The digital divide: Patterns, policy and scenarios for connecting the 'final few' in rural communities across Great Britain

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ABSTRACT

The Internet can bestow significant benefits upon those who use it. The *prima facie* case for an urban-rural digital divide is widely acknowledged, but detailed accounts of the spatial patterns of digital communications infrastructure are rarely reported. In this paper we present original analysis of data published by the UK telecommunications regulator, Ofcom, and identify and reflect on the entrenched nature of the urban-rural digital divide in Great Britain. Drawing upon illustrative case vignettes we demonstrate the implications of digital exclusion for personal and business lives in rural, and in particular remote rural, areas. The ability of the current UK policy context to effectively address the urban-rural digital divide is reviewed and scenarios for improving digital connectivity amongst the 'final few', including community-led broadband, satellite broadband and mobile broadband, are considered. A call is made for *digital future proofing* in telecommunications policy, without which the already faster urban areas will get 'faster, fastest' leaving rural areas behind and an increasingly entrenched urban-rural divide.

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1. Introduction

For many it is difficult to imagine life without digital modes of communication. In the discourse that the Internet bestows significant benefit upon those who use it, global media assume that digital connectivity is ubiquitous and governments exhort citizens to interact with the state online. However, despite the digital society's apparent pervasiveness, not everyone is digitally connected: for example, in Britain in 2014, 16% of households, approximately 4 million, were not online (Office for National Statistics, 2014). In the Global North digital non-participation is, for some, a personal choice. Others may lack digital literacy skills or be unable to afford a digitally-enabled device and/or an Internet Service Provider (ISP) contract, reinforcing a close association between financial exclusion and social exclusion (Chen and Wellman, 2005; Fuentes-Bautista and Inagaki, 2012; Warren, 2007). However, other barriers to digital participation result from the geography of digital telecommunications infrastructure: such territorial

based barriers are often overlooked as mediating a lack of digital connectivity, especially at national levels.

The aims of this paper are threefold. Firstly, we reflect on the extent of territorial digital divides in England, Scotland and Wales based on our analysis of data published by the UK telecommunications regulator, Ofcom. Secondly we consider the implications of digital exclusion for rural and, particularly, remote rural, areas, illustrated through a series of case vignettes. Thirdly we review the policy context of broadband and mobile internet infrastructure in Britain and offer critical reflections on alternatives to publicly subsidised and industry-delivered fixed broadband infrastructure improvements that could play a role in addressing territorial digital divides.

2. Digital divides, digital exclusion and digital inequalities

Since the early 2000s, digital divides and related topics such as digital exclusion and digital inequalities have received considerable attention from national and international policy communities and from scholars in a wide range of disciplines, including, for example, Human Geography (Malecki, 2003; Riddlesden and Singleton, 2014; Warren, 2007), Media, Communication and Telecommunications (Helsper, 2012; Howard et al., 2010; LaRose et al., 2007;

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Sparks, 2013), Sociology (DiMaggio et al., 2010; Blank and Groselj, 2015; Khatiwada and Pigg, 2010; Nephew Hassani, 2006; Stern and Wellman, 2010; White and Selwyn, 2013) and Public Policy (Prieger, 2013; Skerrat, 2013). However, relatively little of this research has offered explicit rural perspectives on digital challenges. The Organisation for Economic Co-operation and Development (OECD, 2001) offered a useful working description of the term 'digital divide', stating that it "refers to the gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard to both their opportunities to access information and communication technologies (ICTs) and to their use of the internet for a wide variety of activities" (p5). In the same year, DiMaggio et al. (2010) described the *digital divide* as being "inequalities in access to the Internet, extent of use, knowledge of search strategies, quality of technical connections and social support, ability to evaluate the quality of information, and diversity of users" (p310). Over a decade later, Sparks (2013, p28) noted that the digital divide is a term "used to cover a broad range of social differences in access to and use of digital equipment and services, most notably personal computers, and the ability to access the internet in terms of both physical connection and facility of use". These definitions allude to two broad, interrelated digital divides: (i) socio-economic digital divides and (ii) divides resulting from inequalities in the technological infrastructure required to support digital connectivity.

2.1. Socio-economic digital divides

Research that pays attention to relationships between socio-economic factors and digital divides falls into two broad categories that, at least in part, reflect the impact of Internet diffusion over the past three decades. One category, described by Blank and Groselj (2015, p2763) as studies of a "first level digital divide", has focused upon who is online/offline or who is a digital have/have not and how this has changed over time. In essence, this work is concerned with who does and does not have access to computers and to the Internet. Internet use/non-use has been shown, at the level of the individual, to reflect differences in education, ICT skills, attitudes (notably whether or not an individual thinks the Internet is of use or of interest to them), financial circumstances, social capital, and age. The second category is, according to White and Selwyn (2013, p2), a "more sophisticated" understanding of socio-economic digital divides that has emerged out of research conducted since the early 2000s, research that has cemented a recognition that "the crude notion of 'the digital divide' is better understood as a set of digital divides or inequalities … or as a spectrum or continuum of difference" (*ibid.*). In part this more nuanced understanding reflects the efforts of researchers to keep up with the very fast pace of change in the digital landscape. Early research about Internet use was predicated on users accessing the Internet via a fixed Internet connection in the home or in a public place such as a library via a personal computer. Now the Internet can be accessed in many ways, including via fixed, mobile, public and private connections, from multiple locations and by using different types of Internet enabled devices. Developments such as Wi-Fi connections, 3G and 4G mobile Internet networks and the proliferation and ownership of multiple devices such as laptops, tablets, smart phones and other Internet enabled devices which facilitate Internet connectivity on the move introduce greater complexity into discussions about Internet use and digital divides. A more sophisticated understanding of digital divides encompasses a move towards exploring who is able (or not) to make use of the many potential benefits the Internet offers. Blank and Groselj (2015) suggest that this represents a shift of focus from digital divides to digital inequalities and identify four themes that illustrate this shift: (i) digital skills/literacy; (ii) the autonomy of users in accessing the Internet; (iii) the social support available to those who want to use the Internet; (iv) and the extent to which individuals are integrated into the prevailing 'techno-culture'. Interestingly Blank and Groselj position digital inequality as being associated with individuals and their socio-economic circumstances: mention is not made of the influence of digital infrastructure provision and availability on digital behaviour.

2.2. Digital infrastructure and digital divides

Internet adoption and use by individuals, households and businesses is contingent on the availability of a telecommunications infrastructure delivered and maintained via the public and/or private sector. Reflections on the digital divide must therefore be cognisant of the digital infrastructure environment that influences how a user gains access to the Internet. The extent, type, reliability and quality of digital infrastructure varies at global, national and sub-national levels and these variations have a profound effect on the ability of Internet users, or those who would like to become Internet users, to be digitally connected and their corresponding online experiences.

Warren (2007, p375) defined *digital exclusion* as a situation where " … a discrete sector of the population suffers significant and possibility indefinite lags in its adoption of ICT through circumstances beyond its immediate control". One such type of digital exclusion is territorial and reflects variations in the availability and quality of telecommunications infrastructure at different spatial scales. An urban-rural digital divide across many countries in the Global North has been acknowledged for some time in academic and policy circles. In 2001 the OECD identified, at the international level, an urban-rural digital divide that was framed by cost and quality of access and related network costs and infrastructure capabilities. Research conducted in North America (e.g. Howard et al., 2010; Carson, 2013; Stenberg et al., 2009; Malecki, 2003), Australasia (e.g. Black and Atkinson, 2007; New Zealand Department of Internal Affairs, 2011) and Europe, including the UK (e.g. Johnson et al., 2012; Peters et al., 2013), reports attempts to improve digital telecommunications infrastructure in remote rural communities but also illustrates the stubborn nature of rural digital exclusion. A common finding is that the rural telecommunications infrastructure is inferior to that serving urban areas. This results in large numbers of people being unable to fully exploit the potential of ICTs because of where they live and work: yet there is a paucity of literature about the specific spatial nature of rural digital exclusion and the ramifications of this.

Improvements to the fixed telecommunications infrastructure, in particular the roll out of superfast and fibre broadband networks and 3G and 4G mobile Internet coverage, have been spatially uneven. In many countries, the UK included, most urban telecommunications networks, along with those serving other areas with reasonably high population densities have been improved. However, more sparsely populated and rural areas commonly lag behind. A small minority of rural residents and businesses in the UK cannot secure a fixed Internet connection. Others can only obtain a slow, unreliable fixed connection. With the gap between Internet users and non-users having contracted in recent years, concerns about digital exclusion, in a rural context or otherwise, are as likely now to arise from the challenges of broadband infrastructure that is unfit for purpose as they are to be concerned with inequalities arising from potential users, by choice or otherwise, not being able to access a service at all.

2.3. Digital divides and the UK policy context

Sparks (2013 p29) noted that " … the continued existence of a digital divide, however defined, is an obstacle to any agenda of social inclusion. If societies are today partly, and will in the future be more or less completely, structured around the internet, then the demands of economic efficiency as well as social and political equity require that no social group finds itself excluded from participation". It is unsurprising then that national governments across the world have attempted to address aspects of digital divides such as providing access to Internet enabled computers in public places, supporting measures to increase ICT literacy, promoting the use of public services delivered via online platforms and supporting the establishment and upgrading of telecommunications infrastructure.

In the UK, the Westminster Government-led initiative to improve digital infrastructure - the Broadband UK (BDUK) programme - plans to roll out superfast broadband infrastructure to all areas of England, Scotland and Wales. Superfast broadband is defined by the UK government as that supporting sync speeds above 24Mbit/s. Superfast broadband for all in reality means superfast broadband for the majority, 95% of the population. The current UK government commitment is broadband for 'all' at only 2Mbit/s, a speed inadequate to support effective digital participation. The remaining 5% are almost all located in the most peripheral 'hard to reach' rural areas where there are no plans for fixed infrastructure improvements. Thus in the context of digital infrastructure improvements the already 'faster' areas are 'getting faster, faster' whilst many rural areas are continually trying to 'catch up'. The current policy context raises questions about how digital connectivity may be brought to the 'hard to reach' 'final few' particularly against a backdrop of the public's and businesses' ever increasing demands for digital data and the UK government's 'Digital by Default' objective to shift government services from a mixed on- and off-line mode of delivery to online-only. Although public funding is supporting the BDUK infrastructure improvements, it remains likely that the BDUK programme will not deliver fixed digital infrastructure across peripheral rural areas of the UK of the current urban average standard, let alone a future-proofed infrastructure. The continued development and deployment of new, alternative models of digital infrastructure provision is thus crucial to alleviate further entrenchment of (territorial) rural digital exclusion.

3. Telecommunications infrastructure

In Britain, most fixed Internet is provided over a broadband connection, data transmission along a single line which can carry two or more channels, e.g. voice and data, simultaneously. The type of line serving consumers ('traditional' or 'next generation' copper lines, cable TV lines or fibre-optic lines), and the 'final mile' distance between users and the communications network (the 'cabinet'), determine speed and reliability of the connection.

In the late 1980s and the 1990s the first domestic fixed Internet connections utilised existing copper telephone lines and users accessed the Internet via a modem that allowed their telephone line to be converted into a technology that could send and receive data. These 'dial up' or narrowband connections were capable of supporting download speeds of between 0.5 and 2Mbit/s. The introduction of broadband connections came with Digital Subscriber Lines (DSL). In the year 2000 an improved copper line infrastructure — Asymmetric Digital Subscriber Lines (ADSL) - was introduced in the UK. ADSL lines support an advanced (or 'current generation') copper network capable of supporting download speeds up to 24Mbit/s. Connection speeds on ADSL lines are influenced by the distance between the users' premises and the cabinet. If the 'final mile' exceeds 1.2 km, speeds are compromised and superfast broadband cannot be delivered. The most advanced technology, capable of supporting download speeds of between 30Mbit/s - 1Gbit/s, is delivered via a cable or fibre-optic network. Signals sent along fibre-optic lines (comprising thousands of very thin glass fibres) do not weaken over long distances meaning that users of fibre to the home infrastructure do not experience a slow connection if their premises are at a distance from the cabinet. In reality, many fibre installations only go as far as the cabinet, relying on existing copper telephone lines to link the upgraded network exchange to individual homes and business premises. The length of this final part of the connection determines the extent to which a user benefits from their cabinet being upgraded. The geographical coverage of cable and fibre lines is far from universal. High installation costs are offset against prioritising roll out in areas where the density of potential subscribers is high enough to make the service commercially viable.

Alternatives to fixed Internet connections are available. Europe-wide, territorial satellite coverage is at 98.6% (European Commission, 2013). The satellite broadband market is becoming increasingly competitive (Ray, 2012), yet take up of satellite broadband remains a very small share of the British broadband market. Internet access 'on the go' is supported by mobile Internet services delivered over 3G and 4G networks and by increasing numbers of wireless (Wi-Fi) hotspots. Although access to the Internet by mobile phone in the UK "more than doubled between 2010 and 2014" (Office for National Statistics, 2014, p1), latest estimates suggest that 28% of rural areas in the UK are 'not spots' in that homes are without adequate mobile phone coverage (Ofcom, 2015, p32). In the UK digital telecommunications service providers operate in the private sector and commercial priorities mean that their infrastructure developments focus on populous areas with the largest potential number of consumers. This helps to explain why urban digital infrastructure - fixed and mobile - is rarely matched in quality and reliability by the infrastructure servicing less populated rural areas.

The *prima facie* case for an urban-rural digital divide, largely as a result of variations in the quality of the digital infrastructure serving different areas, is acknowledged, but detailed accounts of the spatial characteristics of digital communications infrastructure are rarely reported. We now present an analysis of fixed and mobile broadband infrastructure attributes for England, Scotland and Wales which clearly shows an urban-rural digital divide, but more specifically a 'deep' rural versus 'shallow' rural and urban divide.

4. Evidencing an urban -rural digital infrastructure divide in Britain

4.1. Ofcom's digital infrastructure data

The telecommunications regulator Ofcom publishes data about the fixed broadband network for each Local Authority in England, Scotland and Wales. It also publishes much smaller scale - unit postcode level - data, the most recent of which at the time of writing were published in December 2013. The Ofcom datasets include variables reporting the proportion of lines with speeds below 2.2Mbit/s, average speeds and the availability of superfast broadband. Ofcom does not report equivalent data about satellite broadband in the UK. Data about the mobile Internet networks available across Britain are available at Local Authority level and include variables based on geographical and premises coverage and about 2G and 3G provision.

Our interrogation of the Ofcom data for evidence of an urban-rural digital divide began with the application of urban-rural

classifications to Ofcom data. There is no official Britain-wide urban-rural definition; different definitions are in place for England, Scotland and Wales that reflect the different geographies of the three nations. Firstly, to support our local authority level analysis, we applied the following urban-rural classifications established by DEFRA, the Scottish Government and the Welsh Assembly Government to Ofcom's English, Scottish and Welsh data respectively:

(1) For England, a 3-fold urban-rural classification of local authorities - urban, significantly rural and predominantly rural - is used following the classification outlined by the English Department of the Environment, Food and Rural Affairs (see Figure 4 in DEFRA, 2005);

(2) The Scottish local authorities are classified following the two-fold Randall classification - urban and rural (Scottish Government, 2009; no page numbers);

(3) For Wales, the Welsh Government's 'Four way classification' of Urban, Rural, Valley and Other is used (Welsh Government, 2008, p8–9).

Secondly, to support finer grained analysis of Ofcom's fixed broadband infrastructure data set, unit postcodes (the smallest geographical unit in the UK postcode system) were geo-coded as being either urban, shallow rural or deep rural based on based on DEFRA's six-fold urban-rural definition (applied across England and Wales) and the Scottish Government's six-fold urban -rural classification using postcode matching of files published by DEFRA (https://www.gov.uk/government/collections/rural-urban-definition) and the Scottish Government (http://www.scotland,.gov.uk/Topics/Statistics/SIMD.SIMDPostcodeLookup). Our three-fold categorisation is as follows:

Urban. England and Wales: urban/rural classification categories 'urban − less sparse' and 'urban − sparse'. Scotland: urban/rural definition categories 'large urban areas' and 'other urban areas'.
Shallow Rural. England and Wales: urban/rural classification categories 'town & fringe − less sparse' and 'village, hamlet & isolated dwelling − less sparse'. Scotland: urban/rural definition categories 'accessible small towns' and 'accessible rural areas'.
Deep Rural. England and Wales: urban/rural classification categories 'town & fringe − sparse' and 'village, hamlet & isolated dwelling − sparse'. Scotland: urban/rural definition categories 'remote small towns', 'very remote small towns', 'remote rural areas' and 'very remote rural areas'.

Our analysis of Ofcom data addressed three questions. Firstly, what is the local authority level picture of fixed Internet provision across Britain? Second, what evidence of an urban-rural digital divide does analysis of unit postcode level data provide? Thirdly, can mobile Internet infrastructure compensate for an urban-rural divide in fixed broadband infrastructure provision in England, Scotland and Wales?

4.2. Speed matters: attributes of fixed internet infrastructure at national and local authority level for England, Scotland and Wales

In December 2013 there were 22.6 million fixed broadband connections serving private residences and the premises of Small and Medium sized Enterprises (SME) in the UK (Ofcom, 2014c). As noted above, broadband connections vary greatly in the speeds that they support. Many consumers live in areas where the local ICT infrastructure capability is insufficient to allow their ISP's headline speeds to be achieved. The range of activities routinely undertaken online is increasing, the data requirements of many applications and web sites are growing, and home broadband is now expected to support multiple device-owning and simultaneous-user households. A broadband service that meets these expectations is not available to all British households.

The speed of broadband service received is an effective measure of expressing the variability of Internet provision. Our analysis of Ofcom broadband speeds data clearly shows there is a 'two-speed' Britain. As reported in Table 1, the overall pattern is that broadband speeds in rural areas are consistently lower than those received in urban areas and that rural areas are the least likely to be served by superfast broadband infrastructure.

In 2016 the UK's Department of Culture, Media and Sport (DCMS) observed that when the Communications Act (2003) regulating Internet infrastructure was introduced, home broadband services typically delivered speeds up to 0.5Mbit/s. Over a decade later a broadband connection operating at or below 2.2Mbit/s is considered to be very slow, providing an inadequate service. Table 1 reports that a sizeable minority of broadband connections across the UK in December 2013, in both urban and rural areas, had sync speeds of less than 2.2Mbit/s. Such slow connections are incapable of supporting many now routine online applications (e.g. streaming a movie clip) and other ubiquitous online activities such as uploading or downloading photographs are very slow. These inadequate connections cannot support 'next generation' households (Dutton and Blank, 2011), where several members of a household use multiple devices to be online simultaneously.

National speed data hide considerable variability at local authority level, let alone at smaller spatial scales. For example, in England the proportions of very slow connections range from 3.1% (in City of Kingston upon Hull) to 22.3% (Isles of Scilly). Table 1 shows that rural local authority areas are more likely than urban local authority areas to have sync speeds of less than 2.2Mbit/s. In rural and especially in the more sparsely populated and peripheral 'deep rural' areas, consumers' distance from the cabinet and a long 'final mile' connecting their home to the telecommunications network is the predominant reason for slow broadband connections (Williams et al., 2016).

Following considerable public and private sector investment under the BDUK programme, 78% of UK properties were able to receive superfast broadband in June 2014 and there were 6.1 million superfast broadband connections in the first quarter of 2014 (Ofcom, 2014c). However, as noted earlier, infrastructure improvements bringing superfast broadband to consumers have been concentrated in densely populated, urban areas. Table 1 reports that it is more readily available in England than in Scotland and Wales. Variations in superfast broadband availability across urban and rural areas are also evident. English local authority areas defined by DEFRA as predominantly rural fare much worse than English urban and significantly rural local authority areas, yet they are more likely to have superfast broadband available when compared with the local authority areas classified as 'rural' in Scotland and Wales.

Ofcom report average sync speed data, figures which provide a reliable indication of the actual broadband speeds customers receive. At the end of 2013 the average sync speed for England, Scotland and Wales combined was 16.0Mbit/s but, as reported in Table 2, there are large variations between the three nations and between the urban and rural local authority areas across Britain as a whole. Average sync speeds are highest in England, reflecting the more widespread availability of superfast broadband in England than elsewhere in Britain. However, none of the predominantly rural English local authority areas had average sync speeds matching the English average. Likewise, none of the Welsh rural local authorities reported average sync speeds that matched the Welsh average. In Scotland, only one rural local authority's average sync speed matched the Scottish average and only four of the 14

Table 1
Overview of the availability of superfast broadband, local authority level, England, Scotland and Wales.

	England				Scotland			Wales				
	Urban	Significantly Rural	Predominantly rural	England	Urban	Rural	Scotland	Urban	Valley	Other	Rural	Wales
Average % availability of superfast broadband	85.0%	70.3%	45.6%	76.3%	65.5%	15.7%	43.7%	84.2%	36.5%	62.4%	14.9%	40.1%
Range of superfast broadband availability	12.1%–91.8%	21.6%–90.8%	0%–82.5%	0%–91.8%	20.1%–95.1%	0%–59.5%	0%–95.1%	77.5%–91.1%	0%–65%	56.7%–70.0%	0%–45%	0%–91.1%
Area type's relationship to national average superfast broadband availability	17/82 areas below English average	12/18 below English average	19/20 areas below English average		3/18 areas below Scottish average	12/14 areas below Scottish average		No areas below Welsh average	2/5 areas below Welsh average	No areas below Welsh average	8/9 areas below Welsh average	

Source: Authors' analysis of Ofcom's December 2013 local authority broadband infrastructure data. Data available at http://maps.ofcom.org.uk/broadband/

Table 2
Average Sync speed, urban, significantly rural and predominantly rural local authority areas, England, Scotland and Wales.

	England				Scotland			Wales				
	Urban	Significantly Rural	Predominantly rural	England	Urban	Rural	Scotland	Urban	Valley	Other	Rural	Wales
Average sync speed (Mbit/s)	19.3	16.0	11.4	17.5	17.4	8.8	13.6	20.1	10.8	13.6	8.1	11.4
Range of average sync speed (Mbit/s)	10.4–24.9	11.6–22.3	4.4–15.8	4.4–24.9	8.5–23.9	5.1–14.1	5.1–23.0.9	19.4–21.3	6.8–11.8	10.3–17	6.3–10.8	6.3–21.3
Relationship to English average sync speed	20/82 areas below English average	14/18 areas below English average	All predominantly rural below English average		5/18 areas below Scottish average	13/14 areas below Scottish average		No urban areas below Welsh average	3/5 below Welsh average	2/5 below Welsh average	All rural areas below Welsh average	

Source: Authors' analysis of Ofcom's December 2013 local authority broadband infrastructure data. Data available at http://maps.ofcom.org.uk/broadband/

Scottish rural local authorities reported average speeds that matched or exceeded the rural average. Almost a fifth of British local authorities had average sync speeds at or below 10Mbit/s - the minimum speed the British government now considers necessary to allow 'full participation in our digital society' (DCMS, 2016, p11). Of these, 5 were predominantly rural authorities in England, 13 (10 rural) were in Scotland and 10 (8 rural) were in Wales.

Ofcom reports overall broadband and superfast broadband take-up rates separately. Take-up of broadband overall varies little between England (73.0%), Scotland (71.9%) and Wales (69.8%) and negligibly between urban and rural local authority areas. Across Britain there is a strong, positive correlation between the availability and take-up of superfast broadband (England $r_s = 0.863$, df 118, $p \leq 0.01$; Scotland $r_s = 0.978$, df 30, $p \leq 0.01$; and Wales $r_s = 0.885$, df 20, $p \leq 0.01$). This suggests that as superfast broadband availability continues to improve take-up rates will also increase. Interestingly, in England, the positive association between superfast broadband availability and take-up in the predominantly remote rural local authorities ($r_s = 0.819$, df = 18, $p \leq 0.01$) is as strong as it is in the urban and significantly rural local authorities ($r_s = 0.719$, df = 80, $p \leq 0.01$ and $r_s = 0.756$, df = 16, $p \leq 0.01$ respectively). In Scotland there is an almost perfect association between superfast broadband availability and take-up rates in both urban and rural areas ($r_s = 0.973$, df = 16, $p \leq 0.01$ and $r_s = 0.932$, df = 12, $p \leq 0.01$ respectively). This infers that, in both urban and rural areas, as superfast broadband becomes available, similar proportions of the population will sign up to receive it from their ISP.

4.3. A more nuanced picture: attributes of fixed internet infrastructure in urban, shallow rural and deep rural areas across Britain

Our analysis of fixed broadband speed and take-up data at local authority level has shown clear variations between urban and rural areas of England, Scotland and Wales, amounting to evidence of a digital divide. Focusing upon local authorities as the unit of analysis may not, however, provide the clearest picture. Many 'rural' local authority areas contain large settlements (i.e. urban areas) and 'urban' authorities often encompass sparsely populated communities. We now turn to our analysis of Ofcom unit postcode area data, geo-coded as urban, shallow rural and deep rural, to provide a much more detailed picture of the urban-rural digital divide. Following Ofcom's data reporting style, maximum speeds in the three geographical categories were top-coded at 30 Mbits/s. Table 3 shows considerable differences in attributes of fixed broadband connections in urban, shallow rural and deep rural areas across Britain. Perhaps the most striking difference is in the availability of Next Generation Broadband (NGB),[1] which ranges from a high of 86.43% of postcodes in urban England to a low of 1.18% of postcodes in deep rural Wales. Also striking are the differences in maximum speeds which range from a high in urban England of 25.9 Mbit/s to

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[1] Defined by Ofcom as, "This field indicates whether Virgin Media or Openreach are able to provide superfast broadband services to one or more premises in the postcode. Note, not all premises will necessarily be able to order the service and, for fibre to the cabinet technologies, not all connections will necessarily be able to achieve superfast speeds." (Ofcom, 2013).

Table 3
Selected attributes of broadband infrastructure by urban, shallow rural and deep rural areas, England, Scotland and Wales.

	England			Scotland			Wales		
	Urban	Shallow Rural	Deep Rural	Urban	Shallow Rural	Deep Rural	Urban	Shallow Rural	Deep Rural
Total number of unit postcodes	1,117,290	382,200	30,998	98,368	42,210	24,255	54,484	24,532	21,314
Postcodes with valid* data (%)	71.65%	62.22%	51.78%	77.50%	66.50%	62.70%	73.16%	62.70%	54.04%
% of Postcodes with Lines < 2Mbit/s	37.88%	51.25%	45.31%	28%	46.50%	41.30%	45.17%	54.97%	52.25%
Postcodes where Next Generation Broadband connections are available	86.43%	23.73%	9%	72.00%	9.10%	1.70%	65.05%	18.14%	1.18%
Average speed (Mbit/s)	18.8	8.9	7.4	18	8.3	7.9	15.1	8.0	6.4
Maximum speed (Mbit/s)	25.9	13.4	10.5	24	12.1	11.1	22.1	12.7	9.27

* Ofcom do not report data for all unit postcodes. Those classified as having 'no premises', or 'insufficient' data were removed from the data set, with the analysis using only those remaining postcodes, described as having 'valid data'.
Source: Authors' analysis of Ofcom's December 2013 postcode infrastructure data. Data available at http://maps.ofcom.org.uk/broadband/

Table 4
Summary Descriptive Statistics, broadband speed by urban, rural and deep rural areas, England, Scotland and Wales combined.

	Mean Average Speed	Maximum Speed
Urban	18.58	25.57
Shallow Rural	8.80	13.23
Deep Rural	7.32	10.40
Great Britain	**16.08**	**22.38**

Source: Authors' analysis of Ofcom's December 2013 postcode infrastructure data. Data available at http://maps.ofcom.org.uk/broadband/

a low of 9.27 Mbit/s in deep rural Wales, reflecting at least in part the national differences in superfast broadband availability. Table 4 reports the mean average and the maximum speeds for urban, shallow rural, and deep rural postcodes for Britain as a whole and shows how national figures 'hide' the variations between urban and rural contexts. Average and maximum speeds in shallow and deep rural areas are much lower than those in urban areas, reflecting the impact of infrastructure upgrade programmes that have seen urban networks improved ahead of most rural networks. Rural infrastructure improvement programmes have, to date, tended to prioritise the more populous shallow rural areas, and this is illustrated by the comparatively better position of shallow as compared to deep rural areas reported in Table 4. Sparsely populated and peripheral deep rural areas are the last in line for infrastructure upgrades, if they are scheduled at all, and these are the areas where the urban-rural digital divide is most pronounced. This point is illustrated visually in Map 1 where Ofcom unit postcode level maximum broadband speeds data have been mapped for three areas of the UK which, whilst all predominantly rural in character, contain urban, shallow and deep rural areas and have areas where the maximum speed that can be received varies hugely. The areas with the highest average maximum speeds align with the urban centres of North-East Scotland (the local authority areas of Aberdeen City, Aberdeenshire and Moray), Dumfries and Galloway in southern Scotland and Shropshire in England. The lowest speeds are found in the more sparsely populated, but geographically extensive, deep rural areas of these parts of Scotland and England.

4.4. Mobile internet infrastructure in Britain

A feature of online behaviour worldwide over the last decade is the move from fixed connection to 'on the move' Internet access facilitated by the growth of public Wi-Fi hotspots providing Internet access in public places to those with a laptop or a tablet, by the use of USB dongles, external modems and microSIM for tablets, and, most markedly, the introduction and rapid uptake of Internet enabled mobile telephones (smartphones). All of these 'on the move' technologies rely on the user being in a location where the mobile telecommunications infrastructure supports Internet access, i.e. areas where a 3G or 4G signal is available. 4G was introduced to the UK in 2012 and two years later there were over 6 million active 4G mobile subscriptions (Ofcom, 2014c). However, many parts of the UK, including most deep rural areas, are not served by this technology. To date, Ofcom has not published sub-UK data about 4G infrastructure or take-up, but data about 2G (telephone phone only services) and 3G networks are available at local authority level.

Despite the widespread adoption of mobile phones in the UK and elsewhere - 93% of adults in the UK in the first quarter of 2014 had a mobile phone, and 61% owned a smartphone (Ofcom, 2014c) - no 2G mobile signal is available across 12.79% of the UK land mass (Ofcom, 2013). There is no 3G signal across 22.9% of the UK land mass (ibid.). Poor 3G coverage, mostly affecting rural areas, curtails the ability of Internet users to be online, 'on the move', across large swathes of Britain.

Table 5 reports clear urban-rural variations in 2G and 3G coverage across Britain. At a national level, mobile infrastructure is best across England and worst in Scotland and premises-level coverage is much better than geographical coverage. At sub-national level, mobile infrastructure is poorest in rural areas of Scotland. The geographical coverage data reports that across almost a quarter of rural Scotland there is no reliable 2G signal from any operator. Almost half of rural Scotland does not have a reliable 3G signal from any operator. Across half of the Scottish land mass it is impossible to be online, on the move, unless the user finds a Wi-Fi hotspot. Most urban areas are served by 2G and 3G coverage from all operators, but many rural areas are only served by a single operator, largely as a result of British mobile telecommunications operators not supporting data roaming across their networks for domestic consumers. This situation reduces rural consumer choice, a situation described as 'absurd' in a recent British Cross-Party MPs Report (British Infrastructure Group, 2016). Poor rural network coverage also inhibits the ability of domestic consumers visiting rural Britain to pick up a signal from their usual operator and to remain connected on the move and where no 3G signal is available at all those living, working and visiting rural areas cannot be online 'on the move'.

There is considerable overlap between areas of England, Scotland and Wales with a poor fixed broadband service and areas with the worst 3G coverage. Ofcom's suggestion that the limitations of fixed Internet infrastructure could be overcome by consumers using mobile Internet services is not feasible across most of rural Britain. Though of considerable potential benefit to rural areas, without adequate infrastructure it will be difficult, if not impossible, for rural residents and businesses to make full use of mobile
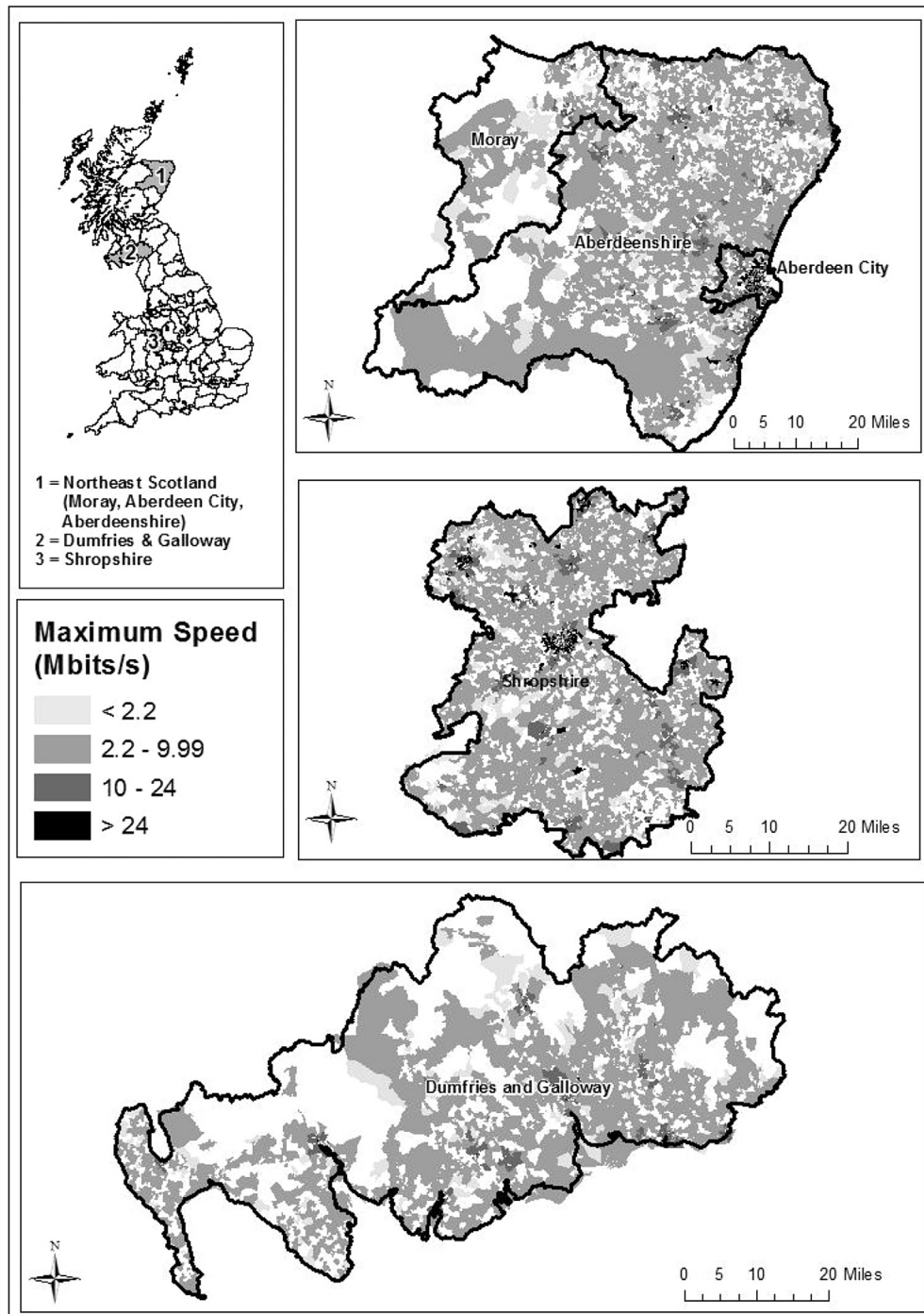
Map 1. Maximum broadband speeds in selected rural areas of the UK.
Source: Authors' analysis of Ofcom's December 2013 postcode infrastructure data. Data available at http://maps.ofcom.org.uk/broadband/. Postcodes for which Ofcom report there were insufficient data collected or which had no or insufficient premises included were filtered out for simplicity of visualisation, and are shown as white areas on the maps. Baseline postcode data were obtained from the EDINA Digimap Ordnance Survey Service (2016). OS Code-Point with Polygons [Shapefile geospatial data last updated in May 2008 were used and are available from http://edina.ac.uk/digimap].

telecommunication opportunities unless network coverage is extended.

Our analysis has shown that those who live and work in rural areas of Britain, especially deep rural areas, are less likely than their urban counterparts to be able to fully exploit the many benefits the Internet confers, not because they choose not to be online in higher proportions than urban residents, but because of the limitations of the fixed and mobile telecommunications infrastructure by which

they are served. In an increasingly digital society such territorial digital inequalities can have profound implications for those who live and work in rural areas, constraining Internet use for personal and business activities and affecting how people of all ages can be engaged in the digital society. We now illustrate some of these challenges.

Table 5
Attributes of mobile infrastructure at local authority level, England, Scotland and Wales.

	England				Scotland			Wales				
	Urban	Significantly Rural	Predominantly Rural	ALL	Urban	Rural	ALL	Urban	Valley	Other	Rural	ALL
% of area with no reliable 2G signal from any operator, geographic coverage	0.3%	1.5%	5.6%	1.7%	3.6%	24.3%	12.7%	1.3%	2.6%	5.0%	15.1%	8.1%
% of area with 2G signal from all operators, geographical coverage	95.2%	84.0%	72.1%	89.7%	81.7%	42.0%	64.4%	88.9%	83.0%	75.7%	51.6%	69.3%
% of area with no reliable 2G signal from any operator, premises coverage	0.0%	0.1%	0.9%	0.2%	0.1%	3.1%	1.4%	0.1%	0.1%	0.5%	3.0%	1.4%
% of area with 2G signal from all operators, premises coverage	98.3%	93.8%	85.9%	95.6%	96.2%	77.6%	88.1%	97.5%	92.0%	88.9%	75.7%	85.4%
% of area with no reliable 3G signal from any operator, geographic coverage	0.4%	2.5%	13.8%	2.9%	6.2%	46.9%	24.0%	1.4%	3.7%	5.0%	20.6%	10.6%
% of area with 3G signal from all operators, geographical coverage	82.7%	44.5%	21.7%	66.8%	50.3%	2.9%	29.6%	76.1%	47.9%	43.7%	5.2%	33.3%
% of area with no reliable 3G signal from any operator, premises coverage	0.1%	0.3%	7.0%	1.2%	0.3%	13.8%	6.2%	0.1%	0.7%	0.8%	6.0%	2.8%
% of area with 3G signal from all operators, premises coverage	93.2%	74.7%	50.3%	83.3%	80.9%	28.2%	57.8%	94.0%	63.9%	70.8%	27.8%	54.8%

Source: Authors' analysis of Ofcom's December 2013 local authority mobile infrastructure data. Data available at http://maps.ofcom.org.uk/mobile/

5. Implications of poor (or no) digital connectivity in rural areas of Britain

Research conducted under the auspices of the UK Research Council's award to the Rural Digital Economy Hub − dot. rural − based at the University of Aberdeen (2009−2015) highlights aspects of digital exclusion. Participants in four recently completed research projects[2] who lived in deep rural areas of England and Scotland discussed day-to-day digital connectivity challenges they faced. Some of them want to be online but the infrastructure where they live cannot support a home broadband connection. Others struggle with inadequate connectivity, with implications for business and personal lives. The vignettes below illustrate a new form of social exclusion affecting many deep rural communities in the UK and elsewhere.

5.1. Farm businesses

Evan* is a hill farmer. His wife Vicky* moved to the farm seven years ago, and the couple attempted to get broadband at the farmhouse. Vicky spoke of the challenges:

"… it was really dodgy wasn't it and I used to spend virtually every Saturday on the phone to [providers] to try and get them to fix it. … And then they re-laid the whole cable […] and it got even worse after that … And they said sorry there's nothing we can do to get you Internet please don't phone us again."

In the absence of an alternative, Evan and Vicky use a dongle to access a broadband service via a mobile signal: this is proving increasingly ineffective. During the interview, Vicky loaded a Sheep Society web page - it took 4 min and 49 s.

For those who had an Internet connection, a recurring issue was that their broadband service was too slow and/or unreliable. Offline modes for commercial transactions and regulatory paperwork are being withdrawn and digital connectivity is crucial for rural business. Sheila*, who farms with her husband in the north-west of England, has signed up to a community broadband scheme, and talked about her use of the Internet:

"Well, for business, I need it for registering calves; when calves are new-born, they have to be registered within 28 days, which has to be done online with BCMS [British Cattle Movement Service]. So I use it for that, and for tax purposes, doing my tax work online, my VAT returns have to be done online now: you've no option, now they have to be done online, so I'm grateful that we've got it".

Sheila's comments indicate how important a reliable Internet connection is for her farm business: without the community broadband service her business would be disadvantaged because of the 'push' to undertake farm regulatory administration and management activities online and the difficulties and financial penalties incurred if using (diminishing) offline alternatives. Evan provided

illustrations of such financial penalties:

> "Fees for 2014, birth notifications, each one's costing £1.80 including vat - if you were to do the paper system … that's £1.98. Yeah, so it's 18 pence more [than online registration] by 450. Well we birth notify on average about 450 lambs, so … it's £81 pounds just on birth notifications …

5.2. Non-farming businesses

Non-farming businesses are also adversely affected by poor connectivity. Edward*, who lives in the rural north-west of England and works as a business consultant, found that "*at the moment the speed is pretty useless for anything*". This was having a considerable impact on his work: "*from a business point of view it means you can't effectively download videos, transmit video clips, it's just not practical*". As a business in an increasingly digitally connected economy, "*we're dealing with suppliers online a lot more than we ever did*" making the lack of connectivity even more apparent.

Employers routinely expect their employees to be digitally connected, especially if they regularly work out of the office. John*, who lives in rural Shropshire, works for a utilities company and is rarely desk-based. He runs his work mobile phone off a fixed broadband connection when he is at home and accesses his work schedule for the day on a work laptop via his home broadband. He is often 'on call'. The household's unreliable and slow broadband connection (compounded by lack of access to any mobile connectivity in the village where John* lives) causes problems:

> "when they ring me [when 'on call'] I've got to be where I've got to be within two hours […] So to go from here to [large conurbation] in two hours you don't want to spend three quarters of an hour trying to get the job down on your laptop. … like I was called out last night, I stopped on the way home to send my job back … because I knew that when I came home I'd have to try and log on via the Internet at home and I may or may not get it, in which case if I haven't sent my job back, they don't know I've left site […] eventually they're going to turn around and say the job is still there and try and send it out again."

These illustrations underline real threats to rural economic competitiveness and the potential curtailment of some job opportunities for rural residents because of poor connectivity.

5.3. Individuals

Individuals of all ages are increasingly turning to the Internet for health information. Moira*, who is in her 60s and suffers from a chronic long-term illness, and her spouse, Frank*, were asked whether they used the Internet to look for information about Moira's medical condition. They live on a remote Scottish island and their home broadband is very slow. Frank mentioned:

> "I've got a couple of websites that actually come up automatically every so often, … and they are very much into the things to help [specific medical condition]. But again, a problem here is that the Internet is so slow so you've got to have time to sit and let it — it can take two or three minutes for a page to load …"

Young adults have grown up in a digitally connected world. Familiar with a range of Internet enabled technologies they tend to use their mobile phones to communicate via social media platforms as well as using their handset's telephone and text messaging functions. Rural young adults complain about poor 3G coverage. Julie* lives in northern Scotland and was due to leave the area to go to University when she was interviewed. Her home Internet service is poor and she often went to a nearby café to access the Internet via her smartphone. She said:

> "With my iPhone I kind of … Well I text people, I use it for Facebook, for my emails, umm … games, of course … typical iPhone games. Angry Birds … I just use it for — mainly for texting and contacting friends via Facebook and Twitter and looking at my emails as well. Recently, it seems like I've just started doing all my University stuff, and trying to sort out my accommodation I've been using my emails a lot more than I used to."

Julie complained that the 3G phone coverage in her village is sporadic and this constrains use of her smart phone:

> "… it's absolutely rubbish. It's awful. There's some streets where you can't get it at all and there's some streets where you can't really get it in the middle of the house; you just have to like go up to the windows and put it against the windows."

Two teenage girls, Carol* and Christine* live with their parents John and Fran* in a small Shropshire village. Challenges arising from their poor quality home broadband are compounded by the absence of a mobile signal in the village. Carol recollected that, "… *since about the age of 10 … I've relied on it* [Internet] *quite a lot*" and when asked for what reasons she said:

> "… school and like there's a lot of research that you can do on line, yeah, and talking to friends because there's no mobile signal here and you know it's silly to call one friend when you can talk to several […]. We don't get sent it [homework] via Internet but most of it needs Internet."

Along with their parents these girls comprise a 'next generation' household. The family attempt to operate two laptops, two iPads, two mobile phones, a desktop, an iPod and their satellite television (recordings) off their home, fixed broadband service. Poor digital connectivity cannot support this type of behaviour. The demands made on the "*half a Meg to a Meg*" service cause tensions, as Fran* explained:

> "The biggest bug bear I hear is ' … this is so slow, why's it going so slow, oh it's buffering, oh it's dropped out' and well, you're saying, 'there's too many of us online now […]. And it's just horrendous and she wants to do her homework then Carol's streaming something, you're on the Internet and I'm trying to do a bit of shopping and there's frustration all the time."

The vignettes presented above neatly illustrate the digital connectivity difficulties faced by many living in deep rural areas of Great Britain today. Those living and working in such areas feel poorly served by their Internet connection, are aware that they are excluded from participating in activities that people living elsewhere take for granted and can undertake unhindered, and are aware that digital provision in rural areas is worse than in urban areas. They are also aware that by themselves they can do little to improve their connectivity. The urban-rural digital divide has quickly become an entrenched facet of exclusion facing rural communities. Without continued commitment by public bodies to invest in digital infrastructure and policy mechanisms to encourage

and support the development of acceptable alternatives to fixed broadband connections, the digital cleavage between urban and rural communities will become even more pronounced.

6. The UK digital policy context and options for connecting the 'final few'

Governments around the world have invested considerable sums of public money into digital telecommunications networks supporting fixed, mobile, satellite and other forms of Internet connectivity. The UK is no exception and its response to the territorial digital divide, the BDUK programme, represents a total public sector investment of £780 million in the UK's digital infrastructure (Department of Culture, Media and Sport (DCMS), 2013), designed to support industry-led deployment of both 'superfast' and 'standard' broadband across the UK. BDUK's emphasis is on fixed broadband connectivity. Its revised aims, announced in June 2013, are to (a) provide superfast broadband of 24Mbit/s or above to 95% of premises in the UK by 2017 and (b) to ensure that 'virtually all households' benefit from a speed of at least 2Mbit/s, again by 2017. £530 million has been allocated to stimulate commercial investment to bring high speed broadband to rural communities, and a further £250 million to extend superfast broadband to 95% of the UK and explore approaches for delivering superfast broadband to "the remaining hardest to reach areas" (Department of Culture, Media and Sport, 2013; no page numbers) initially through a £10 million competitive fund.

BDUK rollout plans recognise that it is not commercially viable for private sector ISPs to install fixed broadband infrastructure in 'harder to reach areas'. In practice, however, the hardest to reach areas and the 'final few' households are still, by virtue of geography and economics, predisposed to fall further behind in terms of connectivity and speed. A number of inter-related reasons are posited for this situation, not least the emphasis in UK policy on superfast broadband. UK Government's targets for superfast broadband availability are broadly consistent with a target set by the European Commission in its 'Digital Agenda' (European Commission, 2012), but the focus on speed for the majority detracts from universal access across all of the UK. Superfast broadband rollout favours investment and development in speed-induced technologies such as fibre and high-speed cellular services and diverts investment away from other technologies, arguably those better suited to achieve universal access, such as satellite services.

Assessments of the state of the UK's digital telecommunications infrastructure report overall improvements, suggesting that the BDUK investments are having a positive effect. The increases in average download speeds in urban and suburban areas between May and November 2013 reported by Ofcom were statistically significant but the increase reported for rural areas was not (Ofcom, 2014a, 2014b). The most remote, sparsely populated areas, the 'hard to reach' communities, are still lagging behind in terms of digital infrastructure improvements. As fibre infrastructure (which supports superfast broadband) availability increases in rural areas, Ofcom expects urban-rural differences to contract in the short term but, to date, there are no published plans for fibre broadband to be rolled out UK-wide. As illustrated in Map 1, aggregated statistics obscure the range of download speeds experienced by individual consumers in 'rural' areas. There is no obvious method of ascertaining if improvements to the rural average reported by Ofcom represent rural-wide improvements or significant improvements in a handful of locations.

Efforts in the early phases of BDUK-supported superfast

broadband rollout tended to focus on 'cheaper' areas to upgrade. Subsidies can be quickly absorbed in connecting the majority instead of being held back to help fund the more expensive initiatives required to connect the 5% of the population living in areas which will be most challenging to upgrade. Some commentators have argued that a longer-term strategy to improve broadband provision for all should focus on universal access "that begins at the edges and prioritizes those who currently have no (or poor) broadband connectivity" (Townsend et al., 2013, p590). Only then will the benefits of digital inclusion be achieved and the British urban-rural digital divide begin to close.

UK policy includes explicit attempts to address the challenges of the 'hard to reach'. The up to £20 million Rural Community Broadband Fund (Department of Culture, Media and Sport, 2011) was launched alongside the BDUK programme in 2011 and, in 2013, a £10 million Rural Broadband Trial fund, designed to support the development of alternative, wireless technologies such as satellite, fixed wireless and line-of-sight, was announced (Department of Culture, Media and Sport, 2014). In response to the importance placed on securing higher speed connections illustrated above in the vignettes, we now turn to consider responses to inadequate fixed broadband, describing scenarios in which community-led broadband, and satellite broadband deployment have attempted to improve connectivity in deep rural areas. We also consider what role an improved mobile internet infrastructure could play.

6.1. Options for connecting the 'final few'

The drive towards ubiquitous Internet access, the inadequacies of fixed line broadband provision, and the social and economic cases for connecting the 'final few' will not be met by focusing upon improvements to fixed telecommunications infrastructure delivered by private ISPs alone. A mixed provision model for rural digital infrastructure is called for. A combination of market, government and local forces may be best suited to address rural needs and appropriately future-proof rural digital infrastructure (Carnegie UK Trust, 2012). Having recognised their own need to be online and having lost patience with the slow pace of the commercial roll out of BDUK funded infrastructure improvements some households, businesses and rural communities have taken matters into their own hands. Several communities in Britain have organised themselves and raised funds to develop their own broadband infrastructure, while others based in remote and other underserved localities have taken advantage of devolved government funded initiatives to install satellite broadband.

The ability of communities to "pool resources, plan jointly, and look across needs to achieve economies of scale, better services, and more robust community technology infrastructure" (Mandel et al., 2012, p142) demonstrates the potential for community actors at differing levels to respond to the currently uneven broadband market. Gillett et al., (2004) and the Carnegie UK Trust (2012) have recognised the central role of local communities in the development of broadband infrastructure responsive to local needs and circumstances. Community-led development of local broadband services in the UK is commonly a response to inadequacies in broadband provision by commercial operators. Financial support may be applied for from public bodies. The type of Internet infrastructure developed by community-led providers varies and the model adopted depends on factors including geography, community capacity, and funding. There are live examples of completely community-run broadband service providers in the UK (e.g. Cybermoor, Ltd., Broadband for the Rural North (B4RN) and Lothian Broadband) and this model has also been deployed elsewhere in

Europe and in North America (e.g. guifi.net in Catalonia, Spain; Freifunk in Germany; wlanslovenija in Slovenia; and the Olds Institute, in Alberta, Canada).[3]

Community-led models, although demonstrably successful in connecting the 'final few', are not without their challenges. This was clearly exemplified in Ashmore's doctoral research (Ashmore, 2016), which examines two community-based organisations in the UK whose operations are based on similar models but which have, to date, experienced very different outcomes. The Broadband for the Rural North (B4RN) community organisation deployed a 1Gbit/s Fibre to the Home (FTTH) connection in rural Lancashire. Construction began in 2012 and, by the end of 2014, over 570 homes had been connected. The organisation advertises itself as providing 'The world's fastest rural broadband' (b4rn.org.uk). A second community-led broadband organisation, Broadband for Glencaple and Lowther (B4GAL), was set up in South Lanarkshire, Scotland in 2013. Modelled on the ideals of B4RN, the intention was to roll out FTTH superfast connections. As of mid-2016, however, the group had not successfully achieved this aim.

Ashmore's study identified four key factors that support or hinder community-led broadband projects: access to technical expertise; volunteerism; funding arrangements; and geography (as it relates to the suitability of fixed or wireless broadband provision). B4RN benefited from access to technical expertise within the community, which facilitated planning of a technically robust fibre broadband network and a realistic deployment plan that afforded the project credibility when securing funding. A lack of technical expertise in B4GAL during initial planning was a hindrance and the organisation's project plans needed re-evaluation after both the expense of fibre cabling and difficulties in reaching all households in a timely manner were recognised. This early set-back had knock-on effects because technological and cost uncertainties stalled business plan development and constrained efforts to prepare funding applications to secure the capital required to allow the project to proceed. B4GAL's experiences suggest that regulatory frameworks for telecommunications and high-level policy decisions about community-led models are not always conducive to this type of deployment of infrastructure improvements. Volunteerism and community commitment in both B4RN and B4GAL has been strong but the B4GAL project has had numerous setbacks that have made it challenging to sustain volunteers' engagement in the long term. B4RN relied almost entirely on volunteers for all stages of the project, from writing plans, fundraising and building the fibre network. Volunteers' fundraising efforts were essential to B4RN's success. The project's funding was eventually secured via an ambitious community self-funding model that utilised both cash and volunteer labour (obtained by, for example, individuals digging trenches or laying fibre cabling).

Both the B4RN and BGAL projects have strengths and weakness but what undoubtedly gave B4RN 'an edge' was the technical expertise held within the local community, resourcefulness, and the willingness (and ability) of members of the community to pay in cash or in kind to develop this local broadband service. However, such community capacity is not available in every village or rural locality. Lessons should be learned from the B4GAL experience where, through no fault of the community, a succession of external setbacks has resulted in the project remaining in the planning stages.

Recent technological advances have allowed satellite broadband to emerge as an alternative to connectivity delivered over copper (DSL) lines and fixed wireless broadband technologies. Satellite services can be deployed to provide broadband infrastructure in a variety of physical situations across the world. It can be economically attractive when large-scale rapid deployment is required or there is a greater than normal distance to the point of service provision, as in the case of 'hard to reach' deep rural areas. Analysys Mason (2012) noted that, in a UK context, satellite broadband has considerable potential as a complementary means of delivering broadband. Within the context of the EU Digital Agenda, Johnson et al. (2012) highlighted instant availability and improved performance as factors supporting a market for satellite broadband in Europe. Satellite solutions for rural areas underserved by fixed broadband are increasingly common, with examples of current innovations and initiatives reported from Western Europe (Peters et al., 2013) and North America (International Telecommunication Union, 2012). In Britain, the Welsh Government is supporting a satellite broadband programme to compliment the Welsh BDUK fibre rollout *Superfast Cymru* programme. *Access Broadband Cymru* is explicitly geared towards 'difficult to reach' (Welsh Government, 2014 no page numbers) households and communities. Grants to meet up to 90% of the installation costs from a private satellite ISP are available to individuals, businesses, third sector organisations and communities in Wales currently with fixed broadband speeds of less than 2Mbit/s.

The speed of satellite broadband Internet services available to UK consumers at the time of writing cannot match the speeds available on fixed, fibre services but they do provide a realistic alternative for remote rural consumers who cannot be served by a fixed connection or who can only obtain a very slow fixed Internet service. Latency (a delay in sending/receiving data) can be a problem with satellite broadband and unlimited download allowances, common for fixed broadband services, are rarely offered to satellite broadband customers, which can make contracts for a satellite service more expensive than a standard fixed broadband contract. If these limitations of satellite broadband could be overcome satellite technology could offer Internet access on a par with fixed broadband infrastructure.

Shortcomings of mobile telecommunications networks in the UK have already been highlighted in this paper. A significant improvement in rural mobile coverage could be realised if all service providers agreed to allow 'roaming' on their networks, as happens when a handset is taken abroad, or when the emergency services number (999 in the UK) is dialled from a mobile phone. UK mobile operators have resisted proposals to promote roaming, and "mobile coverage in the UK has not improved significantly in the past two years" (British Infrastructure Group, 2016 p5). The UK Government's Mobile Infrastructure Project (MIP) included a plan, launched in 2013, to fill in the mobile 'not spots' by building masts in 600 locations. This plan has failed: only 75 masts were built before the MIP closed (*ibid.*). With many deep rural areas still waiting for reliable 2G and 3G mobile services, speculation about further roll out of 4G and plans for new 5G networks (projected to be available from 2020) offer little comfort. The focus on speed, rather than universality articulated around fixed broadband policy, appears to apply equally to efforts to upgrade the mobile telecommunications infrastructure. In consequence better mobile Internet provision is not a realistic short to medium term alternative to inadequate fixed broadband in deep rural areas of Britain.

7. Conclusions

From our analysis of Ofcom infrastructure data we have evidenced some characteristics of the 'urban-rural digital divide' in Great Britain; there are territorial inequalities in digital

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[3] Further information about these community-led broadband projects is available at http://www.cybermoor.org/; http://www.b4rn.org.uk; http://lothianbroadband.coop/; http://guifi.net; http://freifunk.net/en/; https://wlan-si.net/en/; and http://www.o-net.ca/.

infrastructure that, as illustrated in our vignettes, have negative impacts upon personal and business lives in deep rural areas. Broadband take up rates vary little across urban and rural Britain suggesting that rural households and businesses are as likely as any others to want to be part of a digital society. However, a sizeable minority cannot engage in online activity considered to be 'normal' and increasingly expected of private citizens by Government, commercial customers, suppliers, retailers and utility companies. This digital divide is largely due to inadequate infrastructure. In the UK context − and in other national contexts where efforts to improve telecommunications infrastructures have followed a similar approach - it is likely that these territorial divides will persist for the foreseeable future, and may become more pronounced as private sector service providers prioritise new investments in profitable (urban) markets and public-sector interventions fail to bring superfast broadband to all.

Addressing the urban-rural digital divide and the digital exclusion it brings to many rural communities across the UK, Europe, North America and Australasia will almost certainly involve deploying a number of different solutions to bring connectivity to the 'final few' and to improve connectivity for the underserved. These, we suggest, will include some or all of the following: non-fixed connection via satellite or wireless, particularly for the especially 'hard-to-reach' or 'final few' users; community-led initiatives which should be considered more systematically in public policy, especially in terms of financial and technical models most suited to local geographies and the socio-technical capacities of individual communities; and re-scoping potential models for collaboration between commercial service providers and the public sector (through public finance and/or provision of in-kind expertise). Foreseeable technical developments could help to improve Internet use for those currently under- or poorly-serviced by their broadband connection, such as progressive compression of web content, selective display of 'wanted' functions on websites (such as actual processes on booking sites) and suppression of 'unwanted' functions such as videos. Increased satellite coverage, already in progress, could if suitably priced (possibly involving the public sector to support costs) provide wider territorial coverage as well as increasing connection speeds.

Digital communications policy and regulation in the UK would, we suggest, benefit from *digital future proofing* to ensure that any public sector market interventions in broadband infrastructure developments are as effective as possible in addressing territorial digital divides. Current government targets, even for 'superfast broadband', do not aspire to provide 'normal' levels of connectivity for all households and businesses in Britain today or for the medium term. Looking beyond the next five years and from an international perspective, the likely scenario of 'urban' speeds continuing to increase rapidly and digital services developing applications that are more 'data heavy' means that what is considered to be an acceptable broadband speed will also increase. Digital future proofing would drive a re-examination of current models of market interventions and incentives by the public sector, and should aim to generate new models of delivering and sustaining a telecommunications infrastructure fit for future purpose in terms of Internet access and use in rural Britain.

Acknowledgements

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