DCMS Future Telecoms Infrastructure Review: Call for Evidence, BT's response (January 2018)

Annex 5: Infrastructure and policy requirements to support the mobile evolution to 5G and converged network architecture

This Annex explores the mobile sector's evolution towards 5G and the converged network approach of the future, when wireless and fixed access will provide users with seamless, ubiquitous connectivity. It builds on the historic and current approach to mobile infrastructure in the UK that has led to the widespread 4G coverage we have today. It then looks at how, at least initially, the transition to 5G capabilities will leverage this 4G network capability, evolving to 5G small cells in the higher frequencies from 2020 and beyond.

We first describe how mobile infrastructure has developed to date and how we expect it to evolve as the sector deploys 5G. Then we focus on three current and emerging challenges for mobile policy to support this evolution:

- **challenge 1**: supporting competition between mobile operators in delivering coverage and capacity as far as commercially feasible, as well as supporting initial 5G roll-out. This is where the ***'market driven'*** **(model 3)** has worked well, in conjunction with commercial infrastructure sharing
- **challenge 2:** an effective framework to address complex deployment environments where infrastructure competition alone is unlikely to be sufficient. This applies to delivering coverage to the most hard-to-reach, commercially unviable rural locations and addressing enduring pinch points, such as indoor and on-train. This is where the market driven model may need to be complemented by further commercial infrastructure sharing as far as possible combined with **Government-led approaches (model 5)**
- **challenge 3:** applying a longer time horizon (2020 and beyond), supporting a growing need for cell densification. This is where there could be a case for the Government to facilitate deployment with additional measures in particular around planning and access rules specific to small cells.

The specific measures we suggest to help reduce the cost of deployment in capacity pinch-points and of small cells can be found in Annex 6.

<u>The shape of mobile infrastructure in the UK and anticipated 5G deployment over the next decade</u>

From an infrastructure perspective, the UK mobile sector has evolved over three decades as new network operators entered the market followed by some consolidation, as described in our main response. The current structure of four vertically integrated network operators, operating from a combined total of c.35,000 macro sites, has been supported by the creation of two joint ventures (between EE and Three, and O2 and Vodafone) to achieve better coverage and reduce network deployment capital and operational costs. Additionally, there is significant site sharing between the joint ventures, and the utilisation of wholesale infrastructure providers.

Whilst site sharing on a commercial basis is common-place, infrastructure-level competition is the driver of industry investment as there remains significant scope for operators to differentiate in terms of network quality, principally geographic coverage and capacity/data speeds. EE, for example, has pursued a strategy of building the biggest and fastest 4G network, now covering over 88% of the UK's landmass and delivering average data speeds of 20-30Mbps in independent tests. More generally, operators also compete on brand, price or non-network related factors.

5G networks are now being deployed in experimental and pilot forms and this will continue. Although much of the debate and focus for 5G appears to be on the expected huge increase in cell density and so-called 'small cells', the near-term issues for continuing 4G deployment and initial 5G roll out relate to further macro-cell deployment, and ensuring the policy environment enables small-cell deployment.

Challenge 1: supporting market-driven investment in coverage and capacity, including initial 5G roll-out

We are confident that a market-driven model can support further deployment and should therefore be promoted and facilitated as far as possible. However, the progress made to date has been made in spite of rather than because of the deployment environment faced by operators.

Mobile-network operators face too many battles in rolling out our networks, increasing costs and reducing certainty, leading to less efficient network investment and, at the margins, a lack of a business case for further investment. This is particularly true in increasingly hard-to-reach areas where the revenue potential of a cell declines and deployment costs increase (particularly in relation to power and backhaul). The differences in deployment costs faced by mobile operators relative to, say, utility companies is stark. These barriers are also being thrown into sharper relief as operators consider the scale and shape of the investment needed to 'densify' networks in urban areas and begin 5G deployment, as discussed below.

To meet the Government's world-leading ambition, and ensure we have the right mobile infrastructure for the deployment of 5G, policy-makers need to create a new framework in which the incentives of all stakeholders: MNOs, central and local government, regulator, land-owners, infrastructure providers, power companies, etc, are much better aligned to supporting infrastructure investment. Annex 6 provides an overview of the reforms we believe are necessary to achieve a more benign deployment environment, not only to support the model of infrastructure competition, but to underpin the success of any other required market model.

The DCMS Barrier Busting Task Force is welcome in this regard, as is the proposed Local Area Connectivity Group and its objective to improve the relationship between industry and local authorities to support further connectivity improvements. It will be important that tangible, early progress is made on both fronts.

We are also concerned that the Annual Licence Fee (ALF) regime, as interpreted by Ofcom, places undue additional financial burden on spectrum holders (beyond what is required to ensure efficient use of spectrum) at a time when they face significant 5G investment costs. The annual fees imposed in the UK on 900/1800MHz spectrum (and in the future on the 2.1GHz spectrum) are extremely high and unprecedented in Europe. DCMS should therefore usefully use this Review to fully consider the future ALF framework to ensure it does not act as an inappropriate brake on network investment.

More broadly, a policy and regulatory framework that prioritises commercial investment through the promotion of competition should be encouraged. Operators' ongoing and significant network investment is enabled through a consistent and fair regulatory environment, relying on competition to deliver good consumer outcomes, as it does in the UK.[1] Intervention to address any perceived

[1] Ofcom has recently presented evidence showing that the UK market is among the most competitive in the world driving excellent consumer outcomes – for example, average prices for handset plans are significantly below those of most other comparator countries (Ofcom, Award of the 2.3 and 3.4 GHz spectrum bands – competition issues and auction regulations, November 2016) and the "price of mobile services has remained stable despite very large increases in data use" (Ofcom, Pricing trends for communications services in the UK, March 2017), which equates to a quality-adjusted price reduction.

consumer harm should only be undertaken very selectively and in a targeted manner where competition has not worked. There are risks that poorly targeted pro-consumer interventions can create uncertainty and weaken investment cases for operators, particularly if the impact on the market is not properly assessed in advance. For example, mandated bill capping (at a customer's request) was introduced by the Digital Economy Act 2017 without any proper assessment as to its proportionality or likely effectiveness. Ofcom has sufficient powers to address any failures in competition in most cases, without any need for the Government to take action.

Challenge 2: providing an effective framework to address complex deployment environments

Network solutions are becoming necessarily more complex as operators seek to address existing and emerging deployment challenges, including:

- further extending geographic coverage to ever more remote locations
- delivering connectivity in specific locations (such as on-train or indoor) that are hampered by limited deployment opportunities.

This will require a more sophisticated public policy framework to support commercial investment across a number of market models, including greater infrastructure collaboration, the enduring need for more effective framework for access to land, sites and masts in specific circumstances (keeping the current ECC under review) and a Government-led approach in wholly uneconomic areas.

We believe that the Government should keep an open mind on solutions needed to these problems, with the infrastructure competition model promoted and supported. However, we recognise that this model may not provide effective solutions to specific challenges for example, railway coverage, remote rural coverage and dense small cells to meet much higher bandwidth requirements from multiple users that we address in challenge 3.

Addressing these challenges will require continued innovation from industry, policy makers and public authorities. Industry must develop and deploy different architectural and commercial models. The policy framework must support non-traditional deployment on a larger scale, ensuring cost reduction, and access to viable sites. Mobile network architecture will become more complex, and the public policy framework must become more sophisticated and targeted to support investment.

Extending geographic coverage to the most hard-to-reach rural locations

To extend rural networks to wherever people live, work and travel will require deployment economics to change markedly. Not only do remote cells serve very few customers, the costs of deployment to hard-to-reach locations are often significantly greater, mainly due to the challenges of providing power and backhaul. EE 4G geographic coverage is expected to reach circa 92% in 2018 and we retain the ambition to achieve 95% by 2020. This ambition was set in 2016[2] and was subject to the delivery of policy reform to reduce deployment costs. Whilst we continue to have an ambition to extend geographic network leadership, the business case is challenging while deployment costs remain high.

Increased infrastructure sharing is seen as a means to reduce deployment costs. However, sharing on a commercial basis already takes place wherever expedient.[3] Business as usual in the sector has MNOs looking for site sharing opportunities as part of any site identification and acquisition process, in

[2] http://newsroom.ee.co.uk/ee-launches-new-strategy-to-onshore-100-of-service-calls-and-expand-4g-coverage-to-95-of-uk/

[3] Operators have reciprocal commercial sharing arrangements in place, including template site-sharing licences and umbrella terms which govern site access and occupation, and a well-established process for processing site-share applications.

addition to the extensive sharing that already exists through (and between) MBNL and CTIL. The extent of further sharing is limited by:

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- differing MNO network topologies as a result of differences in spectrum holdings and business strategies. Different site locations are often required to fill different operators' coverage not spots (as demonstrated by the challenges faced by the Mobile Infrastructure Programme)
- planning constraints. Infrastructure that is capable of accommodating multiple operators is also larger and therefore securing planning permission is significantly more challenging
- terms of access to third-party infrastructure. We are concerned that the exclusion of telecoms infrastructure from the scope of the new Electronic Communications Code (ECC) may create an environment where access terms for third-party mobile infrastructure may not be fair or appropriate, enabling wholesale infrastructure providers to further seek excess rent.

The economic challenges of rural deployment are incentivising industry players to innovate and consider alternative solutions. For example, EE is trialling rural small-cell solutions and working via the Scottish Innovation Programme to develop community-based and open source solutions to reduce costs. Ensuring planning regulations, for example, restrictions on small-cell deployments on dwellings, do not inhibit such approaches will be key. However, in the short to medium term at least, these innovations will not be sufficient to overcome enduring deployment barriers (see also Annex 6).

Coverage obligations attached to spectrum licences, particularly with regard to the upcoming 700MHz auction, are also being explored as a powerful lever to further improve rural coverage. For these to be most effective, there is a strong case to make any such obligations contingent on improvements in the deployment environment via policy reforms, such as greater liberalisation of planning regulations and other measures as outlined in Annex 6.

Ofcom does not have direct influence over these aspects of public policy, but this issue can be addressed by effective collaboration between the Government and regulator. A more benign deployment environment could allow more stringent coverage obligations as operator costs of meeting them will reduce and will ensure operator resource is not inefficiently diverted away from other network investments that may deliver greater improvements in overall customer experience.

In certain areas, there will be a case for consideration of direct Government intervention to subsidise deployment (Model 5). The lessons from the Mobile Infrastructure Project (MIP) should be carefully considered in this regard, but we welcome in principle, for example, the 4G Infill programme initiated by the Scottish Government.[4] The Government should also consider initiatives such as rent-free access to public land or assets, or business rates relief, in areas that will likely be enduring rural not spots. Government should also use, as a first step, its convening role to explore what more electricity companies could do to support the delivery of power to remote masts.

We also note that national roaming is proposed by some as a solution. Whilst we understand the attraction and ostensible consumer benefits, nothing has changed since this issue was previously examined by the Government in 2014. Mandated roaming would significantly dilute the incentive for operators to invest in extending coverage as it would no longer be a feature allowing an operator to differentiate from the competition. Furthermore, the technical and customer experience challenges would be difficult and disproportionately expensive to address.

[4] http://www.gov.scot/Publications/2017/08/1017

Developing solutions to address user experience in enduring pinch points, particularly indoors and on-trains

To date, the most common deployment method used to deliver services to end users, for in-building coverage and on rail, is a so-called 'outside in' method using macro networks. This relies on sites outside or away from the trackside to provide coverage. A number of solutions have been employed to help improve the consumer experience by augmenting the 'outside in' approach by adding cells that can help propagate signals originating at a distance, indoors:

- consumer voice: using either 3G femto cells (sometimes known as home signal boxes[5]); and WiFi calling[6]
- consumer data: use of improved Wi-Fi in delivering data services to mobile devices in homes and public spaces indoors (Wi-Fi offload)
- corporate voice and data solutions, including specific in-building solutions
- use of voice and data in public buildings and transport hubs: often achieved by collaboration between multiple operators or third parties providing access to MNOs (these solutions can entail various technologies). Such collaborative approaches are frequently applied in stadia, airports, shopping centres and similar venues
- in rail today, a complex mixture of arrangements applies including repeaters on trains, Wi-Fi, backhaul over mobile, and bespoke deployments in tunnels and cuttings, as well as some deployments in stations similar to those in buildings noted above.

This patchwork of solutions is not fully meeting the expectations of users. At the same time as demand is growing, the challenges presented by building construction techniques which impede wireless signals are increasing. It is clear to us that the current solutions above will not scale cost-effectively.

Whilst we have been exploring commercial solutions and models (see also challenge 3 below where similar issues potentially emerge as we move to dense small cells), impediments remain, including:

- complex operating models where MNOs must coordinate with many other third parties who may be pursuing other goals than providing a communications service
- challenging technical environment, such as hard to reach locations, building structures which block radio signals, or lack of suitable internal wiring
- access to third-party infrastructure on reasonable terms, which can be essential in delivering the most efficient deployment solutions.

There is a role for policy-makers and regulators to support the development of these solutions and address the challenges we (and other MNOs) currently face. There may be opportunities to facilitate the development of multi-operator solutions through bringing together the parties, or making available public infrastructure at cost.

Rail is an example where there is a clear experience issue and demand for improvement, but also where the complex environment and factors such as safety tend to prevent solutions evolving naturally. There are solutions that are likely to be cost effective and practical such as creating the opportunity for MNOs to easily and cost effectively access Network Rail's trackside infrastructure (duct, fibre and mast sites with good coverage of the track), to ensure the effective placement of additional cell sites. This could help provide competitive high-quality mobile coverage on trains at a realistic cost. We are pleased that the Government, via DCMS and DfT, is separately exploring this issue and we will respond to that consultation in due course.

[5] http://ee.co.uk/help/help-new/network-and-coverage/coverage-and-speed/improve-your-signal-at-home-using-signal-box

[6] http://ee.co.uk/why-ee/wifi-calling

Finally, if obligations for indoor coverage were considered in the upcoming 700 MHz auction, we believe that there is a case to make these obligations contingent on improvements in the deployment environment. This should include policy reforms, such as making available physical infrastructure, or in building planning regulations for larger buildings (see Annex 6 for detailed suggestions).

Challenge 3: over a longer time horizon (2020 and beyond), supporting the growing need for cell densification required to realise the potential of 5G and network convergence

UK mobile and fixed networks are at a potential inflection point with increasing pressure for high-capacity fixed/fibre networks coupled with the demand for increasingly sophisticated, diverse and high-capacity services on mobile devices. As discussed above, this is driving a need for a more complex radio access network (the 'wireless edge') and consideration as to how it is connected into the fixed network for wider connectivity.

BT has for some years promoted a general converged network principle of 'fibre as far as possible, wireless at the edge'. This approach leaves significant flexibility as to:

- where the transition from and to fibre actually occurs (eg, at the cabinet, pole, premises or elsewhere)
- how big any 'wireless edge' actually is (macro cell, small cell, femto cell, in home, etc)
- what form of 'wireless edge' is actually used (Wi-Fi, 'mobile', 4G/5G, FWA etc).

The underlying physics of radio spectrum influence the choice of network architecture that delivers and supports wireless solutions at the edge of the network. Different portions of the radio spectrum differ with regard to their capabilities.

To deliver broad and deep **coverage**, typically lower frequencies are needed (<1 GHz). These allow radio signals to travel further, are much less subject to blocking by buildings, tunnels, etc. They provide good wide-area coverage from very few sites.

However, spectrum <1 GHz is relatively more scarce, leading to use of higher frequency spectrum such as 1800 MHz and 2600 MHz, and to 5G standards being developed initially in the 3.4-3.8 GHz and 26-28 GHz frequencies where contiguous blocks of 100MHz can be found.

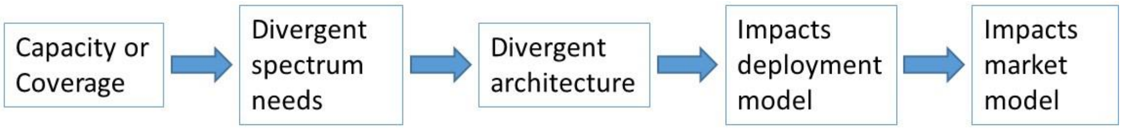
More spectrum re-use is another opportunity. This can be achieved by further sectorisation of macro sites or deployment of a small cell layer in addition to macro sites. Additional cells, such as small cells can reuse the same spectrum as on a neighbouring site or a macro, and hence increase the total traffic carried across the system with the same spectrum.

Moreover, new antenna technology can be deployed. For example, 4G LTE was initially deployed using two antennas on the cell site and device (2x2 MIMO (multiple input multiple output)), now moving to 4x4 MIMO and possibly 8x8. Future technologies involve 'Massive MIMO', up to 64 antennas. Higher frequencies have small antennas, and hence are more suitable for these techniques.

A future high-capacity, high-coverage converged network will combine the various spectrum needs; high and low frequency spectrum are both required, but for different purposes. In most 5G architectures these will cater to different types of consumer needs:

- localised requirements for high capacity, and innovative uses
- extensive coverage to provide an enhanced and ubiquitous mobile experience for everyone.

Finally, the different architectures inevitably require different deployment models if they are to succeed.



In Annex 2, we describe the main use cases for 5G: Enhanced Mobile Broadband, Massive Machine-to-Machine and Ultra-Low-Latency communications. While all of these use cases may in the long run be delivered via 5G, not all may require 5G in the very high frequencies, at least not in the near future. In particular, as we set out above in the near future, coverage will still continue to be delivered via the macro-cell network in the lower frequencies. Capacity will need to be delivered via a mix of approaches, including Wi-Fi and 5G, all via an increasingly large number of small cells.

However, wireless and fixed access services will need to be integrated to deliver against different consumer needs and use cases in a flexible and seamless manner. The 5G radio interface will enable this as it will be developed in parallel with increased software capabilities enabling the remote control of different network elements.

For example, data from a wireless connected device, whether connected via macro-cell, small cell or micro cell (outdoors and in-building), will travel seamlessly across the network utilising low-cost fibre and microwave for backhaul and core connections. Service quality is likely to be improved as a result of this flexibility particularly in 'pinch-point' areas of high footfall such as railway stations, roads and rail or sports stadia.

The mobile aspect of any future 'converged network' is therefore likely to comprise:

- tens of thousands of macro cell sites as in the current infrastructure competition model ensuring geographic coverage
- many more thousands of small cell sites (on lamp posts, bus stops, external building walls, etc) in population centres, traffic corridors, etc, providing very high speed and capacity within this wider coverage
- a greater number (perhaps millions) of additional 'in-building' sites providing in-fill and focussed coverage and capacity in commercial and other buildings as required by the business/building owner. These in-building cells will need to connect seamlessly with the wider geographic network.

This scale of small-cell deployment clearly raises questions regarding the availability of suitable sites and the sustainability of the costs involved. This is likely to drive a more compelling case for increased sharing, albeit the exact models to be utilised are currently less clear.

A range of different sharing models are being considered in the UK (and to an extent already a reality in some cases with public Wi-Fi) and commercial agreements already exist in the US. There are a number of potentially different approaches depending on the extent of common assets and sharing, eg, sharing of sites only; sharing of sites, power and backhaul; sharing of all of the above plus electronics; and active sharing. In principle, such an approach may also be relevant for in-building coverage solutions. However, if the degree of sharing increases, although the economics of infrastructure investment could improve, competition/differentiation options will decline.

Collaborative approaches could take different forms, based on voluntary commercial agreements, in order to maintain incentives to invest in infrastructure and to maintain competing networks to support retail competition. In the absence of such collaboration based on voluntary commercial agreements, and where such assets represent bottlenecks, then regulatory involvement may be required to ensure effective access.

At this stage, we believe public authorities and policy makers need to be alive to two major concerns to ensure suitable models for small cell deployment can be developed and sustained:

- the availability of, and approach to, the use of publicly owned assets. We anticipate that street furniture, for example, will be attractive. We would urge local authorities to think strategically about how they allow access to these sites and the benefits to residents. Viewing them solely as revenue-raising opportunities and selling concessions to third parties may mean these assets are effectively priced out of the market. We believe the DCMS-led Local Area Connectivity Group could usefully explore these issues and advise on best practice

- access terms to third-party infrastructure remain appropriate and do not become bottleneck assets. It is important that the new ECC is kept under review to ensure it is fit-for-purpose as we move into a 5G, small-cell dominated world.