5G Consultation- Call for Evidence

18 July 2016

Consultation Response - Institution of Civil Engineers

The ICE is a UK-based international organisation with over 91,000 members ranging from professional civil engineers to students. It is an educational and qualifying body and has charitable status under UK law. Founded in 1818, the ICE has become recognised worldwide for its excellence as a centre of learning, as a qualifying body and as a public voice for the profession.

ICE would like to thank the National Infrastructure Commission for the invitation to take part in the consultation.

Introduction

As a centre of knowledge and excellence in physical infrastructure planning, design and delivery, our response is framed primarily in relation to how 5G might impact upon other key infrastructure areas: water, transport, energy, flooding and waste, and their interdependencies. It also considers other underpinning factors, such as availability of the necessary skills to support the 5G rollout.

ICE is strongly supportive of the NIC's essential exploration of 5G roll-out in the UK, and the UK Government's ambition to make the UK a world-leader in 5G technology. ICE recognises that 5G has the potential to change how we design, deliver and operate our key infrastructure assets, create significant efficiencies in the construction industry, and change the face of our built environment.

- **As with all major infrastructure programmes, the success of a 5G programme will depend on getting the following right:**
  - **Approval, regulation and planning**
  - **Programme**
  - **Funding**
  - **Policy**
- **The security and resilience of future infrastructure which is dependent on 5G connectivity is vital to avoid cascade failures in increasingly interdependent systems**
- **Industry requirements of 5G will be different from those of consumers and this need to be considered.**

Preamble

As yet, there is still no standard definition for 5G. Two possible directions have been suggested:

- 5G will 'consolidate' previous generations, expanding coverage and improving reliability
- 5G will considerable reduce end-to-end latency, and improve data transfer speeds

This may be in part dictated by what we expect 5G to do, what we expect the coverage to be, and who it is primarily envisaged benefiting. The requirements of consumers will be different from those

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of industry. It needs to be clear what 5G will and won't do, what its strengths and weaknesses will be, to inform decision making.

It is worth noting that there will be a lot of Kudos associated with the race to market. Computer Service Providers (CSPs) will be under pressure to deliver to published deadlines and this may mean shortcuts being taken, including with security. There is anecdotal evidence that UK CSPs who went live in the early days of 4G were delivering to deadlines and letting the security catch up later.

While the consumer benefits of 5G are broadly understood, more focus on the design and operations side of the 5G discussion is required.

Questions

4.1.1 What uses have been envisaged for 5G?

5G is potentially relevant to a host of applications:

- Building Information Management (BIM)[1] – level 2[2] and level 3[3] – including, but not limited to:
  - 'As designed' vs 'as built' construction monitoring
  - Augmented reality for construction monitoring visualisation
  - Facilities and asset operation and management
- Smart cities
- Transport infrastructure operation
- Structural health monitoring of physical infrastructure assets (especially in remote or rural locations)
- Autonomous vehicles/connected cars/smart road infrastructure
- Improved HD/UHD video streaming (drones for inspection of infrastructure assets like bridges, virtual/augmented reality)
- Security services and data
- 'Internet of Things'
- Infrastructure for education and health services (eHealth, assistive devices)
- Smart meters (gas, electricity, water) and systems

While some of the use-cases outlines above can be delivered without 5G, the full realisation of others will be dependent upon the reduced latency and increased capacity 5G could offer. For example, for BIM level 3 to be used effectively, and for machine to machine (M2M) systems – such as smart highways and autonomous vehicles – improvements in end-to-end latency beyond what is available with 4G LTE will be required.

> **Case Study:** The UK Connected Intelligent Transport Environment (UKCITE) project[4] aims to create the most advanced environment for testing connected and autonomous vehicles. It involves equipping over 40 miles of urban roads, dual-carriageways and motorways with

[1] BIM is a value creating collaboration through the entire life-cycle of an infrastructure asset, underpinned by the creation, collation and exchange of shared 3D models and intelligent, structured data attached to them. (UK BIM Taskforce)
[2] BIM level 2 (procurement BIM) is now mandated for use on the procurement by UK Central Government of all significant building and civil infrastructure projects.
[3] BIM level 3 (lifetime BIM) is not yet defined, other than in an initial strategy document published by UK Government in Feb 2015 (see http://digital-built britain.com/DigitalBuiltBritainLevel3BuildingInformationModellingStrategicPlan.pdf).
[4]http://www2.warwick.ac.uk/fac/sci/wmg/mediacentre/wmgnews/?newsItem=094d434554f376b501551675dc2229b4

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combinations of three ‘talking car technologies’, and testing for a fourth, known as LTE-V. The project will establish how these technologies can improve journeys, reduce road traffic congestion, and provide entertainment and safety services through better connectivity. Initial work by the project to test 4G/LTE connectivity in the Coventry/Birmingham area has highlighted some serious capacity/connectivity issues in the existing cellular infrastructure that would severely limit the ability to use of vehicle processing.

Physical and communications infrastructures can be thought of as aspects of an interdependent system, where physical infrastructure is the ‘skeleton’, sensors are the ‘senses’, and 5G could be the nervous system. Together the system operates effectively, but if missing one of these aspects then it can only be partially effective. 5G has the potential to better/fully enable other physical infrastructure and their interdependencies.

4.1.2 Of those use cases identified, which appear most credible from a UK perspective, and over what timeframe?

Currently, there is no one single core application which will drive 5G development and deployment, but a number which might benefit directly from it – BIM, structural sensors, smart highways. While current use cases are limited, the market has historically tended to deliver services which make use of new capacity.

Some use cases most relevant to civil infrastructure design and operation will benefit from improved latency and reliability. Others however would benefit from an increase in available bandwidth. For example, dynamic structural health monitoring of infrastructure assets, such as bridges, would benefit from an increase in bandwidth available, particularly in the upstream direction (which is often significantly less than in the downstream direction with current asymmetric communications technologies). Construction technologies, like reality capture[5] require a lot of bandwidth.

> **Case study**: Changes in legislation can affect the demand for digital communications services. For example, from 1st October 2016, privately owned waste water pumping stations will be adopted by the local water companies. Maintenance was previously the responsibility of the private owners. There are potentially a large number of these pumping stations, each relatively small and serving maybe one or two properties, most likely in rural areas. A potential use for 5G would be to provide an M2M always-on fault reporting system for this type of physical asset, as and when they are identified.

4.1.3 What is the potential scale of benefits?

It is hard to tell due to the potential number of variables and the undefined nature of 5G. The benefits are potentially considerable, but it’s worth noting that needs and benefits will be different for consumers and for industry. Clarity about each will be vital. A ‘truth matrix’ mapping different stakeholders against the foreseen benefits of 5G rollout could be helpful in establishing measures of success for a 5G project. For an example, see Annexe 1.

For industry, increased coverage and capacity of mobile connectivity by 5G could enable many organisational efficiencies. For example, the construction of transportation projects are often in rural or remote areas by virtue of their connecting role between cities (such as the proposed HS2

[5] Reality capture technologies include 3D laser scanning, mobile and aerial LiDAR, and photogrammetry to capture the existing conditions of an area/asset and store them in digital form.

development, initially connecting London and Birmingham). The use of new technologies dependent on high-capacity connectivity (low latency video transfer) have the potential to enable time savings. Constant access to sensors and systems enabled by improved coverage and connectivity, too, is a high-use-high-value proposition for industry. Real-time monitoring of infrastructure assets and their interactions, the ability to gather information from remote assets, and many other benefits can delivered at a range of scales.

> **Case Study**: Augmented reality (AR) has a role in helping construction teams on site understand how various systems and components fit together during production. Construction could be assisted by the use of tablets on-site with apps to render 3D models to allow construction teams can compare the models to plans, reducing human error. AR would allow a user to see exactly how a design fits into the construction site, including how parts and systems that have yet to be constructed will with those already in place. This can be made to work not just with a tablet, but with VR headsets for a more flexible approach. Bentley Systems and others have speculated (Côté 2013) that this could also be used in conjunction with BIM plans, creating rich data availability on site.

Moreover, having 'always-available' mobile connectivity that can deliver near-ubiquitous data access will enable operatives working on-site to immediately access required information.

> **Case study**: In the Construction industry, on-site connectivity is often problematic. Initially mobile connectivity will be deployed, but this can be hampered by the existence of 'not spots' for 2G, 3G and 4G LTE. Where mobile connectivity is established, it is usually superseded by fixed access connectivity where feasible. This is to allow effective use of BIM and cloud technologies, which aren't fully supported by 4G LTE access, but could be supported by 5G.

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

Planning: We can expect the densification of mobile communication infrastructure for 5G. This is a consequence of using higher frequency bands within the radio spectrum, which will result in a decrease in signal propagation. Several areas of planning legislation will need to reflect this.

Energy: New applications enabled by 5G may have unforeseen impacts on our energy requirements. It will be necessary to consider what this means in the context of already growing energy demands, green energy production, and carbon impacts. There are hidden costs and currently poor data. The resilience of energy supply in the current challenged market is also an issue.

Unforeseen consequences: There is a need to consider the impacts of increased coverage, and associated infrastructure, on wildlife, quality of human life and broader societal impacts, amongst other issues. Technological choices are not binary, by which we mean it is not simply a do it/don't do it choice - there are many other questions that arise in taking forward a pro-5G option.

Spectrum allocations: This will be key, and how spectrum is allocated will impact upon how the technology operates. Certain things – like satellites - have fixed allocations. There is still uncertainty around which frequency bands in the radio spectrum may be used for 5G. International discussions via the ITU may be a cause of delay as a consequence.

Europe: The degree to which the UK wishes to harmonise itself with the Digital Agenda for Europe and the digital single market will be an ongoing challenge to determine, following the decision in

June 2016 for the UK to leave the European Union. The UK is ahead of most other countries in the provision of digital infrastructure, but for example, the European Commission is currently consulting on the coordinated introduction of 5G networks in Europe, and the UK may lose influence in determining the overall 5G agenda as well on enablers such as spectrum, standards and investments.

Coverage: If 5G is going to be used to support initiatives such BIM, smart cities and smart transport, and act as an enabler for communications with objects (i.e. the IoT) then the operating licences need to address the delivery of a ubiquitous, high availability service, with 100% coverage of all population centres (cities, town and villages). The coverage should provide a guaranteed minimum level of connectivity in terms of data throughput and latency of the network.

Regulation: The regulatory regime needs to address the policy issues regarding the type of communications traffic/use that the cellular coverage will provide. For example, we already encounter performance and capacity issues with the wired broadband as a result of the increasing use of broadband to carry streamed audio and video services. This is despite having a sophisticated and virtually universal terrestrial and satellite RF distribution network carrying video content. The Infrastructure Commission may wish to consider whether use of the 5G cellular network for such transmissions, including for example the move to 4K video represents value for money or a prudent use of cellular bandwidth, when such transmissions can be handled though other communications channels.

4.2.2 Are there planning or wider legal issues which have the potential to hold back the deployment of 5G networks?

- Spectrum allocation;
- Planning controls on new base station deployments & use of public sector land;
- Sharing of fixed broadband access points for new base stations
- Exploring regulatory infrastructure sharing to reduce costs and avoid redundant use of capital in duplicating infrastructure.

4.2.3 Are there issues around working across industry sectors which may hold back the deployment of 5G networks?

Interdependencies: Infrastructure systems are becoming more interconnected as a consequence of (primarily) the ongoing integration of digital technologies (Hall et al. 2016). This means that infrastructure sectors (energy, transport, waste, water etc.) rely more on the continual, uninterrupted operation of digital communications. For example, digital technologies which use communications networks are now being used widely in energy and transportation. For example, the implementation of Smart Grid technology in the electricity sector enables better monitoring, performance and reliability of the electricity system using thousands of remote controlled devices installed at various points in the grid. Key to the Smart Grid development "is a modernised electricity grid that uses information and communications technology to monitor and actively control generation and demand in near real-time, which provides a more reliable and cost effective system for transporting electricity from generators to homes, businesses and industry" (DECC and Ofgem, 2014). Digital communications systems such as 5G are highly dependent on electricity to operate. Failure in one system could lead to cascading failure. These interdependencies might not necessarily 'hold back' the deployment of 5G, but they serve as important examples of why we need to make sure that we get the delivery of the next generation of communications technologies correct.

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From both the Level 3 work and the UKCITE work (at Warwick Uni) on connected vehicles, there are critical issues concerning the capacity, reliability and resilience of the connectivity via mobile communications. By way of example, the following quote is from a Royal Academy of Engineering report "Living without electricity"[6] on the power outage in Lancaster during the floods in December 2015:

> *"Telephones and the internet*
>
> *The wired telephone system, powered from batteries in the exchange, continued to operate over most of Lancaster. Some areas were out of action but that was largely caused by flood water saturating the connection boxes, rather than the loss of electricity supply. Many people who had replaced wired handsets with wireless discovered that these do not work without a mains supply.*
>
> *Mobile phone systems did not hold up. On most networks, the base station (the transmitter that provides the radio signal to communicate with phones in that area) is powered from the local 230V electricity supply. Some have a battery back-up that continues to provide a service for an hour or two but few, if any, cope with the 30-hour loss or supply experienced over much of Lancaster. Inevitably, the loss of a mobile signal resulted in the inability to send or receive text messages or to use 3G and 4G internet services."*

Skills: 5G, and broader technological changes, will create a new set of skills requirement for those working in key economic infrastructure areas. In the future we may see job requirements changing more rapidly, and both people and companies will need to be more flexible to changing requirements. Foresight and agility will be key, and retraining may need to be approached in a more modular way in the future.

Security: Security tends to be thought of in terms of data security, but security of infrastructure also vital to avoid domino effect/cascade infrastructure failure. The interdependencies of different infrastructure systems have the potential to be better understood and modelled with the increased connectivity, use of sensors and generation of data. However, we have to acknowledge that it can be exploited. A recent study estimated the impact of a cyber-attack on London's electricity distribution network. An attack on 65 substations in London and the South East could leave 9 million customers without power, leading to an economic loss of £49 billion over 11 days (Kelly et al. 2016). The cyber-attack in this scenario is similar to the type which caused the blackout in the Ivano-Frankivsk region of the Ukraine on 23rd December 2015.

For all security to be effective it needs to be end-to-end. Work across a whole supply chain it's not good enough for one 'piece' to be secure when the rest of the chain is more vulnerable. We also need to be aware of 'local network risks' – for example, hacks to smart meters which can propagate to other smart meters in the area.

The security of operators needs to be considered as well as that of consumers. As now, the security team will hold the line that it is up to industry to make sure their communications links are fit-for-purpose by a combination of supply chain and by encryption of sensitive data. 5G will continue the trend started by 4G of seamless switching between different radio access protocols so keeping control of the route taken by your communications traffic will become even more difficult.

[6] http://www.raeng.org.uk/publications/reports/living-without-electricity

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5G is likely to drive the requirement for Internet Protocol version 6 (IPv6) to become standard (instead of operating in the background to IPv4 as it has been since 1998). IPv6 has the potential for better security, although it has been watered down to "must be included" instead of "must be enabled" in many parts. However, much of the rest of the network and cyber security is based around IPv4; widespread adoption of IPv6 may circumvent a lot of current defences.

There may also be issues in terms of attractiveness to a denial of service attack (by, for example, a hostile foreign actor) and the consequences of that needs to be assessed if there is reliance/dependence on network availability.

Skills availability in cyber security is also an area which needs to be considered.

Other issues that will need to be considered include:

- Privacy/use of information
- Reliability
- Coverage & cross-border interoperability
- Capacity
- Power & Environment
- Infrastructure reusability

4.3.1 What are the infrastructure requirements for 5G deployment likely to be?

For near-ubiquitous coverage of 5G there would need to be considerable infrastructure densification. This is a consequence of using higher frequency bands of the radio spectrum, as signal propagation would decrease. It is likely that we will see a further blurring of the boundaries between operator-provided publicly accessible base stations and private user-provided base stations on private premises.

If 5G is to be the basis for smart infrastructure, IoT, etc., we need to put in place a resilient, secure 5G infrastructure that addresses both physical and cyber security issues and has a fault-tolerant communications and energy supply network supporting its operation. The deployment of the communications sites needs to be managed strategically to ensure that the hubs are located so as to eliminate not-spots and reduce the physical vulnerability to interference and harm (from both natural and human causes).

4.3.2 What do the services and uses for 5G suggest about the infrastructure requirement?

Future uses may require symmetric upstream/downstream data capabilities, as opposed to the currently available consumer-focused asymmetric services. The Construction industry, in making use of drones, virtual reality/augmented reality, cloud technology and BIM will require better upstream capability in the creation of richer built environment data.

As in our response to the previous question, for near-ubiquitous coverage of 5G there would need to be considerable infrastructure densification. A dramatic increase in cell stations will be required to enable 5G capabilities.

For the full social and economic benefits of 5G to be realised then near-ubiquitous coverage may be required. The current model tends to ‘write off’ consumers who are geographically and socially ‘hard-to-reach’. Therefore, there ideally needs to be sufficient coverage and capacity to enable 5G content, applications and services to work, even in hard-to-reach areas. This may be more easily achieved than with previous technologies, because much of the required infrastructure (fibre, copper using G.Fast etc.) will already be in place, requiring less fixed capital expenditure to upgrade.

4.3.3 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?

Societally, those who would benefit most from improved access are often those living in remote and rural areas. They are also the most likely to suffer poor access to good social and economic infrastructure, poor health etc. Better connectivity may have the greatest net social benefit for these communities, and be beneficial in terms of consequential savings to other budget lines, for example, remote health care meaning lower high-intensity care requirements. Economically speaking, it is likely that 5G will be rolled out initially in the urban context due to the advantages of economy or scale.

M2M connectivity will require far lower latency to be effective, and as explored in other areas of the response, some use cases - such as autonomous vehicles - will require full coverage.

4.3.4 Are there any ‘no regrets’ and ‘low regrets’ infrastructure investments that can be made to support 5G deployment?

We suggest a number of options which could fall into this category:

- Remote devices (collection);
- Autonomous vehicles (use); and
- Allocation of high-frequency spectrum to technology experimentation.

The built environment is suited to being an early test programme subject, and that there are a number of specific infrastructure interventions (as above) and programmes (such as BIM level 3) which may support the case for 5G deployment.

4.3.5 In what ways could collaboration between infrastructure sectors speed up and improve deployment, and how might it be incentivised?

Many key physical infrastructure providers and operators are laying fibre which could be utilised for deployment of 5G. One example is Network Rail, which is laying a fibre network for its own networking purposes along rail lines. Fibre assets could be utilised via infrastructure sharing schemes which could bring the cost of 5G delivery down, especially in rural or remote areas.

In driving collaboration between relevant sectors it is worth considering what each sector has in common with the others. Many fundamental processes will be similar or the same. By considering these processes and approaches in common, then there is a chance to create common approaches and efficiencies. Then each sector can specify individually for the areas of difference. This has the potential to deliver cross-sectoral learning and create time and resource efficiencies.

4.3.6 Are there any relevant international examples in the deployment of telecoms infrastructure that the UK can learn from?

In China and India it has been observed that communications infrastructure is often being deployed before ‘traditional’ infrastructure. And Korea has funded studies by private companies to see what could be delivered.

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4.4.1 Who should bear the deployment costs of 5G?

Realistically, operators have to bear the majority of the deployment costs in the first instance, as they are generating revenue from customer subscriptions / selling wholesale business services. But consumers ultimately bear the cost whether it's delivered via telcos or government.

4.4.2 What is 5G deployment likely to cost the UK?

A Real Wireless study suggests £9.9bn would be representative of the potential cost of 5G roll-out. However, this figure was extrapolated from previous generations of technologies and therefore may need further investigation.

4.4.3 Are there international examples to draw on?

South Korea has allocated spectrum to the key mobile network operators to test 5G technologies.

Moreover, Japan is a classic example of a country that has tended to take political decisions to overinvest in civil infrastructure traditionally. We may want to be cognisant of the fact that returns on investment are non-linear, and once you pass a certain threshold, the benefits of further investment begin to diminish.

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

It is arguable that since the existing UK telecommunication model still struggles to deliver 3G and 4G LTE to many areas of the country (and 2G in some cases) that 5G may require a different approach.

4.5.2 Is spectrum policy and its management well placed to support future 5G technologies?

In light of the recent UK referendum decision to leave the EU, spectrum management policy in relation to the Digital Agenda for Europe will need to be considered. Alignment with the approach of the Commission may be important.

References

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ANNEXE 1

STAKEHOLDER/5G 'VIRTUE' – PROJECT SUCCESS MEASURES	DESIGN	OPERATION	MAINTAINANCE	MANUFACTURER	CONSUMER
INCREASED RELIABILITY	More smarts are designed into systems, networks and assets	Connectivity is ensured, enabling real time operational services	Businesses can plan and budget ahead more accurately for asset maintenance, using on line condition and performance monitoring	More likely to implement IoT solutions in manufactured products which will provide value add services	Access to real time service data to plan service consumption
REDUCED LATENCY	More opportunities to use connected systems	Virtually instantaneous feedback allows swift decision making and system correction where necessary	Real-time feedback about asset conditions foresees maintenance requirements, allowing pre-breakdown intervention and continued smooth delivery of service.	Ability to increase systems functionality	Better end-to-end latency providing a better interactive user experience - e.g. for video calls/gaming
INCREASED CAPACITY	Ability to use BIM/cloud technologies, reducing human error, creating greater delivery efficiencies.	Ability to transfer large amounts of data upstream and downstream at low cost.	Enable more products to be connected. Allows greater use of structural health monitoring sensors that require larger bandwidth (e.g. Videogrammetry)	Enable more products to be connected	Ability to transfer large amounts of data upstream and downstream at low cost. New consumer technology uses emerge on the market.
FULL COVERAGE	Instant access to technologies – BIM/Cloud etc – reducing delays and inefficiencies on site.	Full knowledge of how a whole system is performing regardless of scale.	Use of sensors regardless of location allows full knowledge of how assets are performing and better knowledge of maintenance needs.	Enable more products to be connected	Able to access/upload regardless of physical location to at least a set minimum level.
SECURE METHODS	Security designed in at the outset.	Systems operate securely and are not compromised.	Systems operate securely and are not compromised.	Individual systems remain intact and secure	A high degree of security and dependability.

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