The Institution of Engineering and Technology

5G Networks for Policy Makers

An IET guide to what's real, what's not and what could be deployed by 2020

www.theiet.org/5GNetworks

Contents

Foreword

The IET Guide "5G Networks for Policy Makers" makes 5G more accessible to the policy makers and assists in identifying the most important 5G network changes ready to be rolled out from 2020. The guide is produced by the Institution of Engineering and Technology's Communications Policy Panel, a group of industry and academic telecommunications experts, with the aim of offering independent and impartial advice to help policy makers cut through the many, and potentially confusing, visions of 5G – and focus on the key policy challenges that need addressing to get 5G off the ground by 2020, and then onto a track to be transformational for the UK economy by 2025.

The main point for policy makers from the guide are:

- Clearly define the scope of the 5G fabric: There needs to a clear and shared understanding of what sits inside and what falls outside of the 5G policy focus so that silos can be bridged (eg fixed-mobile) and the agendas of operators, industry, the regulator, and policy makers can be efficiently aligned. The term "5G infrastructure fabric" is used to delineate this boundary and **the IET makes a specific proposal for what this should be.**
- Focus on securing reliable universal coverage as well as high capacity urban coverage: Coverage (or lack of it) will be the big 5G policy headache, as consumer and business expectations will no longer be restricted to securing coverage to make a telephone call. Instead, they will expect fast reliable connection, browsing and data streaming. Dependable pervasive coverage is essential if 5G is to modernise commerce, industry, and public services as **5G cannot modernise what it does not cover.**
- Modernise the regulatory framework to reduce the cost of maximising coverage: There will be a huge investment gap between the coverage deliverable by the market with today ways of doing things and the 5G quality of coverage needed to transform the economy. Some argue that the gap could be bridged through industry consolidation and others that significant public funding will be needed. A third possibility is to change the regulatory framework to allow things to be done differently in a way that brings down cost, for example permitting deeper Radio Access Network (RAN) sharing with Open Hosting, inversion of the site rental model and better ways to harness spare private small cell capacity in a more integrated way than current Wi-Fi off-load. **The IET believes this third possibility may be the most productive** for new 5G dense small cell networks and merits early policy attention.

The guide calls on the Government and Ofcom to adopt a bold and ambitious approach in making the right decisions now to deliver the world class digital infrastructure that consumers and business will need over the next decade. It offers a useful reference to-do list of many specialist policy issues such as passive infrastructure access and identifies some critical areas, such as the need for RF channel widths of at least 100 MHz in the 5G pioneer band 3.4-3.8 GHz.

Executive Summary of Recommendations

BROAD POLICIES

Recommendation 1
The Government and Ofcom need to be ambitious, radical, and bold as the right decisions taken now will deliver the world class wireless digital infrastructure that consumers and businesses will find essential 7-10 years from now. (Section 13)

Recommendation 2
The Governments approach to 5G should be based on the overall "5G fabric" and not just the new 5G component parts. (Section 11.1)

Recommendation 3
The 5G fabric also includes the fixed network, fibre has a pivotal role and help must be given to its availability to support 5G at the right price, location, and time. (Section 12)

Recommendation 4
The Government and Ofcom need to place "coverage maximisation" at the top of the list of priorities in driving the modernisation of the regulatory framework for 5G networks. Coverage is not just about getting a signal for a voice call anymore but getting the necessary "Quality of Coverage" for a thriving digital economy and Gb/s digital society. (Section 6)

Recommendation 5
UK global leadership in 5G is likely to require a lot of thought on the part of the Government and Ofcom on the right combination of Government intervention, regulatory changes, industry co-operation, structural co-operation, competition, and market forces. (Section 5)

Recommendation 6
The Government and Ofcom need to proactively sustain an engagement with Europe over 5G through and after Brexit. (Section 14)

Recommendation 7
The Government should bring together a coalition of the willing to deliver the launch of 5G networks in the UK by 2020. (Section 7.1)

GENERAL REGULATORY REFORMS

Recommendation 8
There will likely be a need to reconsider various aspects of regulation as connectivity blurs across cellular and Wi-Fi. For example, when assessing competition, regulators may need to consider broader definitions of relevant markets and a wider set of possible actors. (Section 11.2)

Recommendation 9
The Passive Infrastructure Access issue (ducts, poles etc.) is complex, likely to be controversial but must be tackled by the Government and Ofcom to deliver the benefits of 5G to the largest number of consumers. The focus needs to be widened to include all public utility facility owners. (Section 12.2.2)

Recommendation 10
Active Network Sharing for fibre backhaul should be encouraged by the Government and regulators as it enables new wholesale commercial models with greater potential for control and differentiation (e.g. for Access seekers wanting to provide mobile backhaul). (Section 12.2.3)

Recommendation 11
The balance between landowner rights and network developer "rights" is another issue that is complex, controversial but needs to be tackled by the Government if the reach of the benefits of 5G are to be maximised. (Section 12.2.4)

Recommendation 12
A single approval of standard street furniture designs would significantly reduce Local Council effort and hence costs (at a time when Council budgets are under huge stress) compared to producing and approving site designs on a case by case basis. (Section 12.2.4)

Recommendation 13
5G Test Beds could be used to trial street furniture, small cell packages and high performing antenna designs with the aesthetics in mind to inform national standards acceptable to Local Authorities. (Section 12.2.4)

SPECTRUM

Recommendation 14
Great thought is needed into how to define a coverage obligation to attach to the 700 MHz spectrum release…it is a once in a decade opportunity. The National Infrastructure Commission recommendation is a good place to start. (Section 10)

Recommendation 15
Band fragmentation in the range 3.4-3.8 GHz needs to be cleaned up as a matter of priority. Wide RF channels (80-100 MHz) are essential to *drive* 5G in this pioneer band. (Section 9.1)

Recommendation 16
Ofcom needs to make every effort to ensure at least one very wide RF channel (80-100 MHz wide) is available in this spectrum range by 2020 for an Operator to begin to deploy the first 5G dense small cell network clusters. There are areas of the country (eg Scotland) where the entire 400 MHz could be deployed for 5G. The mechanism for doing this will need to pay due regard to promoting competition. (Section 9.1)

Recommendation 17
Ofcom may take benefit in changing from "thinking national" to "thinking local" in their spectrum approach to 26 GHz. (Section 8)

ECONOMICS DRIVEN REGULATORY MODERNISATION

Recommendation 18
A critical phase is to get 5G networks off the ground. It is important for the Government and Ofcom to put in place the right investment climate for Operators to want to take up the challenge of being first mover of 5G network deployment in the UK 2020. (Section 7.1)

Recommendation 19
Reducing small cell unit cost is essential. This will only be feasible by doing things differently and modernising the regulatory model to enable it. (Section 9.2)

Recommendation 20
Ofcom should encourage voluntary commercial agreements that facilitate the most comprehensive aggregation of coverage areas of different entities (public and private). (Section 9.3)

Recommendation 21
The Government and Ofcom needs to create the financial incentives to modernise the national mobile mast infrastructure in a steady long term programme. Allowing Operators to off-set a percentage of the costs against annual spectrum fees might be considered amongst the various options. (Section 10)

Recommendation 22
The Government should extend business rates relief on the deployment of new fibre (and new 5G rural passive infrastructure fabric). (Section 12.2.1)

Recommendation 23
There is not a silver bullet to get the long-term investment conditions right for 5G Quality of Coverage maximisation but one policy option that may be fruitful to explore is a new regulatory model that enables things to be *done differently* to significantly reduce the level of investment needed for a given coverage. (Section 7.2)

1. Introduction

The term "5G" on its own is a marketing wrapper that nobody owns. Its significance is the voluntary global consensus that builds up behind it. That has now reached critical mass and over the coming decade 5G will stretch the capabilities of wireless infrastructures across the world well beyond the capabilities of current technologies. In the early stages, it is normal for ideas to come in from everywhere. At the end of the day, what gets built depends upon private sector investment decisions, regulations, and Government policies. As things stand a sizeable fraction of what is under discussion will be ready to roll out by 2020/21. Another sizeable fraction will come to maturity but only at a much later date. The remainder may never happen. The purpose of this guide is to filter out from the mass of information on 5G what is real, what is useful and what is ready to go. The scope has been limited to 5G network infrastructure. The activity on new services and applications under the 5G wrapper is not covered as it is of a different character touching on a much wider range of policy interests (eg transport, health etc.).

The priority has been to identify those 5G network aspects where Governments and regulators will, by action or inaction, have a direct impact on the outcome and whose help may even be essential for some outcomes to be achieved. A new generation of mobile technology throws-up new spectrum and regulatory problems. How well spectrum/regulatory policies are modernised to address them is mission critical. The policy makers affected are not just confined to those in DCMS and Ofcom but in other Whitehall Departments and even Devolved Governments and Local Authorities.

2. The "DNA" of a Cellular Network Generation Change

A mobile network generation change brings together five key elements:

Figure 1 – DNA of cellular network generation changes.

3. Spectrum Choice and Network Outcomes

The choices of spectrum bands for 5G shape the network opportunities as *never before*:

5G brings such an unprecedented spread of spectrum bands that it is no longer sensible to think of 5G as a single network. The choice of spectrum bands largely determines whether a network will deliver better coverage only, better capacity only or a compromise between better coverage and better capacity. Therefore, Europe's spectrum managers have defined three different 5G pioneer bands. Each does a different job in stretching the capabilities of the UK wireless digital infrastructure over the capabilities of today's 4G and WiFi, as discussed in the next section.

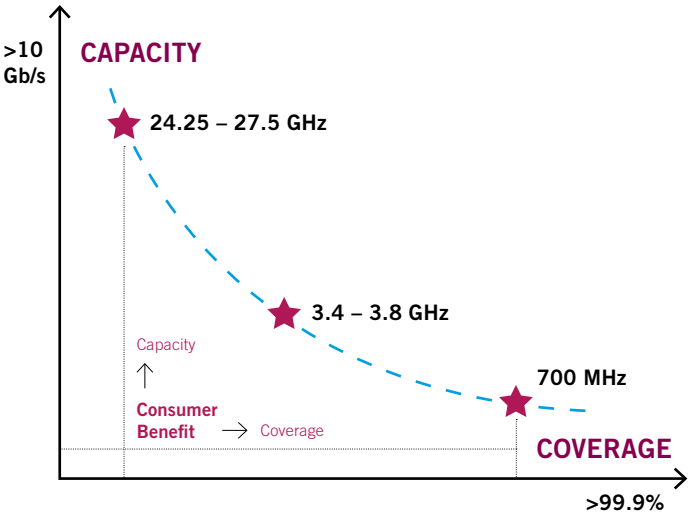

Figure 2 – Purely illustrative curve to show how the spectrum band choice shapes the network capacity or coverage outcome.

4. What is a 5G Network?

The choice of "5G pioneer bands" has opened-up three distinct 5G network opportunities:

The 5G networks outcomes will be based on which of the 5G pioneer bands attract the European and global investments *and that in turn will be impacted by regulations and Government policies*.

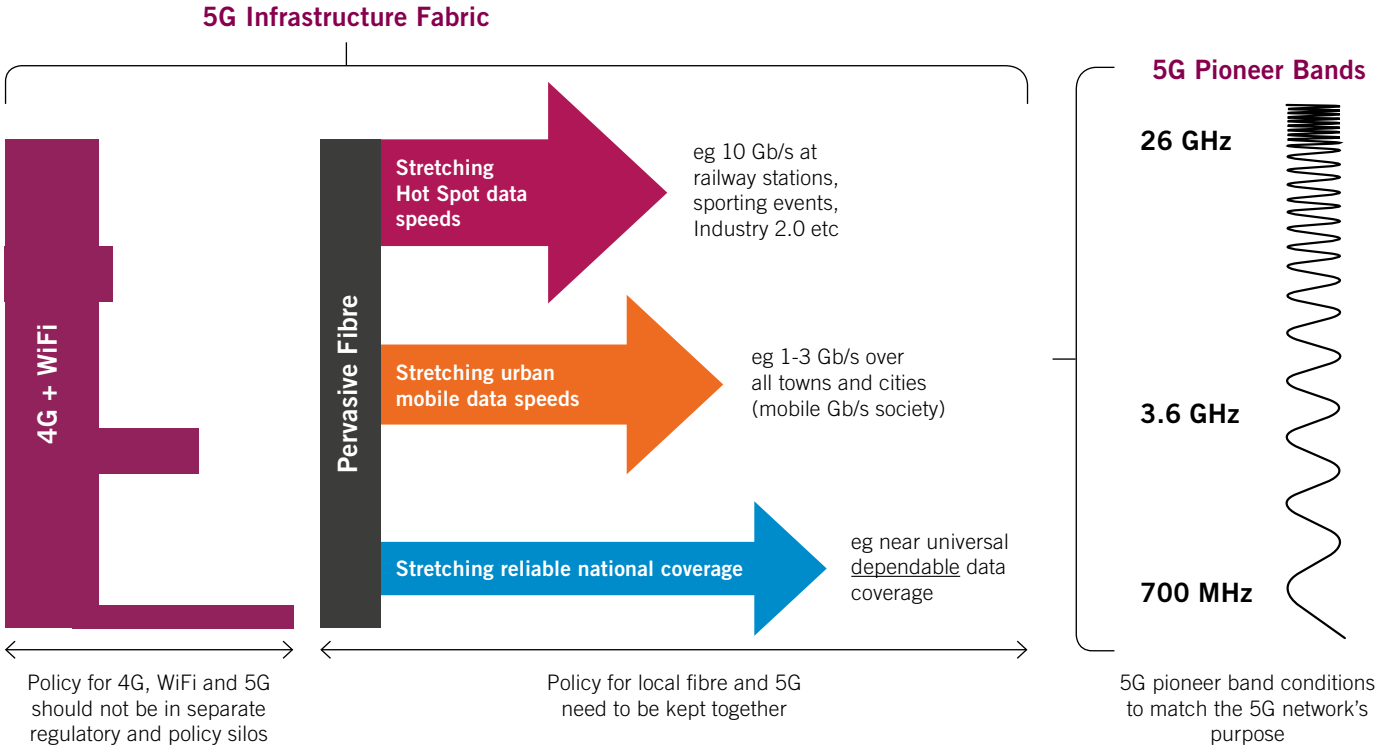

Figure 3 – IET definition of the "5G Infrastructure fabric" for policy purposes.

5. How Spectrum and Regulatory Policies Impact Mobile Revolution Outcomes

The impact of spectrum and regulatory policies on earlier mobile network generational changes illustrate how far reaching they can be on outcomes:

		Control of Regulators	Influence of Governments and Regulators	
Generation	**Spectrum**	**Competition**	**Cooperation**	**Outcome**
1G	900 MHz	Duopoly	None	Successful but limited to UK & Nordic
2G (GSM)	900/1800 MHz	4 competitors	Standards + GSM MoU + Global Roaming + SMS	Highly successful and global
3G	Ill timed spectrum auction	5 competitors	Standards Little else	Underwhelming
4G	800 & 2.6 GHz + 1800 MHz	4 competitors (asymmetric)	Standards Little else	Work in progress but late in UK

Success factor

Failure factor

Figure 4 – How policies to promote competition and cooperation have combined in the past to deliver cellular mobile infrastructure outcomes.

The table above contains some token examples. Shown in red squares are policies that have been damaging to that generation of mobile technology and in red letters policies that were unhelpful. The lack of common standards for 1G fragmented the European market into sub-scale economies. The timing of the 3G spectrum auction near the peak of the telecoms bubble got 3G off to the worst possible start. Shown in blue squares are policies that were a major boost to that generation of mobile technology and in blue letters policies that were helpful. The introduction of network competition with 1G in the UK and with 2G in the rest of Europe added huge dynamism to the market. *The exceptional level of cooperation with GSM (a partnership of the Government, regulators, and industry) led to an exceptional outcome.* The Government should not underestimate the valuable role they can play just getting key players around the table, facilitating structural cooperation and setting broad objectives that can bring cross-industries together to share common goals.

Recommendation

UK global leadership in 5G is likely to require a lot of thought on the part of the Government and Ofcom on the right combination of Government intervention, regulatory changes, industry cooperation, structural cooperation, competition and market forces.
(EXECUTIVE SUMMARY – RECOMMENDATION 5)

6. What is the Greatest Network Challenge for the 5G Era?

The greatest network infrastructure challenge of the 5G era will be "coverage"[1].

The challenge for policy makers is to recognise the quite different sort of coverage issues now emerging:
First is a distinction between enough signal just to make a telephone call and enough signal to support a sustained data speed of say 500 Mb/s or 1 Gb/s. *5G will drive a huge disparity between the "data speed rich" and the "data speed poor" on a geographic basis.*

Second, many of the new applications and services for modernising the rest of the economy need not just pervasive national coverage but dependable coverage. That is expensive and needs to be prioritised. A good starting point is the National Infrastructure Commission report on 5G that places a priority on solid coverage of major roads and rail links. But there are other needs to satisfy:

- Outdoor and land coverage including rural (modernising agriculture, tourism and emergency service's needs)
- Indoor coverage (for business and leisure)

The more we depend upon wireless connectivity the more reliable and pervasive we need to make it

- **Existing mobile coverage is getting worse. Mast heights are too low in many places, far too many spectrum bands are leading to device RF performance collapsing and Interference Noise Floors are rising at mast sites**
- **Higher spectrum bands = poorer mobile coverage**
- **For 4G (& 5G) capacity falls sharply at the cell edge in busy cells - leading to a loss of "Quality of Coverage"**

Figure 5 – Summary of existing coverage challenges even before 5G arrives.

The cost to address these issues is huge and the coverage problems will never be solved by the market alone. Even where the investment is available there is a significant lead time in solving coverage problems. This means that, if Ofcom can anticipate the new coverage issues that will come with 5G, it can get in place the measures at the outset to steadily remedy them along the way. In this way, it can head off another wave of coverage complaints from consumers and businesses, this time about 5G data "quality of coverage".

Recommendation

The Government and Ofcom need place "coverage maximisation" at the top of the list of priorities in driving the modernisation of the regulatory framework for 5G networks. Coverage is not just about getting a signal for a voice call anymore but getting the necessary "Quality of Coverage" for a thriving digital society.
(EXECUTIVE SUMMARY – RECOMMENDATION 4)

[1]There are many other policy issues that, in other contexts, are a priority but the scope of this documents is 5G networks…where coverage will be policy issue number 1

7. Investment Environment for 5G

7.1 Getting 5G off the ground

The first hurdle is to get 5G off the ground in the UK. The business case to be the first is not compelling. It generally falls to the strongest Operators but they must justify the commercial risks. It is of critical importance for the Government and Ofcom to put in place the right investment incentives for Operators to want to take up the challenge of being 5G network deployment first movers.

Recommendation
A critical phase is to get 5G networks off the ground. It is important for the Government and Ofcom to put in place the right investment climate for Operators to want to take up the challenge of being first movers of 5G network deployment in the UK from 2020.
(EXECUTIVE SUMMARY – RECOMMENDATION 18)

Recommendation
The Government should bring together a coalition of the willing to roll out 5G networks from 2020.
(EXECUTIVE SUMMARY – RECOMMENDATION 7)

7.2 Meeting the long term 5G "Quality of Coverage" challenge

The "status quo" will not deliver the investment climate needed for the private sector to attract the substantial levels of investment needed to meet the long-term coverage challenges identified above. So, sitting behind the great coverage challenge of the 5G era will be a great investment challenge. It is a political choice how to address the likely substantial funding gap. The policy options include:

i. Market consolidation.
ii. Inject public money eg grants, relief of spectrum fees and rent free access to public structures to site cells etc.
iii. Frame new policies and regulations that *lower the level of investment needed for a given level of coverage.*

Lowering the level of investment needed for a given coverage requires thinking how things can be done differently and the modernisation of regulations to achieve this. The possibilities include:

a. Regulatory reform around access to fibre at the right price, place and time
b. Helpful conditions attached to the release of new spectrum
c. Lead the inversion of "the site rental model" from low number of sites incurring high rents to large numbers of sites incurring low rents through an offer of new deals for small cells attached to all public and public utility properties
d. Access to public land for sites
e. Creating a framework for aggregating 5G coverage, however it is provided, including private provision
f. Allow deeper infrastructure sharing eg the Neutral (or Open) Host and a spectrum pooling approach for small 3.6 GHz cells.

It is important for the Government to recognise these two distinct periods of investment climate for 5G networks. The business case to be a 5G first mover is very challenging. Generally, it is only the largest Operators with the capacity to take on this challenge. Thereafter the momentum builds up and the 5G business case will becomes far more compelling. Getting the launch conditions right for 5G network is essential if the UK is to be a global leader in 5G.

Recommendation
There is not a silver bullet to get the investment conditions right for 5G but one policy option that may be fruitful to explore is a new regulatory model that enables things to be done differently to significantly reduce the level of investment needed for a given coverage.
(EXECUTIVE SUMMARY – RECOMMENDATION 23)

8. Policy Challenges for 26 GHz 5G Networks (Hot Spots)

Any sort of licence coverage obligation at 26 GHz is a non-starter. Yet the spectrum is likely to remain unused over a huge percentage of the UK.

The challenge is a spectrum approach that can resolve conflict where everyone wants to co-locate but frees up spectrum usage over the rest of the country with a "lightly licenced" or "license exempt" approach.

Recommendation
Ofcom may take benefit in changing from "thinking national" to "thinking local" in their spectrum approach to 26 GHz. (EXECUTIVE SUMMARY – RECOMMENDATION 17)

9. Policy Challenges for 3.6 GHz Networks (Gb/s Urban Mobility)

The best Gb/s mobile network will deliver the largest number of sq. km of contiguous small cell cluster coverage at 1-3 Gb/s peak rates. *The Public policy contribution to achieve this can be summed up as: Widen RF channels-reduce cell cost – aggregate coverages.* These three components are expanded upon below:

9.1 Widen RF channels

What differentiates a 5G radio channel is that it is much wider than a 4G radio channel and this allows it to carry a much faster data rate and boost efficiency. The table below shows some theoretical numbers[2] with a relatively simple antenna:

RF Channel Width (MHz)	Peak Data Rate (Gb/s)	Average Data Rate (Gb/s)
40	1.2	0.3
100	3.0	0.8
200	6.0	1.6
400	12	3.2

[2](ref: 5G PPP response to CEPT questionnaire)

Very much high rates are possible with more advanced antenna systems (called massive MiMo). Very fast data rates are needed for four reasons. First, peak data rates are shared between multiple users and applications so the faster the peak rate provisioned the lower the network contention. Second, it brings down the unit cost of transporting data. Third, there is no evidence that mankind has stopped being inventive, so a plentiful supply of cheap data transport available everywhere stimulates innovation of new mobile applications and services across smart cities, towns, roads, businesses, and homes. Finally, the new needs may be for very fast bursts of data rather than continuous streaming.

The challenge to enabling wide RF channels in the 3.4-3.6 GHz band is the incumbent services in the bands (largely in London and the SE England) and spectrum policies (including auction design) that lead to band fragmentation. The 3.4-3.6 GHz portion and 3.6-3.8 GHz portion are two routes to find a single 80-100 MHz wide channel to get 5G started, each with different policy challenges. For the 3.4-3.6 GHz band the policy issue is how much can be done ahead of the spectrum auctions (by minimum bidding blocks), during the auction (allowing bidders to consult during the latter auction assignment stage) or afterwards through spectrum trading. It is a feasible path in theory but an uncertain one. It is important to some Operators that this uncertainty does not translate into undue delay. The second path would be to find the 80-100 MHz from the 3.6-3.8 GHz band. That creates less uncertainty and could happen relatively quickly. But the existence of incumbent services means the opportunities will be local and not national. Wide RF channels also have competition implications. Options to address this include spectrum sharing, Neutral Hosting and Open Hosting (See section 15 for more detail).

Recommendation
Band fragmentation in the range 3.4-3.8 GHz needs to be cleaned up as a matter of priority. Wide RF channels (80-100 MHz) are essential to drive 5G in this pioneer band. (EXECUTIVE SUMMARY – RECOMMENDATION 15)

Recommendation
Ofcom needs to make every effort to ensure at least one very wide RF channel (80-100 MHz wide) is available in this spectrum range by 2020 for Operators to begin to deploy the first 5G dense small cell network clusters. There are areas of the country (eg Scotland) where the entire 400 MHz could be deployed for 5G. The mechanism for doing this will need to pay with regard to promoting competition. (EXECUTIVE SUMMARY – RECOMMENDATION 16)

9.2 Reduce cell unit cost

Unit cost of small cells is critical as it is multiplied by a very large number. The cost is not just the up-front costs but the running costs. See section 7.2 for some of the options. Ideally a policy framework is needed that allows “the mass production” of installed small cells rather than today’s bespoke approach.

Recommendation
Reducing small cell unit cost is essential. This will only be feasible by doing things differently and modernising the regulatory model to enable it. (EXECUTIVE SUMMARY – RECOMMENDATION 19)

9.3 Aggregating Coverage

Covering every UK city and town with continuous coverage using dense small cell clusters at 3.6 GHz is such an enormous financial undertaking that it is probably not a feasible proposition as things stand for one operator, let alone four. There is a parallel to this. 30 years ago, it would not have been feasible for one entity to have built out from their national network a European wide coverage extension for just their customers travelling across Europe. The solution was to aggregate 28 national coverages within a voluntary agreement to deliver one continuous service area for consumers.

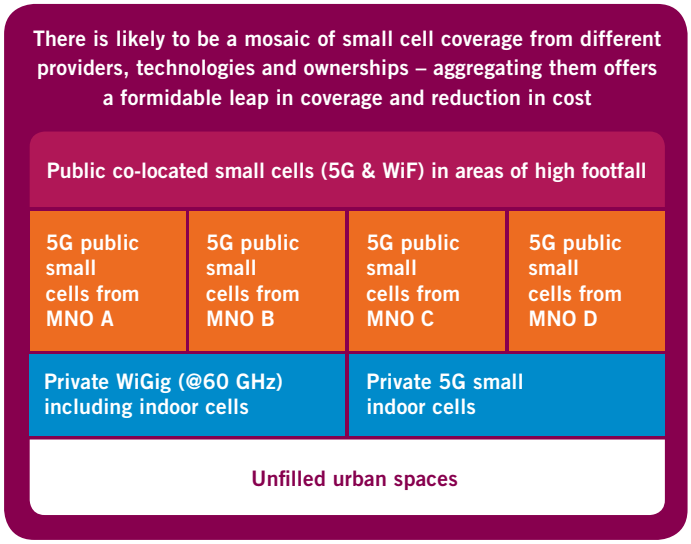

Figure 6 – Transforming urban Gb/s small cell coverage by everyone pooling their sub-optimal coverage, whether indoors or outdoors.

Dense small cell networks offer a similar challenge. The illustration shows the huge potential benefits from applying the same principle to deliver for consumers a continuous service area across all UK cities and towns by aggregating the different coverage provisions in place by different entities – both public and private. Most can agree on the value of the end destination and the complexity is the road map to get there.

Recommendation

Ofcom should look favourably on voluntary commercial agreements that facilitate the most comprehensive aggregation of coverage areas of different entities (public and private). (EXECUTIVE SUMMARY – RECOMMENDATION 20)

The 3.4-3.8 GHz band will also be needed for Macro sites as well as for small cell clusters. Indeed, in urban areas of lighter traffic it is an essential means to bring more capacity at a lower level of investment. In this way, the Macro use of 3.6 GHz is an evolutionary step to small cell clusters.

10. Policy Challenges for 700 MHz Networks (Pervasive National Coverage)

700 MHz offers huge potential for a leap in reliable national coverage but it will not be delivered by the market alone. How to frame this for data brings is new issues that calls into question whether it can remain just defined by a signal level or needs to embrace the certainty of what users actually experience? Does it apply to just major roads (as the National Infrastructure Commission Report recommends) or wider to underpin a "universal control plane" of last resort (the "Home Page" of spectrum bands) as others propose? How can a new type of coverage obligation be measured for compliance? It is something a single operator, through the traditional auction process, is willing to bid for or does it need a common shared infrastructure to deliver the much-needed leap in pervasive reliable national coverage including rural areas?

Recommendation

Great thought is needed into how to define a coverage obligation to attach to the 700 MHz spectrum release…it is a once in a decade opportunity. The National Infrastructure Commission recommendation is a good place to start. (EXECUTIVE SUMMARY – RECOMMENDATION 14)

Masts are ageing, many are overcrowded (making it difficult to get the ideal antenna height for new 5G antenna), many are sited where trees screen radio signals (the trees grow each year but established mast heights do not) and some are not in ideal locations. Mast replacement is the boring often forgotten running cost of a mobile infrastructure. The rural masts will need a modest but steady long-term stream of public contribution to make the most of the 5G fabric that attaches to them.

Recommendation

The Government and Ofcom need to create the financial incentives to modernise the national mobile mast infrastructure in a steady long term programme. Allowing Operators to off-set a percentage of the costs against annual spectrum fees might be considered amongst the various options. (EXECUTIVE SUMMARY – RECOMMENDATION 21)

11. The Overall 5G Network Fabric

11.1 Other Wireless Networks

It will be a far more useful national infrastructure for a lower cost if the existing network technologies that are doing a useful job are not treated as parallel worlds but integrated seamlessly with the 5G networks as they are added. For this reason, a useful term to capture this holistic approach is “the 5G fabric”.

Recommendation
The Governments approach to 5G should be based on the overall “5G fabric” and not just the new 5G component parts. (EXECUTIVE SUMMARY – RECOMMENDATION 2)

The first existing infrastructure to be closed-down is likely to be 3G. GSM may remain important for global roaming for some time. What will remain important components of the overall 5G fabric are 4G for wide area coverage and WiFi. (See illustration in section 4). The role of WiFi in the 5G era is expanded upon below.

11.2 Specific role for WiFi

There are some areas where Wi-Fi may be better positioned to providing capacity and connectivity than 5G cellular systems. These include planes and trains in the short to medium term where Wi-Fi deployments are already underway. They also include buildings where capacity is typically best provided from indoor cells that do not have to transmit signals through exterior walls and indeed can use these walls to gain shielding from interference. In the early days of 5G small cells (until they secure comparable scale economies) WiFi is likely to be a more competitive approach.

In this way, Wi-Fi needs to be viewed as a valuable component of a 5G fabric. It can deliver very high data rates and has good capacity, especially where frequencies bands such as 2.4GHz, 5GHz and 60GHz are used in combination. But it suffers from uncoordinated deployment and dispersed control. This can be seen in dense areas like train stations where large numbers of Wi-Fi access points interfere with each other and there is a need to manually log on to many access points. For Wi-Fi to play a fuller role in a 5G future there are a number of policy areas that need to be addressed including:

- Ensuring Wi-Fi can be readily deployed on trains and backhaul from train carriages provided alongside tracks.
- Providing Wi-Fi in Government buildings such as hospitals, schools and museums that is freely accessible by the public in a simplified manner.
- Helping the broader industry achieve a single identification scheme that enables secure access from users without needing passwords.
- Requiring some form of coordinated planning of frequencies and access point locations in dense areas to avoid the problems caused by lack of coordination (an approach that could be shared with lightly licensed indoor 5G small cells, see section 15.2).
- Requiring the Wi-Fi and cellular industry to work together to allow users to always connect to the nearest cell, whether be it 5G or WiFi.

Recommendation
There will likely be a need to reconsider various aspects of regulation as connectivity blurs across cellular and Wi-Fi. For example, when assessing competition, regulators may need to consider broader definitions of relevant markets and a wider set of possible actors.
(EXECUTIVE SUMMARY – RECOMMENDATION 8)

12. The Supporting Fixed Network

The fibre technology standards and roadmaps are well understood. Its importance to 5G needs to be highlighted together with the policy help it needs to make it happen in time.

12.1 The importance of fibre back haul for 5G

The deployment of 5G is critically dependent on fibre backhaul from base-stations (both macro sites and small-cells). When a 5G small cell can support speeds of hundreds of Mbit/s or even Gbit/s per user it is obvious that the backhaul network needs to have sufficient bandwidth (combined with low-latency and reliability) so as not to compromise performance. *Pervasive fibre plays a central role in 5G.*

Fibre to the Home (FTTH) technology is standardised, mature and the Passive Optical Network (PON) variant is widely deployed in many countries[3].The expensive part is getting the fibre into the ground (or overhead). The civil engineering costs often constitute at least 80% of the cost.

FTTH technology has a clear roadmap with both standards bodies (ITU-T, FSAN, BBF) and vendors that will enable it to increase capacity of the fibre infrastructure by over two orders of magnitude[4]. This is achieved by adding more optical wavelengths and increasing bit-rate per wavelength in an incremental step-by-step approach.

FTTH technology is not just about consumer broadband. It can be used to connect businesses and for mobile backhaul[5]. The industry focus on the mobile backhaul use-case has grown with the advent of 5G due to the increased densification arising from small-cell at 3.6 GHz and 26GHz.

Hence a common fibre access infrastructure can serve consumer, business and mobile backhaul markets. The fibre access network architecture is “adaptable” to new use-cases and business models (including wholesale and sharing) and hence is future proof beyond just bandwidth. Copper-based access technologies such as VDSL and G.fast simply don’t support the long-term bandwidth required for 5G mobile backhaul which will continue to grow over time. We also need to consider latency, consistency of performance (e.g. immunity to external noise), reliability and security. These are all backhaul connectivity attributes for which full-fibre (i.e. FTTH, not fibre to points further back in the access network) provides a “no regrets” solution.

Point-to-point fibre leased lines have the technical merits of FTTH but the associated network architecture is too expensive to be viable for a mass densification of 5G small cells. FTTH technologies such as the Passive Optical Network family of standards can now deliver high-capacity virtual leased lines over the same physical fibre

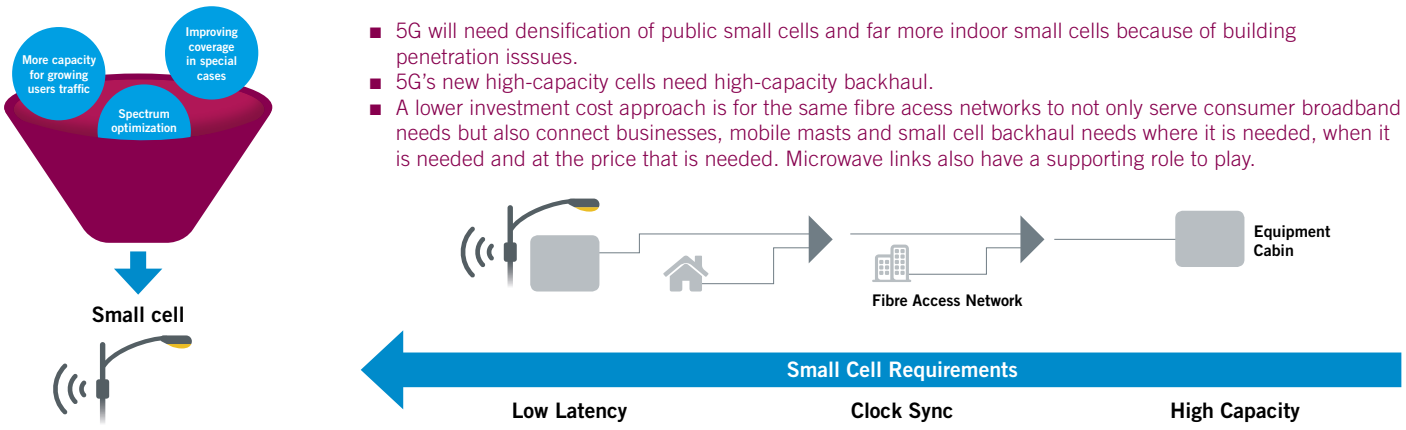

Figure 7 – Pervasive local fibre sits at the heart of a 5G small cell revolution.

[3]Other FTTH architectures are also feasible such as Active Ethernet
[4]eg from todays 2.5 Gbit/s GPON to technologies such as XGS-PON, TWDM-PON & WDM-PON
[5]Many vendor’s products now support the capability to support synchronisation which is necessary for the mobile backhaul scenario.

infrastructure used for consumer and business broadband. Hence there are economies of scale (such as for the customer equipment, network operations costs etc.) from having a common FTTH architecture addressing multiple market segments within a geographic area.

Where a fibre cable cannot reach a cluster of cells for practical or economic reasons then mm Wave backhaul plays a vital role. The same 5G mobile technology can be exploited for back-haul links. Daisy chaining radio links in this way can build up a demand for a huge fibre capacity to be available at the pick-up point.

Recommendation The 5G fabric also includes the fixed network, fibre has a pivotal role and help must be given to its availability to support 5G at the right price, location and time. (EXECUTIVE SUMMARY – RECOMMENDATION 3)

12.2 The help that is needed to enable it to happen

12.2.1 Fibre Business Rates

The Chancellor's autumn 2016 statement gave reliefs on Business Rates from 2017 for the deployment of new fibre. This is effectively a 5-year grace period to stimulate fibre build. However, this runs out just around the point that 5G small cell deployments are being ramped-up (ie 2022-2025). Fibre Business Rates (Cumulo) will be a deterrent or tax on investing in 5G capacity. Thought might be given to rates relief to other areas where attracting private sector investment is challenging eg rural passive facilities.

Recommendation

The Government should extend business rates relief on the deployment of new fibre (and new 5G rural passive infrastructure fabric)
(EXECUTIVE SUMMARY – RECOMMENDATION 22)

12.2.2 Passive Infrastructure Access (Poles, Ducts etc))

Without access to low cost fibre backhaul where it is needed, when it is needed and at the price that is needed, the viability of extending 5G dense small cell networks pervasively across all cities and towns is problematic.

More generally access to ducts and poles will be key to building fibre networks cost-effectively to reduce dig costs (which can easily be ~80% of the cost). The approach to solving this issue that has been most discussed is PASSIVE network sharing. Ofcom has progressed regulation of Passive Infrastructure Access and Dark Fibre access with BT. However, the impact of 5G calls into question the siloed market review approach taken to regulation and whether this should just apply to BT and just to network operators but to all public utilities. The "access seeker" is prohibited from using Passive Infrastructure Access for mobile backhaul (or business access connectivity) for example. This may no longer make sense from an engineering or business case perspective in a 5G era when seeking to construct a common fibre network to serve consumers, businesses and 5G backhaul. Constructing independent parallel networks to serve different market segments is obviously inefficient and impractical. There is a case to be made for exploring a new more holistic approach with no usage restrictions on operators seeking to use Passive Infrastructure Access for 5G backhaul. There may be other alternative solutions from incumbent fixed wireline operators that also merit being explored.

Recommendation

The Passive Infrastructure Access issue (ducts, poles etc) is complex, likely to be controversial but must be tackled by the Government and Ofcom to deliver the benefits of 5G to the largest number of consumers. The focus needs to be widened to include all public utility facility owners. (EXECUTIVE SUMMARY – RECOMMENDATION 9)

12.2.3 Virtualisation

The advent of "Network Function Virtualisation" (NFV) enables a new form of ACTIVE network sharing (beyond simply different operators using different optical wavelengths on the same fibre). It is now possible to implement "multi-tenancy" capabilities on the active PON equipment in the fibre network.

Recommendation

Active Network Sharing of fibre networks should be encouraged by the Government and regulators as it enables new wholesale commercial models with greater potential for control and differentiation (e.g. for Access seekers wanting to provide mobile backhaul).
(EXECUTIVE SUMMARY – RECOMMENDATION 10)

12.2.4 Public policy contribution: Rights of Way & Planning Permission

The Government is reforming the Electronic Communications Code to enable easier access to existing infrastructure to reduce the costs of new fibre build. Clause 7 of the Digital Economy Bill enables the planning relaxations introduced in 2013 for broadband cabinets, poles and overhead lines to be made permanent. The potential to use such regulatory and statutory powers to enable use of existing building facades and utility company infrastructure for fibre network build should also be explored. It may be feasible to reduce costs (and process complexity) for securing access to land in order to dig fibre. Today, one landlord on a preferred fibre route can hold the entire project to ransom. There needs to be a balance between landowner rights and network developer "rights" but often the latter is held hostage by the former. Access to land and buildings for maintenance is another practical issue that is useful to address as the numbers of cell sites grows.

Recommendation

The balance between landowner rights and network developer rights is another issue that is complex, controversial but needs to be tackled by the Government if the reach of the benefits of 5G are to be maximised.
(EXECUTIVE SUMMARY – RECOMMENDATION 11)

A PON-based FTTH network needs no active (powered) electronics in the street. However, it is beneficial to be able to use small pedestal enclosures to house passive splitters and fibre splicing points. This provides greater flexibility to exploit the fibre infrastructure in a multi-operator environment. It would be desirable to have a form of "single" approval of "standard" FTTH street furniture designs having de minimis impact on the streetscape. The pedestal/housing would be small and noise free and could be made to blend in, especially when painted an environmentally friendly colour. Local Councils can then classify the use of such housings as "de minimis" within their streetscape. They could approve one design for all local deployment scenarios (within guidelines) instead of on a site-by-site basis.

Recommendation

A single approval of standard street furniture designs would significantly reduce Local Council effort and hence costs (at a time when Council budgets are under huge stress) compared to producing and approving site designs on a case by case basis.
(EXECUTIVE SUMMARY – RECOMMENDATION 12)

Recommendation

5G Test Beds could be used to trial street furniture, small cell packages and high performing antenna designs with the aesthetics in mind and develop, from this, national standards acceptable to Local Authorities
(EXECUTIVE SUMMARY – RECOMMENDATION 13)

13. 5G Time-lines

The global consensus is for 5G networks to begin to be rolled out from 2020. Normally mobile devices lag by 18 months. There must be a reasonable extent of coverage before consumers are attracted in numbers. This puts 2024 as the ball-park when 5G will begin to have an impact. It also indicates the scale of risk of leading the 5G network revolution. Within a few years of this 5G will become a vital part of the national infrastructure. *Policy for 5G networks is about long term planning where "the quality of coverage" for data services will present a huge policy challenge.*

Recommendation

The Government and Ofcom need to be ambitious, radical and bold as the decision taken now will deliver the world class wireless digital infrastructure the consumers and businesses will find to be essential 7-10 years from now. (EXECUTIVE SUMMARY – RECOMMENDATION 1)

14. 5G and Brexit

The UK does not have the market size or the industrial depth to push ahead with 5G on its own nor to depart from global standards. The UK also has radio frontiers with Ireland, France, Belgium, and Holland and for low bands, Denmark and Norway as well. So, we are locked into the European framework of spectrum allocations and the regulations supporting them through the Laws of Physics. The coming together of global standards with local spectrum regulations will create distinctive European versions of some 5G networks and devices.

Fortunately, much of technical side of spectrum and spectrum related regulations are handled by BEREC, RSPG, CEPT and ETSI so leaving the EU does not mean losing influence over these issues. Ofcom's leadership in Europe on 5G pioneer bands, for example, has been quite outstanding. But that influence depends upon sustaining an engagement on 5G with Europe. There will be much to be gained, even after the UK leaves the EU, to associate ourselves on a voluntary basis with EU 5G initiatives (such as the 5G action plan) where this can contribute to early economies of scale to the benefit of UK consumers and benefits of 5G roaming across the EU. It also benefits the EU by extending the reach of 5G roaming for EU citizens and access for their industries to the often-innovative UK mobile market.

Recommendation

The Government and Ofcom need to proactively sustain an engagement with Europe over 5G through and after Brexit. (EXECUTIVE SUMMARY – RECOMMENDATION 6)

15. Some Regulatory Innovation to Deliver a Better 5G Outcome

The suggestions that follow are intended to stimulate a constructive debate on new approaches:

15.1 Spectrum Sharing

The National Infrastructure Commission report on 5G offered some leadership in spectrum management innovation and is worth quoting in full:

"Government and Ofcom should review how unlicensed, lightly licensed spectrum, spectrum sharing and similar approaches can be utilised for higher frequencies to maximise access to the radio spectrum. Spectrum decisions should where possible enable:

- Community or small provider solutions to meet the needs of local areas if they remain unserved or poorly served.
- Niche entrants or sub-national players to access the higher frequency spectrum anticipated for 5G. Allocation of nationwide spectrum licenses to a small number of operators could leave large areas of the UK fallow.
- Businesses, universities and others to access spectrum where they need to within their factories or buildings, including already licensed spectrum if there are no interference risks. This will unlock multiple wireless service provider options, including self-provision, spurring the innovation in industrial internet of things, wireless automation and robotics."

15.2 Trusted Interference Control Agents

There have been studies done by the IET of how trusted 3rd parties could significantly improve the interference environment for WiFi in congested areas. The same principles could be applied to lightly licence 5G spectrum for privately owned indoor 5G small cells. This Interference Control Agent would remotely (on-line) deal with any harmful interference leaking outdoors and affecting public 5G cells. The Public Network Operators are particularly well positioned to carry out this function as it is their services most at risk and they have a trusted relationship with 10's of millions of consumers. They might ask, in return, for access to some partitioned off capacity of the private cell for public use (instead of payment for the service) …thus contributing to extending 5G coverage. Other ISP's could also offer this service in competition.

15.3 Open Hosting or Neutral Hosting

Outside of the areas of high footfall the traffic through a small cell drops to the level that, in total, barely supports the viability of the cell. This means that the first mobile network operator to put a cell in that location removes any rational business case for a second or third Operators to co-locate. But if they do not, their customers get coverage gaps. Under these circumstances, it makes economic sense for the first operator to not only serve their own customers but secure wholesale revenue from serving everyone else's' customers. This Open Hosting model provides the means of not only taking significant cost out for all the mobile network operators but aggregates coverage areas to deliver a more compelling Gb/s mobile service. Where the spectrum is also pooled, it could allow an Operator at that location to use the entire 3.4-3.8 GHz band with a huge increase in data rates and capacity (see earlier table in section 7.1). This dynamic spectrum expansion, where local circumstance permits significantly, improves geographic spectrum efficiency). Neutral Hosting only differs from Open Hosting in that it is run by a third party rather than one or more Operators.

16. Conclusions

The track-record of the mobile industry in making these big generation transformation is excellent. Some have been more successful than others but none have failed. The main reason for this impressive outcome is that the 5G wrapper has been used selectively to embrace those things a single company (however big) cannot do on its own but must act collectively, either for reasons of compatibility across the supply chain or for economies of scale or for regulators to pay attention and prepare the necessary spectrum.

Often many useful changes unrelated to the radio access are drawn in the wake of these network technology changes and take benefit from its high profile and momentum. It has featured in all previous technology generation changes. This wide interpretation of "what is 5G" is entirely beneficial providing the cross- linkages are only made where they are essential. Examples have been given above of passive infrastructure regulatory changes that can only benefit being brought under the 5G wrapper. The converse is to recognise what needs to remain outside of the 5G wrapper to allow the market and competition to play its vital role in driving 5G into the market and responding to the changing needs of the market.

"5G Networks for Policy Makers" is a condensed analysis of what policy makers need to know now about that part of the 5G network change due to arrive by 2020. There will be further 5G policy issues arising in the evolution of 5G (eg security, privacy, resilience, modernising Internet protocols etc). Other issues not covered including Governments role on the demand side and mobile-broadcasting convergence. They all merits later examination.

The Institution of Engineering and Technology

IET Offices

London
Savoy Place
2 Savoy Place
London
WC2R 0BL
United Kingdom
www.theiet.org

Stevenage
Michael Faraday House
Six Hills Way
Stevenage Herts
SG1 2AY
United Kingdom
T: +44 (0)1438 313311
F: +44 (0)1438 765526
E: postmaster@theiet.org
www.theiet.org

Beijing
Suite G/10F
China Merchants Tower
No.118 Jianguo Road
Chaoyang District
Beijing China
100022
T: +86 10 6566 4687
F: +86 10 6566 4647
E: china@theiet.org
www.theiet.org.cn

Hong Kong
4405-06 Cosco Tower
183 Queen's Road
Central
Hong Kong
T: +852 2521 2140
F: +852 2778 1711

Bangalore
Unit No 405 & 406
4th Floor, West Wing
Raheja Towers
M. G. Road
Bangalore 560001
India
T: +91 80 4089 2222
E: india@theiet.in
www.theiet.in

New Jersey
379 Thornall Street
Edison NJ 08837
USA
T: +1 (732) 321 5575
F: +1 (732) 321 5702

IET Venues

IET London: Savoy Place
London
T: +44 (0)207 344 5479
www.savoyplace.london

IET Birmingham: Austin Court
Birmingham
T: +44 (0)121 600 7500
www.ietvenues.co.uk/austincourt

IET Glasgow: Teacher Building
Glasgow
T: +44 (0)141 566 1871
www.ietvenues.co.uk/teacherbuilding

@TheIET

www.**theiet**.org