ROYAL ACADEMY OF ENGINEERING

National Infrastructure Commission 5G call for evidence

Response to the consultation, 11 July 2016

This evidence is submitted by the Royal Academy of Engineering. As the UK's national academy for engineering, we bring together the most successful and talented engineers from across the engineering sectors for a shared purpose: to advance and promote excellence in engineering.

The evidence in this response was assembled in consultation with our Fellows. These include experts in telecommunications, cybersecurity, digital systems and infrastructure from industry and academia.

The Academy would also note the response from the Institution of Engineering and Technology (IET), which focuses on the technical aspect of 5G and which we support. We are making our own response in order to emphasise other issues.

Key messages:

The economic case for investment

1. Broadband (and especially *mobile* broadband) coverage and speed are critical issues for UK competitiveness. Investment in the digital technologies and infrastructure that enable connectivity is essential to ensure that the potential of the digital economy - currently underexploited - is fully realised[1].

A systems approach to the digital landscape

2. The UK needs to look at the entire digital landscape using a systems engineering approach that sets out a vision and road map for the utility of spectrum and what it means to the range of sectors that stand to benefit from digitisation. 5G should be an instrument for making the digital economy more competitive, rather than an end in itself.

3. A systems view of 5G infrastructure should take into account other connectivity infrastructures, such as optical fibre, WiFi and transport. Many of the potential end uses of 5G will require wireless-enabled services and connectivity when a person or object is moving. Conversely WiFi - static wireless connectivity to a person or object - is becoming increasingly available, particularly in urban areas. Public transport vehicles such as the tube or trains are also increasingly offering WiFi for free. 5G will be particularly valuable in rural areas where WiFi connectivity tends to be expensive as well as in private vehicles. The 5G strategy must therefore be very closely tied to other strategies such as the transport strategy - both private and public - and the provision of broadband connectivity to rural areas.

A strategy for spectrum

4. Radio spectrum is a limited and extremely valuable resource. Decisions taken now will constrain the options for spectrum use in the future. A dynamic, joined-up spectrum release strategy should dictate both what spectrum should be released and when.

5. The economic case for mobile communications services has been made extensively, but that for other uses of spectrum, for example space-based earth observation, science

[1] This was emphasised at the recent OECD's 2016 Digital Economy Ministerial Meeting in Cancun, Mexico, by the OECD Secretary-General Angel Gurría and is also a major concern of the EU Digital Economy.

and meteorology, is only now been developed on a comparable basis. This will need to be considered in any spectrum release strategy.

Demand generation to stimulate investment

6. Demand generation is essential for ensuring an early flow of investment towards 5G and needs to start now. Government and the National Infrastructure Commission can both play a role in this – for example, in ensuring that digital infrastructure is integrated with the delivery of new infrastructure such as road, rail and smart cities, or the upgrade of existing infrastructure. This will require a systems approach and joined-up thinking[2,3].

Ensuring international competitiveness

7. The UK's international competitiveness depends on common standards and approaches to spectrum. Lessons need to be taken from the launch of GSM[4] in this respect and applied internationally to 5G. For example, measures such as common launch dates and trials in cities across Europe should be considered to create economies of scale.

Improving access to sites for infrastructure

8. Improved access to fibre-ready sites is critical in order to achieve better coverage.

Building on what is there already

9. We understand 5G to be a holistic vision rather than a specific new technology. 5G will need to build on what already exists and where investment has already been made. The management of the bridge between 4G and 5G will need careful consideration.

Question 1: What uses have been envisaged for 5G?

- ***of those use cases identified, which appear most credible from a UK perspective, and over what timeframe?***
- ***what is the potential scale of benefits?***

Internet of things – a key use

10. 'Massive internet of things', is one of the eight use-case families defined by NGMN in its 5G white paper[5]. The internet of things is also identified as a key element of a 'data-enabled economy' in the joint RAEng/IET report *Connecting Data: driving productivity and innovation*. The benefits of data generated by the internet of things are subsequently realised by applying data analytics to extract useful information from the data.

[2] For example, the recent announcement by TfL to introduce 4G mobile coverage into the tube network is welcome but could have occurred sooner with the right joined-up discussions.

[3] For example, in France civil engineering infrastructure is being opened up so that mobile operators have access "under reasonable technical and pricing terms and conditions".

[4] GSM is the telecommunications standard for the second-generation (2G) digital cellular networks used by mobile phones.

[5] NGNM Alliance (June 2015), *NGMN 5G White Paper* https://www.ngmn.org/uploads/media/NGMN_5G_White_Paper_V1_0.pdf

11. The *Connecting Data* report explored applications across seven sectors including the smart grid, smart cities, smart buildings, intelligent mobility, autonomous vehicles and connected cars, remote monitoring of infrastructure assets and manufacturing products, and telehealth. The report found that, although many applications are still immature, there are pockets of excellent practice and considerable future potential for innovation and value generation in future years.

12. The report concluded that ubiquitous access to high-speed mobile broadband services, as well as fixed access, is a prerequisite for a data-enabled economy. This is crucial for enabling the transfer of real-time data in large volumes and at high speeds, or the resilient transfer of data in both rural and urban areas.

13. A paper by 5GIC[6] acknowledges the diverse applications that make very different demands on the supporting infrastructure, and divides them into three types of opportunity: broadband++ (high throughput), M2M (low cost, low battery consumption) and critical communications (low latency, high reliability). The internet of things crosses this range of opportunities.

14. The *Connecting Data* study found that, while all sectors perceived advanced connectivity to be a key enabler, a variety of different requirements emerged, for example:

    a. Advanced manufacturing, although making a significant contribution to UK GDP and rural economies, is at a significant disadvantage as a result of poor connectivity in rural locations. The same is true of precision agriculture (although not explicitly explored in the report).

    b. Health applications such as monitoring of patients outside healthcare environments will require robust connectivity to ensure that any adverse event needing an immediate response is rapidly communicated.

    c. For distributed systems such as those that might be used in the energy sector to share information between micro-energy management systems and a central system, latency may be an issue. Limitations in connectivity can compromise the timeliness of the processing if the transfer of data between different systems is too slow.

15. CEBR has estimated that, over the next five years (2015 to 2020), the value to the UK economy of big data analytics and the internet of things combined could accumulate to £322 billion (expressed in 2015 prices), roughly equivalent to 2.7% per year of annual GDP between 2015 and 2020[7]. Other studies focus on big data[8].

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[6] 5GIC, University of Surrey (2015), 5G White Paper: Meeting the challenge of "universal" coverage, reach and reliability in the coming 5G era, https://www.surrey.ac.uk/sites/default/files/White-Paper-Rural-5G-Vision_0.pdf

[7] CEBR (2016), The value of big data and the internet of things to the UK Economy, Report for SAS http://www.sas.com/content/dam/SAS/en_gb/doc/analystreport/cebr-value-of-big-data.pdf

[8] A study by Imperial College that looked at only big data acknowledged an increase in the contribution to GDP over the next few years, although its estimate was lower: in the coming decade, data-based assets may contribute around 0.07% to 0.23% pa of annual growth on average. Goodridge, P. and Haskel, J. (2015), *How does big data affect GDP? Theory and evidence for the UK*, Discussion Paper https://spiral.imperial.ac.uk/bitstream/10044/1/25156/2/Goodridge_2015_06.pdf

Future requirements for 5G: ubiquitous mobility; high integrity, availability and resilience; and security

16. The last link to almost all devices in achieving ubiquitous mobility is increasingly radio-based with major use of WiFi alongside the use of 3G, 4G and in the future 5G technologies. How these co-exist, both in terms of spectrum sharing and seamless handoff of connections between different technologies will remain important areas of work.

17. There will be a need for a high-integrity 5G service, with guaranteed integrity, throughput and resilience to failure, for safety-critical and security-critical uses such as railway signalling, supporting driverless cars and other unmanned vehicles, in national critical infrastructure such as energy and water supply systems and in health-intervention devices such as insulin pumps. The current wired and wireless networks in the UK are insufficiently reliable to allow any safety-critical control of constituent physical parts.

18. While there are tools and techniques for wireless networking to achieve high availability and resilience, they may depend on massive cooperation between different providers in the future, much more so than 3G or 4G have done. It is not obvious what manner of business landscape will support a combination of cooperation and competition at every scale, from small household to entire cities to national infrastructure.

19. There has been a lot of work on tools for privacy in the internet, and much is transferable to 5G. However, the current security architecture of cellular data networks is insufficient to protect resources, especially when they are not just information sources but are also mechanisms for sensing and controlling cyber-physical systems such as the internet of things. The creation of a regulatory and economic environment that places incentives on suppliers to provide high quality networks, devices and cloud controls is needed. The possibility of vulnerabilities being introduced through the supply chain for critical components should also be addressed.

Question 2: What regulatory, planning and other key challenges need to be overcome to support the rapid and cost effective deployment of 5G across the UK?

- ***are there planning or wider legal issues which have the potential to hold back the deployment of 5G networks?***
- ***are there issues around working across industry sectors which may hold back the deployment of 5G networks?***

The international perspective

20. International agreements and standards are essential so that products can be sold internationally and used internationally. Key decision processes are already in progress at an international level. It is essential that the voice of potential UK users is heard in that process as the options for 5G technologies are discussed.

21. The process of identifying and aligning internationally around common bands for 5G will depend on the technology that can be identified to overcome band usage in high frequencies for wide area coverage.

22. The UK Spectrum Policy Forum has achieved a broad consensus on a UK contribution to the definition of 5G. This is being carried forward into the appropriate ITU[9] Working Group (5D) through Ofcom.

A coordinated response across stakeholders

23. The need for cooperation across a range of stakeholders is critical. There is already a range of bodies doing excellent work in this area such as the 5G Innovation Centre at the University of Surrey and the UK Spectrum Policy Forum. However, a larger body that includes government departments such as BIS and DCMS is needed to act as UK coordinator and ensure an inclusive approach to obtaining the greatest economic benefits from 5G.

24. 5G should not be planned in isolation. 5G is part of a much larger system that needs rigorous, professional systems engineering in the national interest, not in any narrow commercial interests. The systems architecture and systems engineering should be managed centrally by an independent organisation accountable to government, possibly funded by the spectrum auction.

25. In its 2014 *The UK spectrum strategy: delivering the best value from spectrum for the UK*, government stated that they 'intend to be at the forefront of developing 5G mobile technology'. Continued R&D investment into spectrum-related technologies is needed to ensure that the UK maintains a position at the forefront of this area.

Planning

26. Through the new Electronic Communications Code, government is putting forward a package of legislative reforms to improve the case for private investment in digital infrastructure[10]. It intends to bring these reforms forward through primary legislation at the earliest possible opportunity to support Ofcom as they work with stakeholders to establish a robust and clear code of practice to support the Code. This is essential and is indeed a *quid pro quo* for the actions committed by operators to substantially enhance coverage. The charging regime for mobile operators will need careful consideration alongside access to sites.

27. The mobile network cannot work to its full potential until fully capable backhaul[11] is available. It should be possible for mobile operators to exploit the fibre backhaul that will be installed as part of delivery of the government's broadband USO commitment.

[9] ITU is the International Telecommunication Union.

[10] DCMS, May 2016, A new electronic communications code https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/523788/Electronic_Communications_Code_160516_CLEAN_NO_WATERMARK.pdf

[11] 'Backhaul' describes the intermediate links between the core network and smaller sub-networks.

Question 3: What are the infrastructure requirements for 5G deployment likely to be?

- ***what do the services and uses for 5G suggest about the infrastructure requirement?***
- ***what level of UK coverage will be optimum and what does this mean for the challenge of delivering higher speeds and lower latency? Are there particular issues faced by urban, suburban and rural areas?***
- ***are there any 'no regrets' and 'low regrets' infrastructure investments that can be made to support 5G deployment?***
- ***in what ways could collaboration between infrastructure sectors speed up and improve deployment, and how might it be incentivised?***
- ***are there any relevant international examples in the deployment of telecoms infrastructure that the UK can learn from?***

28. There is both a capacity challenge and a coverage challenge. The economic case for high coverage in rural areas will be particularly challenging[12]. Notwithstanding, the use of high frequency radio spectrum combined with new technologies such as beam-forming[13] and MIMO technology[14] in mobile devices is being investigated to meet these challenges[15]. It would be helpful to see trials of 5G in the UK to complement those proposed in the Netherlands by Huawei - on a very different landscape – that focus on developing practical applications in rural areas[16].

29. The use of Demand-Attentive Networks[17] that supply bandwidth whenever the demand arises and create the perception of unlimited bandwidth should be considered.

30. Critical elements of spectrum management that are central to the success of 5G include[18]:

    a. Access to wider radio frequency channels in GHz Bands that will be needed for 5G to improve performance.

    b. The use of 700 MHz spectrum to drive up national coverage and its reliability.

31. In order to deliver key elements of the infrastructure for 5G, the following will be necessary[19]:

[12] 5GIC, University of Surrey: 5G Whitepaper: Meeting the challenge of "universal" coverage, reach and reliability in the coming 5G era https://www.surrey.ac.uk/sites/default/files/White-Paper-Rural-5G-Vision_0.pdf

[13] Beamforming is a signal processing technique for improving the performance of wireless networks.

[14] MIMO - 'multiple-input and multiple-output' - is a method for increasing the capacity of a radio link.

[15] GSMA Intelligence (December 2014), Understanding 5G: Perspectives on future technological advancements in mobile https://www.gsmaintelligence.com/research/?file=141208-5g.pdf&download

[16] June 10th 2016, Huawei, Ericsson among 10 partners to launch rural Dutch 5G test bed,

[17] IET (2013), Demand-Attentive Networks, Creating the perception of unlimited bandwidth in an untethered fibre-wireless world http://www.theiet.org/factfiles/comms/dan-page.cfm?origin=/dan

[18] This is presented in greater detail in the IET's response to this consultation.

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a. Access to sites for small cells requiring a radical change in the site access / rental model, since current models will not scale up to deal with the number of cells that will be required. The use of buildings and other structures owned by the public sector to mount antenna would provide a basis for transforming the model.

b. Mechanisms to encourage the enhancement of existing infrastructure – for example, raising existing mast heights.

c. Access to space for hosting distributed computing/processing/storage for operators to support some of the new software-based technologies that will improve coverage and capacity.

d. Incentives to encourage fast roll-out of the new technologies so there is reasonably fast step-change in performance that incentivises new customer demand.

e. Measures to ensure sufficient coverage of fibre optic cable.

Question 4: Who should bear the deployment costs of 5G?

- ***what is 5G deployment likely to cost the UK?***
- ***are there international examples to draw on?***

32. Future investments will need to build on current investments in 4G and earlier technologies, and will involve both the incumbents such as mobile phone operators and new players.

33. The existing structure of mobile operators and other players will need to be considered, as well as the business cases for 5G and ways to incentivise investment[20].

34. Co-use models should be increasingly applied. For example, these could take further the work of the Emergency Services Network (ESN) contract awarded to EE[21]. Real-time critical communications are key for many areas of the public sector as well as private sector.

35. As part of the systems approach to the digital landscape, future environmental costs of the different communications infrastructure solutions will need to be considered alongside future communications requirements. For example, countries such as New Zealand have chosen to invest heavily in optical fibre[22].

[20] Webb, W. 2016 *What is wrong with the 5G vision*. This paper provides an opinion that the current business case for 5G is weak, although this view is not universally shared.

[21] 10th December 2015, EE selected to deliver critical new 4G voice and data network for Britain's emergency services

[22] Cochrane, P., Reed, D. and Thomas, H. (July 2016), *Oxford and Cambridge Plan - World leader @ 5G deployment - an unworthy aspiration?*; ComputerWeekly.com, May 2016, *New Zealand reaps fibre benefits as copper-choked UK risks digital exclusion*. This paper and article give the opinion that FTTP (fibre-to-the-premises) is more strongly placed to

Question 5: Is the existing UK telecommunications model able to facilitate the efficient roll out of 5G infrastructure and technologies?

- ***is spectrum policy and its management well placed to support future 5G technologies?***

36. A strong spectrum release strategy is fundamental to supporting future 5G technologies.

37. If spectrum auctions are used in future, lessons should be learned from previous auctions as mistakes were made across the world by inexperienced governments primarily around the setting of reserve prices. Lessons learned from 3G and 4G auctions include the following:

    a. The auctions took place at particular moments of time when market conditions were very different to how they are now - for example, there has been a large increase on the popularity of tablet computers since auctions first took place.

    b. In the future, those responsible for the auction should not predict to Treasury what the auction will raise.

    c. Auctions are the most economically efficient way of allocating scarce resources and favour bidders who have credible plans to extract the maximum economic value from the services supported.

    The creators of and bidder in spectrum auctions are much more sophisticated and rational about spectrum now and the factors to consider in the allocation of 5G resource such as universal coverage and consumer expectation.

meet future communications and environmental requirements than 5G and the UK should learn from New Zealand's fibre strategy, although this view is not universally shared.