5G RuralFirst: New Thinking Applied to Rural Connectivity

October 2019

About this study

The 5G RuralFirst consortium, led by Cisco alongside principal partner University of Strathclyde, and part of the DCMS 5G Testbeds and Trials programme, has since early 2018 been developing a range of technology trials and use cases to explore the potential for rural deployment of 5G networks. Drawing on the collective experience and learnings of the 5G RuralFirst consortium members, and the expertise of Plum, a leading independent consulting firm focused on the telecoms, media and technology sectors, Broadway Partners has evaluated a range of innovative commercial models for 5G deployment in rural areas in the UK, and the associated potential benefits.

Cisco – Lead Partner

University of Strathclyde – Principal Partner

Department for Digital, Culture Media & Sport

5G Testbeds & Trials

Associate Partners:

plum

Plum is a leading independent consulting firm, focused on the telecoms, media, technology, and adjacent sectors. Plum applies consulting experience, industry knowledge, analysis, and clients' understanding and perspective to address challenges and opportunities across regulatory, policy, commercial, and technology domains.

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1 Executive summary

This report draws on the experience and learnings of the 29 members of the 5G RuralFirst consortium, part of the DCMS 5G Testbeds and Trials Programme. Our assessment recognises that 5G represents more than 'just' a faster, cheaper and better form of 4G, but rather an opportunity to do different things, differently. We focus in particular on the potential for new industry structures and innovative business models to stimulate and sustain 5G and 5G-like investment in rural areas – even where such investment has not yet taken place with 3G and 4G.

Seven key takeaways:

- **Rural matters!** – In GVA terms, the UK's rural economy is worth some £300bn, or 16% of the UK total; for Scotland, the rural economy represents fully 27% of the country's economic output, by far the largest proportion of the four nations of the UK. The lack of even basic broadband connectivity in many rural areas significantly impacts the economic vitality and even the viability of rural communities, and represents a significant opportunity cost for the UK as a whole.
- **New thinking required** – The causes of a rural broadband deficit are well understood, being a function of low population density, challenging geography and a weak business case. 'Business as usual' is therefore unlikely to deliver Government policy targets of Gigabit capability for all by 2025, and majority coverage of 5G by 2027, let alone ubiquitous rural coverage. To stimulate and sustain investment, most particularly in rural areas, new commercial, pricing, business and funding models will be required.
- **Doing different things, differently** – At a minimum, new technology and new spectrum bands will deliver 'cheaper, faster and better' access to digital services. More interesting, it also promises 'to do different things, differently' – through a shift from consumers merely consuming, to businesses improving productivity. This will principally be via connectivity-based applications and intelligence – IoT, or Industry 4.0 – and through new, collaborative ecosystems and innovative business models.
- **The rules are changing** – Government and regulators fully recognise the rural challenge – and the potential for new technology and regulatory models to meet that challenge. The UK Government's *Future Telecommunications Infrastructure Review* and more recent consultation on the *Statement of Strategic Priorities*, together with Ofcom's consultation on *Enabling Opportunities for Innovation* and its July statement *on Enabling Wireless Innovation Through Local Licensing* clearly provide a highly supportive backdrop, underpinned by targeted interventions such as the Barrier Busting team, facilitated site access, business rate relief for fibre networks, and easier access to Openreach's network.
- **Needs must!** – Early deployment of 5G networks will inevitably be led by traditional mobile operators and will be focused on urban areas. However, the combination of lower barriers to entry with easier access to spectrum, lower costs, new pricing, revenue, business and funding models, the broadening of the supplier base, and the pressing needs of rural businesses, should also support investment in rural areas, predominantly led by new players in collaboration with mobile operators.
- **Government is a key player** – Central, National and Local Governments have key facilitating roles – in ensuring a supportive regulatory environment, as a commissioner of services, as an owner of assets, in promoting the 'cluster' or multi-stakeholder approach to the development of these ecosystems, and by incentivising investment. Precursor technologies such as enhanced LTE and shared spectrum TVWS, and the experience afforded by the DCMS test-bed programme, provide valuable proving grounds for the development of specific industry vertical expertise and applications, and of new business models. The next challenge is to take these learnings to scale.
- **The bang for the buck** – We estimate that, in GVA terms, the UK's rural economy could benefit by several percentage points, equivalent to around £17bn over 10 years, through improved and more ubiquitous access to high quality digital services, with the move towards 5G as a catalyst. Other studies have projected similar or even greater benefits: a recent Deloitte study for the Scottish Government estimated a relative boost to the overall Scottish economic trend-line growth from a base 1.5% to 2.0%. Equally important, in the report author's view and as recognised in many reports, is the non-financial benefit to community vitality, social cohesion and individual welfare that will flow from a significant reduction in the rural broadband deficit.

2 Introduction

For reasons of low population density and challenging terrain, rural areas tend to suffer from poor or even non-existent digital services, both fixed and mobile: on copper, digital signals attenuate rapidly over distance, while macro-cells that are typically deployed by mobile operators to provide coverage to large areas necessarily sacrifice speed to coverage. Overall cost for service providers is also highly impacted by radio spectrum licence fees, further diluting the rural investment case. Even where low cost deployment models are developed, lack of spectrum results in limited market access for new players. These factors help to explain low levels of digital connectivity in rural areas, with consequential drag on economic performance.

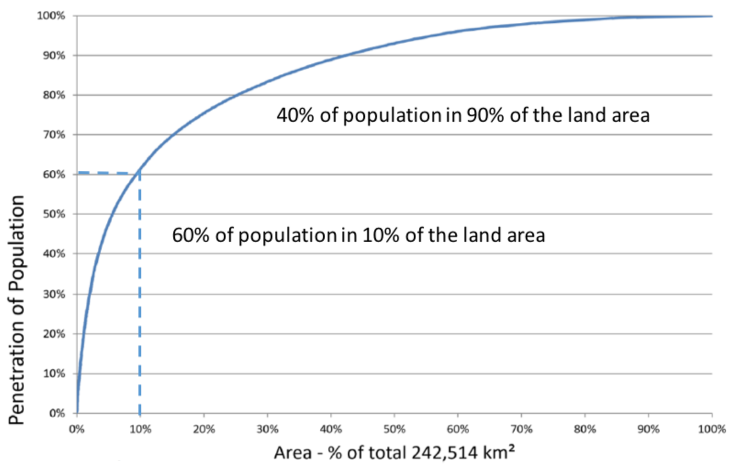
However, there have been recent significant developments in respect of both UK Government and Ofcom regulatory policy, providing a favourable backdrop to a more expansive and dynamic approach to market development in rural areas. Moreover, as technology continues to develop, costs are declining with small radio cells and software defined network technologies, allowing more focused, smaller scale deployments.

This report provides a contextual analysis of the work of the ongoing 5G RuralFirst project – one of six consortia within the DCMS[1] 5G Testbeds and Trials Programme, focusing specifically on rural areas. Our own priority in this report has been the examination of novel commercial models and the potential benefits that could accrue in rural areas from the development of more advanced and more available digital services, enabled by 5G and other 'precursor' technologies, and by emerging regulation.

Broadly, our approach has focused on the following areas:

- Review of relevant policy and regulation, as expressed in the 'Statement of Strategic Priorities' consultation from DCMS and the 'Enabling Opportunities for Innovation' consultation from Ofcom.
- Review of emerging 5G radio technology and cost-efficient networks, through discussion with network equipment vendors and telecommunications operators.
- Review of the 5G RuralFirst consortium members' experiences and insights, focusing on cost trends, novel network architectures, and innovative commercial and funding models.
- Discussion with rural businesses and key stakeholders via a survey of views across many rurally located local authorities and businesses throughout the UK.
- Analysis of potential commercial and economic benefits based on published economic data and our own economic models to assess the scale of the potential benefits of ubiquitous rural connectivity.

The Challenge of Rural Connectivity



Source: RTACS analysis of ONS data

[1] Department of Digital, Culture, Media and Sport

3 The importance of rural connectivity

The UK and Scottish rural economies

The rural economy is rising up the political agenda. The April 2019 report from the House of Lords Select Committee on the Rural Economy, "Time for a strategy for the rural economy"[2] stresses the importance of the rural economy to overall national output and wellbeing, concluding that "a new architecture is needed urgently to transform the way national and local governments and public bodies think about rural policy-making. In the same way that the Government has recently introduced an Industrial Strategy, we propose the development of a new rural strategy outlining a long-term, overarching vision for the countryside."[3]

Approximately 17% of the UK's population are recorded as residing in rural areas that represent around 75% of the landmass[4]. Studies[5] have indicated that the economic contribution from rural regions across the UK amounts to around £300bn in GVA[6], or 16% of the UK's national economy. By comparison, London contributes £425bn of GVA, and 23% of the national economy[7]. Across the UK nations, while England's rural economy is by far the largest (81% of the UK rural economy), followed by that of Scotland at 12%, the rural economy in Scotland contributes a significantly larger share of its national GVA than in the other UK nations – fully 27% of total national output.

Gross Value Added (GVA) by UK nations (2017, total and rural)[8,9]

Nation	GVA – total economy (£m)	GVA – rural economy (£m)	Rural GVA (% nation)	Rural GVA (% UK)
England	1,562,707 (85.9%)	246,200 (81.1%)	15.8%	13.5%
Scotland	138,231 (7.6%)	37,581 (12.4%)	27.2%	2.1%
Wales	62,190 (3.4%)	12,476 (4.1%)	20.1%	0.7%
Northern Ireland	39,613 (2.2%)	7,319 (2.4%)	18.5%	0.4%
Extra regio[10]	17,012 (0.9%)	-- (0.0%)	--	--
Total UK	1,819,753 (100%)	303,577 (100%)	--	16.7%

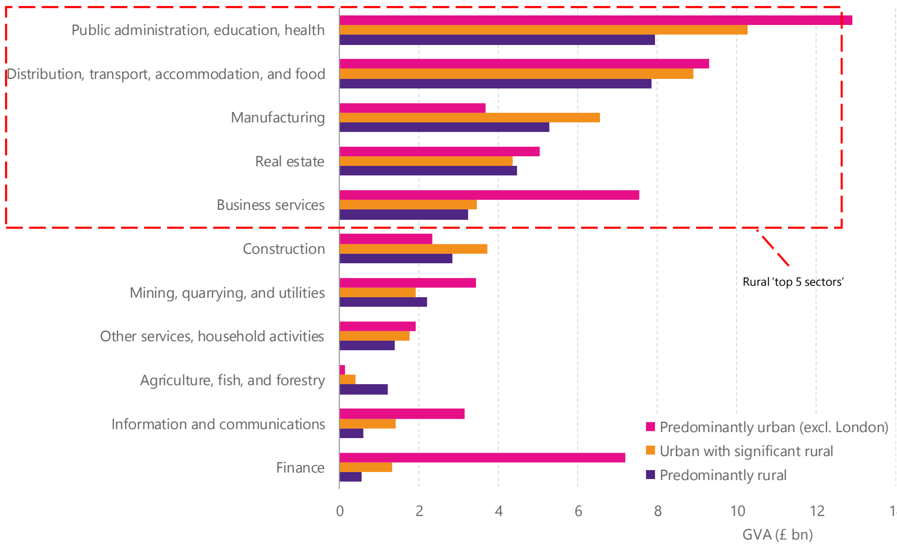
Notably, the mix of commercial activities found in rural areas of Scotland differs significantly from that in urban centres[11]: using official classifications on industry segments, particularly significant sectors in the rural economy include distribution, public services, real estate, manufacturing, and professional services. Self-evidently, agriculture is a predominantly rural economic activity, albeit small in relative terms.

Overall population levels in both urban and rural areas have increased over recent years across the UK, with a marked trend towards an ageing of the rural population relative to the urban population, itself partly a function of poor connectivity and the consequent population drift towards urban areas, as well as the reverse migration of older people to the countryside.

[2] https://publications.parliament.uk/pa/ld201719/ldselect/ldrurecon/330/330.pdf
[3] https://publications.parliament.uk/pa/ld201719/ldselect/ldrurecon/330/330.pdf page 8
[4] See: http://www.worldbank.org/
[5] See: https://ruralengland.org/wp-content/uploads/2018/03/Unlocking-digital-potential-website-version-final.pdf
[6] Regional gross value added is the value generated by any unit engaged in the production of goods and services (essentially saleable value of outputs less production costs). See: https://www.ons.gov.uk/economy/grossvalueaddedgva
[7] See: https://www.london.gov.uk/business-and-economy-publications/londons-economy-today-issue-197-january-2019
[8] Source: ONS 2017 data, with Plum adjustments on annual data: https://www.ons.gov.uk/economy/grossvalueaddedgva/bulletins/regionalgrossvalueaddedbalanceduk/1998to2017
[9] See also: http://researchbriefings.files.parliament.uk/documents/LLN-2016-0020/LLN-2016-0020.pdf https://www.sruc.ac.uk/download/downloads/id/3810/342_definitions_measurement_approaches_and_typologies_of_rural_areas_and_small_towns_a_review.pdf https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/775109/01_Statistical_Digest_of_Rural_England_2019_January_edition.pdf https://www.gov.scot/binaries/content/documents/govscot/publications/research-publication/2018/02/understanding-scottish-rural-economy/documents/00531667-pdf/00531667-pdf/govscot%3Adocument https://www.ons.gov.uk/economy/grossvalueaddedgva/datasets/regionalgrossvalueaddedbalancedbylocalauthorityintheuk http://www.ninis2.nisra.gov.uk/public/PivotGrid.aspx?ds=3956&lh=73&yn=2011&sk=136&sn=Census%202011&yearfilter= https://statswales.gov.wales/Catalogue/Business-Economy-and-Labour-Market/Regional-Accounts/Gross-Value-Added-GDP
[10] Extra regio: economic activity not assignable to nation state (typically from North Sea oil).
[11] Note: GVA data is typically recorded based on location of firms. Thus, GVA per area and per workforce job tends to provide better insight on regional economic activity than GVA per capita (population based). In areas with high levels of commuting, GVA in some sectors may be impacted (for example, in rural areas with high levels of commuting to urban areas for work, rural GVA in the retail sector may be increased, with city workers spending in rural shops and businesses).

One of the more obvious consequences of this shift is that an ageing rural population has clear adverse implications for the provision of health and social care services, in respect both of rising care needs and reducing care resources.

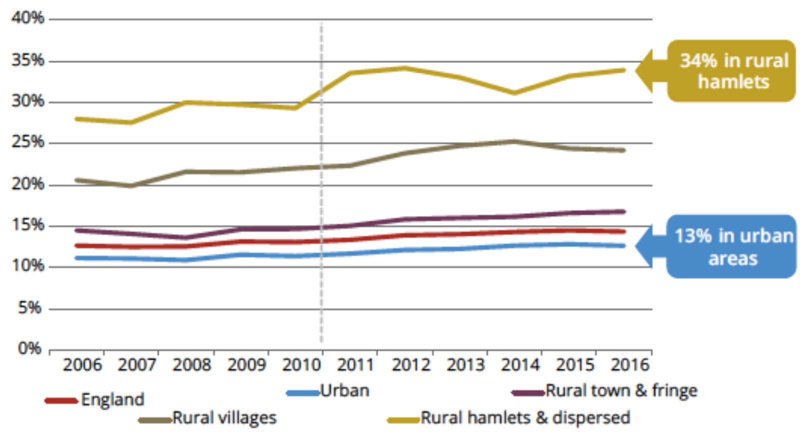
Mix of economic activities: GVA by sector and rural-urban split (Scotland, 2017, £bn)[12]



Source: Scottish Government data

Finally, one can note there has been significant growth in information, professional, administration and technical related businesses in rural areas in recent years (c. 20-40%[13]) – economic activities that are all dependent on and enabled by good digital infrastructure.

Home-workers as a percentage of all workers, by rurality



Source: Defra

The House of Lords report paints an optimistic picture of the potential of the rural economy: "At their most successful, rural economies have a diversity and dynamism that matches and often surpasses their urban counterparts. Agriculture, farming and other land-based trades continue to define the character of rural areas, but services and the public sector are now the driver of rural economies. Manufacturing also plays a

[12] See: https://www.gov.scot/binaries/content/documents/govscot/publications/research-publication/2018/02/understanding-scottish-rural-economy/documents/00531667-pdf/00531667-pdf/govscot%3Adocument, plus Plum adjustments on annual data

[13] See: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/775109/01_Statistical_Digest_of_Rural_England_019_January_edition.pdf

significant role, with knowledge-intensive and creative industries also on the rise. As the Rural Services Network notes, “enterprise and opportunity are abundant with rural areas often providing a breeding ground for high growth business which can migrate to more populated areas as expansion plans require”[14].

The Deloitte report, commissioned by the Scottish Futures Trust, specifically argues that the proportionate impact of 5G deployment will be greater in rural areas than in urban areas[15]. This is echoed by the Scottish Government’s recently published document, ‘Forging our Digital Future with 5G: a Strategy for Scotland’[16].

The importance of digital connectivity

Digital communications technologies are widely acknowledged to be a key driver of economic growth[17]. Numerous studies have analysed the link between the two, assessing, for instance, the impact of mobile take-up on economic growth[18], the impact of broadband adoption and speed on economic growth[19], and the impact of digital communications services on productivity[20]. Growth of the digital communications sector is not only important in its own right, but also because of the related effects on productivity and growth in the wider economy. Ofcom’s recent statement, ‘Supporting the expanding role of wireless innovation in UK industry’[21], cited CBI research that indicated that 94% of businesses believe that digital technologies are a crucial driver of increased productivity[22].

Access to good quality broadband services can enhance productivity with time savings and facilitation on more efficient ways of working, though these impacts can be difficult to quantify[23]. Thus, established economic methods for productivity assessment often focus on changes in long-run GDP or GVA growth.

Numerous studies have assessed GDP linkages with increased fixed or mobile broadband penetration. Koutroumpis’s[24] recent study for Ofcom finds that increased penetration in broadband services over 15 years leads to a mean increase in GDP growth of around 0.3% per annum. Rohman and Bohlin[25] found a similar productivity gain when broadband speed (rather than adoption) increased, concluding that a doubling in broadband speed will increase GDP growth by 0.3 percentage points. Ofcom noted further in its recent paper[26] on the role of wireless innovation for UK industry – that digital services can lead to increased efficiency, better productivity, and lower costs for businesses and consumers.

Key benefits with better digital services in rural areas are noted as remote working, business connectivity, and general productivity benefits. Such benefits are seen by rural stakeholders to materialise with superfast or better connection speeds. The report also notes that, with an ageing population in rural areas, often combined with poor levels of public transport, healthcare access and efficiency are critical policy issues that should benefit from better digital services.

The House of Lords report supports this view, arguing that “the digital revolution has the ability, properly managed, to transform the rural economy, reverse years of underperformance and improve the quality of life not just for those living in rural areas, but for the nation as a whole… […] Poor digital connectivity has had far-reaching consequences for rural communities and economies. Better broadband and mobile infrastructure has the potential to transform the rural economy with greater potential for home working and small business growth, and fewer constraints on operating from remote locations. While the record of successive Governments on rural connectivity has been poor, recent policy and funding announcements are

[14] https://publications.parliament.uk/pa/ld201719/ldselect/ldrurecon/330/330.pdf page 23
[15] https://www.scottishfuturestrust.org.uk/storage/uploads/deloittesfteconomicimpact4g5gfinalreportforpublication.pdf
[16] https://www.gov.scot/publications/forging-digital-future-5g-strategy-scotland/
[17] For example the European Union (https://europa.eu/european-union/topics/digital-economy-society_en) and OECD (https://read.oecd-ilibrary.org/science-and-technology/oecd-digital-economy-outlook-2015_9789264232440-en#page1)
[18] See: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1889951
[19] Ofcom (2018), The economic impact of broadband, https://www.ofcom.org.uk/research-and-data/telecoms-research/broadband-research/economic-impact-broadband
[20] See: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/77465/FE-Economic-Analysis-Paper_digitalcomms_economicgrowth.pdf
[21] See: https://www.ofcom.org.uk/spectrum/spectrum-management/supporting-role-wireless-innovation-uk-industry
[22] See: http://www.cbi.org.uk/index.cfm/_api/render/file/?method=inline&fileID=EBE91939-C93C-49DB-9DF770ACD5166F2A
[23] See: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/714112/The_impacts_of_mobile_broadband_and_5G.pdf
[24] See: https://www.ofcom.org.uk/__data/assets/pdf_file/0025/113299/economic-broadband-oecd-countries.pdf
[25] Rohman and Bohlin (2012), “Does broadband speed really matter as a driver of economic growth? Investigating OECD countries”, *International Journal of Management and Network Economics*, 2(4).
[26] See: https://www.ofcom.org.uk/__data/assets/pdf_file/0020/135362/supporting-role-wireless-innovation-uk-industry.pdf

encouraging and the Government appears to be giving greater focus to rural areas with regard to future connectivity.”[27]

Further studies examining the linkage between increased broadband access and GDP levels are summarised in Appendix B.

The challenge of rural coverage

There are a host of reasons for poor rural coverage, which essentially reduce to **geography, pricing effects, and business model** – all of which should be ameliorated by the adoption of 5G technology and the new business models that it enables.

Geography

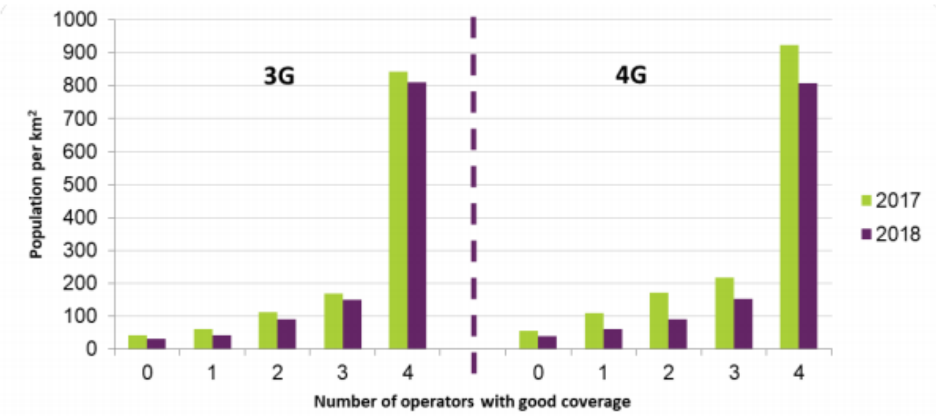
According to Ofcom data, only around 40% of the Scottish landmass has coverage by all four mobile operators, while as much as 9% of the UK landmass has no good 4G coverage from any operator[28]. A recent report from Rural England[29] estimates that in rural areas 59% of premises do not have access to good mobile service indoors[30]. This reports also notes that in 2017, half of farming businesses across the UK only had access to broadband services at a mere 2 Mbps or less.

The reasons for the persistent shortfall in rural fixed and mobile coverage are obvious at the physical layer: it is well understood that, in rural areas, at lower levels of population density and at lower demand levels, the case for investment in digital networks becomes increasingly challenging – whether for fixed or mobile services.

In December 2018, Ofcom published a statistical analysis[31] to help explain variations in 3G and 4G coverage across the UK, by region, updated in May 2019, the principal conclusion of which was that population density and distance from fibre backhaul were the two most significant explanatory variables.

The following chart makes clear the relationship between population density and the likelihood of coverage by all four operators. For reference, population density outside Scotland’s towns and cities averages less than 20 per sq. km. – in fact, any sort of coverage in areas at these levels of population density will likely be the result of accidental spillover from adjacent, more populous areas.

Mobile coverage by population density

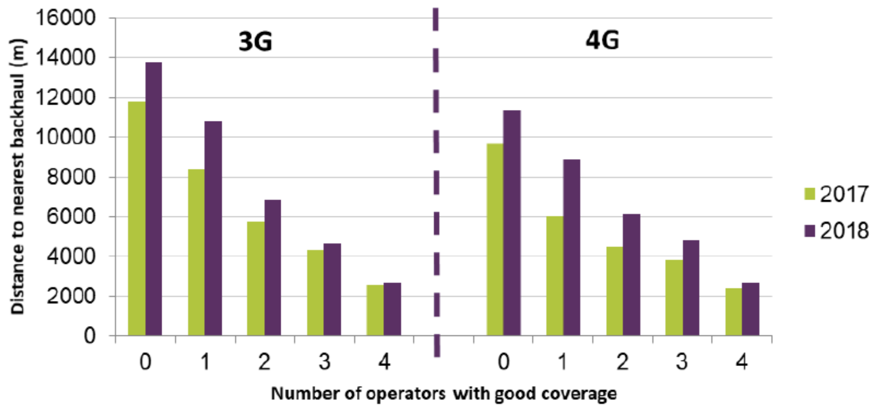


Source: Economic Geography 2018, Ofcom

[27] https://publications.parliament.uk/pa/ld201719/ldselect/ldrurecon/330/330.pdf page 11
[28] See: https://www.ofcom.org.uk/__data/assets/pdf_file/0020/130736/Connected-Nations-2018-main-report.pdf
[29] See: https://ruralengland.org/state-of-rural-services-report-2018/
[30] See also: https://ruralengland.org/wp-content/uploads/2019/02/SORS18-Full-report.pdf
[31] See: https://www.ofcom.org.uk/__data/assets/pdf_file/0019/130681/Economic-Geography-2018.pdf

The following chart provides an even starker illustration of the relationship between rurality – this time measured by the distance from backhaul – and the likelihood of having good mobile coverage.

Mobile coverage by distance from backhaul



Source: Economic Geography 2018, Ofcom

The obvious implication for future 5G deployment is the likelihood that, as indicated by the first offerings from EE, Vodafone, Three and O2, operators will tend to prioritise their network investment and deployment in urban areas – where fibre backhaul is readily available, where capacity uplifts are required, and where highest and most predictable revenue returns will be seen.

But it is **not just about the raw physics and the economics of density** – although these are undoubtedly critical factors which, as discussed later, may be mitigated in a 5G world with the adoption of software-defined radio (SDR), small cells and other innovative network architectures, and with easier access to affordable spectrum, promising significant reduction in unit costs of equipment and service and effectively lowering the minimum sufficient scale.

Pricing

The **revenue model is also a critical determinant**. The fixed broadband market model is particularly challenged: while the UK boasts some of the lowest fixed broadband pricing in Europe, it also has amongst the lowest penetration of FTTH – and the two are closely related. BT faces network competition from Virgin Media only in urban and suburban areas of the UK, representing a mere 50% of premises (projected to rise to nearer 60% with Project Lightning). Furthermore, Virgin Media's 'closed' platform requires independent ISPs such as TalkTalk and Sky to resell BT's wholesale FTTC (Fibre to the Cabinet) product or their own VDSL (Very high speed Digital Subscriber Line) product on BT's underlying copper network. TalkTalk's launch of 'free' broadband in the early 2000s accelerated the commoditisation of an otherwise undifferentiated service, removing an important incentive to invest in significant network upgrade and renewal. This partly explains BT's focus over many years on incremental FTTC upgrade, supported by Government subsidy – an 'inside out', essentially low risk strategy that penalised rural areas.

On the mobile side, it is well recognised that the transition from 3G to 4G technology has, in developed markets, led to a very meagre revenue uplift for mobile operators, and thus a modest relative return on the incremental investment. There is therefore a clear risk that the simple data subscription model that has supported 3G and 4G deployment to date will not be sufficient of itself to sustain 5G investment.

In both the fixed and mobile models, there is also a seeming disconnect between the current streaming-and-user-generated-content world, fuelling 46% annual growth in mobile data traffic, according to Cisco's annual Visual Networking Index[32] – and the user's unwillingness to pay for, and therefore the operator's ability to invest in, its delivery.

[32] https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-741490.html

We would argue that, in creating opportunities for multiple use cases, applications and service layers, 5G potentially also offers a route to a richer and more sustainable revenue model – and one that is based on content and applications rather than on raw capacity or bandwidth.

A further disincentive to network investment in rural areas is provided by the **geographic averaging of prices**, with national price levels set by a regulatory cost model based on average national costs. Full geographic de-averaging of prices would clearly help, but would be politically contentious, as prices would inevitably rise in rural areas to reflect the higher cost of delivering service. Ofcom's recent proposal[33] to have wholesale regulation of Openreach based on three geo-types – areas with significant, some and no network competition – is therefore a key step forward towards eventual geographic de-averaging, thereby strengthening the business case for rural broadband investment.

Business models

Finally, it is worth noting the role played by **competitive strategies**. The game theory case of the prisoner's dilemma illustrates the situation: in a low density market where collaboration between players is discouraged, operators are reluctant to invest. Although mutual benefits could be gained through collaboration, lack of knowledge on competitive response and potential benefits precludes this taking place.

Thus the relevance of the recent Statement of Strategic Priorities (SSP) from DCMS which confirmed the potential value of the Neutral Host model, building on the network-sharing initiatives of MNOs; and of the suggestion to introduce national roaming to help support rural coverage – the ultimate form of collaboration between operators. Although Ofcom is obliged, when considering this policy option, to weigh up the potential loss of incentive to invest, 30 years of poor rural mobile coverage suggests that a new policy direction is warranted.

[33] https://www.ofcom.org.uk/__data/assets/pdf_file/0021/142572/promoting-competition-investment-overview-of-plans.pdf

4 Policy and regulation as enablers

Developments in Government policy

Achieving consistent fixed and mobile coverage in lower density rural areas has long been a policy aim, but only recently a specific policy objective. From 2010 to 2017 Government broadband policy was dominated by the multi-year BDUK Phase I and II Superfast programmes, investing in FTTC technology as an incremental upgrade to BT's predominantly copper network. This was the subject of some criticism at the time, as it followed an 'inside out' approach, delivering performance upgrades to premises that already enjoyed reasonable service, while effectively crowding out longer term fibre investment.

Since the completion of this programme in December 2017, having achieved the official target of 95% of UK homes being served by fibre-enabled cabinets, UK Government policy has noticeably shifted, with the whole-hearted embrace of the vision for 'Full Fibre' connectivity by 2033, recently revised to 2025, supported by the Local Full Fibre Network (LFFN) initiative, City Growth Deals and demand-side interventions such as the Gigabit Voucher and Rural Gigabit Connectivity schemes.

The 'Full Fibre' target is certainly ambitious. From an industrial capacity perspective, at the current rate of roll-out of full fibre of around 1 million premises per year[34], the Government's initial target of 15 million premises by 2025 and 30 million premises by 2033 was unlikely to be met, and certainly not by the recently revised target date of 2025. Moreover, it is questionable[35] whether Full Fibre will ever be economical and feasible to provide to very remote rural areas, and the speed and rate of deployment outside urban areas will almost inevitably be lower. It is welcome therefore that the ambition has been softened to the more realistic because more easily achievable target of being 'Gigabit capable'.

The UK Government's 'Full Fibre' vision matches the ambition of the Scottish Government's R100 (Reaching 100%) programme, which seeks to enable superfast 30Mbps connectivity to 100% of Scottish premises by 2021, supported by an initial £600 million tranche of public money (equivalent to around £2,640 per premise, on average) – announced with the December 2017 Scottish Budget. Significantly, the R100 programme involves a two-step procurement, the first and larger phase requiring firm commitments by the winning bidders to deliver fibre-to-the-premise (FTTP), the second phase being subject to the so-called 'Aligned Intervention', with vouchers. This programme promises to be transformative to the Scottish digital landscape, and is expected to push fibre ever further into rural areas – essential for the enablement of ubiquitous 5G services – while formally acknowledging the key role that wireless technology has to play in delivering to 'not spots', i.e. those areas and premises that do not receive adequate broadband.

Seen as a backstop measure, the UK Government's Broadband Universal Service Obligation[36] (USO), the consultation around which was launched in March 2018 and still continues, is aimed at providing UK homes and businesses with a legal right to request 'decent' fixed broadband access (including download speeds of at least 10 Mbps, upload speeds of at least 1 Mbps)[37]. Current Ofcom figures indicate that around 12% of premises in rural areas still cannot access such services, and this figure increases to 26% if superfast (30Mbps downlink) service is required over time, as is likely. While fixed link 4G solutions have been deployed to address the gap in rural broadband, there is some concern as to whether these will offer sufficient data rates if the USO specification is revised; also, where existing 4G sites do not already exist, the problem of a weak investment case remains.

On the **mobile** side, intervention to expand geographic coverage has until recently been sporadic and only modestly successful, if at all, confined to the imposition of coverage obligations on some spectrum recipients, to the BDUK-led Mobile Infrastructure Project, where MNOs were encouraged to build masts via subsidy, to the ongoing Scottish 4G Infill Programme, where the Scottish Government carries the full capital cost of new, shared mast infrastructure, and to relaxation of restrictions on the use of BT's wholesale capacity.

[34] See: https://www.ofcom.org.uk/__data/assets/pdf_file/0020/130736/Connected-Nations-2018-main-report.pdf
[35] See: https://www.ispreview.co.uk/index.php/2018/11/doubting-the-uks-ability-to-rollout-full-fibre-networks-by-2033.html
[36] See: https://www.ofcom.org.uk/phones-telecoms-and-internet/advice-for-consumers/broadband-uso-need-to-know
[37] Up to a threshold level of £3,400 per connected line.

More recently, however, inadequate rural coverage by mobile networks has risen up the agendas of Ofcom and policy makers. In its recently published Annual Plan[38], Ofcom set rural coverage as its Number One priority for the coming year:

> ***"Better broadband and mobile** – wherever you are: we will help to encourage investment and improve broadband and mobile coverage across the country, so everyone benefits from the services they deliver."*

The UK Government's new policy priorities were clearly stated in the publication in July 2018 of DCMS's 'Future Telecommunications Infrastructure Review'[39] (FTIR). *Inter alia*, this concluded that a 'market expansion model' could bring advantages with the introduction of new infrastructure and service players in the UK's wireless market (for example, through the development of small cell clusters, notspot solutions, and service to niche vertical sectors or micromarkets).

The Government's recent consultation[40] on the Statement of Strategic Priorities (SSP), which Ofcom must have regard to when carrying out its regulatory functions, further notes that:

> *"Government believes that there should be greater liquidity in the spectrum market and barriers to spectrum trading should be removed".*

The SSP consultation further endorses points of Government policy as raised in the FTIR, and notes that national roaming should be considered to support the objective of bringing mobile coverage to 95% of the UK's geography by 2022 and majority national coverage by 2027, with particular reference to rural areas and 5G. The draft SSP states that:

> *"The Government's view is that there would be strategic advantages in a model that maintains the benefits of network competition between multiple mobile network operators, while enabling new solutions to connectivity challenges, including in-building coverage, rural coverage and industrial applications".*

It also notes that new commercial approaches (e.g. neutral host, wholesale) should be supported to enable this model, and that shared spectrum access is a strategic priority, but stops short of defining any details as to how this might be realised. What is clear, however, is that Government policy is firmly behind an approach to solving the rural digital deficit that is supportive of new players and innovative business models.

Developments in spectrum policy

In response to the Government's policy statements, a range of alternative models for spectrum allocation have been proposed. Responding to the Government's FTIR statement in July 2018, the 5G RuralFirst team produced a White Paper in October 2018, 'Rural Britain needs a new spectrum model to drive modernisation of the rural economy'[41]. This added significantly to the public discussion around the need for greater and easier access to 5G spectrum.

This was followed in February this year by a collaborative group comprising 5G RuralFirst, Autoair, the Worcestershire 5G Testbed and the University of Surrey's 5G Innovation Centre, which published a '5G Spectrum and Neutral Hosting' paper[42], which provided a comprehensive review of the 5G spectrum landscape and the options available for different spectrum sharing and licensing models.

In turn, the IET's 5GFF group[43] and others[44] [45] put forward the idea of a national 'innovation band'. However, there is a risk that the established mobile operators would not be supportive of this approach, rendering any collaborative ecosystem across varied market players difficult. An alternative approach proposed by the 5GFF group envisaged a more collaborative approach that involves the construction of an 'inverse coverage' database being constructed from the data that MNOs submit to Ofcom on where they will not allow their spectrum to be borrowed.

[38] https://www.ofcom.org.uk/__data/assets/pdf_file/0020/141914/statement-ofcom-annual-plan-2019-20.pdf
[39] See: https://www.gov.uk/government/publications/future-telecoms-infrastructure-review
[40] See: https://www.gov.uk/government/consultations/public-consultation-on-the-statement-of-strategic-priorities
[41] https://uk5g.org/discover/research/rural-britain-needs-new-spectrum-model-drive-moder/
[42] https://uk5g.org/media/uploads/resource_files/Spectrum_NH_discussion_paper_20Feb19.pdf
[43] 'IET 5GFF views on the Consultation Documents', IET meeting with Ofcom, 28th January 2019.
[44] See: https://www.theiet.org/media/2591/rural-first.pdf
[45] https://www.gov.uk/government/consultations/future-telecoms-infrastructure-review-call-for-evidence

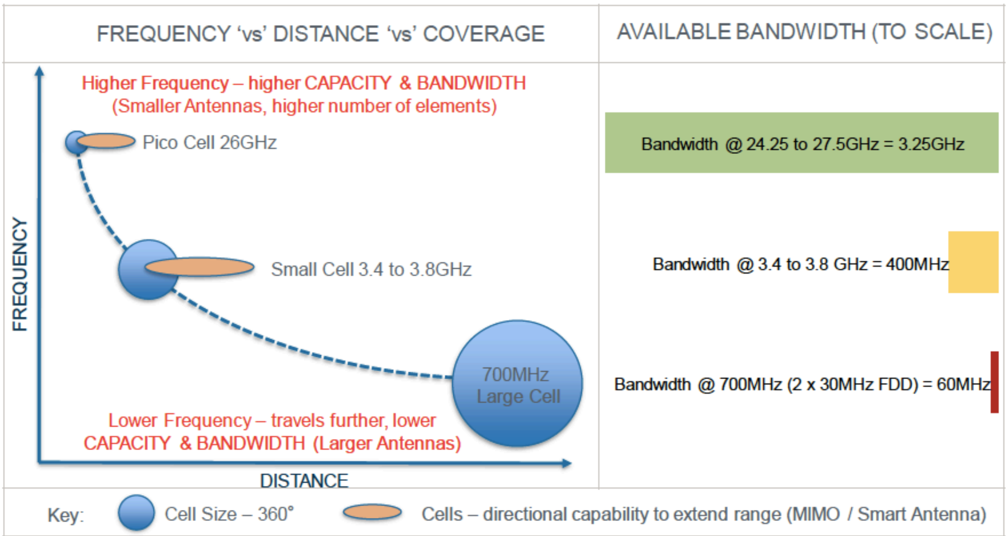
This would allow spectrum at a specific location to be borrowed on a presumption of 'prior consent', and allocated automatically, making no demands on the MNO's or Ofcom's time and manpower. To encourage and incentivise applicant and MNO to come to a long term leasing arrangement, the borrower of the spectrum would have an obligation to provide 15% of the cell capacity to the spectrum owner, if asked for, for their own use for providing service to their own customers.

Ofcom has clearly responded to the policy shift towards more open access to spectrum. Access to licensed spectrum with good physical propagation characteristics has typically been a costly business, affordable only to large players such as established mobile operators. For example, in the April 2018 UK auction for the 3.4 – 3.6 GHz band, an average of approximately £7.6m/MHz was paid by mobile operators for national licences – compared with a reserve price set by Ofcom of £0.1m/MHz.

For this reason, recent moves by Ofcom pointing to a more open and accessible spectrum market are supportive of the development of a vibrant ecosystem of innovative commercial players. In particular, Ofcom's decision in July concerning its proposals for innovation in spectrum use[46] reflect a significant shift in Ofcom's thinking towards a more accessible, enabling policy framework, with proposals for concurrent regional licences in the mobile bands[47], subject to Ofcom approvals. Importantly, consideration is given towards the potential for concurrent use across all mobile bands covered by the Mobile Trading Regulations[48], including the 3.4 – 3.6 GHz band and forthcoming awards of the 700 MHz and 3.6 – 3.8 GHz bands.

Although 'the devil will be in the detail', and the principle of Ofcom acting in a brokering role between applicant and MNO still clearly has to be tested, the Ofcom proposals look to provide a platform for innovation, significantly reducing the cost of access to high quality spectrum in regional areas. As proposed by Ofcom, spectrum-sharing will be an essentially administrative, manual process, rather than dynamic as already deployed with TV White Space, although Ofcom has stated that it will investigate whether it would be appropriate in the future to transition towards dynamic spectrum access.

Coverage and Bandwidth, by Frequency



Source: RTACS

[46] https://www.ofcom.org.uk/consultations-and-statements/category-1/enabling-opportunities-for-innovation
[47] The Ofcom consultation on the 3.6-8 GHz band refers to mobile usage of the these bands, in line with European legislation on harmonisation of mobile spectrum; see Article 54 (Coordinated timing of assignments for specific 5G bands) in the European Electronic Code on Communications; see: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32018L1972&from=EN
[48] See: para 8.18 of the Innovation consultation document.

5 Technology as enabler

Until recently, UK policy makers and industry players have had a relatively limited technology toolkit with which to work to provide the holy grail of universally available and affordable digital connectivity. On the fixed side, the physical network largely comprised copper wires, BT's 'twisted pair' or Virgin Media's co-axial cable, with fibre confined to the core network. On the wireless side, mobile operators relied on 3G and 4G radio operating in macro-cell configuration, with smaller independent FWA operators relying on expensive licensed microwave for point-to-point transmission and unlicensed line-of-sight 5GHz radio in the access layer.

More recently, there has been a veritable explosion of new technologies becoming available, through both technical innovation and regulatory initiative. Before considering 5G's role in improving rural connectivity, it is worth briefly reviewing some of these 'precursor' technologies, anticipating three important defining characteristics of 5G:

- Internet of Things
- Connectivity, not 'just' mobility
- Spectrum-sharing.

LPWAN

Various low power wide area network (LPWAN) wireless technologies, including LoRa/LoRaWAN, Sigfox, Weightless, and 3GPP's own Narrowband (NB)-IoT and LTE-M have been developed to support relatively low data rate, low cost, high coverage, resilient radio power link budget solutions – as required for many monitoring and IoT situations.

LoRa, Sigfox, and Weightless technologies all typically operate on sub-1GHz unlicensed radio bands, and have been deployed commercially in various markets around the globe, including the UK[49,50,51]. Downlink data rates of up to around 50kbps are typically supported.

NB-IoT, a variation of 3GPP's 4G LTE mobile technology, standardised in 2016, supports downlink data rates up to 250kbps. LTE-M (LTE for Machine communications), a further variation, offers higher data rates (downlink up to 1 Mbps), but requires higher channel bandwidths, and is typically more costly. Both NB-IoT and LTE-M support operation in the licensed cellular bands. Cellular based IoT networks have been launched commercially in numerous countries[52].

LPWAN solutions are not designed to support broadband data services, but can support low rate machine and monitoring requirements. Support for 5G IoT functionality, based on LTE-M and NB-IoT, is planned in the 3GPP Release 16 technical standards for 5G, expected to be published in late 2019.

As discussed below, start-up company SmartRural, working with SAOS (Scottish Agricultural Organisation Society), the umbrella body for Scottish farming cooperatives, is deploying LoRaWAN networks in rural Aberdeenshire using a form of neutral hosting model, where physical infrastructure is shared between neutral, third-party players.

Fixed Wireless Access

Mobile (cellular) systems can be used to provide fixed wireless broadband (and IoT services, as above), and these are already offered commercially in the UK[53] using 4G LTE technology and licensed radio spectrum. However, such solutions are likely to be used only where the cellular investment case is already proven, and where radio sites already exist. Unsurprisingly, for reasons of geography and population density, there is a high correlation between poor broadband availability and poor mobile coverage.

[49] See: https://www.sigfox.com/en/news/wnduk-sigfox-network-operator-uk-announces-1000-base-station-installs-covering-more-50-million
[50] See: https://www.connexin.co.uk/2018/07/connexin-delivers-uks-largest-commercial-citywide-lorawan-network/
[51] See: http://www.weightless.org/about/another-day-another-weightless-network
[52] See: https://www.gsma.com/iot/deployment-map/
[53] See: https://shop.ee.co.uk/broadband/4g-home-broadband

The efforts of the Scottish Government, for example, to promote greater rural coverage through the Scottish 4G Infill Programme speaks to the challenge of extending mobile (or fixed cellular) coverage in low population areas where the business case, based on traditional cost structures, is not strong to start with.

Dedicated FWA solutions – i.e. not relying on expensive licenced mobile spectrum – are already deployed commercially, as examined in some detail in a previous Plum study[54]. These typically operate in the 5.8 GHz lightly licensed bands in the UK, and can offer superior coverage, capacity, and cost structure over 4G cellular solutions, as a result of using more highly optimised radio engineering and lower infrastructure cost structures, whilst also leveraging scale economies with chipsets from the mobile industry. Lower spectrum access costs (essentially free) mean that the market is accessible to a large number of players, thus supporting vibrant levels of competition. Such solutions typically support superfast broadband services. This has comprised the core of the business of 5G RuralFirst consortium members Cloudnet IT Solutions on Orkney and Broadway Partners, and of numerous other Wireless ISPs (WISPs).

Beyond the well-established 5.8GHz band, there is growing interest in the use of millimetric radio bands (e.g. 26 GHz and 60 GHz) for development of broadband solutions for rural areas, including with beamforming technologies to extend range. While such solutions are not yet commercially fully mature[55], and bands are not yet globally harmonised, other DCMS-supported 5G consortia have been experimenting with 60GHz radio, the point-to-multipoint use of which spectrum was only liberalised last summer. Earlier this year, Broadway Partners demonstrated what is understood to have been the first commercial deployment of 60GHz mesh networks in a deeply rural context, in Llanddewi Rydderch in Monmouthshire, with the capacity to provide gigabit access to a small rural cluster, and deployed in a matter of a few weeks[56].

TV White Space

TV White Spaces (TVWS) exist between airwaves primarily used for digital terrestrial TV (DTV) broadcasting (470 MHz to 790 MHz[57]). White Space devices (WSDs) work by communicating their location and other characteristics to a White Space database which performs coexistence calculations and responds to the WSD with a set of operational parameters including the frequencies and maximum powers at which the WSD can transmit[58]. TVWS solutions provide an alternative means for provision of fixed wireless access services at superfast broadband data rates, utilising the particular propagation characteristics of sub-1GHz spectrum to serve non-line-of-sight (NLOS) situations. In the UK, Ofcom has made white space radio spectrum available on a licence exempt basis[59], and various trials[60] and commercial deployments are being carried out[61,62,63].

Strathclyde University's pioneering work with TVWS on Orkney since well before TVWS spectrum liberalisation in 2015, working with local WISP Cloudnet IT Solutions, and co-funded by the Scottish Government, formed the basis of the choice of Orkney as a test-bed location for the 5G RuralFirst project. 5G RuralFirst partner Broadway Partners also has experience of deploying TVWS radios in rural areas such as the Scottish Highlands and Islands, and also in rural Wales. Although the technology had early teething troubles with respect to the required database integration, it has continually met expectations for basic radio performance, with recent deployment of three-channel versions demonstrating download speeds of 50-60Mbps – well beyond the requirement of basic Next Generation Access (NGA) access technologies and fully compliant with, for example, the Scottish Government's R100 objectives for universal access to superfast service.

TVWS can still be regarded as a slightly 'niche' technology, with relatively few manufacturers actively developing it. However, given the global sponsorship of the technology by Microsoft, as part of its original 'Affordable Access' and more recent Airband initiatives; given the steady expansion in the number of manufacturers; given the growing user base; given the rapid evolution of the technology towards 100Mbps

[54] See: http://plumconsulting.co.uk/high-performance-wireless-broadband-opportunity-rural-enterprise-5g/
[55] See: https://www.anandtech.com/show/13966/qualcomm-announces-x55-modem
[56] See: https://www.southwalesargus.co.uk/news/17491522.praise-for-monmouthshire-villages-state-of-the-art-broadband-scheme/
[57] Note: bands available for TVWS are expected to reduce when 700 MHz bands become available for mobile services.
[58] See: https://www.ofcom.org.uk/spectrum/radio-spectrum-and-the-law/licence-exempt-radio-use/licence-exempt-devices#collapsible-85766
[59] See also: https://www.ofcom.org.uk/spectrum/spectrum-management/TV-white-space-databases
[60] See: https://www.microsoft.com/en-us/research/project/project-belgrade/
[61] See: https://www.ispreview.co.uk/index.php/2018/12/whitespace-technology-and-microsoft-target-faster-rural-broadband.html
[62] See: https://www.broadwaybroadband.co.uk/
[63] See: https://whitespacetechnology.net/

speeds in a multi-channel context; and given the centrality of spectrum-sharing to the 5G spectrum universe, TVWS retains a significant role in the broader 'next generation' world.

So, what is 5G?

5G network technology represents the next wave of commercial wireless systems, following on from previous generations: 2G (GSM) which brought digital voice and data mobile services, 3G (UMTS) which developed mobile broadband data services, and 4G (LTE) which improved data speeds still further. All of these technologies have been developed through the mobile side of the industry, with commercial models capitalising on the scale of global mobile demand. 5G technology has emerged in a similar way – with global support from major equipment vendors, standards development organisations (SDOs), and industry bodies (such as the GSMA and GSA).

In part, the drive towards 5G is driven by ongoing growth in global demand for data services, and consequential needs for cost efficiency in infrastructure deployments, and sustainability for operators' margins. At a basic level, 5G is about improvements in both radio technology and overall network architecture.

Within the radio access network (RAN), 5G brings improvements in the low level radio design, with support for higher modulation orders and novel high order antenna matrix designs. These innovations are expected to bring improvements in both capacity and coverage, relative to comparable 4G designs. Also at the radio bearer level, 5G radios are expected to provide enhanced support for low latency, and machine-to-machine communications.

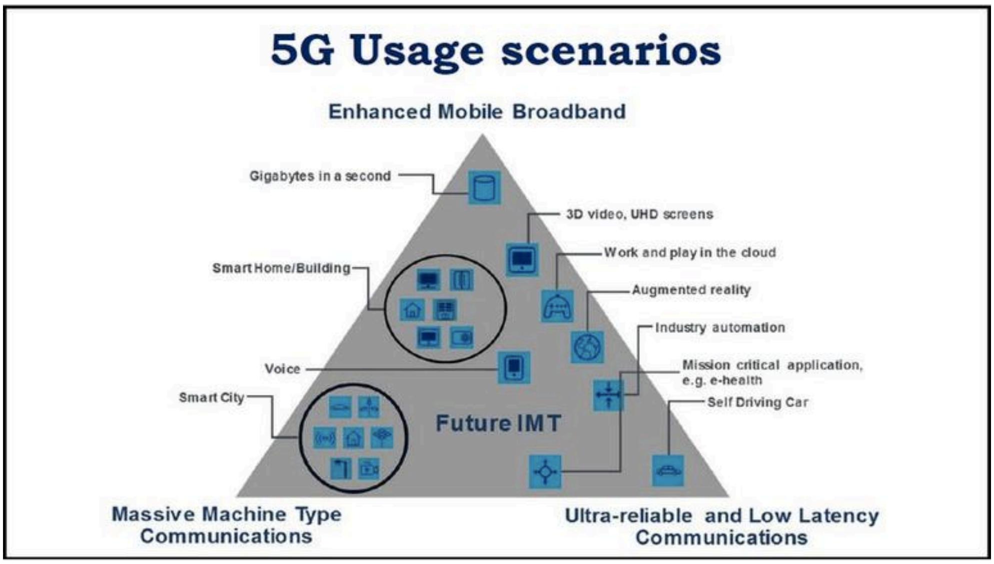
In our discussions with vendors[64], we questioned the differences between 4G and 5G technologies and related system capabilities. We expect the 5G technical standards and related products to incorporate various technologies and to exhibit various attributes including:

- Physical layer improvements (e.g. support for higher order modulation schemes such as 256-QAM)
- Antenna array innovations (e.g. massive / multi-user MIMO)
- Software defined network elements and 'slicing'
- Support for various radio spectrum bands (including 700 MHz, 3 GHz, and millimetre waves)
- Enhancements for radio access network integration (e.g. heterogeneous networking)
- Support for spectrum sharing
- Lower latency
- Enhanced support for machine-to-machine communications

The standard view of the defining usage characteristics of 5G is illustrated below: as can be seen, the emphasis is on the use cases and applications, enabled as they are by the raw performance attributes of high speed, high capacity and low latency.

It is widely accepted, therefore, that 5G solutions will be able to, and must, offer more than merely speed, capacity and latency improvements over previous generations. In short, 5G must be not only 'faster, cheaper and better' than 4G, but must also be 'different' – able to support new revenue models, new business models, and a more diverse ecosystem of suppliers, users and other stakeholders.

[64] We consulted with Accelleran NV, Parallel Wireless, and Cambium Networks Ltd.



Source: Researchgate.net, and others

The following graphic provides a sense of the multi-factorial nature of the change that 5G represents. The overwhelming point of differentiation from the strictly consumer-centric world of 4G is the wealth of applications expected to be enabled by 5G, and the focus on the business enterprise.

				Likely monetisation models		
Types	**Key Use Cases**	**Example Applications**	**Market maturity**	**B2C**	**B2B2C**	**B2B**
Enhanced Mobile Broadband	Fixed Wireless Access	Fixed wireless access as a substitute for fixed broadband connectivity		✔		
	5G hot-spots EMBB boost	Smart helmets		✔	✔	✔
		Cloud gaming		✔	✔	
		Streaming and live broadcasting HD video		✔	✔	✔
		Cloud office storage				✔
	Virtual and Augmented Reality	Cloud AR/VR				✔
		Interactive AR/VR gaming		✔	✔	
		HD streaming				✔
	In-vehicle infotainment	Video conferencing				✔
		Gaming				✔
IoT and Mission-Critical Control	Autonomous Vehicles	Aided driving		✔	✔	
		Platooning			✔	✔
		Autonomous driving		✔	✔	
	Drone applications	Field mission, e.g. agriculture, aquaculture				✔
		Safety and emergency interventions				✔
		Logistics (delivery)				✔
	Tactile Internet	Remote surgery				✔
		Remote health monitoring		✔	✔	✔
		Security/natural disaster interventions				✔
	Industry 4.0	Predictive maintenance				✔
		Advanced manufacturing				✔
		Crop, soil sensing				✔
		Environmental monitoring				✔

Short term, 2020
2020-25
2025+

Source: TM Forum, adapted by Broadway

6 The 5G RuralFirst programme

Introduction

In its Autumn Statement 2016, the UK Government announced the intention to invest in a nationally coordinated programme of 5G testbed facilities and trials, as part of over £1bn of funding announced to boost the UK's digital infrastructure. The 5G Testbeds and Trials Programme at DCMS was set up as a centre of excellence in 2017, to press forward the work in this area. The Programme aims to encourage and fund the creation of a series of testbeds and trials in a range of geographic and vertical market segments[65]. It explores the benefits and challenges of deploying 5G technologies in line with the following key objectives:

- Aim to stimulate market development and deployment of 5G technology and infrastructure in the UK.
- Create new opportunities for businesses, developing capability and skills, and encouraging inward investment.
- Ensure the UK secures an 'early mover advantage' in the investment and development of capability and skills as future 5G products, services and applications evolve.

Testbeds have been designed to help industry understand the challenges of deploying new technologies according to the developing international standards for future 5G networks. Testing 5G applications will help prove different applications (use cases), bringing ideas closer to commercial viability for future markets.

In March 2018, the six winners of the first Phase of the 5G Testbeds and Trials competition were announced. One of these projects was the 5G RuralFirst initiative, with £4.3m of Government support. Partners include Cisco Systems, University of Strathclyde, BT, the BBC, and a number of SMEs including Zeetta Networks, Parallel Wireless, Cloudnet IT Solutions, Broadway Partners, and others.

The ambition of 5G RuralFirst[66] is to create a complete end-to-end rural 5G testbed system for trials of new wireless and networking technologies, spectrum sharing, and new applications and services. The project, with Cisco as commercial lead and the University of Strathclyde as academic lead, has been delivered by a consortium of 29 organisations, and focused on testing innovative approaches and stimulating new business models, with a view to ensuring 5G connectivity is accessible and affordable in hard-to-reach rural areas[67].

Based primarily on the Orkney Islands, and in the farmlands of Shropshire and Somerset, the project integrated spectrum sharing strategies for 5G, bringing connectivity to rural communities. It explored smart farming in partnership with Agri-EPI Centre (including drones, autonomous farm vehicles and remote veterinary inspections), innovative methods of delivering broadcast radio over 5G working with the BBC, and delivery of connectivity for IoT[68] in utility and other industries in rural areas.

These trials have been designed to demonstrate the value of connectivity to rural areas and to explore new emerging business models, across a number of broad themes:

- **5G Core Network** – including 5G network slicing.
- **5G Radio Access Technology** at pioneer band frequencies (700MHz, 3.5GHz and 26GHz) and integration of other bands including ISM (2.4GHz/5GHz) and spectrum available for sharing.
- **Dynamic Spectrum Access** – testing the feasibility of dynamic and shared spectrum for 5G to demonstrate the benefits and operability in rural areas.
- **Neutral Host** – providing feedback to regulators and incumbent spectrum licence holders to progress spectrum sharing and allocation policies and enable independent 'neutral host' (RAN sharing) operators to deliver connectivity in rural areas.
- **Broadcast** – testing the feasibility of 5G standards to provide a more efficient distribution mechanism for broadcast – both narrowcast, and wider national broadcast.

[65] See: https://www.gov.uk/government/collections/5g-testbeds-and-trials-programme
[66] See: https://www.5gruralfirst.org/
[67] See: https://www.gov.uk/government/case-studies/5g-ruralfirst-rural-coverage-and-dynamic-spectrum-access-testbed-and-trial
[68] IoT: Internet of Things, meaning machine to machine communications.

- **Agri-tech** – testing the potential of 5G technologies to improve how farms grow crops and look after livestock.
- **Industrial IoT** – testing applications for renewable energy, power generation and industrial equipment.
- **Community & Infrastructure** – testing a range of use cases across the chosen test-bed of the Orkney islands, demonstrating and assessing the benefits to local residents in extreme and very remote rural environments.

Background and Context

The project consortium believed from the start that 5G needs to be more than simply 'better 4G', otherwise rural communities will remain poorly connected as the business models and barriers to deployment in remote locations will be no different from those of 4G and 3G. In particular, it is the consortium's belief that opportunities exist for the development of a 5G eco-system that goes beyond being purely MNO-centric, and that instead embraces new approaches to enabling rural communities and alternative communications providers to deploy 5G services in areas where traditional MNOs are not operating, or, where appropriate, to provide enhanced services that complement those being provided by MNOs. Affordable infrastructure and access to spectrum are key enablers in this regard, both of which form a key theme in the project.

The 5G RuralFirst project comprised three rural testbed locations in Orkney, Shropshire, and Somerset, linked to a 5G Network Cloud Platform at DataVita's Tier III data centre facility near Glasgow. The project aimed to support trials of innovative technology, applications, and business models aimed at improving the potential of the UK's 5G eco-system to deliver cost-effective connectivity for a range of applications and usage scenarios in hard-to-reach rural locations.

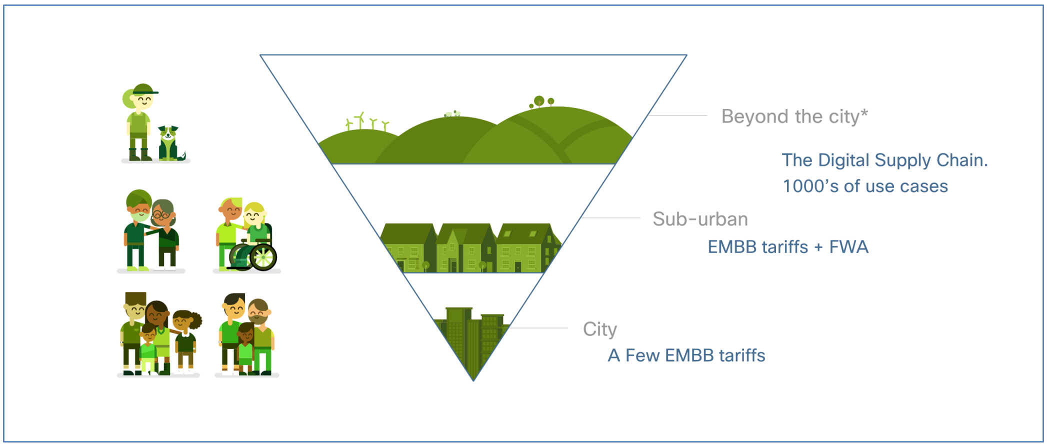
The overall goal of the project has been to support and inform the development of the UK's 5G eco-system so that it is able to address the needs and aspirations of communities and businesses in rural locations in ways that 4G, 3G, and 2G have not been able to do.

5G RuralFirst perspectives

The first 12 months of the 5G Testbeds and Trials programme have provided the 5G RuralFirst consortium and its members with a rich body of experience in relation to the practical challenges and opportunities associated with rural deployment of advanced wireless networks.

As 5G RuralFirst testbed design and trials progressed, consortium members engaged with an expanding range of stakeholders in the rural economy. While the challenges of economic rural coverage should not be underestimated, there are clear opportunities to think differently regarding rural 'beyond the city' connectivity. In particular, MNOs are in prime position to provide services to significant vertical industries with facilities in rural areas, and to collaborate with the digital supply chain, opening up a significant revenue-generating potential for enterprise class service offerings, as illustrated below.

The Opportunity of the Digital Supply chain



Source: 5G RuralFirst

For example, 5G RuralFirst project team members designed low latency services for agriculture, discovered the demand from salmon farms for 4K video (upload), and discovered at first hand the challenges of Scotland's £11.5 billion tourism sector, where technology based upon 5G communications could transform the tourist experience in hotspots such as the Orkney Islands, over and above the benefits to be derived from better broadband connectivity. The current mantra of "but nobody lives there" is hard to understand given the importance of major exporting industries such as whisky and salmon, tourism and agriculture. Population density many be low, but the economic impact of these industries is obviously high.

There is a growing recognition in the service provider industry that the first wave of 5G adoption will be driven, not by consumer needs, but by enterprise business models – that is, specific high value services targeted to precise enterprise needs. While consumer services will obviously remain core, it is these enterprise services that are predicted to generate the most significant early adopter growth.

What other market segments, then, could help drive growth or at least make a contribution to the revenue opportunity in rural areas?

For BT/EE, the Emergency Services Network (ESN) is one contributor to the rural business model, Government funding for which is helping drive significant network expansion.

Another SP revenue opportunity from the 5G RuralFirst project is Broadcast over 5G. As broadcasters such as the BBC move to transition radio and TV traffic from terrestrial and satellite broadcast services, a revenue opportunity is presented to MNOs who can take over such service delivery – assuming that they have the required geographical network coverage (which organisations such as the BBC would mandate).

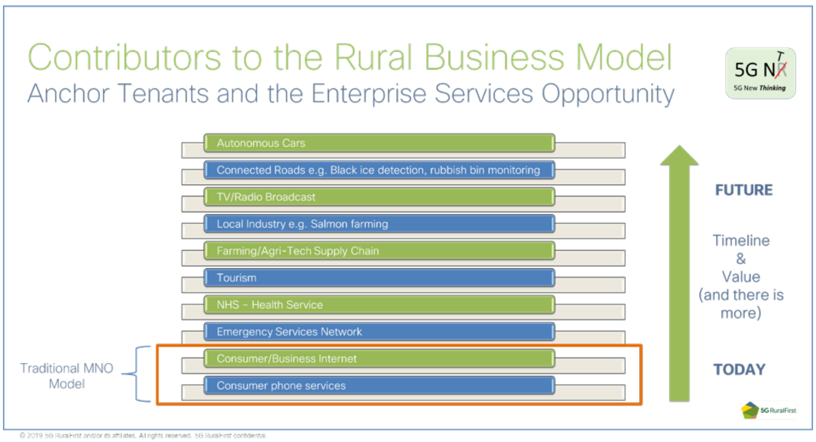
Also emerging from the 5G RuralFirst project are strong 5G service examples aligned to vertical industries, such as low latency services for agriculture, 4K video upload from salmon farms, or IoT services for the renewable energy industry.

From the earlier sections of this report, it is clear that there is no 'magic bullet' that will solve the economic challenges of rural connectivity. However, the 5G RuralFirst work does indicate that 5G revenue opportunities do exist in rural areas that can enhance the returns available and reduce the level of public subsidy required to support rural connectivity. This approach is explored below.

Contributors to the Rural Business Model: Market Segments or "Layers"

The examples above from 5G RuralFirst then suggest a model aligned to market segments or market opportunities – and this is illustrated in the diagram below. The opportunity for service providers is to develop specific offerings aligned to these important rural economic segments, to form appropriate ecosystems to deliver these offerings, and to exploit the economies of scale and structure of these market segments. The 5G RuralFirst consortium investigated agri-tech business models, for this purpose, discussed below.

5G Business Model Layers for Rural Areas



Source: 5G RuralFirst

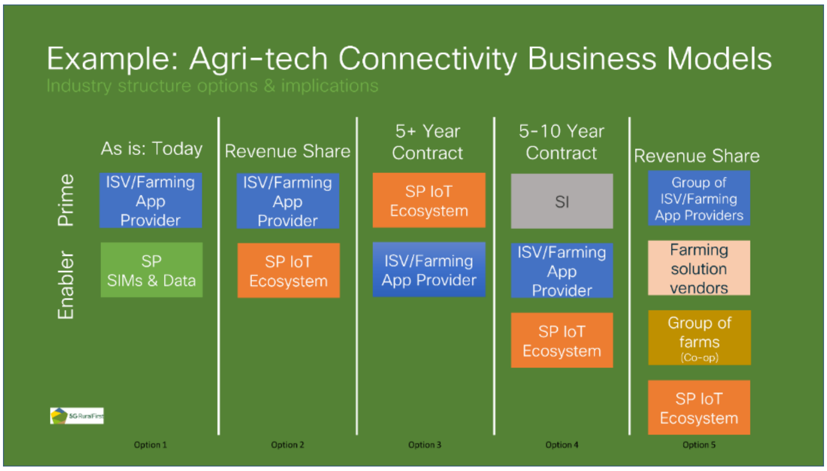
Example: Agri-Tech Business Models

5G RuralFirst consortium members investigated Connected Cow IoT services and also low latency drone/autonomous tractor operations to consider, inter alia, what are the service provider revenue opportunities with these types of services. The diagram below teases out some of the options.

Option 1 is essentially the MNO model today. If a farmer wanted a Connected Cow or a Precision Agriculture solution today, he or she would engage the application provider – e.g. connected cow app or autonomous tractor solution. For communications, the farmer would purchase a 4G router, SIM card and data pack from an MNO (assuming service is available for the farm). This is the standard MNO business model today and assumes connectivity exists. What about the cases where it does not? How can the MNO proactively attract co-investment that is incentivised to provide connectivity?

There are options to evolve this model to target more specific MNO services for the farming sector. For example, as Option 2 above shows, the MNO or other service provider could form an IoT ecosystem with key participants in the agri-tech supply chain and agree some kind of revenue share model in exchange for providing connectivity. There are two variants in this model. The first model (Option 2 above) is where the SP IoT Ecosystem is formed as a marketing program – and as such, the likelihood of revenue share is poor.

Options for Ecosystem Evolution: What will the MNO role be?



Source: 5G RuralFirst

Option 3 is a variant of this model, where the service provider decides to act as prime contractor for specific IoT market segments – and as such can aggregate solutions and, rather than sell connectivity, sells the solution – the app plus connectivity. Farmers we have found tend to form long term supply relationships – hence it is reasonable to expect that five year contracts are feasible, as NTT Docomo in Japan has demonstrated with some of its IoT solutions. Five-year contracts for an industry used to 30 day PAYG (pay as you go) and annual phone upgrades must be an attractive proposition.

There is a chance, of course, that SPs will not step up to the integrator opportunity – leaving the door open for a systems integrator to step into the space. This would likely leave the SP in a relegated role, as a provider of "dumb pipes" and base level connectivity services, with the service integrator (SI) owning and monetising the farming opportunity. Option 4 in the above diagram illustrates this model.

Finally, Option 5 illustrates a further opportunity – leveraging the economy of scale of farming co-operatives. In the UK today, farms gather in "co-operatives" and collectively negotiate larger supply contracts. Such co-operatives are typically regional based, with as many as 3,000 farm members in part of the UK. Such a "single point of contact" presents an opportunity for the service provider to engage on a mass scale with the farming community.

Of all them, option 5 seems to present the most attractive model, with potentially the biggest economy of scale that would encourage service providers to form ecosystems in order to tackle the revenue opportunity that farming collectives present.

Coupled with lower cost local small cells and other technologies investigated by 5G RuralFirst, the farming industry could be one to change the economics of rural mobile/5G coverage.

One of the consortium partners, and co-author of this report, **Broadway Partners** has based its commercial model on the application of new technologies, such as TV WhiteSpace, in which it was an early commercial user, and 60GHz mesh networks, as well as the use of innovative commercial models.

It has also sought to employ novel approaches to the development of viable and sustainable commercial models supporting investment in rural broadband. Thus from its earliest pilot deployments on the Isle of Arran, Broadway has been an enthusiastic advocate of **small cell infrastructure** – partly a matter of practical necessity, partly an almost philosophical approach to building networks close to the people they serve. Thus, existing built infrastructure – i.e. houses and farm buildings – is used in strong preference to stand-alone, dedicated infrastructures such as a mast. This is typically carried out on a cooperative principle, with free broadband offered to the property owner for as long as they agree to host radio equipment. This represents a £300 p.a. 'opportunity cost', by comparison with a possible £2,000 annual rent for one equipment slot on a 30 metre tower. The economics are obviously very different, but the flexibility to think in minimum scale terms of as little as a 10-house cluster, clearly allows for a more finely-tuned approach to network deployment. Other practical advantages include the avoidance of planning permission delays and uncertainties, ready access to power supplies, a willing 'pair of hands' to respond to routine, trivial but potential time-consuming outages such as a tripped router switch. There is an unquestionable intangible benefit to be derived from the sense of community buy-in.

Other relatively novel approaches include the use of **anchor customers** when approaching a new area for the first time. Working with isolated fish farms, for example, is a clear 'win-win', whereby the company pays for a reasonable share of the start-up and mobilisation costs, providing a degree of local technical resource and local community credibility, in exchange for being able to access broadband at less than fully allocated cost, for enabling the migration to advanced monitoring of water and environmental quality and fish health, and for substantially enhancing its standing with the local community.

Broadway's approach is essentially about risk management and risk reduction: partnering with significant local employers, using existing built infrastructure, using bonded VDSL as a stepping-stone to full gigabit backhaul capability, working with local community associations – it is all about minimising the upfront exposure and managing capital commitments in relation to the expected returns.

The report authors also spoke with **Ch4lke Mobile**[69], which described its newly developed commercial model, recently launched in the UK market. This provides mobile service in areas not covered by incumbent mobile operators, based on: cost-efficient radio access with small cells; light cost core networks, based on software defined elements; and shared spectrum, sourced from cooperating mobile operators. This represents an interesting development of the traditional MNO-centric deployment model and, while the commercial terms of spectrum access are confidential between Ch4lke and its MNO partner(s), it is understood that, at least for this pilot exercise, spectrum is essentially costless to both parties – i.e. there is little if any charge to Ch4lke for the use of mobile spectrum within its coverage area, equally there is little payment to Ch4lke for the carrying of roaming traffic on its network. On this basis, Ch4lke's commercial model is rooted in the economics of conventional FWA broadband service, supplemented by the additional service opportunities that mobile spectrum might afford, plus any additional 'stickiness' resulting from being able to offer a bundled service package.

The model also incorporates a level of infrastructure sharing (i.e. neutral host, wholesale), which provides further cost efficiency benefits. The approach is not dissimilar to those using multi-operator core network

[69] See: https://ch4lke.co.uk/

(MOCN[70]) technology, and is in line with developments in spectrum management as with the Ofcom consultations referred to above. A similar model, also in the UK, is being developed by Anywhere SIM[71].

We noted that WiFi calling and equivalents (e.g. Skype, Apple Facetime) are now popular and supported by many operators, and, whilst these can be useful in some cases, practical use is contingent on quality of service. In cases with high levels of network congestion, or radio interference, as can occur with use of unlicensed radio bands, these solutions become unusable.

We also spoke with **SmartRural**[72], a provider of LoRaWAN services to the farming community, under the auspices of SAOS, 'the Co-op for farming Co-ops' in Scotland. SmartRural is developing a variation on the neutral hosting model, making its small cell mast and power infrastructure available to third-party operators (fixed wireless and mobile) on a highly economical basis – underpinned by the overarching not-for-profit Co-op structure, and by individual farmers' willingness to offer 'free' site access in return for LoRaWAN services.

[70] See: http://plumconsulting.co.uk/review-efficiencies-multi-operator-core-network-mocn-technology/
[71] See: https://anywheresim.com/
[72] See: https://smartrural.coop/

7 Alternative commercial models supporting rural deployment

The traditional approach

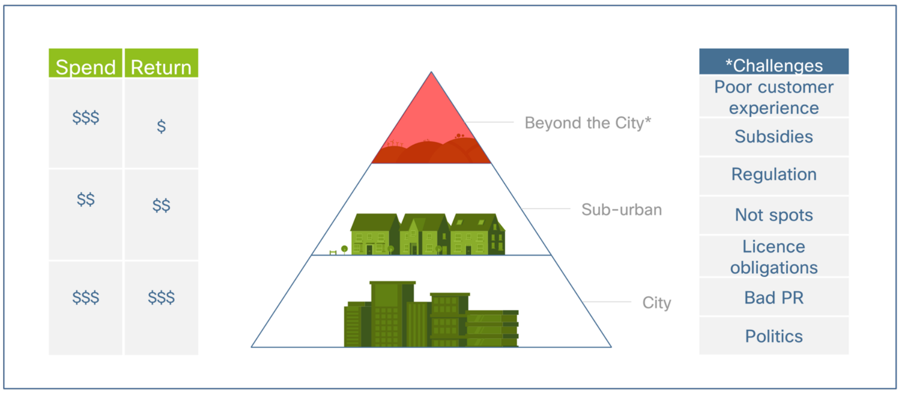
To date, the mobile industry has been dominated by mobile network operators (MNOs) that have followed a conventional, vertically integrated business model. By and large, each operator owns its own spectrum, designs, builds, owns and operates its own network, and markets directly to its own end customers.

This vertically integrated and broadly competitive model has served the market reasonably well, as evidenced by the continued expansion of geographic coverage over time, to the present condition where, according to Ofcom data, 66% of the UK landmass is served by all four MNOs.

The question posed by Ofcom in its Economic Geography analysis (and posed by the 59% of the rural population identified in the report as not having the same degree of competitive choice as those living in urban areas), is why more people do not have complete competitive choice – i.e. access to 4G mobile services regardless of operator. Just as Government targets of achieving 100% fibre-to-the-home connectivity by 2025 or even 2033 look unlikely to be met at current rates of investment, so will current rates of mobile network expansion fail to meet the expectations – or hopes – of many rural communities for good quality coverage in any realistic timescale, even with the stimulus of, for example, the Scottish Government's Scottish 4G Infill (S4GI) programme.

As discussed above, the reason is the unfavourable economics of rural deployment – high capital costs meeting small addressable market – reflected in the incumbents' inevitable focus of investment in areas of highest population density.

The Service Provider Dilemma in Rural Areas



Source: 5G RuralFirst

The question therefore is twofold. First, does 5G provide the tools to shift the relative economics and thereby to help close the rural digital divide? And second, to what extent are new commercial models required in order fully to exploit the opportunities of 5G, including to close the rural divide, both within incumbent operators and amongst new, emerging players?

It is widely and reasonably expected that the incumbent MNOs – EE, Vodafone, O2 and Three – will continue to be dominant across the national 5G landscape, just as they have dominated the 2G, 3G and 4G landscapes. Given the strength of their market position and cashflows, and given the stimulus of direct competition, it is reasonable to assume that, **all else being the same**, their investment in 5G will follow a broadly similar pattern to that of previous technology generations – with an initial focus on high-density urban areas, and only subsequent deployment to more rural areas as economics justify. Indeed, all four operators have indeed followed this pattern, targeting their initial deployments to the 'top' cities in the UK.

The innovative approach

The development of 5G technology, combined with regulatory moves to free up spectrum, creates important opportunities for narrowing, if not completely eliminating, the rural digital deficit – a combination of lower costs, greater revenue potential, and the emergence of more collaborative business models.

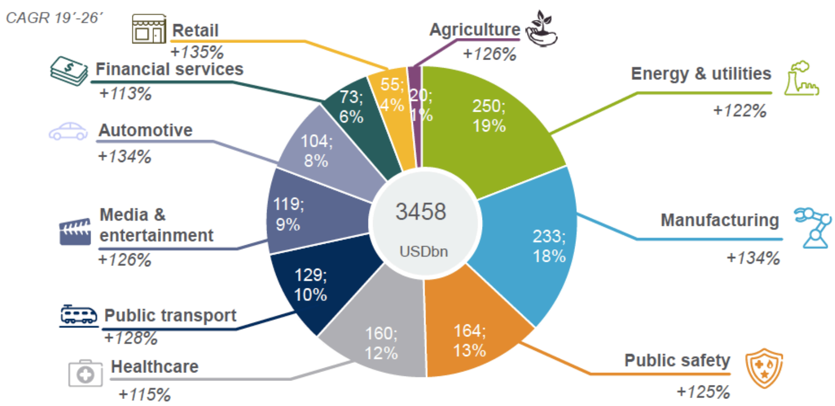
Cost-driven benefits – For incumbent operators, the transition to a 5G world will entail substantial investment in new network architectures and radio access technologies, in addition to existing 4G capital commitments. For the wireless ISP, however, 5G represents **a greenfield opportunity**, promising a relatively low cost of entry and potentially higher returns than might be available from the FWA (Fixed Wireless Access) business case.

It is beyond the scope of this paper to quantify the unit cost reductions likely to flow from the adoption of 5G architectures, and it would be premature to attempt to do so. Illustrative examples are however legion:

- The move from operator-owned equipment, dedicated to a particular frequency band, towards Software Defined Radio, can be expected to deliver significant capital cost savings relative to traditional vendor-specific equipment.
- Small cells, using existing built infrastructure such as the roofs of houses and farm buildings, can reduce the minimum sufficient scale of addressable market from the thousands of premises or people for a conventional macro-cell costing upwards of £200,000, to as few as 10 for a cell site costing a few hundred pounds.
- Access to shared spectrum will, according to Ofcom's current proposals, be subject to an administration fee of a few hundreds of pounds.
- Cost-sharing initiatives, such as between MNOs and FWA providers with respect to backhaul costs.
- Risk-mitigating measures such as community sponsorship and engagement and the use of corporate and Local Authority anchor customers to underwrite initial deployment, can take multiple percentage points off the investors' required return. Taken to its logical conclusion, the SmartRural variant of the neutral hosting model described below is predicated on a co-operative structure that is essentially not-for-profit, implying a zero real return on capital – theoretically equivalent to as much as £5 of monthly ARPU, by comparison with a requirement for a, say, 20% IRR.

Revenue-driven benefits through a proliferation of service and revenue models based on network slicing and the greater functionality that comes with the combination of ultra-high speed/ultra-low latency/massive machine communications. These are discussed in more detail below, along with some of the new revenue models that are expected to emerge from the expected multi-stakeholder approach.

The opportunity is certainly large. A survey conducted by Ericsson and Arthur D. Little of 400 potential industry use cases across 10 industries predicted transformative benefits to virtually all sectors resulting from the interaction of digitisation and connectivity as enabled by 5G – amounting to an incremental $3.5 trillion of revenues, from a current operator service revenue base of ca. $1.5 trillion.



Source: Ericsson 5G Research

New business models, across the operator supplier base, and amongst the wider group of stakeholders.

The same Ericsson research concluded that the MNO-addressable portion of the $3.5 trillion opportunity described above amounts to $619 billion – at one level, a mere fraction of the total opportunity; at another level, still a substantial uplift from the $204 billion of incremental revenues available to the MNOs if they remain solely in their traditional role as network providers – and effectively tripling annual revenue growth from a relatively pedestrian 1.5% annual growth rate, to a more interesting 4.6%.

As the Ericsson research makes clear, whether incumbent operators achieve higher than 1.5% annual revenue growth will be a function of strategic choices that they make in the next few years.

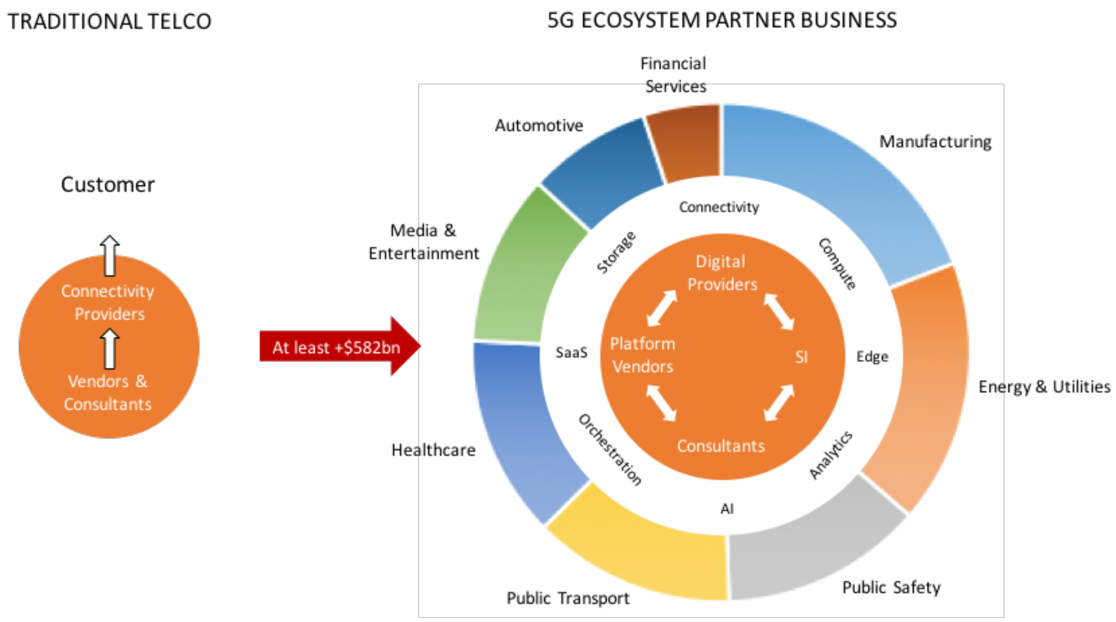
At the MNO level, it is clear that the thrust of policy and regulation is to foster a more genuinely collaborative approach between incumbent operators, fixed and wireless, and the smaller, more adaptive new entrants.

At the simplest level, that of the **network provider**, while the benefits of 5G over 4G may not be sufficient to raise the returns to an incumbent operator from rural investment above those from urban investment – they may be sufficient to raise the returns for a new entrant, greenfield operator, whose base line is a 'plain vanilla' 5GHz WISP business model. Moreover, if otherwise unused spectrum can be shared, and its economic value can be harvested; and if common costs such as mast infrastructure and backhaul can also be shared between MNO and, for example, a community-backed FWA scheme – then meaningful returns look ever more likely.

Hence the Statement of Strategic Priorities' reiteration of the Government's proposal for national roaming and support for neutral hosting, and Ofcom's recent consultation articulated the case for a 'use it or share it' spectrum regime. 5G promises a more dynamic, collaborative, multi-operator model, able to develop and adopt alternative commercial models that encourages the pooling of investment and the sharing of returns, and thereby greatly enhancing the likelihood of that investment being made in the first place.

At the **applications level**, while all MNOs have their own strategies for embracing and exploiting the applications potential of 5G, it is possible that some MNOs may not be resourced sufficiently, nor may have the necessary risk appetite, to become their own systems integrators, and instead may need to embrace and foster a wider ecosystem of engaged and qualified players – industrial, public sector and technology.

With such developments, we see the potential for mutually beneficial commercial cases to be developed between established mobile operators and new entrants. The cooperative ecosystem is key.



Source: Ericsson 5G Research

To illustrate the point, McKinsey & Co research has indicated that only a fraction of incremental revenues from 5G IoT will flow to the pure connectivity portion of the MNO's value chain, with the majority accruing to services and applications.

IoT Market Size by Industry Verticals, € billion

	Connected Car	Industry 4.0	Smart Utilities	Retail	Public Safety	Smart City	IT	Smart Home	E-Health	Total
Services/applications	90.0	70.0	14.1	12.9	13.0	7.2	6.1	1.7	2.9	217.9
Enablement platforms	6.5	2.4	4.2	0.5	0.4	1.7	0.3	0.6	0.5	17.1
Cloud infrastructure	1.4	0.3	0.5	0.1	0	0.1	0	0.1	0.1	2.6
Connectivity	2.6	0	0	0.4	0.6	0.5	0	0	0.1	4.2
Connectivity hardware	1.6	2	1.1	0.2	0.1	0.3	0.5	1.8	0.5	8.1
Total	102.1	74.7	19.9	14.1	14.1	9.8	6.9	4.2	4.1	249.9

Source: McKinsey & Co.

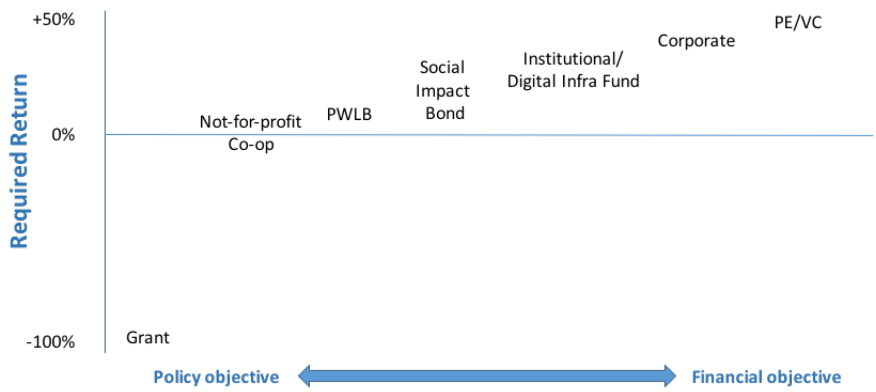
New funding models – The perennial question posed in almost any discussion of 5G's potential is "who pays?". Historically, vertically integrated MNOs (and their investors) have been responsible for virtually all network investment, and also for virtually all of the returns. But 30 years of only modest investment in rural areas suggests that a new approach to funding is required to match the newly emerging commercial models. There are two key aspects to this, basically a question of capex and opex – or, who pays, and who pays back?

Sources of funds – The institutional investor that typically manages the world's long-term retirement savings willingly invests in (relatively) predictable, mature, cash-generative and dividend-yielding incumbent MNOs. For them, the projected risk-adjusted return on an investment in a 5G capacity upgrade in a metropolitan area is always likely to be more attractive than an equivalent investment in the expansion of rural coverage. While a typical MNO will invest in 5G-related development activity, the bulk of its investment will be dictated by the fiduciary requirement to invest in highest return projects – which are not likely to be in rural areas.

But the return on investment by a FWA provider in a neutral-hosting platform that expands its revenue opportunity might just be higher than its alternative investment options – in which case, it should be able to attract investment. The key difference is their own investment alternatives and the risk appetite of their respective investors.

The chart below provides a simplified illustration of the range of funding sources available – from the 'free' money available from Government in the form of grants, justified in the pursuit of policy objectives; through the modest returns required of the PWLB (Public Works Loan Board), to the high returns required by the typical Private Equity (PE) or Venture Capital (VC) investor.

Funding Spectrum



Source: 5G RuralFirst

Note the difference between the grant provided by central and local Government and the 'zero' returns expected of the not-for-profit investor such as the Scottish farming and other co-ops: a grant has no expectation of the return of the principal amount, whereas the not-for-profit still expects that amount to be returned, albeit with no, or minimal, return.

So, part of the solution is to identify the 'right' investor, part of the solution is to manage the risk to the point that the risk-adjusted return becomes sufficiently compelling to trigger investment – and part of the solution is to capture the non-financial objectives of the investment.

While early development activity promoted by DCMS's testbed programme has been grant-funded, the challenge is to reduce the absolute level of grant required to stimulate activity, or at least to reduce the intervention rate, and to ensure an economically viable and sustainable business model.

In the author's view, just as a broad range of technologies and business models will be engaged to support rural 5G deployment, so will a broad range of funding sources be available, depending on the return requirements of the funder – from the social and industrial policy objectives of Government grants and vouchers, through to the pure financial return requirements of the Private Equity (PE) investor.

Sources of returns – The second key issue is that the mobile and broadband revenue and pricing model is not 'fit for 5G purpose' – pretty much 100% reliant on the consumer, and geographically averaged pricing, reflecting a commoditised 'plain vanilla' offering.

As mentioned, Ofcom's recent move to recognise three distinct geo-types of network for the purpose of price regulation is an encouraging move in the direction of pricing differentials that reflect cost differentials. The challenge therefore is to ensure that the value flowing from 5G is efficiently captured: the collaborative ecosystem that characterises the new 5G paradigm has to find a way for each player to contribute to, and earn a return, financial or policy, from the investment – in other words, it cannot all come down to the individual's monthly subscription.

The Ericsson 5G research describes six different mechanisms for MNOs to charge for IoT-related services:

- **Project-based**, a (generally) one-off fixed fee;
- **As-a-service fee**, an agreed fee based on the solution provided;
- **Revenue share**, a share of the beneficiary's achieved revenue;
- **Subscription**, a pre-arranged periodic payment (e.g. monthly) for the solution;
- **Licencing**, selling the rights to use part of the solution, receiving licencing income; and
- **Benefit-based**, payments based on the cost savings or benefits an application generates.

While these are all valid approaches to monetising the value that derives from enhanced interconnectedness, they tend to assume a conventional customer/supplier relationship, whereas our sense is that in a complex, multi-stakeholder environment, it is at least as important to identify the range of payees. Thus, the following potential beneficiaries of ubiquitous 5G rural coverage should all pay their way:

Government – as it is doing, can provide explicit support via customer-led vouchers and development grants.

Local Government – the local authority or Health and Care Services provider can contribute to the deployment that enables more efficient and effective delivery of public services, whether by grant, or by free contribution of public sector assets; or by contracting to receive services over a multi-year term (contracted revenues are very 'bankable' and could themselves support the raising of new financing).

Corporates – the fish-farm, for example, can pay an anchor customer fee, if that precipitates the network deployment that delivers the connectivity and IoT solution that it needs to allow effective environmental and fish health monitoring to support growth.

Farmers – can contribute their assets, land or buildings, in the support of low-cost infrastructure that delivers standard connectivity and also 'Connected Cow' and other application services.

And **individuals** – as they already do, contribute via their monthly bill, to allow them to stream Netflix, to support multiple devices, to upload rich user-generated content… and also to be able to keep an eye on elderly relatives or to run their micro-businesses.

The following graphic brings these elements together, illustrating the range – and richness – of the sources of investment and returns, of capex and opex, both cash-based and PIK (payment in kind).

Sources of Funding of Capex and Opex

	Investment	Cash or PIK?	Returns	Cash or PIK?
MNOs	Contributed spectrum	PIK	Subscription income	£
	Share of backhaul opex	£	Customer experience	£
			Share of IoT Apps income	£
Wireless ISP	Site planning & acquisition	£	Subscription income	£
	Incremental capex	£	Share of IoT Apps income	£
	Share of backhaul opex	£	Roaming revenue	£
			Customer experience	£
Community	Site permissions	PIK	Better connectivity	PIK
	Demand stimulation	PIK	Inward investment	PIK
	Subscriptions	£	Better public services	PIK
Local businesses	Anchor customer commitment	£	Better connectivity	£
			IoT Apps	£
Local Authority	Grants	£	Lower cost public services	£
	Loans	£	Business rate income	£
	Commissioner of services	£		
	Site permissions	PIK		
Central Government	Grants	£	Tax income	£
	Barrier Busting	PIK	Business rate income	£

Source: 5G RuralFirst

It is clear that, given the pressure on budgets and the need to improve efficiency, and given the increasing competition between authorities to attract investment, local authorities are emerging as key players in the 5G debate – as promotor of 'clusters', as commissioners of services, and also as part-funders.

Although all local authorities face their own funding pressures, three financial instruments are available that the author believes merit greater attention as being particularly well suited to the challenge of funding the next generation digital infrastructure.

Social Impact Bonds – Drawing on the expanding pool of institutional investment funds mandated to have a positive social impact in addition to generating a financial return, the local authority could in principle raise a Social Impact Bond[73] to part-fund the investment. This would agree in advance a series of measurable positive social outcomes – reduced elderly isolation, increased elderly independence, better educational outcomes, more efficient use of resources, and so on.

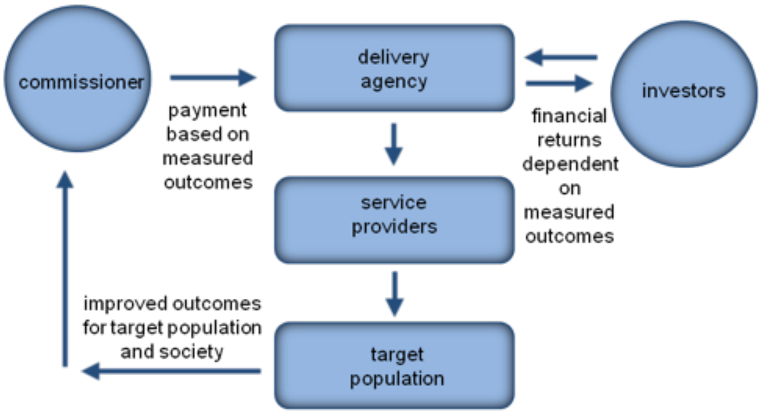
Having been for many years an under-used mechanism for raising funds, a number of local authorities are now understood to be preparing to issue SIBs for the support of early-life intervention and other children's services, the logic being that investment in early-life support will yield significant savings to the local authority in the form of reduced crime rate and welfare dependency – as well, of course, as delivering better outcomes for the individuals.

By comparison, a Social Impact Bond that was issued to part-fund the deployment of 5G-like services in rural areas would potentially yield efficiency and cash savings in a far shorter timeframe than, for example, the lifetime of a child that was subject to early intervention.

Aside from drawing on risk capital on favourable, below-market terms, the use of a SIB would have the additional virtue of requiring the commissioning authority – i.e. the local authority – to be concrete in its thinking as regards 5G strategies and benefits, and to be a committed stakeholder, with skin-in-the-game.

[73] https://www.gov.uk/guidance/social-impact-bonds

Social Impact Bonds



Source: Big Society Capital

Tax Increment Financing (TIF) – Although long established in the US as a source of funding for urban regeneration projects, Tax Increment Financing was first pioneered in the UK by the Scottish Futures Trust (a member of the 5G RuralFirst consortium), as part of the Edinburgh Leith Docks regeneration[74]. Six different projects across Scottish Local Authorities – in Glasgow City Council, Fife, Argyll & Bute, Fife, North Ayrshire and Falkirk – are reported to be currently working on TIF financings, looking to raise more than £200 million in aggregate[75].

The principal is relatively straightforward, whereby a local authority raises a bond on the public markets, the bond being serviced by the pledged income from future tax receipts. The similarity with the Social Impact Bond is clear, the difference being that the returns are dictated by the level of externally/HMT-verifiable tax receipts (could be incremental business rates, could be incremental Council Tax receipts), rather than by the pre-agreed social benefits.

Local Authorities across the UK have sought to develop an active and liquid local municipal bond market, to match the successful 'munis' market in the US and Germany for example, notably via the Municipal Bond Agency, and the aggregate imperative to develop a genuinely 21st Century-ready digital infrastructure could be an important catalyst for bringing this to reality.

Public Works Loan Board – Established back as 1793, and therefore enjoying the obvious merit of being thoroughly tried and tested, the PWLB provided some £5.2bn of loans to local authorities for infrastructure projects last year, a seven-year high. Constituted specifically to facilitate local infrastructure investment, the Debt Management Office's PWLB has as its primary purpose to provide loan capital to Local Authorities on inexpensive and flexible terms[76]. The advantages are clear. First, financing is **inexpensive**, based on the Government's own borrowing costs, and interest rates are currently only 2.2% for 10-year, and 1.8% for 5-year**.** And second, the loans are relatively **simple to arrange**, as the PWLB is a non-discretionary lender – i.e. the applying authority does not have to explain or justify the loan, although the local authority must 'have regard' to the Prudential Code in determining its own risk exposure. The downside is that the loan cannot be secured against the project's assets, but only against the Council's own revenues – i.e. it is on balance sheet.

In the author's view, a compelling financing package to support 5G rural deployment would comprise a combination of the above instruments. Infrastructure investors, perhaps in conjunction with the Treasury's Digital Infrastructure Fund (DIF), would support the provisioning of fibre backhaul, perhaps supported by grant funding as part of Government procurement such as the R100 programme. Grants and low-cost local authority loans would support the fibre and wireless core network, perhaps in conjunction with a not-for-profit CIC (Community Interest Company) or co-op structure around the Neutral Host model. And investors would assume the funding burden for the access layer, supported by voucher-based grants.

Sert out below is a highly simplified model of how the various layers of the 5G value chain might be funded and delivered.

[74] https://www.bpf.org.uk/sites/default/files/resources/Tax-Increment-Finance-tool-for-funding-regeneration.pdf
[75] https://www.scottishfuturestrust.org.uk/page/tax-incremental-financing
[76] https://www.dmo.gov.uk/responsibilities/local-authority-lending-pwlb/

Funding and Delivery of 5G

Source of Funds	Use of Funds	Return of Funds
Corporates	Applications	Corporates
Investors + Vouchers	Fibre & Wireless Access	ISPs
Investors + Loan + Grant	Fibre & Wireless Core	Open Access ISPs
Social Impact Investors + Loan + Grant	Neutral Hosting	CIC or Co-op
Corporates + Grant	Fibre & Wireless Backhaul	Corporates

Source: 5G RuralFirst

Commercial analysis

To assess the viability of an innovative commercial model for provision of 5G services in rural areas, we asked Plum Consulting to develop a cashflow model for a hypothetical operator, using cost-efficient infrastructure and affordable access to radio spectrum. As 5G products and commercial models are still under development, we have based our assessment partially on our own judgement and experience of the telecommunications industry, and partially on dialogue with vendors and operators[77]. Details on our modelling approach are included in Appendix C.

We assume a rural village scenario, with 5G fixed wireless links between radio access point sites (APs) and user premises. We assume regional shared spectrum access, with uplink and downlink transmit power levels in line with the Ofcom Innovation consultation (i.e. 23dBm transmit EIRP); that is, relatively small radio cells are assumed. We model a rural market area scale typical with current fixed wireless commercial deployments, though we vary premises density per square kilometre, commensurate with rural area profiles in the UK[78]. Our model is conservative on spectral efficiency per sector, with a level set at 3 bps/Hz[79]. Service pricing is assumed at £30 per subscriber per month, in line with our discussions with local authorities and business groups representing rural areas. We assume a mature 5G ecosystem and supply chain.

Our model shows that with low premises density scenarios, cost structure is driven by area coverage requirements. As demand density increases, service capacity takes over as a key cost driver.

With the assumptions shown, the model confirms that with premises density levels of more than around 30 premises/km^2, positive net cumulative cashflow results can be attained[80].

If mobile service coverage is required, the investment case may become more challenging, as directional antenna gains cannot be implemented with mobile devices. In these cases, it may be necessary to consider ‘compromise’ scenarios, where ‘islands’ of 5G mobile coverage are provided in key areas (e.g. main roads, train stations, village areas).

Key assumptions with our model are summarised below.

Modelling parameter	Value assumed (2019 data)
Monthly service charge, 30Mbps fixed downlink, 3Mbps committed data rate (contention ratio at 10:1)	£30 pcm per subscriber (incremental pricing on vertical services excluded)
Market scaling	Rural village, 50 km2, variable premises density: 0 to 2000 premises per km2, max. penetration = 60%
Radio spectrum licence charges	£1k per site one off charge, plus £160 per site annual fees, per 20 MHz band, in line with Ofcom Innovation consultation
Radio network: 5G site, 4 sectors, 3.6 GHz carrier, 20 MHz band, frequency reuse = 1	£4k cost per sector-carrier radio, plus site costs, no neutral hosting applied, regional shared spectrum access
Sector coverage	Based on 23dBm Tx EIRP, 15dB clutter losses in radio model, in line with Ofcom Innovation consultation, 15dBi transmit antenna gain
Core network, backhaul	Dual redundant ‘light’ software defined core / data centre. Gigabit microwave backhaul links at £3k capital cost per link, nominal light licence charges per link per annum
CPE costs	£100 one-off installation charge, plus £150 per CPE (non-subsidised)

[77] We use a modified COST-231 radio propagation model, with radio power link budget calculations, based on dialogue with vendors.
[78] Typical premises density in UK rural areas varies; therefore we selected variable levels. As an example, mean premises density in the county of Shropshire (considered largely rural) is documented at 44 premises per km2, see: https://shropshire.gov.uk/committee-services/documents/b9987/Reports%206%20and%208%20marked%20to%20follow%2012th-Nov-2015%2010.00%20Enterprise%20and%20Growth%20Scrutiny%20Committee.pdf?T=9; see: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/591466/Local_Authority_Districts_ranked_by_rural_and_rural-related_populations_with_Rural_Urban_Classification.pdf
[79] Higher spectral efficiency levels may be possible with 5G systems, depending on product configurations (e.g. antenna matrix – MIMO scale).
[80] Note: excludes staff costs; ‘clear’ profit assumed. Assumes 5G ‘component’ (e.g. chipset) costs at scaled levels.

8 Potential benefits

In this section, we examine potential benefits likely with access to 5G services in rural areas, as may be enabled with innovative commercial models as above.

We adopt two approaches:

- Primary research – dialogue and survey questions with stakeholders with interests in rural areas, focused on service requirements and pricing levels, and
- Macroeconomic study, based on productivity analysis, applied to rural areas.

Stakeholder dialogue, by sector

Through our dialogue with stakeholders, we have noted interest for 5G applications across various sectors (see below).

- Roads and autonomous cars
- Public broadcasting
- Broadcasters and content providers
- Logistics providers (rural)
- Local industry (e.g. salmon farming)
- Farming solution suppliers / ecosystems
- Farming – farms and cooperatives
- Tourism
- Local government
- Consumer / business internet
- Consumer phone services
- Emergency services network (ESN)

To assess views on benefits and acceptable pricing levels with 5G services, we spoke with a range of stakeholders with interests in rural areas.

National bodies

There is significant activity and interest in observing the potential for growth in rural areas, as enabled with digital services.

The recently published report from the Rural Services Network[81] calls upon Government to develop a firm strategy for development of rural areas, and notes that rural areas should not be overlooked or conflated merely with agriculture or land-based industries. Meanwhile, the House of Lords Rural Economy Committee has worked to produce a new report on rural affairs, and has amassed significant evidence on key matters, including breakdowns on local GVA levels[82]. Within this evidence base, The Chief Economic Development Officers Society (CEDOS[83]) notes that:

> “ CEDOS members believe there is potential for growth in the digital and innovation (including automation and artificial intelligence) sectors [in rural areas]. This potential will be realised if the following are prioritised:
>
> The provision and application of digital and smart technology, including the encouragement of innovation and
>
> The development of a resilient and skilled workforce.
>
> Whilst these do not differ significantly from the urban agenda, the models and delivery mechanisms for investment and business support for them do. They must be resourced to ensure specific barriers to rural areas are overcome and opportunities realised. Moreover, rural areas could – with the right investment and support – benefit more from advances in technology than their urban counterparts. They are less at risk of automation (due to the nature of the businesses generally found in rural areas). In particular, the roll-out of superfast broadband and 5G etc should address issues of rural isolation and increase agglomeration affects. ”

During the course of our study, we spoke directly with various stakeholders with both public and private sector interests in rural areas (see list of contributors). Broadly, many commented that the fixed link broadband specification currently defined by the Universal Service Obligation (10 Mbps downlink, 1 Mbps

[81] See: https://rsnonline.org.uk/images/publications/rural%20strategy%202019/2019_Rural_Strategy.pdf
[82] See: https://www.parliament.uk/business/committees/committees-a-z/lords-select/rural-economy/publications/
[83] CEDOS is the voice of Heads of Economic Development and senior economic development professionals from across England.

uplink) is not sufficient to meet the needs of many economic operators located in rural areas, with many stakeholders noting that uplink service supporting several Mbps is required, along with superfast rates, or better, on downlinks. No such USO exists pertaining to mobile services (though Ofcom's consultations refer to 'basic' mobile service at a mere 2 Mbps).

Whilst many called for improved access to good quality broadband services (fixed and mobile), the need for 5G services including vertical slicing models appears, at present, unclear in some cases[84].

At an individual local authority level, figures of around several hundreds of millions of pounds benefit (in GVA terms) were noted as having been achieved with advent of good quality digital services[85] (see also economic assessment below) – around two percentage points net improvement in regional GVA.

Healthcare sector

In the healthcare sector, stakeholders noted that access to digital records, supporting patients and services, is becoming essential, and in cases where access to digital connectivity is poor, ability to provide effective healthcare at key locations and in the community is materially impeded.

This need is driven, in part, by the ageing nature of populations found in rural areas[86]. In such cases, access to good quality mobile and fixed line broadband connections is required to increase the reach and effectiveness of the health and social care sectors.

Key benefits expected with better access to good quality digital service include reduced travel – supporting lower road vehicle traffic levels, reduced fuel consumption levels, and greater efficiency with NHS facilities and resources.

A key comment noted by several, pertaining to both health and social care, was the need to avoid isolation (loneliness being an acknowledged predictor of ill-health), and to prevent 'blackspots' in terms of ability to deliver care in the community. Willingness to pay for services was felt to be variable, with a need to look at specific issues case by case.

Business users

In speaking with local authorities covering rural areas across the UK, we noted that many small businesses and users operating in rural areas have commented that significant benefits can be attained with access to good digital services. These include:

- productivity and value benefits (e.g. reliance on online trade
- database access
- flexible working
- remote emailing
- virtual team working
- increased employment levels
- reduced travel time and costs
- ability to work from home or satellite offices (thus reducing commuting costs and road traffic levels)
- access to online public services (e.g. planning applications, social care, monitoring and alarms)
- family support (e.g. access to schools' intranets and internet for learning and leisure)
- household support (e.g. access to online shopping, internet banking)
- sustainability of communities (e.g. greater needs for rural retail)
- improved work-life balance (e.g. better access to local childcare, more effective use of personal and business related time)

[84] However, this is not necessarily a reflection on lack of need; in many cases, the benefits of advanced 5G services, such as slicing, appear nascent.

[85] Superfast Cornwall: "our evaluations work shows huge economic, social and environmental benefits from the rollout across Cornwall and Isles of Scilly – e.g. 3,500 / 4,200 jobs created / safeguarded, £300m of GVA impact and 3,850 new businesses (as at 31/3/2018)". See: https://www.superfastcornwall.org/current-programme/evaluation-2011-2015-programme/

[86] Education on effective use of digital services (e.g. with elderly people) may be important and was noted during our dialogue with stakeholders.

Many see good digital services as a critical enabler to opening businesses in rural areas; conversely several stakeholders cited lack of access to good digital services as a driver for younger people moving to urban areas.

Essentially, it was noted that economic benefits would ensue with the potential for increased economic value in rural areas. Willingness to pay (broadband service pricing) at around £30 per month was felt to be a broadly acceptable level for small businesses and consumers, and it was noted that competition on digital services would help to keep pricing at acceptable levels, and promote build-out on services with acceptable quality.

However, some small businesses, including drone services supporting digital imaging and Cloud services for crop and land management – i.e. in cases where digital connectivity is deemed critical to business needs, and losses without digital service could exceed pricing levels – commented that even pricing around £100 per month could be acceptable. Again, access to bitstream broadband – at least superfast fixed and 4G mobile – was felt to be essential, enabling subsequent access to essential internet services (e.g. specific business applications, online accounting solutions, public services, general internet content).

There was mixed comment on how digital services and Brexit might relate; some felt that improved digital services could be a platform for innovation, perhaps enabling the UK to improve competitive positioning at an international level, but this might require centralised funding and focus if it were to be effective. It is worth noting that many in the telecommunications industry have voiced concerns on labour levels in connection with Brexit.

Agriculture and estate sectors

Within the agriculture, land management, and real estate sectors, innovative stakeholders with businesses in these areas informed us of various developing use cases which are being used and developed with 5G and full fibre solutions. These include:

- public and private safety
- driverless tractors and other automated vehicles,
- drone and light aircraft surveys and image processing with crop management
- augmented reality (AR) solutions for livestock care
- milk yield monitoring systems
- crop sensors,
- water flow management,
- property and land security solutions,
- real time cloud based processing systems
- improved tenant occupancy rates and enhanced property values

As above, a combination of both fixed fibre and wireless solutions for mobile access to digital services was considered essential, with mobile coverage in many rural areas considered generally poor and 'patchy' – as noted above.

Pricing on specialised digital services for particular business needs appears somewhat nascent in the UK market, with expectations for pricing typically based around value levels likely to be offered to particular businesses. For example, with crop management, typical crop values in today's market sit at around £200 per hectare. If digital services can be invoked to prevent loss, or support more efficient production, then value on such services will, respectively, be related to reduction in revenue leakage or incremental profit earned.

Tourism sector

The tourism industry in rural areas, worth around £12bn GVA in England[87] and £1.2bn GVA in Scotland[88], in 2017, also presents potential for growth.

[87] See: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/775109/01_Statistical_Digest_of_Rural_England_2019_January_edition.pdf, with Plum estimates.
[88] See: https://www.gov.scot/publications/understanding-scottish-rural-economy/pages/3/, with Plum estimates.

Stakeholders noted that lack of good quality digital services – fixed and mobile – in rural areas can have direct bearing on tourism levels – as visitors increasingly expect pervasive access to good online facilities, whether at home, or on holiday.

More specifically 5G-relevant, augmented reality and virtual reality (VR) use cases are being developed and assessed by various players around the UK, and there is significant interest in using these in the tourism sector – for example: to provide area guides, location guidance, local advertising, and promotional guides. However, these appear as yet unproven in the market place – which remains fragmented[89].

Aquaculture sector

Aquaculture is also an important segment, representing around £0.62bn GVA in Scotland[90].

A report, A vision Towards 2030[91] produced for the Scottish Aquaculture Innovation Centre, argued the strategic importance of fish farming to the Scottish agriculture and food industries, setting a target to double production by 2030 – merely to keep pace with the worldwide growth in demand for fish products. To achieve this goal in environmentally sensitive areas such as the Scottish north and west coasts, there is a clear need to ensure strict environmental and fish health monitoring procedures, for which efficient connectivity is a pre-requisite. Thus, Cloudnet IT Solutions on Orkney and Broadway on the mainland have viewed the in-shore fish-farming sector as a key consumer of standard broadband connectivity, as well as a risk-sharing partner in new network deployment.

We do not address satellite solutions here, but note that high cost and high latency ensure that satellite will likely remain at best a complementary technology to terrestrial 5G, most obviously providing backhaul to remote terrestrial networks.

However, it is worth describing an interesting 'industry vertical' application, enabled by satellite, which is the use by the fish-farming industry of satellite imagery to track, and alert to the arrival of, algal blooms, potentially toxic to marine life: once the blooms are detected, terrestrial networks can trigger changes to feeding cycles, ensuring potentially vulnerable fish stock remains in deep water, below the passing bloom.

Scottish whisky industry

The Scottish whisky industry (within the food and recreation segments) is reported to contribute around £4bn in GVA to the UK economy, supporting 40,000 jobs, 7,000 of which are in rural areas[92].

With industrial IoT, the industry could see a reduction in costs and an improvement in operational efficiency, positively impacting the UK economy even further.

Economic assessment

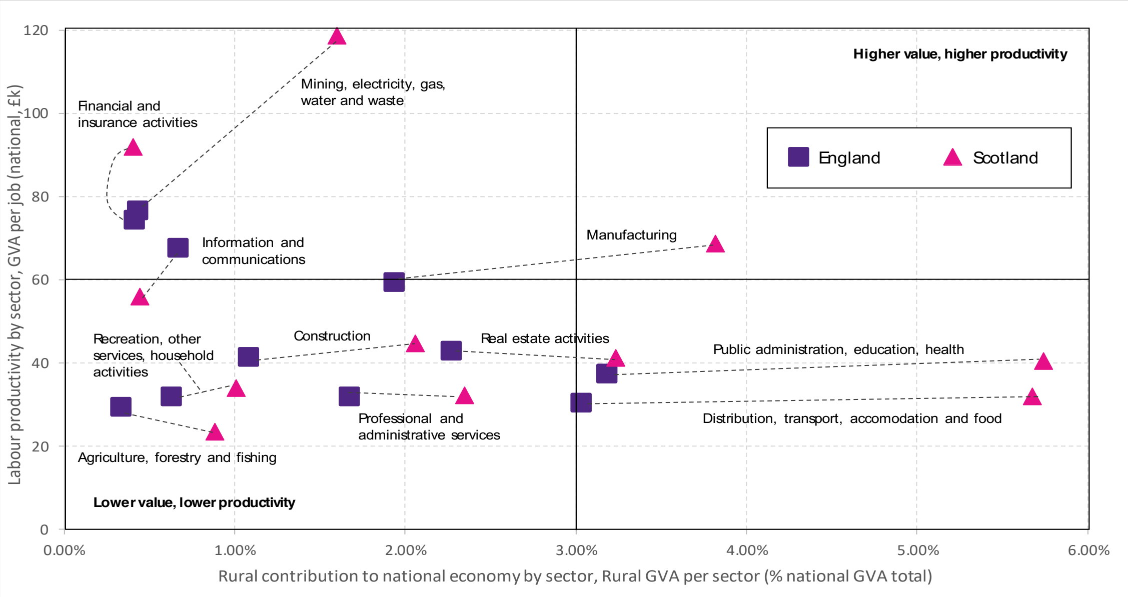
With potential for benefits across various sectors, we examined reported data on GVA per sector (rural areas), GVA per job (national averages), and sector growth levels (national and rural data), categorised across all sectors.

On average, GVA per job is higher in London (138% on national average) than in rural areas (85% on national average), though if London data is excluded from urban areas (92% on national average), differences are less marked.

The diagram below indicates the scale of segments of the rural economy, together with labour productivity levels. Significant productivity benefits could ensue from those segments with relatively high scale and labour productivity levels.

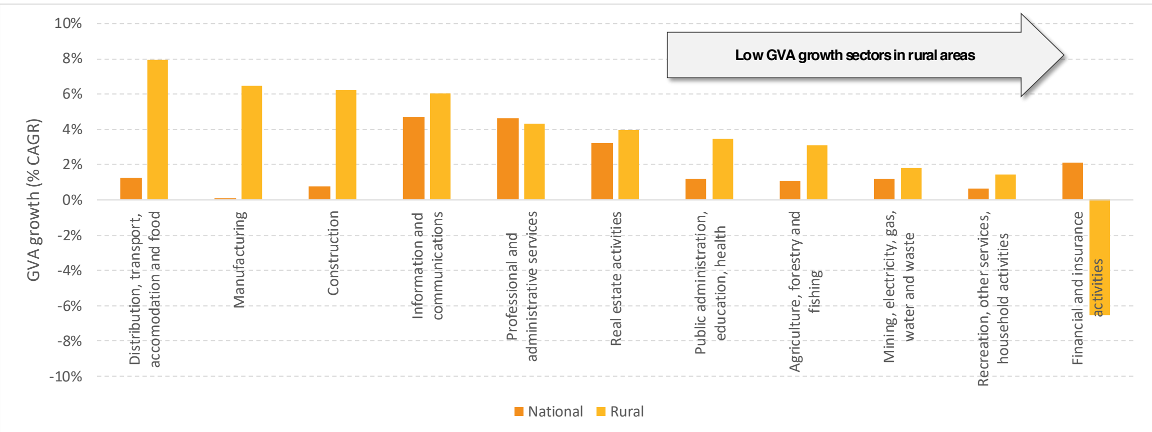
89 Examples of AR and VR applications include those being developed by firms such as 'World Around Me' (https://worldaroundmeapp.com/) and 'Living Popups' (https://www.livingpopups.com/).
90 See: https://www.gov.scot/publications/scotlands-10-year-farmed-fish-health-framework/pages/2/
91 See: http://imanidevelopment.com/wp-content/uploads/2017/03/Scottish-aquaculture-a-view-towards-2030.pdf
92 See: https://sp-bpr-en-prod-cdnep.azureedge.net/published/2018/10/11/Brewing-and-distilling-in-Scotland---economic-facts-and-figures/SB%2018-64.pdf

Rural GVA scale and labour productivity levels, by sector, 2016 comparative data[93]



Source: Understanding Scottish Rural Economy and Statistical Digest of Rural England

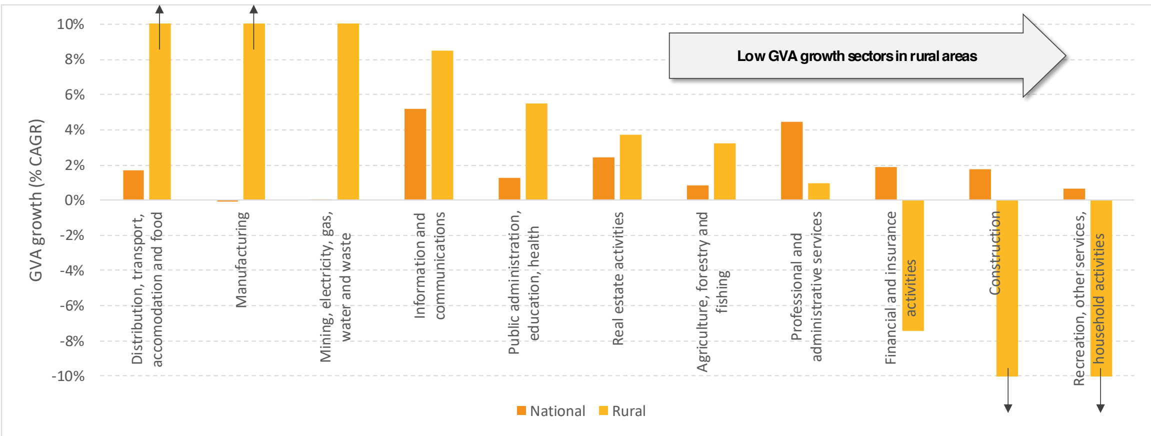
Scotland: GVA growth levels by sector (national, rural) (% CAGR)



Source: ONS

[93] See: https://www.gov.scot/publications/understanding-scottish-rural-economy/pages/12/ https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/579598/Statistical_Digest_of_Rural_England_2016_December_edition.pdf,

England: GVA growth levels by sector (national, rural) (% CAGR)



Source: ONS

The data show differences in sector growth levels across the rural-urban divide, together with relative scale of sectors in the rural economy. GVA per workforce job data gives some indication on those sectors that may be considered more productive than others (i.e. with high GVA output per employee).

We would expect benefits to accrue, with 5G digital services, in those sectors where significant scale, growth, and productivity can be enhanced with access to such services.

Macroeconomic assessment

The introduction of 5G digital services can be expected to deliver a range of economic benefits, including increased productivity resulting in economic growth, and consumer and social benefits derived from improvements in welfare.

There is likely to be direct impact on economic growth through investment expenditure and commercial rollout of 5G networks[94]. However, the majority of the economic benefits delivered are expected to relate to the uptake of new and improved digital services.

Only limited assessment on productivity benefits specific to 5G exists, and previous studies have largely addressed the potential for national, rather than regional benefits. For example, the Bureau of Communications and Arts Research[95] in Australia has examined potential benefits in that market and used a growth accounting approach to illustrate likely increases in GDP per capita.

To estimate the scale of economic benefits likely with rural areas of the UK attaining good quality 5G digital services, we assumed a linkage between GVA growth and access to digital services in line with established studies, as above. We also draw upon the GVA linkage evidence reported in Cornwall[96]. Details of our economic modelling are included in Appendix C.

We assumed two levels of growth in GVA: a base (counterfactual) case, and an enhanced case with higher GVA growth per annum levels – resulting from digital services take-up. Take-up levels were modelled over a ten year period using a Bass diffusion method, based on empirical data for wireless services.

Our analysis suggests that, over a 10 year period, the UK's rural economy could grow by an additional £17bn if good quality 5G services are accessible.

Overall, our model suggests that the UK rural economy stands to benefit by several percentage points on GVA with 5G developments, based on factor productivity analysis. Additional benefits are likely as a result of social and environmental factors that are typically not addressed with productivity-based analyses.

[94] Much of the economic literature referring to investment in telecommunications networks considers investment to be synonymous with uptake of services.
[95] See: https://www.communications.gov.au/file/35551/download?token=0MlSFttv
[96] See: https://www.superfastcornwall.org/wp-content/uploads/2018/07/Superfast-Evaluation-Report-June-2018-Final-Issued-190618.pdf

9 Lessons Learned

The House of Lords Rural Select Committee report published in April rightly highlighted the importance of the rural economy to the UK as a whole, and the potential for new technology "to transform the rural economy, reverse years of underperformance and improve the quality of life not just for those living in rural areas, but for the nation as a whole"[97].

We agree, and estimate that the rural economy could benefit from improved digital services by several percentage points, in GVA terms[98], worth some £17bn to the UK economy over a 10-year period, with additional unquantified, but no less real, social and welfare benefits on top.

In urban areas, widespread deployment of 5G is a matter of "when", not "if", with initial improvements in speed and latency eventually leading to to significant gains in business productivity and consumer welfare.

In rural areas, widespread deployment is not a given. However, the experiences of 5G RuralFirst partners throughout the first 12 months of the 5G Testbeds and Trials programme suggest a narrowing of the digital divide triggered by supportive policy shifts, enabled by lower cost, more capable and more flexible technology, and delivered through alternative and innovative commercial models. These could incorporate some, if not all, of the following characteristics:

- A 'small cell' deployment strategy, minimising 'hard' infrastructure and 'soft' planning costs.
- A hybrid, pragmatic approach to technology adoption: better a 'gigabit capable' Fixed Wireless Access solution in two months than a Full Fibre solution in 2025, 2033, or even later; and better a 5G-like service than no service at all.
- Extensive use of low-cost RAN and SDR equipment.
- Use of the neutral hosting model, to minimise duplication of both passive and active infrastructure.
- Cooperative, symbiotic relationship with one or several MNOs, enabling essentially 'free' access to spectrum in return for supporting more extensive geographic coverage, or a dynamic, shared spectrum approach.
- Commitment to developing innovative and high-value application layers.
- Commitment to educating potential users of the value of Industry 4.0 - applying connectivity to remote sensors and intelligence to the evaluation of resulting data.
- Commitment to developing and incorporating an ecosystem of interested and qualified stakeholders. This can be as straightforward as securing a remote fish-farm as an anchor customer to underwrite the risk of initial network deployment. Or it can be as 'soft' as engaging local community support, perhaps via a not-for-profit structure such as a Community Interest Company, Bencom or Co-op, as SmartRural is doing as part of its membership of SAOS.
- Acceptance that 5G and 5G-like networks will not initially be deployed across wide areas, as part of any grand plan, but will likely emerge as islands of activity, clustered around specific use cases, anchor customers, 4G infill initiatives, or progressive communities. The challenge will be how to capture at least some of the benefits of scale across a multitude of small-scale, community- and use case-centric deployments.
- Consideration of the need to accept unconventional thinking – for example, the abolition of geographically averaged pricing, and the introduction of more cost-based pricing; or the acceptance of non-carrier grade, 'best efforts' connectivity.
- Adoption of a range of financing sources, from Government grant through local bond issuance, to established infrastructure investors, reflecting the range of players involved, at different points in the value-chain, with different return requirements and risk tolerances.

[97] https://publications.parliament.uk/pa/ld201719/ldselect/ldrurecon/330/330.pdf page 5
[98] Based on productivity improvements, with broadband services only.

While the report's authors are generally optimistic about the potential impact of the migration towards 5G on the quality and availability of advanced digital services in rural areas, risks and issues remain:

- Full fibre is unlikely to be rolled out in many rural areas any time soon, with current public procurements such as the R100 and Superfast Cymru programmes likely to focus on incremental extension of existing fibre footprints. As acknowledged by the R100/Aligned Intervention programme, wireless options should be considered as natural 'force extender' technologies. However, both fixed and mobile wireless solutions (whether 4G or 5G based) can only be seen as offering a comparable alternative to ultrafast broadband, if dense fibre access is also made available on a ubiquitous basis. In the meantime, solutions should be supported which are sufficient to meet the needs of users, with acceptable downlink *and* uplink data speeds, plus specialist vertical services.
- Convergence may support market development. That is, where fibre operators are willing to develop or support 5G deployments, greater potential for investment in regional areas will exist. Policy and regulation should therefore be supportive towards converged players and models.
- 5G technology is developing in line with software defined and 'light' cost core networks, which offer the potential for cost-efficient development of specialised ('sliced') digital services meeting the particular needs of various vertical markets. However, many local authorities and stakeholders with interests in rural areas are unaware of such specialised services and the potential benefits. Campaigns to raise awareness and promote novel services are likely to be important.
- 5G radio access networks are being designed to support multiple use cases at the bearer level, including low latency, high data rate, and machine-based (IoT) communications. Support across these multiple areas within one global technology is likely to offer significant cost benefits due to high scale economies in the long run. However, scale and cost efficiency may evolve over time as 5G markets grow globally. It may be necessary to leverage elements of 5G technology with other solutions, to ensure cost efficiency as markets evolve. It will be necessary to access scale in line with global and international harmonisation of 5G technologies and radio bands.
- Government policy and regulation is evolving to support industry in providing commercially feasible solutions to rural areas, where investment cases have typically been difficult. Regulation which recognises geographical differences, and supports collaboration between and market access for service providers will enable market expansion and promote feasible solutions. A key component will be access to suitable radio spectrum bands at affordable cost levels.
- Policy and regulation need to be supportive towards balanced access to spectrum, to ensure vibrant competition and service access. Complex and overly bureaucratic management of spectrum will not enable innovation and may depress demand.
- Policy and regulation should also support ongoing innovation, including neutral hosting, national roaming, and localised site deployments, where these prove relevant for development of both fixed and mobile services in rural areas. Balance must be struck between enabling deployment of cost efficient networks and ensuring competition for users at the service level. Current FWA deployments often rest on local support groups; some form of co-ordinated support from central Government could help rural communities to develop solutions with industry. National roaming need not necessarily be freely available where this would disincentivise investment in rural coverage, but it should at least be made available as a fairly priced premium service.
- Scale economies are vital for a rural economy, where the business cases will already be marginal. This underpins the importance of shared access in the 3.4-3.8GHz and other bands.

Overall, 5G solutions offer real promise for the rural economy, but success and realisation of the commercial and economic benefits will require active promotion of services tailored to rural needs, leverage of cost efficient solutions, and development and exploitation of new commercial models and supporting policies and regulation.

Appendix A – List of contributing organisations

In the initial preparatory phase of this research, Plum Consulting engaged with a number of organisations in the development of this paper, including those listed below.

List of contributing organisations

Broadway Partners Ltd	Cisco International Ltd
University of Strathclyde	Accelleran NV
Parallel Wireless UK Ltd	Ch4lke Mobile Ltd
Overbury Enterprises Ltd	Hummingbird Technologies Ltd
Orkney Islands Council	Cloudnet IT Solutions Ltd

List of local authorities and related bodies providing feedback on survey questions

Connecting Cheshire, Cheshire	North Yorkshire County Council, North Yorkshire
Connecting Devon and Somerset, Devon and Somerset	Nottinghamshire County Council, Nottinghamshire
Connecting Shropshire, Shropshire	Pym's Consultancy, Lincolnshire
Cornwall Council, Cornwall	Richmondshire District Council, North Yorkshire
East Lindsey District Council, Lincolnshire	Shropshire Council, Shropshire
Forest Heath District and St Edmundsbury Borough councils, West Suffolk	South Lakeland District Council, Cumbria
Harrogate Borough Council, North Yorkshire	South Somerset District Council, Somerset
Huntingdonshire District Council, Cambridgeshire	Staffordshire County Council, Staffordshire
Lincolnshire Coop, Lincolnshire	Superfast Cornwall, Cornwall
North Somerset Council, Somerset	Teignbridge District Council, South Devon
North Warwickshire Borough Council, Warwickshire	Torridge District Council, North Devon

Appendix B – References

Notable references on productivity benefits associated with development of digital services are summarised below.

List of economic studies on productivity benefits with digital services

Authors (date)	Impact on GDP[99]	Context and comment
Deloitte (August 2019)[100]	In upside 'Revolutionary' scenario, ubiquitous 4G/5G translates to additional £17bn or 0.5% of GDP growth.	Scotland-specific analysis.
BCAR, Australian Government (2018)	5G services could add an additional AUD$7,580 to per capita GDP by 2050.	Study of the impact of 5G on productivity and economic growth.
Allen Consulting (2010)	A 20% increase in household internet connectivity increases multifactor productivity by 0.07 percentage points.	Computed for Australian economy using dynamic general equilibrium model.
Bohlin (2013)[101]	Finds 1% higher (mean) broadband speed contributes to approximately 0.003% additional GDP growth over 3-year period.	Panel data of 33 OECD countries from 2008 (base year) over 12-quarters/3 years.
Kongaut and Bohlin (2014)[102]	Finds a 10% change in broadband speed will increase GDP per capita by 0.8 percentage points.	Panel data on 33 OECD countries from 2008-2012; split as 16 lower-income and 17 higher-income countries.
Czernich et al (2009)[103]	Impact of 10% change in broadband penetration is a 0.9-1.5 percentage point increase in GDP growth rate. The introduction of broadband (nationally) increases GDP by 2.3-3.9%.	Panel data of OECD countries in 1996-2007.
ACMA (2014)[104]	A survey of businesses in Australia found that the use of mobile broadband had generated cost savings of 1.4% and time savings of 2.3%	Data from Australia from 2006 to 2013.
Williams et al (2012)[105]	10% substitution from 2G to 3G increased GDP per capita growth by 0.15%. Doubling mobile data increases GDP per capita of 0.5 percentage points.	Data from Cisco's VNI Index for 14 countries; looks at number of 3G connections and 3G data consumption.
Gruber and Koutroumpis (2011)	Mobile telecommunications contributed to 0.39% increase in annual GDP growth for high income countries.	Panel data from 192 countries from 1990-2007.
Edquist et al (2017)[106]	Finds a 10% increase in mobile broadband adoption causes 0.6-2.8 percentage point increase in economic growth.	Data for 135 countries from 2000-2014.

[99] For clarity, when we note a 2-percentage point increase in GDP growth, this means that GDP growth would increase from (for example) 5% to 7%.
[100] https://www.scottishfuturestrust.org.uk/storage/uploads/deloittesfteconomicimpact4g5gfinalreportforpublication.pdf
[101] Bohlin (2013), Broadband speed impact on GDP growth and household income: Comparing OECD and BRIC, Presentation for *the ITU Workshop: New Trends for Building and Financing Broadband: Policies and Economies*, 24-25 September, Manama, Bahrain.
[102] Kongaut and Bohlin (2014), Impact of broadband speed on economic outputs: An empirical study of OECD countries, Conference paper for the *25th European Regional Conference of the International Telecommunications Society (ITS)*, 22-25 June 2014, Brussels, Belgium.
[103] Czernich, Falck, Kretschmer and Woessman (2011), "Broadband infrastructure and economic growth", *The Economic Journal*, 121(552), 505-532.
[104] ACMA (2014), "The economic impacts of mobile broadband on the Australian economy, from 2006 to 2013", https://www.acma.gov.au/~/media/Numbering%20and%20Projects/Report/pdf/Economic%20impacts%20of%20mobile%20broadband_Final%20pdf.pdf
[105] Williams, Solomon and Pepper (2012), "What is the impact of mobile telephony on economic growth – A report for the GSM Association", Deloitte LLD, London
[106] Edquist, Goodridge, Haskel, Li and Lindquist (2017*), "How important are mobile broadband networks for global economic development?",* Imperial College Business School, Discussion Paper 2017/05, June 2017.

Appendix C – Details on modelling

Commercial modelling

To examine commercial feasibility for a 5G deployment in a rural area, Plum Consulting built a cashflow model. It assumed an innovative deployment, using low cost small cells and a low cost 'light' core network, with network costs informed by established commercial deployments using 4G equipment. That is, critically, it assumed a mature 5G ecosystem, with significant scale economies.

An overview on our modelling approach is shown below.

Technical specifications were informed by dialogue with vendors, Plum's own industry experience, and the Ofcom Innovation consultation.

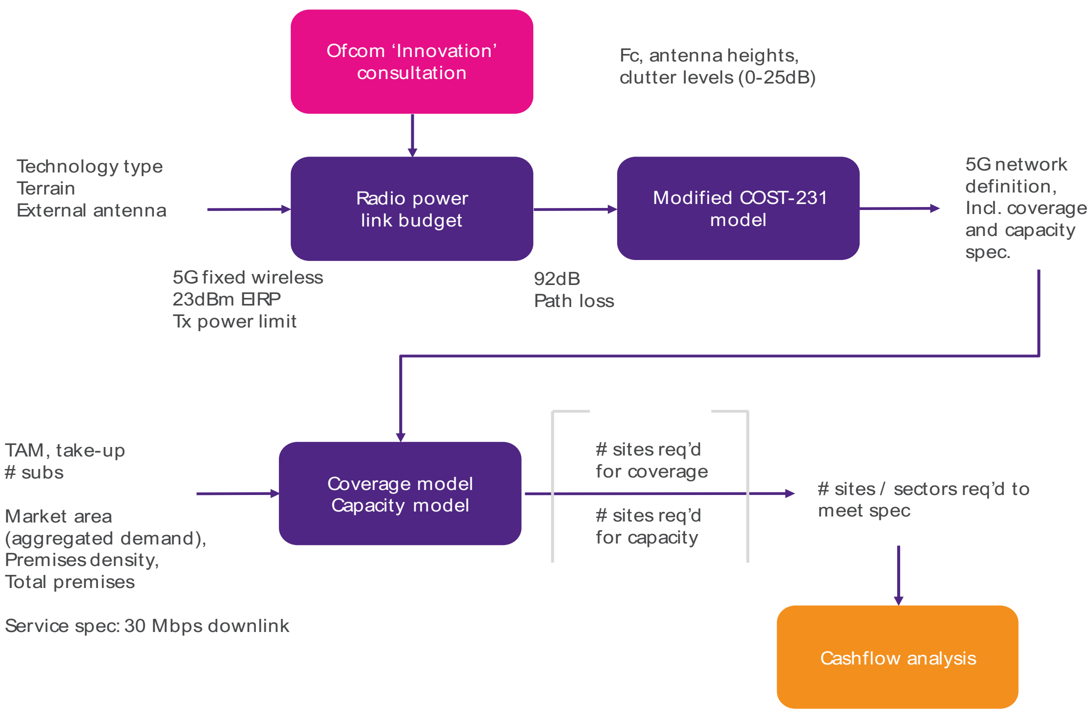
Market specifications were defined with variable premises density, based on typical UK rural levels.

The model switches between coverage and capacity limited scenarios, according to variable market conditions, which are provided as inputs.

Cashflow is then derived, with network and market dimensioning, together with cost and price data.

Net NPV is calculated using a weighted average cost of capital set at 10%.

Cashflow model summary: 5G fixed wireless small cell rural deployment



Economic modelling

Plum developed a model to estimate the potential benefit to the UK economy from a factor productivity uplift due to the adoption of improved communications services. These services are assumed to offer enhanced broadband speeds and quality of service, which can be used by businesses and enterprises to improve productivity and reduce costs.

Plum's main assumption is that 100% adoption of improved communications services will generate a 0.3 percentage point uplift to economic output, which will persist for 10 years. This is based on analyses of how output and productivity have been affected by incremental advances in communications technology to date. In particular:

- The Australian Bureau of Communications and Arts Research (2018)[107] assumed 5G would allow for faster output growth of 0.3 percent per year.
- Rohman and Bohlin (2012)[108] found that a doubling of broadband speed contributed 0.3 percentage points to growth compared with growth in the base year.
- A survey[109] of businesses in Australia found that the use of mobile broadband had generated cost savings of 1.4% and time savings of 2.3%.
- Williams et al (2012)[110] found that 10% substitution from 2G to 3G increased GDP per capita growth by 0.15%.

Plum also referred to GVA benefits as recently reported[111] in the UK.

It is possible that 5G technology may lead to a 'step change' by enabling entirely novel applications, leading to a wide-ranging impact on productivity and economic growth. Plum's modelling assumption is conservative insofar as it assumes 5G will offer more of an incremental, rather than revolutionary, advance on existing technologies (for example, improvements to speed and latency).

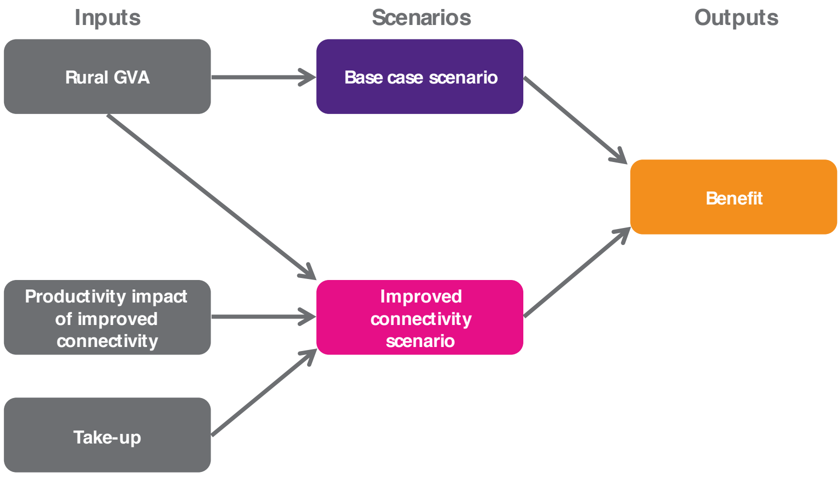
The model examines rural areas of the UK as defined according to the definitions of the UK nations – comprising around 17% of the total UK population.

Plum compared two different scenarios. In the *base case* scenario, the gross value added (GVA) in rural areas (as defined above) is projected forward. In the *improved connectivity* scenario, an increment is applied to the GVA growth rate, according to the level of take-up of improved communications services (modelled by a Bass diffusion model[112]). By comparing the two scenarios, it is possible to calculate an economic benefit.

Plum's estimate of the economic benefit is likely to be conservative in that it does not fully take into account the social and environmental factors that are not captured in the economic statistics. These include cost and time savings for households, environmental benefits from smart cities and smart grid applications, and benefits from improved accessibility and engagement with healthcare services.

An overview of Plum's modelling approach is shown below.

Overview on economic modelling approach



[107] Bureau of Communications and Arts Research, Australian Government (2018), Impacts of 5G on productivity and economic growth, https://www.communications.gov.au/file/35551/download?token=0MlSFttv
[108] Rohman and Bohlin (2012), "Does broadband speed really matter as a driver of economic growth? Investigating OECD countries", *International Journal of Management and Network Economics*, 2(4).
[109] ACMA (2014), "The economic impacts of mobile broadband on the Australian economy, from 2006 to 2013", https://www.acma.gov.au/~/media/Numbering%20and%20Projects/Report/pdf/Economic%20impacts%20of%20mobile%20broadband_Final%20pdf.pdf
[110] Williams, Solomon and Pepper (2012), "What is the impact of mobile telephony on economic growth – A report for the GSM Association", Deloitte LLD, London.
[111] See: https://www.superfastcornwall.org/wp-content/uploads/2018/07/Superfast-Evaluation-Report-June-2018-Final-Issued-190618.pdf
[112] See: Bass, Frank M. (2004). "Comments on "A New Product Growth for Model Consumer Durables": The Bass Model". Management Science. 50 (12): 1833–1840. CiteSeerX 10.1.1.460.1976. doi:10.1287/mnsc.1040.0300

The steps involved in the modelling process are described below.

- Collect data on gross value added (GVA)[113]. Data on GVA (excluding taxes and subsidies) over the past 10 years by NUTS3 region was collected for the UK from Eurostat. The UK comprises 173 NUTS3 regions in total.
- Estimate rural GVA. Rural regions were identified according to the EU's urban-rural typology[114]. Regions classed as 'predominately rural' were aggregated together. In sum these regions contained around 2.5m people. (Note that the definition of rural employed here is significantly stricter than Ofcom's definition. This is to focus the analysis on regions where improved connectivity is likely to offer the greatest benefit, and to ensure a consistent dataset for analysis).
- Forecast rural GVA. The aggregate rural GVA was projected forward according to a rolling linear trend. This forms the *base case scenario* for the modelling.
- Estimate the likely take-up of new and improved communications services. Take-up was modelled using the Bass diffusion model, which has been used to model the take-up of various communications services and technologies. Plum assumed take-up reaches its long-term value (one of the modelling inputs) around 12 years after services first become available.
- Estimate the impact of improved connectivity on growth. Plum's central assumption is that 100% take-up of improved services will generate a 0.3 percentage point increment to the growth rate of GVA, and that this increment will persist for 10 years[115]. This assumption is based upon our review of the relevant literature on the impact of communications services on economic productivity.
- Develop the counterfactual *'improved connectivity' scenario*. Combining both the take-up and growth impact enables the calculation of a growth rate increment. This increment is added to the base case GVA growth rate in each year. For example, if the base case rate of GVA growth is 2%, 10% take up of improved connectivity services in year 1 gives an adjusted growth rate of 2%+(10%*0.3) = 2.03% in that year. These adjusted growth rates are used to calculate the rural GVA in the counterfactual scenario.
- Compare the two scenarios to quantify the benefit. Plum calculated the difference in rural GVA between the two scenarios as far as 2040. This is then discounted using a social discount rate of 3.5%.

[113] Gross value added represents the value of economic output less inputs consumed in the production process.
[114] https://ec.europa.eu/eurostat/web/rural-development/methodology
[115] We assume that this scales linearly; i.e. 50% take-up will lead to a 0.15 percentage point increment to economic growth.