, knowledge and strengths and signal the UK's ambition and direction of travel, including the adoption of the following areas of strategic intent:

- Leverage UK strengths in system integration and security to address 5G Fabric[3] opportunity:
    - Common Information Platform[4] for all sectors / verticals, including eCommerce and Video convergence.

Leverage unique UK strengths: R&D capability, security and End to End solution / system innovation.

[2] GSMA report source http://gsmamobileeconomy.com/global/GSMA_Global_Mobile_Economy_Report_2015.pdf

[3] 5G Fabric – term developed by the FCCG to describe the UK opportunity and proposition to connect multiple Networks and / or Services using common approaches and interfaces across different networks and boundaries. This will enable a common eco-system for all developers, users and network owners / operators.

[4] Common Information Platform – ambition to define approach for multiple networks, data owners and end use vertical industries to adopt common approach to interoperable solutions.

- Network Management (end to end management and orchestration)[5] with security by design
- Establish collaborative approach to foster innovation, maximising full UK R&D capability to deliver the potential benefits of ubiquitous connectivity and next generation services

- Adopt phased approach described in this document (see Table 1 - Strategy, four phases from research to commercialisation) with a goal to:
  - Create 5G end to end trial by Q1 2018.
  - Provide a catalyst for the development of technologies and early realisation of the benefits of 5G.
  - Open up opportunities for wider Micro and SME involvement which is critical for UK success.

Create test bed(s) to facilitate End to End trial(s) by Q1 2018 with longer term plan committed to 2030

- Create and implement a long term plan (2017 to 2030) for test beds and trials to adopt and deploy 5G in multiple sectors / verticals to enable common approaches and cross vertical interoperability / internetworking:
  - Creating significant economic productivity improvements in: Transport, Health & Social Care, Finance & Business Services, Smart Cities / Living, Creative Industries and eCommerce.
  - The long-term plan will identify that economic and productivity improvements are critically dependent on effective security to underpin the interoperability and internetworking techniques.

Use test beds and trials to engage and deploy 5G in multiple sectors and facilitate Micro and SME company engagement

- Establish a 5G implementation advisory board to monitor and advise on progress. This needs to include expertise on all identified phases (see Table 1 - Strategy, four phases from research to commercialisation), international benchmarking and wider ICT developments.

Establish 5G implementation advisory and steering board

- 5G standardisation is progressing through the ETSI 3GPP process. Additional funding and co-ordination would allow the strengthening of UK technical capability, wider outreach to SME's, leadership, and collaboration with the key driving applications and associated standards bodies.

Establish UK 5G Standards activity and international bridges to drive global adoption.

- Develop strong business cases for investment – whilst this is an issue predominantly for commercial entities, the public sector, as a hugely significant procurer and user, could play an important role as early adopters or anchor tenants of 5G-based services to help create

[5] Network Management, end to end management and orchestration – ability to manage network hardware and software and to supervise the individual components of a network within a larger network management framework and/or eco-system.

accelerated progress. A "Digital first" procurement policy should be applied to major capital projects with the support of the National Infrastructure Commission (NIC)[6].

    - Identify UK flagship projects, for delivery in the 2018 to 2020 timeframe, to provide focus and motivation for getting the strategy and funding in place.

- Improving the economics of network investment – given the infrastructure requirements and the roll-out challenges currently faced, this should be a major focus for legislation and regulatory activity.

- Continue to build UK technology capability and leadership – 5G research activity in Europe is strongly linked to the EU Horizon 2020 research programme, it is essential that a clear position is communicated on what funding will be available after the UK leaves the EU and how the UK will continue to engage in these international collaborative projects.

- Ensuring a supportive pro investment and pro innovation regulatory environment - to minimise the regulatory burden on operators and to free up investment for new 5G services and the generation of reasonable returns.

- Enabling Spectrum availability – 5G will require access to large bandwidths. Over time, 5G will probably be deployed in a mix of frequencies new to mobile use and frequencies re-farmed from the retirement of 2G and 3G. However, in order to enable the early launch of 5G operators will need early access to new, European or internationally harmonised Spectrum.

- New skills creation, critical for future UK competiveness and security:
    - ICT Research and Development community, having the skills and expertise to develop and understand the critical infrastructure and new technology derived from 5G.
    - Create new engineering talent pipeline to design future technology beyond 5G.
    - Security and safety, in-depth 5G knowledge required to ensure we have control and understanding to manage networks and protect users in a safe and secure way.
    - Increase UK competiveness across entire eco-system. End users working in all sectors leveraging advanced infrastructure and capability enabled through 5G.

[6] NIC National Infrastructure Commission https://www.gov.uk/government/organisations/national-infrastructure-commission

1.1 Key actions and recommendations

To execute plan and achieve above intent the FCCG recommend the following:

No.	Area	Recommendation	Section	Page No.
1	Government Funding R&D and Test Beds	Government should focus investment in three areas: **i) ICT Research and Development** – Government to assess current spend and impact in delivering its 5G manifesto commitment.[7] Optimise spend to provide a stronger technology pipeline, generate demand, create the skills base, standards capability and global linkages. ii) **Test Beds and Trials** Initial goal / key milestone - 5G end to end trial by Q1 2018. Government to invest in test beds and trials focused on UK system integration strengths applied to key socio-economic challenges, key sectors or "verticals", and pragmatic use cases. Investment to be made in areas to augment and leverage ICT Research and Development working with industry. Investment decisions will explicitly favour proposals where effective and coherent security is demonstrated in test-bed and trial design. Outputs of work to inform early deployment and infrastructure - National Infrastructure Commission (NIC) report, see Appendix 7.1 iii) **Create Steering Group, Standards and Knowledge Dissemination activity** for R&D, test beds, trials, SME & Micro engagement and associated Standards work, and ongoing advice on international benchmarking and deployment. The new group should be set up initially to implement collaborative showcases, knowledge exchange, dissemination, co-ordination and resulting standards work. See Appendix 7.2 All funding to be aligned across Government funding agencies to ensure synchronisation of criteria, objectives and timing.	3	12

[7] Conservative Manifesto, Page 14 - Improving our trains, roads and broadband helps local businesses grow and create more jobs and opportunities and Page 15 - We will ensure that Britain seizes the chance to be a world leader in the development of 5G, playing a key role in defining industry standards. Source: https://s3-eu-west-1.amazonaws.com/manifesto2015/ConservativeManifesto2015.pdf

No.	Area	Recommendation	Section	Page No.
2	International development and Test Beds	Government should encourage and strengthen the UK / international Science bridges to leading 5G nations for collaborative R&D, Test Beds / Trials, Standards alignment and collaboration into international forums. Targets: China, South Korea, Japan, USA and Europe. This is important for shared costs, maximising economies of scale and future collaboration / export opportunities. This will require leadership by the Department for International Trade (DIT) working with Foreign & Commonwealth Office (FCO) and the Science Innovation Network (SIN) with steering linkage from new body detailed in recommendation 1iii) and Section 7.2.	3.1.4	19
3	Procurement and Digital first implementation	Government to work on encouraging energy efficient and resilient solutions (based on specific use cases), from R&D funding through to local / national procurement. Provide industry direction / procurement signals: A “digital first” Government strategy declaration linked to public funded capital projects would be a desirable goal.	3.2.3	24
4	Policy	Government should assess how 5G adoption can support and deliver core Government policy and associated socio-economic challenges and opportunities across sectors such as: Creative Industries, Transport, Business, Health, Utilities, Manufacturing and Smart Cities. Each Government Department needs to signal the move towards digital operation through policy and procurement and implement strategies to address common approaches and linkage across these vertical sectors, underpinned by a coherent security strategy.	3.3	25
5	Transport and Smart City trials / demonstrators	Explore, through 5G test beds and trials, models to provide coverage alongside roads and rail lines. Link with Smart Cities projects in densely populated areas. Assess the impact to the UK coverage and relative contributions, for fixed and mobile broadband, leveraging public / private partnerships.	3.3	28
6	Policies for investment and deployment	Government should assess whether current plans to simplify or remove requirements for base station deployment planning permission go far enough to support effective 5G deployment. Progress should be accelerated in opening up access to public owned buildings and infrastructure and should consider specific rights to access public infrastructure (e.g. similar to those proposed by ARCEP in France - see Spectrum section 5). Policy should focus on ensuring that access to backhaul AND site locations are open, streamlined and more cost-effective. This is inhibiting investment roll out today.	4	31

No.	Area	Recommendation	Section	Page No.
7	Spectrum strategy and deployment	Government should, as part of its planned strategy for 2017, consider with Ofcom how relevant Spectrum can be brought into use to enable early and rapid deployment of 5G in the UK. This should be consistent with European harmonisation, including 700MHz and 3.4-3.8GHz and support the identification of new globally harmonised Spectrum above 24GHz at WRC-19. Explore potential to access 3.8-4.2GHz range on a shared basis as an extension to adjacent 3.4-3.8GHz Spectrum and promote this in Europe. Longer term strategies for WRC and UK Spectrum needs, should be agreed with the UK Spectrum Policy Forum.	5	34
8	Spectrum and Test Beds	Ofcom should make available on request Spectrum for test beds and trials which have the potential to lead to early deployment and longer term commercialisation. Spectrum recommended for test/trials is follows: Low 700MHz, Mid 3.4 to 4.2 GHz and appropriate High frequency Spectrum in line with European RSPG recommendations and opportunities for global exploitation.	5	35

2 Introduction

5G will provide a set of new revolutionary technologies working alongside existing networks to enable a practical evolution to a far more powerful wireless infrastructure seamlessly integrated across next generation core networks and fibre backbones - delivering massive connectivity, lower and predictable latency, faster data speeds and smarter use of Spectrum, energy and network resources, providing:

1. Higher Speed Broadband (e.g. leading to better video facilities)
2. Increased network Availability, Capacity & Coverage (e.g. leading to better, more consistent internet experience)
3. Eco-system and technology to address Massive / Critical Internet of Things applications

The capability of the new eco-system including 5G will provide the platform for new and enhanced services to be developed and provide an opportunity to create substantial value and new opportunities within a wider Digital economy. In turn it will address major socio-economic challenges across multiple sectors.

The scope and ambition for 5G is much wider than a next generation cellular system, it covers multiple challenges, see Figure 1 below. Industry consensus is emerging across multiple bodies showing a theme of three key areas for 5G:

Radio Access Technology (RAT) is the underlying connection technology for a radio based communication network. Mobile phones support several RATs in one device such as Bluetooth, WiFi, and 3G, 4G or LTE.

The CORE is the central part of a telecommunications network that provides various services to customers who are connected by the Access network.

The 5G FABRIC is a UK proposition to connect multiple Networks and / or Services using common approaches and interfaces across different networks and boundaries. This will enable a common eco-system for all developers, users and network owners / operators.

Network Slicing is a proposal to create 'slices' of network that are optimised for different things e.g. latency or throughput so that industries with very different priorities can achieve what is important for them.

1. Enhanced broadband
2. Massive connectivity and volume of Machine to Machine (M2M) / Internet of Things (IoT) devices
3. Ultra-reliable connections for critical applications

The increased capability and flexibility of 5G will form a new foundation pillar of UK critical national infrastructure, providing the catalyst for competitive growth of the UK Digital Economy and will be fundamental to address major opportunities in areas such as Transport, Health & Social care, Energy / Utilities, Smart Cities and Creative Industries. The technology and innovation developed will be the key enabler to address these challenges and additionally, will create new skills and wealth through international exploitation of the UK developed technology, products and services.

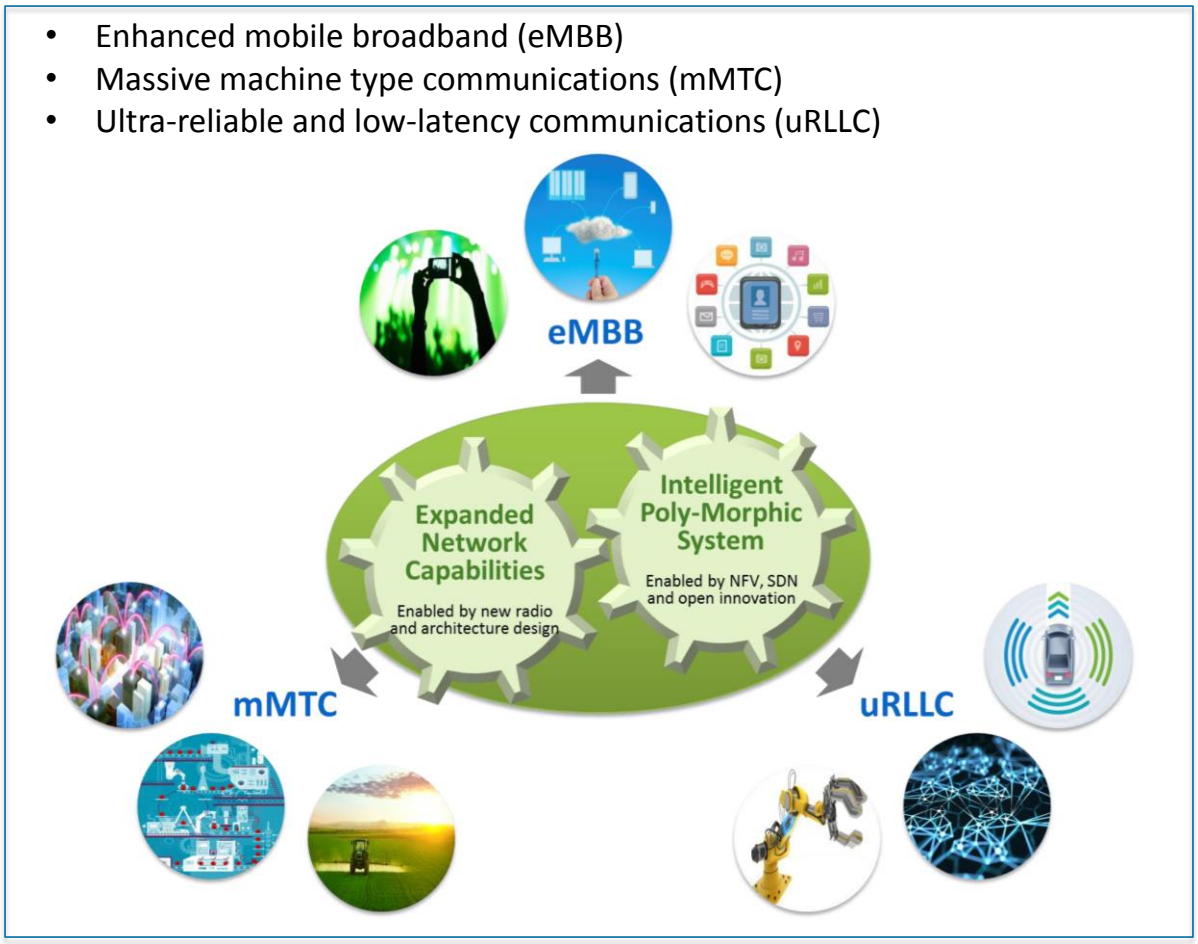


Figure 1 - NGMN Abstract view of 5G

To follow are the key challenges that need to be addressed to realise the 5G vision:

Access Technology, Challenge 1 – Development of next generation Radio Access Technology (RAT):

- Covering multiple band areas addressing different context scenarios:
  - <1GHz - Low capacity, very good for coverage and connectivity control
  - 1 to 6GHz - Medium Capacity, good for coverage and reasonable data rate
  - >6GHz - High capacity, very good for high speed connectivity and capacity
- Able to, share and combine licensed and licence-exempt Spectrum
- Increased Spectrum utilisation and efficiency across all bands.
- Work with and evolve existing network nodes, assets and technologies. e.g. 4G and WiFi
- Work with other Access Technologies - Fixed, Mobile, Satellite, Broadcast and dedicated / proprietary end sector networks.

Core Technology, Challenge 2 – Development of a next generation enhanced Core Network technology:

- Data/service platform for convergence of Mobile / IoT / Fixed networks and services.
- Architecture to support network slicing to provision network resources and assign functions to ensure service can be delivered with the necessary security and quality of service required.
- Ability to create flexible topologies to implement, distributed intelligent networks, cloud, hybrid cloud and Mobile Edge Computing (MEC) solutions.

5G Fabric Technology, Challenge 3 – New 5G RAT and Core technologies to be connected by interoperable infrastructure to enable users to have access to services with the technology working End to End seamlessly across organisation / commercial boundaries:

- Network management and orchestration - evolution/revolution of the management of the 5G network – flexibility and optimisation are critical, closing the control loop (automation) is likely to be required for particular use cases.
- Data/service platform for convergence of mobile / IoT / Fix networks and services.
- Architecture to support network slicing in SDN / NFV / MEC / Cloud.
- Autonomic Orchestrator with security by-design. This will enable slices for any vertical and ability to work across multiple boundaries.
- Provide a common ecosystem enabling slices for any vertical / application usage
- Have the ability to work across multiple boundaries using standardised approach and common interface(s).
- Assign, prioritise and securely manage resources / dedicated functions to deliver critical communications and Internet of Things applications.

Underpinning the three challenges above will be two major cross network design goals:

Design Goal 1 – Security by Design across all network element and layers

5G aims to yield a more virtualised, distributed and fluid environment comprising different communication technologies seamlessly connecting and interacting. It is imperative that security is 'designed-in' at all levels to ensure resilience, robustness and address the future connected world enabled by 5G and critical IoT systems.

- Build effective security and privacy-preserving technologies to support radio access, core network and 5G fabric.
- Creation of new security architectures for slicing, IoT and virtualisation.
- Privacy and customer security to build trust and attract customers.
- Secure and reliable networks to encourage adoption of 5G for critical functions (e.g. critical national infrastructure or high-reliability functions such as healthcare).
- Meeting regulations (privacy regulations and law enforcement)
- Effective prevention of cyber-attacks leading to reduced fraud, fewer network outages and the protection of sensitive data.

Design Goal 2 – Extremely low power / energy efficient solutions

The imminent development of 5G emphasises multiple design challenges and goals, which will require significant investment to develop energy efficient solutions. 5G presents the industry with major battery and energy efficiency challenges from end user equipment through to IT and Telecommunication nodes which will mean careful consideration from component level design, material, through to full system implementation.

This report is generated by the FCCG providing recommendations and plan for the Government, Industry and Academia to act on to ensure the UK is leading the development, deployment and usage of 5G.

3 Research to Commercialisation (Four phased approach)

The scope for the Future Communications Challenges Group involved evaluating the complete cycle from idea to commercialisation. Table 1 below describes four key phases of the proposed strategy starting with: phase 1 Research and Development to develop the Technology, leading to; phase 2 Trials and Test Beds to further develop, test and iterate solutions working with the Verticals (end use cases e.g. Health, Transport etc.), leveraging UK Systems Integrations strength. Following phase 2, early commercial trials for phase 3 can commence to scale and create early deployment infrastructure. Full commercialisation takes place in phase 4. The various technologies and systems explored later in this section are at various stages of development and the flow below will allow for information and challenges to iteratively be passed across the different phases for the community to solve.

High level definition of communities involved:

Academia & Research	Universities and research organisations focused on developing technology, systems, test beds and trials support 5G and Internet of Things
Supply Chain	Organisations who conduct research and development with a view to supplying components, systems and integration services into the Information and Communications Technology (ICT) sector
Operators	Organisations that run ICT networks, virtual and/or physical to deliver services. Operators include Fixed and Mobile services and dedicated function networks. Examples – GSMR for rail, Signage for road systems etc.
Regulator(s)	Ofcom is assumed as principle Regulator. As strategy and plan is developed further Regulators will be required for vertical sector(s) engagement.
Vertical Value Chain(s)	The vertical value chain involves all of the eco-system / supply chain for a particular sector. Example – Automotive = car manufacturers, electronics, component suppliers, sub-system and platforms, road systems and networks, distribution and logistics, fuel, recovery, maintenance, replacement parts, navigation, in-car entertainment etc. Smart Cities will require multiple vertical value chains working together to combine common approaches to a single city solution eco-system.
Investors	Investors from in support of multiple sectors including independent finance organisations, funds, banks, National and Local Government(s), large company venture funds etc.

Table 1 - Strategy, four phases from research to commercialisation

<table>
<tr><th colspan="2">PHASES</th><th>1) RESEARCH & DEVELOPMENT</th><th>2) TEST BEDS & TRIALS</th><th>3) EARLY DEPLOYMENT, INFRASTRUCTURE</th><th>4) COMMERCIALISATION & EXPLOITATION</th></tr>
<tr><td colspan="2" rowspan="3">FOCUS AREAS</td><td>TECHNOLOGY BUILDING BLOCKS</td><td>VERTICAL USE CASES</td><td>VERTICAL USE CASES</td><td>VERTICAL USE CASES</td></tr>
<tr><td></td><td>SYSTEMS INTEGRATION</td><td>SYSTEMS INTEGRATION</td><td rowspan="2">SERVICES</td></tr>
<tr><td></td><td></td><td>SERVICES</td></tr>
<tr><td colspan="2" rowspan="5">Community WHO</td><td>Government</td><td colspan="3">Government & Regulator(s)</td></tr>
<tr><td colspan="2">Academia & Research</td><td colspan="2">Investors</td></tr>
<tr><td colspan="4">Supply Chain</td></tr>
<tr><td colspan="4">Operators</td></tr>
<tr><td></td><td colspan="3">Vertical value chain</td></tr>
<tr><td rowspan="6">FUNDING AND POLICY REQUIRED</td><td rowspan="3">GOVERNMENT FUNDING REQUIRED</td><td colspan="4">Establish steering group, UK events, meetings and standards / dissemination activities.</td></tr>
<tr><td colspan="4">Support for international work / science bridges.</td></tr>
<tr><td>Increase existing funds. BEIS[8], RCUK & InnovateUK.

Implement actions to ensure stronger alignment</td><td>Fund a series of test beds and trials. Goal - 5G Phase 1 end to end trial by Q1 2018.</td><td colspan="2">Potential new funds required 2019 to 2020. Informed by previous test beds and trial work from Phase 2.</td></tr>
<tr><td>INDUSTRY INVESTMENT</td><td colspan="3">Government funding providing catalyst for additional funding and investment</td><td>Funding by Industry / Investors</td></tr>
<tr><td rowspan="2">POLICY & REGULATION</td><td colspan="4">Policy for 5G & IoT alignment and adoption - ICT and Verticals.</td></tr>
<tr><td colspan="2">Stronger alignment - academia, industry and government to steer.</td><td colspan="2">Spectrum, Regulatory, planning and other key challenges required – see sections 4 and 5</td></tr>
<tr><td colspan="2">STANDARDS & DISSEMINATION</td><td colspan="4">UK alignment activities. Collaborate, share and disseminate.
Cross Verticals Workshops. Agree common positions to drive Standards.</td></tr>
</table>

[8] Department for Business, Energy & Industrial Strategy (BIES)

Currently the emphasis of work taking place is in Phase 1, to develop the technology building blocks, we are now entering phase 2 defining the end use cases and test beds and trials to further develop the solutions and provide the platform for systems integration and end sector usage. Phase 2 development will allow an iterative process to identify challenges to hand back to Phase 1 R&D community to solve, standardise solutions through relevant end sector standards bodies and ensure technology is fit for purpose before handing over to phase 3 & 4, early deployment and commercialisation.

It is envisaged that further funding or intervention may be required for phases 3 and 4, across Government multiple departments, to provide the catalyst for public / private partnerships leading to increased industry investment.

3.1 Funding and international engagement

3.1.1 Global 5G Activities

There is significant interest in 5G globally with different territories taking different approaches. Because it will need to involve global standards and work across multiple verticals, it is essential that the UK works to achieve scale through international collaboration, ensuring that the UK supply chain is able to engage with 5G internationally. Some countries (such as USA) are taking a mostly commercial approach whereas others (such as China) are government led and include investment and engagement of national companies and resources at a scale that is hard to compete with as the UK alone.

Identify UK flagship projects, for delivery in the 2018 to 2020 timeframe, to provide focus and motivation for getting the strategy and funding in place.

1. USA, offering reasonable scale, early deployment and global influencer. Although the US has a different commercial model from the UK, their internet and ecommerce adoption are very important to follow for UK purposes. US government recently announced $400m investment in 5G.
2. EU, offering reasonable scale and adjacent market. Commissioner Oettinger announced in Feb16 that the EC would develop a 5G action plan to put Europe at the forefront of deployment of standardised 5G networks by 2020. The commissioner called for industry contributions and expects to present the plan in Sept16. Contributions have included the 5G manifesto signed by CEOs of 17 European Telco's, equipment vendors and satellite operators. Commissioner Oettinger welcomes the 5G manifesto[9].

   It is helpful that the Government has guaranteed funding for EU structural and investment fund projects that are signed before the UK leaves the EU. As a result, the UK should continue to be involved in the €700m EU Horizon 2020 programme in pragmatic studies and to follow EU based standards for compatibility of networks and roadmap towards 5G, See section 6.

[9] Commissioner Oettinger welcomes the 5G manifesto Source https://ec.europa.eu/digital-single-market/en/news/commissioner-oettinger-welcomes-5G-manifesto

3. South Korea, 5G thought leader and leader in current customer equipment design. Clear objectives linked with 2018 technology deployment at the Winter Olympics.
4. Japan, leading operator (NTT[10]) engaged with 5G eco-system supply chain with objectives to supply 5G services as part the 2020 Summer Olympics.
5. China, offering strong R&D proposition, scale and leading manufacturing capability. Expected to be a leader in IoT. As with 3 and 4, strong government direction and drivers are visible (which are less the case in 1 and 2 above) and these appear to be based on a clear industrial strategy.

3.1.2 UK funding

At 2016 Autumn Statement, the Government announced £1bn of new funding to boost the UK's digital infrastructure, including funding for a new programme of 5G and fibre trials. The Government has committed to set out more detail on this programme at Budget 2017, alongside a new 5G strategy.

As stated in the previous section the FCCG group strongly recommends that Government creates a mechanism to provide greater focus and alignment across the phases described in (Table 1 - Strategy, four phases from research to commercialisation.)

Recommendation 1, recognises that many of the existing competitions and funds need to be consolidated, increased and focused to improve the proposition for UK 5G technology leadership. All funding to be aligned across Government funding agencies, to ensure synchronisation of criteria, objectives and timing.

In addition, R&D funds that focused on the end sector applications described in Section 3.3, Test beds and trials - verticals and use cases – (Phase 2) need to be aligned from interoperability and economies of scale perspective. In particular it is critical that there is alignment (across agencies and across verticals) to meet the challenges of 5G security. The National Hub and Spoke strategy needs to include security-by-design from the first year of funding, which should be updated as the additional Hubs are introduced and as the security standards evolve.

We propose a model based on a hub and spoke approach. The hub and spoke approach is intended to create connections between industries and academia to ensure that developments emerge in a way that can be applied across verticals and between academic institutions. This is not only to ensure financial efficiency of development spend, but also to ensure that the 5G 'network of networks' created have been designed in a way that can evolve over time to meet unforeseen future needs.

Appendix 7.1 and 7.2 provide an explanation of the proposed model. The UK's strategy should be focused around an initial hub deployment starting in 2016/17 financial year with funded spokes addressing key vertical applications. This will lead to second and third hubs with further spokes providing multiple test beds and trials interconnected through a hub and spoke model. It will be for

[10] NTT Nippon Telegraph and Telephone http://www.ntt.co.jp/index_e.html

the Government to determine the most appropriate way to identify and allocate funding to the respective hubs and spokes.

RECOMMENDATION 1

Government should focus investment in three areas:
i) ICT Research and Development – Government to assess current spend and impact in delivering its 5G manifesto commitment[7]. Optimise spend to provide a stronger technology pipeline, generate demand, create the skills base, standards capability and global linkages.

ii) **Test Beds and Trials**
Initial goal / key milestone - 5G end to end trial by Q1 2018.
Government to invest in test beds and trials focused on UK system integration strengths applied to key socio-economic challenges, key sectors or "verticals", and pragmatic use cases. Investment to be made in areas to augment and leverage ICT Research and Development working with industry. Investment decisions will explicitly favour proposals where effective and coherent security is demonstrated in test-bed and trial design. Outputs of work to inform early deployment and infrastructure National Infrastructure Commission (NIC), see Appendix 7.1

iii) **Create Steering Group, Standards and Knowledge Dissemination activity** for R&D, test beds, trials, SME & Micro engagement and associated Standards work, and ongoing advice on international benchmarking and deployment. The new group should be set up initially to implement collaborative showcases, knowledge exchange, dissemination, co-ordination and resulting standards work. See Appendix 7.2

All funding to be aligned across Government funding agencies to ensure synchronisation of criteria, objectives and timing.

Timeline and key milestones below:

2016/17	Fund national interconnected development strategy
2017/18	First end to end trial – Q1 2018, facilitated by first Hub and Spoke deployment. Expand focus by introducing second Hub linked to first hub and working with new Spokes / Verticals.
2018/19	Expand focus by introducing third Hub linked to existing hubs working with new Spokes / Verticals.
2019/20	Commercialisation - industry / business funding

The success of the 5G development and deployment will be measured by its uptake, and uptake will be driven through digital innovation. To maximise economic growth opportunities for the UK we should aim to create an ecosystem that fosters innovation and encourages early adoption of 5G infrastructure services as part of its development cycle. To ensure we maximise the significant

opportunities for the UK eco-system and in particular start-ups, Micro and SMEs, we recommend specific steering, standards work, co-ordination and championing at the national level.

The steering activity will ensure industry and academia can steer and assist Government in defining and refining strategy, plan and activities to maximise UK 5G capability and maximise impact of funded project(s) at a national level. The standards and R&D activity streams will be funded to ensure resulting innovation is translated into international standards therefore enabling global economies of scale and opportunities for UK exploitation.

Coordinating the eco-system and building a sustainable user-engagement model with the 5G test beds and trials is a significant task in its own right and one that is necessary to see the full economic benefit of 5G development realised. This coordination action will be a part of the 5G testbeds program that will ensure increasing awareness not only of the 5G developments in the UK, and internationally, but also to identify and engage with the UK start-ups, Micro and SMEs with the UK testbeds and trials activities, ensuring open exchange of knowledge and information, and creating an open access ecosystem that fosters cross-industry translational innovation from organisations of all sizes, micro to large corporations.

The proposed programme will include extending the innovation 5G ecosystem nationally with workshops, specific clinics and boost programs, bringing together medium and large industry players with SMEs, start-ups and Micros to identify key application challenge areas relevant to 5G (e.g. from some of the more advanced use cases) with a view to help/support the development of commercial solutions and deliver economic growth.

3.1.3 UK to leave the European Union (EU) implications

Following the referendum vote for the UK to leave the European Union (EU) on the 23rd June 2016, questions have been raised with respect to EU research funding.

Short term concerns have been addressed by the Statement[11] of 29 June of the Heads of State or Government of 27 Member States, as well as the Presidents of the European Council and the European Commission, confirming that until the UK leaves the EU, EU law continues to apply to and within the UK, both when it comes to rights and obligations. This includes the eligibility of UK legal entities to participate and receive funding in Horizon 2020 actions.

5G activity in Europe is strongly linked to the Horizon 2020 European research programme[12], it is imperative that we communicate the current short term status and we articulate a clear longer term plan on how the UK will continue to collaborate and fund EU collaborative research and projects.

In many respects the outcome of the recent referendum on whether the UK should leave the EU does not affect the way that UK-based companies will be involved with and implement 5G networks. As explained in Standards section 6, mobile network operators and equipment suppliers will continue to need to use and indeed influence the development of global technical standards for networks and equipment. The cost of developing competitive equipment is so high that

[11] Informal meeting at 27 - Brussels, 29 June 2016 – Statement
http://www.consilium.europa.eu/en/press/press-releases/2016/06/29-27ms-informal-meeting-statement/
[12] The EU Framework Programme for Research and Innovation
https://ec.europa.eu/programmes/horizon2020/

manufacturers need to address global markets and it would not be at all economic for them to build equipment only for the UK market.

Similarly mobile handset vendors wish to minimise the number of variants of new handsets (like iPhones or Samsung, HTC and Huawei models for example) that they have to develop and support. Mobile network operators want to buy equipment from manufacturers in competitive markets and they need equipment from different vendors to interwork properly so that they don't become locked into one supplier:

- Mobile operators with networks in different countries will wish to continue to be able to negotiate and place contracts for equipment supply for use in all their different markets.
- The services and applications that are supported by 5G networks need to be able to operate across national borders and to continue to operate when the consumer roams to a network in another country.

It would be quite incorrect to regard Brexit as an opportunity for UK companies to adopt simpler or less prescriptive technical standards, because it certainly is not that. The two main concerns to FCCG members, at this early stage of understanding, is the effect on the referendum decision on:

1 UK universities: will they be able to continue to participate and on occasions lead European and international research programmes. This is partly concern about continued research funding but also the recognition that considerable academic and scientific value is derived from working closely as partners with researchers in leading universities across the world.
2 UK-based network operators: will service providers and manufacturers still be able to get access to a sufficient pool of talented and skilled engineering and technician workers. Global companies will need to continue to be able to rotate staff between their different national operations in order to develop them and to maximise the impact such skilled workers have on their business.

The UK Spectrum Policy Forum (UK SPF) is currently working on a report on the impact of Brexit on Spectrum in the UK. The preliminary key findings[13] are as follows:

1 *There is general need for international coordination of Spectrum use. This has led to the formation of international bodies, in particular CEPT in Europe and ITU at a global level. The UK will continue to play a full part in these, in particular ITU World Radio communication Conferences (WRCs), which make high level decisions on which parts of the radio Spectrum should be used by particular services and applications.*
2 *The implementation of EU regulations for particular frequency bands and applications is 'outsourced' to CEPT (conditions of frequency use) and ETSI (standards for wireless products). The ability of UK (Government, Ofcom and industry) to participate in this work will continue unchanged.*
3 *Member States regard many aspects of Spectrum policy as a national matter. The UK is a major player in European Spectrum policy, and its departure from the EU is likely to shift the balance of influence towards the Member States; they may wish to encourage this shift by maintaining*

[13] UK Spectrum Policy Forum - ***The impact of the UK leaving the EU on UK Spectrum policy (Version 1.0) 15th August 2016*** preliminary findings, subject to change. Final report will be published by the UK SPF and will be available on website https://www.techuk.org/about/uk-spectrum-policy-forum

the involvement of the UK in bodies such as RSPG, in which the Member States have the leading role.

4 *Brexit will not have any impact on current Spectrum use or users; the UK regulatory framework for Spectrum of the WT Act, licences, and Statutory Instruments is self-contained.*

3.1.4 Funding international science bridges and collaboration

Achieving economies of scale for research and eventually commercialisation will be very important for customers as well as key sectors. Lowering the shared costs of R+D, as shown through GSM, delivers lower unit costs to consumers. It will not be within the compass of individual countries to stand alone to achieve these benefits, hence the need for an international approach.

The Government should encourage and strengthen the UK / international Science bridges to leading 5G nations for collaborative R&D, Test Beds / Trials, Standards alignment and collaboration into international forums. Targets: China, South Korea, Japan, USA and Europe. This is important for shared costs, maximising economies of scale and future collaboration / export opportunities. Furthermore, in addition to supply-side collaborations, the demand-side ought to be catered for, thereby allowing UK 5G technologies and services to be exported globally; countries: USA, Brazil, Russia, Turkey, Middle-East, Nigeria, South Africa, Commonwealth countries, etc.

RECOMMENDATION 2

Government should encourage and strengthen the UK / international Science bridges to leading 5G nations for collaborative R&D, Test Beds / Trials, Standards alignment and collaboration into international forums. Targets: China, South Korea, Japan, USA and Europe. This is important for shared costs, maximising economies of scale and future collaboration / export opportunities. This will require funding to be administered by Department for International Trade (DIT) working with Foreign & Commonwealth Office (FCO) and the Science Innovation Network (SIN) with steering linkage from new body detailed in recommendation 1iii) and Section 7.2

Government funding is required for international science bridges which offer stronger, pragmatic, two way bridges to deliver real 5G success stories need to be funded. Funding to be administered by the Department for International Trade (DIT) working with Foreign Common Office (FCO) and the Science Innovation Network (SIN) with steering linkage from new body detailed in recommendation 1iii) and Section 7.2. These should also help drive inputs to World Radio Conference and International Telecommunication Union policy positions based on science and technical facts.

The UK Science bridges are needed now with links to:

1 USA, offering reasonable scale and early deployment and global influencer
2 EU, offering reasonable scale and adjacent market.
3 South Korea, 5G thought leader and leader in current customer equipment design. Clear objectives linked with 2018 technology deployment at the Winter Olympics.
4 Japan, leading operator (NTT[14]) engaged with 5G eco-system supply chain with objectives to supply 5G services as part the 2020 Summer Olympics.
5 China, offering strong R&D proposition, scale and leading manufacturing capability

The advantages of working internationally, with the above partners, will provide the UK early demonstrator systems and global visibility. Encouraging test beds and trials co-operation is vital and will provide the opportunity to exploit our leadership strength (systems integration and security solutions) and provide inward investment opportunities.

[14] NTT Nippon Telegraph and Telephone http://www.ntt.co.jp/index_e.html

3.2 Research & Development – technology building blocks (Phase 1)

The 5G community is working towards a flexible layered architecture based on multiple technology building blocks that can be software selected and implemented to address a user and /or thing requirement in any context. This will mean that the same architecture will be able to provide the secure network connection with the required performance for multiple end applications. To achieve this flexibility, eight design goals have been set by the global 5G community, see diagram below, design goals on outside ring.

Figure 2 - 5G design goals, see GSMA report[15]

These eight design goals can be reduced down to four key performance areas:

1. High Speed Broadband (HSB) 1 to 10 Gbps
2. Network Availability, Capacity & Coverage (AC&C) - 100% perception
3. Massive Internet of Things (MIoT) - Order of magnitude increase in connected objects
4. Critical Internet of Things (CIoT) – Deterministic connections down to 1ms latency

The four areas above will be underpinned by extremely LOW POWER (LP) solutions with Security by Design specified across all layers for each of the following:

- User equipment
- Networks
- Nodes

[15] GSMA report page 6 - Understanding 5G: Perspectives on future technological advancements in mobile, 5G Technology requirements, https://www.gsmaintelligence.com/research/?file=141208-5g.pdf&download

– Components

It is unlikely that any single use will need all of the design goals to address the application. The 5G Core will be designed to use software to select multiple combinations / scenarios to meet the specified connection criteria. The diagram below provides a high level architectural view of a 5G ecosystem.

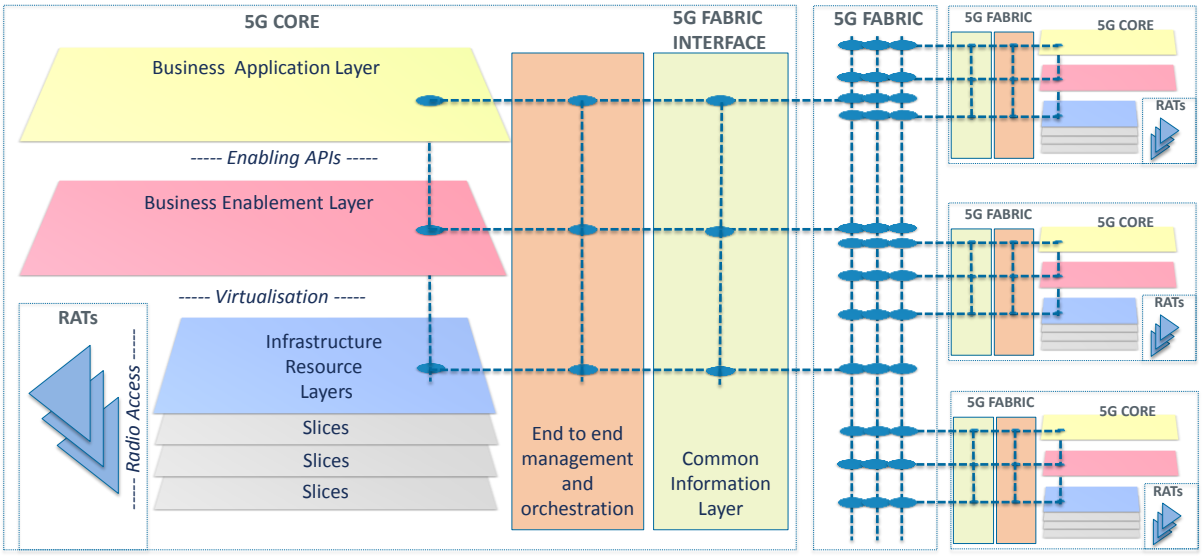


Figure 3 - 5G architecture working across network boundaries

3.2.1 5G Core and Fabric

The 5G architecture will provide the functionality to implement an integrated data and service platform for the convergence of mobile / IoT / fixed networks and services. Reliability, resilience and security will be implemented through a 'security-by-design' standardised implementation. It will be able to support network slicing to provision resources and assign functions to ensure the selected service can be delivered with the necessary security and quality of service.

The network slicing functionality will provide the capability to partition, prioritise and securely manage resources and dedicated functions to deliver critical communications and Internet of Things applications. The 5G community will define a common ecosystem enabling slices for any vertical / application usage - therefore providing the ability to work across multiple boundaries using standardised approach and interfaces. It is worth noting that network slicing and the need to create differentiated service offerings to meet differing needs has caused some concern in terms of net neutrality. Given the wide range of design goals required to meet the entirety of the possible 5G use cases from autonomous vehicles to HD video, it is likely to be pragmatic to put the operators in a position where they can differentiate but not overtly discriminate. However, net neutrality as an issue is not being addressed within the scope of the FCCG work on 5G development.

The end to end management and orchestration will provide the ability to manage individual networks, layers and slices and the 5G Fabric implementation will work across boundaries and provide the Application Programming Interfaces and interfaces for implementing Network of

Networks[16] and large complex system approaches required for critical usage applications in vertical sectors.

3.2.2 5G Radio Access Technology

New Radio Access Technologies (air-interfaces) are being developed to deliver 5G. In addition to the new air-interfaces, the 5G eco-system will work with and evolve existing network nodes, assets and technologies e.g. 2G, 3G, 4G, WiFi, Fixed, Satellite, Broadcast and dedicated end sector networks.

Given the foreseen new applications and end-user services envisaged for 5G, market analysts predict the need for a 1000-fold capacity increase in the capability of wireless bearers compared with today's networks. The limited availability of Spectrum below 6GHz (traditionally used for mobile wireless applications), has driven academic and industrial research to focussed on Spectrum efficiency enhancing techniques as well as explore the use of millimetre wave Spectrum (30-300GHz), where relatively large continuous bands of Spectrum are available.

The table below, Radio Access Technology provides breakdown of challenges and identified Spectrum areas.

Table 2 - 5G core requirements mapped to Radio innovation

<table>
<tr><td colspan="2"></td><td colspan="3">RADIO ACCESS TECHNOLOGY (RAT)
Ability to use, share and combine licenced and licenced-exempt Spectrum.</td></tr>
<tr><td colspan="2">Key 5G technology requirements[17]</td><td><1GHz</td><td>1-6GHz</td><td>>6GHz</td></tr>
<tr><td>1</td><td>1-10Gbps connections to end points in the field (i.e. not theoretical maximum)</td><td colspan="2">Leveraging best available existing air interfaces and evolution to 5G RAT</td><td>Developing new technologies and 5G RAT</td></tr>
<tr><td>2</td><td>1 millisecond end-to-end round trip delay (latency)</td><td colspan="3" rowspan="3">MULTIPLE RADIOS = 5G FABRIC
Spectrum usage and management innovation enabled through trials and test beds. Multiple networks, bands and/or air interfaces and control and/or user plane</td></tr>
<tr><td>3</td><td>1000x bandwidth per unit area</td></tr>
<tr><td>4</td><td>10-100x number of connected devices</td></tr>
<tr><td>5</td><td>(Perception of) 99.999% availability</td><td rowspan="2">Low capacity data, good for control plane / coverage</td><td rowspan="2">Medium capacity data, good for control and user plane</td><td rowspan="2">High capacity data, good for user plane</td></tr>
<tr><td>6</td><td>(Perception of) 100% coverage</td></tr>
<tr><td>7</td><td>90% reduction in network energy usage</td><td colspan="3"></td></tr>
</table>

[16] **Network of Networks** – it is envisaged that 5G will allow seamless operate between multiple networks therefore with internetworking standardised across the boundaries. This will provide the flexibility to create end to end services delivered by multiple parties.

[17] GSMA report page 6 - Understanding 5G: Perspectives on future technological advancements in mobile, 5G Technology requirements, https://www.gsmaintelligence.com/research/?file=141208-5g.pdf&download

8	Up to ten years battery life for low power, machine-type devices	MAJOR CHALLENGE - Radical low energy technology evolution at multiple levels for each area: materials, device, systems and cross network

Research, including a significant body of contributions from the UK, has proposed and conducted some ground-breaking evaluations of potentially disruptive technologies for sub-6GHz wireless access. This includes full-duplex wireless[18], that removes the need for the separation of transmit and receive signal paths in a radio transceiver and facilitates simultaneous same frequency operation of a wireless device. This, when combined with network scheduling, can more than double network capacity. Significant gains (10 to 20 fold) in Spectrum efficiency through the use of massive MIMO antenna technology have also been shown experimentally[19]. Here a base station using an antenna array with a large number of elements (50 to 100) and appropriate signal processing can resolve and separate the spatial streams associated with individual users, thereby offering Space Division Multiple Access with hitherto unsurpassed sum rate capacity.

Although higher losses are found at millimetre wave frequencies when compared to sub-6GHz wireless scenarios, this can be circumvented through the use of high gain directional antennas and small cell deployments (circa 250m). These directional antennas can be realised by means of a beamforming array of antenna elements as demonstrated by a Bristol based SME[20] as well as widely reported by Samsung[21]. This radically different wireless solution should provide more targeted and efficient use of Spectrum above 30GHz, thus providing much needed capacity for ultra-dense 5G deployments.

[18] Full Duplex, Laughlin, L, Beach, MA, Morris, KA & Haine, JL, 2014, 'Optimum single antenna full duplex using hybrid junctions'. IEEE Journal of Selected Areas in Communications, vol 32., pp. 1653-1661

[19] MIMO http://www.bristol.ac.uk/news/2016/may/5g-wireless-spectrum-efficiency.html

[20] Blu Wireless http://www.bluwirelesstechnology.com/

[21] Samsung announces world's first 5G mmWave mobile technology https://news.samsung.com/global/samsung-announces-worlds-first-5g-mmwave-mobile-technology

3.2.3 Delivering ultra-low power solutions

5G is not only about the development of a new radio interface. New technologies like Software Defined Networks and Network Function Virtualisation will help us manage the new demands on the network. But at the same time we need to think about the structure and topology of the network(s) and its impact on energy consumption.

Rethinking the design of the network will help. We will need a flexible network which is capable of transferring and processing data over long distances (as at present) as well as reducing the distances and locating data processing in a variety of places. As indicated in this report this is likely to involve more computing done closer to where data is collected ('edge compute'). This holds out the prospect of ensuring that the ICT network uses energy as efficiently as possible.

RECOMMENDATION 3

Government to work on encouraging energy efficient and resilient solutions, from R&D funding through to local / national procurement. Provide industry direction / procurement signals: A "digital first" Government strategy declaration linked to public funded capital projects would be a desirable goal.

It will require proof of concept use cases involving state of the art servers and data centres which focus on maximising energy efficiency. Industry is only beginning to look at the potential in this area. But it would be helpful if Government could commit to making the UK the best place to trial such solutions, and in due course to base its own procurement decisions on energy efficiency.

In addition it would be worth looking at whether some form of incentive would expedite a phased switch over to more energy and real estate efficient solutions.

3.3 Test beds and trials - verticals and use cases – (Phase 2)

5G systems definition and technology developments are now at the stage where collaborative projects need to move into phase 2, test beds and trials with end use cases. The purpose of the phase 2 test beds and trials is to engage the key end verticals to agree the vision, requirements and define the use cases to be implemented within the test bed(s). This will also inform further phase 1 and 2 work to ensure requirements are built into the appropriate technology building blocks and global standards.

The vision for the 5G capability described in this report is being defined through collaborative work with vertical sectors to understand current challenges and opportunities that can be solved through 5G innovation. Key sectors such as Transport & logistics, Finance & Business Services, Health & Social Care, Retail & Logistics, Digital Creativity & Information Services and Smart Cities / Living offer the opportunity for the UK to lead globally on solving vertical sector challenges, whilst providing a common eco-system to be developed in test beds and trials focused on UK system integration strength applied to key socio-economic challenges.

The future 5G eco-system will leverage common approaches providing significant economies of scale for all public and private network and service providers. The FCCG evaluated prioritising particular verticals and it was decided to focus on multiple verticals to enable common approach and cross vertical interoperability / internetworking. The benefit of this approach would provide significant productivity benefits and the ability for users to utilise multiple networks and services. The diagram

below represents the key focus verticals enabled through a common 5G eco-system connected through the proposed 5G Fabric crossing public and private boundaries.

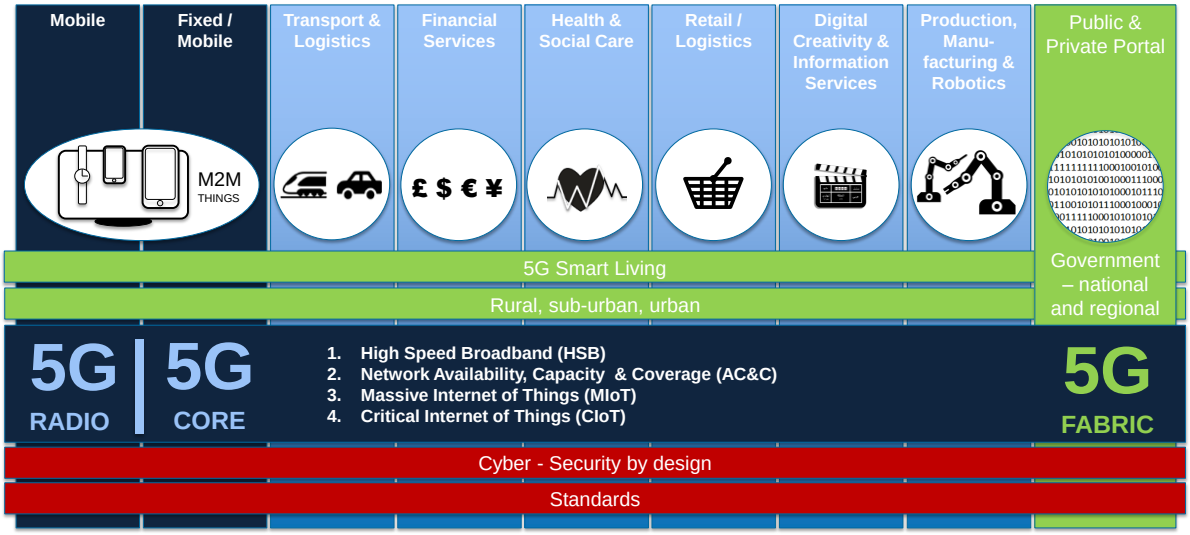


Figure 4 - 5G eco-system

The above diagram shows Mobile and Fixed / Mobile as Verticals, which in the case of broadband and telephony is correct. However, 5G is more than a next generation cellular service and will provide the foundation for Internet of Things applications requiring critical connectivity, quality of service and massive deployment. The same infrastructure and eco-system being able to address the vertical Mobile Broadband and Telephony will also provide a common Internet of Things architecture for applications requiring secure and resilient connectivity with assigned quality of services for the specified application.

RECOMMENDATION 4

Government should assess how 5G adoption can support and deliver core Government policy and associated socio-economic challenges and opportunities across sectors such as: Creative Industries, Transport, Business, Health, Utilities, Manufacturing and Smart Cities. Each Government Department needs to signal the move towards digital operation through policy and procurement and implement strategies to address common approaches and linkage across these vertical sectors, underpinned by a coherent security strategy.

In a 5G world each of the verticals / sectors could be operating their own networks either virtually or with their own assets. The strength of the eco-system will be the ability to create different models and network(s) configured dynamically and transparent to the user and/or thing. The opportunity for productivity gains in each sector will represent significant value. This will be further geared by each sector adopting common approaches and being able to deliver cross sector solutions.
It must be noted that vertical sectors / supply chains may have alternative solutions and approaches to address challenges. In some cases 5G will be complementary and it is possible that the vertical sector may have competing solutions. It is vital that any competing approaches are designed with the necessary interfaces and interoperability from the outset to ensure the ability for the benefits of the 5G common eco-system enabled by the5G Fabric. Capturing these requirements and ensuring

interoperability will be a vital role for the standards work described in Recommendation 1 and section 6.

The diagram below shows an evolution from phase 1 through to phase 3. Section 6, Standards, outlines the different standards bodies and approach required. In terms of the verticals and the test beds and trials a key part of the strategy will be to build consensus and scale through test beds and trials and working with end sector vertical to agree approach and drive into the relevant standards.

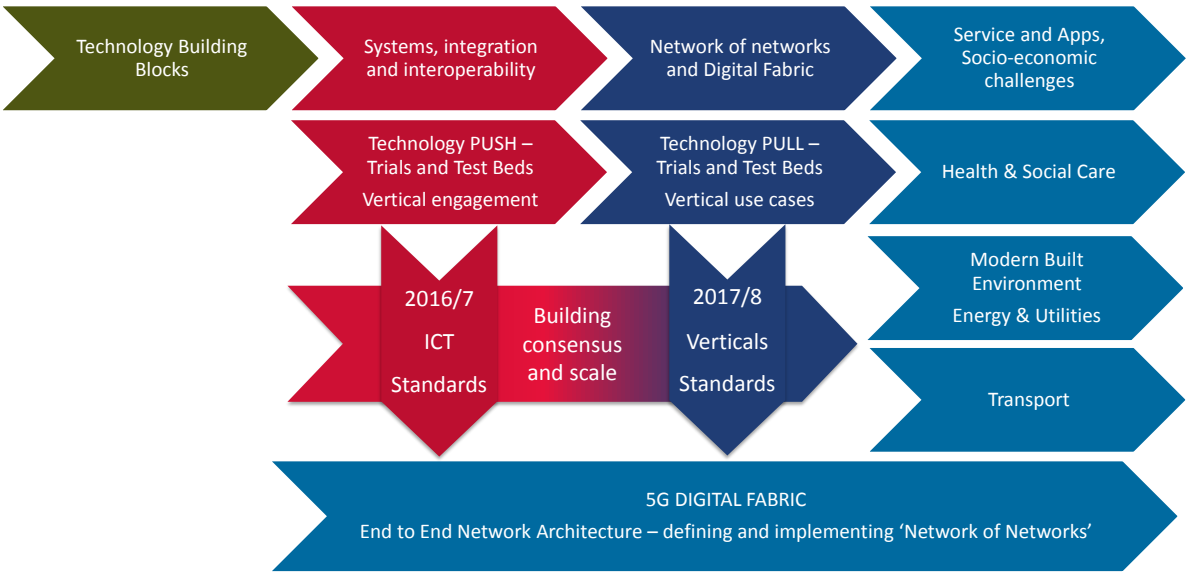


Figure 5 - Phase 1 to Phase 3 evolution and standardisation

Providing this future eco-system will enable significant gains in productivity and efficiencies based on existing services and will enable creation of new applications. It is difficult to predict all of the new applications and as stated elsewhere in the report it is unlikely for any single use will need all of the 5G design goals to address the application. The 5G Core will be designed to software select multiple combinations / scenarios to implement the specified connection criteria. The table below provides a high level view of a sector and use case example mapped to the required 5G goal and functionality.

Table 3 - Use case examples by Sector mapped to 5G design goals

Sector	Use case example	5G Key design goals				
		HSB – High Speed Broadband	AC&C - Network Availability, Capacity & Coverage	MIoT - Massive Internet of Things	CIoT - Critical Internet of Things	5G Fabric and Multiple Networks
Mobile	High Speed Broadband	✓	✓			
Fixed / Mobile	Rural Broadband	✓	✓			
Transport & Logistics	Autonomous Driving		✓	✓	✓	✓
Business & Financial Services	Trading				✓	✓

Health & Social Care	Remote Surgery				✓	✓
Retail / Logistics	Payments		✓		✓	✓
Digital Creativity / Info Services	HD Video	✓	✓			
Public & Private Portal	Emergency Services	✓	✓	✓	✓	✓

The diagram below provides a graphical representation of two of the above use cases working in an automotive application / context: Mobile High Speed Broadband and Autonomous Driving. Mobile wide area coverage layer provides connectivity to all vehicles which could be supplying critical information to work with the infrastructure to provide vital traffic, route planning and safety information beyond the range of the vehicle to vehicle local connectivity. In a 5G world the roadside infrastructure could also be hosting 5G equipment forming part of the 5G wider area eco-system and also hold local information to do very low latency, edge processing and connectivity to the vehicles.

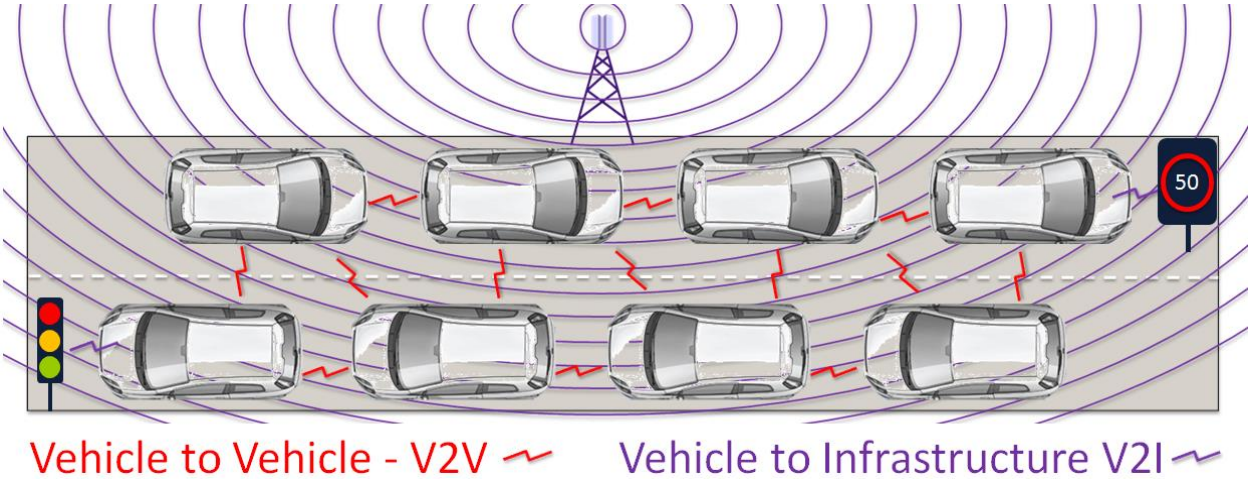


Figure 6 - Broadband and Autonomous Driving, Vehicle to Vehicle and Vehicle to Infrastructure communications

In some cases the V2V can work in isolation to manage the autonomous driving and safety between the local vehicles. When required the V2V connectivity will work with the V2I for more complex environments, decision processes and multi-mode interaction. From an architecture perspective the V2I and V2V will be working in dedicated IoT slices with the necessary safety, resilience and quality of service provided.

The MobileHigh Speed Broadband connectivity, using the same infrastructure implemented on a different network slice can provide other services such as streaming entertainment video to passengers in the vehicle or broadband connectivity to conduct remote working while travelling. As stated in previous sections the use of multiple network assets connected through the 5G Fabric will allow services (use cases) to be delivered with the required parameters through multiple network assets.

The above uses cases demonstrate some key applications in the Automotive transport sector. Equally this could be applied to all transport sectors. The Rail sector provides a plethora of applications and challenges that will require all of the 5G design parameters identified. In particular, Critical IoT applications for safety and signalling from station and trackside to moving stock, emergency and secure communications (voice and data) and high speed broadband to passengers.

The combined capability of Road, Rail and Mobile infrastructure would provide a powerful proposition in terms of a common infrastructure covering multiple applications and services with the CAPEX[22] and OPEX[23] to run the networks amortised across several businesses / funding sources. The FCCG believes that using Rail and Road assets, such as track and roadside access, to implement infrastructure would provide significant benefits to transport users with the additional benefits of providing cost effective coverage to rural communities.

RECOMMENDATION 5

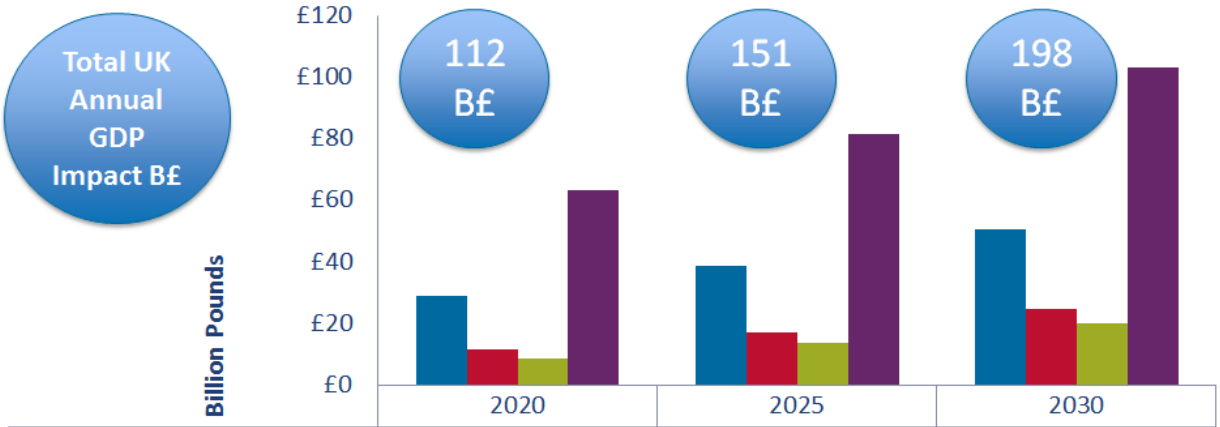
Explore, through 5G test beds and trials, models to provide coverage alongside roads and rail lines. Link with Smart Cities projects in densely populated areas. Assess the impact to the UK coverage and relative contributions, for fixed and mobile broadband, leveraging public / private partnerships.

3.4 Early deployment, infrastructure, commercialisation & exploitation (Phases 3 & 4)

GSMA estimates Mobile contribution to Global economy will be worth $3.9tn[24], 4.2% of global GDP by 2020 of which only 1% is attributed to Mobile therefore demonstrating that 3.2% will be from general economy, supply and the major contributor being end vertical sector productivity improvement.

Further analysis of GSMA data mapped to UK GDP is below. The assumption made by this analysis is conservative, as productivity improvement is based on known models for Mobile extrapolated to 2030. In the case of 5G it will also include productivity gains based on Critical and Mass adoption of the Internet of Things for secure and resilient services which is not captured in this analysis.

[22] CAPEX - Capital expenditure
[23] OPEX - Operating expenditure
[24] GSMA Mobile Economy report source - http://gsmamobileeconomy.com/global/GSMA_Global_Mobile_Economy_Report_2015.pdf

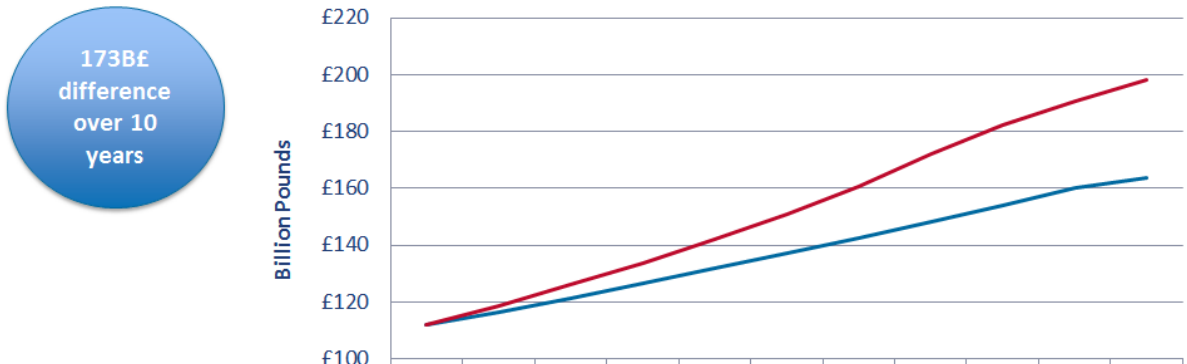


	2020	2025	2030
Mobile Operators B£	£29	£39	£51
Related Industries B£	£11	£17	£24
General Economy B£	£9	£14	£20
Productivity Improvement B£	£63	£81	£103

Source: RTACS Analysis of BIS, ONS and GSMA data
Assumption: Total UK GDP extrapolated using GSMA rates results in total GDP of £2.46tn in 2020, £3.22tn in 2030

Figure 7 - Mobile impact to UK economy, global leadership model [25]

The figure above shows the impact growing to £198bn per annum by 2030 (extrapolated to 2030 using trends forecasted from 2014 to 2020), see section 7.3 for further details of model and assumptions. The model assumes the UK is leading technology development and deployment of 5G, however, using our current trajectory, the model suggests the economic impact would be £112bn in 2020, growing to £164bn in 2030. Therefore not acting upon the report's recommendations would result in losing opportunity to create £173bn of incremental GDP over 10 years, 2020 to 2030.



	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Current trajectory -1.23% Model B£	£112	£117	£121	£126	£132	£137	£142	£148	£154	£160	£164
Global leadship +10% Model B£	£112	£119	£126	£134	£142	£151	£160	£172	£182	£191	£198

Figure 8 - Current trajectory versus Global leadership - UK GDP impact[25]

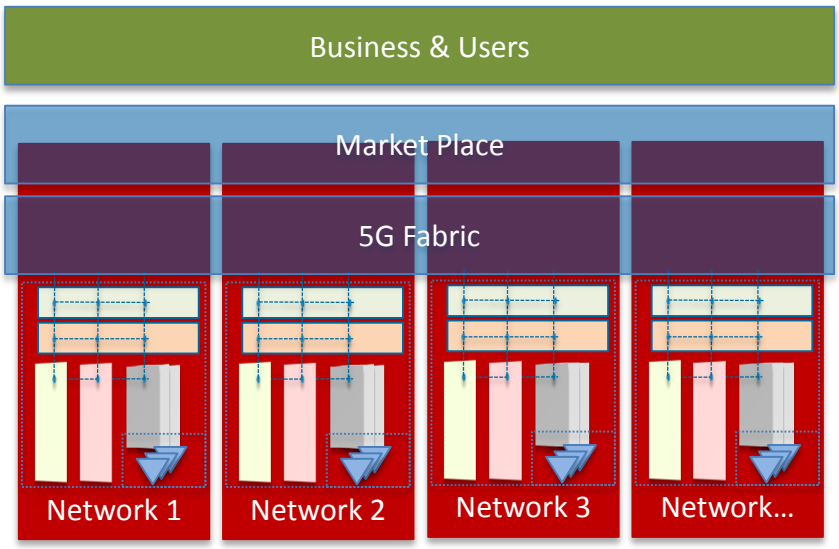
The test and trials described in phase 2, Section 3.3 Test beds and trials - verticals and use cases – (Phase 2), provide the foundation to move to early deployment. The FCCG believe further Phase 2

[25] See section 7.3 for further information on assumptions and model calculations. Source: RTACS Analysis of BIS, ONS, DEI and GSMA data. Contact stuart.revell@rtacs.com for further information.

work is required prior to make recommendations to the extent of funding required for phase 3 interventions. The concept would be to prove applications, technology and services in phase 2 which will allow an evolution to further scaling, early deployment / infrastructure investment.

The 5G technology proposed will provide the essential interconnectivity to interact across boundaries in a safe, resilient manner and have the ability to connect value chains across boundaries with the mechanism and systems to implement monetary systems across multiple players in complex business relationship(s).

The 5G Fabric system described in earlier sections of this report will provide the ability to have different network owners to connect across a common ecosystem, therefore creating economies of scale for new applications and consumer equipment providers to develop solutions with addressable large markets across multiple sectors. The technology and ability to slice networks across boundaries will create an abstraction layer for Business and Users to operate in a common market place, see diagram below.



In the use cases described in the previous section the eco-system and networks described could be owned by a mixture of public and private organisations. For example, network 1 could be a rail operator, network 2 a roadside operator and network 3 a mobile operator working collaboratively to deliver multiple use cases.

Figure 9 - Digital Market Place, enabled by common 5G eco-system

4Regulatory, planning and other key challenges

If the UK is to play a leading role in the development, deployment and usage of 5G a series of regulatory and planning challenges will need to be addressed. This section focuses on three policy areas that could materially enhance the UK's 5G prospects:

- Facilitating operators' ability to deploy network equipment
- Ensuring industry has sufficient Spectrum
- Ensuring application of net neutrality rules is compatible with 5G use cases

One of the government's most fundamental objectives is to encourage economic growth. Economic growth is powered by improvements in productivity, while productivity itself is driven by innovation. In turn, amongst the most effective forces propelling innovation is the availability of connectivity at the lowest unit price. To deliver connectivity at the lowest unit price requires the deployment of the latest technology, and therefore with regards to the telecoms industry, a basic policy goal should be

the development of a healthy and growing mobile sector, with both the ability and incentive to invest.

A persistent problem faced by mobile operators has been the difficulty in obtaining suitable sites for the infrastructure involved – a fact recognised with the proposed reform to the Electronic Communications Code (ECC) and changes to the English planning regime. Impediments stem from a range of concerns, from aesthetic and other objections to planning applications to site rental costs. However, the dictates of radio physics are clear cut. Without sufficient sites, adequate mast heights, and so on, the quality of service will inevitably suffer. This applies not only with respect to binary coverage issues (i.e., the ability to make a phone call or establish a data connection), but also the quality of service (e.g., the data bandwidth achievable).

RECOMMENDATION 6

Government should assess whether current plans to simplify or remove requirements for base station deployment planning permission go far enough to support effective 5G deployment. Progress should be accelerated in opening up access to public owned buildings and infrastructure and should consider specific rights to access public infrastructure (e.g. similar to those proposed by ARCEP in France - see Spectrum section 5. Policy should focus on ensuring that access to backhaul AND site locations are open, streamlined and more cost-effective. This is inhibiting investment roll out today.

Even with regard to present platforms (GSM, 3G and LTE), there is the need to recognise the importance of a consistent approach to the planning permission process, so as to ensure that operators can secure access to the sites required without undue complexity, delay and expense. These considerations become still more imperative in the context of 5G, which is likely to necessitate infrastructure deployment using much larger numbers of cells and in time including higher frequencies with significantly inferior propagation characteristics. As a consequence, operators will need to roll out to far more sites, adding much complexity to the process of planning. Hence there is a strong case that small cell deployments in particular should be exempted (to the greatest extent possible) from onerous planning requirements. Additionally, note that where authorisations are required, planning authorities will need sufficient resources so as to be able to process applications in a timely manner.

The government could not only streamline the process of procuring access to the necessary sites through planning regulation, but could also direct that public buildings and land (as well as perhaps property associated with utilities) should be made available wherever feasible, at low cost, to support the deployment of mobile network equipment. This could build on the principles of the broadband cost reduction directive. ‘Best practice’ guidelines could provide an indication of the government’s aspirations in this area, with an emphasis on maximising the number of sites available. While state aid rules may constrain the scope to specify an approach to the pricing of these sites, there should be ample scope to signal that the objective here is to provide the industry with as many locations as possible, rather than maximising fees on a per site basis. Base station backhaul presents a parallel set of issues. There should be wide industry support for measures that simplify and reduce the expense of the planning process associated with its deployment.

Spectrum remains the lifeblood of the mobile telecoms industry. Forthcoming auctions are important to make more Spectrum available to the UK operators and the regulator has a critical role

to ensure that this happens in a timely manner. The mobile operators will require considerable banks of Spectrum released in a prompt fashion at frequencies that global vendors will support and at prices that will encourage further network investment.

Certain comparatively recent auctions on the continent (such as in the Netherlands and Austria) have proven extremely expensive. The sums expended on Spectrum are plainly not available for investment in network. The government should therefore reaffirm that the central purpose of the Spectrum auctions is to ensure a healthy and vibrant mobile market, and generating economic value and innovation from the use of Spectrum.

Additionally, it is important that the UK makes available Spectrum that has been chosen in accordance with emerging international standards. The UK does not itself possess the critical mass to be able to licence early a given band of Spectrum and hope thereby to create a precedent that others will follow. Vendors are unlikely to produce equipment exclusively for the UK market, and the UK alone is unlikely to be able to galvanise the global supply chain behind it. Here there is instead merit in what might be termed a 'fast follower' approach, with Spectrum bands selected on the basis of the anticipated global standards.

Finally, with regard to implementation of net neutrality regulation in a 5G services context, restricting the circumstances in which packets can be prioritised might be necessary given the objective of securing an open internet, but might also impact the quality of experience for 5G services that could otherwise have benefited from optimisation and better management of traffic. EU regulation on net neutrality allows national regulators some flexibility in the application of the rules and Ofcom – which has shown commendable pragmatism in this field – might opt to make use of the available latitude with a particular eye to fostering 5G innovation.

It will be important how 5G services, which may be delivered using new technology are considered. The BEREC guidelines[26] do not address 5G and consequently, Ofcom will have some discretion to define specialised services in the 5G context and to address any concerns as and when they arise. Similarly, with respect to zero rating, BEREC guidelines require national regulators to assess the impact of such practices on customer choice and variety amongst upstream internet applications. In many cases it seems unlikely that zero rating by UK operators could directly affect choice in the global internet market, which suggests against taking a restrictive view. More broadly, it is important that guidelines that interpret the existing net neutrality laws do not introduce any new barriers to the provision of differentiated 5G services, especially for new market entrants.

5 Spectrum

Spectrum is an essential input to UK 5G deployment. Clarity on Spectrum availability will be required ahead of technology deployment and investment decisions. Appropriate Spectrum policies can enable and stimulate innovation and transformational services for public and industry applications.

[26] BEREC Guidelines on the Implementation by National Regulators of European Net Neutrality Rules, Document number: BoR (16) 127, published 30th August 2016
http://berec.europa.eu/eng/document_register/subject_matter/berec/regulatory_best_practices/guidelines/6160-berec-guidelines-on-the-implementation-by-national-regulators-of-european-net-neutrality-rules

It is important that a range of Spectrum bands are available with licence conditions that promote investment, including long-duration, technology neutral and avoiding excessive fees/costs.

While existing Spectrum can eventually be re-farmed for 5G, existing 2G, 3G and 4G services in those bands have a long tail of usage so these cannot be relied upon for early 5G introduction. Wide contiguous bandwidths will be needed to realise full-rate 5G services and these are not available in many existing bands. Hence new Spectrum will need to be assigned suitable for 5G, but on a technology neutral basis.

5G Spectrum will need to be in three ranges:

- **High**: Most attention internationally is focused on centimetre and millimetre wave bands above 6 GHz and these offer potential access to very wide bandwidths for local area services. There is a well-defined process for selecting such bands to identify for 5G leading into WRC-19[27] and the UK should fully support RSPG[28] and ITU efforts to identify the most appropriate band for Europe in this range, paying close attention to the need for international harmonisation. Ideally there should be a single global band but this may not be realistic and at least it should be clear that a single band is needed for the whole of Europe with appropriate technical characteristics and certainty of the timing and approach to access. However, use of such high bands requires significant new technological and industrial development before they become practical and will require the deployment of high density small cells in relevant areas. The timeline to achieve this is such that these high bands are not expected to be the first to bring the benefits of 5G to the UK.
- **Mid**: The range 1-6 GHz offers a good balance of coverage and capacity and few technological risks. This range has received least attention to date, but probably offers the greatest prospect for early 5G benefits in the UK. Amongst such bands, the range 3.4-4.2 GHz offers the best prospect for availability, global support and wide bandwidths. RSPG has recently provided a draft opinion[29] on 5G Spectrum issues suggesting that the 3.4-3.8 GHz should be the primary band for introducing 5G in Europe, but the 3.8-4.2 GHz range will also be necessary and is lightly used in the UK. Ofcom is planning to auction 3.4-3.6 GHz and is consulting on a shared approach to 3.8-4.2 GHz. A comprehensive overall approach to the whole 3.4-4.2 GHz range is needed to maximise certainty and encourage early investment.
- **Low**: For wide area coverage, additional sub 1 GHz Spectrum is required. Ofcom's existing plan for releasing 700 MHz, aligned with the EC's harmonisation activities in this band, fit this need well and should be continued with no delay to the published timeline with availability by 2020.

[27] World Radiocommunication Conference 2019 (WRC-19), 28 October to 22 November 2019 http://www.itu.int/en/ITU-R/conferences/wrc/2019/Pages/default.aspx

[28] RSPG - RADIO SPECTRUM POLICY GROUP

[29] RSPG - STRATEGIC ROADMAP TOWARDS 5G FOR EUROPE DRAFT Opinion on spectrum related aspects for next generation wireless systems (5G), 8th June 2016 https://rspg-spectrum.eu/public-consultations/#ongoing_consultations

Spectrum for 5G needs to accommodate a wide range of new business approaches, with more diverse customers and deployment styles. This will require a similarly diverse range of approaches to Spectrum access. There will continue to be conventional deployments by national mobile network operators, who need exclusive Spectrum access for investment certainty and to offer good quality of service. This is especially applicable to wide area deployments in the sub GHz range. In the mid and higher bands, however, the large quantity of Spectrum needed to realise 5G benefits, is such that a greater degree of Spectrum sharing may be needed, both between operators and incumbent users (vertical sharing) and amongst operators (horizontal sharing, see for example the recent study for the European Commission[30]). Multi-tier sharing techniques, similar to those being used by the FCC for 3.5 GHz and that proposed by Ofcom for 3.8-4.2 GHz, offer the prospect that a given band can be made available in both a licenced and licence-exempt fashion, with the balance varying by time and location according to need and availability. Such sharing techniques are novel but although complex are demonstrated to be feasible via the FCC's CBRS[31] structure and Ofcom's White Space framework and offer a dynamic approach to both allocation and assignment. In addition other licence-exempt bands such as 5GHz are available on a technology neutral basis and may potentially be used to complement licensed Spectrum for delivery of future 5G services. Such approaches offer both opportunities for investment certainty and for innovation and extend the Licensed Shared Access (LSA) approach to provide greater flexibility. Early promotion of appropriately rich Spectrum sharing approaches will also offer the UK direct opportunities to lead in the development of technology which will be of increasing global importance.

RECOMMENDATION 7

Government should, as part of its planned strategy for 2017, consider with Ofcom how relevant spectrum can be brought into use to enable early and rapid deployment of 5G in the UK. This should be consistent with European harmonisation, including 700MHz and 3.4-3.8GHz and support the identification of new globally harmonised spectrum above 24GHz at WRC-19. Explore potential to access 3.8-4.2GHz range on a shared basis as an extension to adjacent 3.4-3.8GHz spectrum and promote this in Europe. Longer term strategies for WRC and UK Spectrum needs, should be agreed with the UK Spectrum Policy Forum.

Beyond creating an appropriately fully-featured strategy for market access to 5G Spectrum following the considerations outlined here, UK academia and industry will need early access to all three Spectrum ranges for experimentation and testbeds. Although Ofcom has a defined process for applying for such non-operational Spectrum licences[32], a more proactive approach may bring benefits. One such model is recent proposals in Belgium[33] to make available Spectrum for 5G trials as a 'sandbox', but tied to collaboration with local industry and academia. FCCG members in consultation with Ofcom have prioritised 700 MHz, 3.4-3.8 GHz and appropriate high frequency Spectrum for tests/trials, taking into account the RSPG draft opinion on pioneer bands.

[30] Spectrum requirements for 5G in European Commission 5G report http://www.realwireless.biz/2016/03/11/real-wireless-plays-crucial-role-on-spectrum-requirements-for-5g-in-european-commission-5g-report/

[31] United States of America FCC CBRS - Federal Communications Commission Citizens Broadband Radio Service

[32] Non-operational licences, formerly T&D, http://licensing.ofcom.org.uk/radiocommunication-licences/non-operational-tech-licence/

[33] Belgium Proposals http://www.mobileworldlive.com/featured-content/home-banner/belgian-deputy-pm-wants-to-use-spectrum-as-a-test-bed/

RECOMMENDATION 8

Ofcom should make available on request spectrum for test beds and trials which has the potential to lead to early deployment and longer term commercialisation. Spectrum recommended for test/trials is follows: Low 700MHz, Mid 3.4 to 4.2 GHz and appropriate High frequency spectrum in line with European RSPG recommendations and Global opportunities for exploitation.

Given the expected key role of dense small cell networks in the deployment of 5G, the effectiveness of 5G Spectrum is closely coupled to the ease of access to other key network inputs, especially backhaul and site locations on clear and supportive terms. So a broader range of policies is necessary to ensure cost-effective deployment by a wide range of players. For example, French regulator ARCEP has recently proposed[34] to grant wireless and fibre operator's new rights to access transportation, power and water network infrastructures. Access must be provided on "reasonable technical and pricing terms and conditions." Government (DCMS) should consider what action can be taken, including but not limited to the review of the Electronic Communications Code via the Digital Economy Bill announced in the Queen's Speech[35] in May 2016.

6 Standards

The successful generational evolution of mobile communication systems is underpinned by probably the largest globally concerted standardisation activities undertaken in various international organisations such as 3GPP, ETSI, ITU and IETF. The current 5G standardisation roadmap for the period 2016-2020 identifies specific standards outputs addressing radio and core network functionality that will provide systemic support for IoT-like applications and agile networking. However, the mobile communications standardisation development process tends to focus on specific parts or layers of the communication systems and standardise solutions in a segmented manner. This is demonstrated by the lower uptake success rate of standards that address the interface between the communication system services and its users (over-the-top service providers), for example converged generic user profile management.

The global success of the 5G development and deployment will depend on how adaptive the communication system specification will be to meet the whole range of demands from different industry verticals, such as transport, multimedia broadcasting, health, smart cities, and factories. This hyper-connected vision of the 5G fabric requires better standardisation co-ordination than the current practice in a way that is driven equally by the requirements from both the vertical industry adopters of the 5G system and the equipment manufacturers and operators. It is in this space (convergent network and new infrastructure services) where the UK has the potential, and interest,

[34] Autorité de Régulation des Communications Électroniques (French Regulator) ARCEP proposals http://www.arcep.fr/index.php?id=8571&no_cache=1&no_cache=1&tx_gsactualite_pi1%5Buid%5D=1878&tx_gsactualite_pi1%5Bannee%5D=&tx_gsactualite_pi1%5Btheme%5D=&tx_gsactualite_pi1%5Bmotscle%5D=&tx_gsactualite_pi1%5BbackID%5D=26&cHash=8451cdd3f6a8fc1e8def2bfc3d7bfe45&L=1

[35] Queens Speech, May 2016 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/524040/Queen_s_Speech_2016_background_notes_.pdf

to participate more strongly in standardisation to take a leadership position using the 5G Fabric approach.

The UK government desires to ensure that the UK contributions lead in the standardisation space for 5G. Faced with a mobile communication standardisation process that is currently dominated by equipment manufacturers and operators, extremely intensive and time consuming, and with different lead times for successful adoption of standards, it is necessary that the UK identifies, develops and supports activities where it can deliver impact, influence or lead the standardisation process. On the basis of existing engagement and/or UK domain expertise, the following are some of the existing leading edge standardisation activities where UK leads, provides significant/key contribution, or has the potential to do so.

6.1 Radio Access Technology 3GPP

3GPP is the global standards body that define the cellular radio and network technologies for 5G, historically they gave us UMTS and LTE, NR (new radio) is the term used for 5G. For the last 12 months they have been working on 5G, starting with the requirements and progressing through to the technical standards. Features are delivered in releases, at the moment the main 5G standards will be in Release 15 and 16, the agreed dates for the standards completion are:

Rel-14 – 5G requirements – completion September 2016

Rel-14 – 5G technology study - completion target March 2017

Rel-15 – spec covering Non-Stand Alone – freezing target either December 2017 or March 2018 (exact date to be decided in March 2017)

Rel-15 – 5G specification covering Non-Stand Alone and Stand Alone - freezing target June 2018

Rel-16 – 5G specification - freezing target December 2019

Release 15 currently agreed focus is on:

- Use cases: enhanced Mobile Broadband (eMBB), low latency, and high reliability.
- Frequency bands: Low and High
- Next Generation core network connectivity

Trials are most likely to be based upon release 14 and 15, with commercial roll out based on release 15 (non-standalone, anchored using 4G control channels) or release 16 (standalone). 3GPP operates on a membership model, with companies, universities and government departments all providing inputs, some of the companies and many of the delegates are UK based. Over the next few months the scope of the releases will be debated, and any UK position formed in the FCCG can be taken in 3GPP by some of its members. OFCOM and DCMS can also take UK positions. Shorter term timescales can be seen in the figure below.

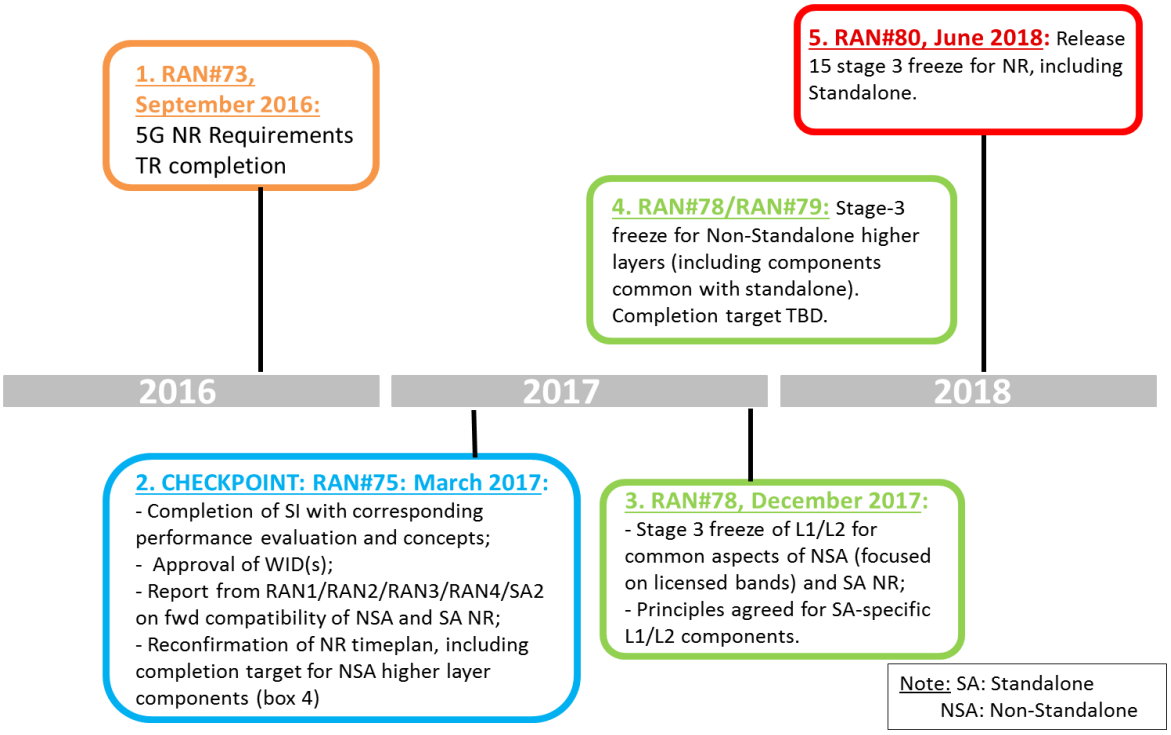


Figure 10 - Standards timeline

6.2 Core Network Architecture and Protocols

Following UK initiative, ETSI has approved (March 2016) an Industry Specification Group on Next Generation Protocols, which is currently led by UK experts. The terms of reference of this group include the revisit and redesign of the most fundamental networking protocols towards proposals that are more efficient, agile and in-tune with the current technology status, practice and thinking for ICT systems.

UK has world-leading expertise in Software Defined Networking, and very strong expertise on Network Function Virtualisation (NFV). However, most of the international specification and standardisation input is not done directly through 3GPP or ETSI, which cover the majority of mobile communication standardisation activities, but through other specific organisations, such as the Open Network Foundation. There are links between ONF and the currently very active ETSI Network Function Virtualisation (ETSI NFV)[36] technical group, with overlap of participation, but the direct UK input in the 5G space could be more direct / stronger.

ETSI ISG Network Functions Virtualisation Security Group. NFV is likely to be a core foundation for 5G and the NFV Security Group is addressing some fundamental security issues which will impact NFV and 5G, including security for edge computing, virtualisation and globalisation.

[36] ETSI NFV In November 2012 seven of the world's leading telecoms network operators selected ETSI to be the home of the Industry Specification Group for NFV. Now, nearly four years and 40 published documents later, we see a large community working intensely to continue developing the required standards for NFV as well as sharing their experiences of NFV implementation and testing. The membership of ISG NFV has grown to over 290 individual companies including 38 of the world's major service providers as well as representatives from both telecoms and IT vendors. Source http://www.etsi.org/technologies-clusters/technologies/nfv

6.3 Internetworking and 5G Fabric

The UK driving need for development of 5G systems (and beyond) is in exploiting the new communication services delivered by the 5G system, and in particular looking at how the 5G fabric converts into a common information platform and continues to support the European lead that the UK digital innovation ecosystem has established. From this perspective there is a need to create a UK standardisation contribution ecosystem whereby UK industry and academia, together, identify requirement gaps from UK-developed use cases and decide to drive 5G standards in areas of crucial interest for the UK digital innovation, and specifically in agile (SDN/NFV) converged networks, security, user privacy and trust service interfaces.

The UK activity must work with 3GPP (SA5 WG), working on network management standards. It will also need to support work closely with 3GPP and ETSI NFV as NFV/SDN require both communities and approaches.

Whilst there is an increased awareness of the need to get vertical industries involved in the 5G development towards successful uptake and deployment, there is a definite need to coordinate the inter-industry standardisation activities in the UK with a view to influence the global standardisation process in a cohesive, intelligent and coherent way from the UK.

6.3.1 ITU activities

Extract from ITU website: http://www.itu.int/en/ITU-T/focusgroups/imt-2020/Pages/default.aspx in italics below.

The Focus Group on network aspects of IMT-2020 was established in May 2015 to analyse how emerging 5G technologies will interact in future networks as a preliminary study into the networking innovations required to support the development of 5G systems. The group took an ecosystem view of 5G research of development and published the analysis in a Report to its parent group, ITU-T Study Group 13.

In December 2015, the Focus Group received an extension to its lifetime. New Terms of Reference call for the group to engage open-source communities, influencing and taking advantage of their work by introducing them to the challenges that telecoms players must overcome in the development of the 5G ecosystem. Specific tasks and areas of work include:

- *Explore demonstrations or prototyping with other groups, notably the open-source community*
- *Enhance aspects of network softwarisation and information-centric networking*
- *Continue to refine and develop the IMT-2020 network architecture*
- *Continue to study fixed-mobile convergence*
- *Continue to study network slicing for the fronthaul/backhaul network*
- *Continue to define new traffic models and associated aspects of QoS and operations, administration and management applicable to IMT-2020 networks*

ITU-T standardization activity based on the findings of the Focus Group will prioritize the alignment of 5G deliverables with those of ITU-R, ensuring that standardization work on the network aspects of 5G is informed by the progression of its radio-transmission systems.

6.4 Vertical Industry solutions

Several activities to jointly define 5G requirement between vertical segment and ICT community are underway.

a. Following UK initiative the (EBU) European Broadcasting Union and ETSI (European Telecommunication Standards Institute) have jointly created an Industry Specification Group on Mobile and Broadcast Convergence (March 2016) (ISG-MBC). The focus is the definition of the requirements for media delivery over converged networks, which will provide input to the on-going work on Enhanced TV Services and eMBMS in 3GPP as well as the development of 5G standards.
b. Following UK initiative, a new ETSI ISG will be considered at industry meeting arranged by the 5GIC and ETSI in November 2016 to address 5G and Transport.
c. UK participation in the Mobile Edge Computing is active, mainly through research laboratories from specific companies.

6.5 Security and privacy

The UK also engages in relevant security and privacy activities. These should be pursued with the aim of providing a secure, privacy-preserving foundation that therefore creates the trust and confidence to allow next generation networks and applications to flourish. This means: enabling critical infrastructures to operate with the highest standards of safety, control and resilience; enabling Enterprise to run secure systems while protecting and controlling their networks and data; enabling UK business and citizens to use secure systems and protect their privacy. These should be supported by government, industry and academic research, building on the UK's respected international reputation in these matters.

The relevant industry fora include:

- TC-CYBER, is the ETSI Technical Committee on Cyber Security, which is providing guidance on security and privacy within next generation networks in liaison with the EU, GSMA, 3GPP and ITU.
- The Alliance for the Internet of Things in Innovation is an EU working group one output of which is to establish how Personal Data is protected in next generation networks.
- The Internet of Things Security Foundation is a UK-industry-led group seeking to establish itself as a home for security advice for next generation networks.

7 Appendices

7.1 Hub and spoke model

Note the following assumptions made to develop the model proposed in main report:

1) The model assumes implementing three HUBs, working independently but having contractual links to ensure common approaches, economies of scale and standards work is driven by all HUBs / SPOKE(s) in a collaborative way.
2) The goal of having three HUBs is to attract different innovation and industry players to invest and develop competitive solutions in each of the HUBs.
3) Each HUB may have multiple universities, companies and other bodies working collaboratively (as well as competitively) to meet the specific aims of each hub, leveraging existing assets, investments and work to date, see section 7.1.1.
4) The three HUBs will work as equals. Integration funds will be used by each HUB to ensure the three HUBs work together, supported by a newly formed independent funded Steering Group, Standards and knowledge dissemination activity, see section 7.2
5) The first HUB ought to leverage on the significant research & innovation already ongoing in the UK, as well as government and industry investment already in place. See section 7.1.1 for examples.
6) Timing of first / single HUB funding critical to meet end to end trial objective by Q1 2018. Timing of second and third HUBs theoretically could be pulled forward, subject to funding, industry commitment, investment and engagement.
7) First Single HUB and SPOKE(s) must provide significant assets with prior 5G track-record and contractually agree to work with subsequent HUB and SPOKE(s) to form the basis of the longer term UK plan and strategy.
8) Further HUB and SPOKE(s) must provide significant assets and contractually agree to work with First HUB and SPOKE(s) as part of UK plan and strategy.
9) Funding to be open to all UK industry and academia through a competitive process to ensure funds are administered and awarded correctly.

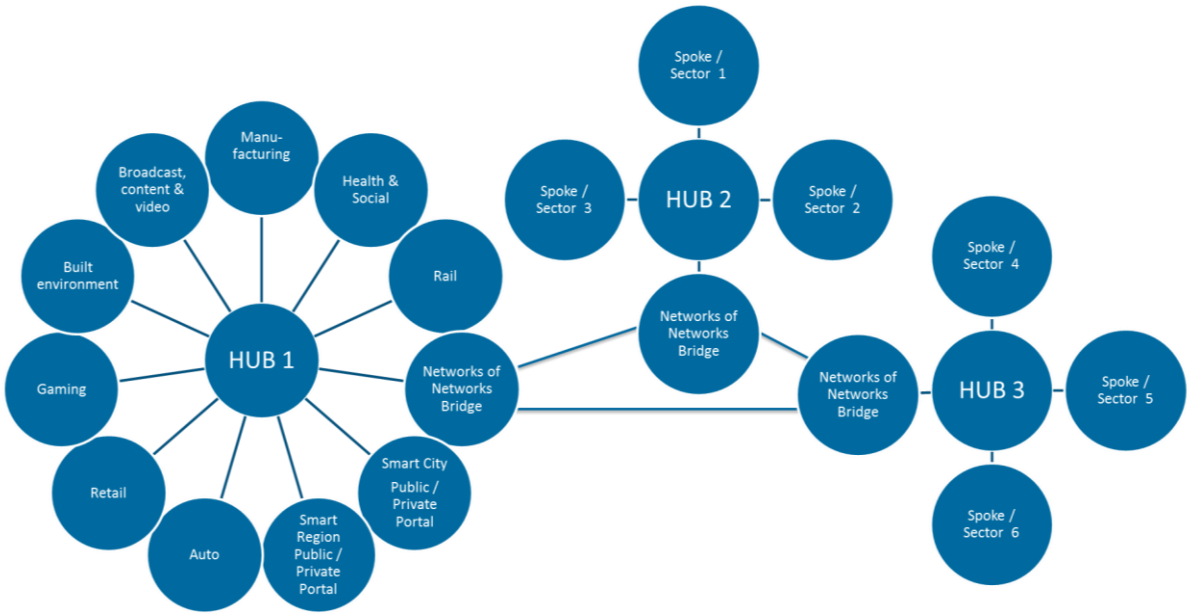


Figure 11 - UK Hub and Spoke strategy, comprehensive UK geographic and expertise coverage

The above diagram is a graphical representation of a three hub and spokes model. The approach described will build on the 5G activity already ongoing in UK Universities, the 'Spokes' representing end sectors and 5G use cases will utilise the research capability and technologies best placed to meet their needs.

Further Hubs, 2 and 3 can be added to start to realise a wider interconnected eco-system and opportunities for more industry investment and engagement.

At 2016 Autumn Statement, the Government announced £1bn of new funding to boost the UK's digital infrastructure, including funding for a new programme of 5G and fibre trials. The Government has committed to set out more detail on this programme at Budget 2017, alongside a new 5G strategy.

FCCG recommendation 1 requests Government to fund three areas using hub and spoke model described above for test beds and trials, item ii):

> i) **ICT Research and Development** – Government to assess current spend and impact in delivering its 5G manifesto spend to provide a stronger technology pipeline, generate demand, create the skills base, standards capability and global linkages.
>
> ii) **Test Beds and Trials**
> Initial goal / key milestone - 5G end to end trial by Q1 2018.
> Government to invest in test beds and trials focused on UK system integration strengths applied to key socio-economic challenges, key sectors or "verticals", and pragmatic use cases. Investment to be made in areas to augment and leverage ICT Research and Development working with industry. Investment decisions will explicitly favour proposals where effective and coherent security is demonstrated in test-bed and trial design. Outputs of work to inform early deployment and infrastructure National Infrastructure Commission (NIC).
>
> iii) **Create Steering Group, Standards and Knowledge Dissemination activity** for R&D, test beds, trials, SME & Micro engagement and associated Standards work, and ongoing advice on international benchmarking and deployment. The new group should be set up initially to implement collaborative showcases, knowledge exchange, dissemination, co-ordination and resulting standards work. See Appendix 7.2
>
> All funding to be aligned across Government funding agencies to ensure synchronisation of criteria, objectives and timing.

By comparison, the US Government is putting $400m into 5G wireless, the Advanced Wireless Research Initiative[37] 'to maintain US Leadership and win the next generation of mobile technology'. The investment includes academic research and investment in tests and trials. They also expect other Federal Agencies to make complementary efforts. Collaborative industry investment and engagement is being sought. The FCC has also committed to designate Spectrum and set out usage

[37] US, NSF to put $400m into Advanced Wireless Research Initiative for 5G networks https://techcrunch.com/2016/07/15/us-to-put-400m-into-advanced-wireless-research-initiative-for-5g-networks/

rules for 5G networks. The US commercial model is and competitive environment is very different from the UK – in the US there is an expectation that market forces can drive most of the investment. Nonetheless, this $400m investment by the US is seen by analysts as relatively modest and they predict the need for more.

7.1.1 Significant research & innovation already achieved by UK institutions

Examples of existing projects / assets:

1. 5G national centre, 5GIC University of Surrey[38]
2. University of Bristol Smart Internet Lab[39]
3. Smart City projects like Bristol is Open[40] and Digital Greenwich[41]
4. Collaboration facilities like 5GIC University of Surrey industry collaboration programme[42]
5. King's 5G Tactile Internet Lab initiative (research, prototyping, standards)[43]

[38] The 5GIC is funded by £12 million from HEFCE (the Higher Education Funding Council for England) and over £68 million co-investment from the Centre's industry and regional partners, including the EM3 Local Enterprise Partnership. Source: http://www.surrey.ac.uk/5gic/about

[39] University of Bristol University of Bristol Smart Internet Lab: http://www.bristol.ac.uk/engineering/research/smart/

[40] Bristol is Open – programmable city http://www.bristolisopen.com/, £75 million co-investment from central, local government (including the West of England LEP) and Industrial partnerships

[41] Digital Greenwich http://www.digitalgreenwich.com/

[42] 5GIC University of Surrey industry collaboration program https://www.surrey.ac.uk/5gic/collaborate/industry

[43] 5G initiative at King's College London http://www.kcl.ac.uk/nms/depts/informatics/News/newsrecords/Ericsson-launches-5G-collaboration-with-the-Department-of-Informatics.aspx and www.ctr.kcl.ac.uk

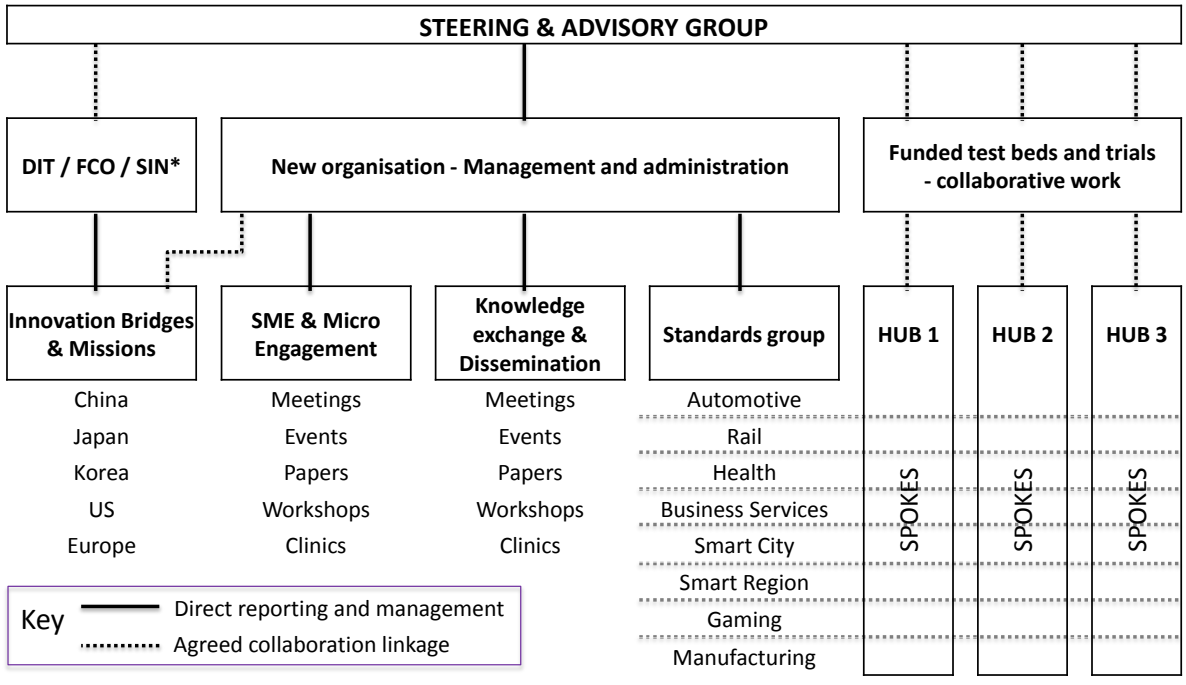
7.2 Steering group, Standards and knowledge dissemination activity

A steering group will ensure we maximise the significant opportunities for the UK eco-system. The steering activity will ensure industry and academia can steer and assist Government in defining and refining strategy, plan and activities to maximise UK 5G capability and maximise impact of funded project(s) at a national level. The standards and R&D activity streams will be funded to ensure resulting innovation is translated into international standards therefore enabling global economies of scale and opportunities for UK exploitation. Staff working on standards involves working with the community, writing standards and influencing relevant bodies.

Coordinating the eco-system and building a sustainable user-engagement model with the 5G test beds and trials is a is a significant task in its own right and one that is necessary to see the full economic benefit of 5G development realised. This coordination action will be a part of the 5G testbeds program that will ensure increasing awareness not only of the 5G developments in the UK, and internationally, but also to identify and engage with the UK start-ups, Micro and SMEs with the UK testbeds and trials activities, ensuring open exchange of knowledge and information, and creating an open access ecosystem that fosters cross-industry translational innovation from organisations of all sizes, micro to large corporations.

The proposed programme will include extending the innovation 5G ecosystem nationally with workshops, specific clinics and boost programs, bringing together medium and large industry players with SMEs, start-ups and Micros to identify key application challenge areas relevant to 5G (e.g. from some of the more advanced use cases) with a view to help/support the development of commercial solutions and deliver economic growth.

To follow is a proposed structure for managing this activity. Initially we envisage that the FCCG will play a major part in defining and implementing this activity.



* Department for International Trade(DIT), Foreign & Commonwealth Office (FCO) and Science Innovation Network (SIN)

Figure 12 - Steering and advisory group and linkage

7.2.1 International collaborations, bridges and missions

Government should encourage and strengthen the UK / international Science bridges to leading 5G nations for collaborative R&D, Test Beds / Trials, Standards alignment and collaboration into international forums. Targets: China, South Korea, Japan, USA and Europe. This is important for shared costs, maximising economies of scale and future collaboration / export opportunities. Furthermore, in addition to supply-side collaborations, the demand-side ought to be catered for, thereby allowing UK 5G technologies and services to be exported globally; countries: USA, Brazil, Russia, Turkey, Middle-East, Nigeria, South Africa, Commonwealth countries, etc.

Lead person -"owner" of collaborations; 24/7 evangeliser:

- role: collect all tech/market input from both sides and share on other side; organise phone conferences; provide input to strategic steering board

Supply-side tech co-developments & knowledge exchange:

- role: co-design technology where applicable, and share insights/achievements on 5G tech development and successful use cases, attendance of standards harmonization meetings
- countries (see more detailed list of cities below): Sweden, Finland, Germany, Switzerland/France, China, South Korea, Japan, Taiwan, USA

Demand-side co-developments & knowledge exchange:

- role: paving the way to sell UK 5G tech and services into the respective countries
- countries: USA, Brazil, Russia, Turkey, Middle-East, Nigeria, South Africa, Commonwealth countries, etc.

Equipment, equipment shipping and support to demonstrate global connectivity features:

- role: additional (light) equipment needed to enable connectivity, lease of connections, support of bridges & testing exercises, etc.

Target countries / cities

- Sweden: Stockholm, Lund
- Finland: Helsinki, Oulu
- Germany: Berlin, Bonn, Dresden
- Switzerland: Geneva (ITU)
- France: Sophia Antipolis (ETSI)
- China: Beijing, Shenzhen, Shanghai
- South Korea: Seoul, Pangyo, Suwon, Pyeongchang (larger delegation)
- Japan: Tokyo, Tsukuba Science City, (Osaka)
- Taiwan: Taipei, Hsinchu
- USA: NYC, Austin, San Diego, San Francisco, (Boston)

7.3 Financial modelling

Table 4 - GDP impact financial model and assumptions

	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Source
Total Global GDP	**T$**	**$92.86**	**$95.40**	**$98.02**	**$100.71**	**$103.47**	**$106.31**	**$109.22**	**$112.22**	**$115.29**	**$118.45**	**$121.70**	GSMA + RTACS
	Annual Growth %	2.35%	2.74%	2.74%	2.74%	2.74%	2.74%	2.74%	2.74%	2.74%	2.74%	2.74%	GSMA + RTACS

	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Source
Mobile Direct and indirect contibution to GDP	%	4.20%	4.27%	4.34%	4.41%	4.47%	4.54%	4.61%	4.68%	4.75%	4.82%	4.88%	GSMA + RTACS
	T$	**$3.90**	**$4.07**	**$4.25**	**$4.44**	**$4.63**	**$4.83**	**$5.04**	**$5.25**	**$5.47**	**$5.70**	**$5.94**	GSMA + RTACS

		RTACS Extrapolation based on historic growth rates of previous generations (1G to 4G, using GSMA data)											
	Unit	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**Source**
Global 4G & 5G estimated subscriber base	4G M#	3077.2	3476.9	3883.0	4286.1	4662.1	5021.7	5329.8	5573.7	5541.2	5230.5	4742.1	GSMA + RTACS
	5G M#	0.2	1.2	4.9	18.7	66.9	176.4	398.1	892.4	1407.5	1824.4	2221.4	GSMA + RTACS
	4G + 5G M#	3077.5	3478.2	3887.9	4304.8	4729.0	5198.0	5727.9	6466.1	6948.7	7054.9	6963.6	GSMA + RTACS

		GSMA	GSMA Figures extrapolated to 2030										
WW Contributions to GDP	Unit	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**Source**
Total	**%**	**4.20%**	**4.27%**	**4.34%**	**4.41%**	**4.47%**	**4.54%**	**4.61%**	**4.68%**	**4.75%**	**4.82%**	**4.88%**	GSMA + RTACS

		GSMA	GSMA Figures extrapolated to 2030										
WW Contributions	**Unit**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**Source**
Mobile Operators	B$	$1,000	$1,044	$1,089	$1,136	$1,185	$1,236	$1,288	$1,343	$1,399	$1,458	$1,519	GSMA + RTACS
Related Industries	B$	$400	$427	$456	$485	$516	$549	$583	$618	$654	$692	$732	GSMA + RTACS
General Economy	B$	$300	$325	$350	$377	$405	$434	$465	$497	$530	$565	$601	GSMA + RTACS
Productivity Improvement	B$	$2,200	$2,277	$2,356	$2,438	$2,522	$2,609	$2,700	$2,793	$2,889	$2,989	$3,091	GSMA + RTACS
Total	**B$**	**$3,900**	**$4,072**	**$4,251**	**$4,436**	**$4,629**	**$4,828**	**$5,035**	**$5,250**	**$5,473**	**$5,704**	**$5,944**	GSMA + RTACS

		GSMA	GSMA Figures extrapolated to 2030 using DEI impact weighting and RTACS subscriber forecast data											
UK GDP impact - Current Trajectory - using ranking derived from RTACS analysis.	**Unit**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**Source**	**DEI Economic Impact weighting**
Estimated Economic Impact Weighting by year	**%**	0.00%	-0.20%	-0.41%	-0.63%	-0.84%	-1.08%	-1.35%	-1.73%	-1.98%	-2.03%	-1.99%	GSMA + RTACS + DEI	-1.23%
Mobile Operators	B£	£29	£30	£31	£32	£34	£35	£36	£38	£39	£41	£43	GSMA + RTACS + DEI	-1.23%
Related Industries	B£	£11	£12	£13	£14	£15	£16	£16	£17	£18	£19	£21	GSMA + RTACS + DEI	-1.23%
General Economy	B£	£9	£9	£10	£11	£12	£12	£13	£14	£15	£16	£17	GSMA + RTACS + DEI	-1.23%
Productivity Improvement	B£	£63	£65	£67	£69	£72	£74	£76	£79	£81	£84	£87	GSMA + RTACS + DEI	-1.23%
Total	**B£**	**£112**	**£117**	**£121**	**£126**	**£132**	**£137**	**£142**	**£148**	**£154**	**£160**	**£164**	GSMA + RTACS + DEI	-1.23%
UK GDP Share	%	**4.20%**	**4.26%**	**4.32%**	**4.38%**	**4.44%**	**4.49%**	**4.55%**	**4.60%**	**4.65%**	**4.72%**	**4.69%**		

		GSMA	GSMA Figures extrapolated to 2030 using DEI impact weighting and RTACS subscriber forecast data											
UK GDP impact - Global Leadership - using ranking derived from RTACS analysis.	**Unit**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**Source**	**DEI Economic Impact weighting**
Estimated Economic Impact Weighting by year	**%**	0.00%	1.67%	3.38%	5.12%	6.89%	8.84%	11.05%	14.13%	16.14%	16.58%	16.20%	GSMA + RTACS + DEI	10.00%
Mobile Operators	B£	£29	£30	£32	£34	£36	£39	£41	£44	£47	£49	£51	GSMA + RTACS + DEI	10.00%
Related Industries	B£	£11	£12	£14	£15	£16	£17	£19	£20	£22	£23	£24	GSMA + RTACS + DEI	10.00%
General Economy	B£	£9	£9	£10	£11	£12	£14	£15	£16	£18	£19	£20	GSMA + RTACS + DEI	10.00%
Productivity Improvement	B£	£63	£66	£70	£73	£77	£81	£86	£91	£96	£100	£103	GSMA + RTACS + DEI	10.00%
Total	**B£**	**£112**	**£119**	**£126**	**£134**	**£142**	**£151**	**£160**	**£172**	**£182**	**£191**	**£198**	GSMA + RTACS + DEI	10.00%
UK GDP Share	%	**4.20%**	**4.34%**	**4.48%**	**4.63%**	**4.78%**	**4.94%**	**5.12%**	**5.34%**	**5.51%**	**5.61%**	**5.68%**		

		GSMA	GSMA Figures extrapolated to 2030 using DEI impact weighting and RTACS subscriber forecast data										
UK GDP impact change to Global Leadership Incremental £s versus current trajectory	**Unit**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**Total 2020 to 2030 Impact to economy**
Mobile Operators	M£	£0	£561	£1,185	£1,872	£2,627	£3,518	£4,583	£6,108	£7,272	£7,784	£7,923	£43,433
Related Industries	M£	£0	£230	£496	£800	£1,145	£1,562	£2,073	£2,810	£3,400	£3,698	£3,820	£20,033
General Economy	M£	£0	£175	£381	£621	£898	£1,236	£1,654	£2,260	£2,755	£3,016	£3,136	£16,133
Productivity Improvement	M£	£0	£1,225	£2,563	£4,016	£5,592	£7,428	£9,605	£12,705	£15,015	£15,958	£16,127	£90,233
Total	M£	£0	£2,190	£4,625	£7,309	£10,262	£13,745	£17,915	£23,883	£28,442	£30,456	£34,392	£173,218

The models utilises multiple data sources and extrapolations to create two views of a model from 2020 to 2030. To determine UK competiveness the model uses data derived from the Digital Evolution Index – DEI[44] which ranked the UK 4th in the world based on analysis working with four variables:

- Supply
- Demand
- Institutional Environment
- Innovation and Change

Using the same four variables the report also shows trend, where the UK is ranked 34th in the world, see diagram below, showing 33 countries to the right of the UK on trending score scale:

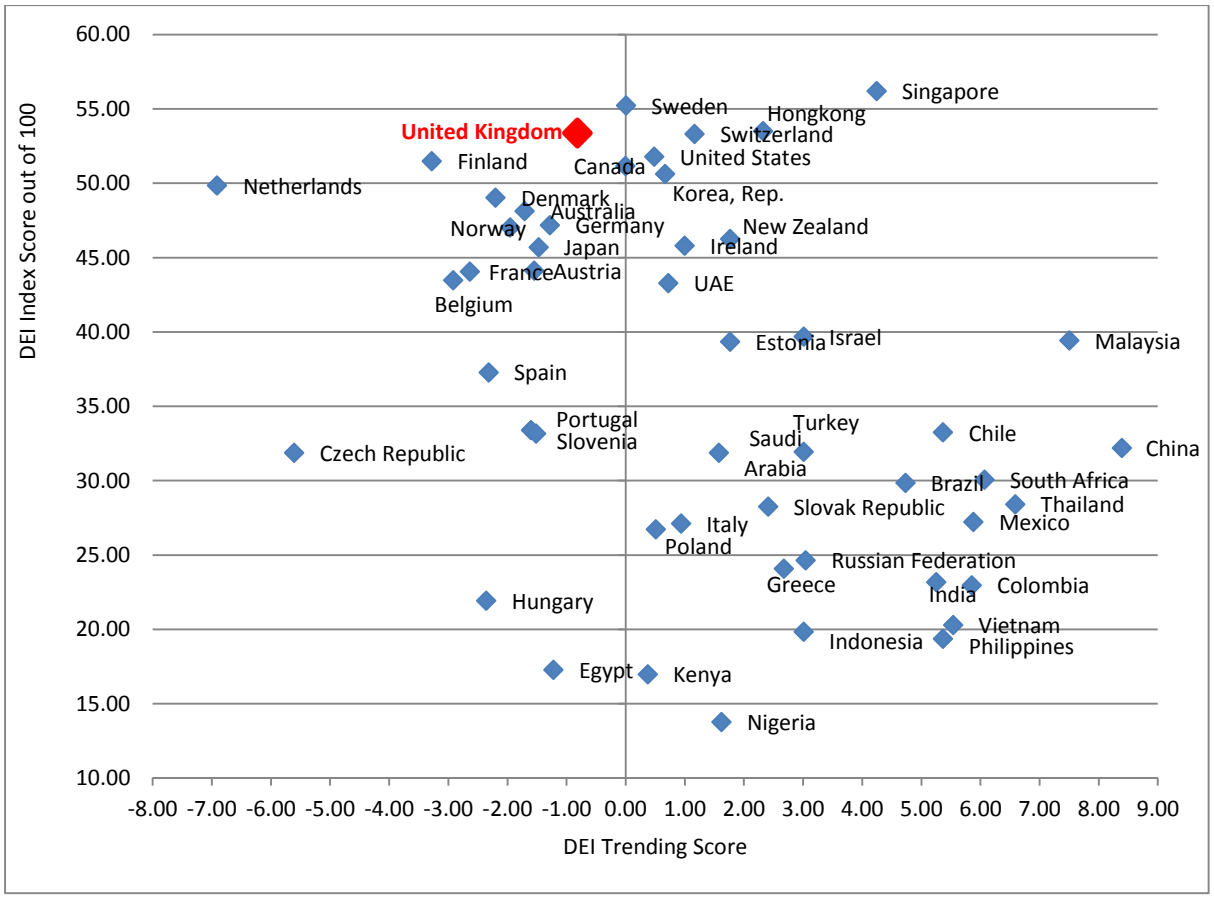


Figure 13 - DEI ranking by country

Based on scale developed using DEI data, the financial model used in this report utilises a competitive league table with each country distributed across an impact scale of +/- 10%. The league table results were used to create a market share change impact to the GSMA model[45] data extrapolated from 2020 to 2030. Global leadership, ranked 1st assumed impact to model of +10%, the UK trend ranking of 34th resulted in an impact rating of -1.23% which is used to model UK current trajectory.

[44] DIGITAL EVOLUTION INDEX – DEI Digital Planet: Readying for the rise of the e-consumer (Source: http://fletcher.tufts.edu/eBiz/Index

[45] GSMA Mobile Economy report source - http://gsmamobileeconomy.com/global/GSMA_Global_Mobile_Economy_Report_2015.pdf

The lowest rate country by trend in the report was the Netherlands and therefore they would have an impact of -10% in this model. The report main section used the +10% model to show the potential for UK Global leadership in support of the Government Manifesto commitment[46].

The profile of the -1.23% and +10% models used where profiled using a 10 year forecast based on 4G and 5G subscriber numbers (see Table 4 - GDP impact financial model and assumptions). The models shows the same starting point in 2020 and the impact of global market share gain or loss is shown by year over a 10 year period, negatively for -1.23% current trajectory and positive for +10% leadership model. The difference between the models demonstrates an overall UK positive impact of £173bn over 10 years.

As with all forecasts and models, the data generated is only valid at the point in time when the model is created using current available data and presents a view to compare scenarios and make decisions on investment and potential returns. It is imperative that this type of model needs to be analysed on a regular basis to ensure the UK remains competitive and the variables and model used are valid.

Different data sources, variables and assumptions can be used providing different levels of GDP impact. However, a common theme is emerging in terms of reports showing Mobile, IoT and 5G being a fundamental competitive differentiator and can provide significant economic gains through productivity improvements, efficiency of critical infrastructure, enhanced services and new business opportunities.

[46] Conservative Manifesto, Page 14 - Improving our trains, roads and broadband helps local businesses grow and create more jobs and opportunities and Page 15 - We will ensure that Britain seizes the chance to be a world leader in the development of 5G, playing a key role in defining industry standards. Source: https://s3-eu-west-1.amazonaws.com/manifesto2015/ConservativeManifesto2015.pdf

7.4 FCCG Members

First	Surname	Affiliation
Naomi	Climer	the IET
John	Baird	RCUK/EPSRC
Mark	Beach	University of Bristol
Howard	Benn	Samsung
Tommy	Charles	NCSC
Mischa	Dohler	Kings College London
Peter	Haigh	NCSC
Simon	Hicks	DCMS
Stephen	Howard	HSBC
Luke	Ibbetson	Vodafone
Nigel	Jefferies	Huawei/WWRF
Dritan	Kaleshi	Digital Catapult
Stephen	Pattison	ARM
Stuart	Revell	RTACS
Simon	Saunders	Independent
Mark	Shepherd	NTAC
Rahim	Tafazolli	5GIC
Steve	Unger	OFCOM
Alison	Vincent	CISCO
Cheng-xiang	Wang	Heriot Watt
Tim	Whitley	BT
David	Wong	SMMT

7.5 Glossary and abbreviations

Abbreviation	Definition
2G	2nd Generation Mobile
3G	3rd Generation Mobile
3GPP	3rd Generation Partnership Project
4G	4th Generation Mobile
5G	5th Generation Mobile, Networks and Internet of Things
5GIC	5G Innovation Centre
AC&C	Availability, Capacity & Coverage
API	Application Programming Interface
ARCEP	Autorité de Régulation des Communications Électroniques (French Regulator)
BEIS	Department for Business, Energy & Industrial Strategy
BEREC	Body of European Regulators for Electronic Communications
BIS	Department of Business, Innovation and Skills
CAPEX	Capital expenditure
CBRS	Citizens Broadband Radio Service
CDN	Content Delivery Network
CEO	Chief Executive Officer
CIoT	Critical Internet of Things
DCMS	Department for Culture, Media and Sport.
EBU	European Broadcasting Union
EC	European Commission
ECC	Electronic Communications Code
eMBB	Enhanced Mobile Broadband
eMBMS	Evolved Multimedia Broadcast Multicast Services
ETSI	European Telecommunications Standards Institute
EU	European Union
FCC	Federal Communications Commission
FCC CBRS	Federal Communications Commission Citizens Broadband Radio Service
FCCG	Future Communications Challenge Group
FCO	Foreign & Commonwealth Office
GDP	Gross Domestic Product
GSM	Global System for Mobile communications
GSMA	GSM Association
GSMR	Global System for Mobile Communications-Railway
HD	High Definition (Video)
HSB	High Speed Broadband (HSB) 1 to 10 Gbps
ICT	Information and Communication Technologies
IET	The Institution of Engineering and Technology
IETF	Internet Engineering Task Force
IoT	Internet of Things
ISG	Industry Specification Group
ISG MBC	Industry Specification Group on Mobile and Broadcast Convergence
IT	Information Technology
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunication Sector
ITU-T	ITU Telecommunication Standardization Sector
LP	Low-Power

Abbreviation	Definition
LSA	Licensed Shared Access
LTE	3GPP Long-term evolution mobile telephony standard also called 4G
M2M	Machine to Machine communications
MBC	Mobile and Broadcast Convergence
MEC	Mobile Edge Computing
MIMO	Multiple-Input and Multiple-Output
MIoT	Massive Internet of Things
mMTC	Massive machine type communications
NFV	Network Function Virtualisation
NGMN	Next Generation Mobile Networks
NIC	National Infrastructure Commission
NR	New Radio
NSN	Non-Standalone
NTT	Nippon Telegraph and Telephone
ONS	Office for National Statistics
OPEX	Operating Expenditure
QoS	Quality of Service
R&D	Research and Development
RAN	Radio Access Network
RAT	Radio Access Technology
RCUK	Research Councils UK
RSPG	Radio Spectrum Policy Group
SA	Stand Alone
SDN	Software Defined Network
SME	Small and medium-sized enterprise
TC-CYBER	ETSI Technical Committee on Cyber Security
UMTS	Universal Mobile Telecommunications System
uRLLC	Ultra-reliable and low latency communications
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
Wi-Fi	Trademark of the Wi-Fi alliance. Wireless Local Area Network technology (IEEE 802.11 family of standards)
WRC	World Radiocommunication Conference