DOI:
10.1108/DPRG-02-2018-0004

The Strategic National Infrastructure Assessment of Digital Communications

Journal:	*Digital Policy, Regulation and Governance*
Manuscript ID	DPRG-02-2018-0004.R1
Manuscript Type:	Original Article
Keywords:	Policy, Digital communication systems, Telecommunication

Purpose

Public policy requires effective identification of the current and emerging issues being faced in industry and beyond. This paper identifies a set of key issues currently facing digital communications and reviews their relevance for the strategic provision of infrastructure, particularly within the UK context.

Design

The methodology focuses on taking a horizon scanning approach to obtaining current information from a range of authoritative decision-makers across industry, government and academia. After structuring the issues identified, these areas are explored by a multi-disciplinary research team covering engineering, economics and computer science.

Findings

Five key categories were identified including (i) future demand, (ii) coverage and capacity, (iii) policy and regulation, (iv) economics and business models, and (v) technology. The results are reported for both fixed and wireless networks. Shared issues affecting the wider digital ecosystem are also identified including Brexit, connecting remote areas, and the degree to which the economics of infrastructure allows for building multiple overlapping infrastructures. We find that future demand uncertainty is one of the major issues affecting the digital communications sector driven by rigid willingness-to-pay, weak revenue and an increasing shift from fixed to wireless technologies. Policy must create the market conditions that encourage the entry of new competitors with innovative thinking and disruptive business models.

Research limitations/implications

A limitation of the analysis is that it is quite UK-focused, hence further research could broaden this analysis to assessing issues at a continental or global scale.

Originality/value

The value of this paper originates from the breadth of the expert elicitation exercise carried out to gather the initial set of issues, followed by the analysis of this data by a multi-disciplinary team of researchers. The results direct a future research agenda, as many issues are indicative of a lack of existing evidence to support effective decision-making.

1 Introduction

The global economy is enabled by national and international infrastructure systems that move goods, people and information. A swathe of reports stating the importance of infrastructure, and the under-investment relative to need, is commonly cited in support of this topic (see World Economic Forum, 2016). Historically, the approach to infrastructure planning and delivery has been relatively piecemeal and fragmented, particularly when it comes to digital. Indeed, infrastructure has been as much the proverbial political football as other areas of government expenditure. Notable examples include Australia's National Broadband Network and the UK's High-Speed 2 rail project.

Attempts have now begun to take a more strategic approach to infrastructure planning, coordination and delivery via the introduction of infrastructure units such as Infrastructure Australia and New Zealand's National Infrastructure Unit. The National Infrastructure Commission (NIC) has been established in the UK to provide impartial and long-term advice to government, and is responsible for undertaking a National Infrastructure Assessment (NIA) once per Parliament, attempting to decouple infrastructure of strategic importance from the electoral cycle. The UK's NIA should outline a strategic vision over a 30-year time horizon, and recommend how future needs should be met. The hope is that this will provide a more stable direction for national infrastructure policy, based on analysis of the needs, costs and benefits of infrastructure investment. However, while NIA has been underway in different guises for most critical national infrastructure sectors, there has historically been a lack of emphasis on digital communications infrastructure, exemplified by the Institution of Civil Engineers (2014) National Needs Assessment. However, the political aims of 5G deployment have begun to change this.

In this paper, we identify a set of key issues affecting the strategic provision of digital communications. The next section outlines the methodology, with Section 3 and Section 4 reporting the results for Fixed Networks, and Mobile and Wireless Networks, respectively. Shared issues across all sectors are then outlined in Section 5, before discussing the implications of these findings in Section 6. Conclusions are finally provided.

2 Methodology

Collaboratively defining key policy issues is frequently used to help bridge the divide between academia and industry on one hand, and government policy priorities on the other (Parker et al. 2014). To collaboratively gather information on key challenges facing digital communication, a workshop was firstly held in Cambridge, UK, to collect structured evidence from 47 authoritative professionals from industry (23 participants), government (7 participants) and academia (17 participants). The workshop took place in February 2017, thereby providing up-to-date information for use in the strategic assessment of digital infrastructure, with a focus on identifying a mixture of UK-specific and global issues. The approach used was to split participants into six groups that comprised a mixture of professionals from all the aforementioned groups. This was to maximise the interaction and discussion between those from different backgrounds, based on there being considerable value in the interaction that takes place among those traditionally pigeon-holed into either the fixed, mobile, wireless or satellite sectors. Two sessions were held where participants were asked to highlight and describe the future issues pertinent to fixed networks, and mobile and wireless communications.

Once complete the results were grouped based on their key dimensions, whether they were specific to one sector or more, and the spatial scale at which these issues most likely manifest. This focused on developing broad categories for the issues gathered, resulting in five key areas; future demand, coverage and capacity, policy and regulation, economics and business models, and technology. This categorical grouping is justified because future demand affects the viability of delivering new digital infrastructure, and coverage and capacity captures two important assessment metrics of digital infrastructure performance. Policy and regulation sets the institutional rules for telecommunications markets particularly how market failure is addressed, and economics and business models includes everything from asset prices to industry profitability and investment. Finally, technology represents the development of new communications infrastructure components and methods that can enhance current capacity and coverage.

Once the workshop had been completed the results were collated with the subject areas being divided based on the expertise of a multidisciplinary research team. Key issues were allocated to the relevant expert. Each expert was tasked with reporting their key issues, and writing up the task in a standard format covering (i) an explanation of the issue and (ii) the relevance for policy priorities moving forward. Evidence was initially collated before undertaking an iterative redrafting exercise where all authors could access and edit the document. This took place over several months but enabled key issues and challenges identified in the horizon scanning exercise to be framed in a clear and informative manner. The findings for each sector are now reported.

3 Fixed Networks

Firstly, an overview of the existing fixed market is provided for context. The market share of the main Internet Service Providers in the UK consists of BT (32%), Sky (23%), Virgin Media (19%), Talk Talk (13%) and EE (4%) (Ofcom, 2016b). These providers deliver services using xDSL and FTTx infrastructure, except for the cable provider Virgin Media which currently uses DOCSIS3 technology and coaxial cable. The remaining share is composed of smaller operators, such as the new entrant fibre providers CityFibre or Hyperoptic. Since 2010, BT and Sky have seen a 4% and 8% increase in their market shares respectively, whereas Virgin Media and Talk Talk have seen a decrease of 3% and 7% respectively.

3.1 Future Demand

Currently over 9 million consumer premises (31%) in the UK are subscribed to superfast broadband (≥30 Mbps), although the rate of adoption for these services appears to be slowing (Ofcom, 2016a). This is concerning because the economics of density in network rollout means that low demand affects viability, making demand stimulation activities increasingly pertinent. Uncertainty in demand also significantly affects Fibre-To-The-Premise (FTTP) network architecture design (Hervet et al. 2013). In fact, current demand for superfast fixed broadband services is approximately a third of the total number of premises covered (Ofcom, 2016a). Take-up of ultrafast broadband (≥300 Mbps) is even lower at just 0.09% of premises, indicating future demand for higher bandwidth services will take time to evolve. Indeed, this indicates that the perceived value for consumers from the use-cases of ultrafast services is still relatively low, although this is likely to change over coming decades as new digital services become available.

Future demand uncertainty is not just affected by the willingness-to-pay of consumers, but also by changing technology trends. The increase in FTTx connections is almost completely comprised of Fibre-To-The-Cabinet (FTTC) products, whereas the willingness-to-pay for full FTTP services is still low. However, the adoption of fibre services is likely to continue to rise over the next decade until FTTC is the most common access type, with early adopters moving closer to full FTTP solutions.

The increasing capacity and use of mobile connections poses a potential risk to fixed network operators. For example, the introduction of 4G LTE-Advanced and potentially 5G means that these wireless technologies *may* increasingly be able to compete with fixed access connections (although evidence is still limited to support or negate this hypothesis). One school of thought is that future demand for fixed access is uncertain over the long-term as users may increasingly moving towards using wireless access methods. Either way, strategic assessment of digital infrastructure should ambitiously seek to enable new investment which can meet and shape demand. This is likely to include full fibre deployment over coming decades to future proof the fixed access network.

3.2 Coverage and Capacity

In 2016, 95% of premises could achieve a broadband speed of ≥10 Mbps, leaving the final 5% to be the aspiration of the newly introduced Universal Service Obligation (USO). Superfast broadband speeds ≥30 Mbps were achievable by most premises (89%), although only a small fraction (2%) were able to achieve Ultrafast broadband (≥300 Mbps) (Ofcom, 2016b). Coverage of superfast broadband has increased considerably between 2011-2016 by roughly 20%, to just below 90% of premises, however coverage of ultrafast broadband remains very low. In terms of take-up, almost 80% of premises have a basic broadband connection, and approximately 50% pay for a service that delivers more than (≥10 Mbps). Whereas over the past ten years, coverage and capacity has been focused on the number of premises receiving 2 Mbps (the old USO), and 30 Mbps (superfast broadband), now that the speed distribution has shifted, the current concern will be 10 Mbps (the new USO) and 300 Mbps (ultrafast broadband). In the future, this will rise as bandwidth demand increases, and we could plausibly see a 30 Mbps USO and a 500 Mbps standard connection speed introduced in future decades. Some consumers may feel the current 10 Mbps USO is set too low, hence ensuring private operators are incentivised to deliver higher capacity infrastructure in the future is crucial, especially over an assessment period of many decades.

Over the past six years there has been a considerable increase in average fixed broadband speed due to investment in FTTx and DOCSIS 3, and this has simultaneously driven data demand due to the relative ease of dealing with the transfer of what was traditionally regarded as large amounts of data. As just one example over this period, in February 2011 there were 117 million monthly requests for TV content via BBC iPlayer which then increased in 2016 to 239 million (BBC, 2017). In February 2017 this increased to 277 million BBC iPlayer requests. As fixed broadband speeds continue to grow, demand across the connection in terms of data throughput is likely to similarly grow, potentially even at a faster rate. Indeed, recently the idea of a ‘capacity crunch’ in optical fibre communications networks has been explored. The key concern relates to whether technological capabilities are keeping pace with dramatic increases in demand, as optical fibre has a finite information flow. Although research is still exploring if a limit exists to the capacity of optical communication, if a practical limit was reached there would need to be increased parallelism in communications networks, requiring more fibre infrastructure. This would have a significant impact on both capital expenditure (equipment costs) and operational expenditure (energy consumption), influencing the overall economic viability of new capacity. The significant issue is whether the market will continue to be able to solve capacity issues via pricing and increased innovation in higher-capacity network technologies.

3.3 Policy and Regulation

The policy and regulatory aspects of fixed broadband networks continues to be a heated area of debate, due to issues in how best to push a previously nationalised network industry towards more competitive dynamics for each major generational upgrade. As identified in the Digital Communications Infrastructure Strategy (DCMS and HM Treasury, 2015), a core part of the UK’s success in attracting investment and ensuring competitive markets, stems from strong, transparent and independent regulation. The UK has long favoured market-based policies in the telecoms sector, with a prudent mix of supply-side (e.g. Broadband Delivery UK's Superfast Broadband Programme) and demand-side (e.g. Broadband Connection Voucher Scheme) policy instruments (only when the market has failed to deliver).

However, in terms of encouraging more investment into fixed networks, the UK has historically pursued a Local Loop Unbundling (LLU) strategy. In 2005 Ofcom implemented the functional separation of BT wholesale and retail services, establishing a separate division within BT known as Openreach, with the aim of providing equal access to the local network. Econometric analysis of this decision found short-run consumer benefits from lower prices, but negative long-run effects on telecommunications investment, customer satisfaction and competitiveness (Sidak and Vassallo, 2015). In 2017, Ofcom announced further legal separation from BT, with Openreach Limited becoming a distinct company with its own staff, management, strategy and a legal purpose to serve all its customers equally (Ofcom, 2017).

Evidence globally suggests that an LLU approach can have a positive impact when introduced, but has less impact as markets start to mature (see Nardotto et al. 2015). Inter-platform competition, therefore, will have more of a positive effect in terms of penetration and quality moving forward, and will be increasingly important for UK digital infrastructure rollout. The main inter-platform competitor to the incumbent is from Virgin Media, although the Project Lightning network expansion will generally target only the infill development within its existing urban-centric footprint. New full fibre entrants such as Gigaclear and Hyperoptic will also be key in driving the benefits of inter-platform competition. International evidence suggests that ensuring open access for new entrants to the incumbent's infrastructure facilities is associated with high-quality broadband infrastructure networks (Rajabiun and Middleton, 2013). Government policy should continue to pursue increased physical infrastructure access for communications providers to reduce the cost of new deployments.

Despite the recent Openreach separation, BT still currently controls the company's budget for investment and has generally resisted large-scale expenditure. Recent announcements saw Openreach increase its commitment to delivering FTTP to 3 million premises by 2020 (up from an initial commitment of 2 million). Yet, some still feel dissatisfied as smaller operators are making comparatively larger commitments. Indeed, a commitment two to three times larger is seen as an appropriately ambitious Openreach target. If the scale of expected investment desired by political decision-makers is not achieved, further regulatory options include a forced full-scale sale of Openreach, floating the company, or as a last resort, nationalisation. Further analysis must make an evaluation of the potential regulatory options available should existing arrangements provide unsatisfactory performance. This must include a formal estimation of both the advantages and disadvantages of each possibility.

3.4 Economics and Business Models

Issues pertaining to the economics of FTTP networks are not new, as making the case for large-scale deployment can be challenging without a defined set of use-cases for fibre, or significant changes in public policy or industrial organisation. In addition to the regulatory issues associated with Openreach identified in the previous section, the two key issues affecting the economics of deployment are firstly the large fixed costs associated with deployment and secondly the uncertainty in future demand. Considerable emphasis is placed on supply-side market failures, but less focus is placed on demand-side issues such as willingness-to-pay, user adoption barriers and demand stimulation activities. By increasing the willingness-to-pay and aggregate demand for higher bandwidth services, more certainty is not only provided for operators making major investments but reductions are also gained in the average cost of delivery per user due to scale economies (Katz and Berry, 2014). Importantly, we need to do more to understand the potential positive effects that demand-side policies may have on increasing the coverage and capacity of ultrafast fixed broadband networks.

In terms of average monthly telecommunications spending for households, between 2008-2014 there was roughly a 10% decrease from £123 in 2008 to £111 in 2014 (Ofcom, 2016b). Although there has been an overall decrease in spending, fixed internet revenue has increased over this period as consumers are willing to pay more to upgrade to superfast broadband services, gaining the benefits of greater bandwidth. As more households move to adopt these services, this average monthly figure will continue to rise, which may also positively impact the viability of future fixed network investment.

Government must seek to ensure that fixed network infrastructure can be deployed as cheaply as possible, as this has consequential benefits for consumers.

3.5 Will technology save the day?

Technology and software development is driving major change in the fixed access, metro and core networks. Due to the civil engineering and planning costs of laying full fibre in the access network, new technologies such as G.fast (offering up to 1 Gbps) or XG-fast (offering up to 10 Gbps) have attempted to make DSL technology competitive with FTTP. Using advanced crosstalk cancellation techniques (vectoring), 500 Mbps has been achieved over 250m (Oksman et al. 2013). Additionally, in cable access the DOCSIS 3.1 specification has been developed with the aim of providing subscribers with speeds of up to 10 Gbps downstream and 1 Gbps upstream (Hamzeh et al. 2015). The delivery of these technologies may delay the case for full FTTP solutions.

A series of new technologies termed Network Function Virtualisation (NFV) can enable the core network's high-volume packet-processing functions to be virtualised, and hence controlled and run via cloud computing platforms (Joshi and Benson, 2016). In communications networks, this has been proposed as a way of increasing the flexibility of network service provision, including reducing the deployment time for new digital applications and services (Han et al. 2015). NFV is commonly referred to in tandem with Software Defined Networking (SDN) which is an approach capable of separating the underlying data plane in the network from the control plane, consolidating control functions in a logically centralised controller (Thyagaturu et al. 2016). These tools will provide greater flexibility and efficiency to infrastructure network operators in the future, and are hoped to be able to reduce both capital and operational expenditure, potentially making new infrastructure delivery more viable.

4 Mobile and Wireless Networks

Firstly, an overview of the existing mobile and wireless market is provided for context. In terms of revenue and subscribers, the UK mobile sector is one of the largest in Europe. Mobile Network Operators with major market shares include EE (29%), O2 (including GiffGaff) (27%), Vodafone (including Talkmobile) (19%), and Hutchinson Three (11%) (Ofcom, 2016b). Other Mobile Virtual Network Operators comprise the remaining 15%, mainly offering alternative low-cost offers. Currently 2G, 3G and 4G technologies are in operation across the UK by most major operators, although 4G rollout is still taking place and is yet to cover many rural areas. While premises coverage of both 3G and 4G is over 70%, geographic coverage lags behind with 4G at approximately 40% of UK landmass. With the increased proliferation of 4G, the average data consumption per user is growing rapidly, which is now over 1 GB per month.

Considerable policy emphasis has been put on the mobile industry in recent years for three key reasons. Firstly, mobile signal can be poor at times in both urban and rural areas even for voice calls. Given the UK is a major economy with one of the fastest growing digital economies, this is surprising and concerning. The operators state that they struggle to get new sites for basestations through planning. Others blame the operators for underinvesting. Either way, there is a desire by government to try to improve the current level of mobile connectivity. Secondly, as the UK was sluggish at gearing up for, and delivering, 4G rollout there has been significant interest in making sure that the UK does not repeat the same mistake with 5G. In 2016, the incumbent chancellor announced the ambitious aim to make the UK a world leader in 5G deployment. Thirdly, the desire to rollout 5G is motivated by the idea of embedding the technology as a key part of the national industrial strategy (often referred to as Industrial Internet of Things), to drive both improvements in productivity and overall economic output.

4.1 Future Demand

There are 91.5 million UK mobile subscriptions, of which 39.5 million are 4G, with approximately 93% of adults using mobile phones. Smartphones are currently used by 71% of all adults and is the key technology driving the demand for more access capacity and data throughput, as they enable a wide range of content, applications and services including wireless HD video access (Ofcom, 2016b). Over the past five years, mobile data traffic has grown by up to 18 times, with mobile video traffic accounting for 60% of total mobile traffic in 2016 (Cisco, 2017). The most recent Cisco mobile traffic forecast for 2016-2021, demonstrates that video is still driving the overall long-term trend with a

Compound Annual Growth Rate of 49%. Fixed traffic is expected to fall from 52% of total IP traffic in 2015 to 33% by 2020, as wireless access grows at a rapid rate and increasingly takes a larger share of the total. Assessment of Internet traffic by access technology shows that by 2020, 17% will be from mobile data, 29% will be from fixed/Wi-Fi from mobile devices, 20% from fixed/Wi-Fi from Wi-Fi-only devices, and 33% from Fixed/Wired technologies (Ibid).

As already highlighted, the future demand for 5G is an issue. Merely because government wishes to deploy 5G infrastructure expediently, it does not mean consumers will be willing to pay extra for these services. This partly relates to use-cases for the additional services as consumers are only willing to increase spending if there is a perceived additional benefit. According to work by Real Wireless (2016), the probable 5G use-cases include connected vehicles, railways, preventative health and remote care, smart utilities, supply chain monitoring and delivery, and media and cloud everywhere. Hence, unless these usage benefits are clearly perceived by consumers there will be reluctance to pay increased additional money for services marketed as 5G, introducing added uncertainty to future demand. Reflecting on 4G deployment in the UK, consumers showed how price conscious they are with many customers eventually being given the 4G service as a free upgrade, rather than paying additional revenue. The current 5G test beds should actively provide an evidence base to support use cases, with current findings being fed into strategic assessment processes at the policy level.

4.2 Coverage and Capacity

In June 2016, a total of 106 PB per month were sent across all mobile networks which was almost a 50% increase on the previous year, although this still only represents about 4% of the data sent across fixed networks. For capacity to meet this growing demand there are three options including integrating newly available spectrum, densifying the network and increasing the spectral efficiency of the basestation technology. To meet long-term data demand, it is likely that a combination of all of these capacity-enhancing techniques will be required, but the main gains will be from densifying the network. As spectrum availability is potentially a key capacity limitation for wireless infrastructure, government should endeavour to make new bands licensable. Currently, the UK has committed to

295 releasing 750 MHz of sub-10 GHz spectrum by 2022. Ultimately, the choice of future spectrum bands themselves will be a key driver for the *type* of infrastructure likely to be delivered by the market, as the characteristics of different bands will affect capacity and coverage.

298 Three pioneer bands have been earmarked for 5G by the EU's Radio Spectrum Policy Group (RSPG) which include 700 MHz, 3.4-3.8 GHz and 26 GHz. These spectrum choices have been selected as options for providing significant performance improvement in current wireless networks. Firstly, while 700 MHz is constrained by the bandwidth available, it is the only band of the three capable of delivering reliable national coverage, especially as it could significantly improve reach into and around buildings. Secondly, 3.4-3.8 GHz has the potential to deliver Gbps to mobile users via dense clusters of small cells (predominantly in urban areas). However, it may not be economically feasible beyond urban areas (Oughton and Frias, 2017). Finally, hotspot locations with very high footfall could make use of 26 GHz, which is capable of delivering multiple Gbps. These spectrum choices mean a 5G world will see a "layered cake" of three new networks aggregated on top of existing 2G, 3G, 4G and Wi-Fi infrastructure, with the aim of advancing fixed wireless capacity, mobile wireless capacity and mobile wireless coverage. Ensuring the efficient use of spectrum resources is an ongoing strategic assessment challenge for wireless systems.

4.3 Policy and Regulation

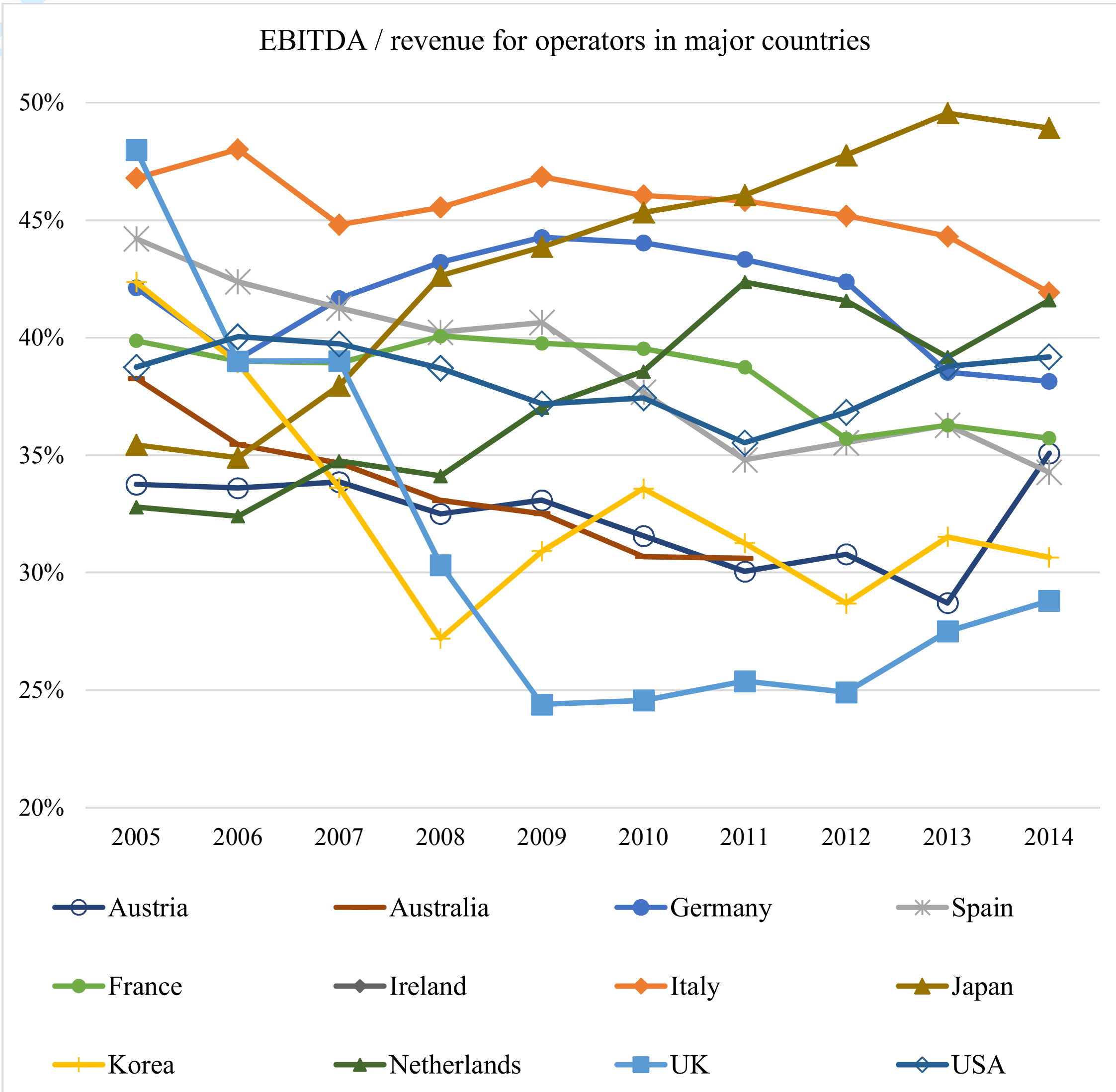
Increasing infrastructure deployment costs combined with declining Average Revenue Per User (ARPU) have led to increased consolidation across the mobile industry in the UK and Europe. However, the degree to which M&A activity has been allowed to take place has been heavily influenced by the regulatory stance of each country. Curwen and Whalley (2016) examine the decision to block the acquisition by 3UK (Hutchinson) of O2 Telefónica, despite a similar reduction to three networks in Germany (with stringent conditions attached however). The main issue is whether consolidation is beneficial or detrimental to prices and infrastructure investment. Some industry analysts believe there would be positive network investment effects from this activity (see Frontier Economics, 2014), although others disagree, stating that there is little historical evidence this would take place (i.e. WIK-Consult, 2015). We must wait for further evidence to undertake a thorough evaluation of the long-term investment impacts due to recent European M&A activity, but there appears to be opposing views held by different stakeholders regarding the optimal industrial structure of the UK mobile industry.

If the UK is to embark on early 5G deployment, numerous planning reforms may need to be implemented for effective and efficient infrastructure deployment for cells of all sizes. Current local planning regimes can be prohibitive for deploying digital infrastructure, with examples including limits on the heights of basestation antennas, as well as the challenges of obtaining planning permission for new sites that are not within permitted development. Hence, planning issues have a significant impact on the available coverage and capacity for users and may further require reform. If 5G is to be driven by small cell deployment, which is a potential option given desired capacity enhancements mooted by various sources (Andrews et al. 2014), this process must be able to take place swiftly and cheaply.

4.4 Economics and Business Models

The average monthly spend on mobile voice and data services has decreased significantly over the past decade. Indeed, falling ARPU is also reflected in the general profitability of the UK mobile sector, which has declined since 2005. A key metric of 'profitability' is Earnings Before Interest, Tax, Depreciation and Amortisation (EBITDA) illustrated in Figure 1. By the end of the 2005-2014 period, the EBITDA for the UK was the lowest out of 11 major OECD countries due to highly competitive market dynamics.

Figure 1 EBITDA / revenue of mobile operators in major countries 2005-2014 (New Street Research, cited in WIK-Consult, 2015)



While countries such as Spain and Korea have also seen declining EBITDA, others have seen a positive increase, such as Japan and the Netherlands. Little change has taken place in the mobile markets of the USA, France and Austria with the EBITDA margin remaining around 35%. In a similar trend, the UK mobile sector was in the middle of this group of countries for Post-Tax Return On Capital Employed in 2015 at ~10% return (Ibid). This generally shows that the UK mobile sector has potentially low investment attractiveness moving forward, which may detrimentally affect infrastructure investment, with knock-on negative consequences for consumers.

4.5 Will technology save the day?

Delivering ultra-dense networks will be essential for meeting the capacity-demand evolution of wireless networks in future decades, and will include both densification of small cell deployments and utilising larger portions of diverse radio spectrum bands (Bhushan et al. 2014). The use of high-frequency millimetre wave spectrum is seen by some as also an increasingly important technical solution for future networks. Despite experiencing much higher path loss than microwave signals, there is an increased availability of spectrum above the traditional microwave frequency bands. The potential benefit of this solution would be to offer multi-Gbps data rates at a lower marginal cost than previous technologies (Murdock et al. 2012). Other technologies contending to be revolutionary in 5G include Massive MIMO and Cloud-Radio Access Networks, as well as the NFV and SDN concepts already identified previously.

5 Shared Issues Across Digital Communications

Having reviewed and outlined individual digital communications sectors, we will now examine the technical, economic and governance issues that are shared across the whole industry.

5.1 Brexit

The UK has one of the largest telecoms industries in Europe, which comprises a major part of the UK's total service exports. In 2012, 18.8% of value-added in the EU-28 telecommunications industry (EUR 31.8 billion) was generated by the UK (Eurostat, 2015). Ensuring a trading arrangement that works for both the UK and the wider European telecommunications industry will be essential to avoid disruptive consequences. Domestically, many of the powers under the UK's Communications Act 2003 originate from the EU Regulatory Framework for Communications (Broadband Stakeholder Group, 2017). Hence, the overarching regulatory framework governing UK digital communications is now under review and there will be considerable uncertainty in the coming years as a result. At least in the medium term it would be sensible to align the UK's regulatory framework with the EU's, in order to avoid a cliff-edge change that could affect investment, operations and hurt consumers. To ensure the viable delivery of digital communications infrastructure, investors require a high degree of

378 predictability. After Brexit, the UK will have the possibility to consider changing the State Aid rules which currently affect the range of options available for resolving coverage and capacity issues in digital infrastructure, although this would need careful thought. Moreover, many areas of the UK currently receive support from the European Regional Development Fund, such as Superfast Cornwall and the Welsh Superfast Cymru, to encourage rollout of broadband in rural and remote areas. To ensure future infrastructure delivery in areas of market failure, this source of European funding will need to be replaced domestically, otherwise it may detrimentally affect connectivity in less viable places.

5.2 Remote Areas

The issue of delivery in remote areas is a challenge for all infrastructure sectors. Ultimately digital infrastructure delivery and operation is a network industry and therefore there are large fixed capital costs associated with building a network capable of delivering even basic services. Broadband services are widely regarded as having a 'broken value chain'. So even if the costs of production are higher to deliver broadband access services in remote areas, users are generally not willing to pay the additional costs to cover the rollout (leading to the need for a USO). Hence, demand stimulation activities are essential, as this can help to improve investment viability and enhance market-based delivery.

In fixed access, Broadband Delivery UK recently reported on the emerging findings from the Market Test Pilots (DCMS, 2016) which explored new ways for delivering superfast broadband services to the least commercially viable parts of the UK (the last 5% of premises). The technologies deployed were a mixture of satellite, fixed wireless, and mixed fibre and fixed wireless access, with a key finding being that non-fibre access technologies can still be a key component in delivering reliable, superfast-capable speeds that satisfy the majority of customers over the next decade. However, future demand may well exceed the capabilities explored in these initial test pilots, and there may be a long-term increase in the USO in coming decades. Hence, activities associated with technology and business model innovation must be sustained after this period with a view to meeting the challenge of long-term demand in the most remote places in the UK.

5.3 Single vs Multiple Infrastructure Networks

Digital communications is not the only infrastructure sector that has been trying to tackle the question of whether to build multiple networks, or a single infrastructure. Decision-makers must deliberate over whether building multiple networks is an efficient use of limited capital. In fixed networks, LLU has been a way to enable facilities-based intra-platform competition between the incumbent and new entrants, and the UK took this approach because it would not be efficient to use capital to build a duplicate local access infrastructure at great expense, when the value of the service delivered to consumers would essentially be similar. Increasingly however, inter-platform competition is becoming favoured for full fibre access solutions as new fibre entrants compete with the incumbent by offering FTTP.

In the mobile and wireless industry, the UK currently has multiple networks although the actual coverage and capacity delivered is different between operators. Due to the industrial supply and demand cost pressures already articulated in this paper, we have seen increased consolidation in the sector, in combination with site sharing agreements between operators. An economic analysis of spectrum and infrastructure sharing in cellular networks by Fund et al. (2016) concludes that 'open' deployments of neutral small cells serving subscribers of any service provider encourage market entry by making it easier for networks to get closer to critical mass. This is one option that requires greater analysis moving forward given that ARPU has been decreasing.

6 Discussion

The results obtained highlighted three key interrelated issues. Firstly, the demand for many of the technologies featured in the media limelight remains inconclusive (e.g., for 5G, gigabit fixed access, connected vehicles etc.), highlighting issues associated with investment viability and risk exposure for those companies who bring them to market. Secondly, the business model currently used in telecommunications is predicated on extracting maximum returns from existing investments in coverage and capacity, for as long as possible, contrasting the political desire to deliver new infrastructure. Thirdly, ongoing convergence between fixed and wireless technologies adds additional uncertainty to this issue. Hence, some operators are currently being relatively risk-averse and attempting to avoid long-term stranded assets by prudent incremental delivery. Opponents of this approach however believe this is deliberately sweating existing assets and therefore holding back new infrastructure delivery. Additional uncertainty is produced when we consider the over-the-top threat (where traditional telecom revenue is disrupted by new online services), as infrastructure operators may continue to fail at capturing the value created from their investments. This may detrimentally affect future infrastructure investment and delivery. Hitherto, fixed and wireless infrastructure have been largely complementary technologies, however the degree to which wireless services will instead become substitutionary may increase in coming years, potentially affecting fixed revenue.

We have found that considerable emphasis is continually placed on supply-side market failures, but less focus is placed on demand-side issues such as willingness-to-pay, the ability to adopt new services and demand stimulation activities. In the UK, the trends shown in current revenue indicators illustrate that infrastructure operators may continue to be ‘squeezed’ moving forward (particularly in mobile and wireless), which may fundamentally affect the ability to deliver the capacity and coverage of digital infrastructure that we require given data demand continues to increase annually. Therefore, we need further analysis on the effectiveness of demand stimulation policies in areas of market failure, as well as greater quantification of the positive externality impacts that could accrue for both users and the wider economy if increased adoption takes place.

The UK’s National Infrastructure Assessment is pertinent to two important policy objectives for digital communications, firstly relating to the ‘digital divide’, and secondly concerning national industrial strategy. Disparities in digital infrastructure frequently feature in the media, as consumers highlight their discontent with current fixed broadband access and mobile coverage, and there is desire in government to address these ‘digital divide’ issues for both equity and economic reasons. Additionally, the lack of progress in labour productivity over the past decade has prompted focus on how technology may help to make industry more internationally competitive. Hence, the UK’s approach to expediting ‘5G’ is increasingly seen as part of the nation’s current and future industrial strategy, where on one hand this is an attempt to boost productivity via potential automation benefits, and on the other, the recognition that existing industries need to stay competitive by having the connectivity to conduct R&D in Britain. However, these two objectives are not necessarily complementary to each other as solving the digital divide requires spreading resources geographically, as opposed to an industrial strategy approach which would favour targeted clustering of resources in cities and industrial areas.

7 Conclusion

This paper identified a set of key issues currently facing digital communications as a source of evidence for the strategic assessment of digital infrastructure, particularly as the UK's NIC moves towards the first NIA. An important finding is the uncertainty associated with future demand for new services and how this is compounded by the fact that the sector is experiencing declining revenue, increasing convergence in digital services, as well as growing fixed-mobile substitution. In evaluating those areas pertinent to the digital sector, we have covered a set of key engineering, economic and policy issues that will affect the future of the industry.

In the large majority of cases, it is highly likely that the market will provide the required infrastructure assets and therefore we have focused on the issues that might constrain this process. We believe that there is considerable emphasis continually placed on supply-side market failures in the delivery of digital infrastructure, but less focus is placed on demand-side issues such as willingness-to-pay, the ability to adopt new services and demand stimulation activities. Indeed, we must better ascertain the services that users really desire and how much they are prepared to pay for them. If market-based methods continue to be the main way to organise the allocation of limited resources in digital communications, which seems to be the case, then operators can only be 'squeezed' so far by government before there is a detrimental effect on infrastructure investment. Hence, demand-side methods play a very important role in providing additional certainty and risk reduction, to operators attempting to bring new digital infrastructure to market. More research needs to be undertaken which explores the sensitivity of future demand in relation to infrastructure performance and cost, particularly under different demographic, economic and technical scenarios.

Finally, a key issue relates to the existing business model used by fixed and mobile network operators which is frequently predicated on extracting maximum returns from existing investments in coverage and capacity, for as long as possible. This model can work in contrast to the policy aim of encouraging near-comprehensive coverage of sufficient capacity, both in fixed and mobile. Consequently, the infrastructure challenge relates to whether fixed and mobile incumbents can genuinely be rivalled by new entrants with different investment and cashflow models. Large-scale infrastructure investment is not necessarily in the direct interest of incumbents due to their dominant position, making it essential that market conditions encourage the entry of new competitors, with innovative thinking and disruptive business models. A limitation of the content presented in this paper is the narrow UK-focus, hence further research could broaden this assessment to assessing issues at a continental or global scale.

8 References

BBC (2017) *BBC iPlayer Monthly Performance Report - February 2017*. London: BBC. Available at: http://downloads.bbc.co.uk/mediacentre/iplayer/iplayer-performance-feb17.pdf (Accessed: 22 April 2017).

Bhushan, N. *et al.* (2014) 'Network densification: the dominant theme for wireless evolution into 5G', *IEEE Communications Magazine*, 52(2), pp. 82–89. doi: 10.1109/MCOM.2014.6736747.

Broadband Stakeholder Group (2017) *Implications of Brexit on the digital communications sector*. London: Broadband Stakeholder Group. Available at: http://www.broadbanduk.org/wp-content/uploads/2017/04/Implications-of-Brexit-on-the-digital-communications-sector-FINAL.pdf (Accessed: 16 April 2017).

Cisco (2017) *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016–2021*. San Jose, CA: Cisco American Headquarters. Available at: http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.pdf (Accessed: 16 April 2017).

Curwen, P. and Whalley, J. (2016) 'European mobile markets and the doctrine of "4 networks good, 3 networks bad"', *info*, 18(5), pp. 1–23. doi: 10.1108/info-05-2016-0021.

Department for Culture, Media and Sport (2016) *Emerging findings from the BDUK Market Test Pilots*. London: Department for Culture, Media & Sport.

Department for Culture, Media and Sport, and HM Treasury (2015) *The digital communications infrastructure strategy*. Available at: https://www.gov.uk/government/publications/the-digital-communications-infrastructure-strategy/the-digital-communications-infrastructure-strategy (Accessed: 16 April 2017).

Eurostat (2015) *Telecommunications services statistics - NACE Rev. 2 - Statistics Explained*. Luxembourg: Eurostat. Available at: http://ec.europa.eu/eurostat/statistics-explained/index.php/Archive:Telecommunications_services_statistics_-_NACE_Rev._2#Country_analysis (Accessed: 16 April 2017).

Frontier Economics (2014) *Assessing the case for in-country mobile consolidation*. Report prepared for the GSMA. London: Frontier Economics.

Fund, F. *et al.* (2016) 'Spectrum and Infrastructure Sharing in Millimeter Wave Cellular Networks: An Economic Perspective', *arXiv preprint arXiv:1605.04602*. Available at: http://arxiv.org/abs/1605.04602 (Accessed: 25 October 2016).

Hamzeh, B. *et al.* (2015) 'DOCSIS 3.1: scaling broadband cable to Gigabit speeds', *IEEE Communications Magazine*, 53(3), pp. 108–113. doi: 10.1109/MCOM.2015.7060490.

Hervet, C. *et al.* (2013) 'Solving the Two-Stage Robust FTTH network design Problem under Demand Uncertainty', *Electronic Notes in Discrete Mathematics*, 41, pp. 335–342. doi: 10.1016/j.endm.2013.05.110.

Joshi, K. and Benson, T. (2016) 'Network Function Virtualization', *IEEE Internet Computing*, 20(6), pp. 7–9. doi: 10.1109/MIC.2016.112.

Katz, R. L. and Berry, T. A. (2014) 'Strategies to Promote Broadband Demand', pp. 295–305. doi: 10.1007/978-3-319-07197-8_8.

Murdock, J. N. *et al.* (2012) 'A 38 GHz cellular outage study for an urban outdoor campus environment', in *2012 IEEE Wireless Communications and Networking Conference (WCNC)*. IEEE, pp. 3085–3090. Available at: http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6214335 (Accessed: 26 October 2016).

Nardotto, M., Valletti, T. and Verboven, F. (2015) 'Unbundling the Incumbent: Evidence from Uk Broadband', *Journal of the European Economic Association*, 13(2), pp. 330–362. doi: 10.1111/jeea.12127.

Ofcom (2016a) *Connected Nations 2016*. London: Ofcom. Available at: http://stakeholders.ofcom.org.uk/market-data-research/market-data/infrastructure/connected-nations-2015/ (Accessed: 1 June 2016).

Ofcom (2016b) *The Communications Market Report 2016*. London: Ofcom. Available at: https://www.ofcom.org.uk/research-and-data/cmr/cmr16 (Accessed: 16 April 2017).

Ofcom (2017) *BT agrees to legal separation of Openreach*, *Ofcom*. Available at: https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2017/bt-agrees-to-legal-separation-of-openreach (Accessed: 18 February 2018).

Oksman, V. *et al.* (2016) 'The ITU-T's new G.fast standard brings DSL into the gigabit era', *IEEE Communications Magazine*, 54(3), pp. 118–126. doi: 10.1109/MCOM.2016.7432157.

Oughton, E. J. and Frias, Z. (2017) 'The cost, coverage and rollout implications of 5G infrastructure in Britain', *Telecommunications Policy*. doi: 10.1016/j.telpol.2017.07.009.

Parker, M. *et al.* (2014) 'Identifying the Science and Technology Dimensions of Emerging Public Policy Issues through Horizon Scanning', *PLoS ONE*, 9(5), p. e96480. doi: 10.1371/journal.pone.0096480.

Rajabiun, R. and Middleton, C. A. (2013) 'Multilevel governance and broadband infrastructure development: Evidence from Canada', *Telecommunications Policy*. (Papers from the 40th Research Conference on Communication, Information and Internet Policy (TPRC 2012)Special issue on the first papers from the 'Mapping the Field' initiative.), 37(9), pp. 702–714. doi: 10.1016/j.telpol.2013.05.001.

Sidak, J. G. and Vassallo, A. P. (2015) 'Did Separating Openreach from British Telecom Benefit Consumers?', *World Competition*, 38(1), pp. 31–75.

Thyagaturu, A. S. *et al.* (2016) 'Software Defined Optical Networks (SDONs): A Comprehensive Survey', *IEEE Communications Surveys Tutorials*, 18(4), pp. 2738–2786. doi: 10.1109/COMST.2016.2586999.

WIK-Consult (2015) *Competition & investment: An analysis of the drivers of investment and consumer welfare in mobile telecommunications*. Bad Honnef, Germany: WIK-Consult. Available at: http://www.wik.org/fileadmin/Studien/2015/Competition_and_investment_mobile_telecommunications.pdf (Accessed: 16 April 2017).

World Economic Forum (2016) *The global competitiveness report 2016-2017*. Geneva, Switzerland: World Economic Forum. Available at: http://www3.weforum.org/docs/GCR2016-2017/05FullReport/TheGlobalCompetitivenessReport2016-2017_FINAL.pdf (Accessed: 27 April 2017).