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'Two-speed' Scotland: Patterns and Implications of the Digital Divide in Contemporary Scotland

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ABSTRACT *Digital communication is a routine element of everyday life. Well-established communications technologies such as telephones and televisions have been joined, more recently, by widespread use of mobile telecommunications and by digital connectivity associated with the Internet. The use of Information and Communications Technology (ICT) relies upon a digital infrastructure comprising telecommunications masts, cables, exchanges and satellites. ICT infrastructure provision is uneven across the UK, resulting in an urban–rural digital divide. In this paper, we present an analysis of the most recent mobile telecommunications and broadband infrastructure data published by Ofcom, the UK telecommunications regulator. Similarities and stark differences between urban, accessible rural and remote rural areas of Scotland are identified. Our analysis demonstrates that there is, in digital communications terms, a 'two-speed' Scotland where (most) urban areas are in the digital fast lane and (most) rural areas are in the digital slow lane. Implications of this geographical digital divide for individuals who live in, and businesses that operate within, rural areas are considered. The findings, though based on an analysis of Scottish data, have relevance in a broader UK context and in Europe, North America and Australasia where an urban–rural digital divide also exists.*

KEY Words: digital divide, broadband, Internet, mobile connectivity, Scotland, urban–rural divide

Introduction

Digital communication is now a seemingly ubiquitous element of everyday life. For decades we have made telephone calls and watched television thanks to a digital communications infrastructure that is readily accessible to millions of homes and business premises worldwide. Over the past two to three decades, these well-established communications technologies have been joined by digital connectivity associated with use of the Internet and more widespread use of mobile telecommunications. Within the UK one could be forgiven for assuming that every household and every individual is digitally connected at home or on the move at all times given the way in which the media in particular discusses online behaviour and wider Information and Communications Technology (ICT) use.

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However, according to Ofcom (2014a), 7% of adults in the UK do not own or use a mobile phone, 39% do not have an Internet-enabled mobile phone, 23% do not use either fixed or mobile broadband and 22% of properties in the UK are unable to receive superfast broadband. As has been reported by the UK Office for National Statistics (2014a) and the Scottish Government (2014a), some people choose not to engage with ICT, some feel that they lack the skills necessary to use computer hardware and to exploit the Internet, and others think that they cannot afford a computer and/or the monthly subscription to an Internet Service Provider (ISP). In such cases a lack of digital engagement is most associated with *personal* attributes. *Place* attributes are often overlooked as reasons for a lack of engagement with digital activities. The digital infrastructure that supports mobile telecommunications and Internet connectivity is uneven across the UK and in many other countries across the world. A territorial *digital divide* often manifests as an urban–rural divide: in other words the type of place in which you live can determine whether or not you are able to make use of the ICTs that are increasingly ubiquitous among the population at large. Those who live in areas poorly served by modern ICT infrastructure may be described as being *digitally excluded,* defined by Warren (2007, p. 375) as being a situation whereby ' … a discrete sector of the population suffers significant and possibly indefinite lags in its adoption of ICT through circumstances beyond its immediate control'.

In this paper we describe patterns and implications of digital divides in contemporary Scotland, providing evidence in support of the assertion that, today, there is a 'two-speed' Scotland. The first section of the paper considers different modes of digital connectivity and why it matters to be online today. The second section presents an analysis of the most recent (December 2013) mobile telecommunications and broadband infrastructure data published by Ofcom, the UK's telecommunications regulator. We highlight differences between urban, accessible rural and remote rural areas of Scotland. The third section reflects on the implications of the geographical digital divide in terms of personal and business lives and touches upon some broader implications for rural sustainability. While the empirical focus of the paper is Scotland, the findings are relevant to many other national contexts across, for example, Europe, North America and Australasia where territorial digital divides exist.

Why is Digital Connectivity Important?

Warren (2007, p. 376) notes that:

> We live in a knowledge-based society, where access to information, and the ability to make economic and social transactions, confer distinct advantages. As governments, agencies, corporations and individuals increasingly rely on electronic means for the transmission and storage of information, the advantages of access to the Internet increase.

The Internet confers many opportunities and advantages upon private individuals, businesses, public sector bodies and voluntary and special interest groups. For private individuals an Internet connection – be it fixed and/or mobile – fulfils a range of functions. For example, it provides access to government information and services (such as, in the UK, NHS-24, and websites hosted under the gov.uk domain name); facilitates commercial

transactions (e.g. e-retailing, online banking); supports various modes of social interaction (including, e.g. e-mail, social networking, voice over Internet calls); provides access to formal and informal learning opportunities (e.g. further and higher education courses delivered online; instructions and 'how to' video clips for a plethora of household activities); is a source of information useful to everyday life (e.g. public transport timetables, online maps, online dictionaries and encyclopaedias); and provides access to entertainment on demand (such as live streaming of radio and TV programmes, downloading music and films, and playing online computer games). The most popular online activities in the UK are sending and receiving emails and finding out about goods and services (Office for National Statistics 2013).

For businesses, the Internet has improved communications with customers and suppliers, supported effective communications between colleagues and collaborators, provided access to new markets and marketing tools, supported flexible working practices (notably the ability to work 'remotely' and 'on the move') and provided new data management and storage solutions. The importance of broadband for business was noted by Townsend *et al.* (2013, p. 586): 'it enables innovation and wealth creation and enhances productivity and growth. Without broadband, rural businesses are unable to compete in the global economy'. For government, at all levels, the Internet has provided a new means of providing information to the public about, for example, facilities, services and benefits. It has also supported service restructuring: information, advice and public services are no longer exclusively delivered in person from physical premises. A presumption of 'digital by default' now informs government decisions about how to deliver many public services across the UK. For example, when the UK government published details of a change to the benefits system that would introduce a 'Universal Credit', in April 2013, it was decided that this change would introduce a system whereby 'most people will apply online and manage their claim through an online account' (Office for National Statistics 2013, pp. 13–14). The Scottish Government has ambitions for a 'World Class Digital Scotland' wherein, by 2020, people will be 'choosing digital first, having access to digital technology and being capable and confident in its use at home, at work and on the move' (Scottish Government 2014b, no page numbers). 'Digital by default' will, however, only succeed if there is universal access to an ICT infrastructure that meets the upload and download standards required to use government services online.

Current Use of the Internet

In Scotland, 76% of households had Internet access in 2012 (Scottish Government 2013), a lower proportion than the 83% reported in 2013 for the UK as a whole (Office for National Statistics 2013). During the first quarter of 2014, 87.1% of Scottish adults were reported as having used the Internet (Office for National Statistics 2014b). Of the 12.8% of Scottish adults who had never used the Internet most were in the older age groups, although age-based differences in Internet use have declined in recent years (Scottish Government 2014a). There were regional variations in the proportions of adults who had never used the Internet; the proportions ranged from 7.5% in Falkirk to 29% in Dumfries and Galloway (Scottish Government 2014a), findings which at least in part reflect the different age profiles found across the country. Findings from the Scottish Household Survey and other research (cf. Dutton & Blank 2011, Dutton *et al.* 2013; Office for National Statistics

2013; Royal Society of Edinburgh 2010, 2014; Scottish Government 2013), consistently report that not liking computers or the Internet, not seeing a need to use the Internet or computers or not knowing how to use a computer are the most commonly cited reasons for people not using the Internet. Sitting alongside these *personal* reasons are *place* factors largely out with the control of individual members of the public, namely deficiencies in the infrastructure required to access the Internet. In these cases even if an individual wants to be online he or she is unable to do so, or can only use an Internet connection that is slow and/or unreliable.

As outlined above, the potential benefits of the Internet are many and for rural communities in particular the Internet offers a means of overcoming barriers such as those associated with accessibility and mobility challenges and provides an opportunity to promote, for example, social inclusion, economic development and new modes of service delivery. However, rural areas have been, and continue to be, unable to fully exploit advantages the digital revolution offers (Grimes 2003; Malecki 2003; Sternberg *et al.* 2009; Royal Society of Edinburgh 2014; Williams *et al*. 2014). This is due to what Townsend *et al.* (2013) described as a complex interplay between the technological challenges of connecting remote-rural communities to the Internet, the costs of providing digital infrastructure in remote and sparsely populated areas and characteristics of the rural population, such as their demographic, income and educational attainment levels, which influence Internet take-up levels. It is widely acknowledged that the ICT infrastructure in rural communities is worse than that available in urban areas (Scottish Government 2013; Office for National Statistics 2013; SRUC 2014; Ofcom 2014b), but how pronounced is this difference? Are territorial digital divides a simple urban–rural divide or are more complex spatial patterns, in particular variations across different types of rural area, to be found?

Digital Divides in Scotland

Having established some of the benefits of being online and having noted that there are *personal* reasons that explain why some people are not users of the Internet, we now turn to consider some *place* factors that influence online behaviour. We present an analysis of broadband and mobile telecommunications infrastructure data published by Ofcom at Scottish Local Authority and at unit postcode levels that allow us to explore the impact that place, in particular urban–rural differences, has upon the ability of the Scottish population to engage in online activities.

Internet access, via a fixed or mobile connection, relies upon a telecommunications infrastructure of masts, cables and exchanges across the country (see Box 1 for a glossary of selected terms used in this paper that are associated with ICT infrastructure). Within Scotland this telecommunications infrastructure is uneven, resulting in spatial variations in the ability of private individuals and businesses to use the Internet at a fixed location or on the move and geographical differences in Internet speed, reliability and choice of service provider. The overall pattern is that urban and accessible-rural areas are the best served while remote-rural areas (which, according to Pateman (2011), account for approximately 60% of the Scottish land mass and are home to around 10% of the population) are poorly served.

Box 1. Glossary of terms

Dial-up Internet connection: A user's computer is connected to a network of computers via a modem that communicates over a public telephone network. If the user's telephone line is being used by the modem telephone calls cannot also be made or received. Dial-up is an analogue connection and connection speeds are typically in the range of 2400 bps–56 Kbps.

Broadband Internet connection: Describes data transmission along a single line which can carry several channels at the same time (e.g. the user may be online and be using the same telephone line to make or receive calls simultaneously).

Digital infrastructure:* Describes the physical, economic and organisational and regulatory structures that combine to provide access and use of digital communications. In this manner digital infrastructure is viewed as being similar to other public utilities (e.g. water, electricity).

(A)DSL – (Asymmetric) Digital Subscriber Line:* DSL lines use existing 2-wire copper telephone lines to carry digital data over the 'final mile' to the users' home/business premises. The length of the final mile copper connection determines the speed of the connection. A next generation of copper lines, ADSL lines, were introduced in the UK in 2000 but even on Very-high-bit-rate DSL download, speeds are compromised if the final mile exceeds 1.2 km.

Final mile: The connection that links a user to the communications network (the 'cabinet'). The type of cable supplying the final mile, and the distance between the user and the communications network interchange determines the speed the user can obtain.

Internet: A global interconnected network of networks that connects billions of digital devices across the world.

Mbit/s: Megabits per second, an expression of a unit of communication bandwidth often used to express the speed of the Internet service a user can obtain (e.g. 2 Mbit/s is considered by the UK Government to be the minimum acceptable broadband speed; superfast broadband is defined by Ofcom as 30 Mbit/s or higher).

Next Generation broadband:* A term used by BT to describe broadband delivered over advanced (next generation) copper network such as ADSL+ and fibre-optic cables.

Superfast broadband:* When first introduced in the UK the term described the next-generation broadband services (those delivered via advanced copper networks and fibre-optic cables) which supported download speeds in excess of 24 Mbit/s (the maximum speed that 'current generation' copper networks can support). Ofcom, and the EU, now consider superfast broadband to be in excess of 30 Mbit/s.

Wireless Internet Connections (Wi-Fi): Radio frequency bands are used to support Internet access. Home routers allow domestic users to access the Internet without having to use an ethernet cable. Wi-Fi networks are increasingly common in public spaces, allowing people to connect to the Internet from a laptop, tablet or mobile phone when they are 'out and about'.

Mobile Broadband or Mobile Internet Access: Describes the use of a mobile telephone handset (effectively a portable modem) to access the Internet over the mobile phone network. In the UK there are two types of networks that facilitate mobile access to the Internet, namely 3G and 4G networks.

Mobile telephone networks

2G: The second generation of mobile telecommunications over which voice and limited data (e.g. SMS messages) could be sent over the mobile network.

3G: The third generation of mobile communications technology which supports voice, data and streaming multimedia over a mobile telephone network.

4G: The fourth generation of mobile telecommunications technology which enables much faster data and streaming capabilities over a mobile network than is possible over 3G networks. Download speeds of up to 100 Mbit/s on mobile devices are possible.

Source: authors' definitions. Those marked * are adapted from the Glossary (Appendix V, pp. 99–102) in the Royal Society of Edinburgh's 2014 report *Spreading the Benefits of Digital Participation*),

A small proportion of home Internet users in Scotland go online using a technology other than fixed home broadband: of the 78% of Scottish households with home Internet access, 95% had a fixed home broadband connection (Scottish Government 2014a). The remaining 5% are likely to be using a mix of mobile Internet (using a mobile dongle) or a satellite service. Ofcom does not report data about satellite broadband uptake and recent Office for National Statistics and Scottish Government reports do not provide information about the extent of satellite broadband use. This technology is not considered further in the paper although we acknowledge that it has considerable potential for deployment in

'hard to reach' areas in the future where more conventional fixed broadband infrastructure is not suitable. In the UK, very few dial-up connections remain. In 2010, only 2% of households were using this means of going online (Ofcom 2010). It is likely that the proportion is even smaller today (on 1st September 2013 the BBC reported that British Telecom stopped offering a dial-up Internet service on that day – see BBC News 2013) but this assumption cannot be verified because Ofcom ceased publishing data about dial-up services in 2010.

Most fixed Internet in Scotland, and in the UK as a whole, is a broadband service. Fixed connections may be delivered over 'traditional' or 'next-generation' copper telephone wires (DSL, ADSL, ADSL2+, VDSL and VDSL2 lines), through cable TV lines or on fibre-optic lines. The type of line serving a property, and the 'final mile' distance between the user and the network exchange (or 'cabinet') determines download and upload speeds. For example, superfast broadband (defined by the UK Government as speeds above 24 Mbit/s and by Ofcom as speeds exceeding 30 Mbit/s) cannot be supported by traditional copper telephone lines and the most up-to-date VDSL and VDSL2 copper lines can 'only deliver speeds over 30 Mb/s over copper lines shorter than 1.2 km' (Royal Society of Edinburgh 2014, p. 100). The Office for National Statistics (2013a) reported that the proportion of the population who used a mobile phone to access the Internet more than doubled between 2010 and 2013, from 24% to 53%. Internet access 'on the move' via tablet and laptop computers has also increased markedly. Mobile Internet services are supported by 3G and 4G mobile telecommunications networks and Wi-Fi services. However, not all operators provide a 3G service nationwide. The situation could be improved if mobile operators shared masts (Meyer 2009). Topography and building materials, such as granite, can block or impede signals. Commercial priorities lead to service providers focusing their infrastructure developments in densely populated areas where they are most likely to secure a profitable return on their investment. Until a year or so ago, the replacement of copper cabling by fibre-optic lines focused on cities and other large population centres. 4G mobile Internet in Scotland is concentrated in the cities and in other large urban areas. A 3G signal, from any operator, is unavailable across half of the Scottish land mass.

Fixed Internet Infrastructure in Scotland

Although the majority of fixed Internet connections in the UK are broadband connections these connections vary considerably in terms of the upload and download speed supported. The package purchased by the consumer from their ISP can determine the quality of the broadband service that is received, but many users are unable to obtain the headline service advertised by their ISP because they live in areas where the capabilities of the ICT infrastructure are such that a fast and/ or consistently reliable Internet service cannot be obtained. The variability of Internet provision is commonly expressed by referring to the download speed of the service received. Although difficult to measure accurately and consistently (see, e.g. Bauer *et al.* 2010) download speed is 'one of the most significant technical characteristics impacting [upon] the quality of the user experience' (Bauer *et al.* 2010 p. 36). In addition, 'the raw data rate that broadband supports is important for the design of applications (e.g. video encoding rates), devices (e.g. I/O speeds supported), and complementary infrastructure (e.g. transport backhaul, required buffer memory, and switching fabric design' (Bauer *et al.* 2010 p. 36).

Current UK policy advocates universal access to broadband of at least 2 Mbit/s. While considered a 'good' Internet speed little less than a decade ago, a broadband connection

operating at or below 2 Mbit/s is now considered to be a very slow service. Indeed, this speed is little better than that achievable on a dial-up connection. Ashton and Girard (2013), reflecting on broadband provision in Canada, referred to households with an Internet connection of less than 1.5 Mbit/s as being 'un-served' and those with a connection of less than 4 Mbit/s as being 'under-served'. The Royal Society of Edinburgh (2010) proposed that, by 2015, a speed of at least 16 Mbit/s should be available across all of Scotland. It is very difficult, if not impossible, to accurately state the minimum upload or download speed required for specific online activities such as posting a photograph or downloading a movie clip (Fairhurst 2014, *pers. comm.*) but, according to the user information provided on the BBC website, a minimum download speed of 3.5 Mbit/s is required to stream the BBC iPlayer. A higher speed would be required to allow more than one person in a household to be online simultaneously because sharing a single broadband connection can lead to congestion, what Bauer *et al.* (2010, p. 3) describe as 'self-congestion', which slows data download and upload speeds.

Ofcom publish fixed Internet infrastructure data at local authority and at unit postcode sector level (e.g. AB24 3UF) for England, Wales and Scotland (all data are available to download at http://maps.ofcom.org.uk/broadband). In this paper we have used three variables from the most up-to-date Ofcom data, published in December 2013, to explore the characteristics of fixed broadband infrastructure in Scotland: percentage of broadband connections that have modem sync speeds of less than 2.2 Mbit/s; percentage of residential and non-residential premises with access to Next Generation Broadband; and average broadband sync speeds. Our analysis of these data provides evidence to support the supposition that there is a 'Two-speed' Scotland and also highlights where, geographically, the digital divide is most pronounced.

Fixed Internet Infrastructure at the Local Authority Area Level

Figures 1–3 present 2013 fixed Internet infrastructure data at the Scottish local authority level and illustrate variations in broadband speed across the country. For this descriptive analysis we coded each of the 32 Scottish local authorities as being either 'rural' or 'urban' following the Scottish Government's (2009) 'Randall' twofold urban–rural definition (see Map 1 and note that Scotland's urban local authority areas, with the exception of Aberdeen City, are all located in and around the Central Belt)). Urban and rural averages were calculated for each of the three Ofcom variables that were analysed. A clear pattern, at the local authority level, is evident from our analysis these data. The key points are that broadband connections with modem sync speeds of less than 2.2 Mbit/s are more common in rural areas than in urban areas, average rural broadband sync speeds are lower than the urban average, no rural local authority area achieves the urban average speed and rural areas are much less likely than urban areas to be served by superfast broadband.

The proportion of Scottish fixed broadband connections receiving less than 2.2 Mbit/s decreased from 13% in June 2011 to 8% in June 2013 (Ofcom 2013). Although modem sync speeds of less than 2.2. Mbit/s are found across Scotland, Figure 1 shows that these low speeds are more likely to be found in rural local authority areas (13% of connections) than they are in urban local authority areas (9% of connections). The highest proportions of connections of less than 2.2 Mbit/s are found in Eilean Siar (the Western Isles) and in Midlothian. Ofcom (2013) cautions that a sizeable proportion of connections operating at below 2.2 Mbit/s could be improved if consumers were to attend to faulty internal telephone

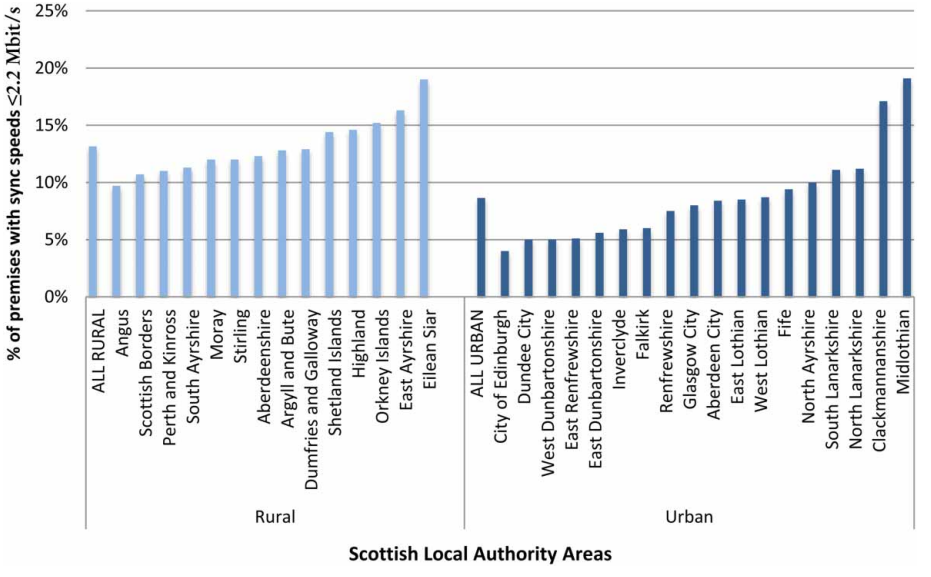


Figure 1. Percentage of broadband connections that have modem sync speeds of less than 2.2 Mbit/s, 2013, by Scottish Local Authority Areas.
Source: Authors' analysis of postcode infrastructure data published by Ofcom, Dec 2013, available at http://maps.ofcom.org.uk/broadband/.

wiring. This is certainly the case in many densely populated areas, but in rural, and especially remote rural areas, consumers' 'final mile', or 'distance from the cabinet' is such that without infrastructure upgrades the ability to improve a slow connection is limited.

The proportion of premises where a Next Generation network is available illustrates where the fastest fixed broadband connections can be achieved. Next Generation networks in Scotland, which support superfast broadband, are steadily being rolled out across the country. A smaller proportion of the Scottish population had access to Next Generation networks in June 2013 than did the UK population as a whole (52% and 73%, respectively, Ofcom 2013). Figure 2 shows that the availability of Next Generation networks in Scotland is concentrated in the urban local authority areas, where an average of 65% of premises have access to Next Generation networks. More than three quarters of premises in East and West Dunbartonshire, Falkirk, East Renfrewshire, Edinburgh and Dundee have access to the networks that support superfast broadband. By comparison, only 16% of premises in the rural local authority areas of Scotland have access to Next Generation networks. In 2013 five areas had no availability at all (Eilean Siar, Moray, Orkney Islands, Shetland Islands, and Argyll and Bute) and only 4% of premises in Highland and Aberdeenshire had Next Generation network access.

The extremes of provision illustrated in Figures 1 and 2 tell us little about the actual broadband sync speeds customers across Scotland are receiving. Figure 3 reports average speed data published by Ofcom in December 2013 and shows a very clear urban–rural divide. The average sync speed across the 18 urban local authority areas is 17.5 Mbit/s, whereas across the 14 rural areas the average is only 8.9 Mbit/s. The urban average

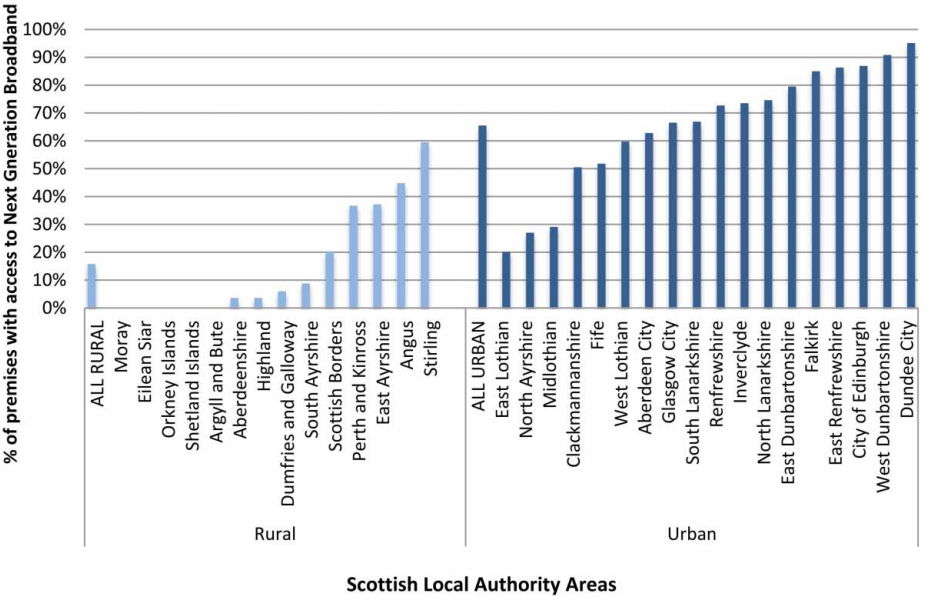


Figure 2. Percentage of residential and non-residential premises with access to Next Generation Broadband (where either Virgin Media cable, Openreach Fibre-To-The-Cabinet or Digital Region networks are available) by Scottish Local Authority Areas.
Source: Authors' analysis of postcode infrastructure data published by Ofcom, Dec 2013, available at http://maps.ofcom.org.uk/broadband/.

speed was not matched by the average speed in *any* of the rural areas. The average speeds reported in December 2013 for 6 urban areas and for all 14 rural areas failed to meet the Royal Society of Edinburgh's (2010) call for universal broadband of at least 16 Mbit/s across Scotland suggesting that this aspiration will not be met by the 2015 target.

Of the urban local authorities, the lowest average speeds are in Midlothian, North Ayrshire, Clackmannanshire and East Lothian (8.5, 9.9, 10 and 10.3 Mbit/s, respectively). However, with the exception of Midlothian, these average speeds are higher than the rural average. Of the four largest Scottish cities, Aberdeen performs the worst[1] with an average speed of 12.6 Mbit/s compared to 17.2 Mbit/s in Glasgow, 23.1 Mbit/s in Edinburgh and 23.9 Mbit/s in Dundee. Ten of the 14 rural local authority areas had average sync speeds below the rural average. The lowest average speeds are found in the areas serving the most remote communities, namely Eilean Siar (5.1 Mbit/s), Argyll and Bute (6.4 Mbit/s) and the Shetland Islands (6.9 Mbit/s).

Fixed Broadband Infrastructure in Urban, Accessible-Rural and Remote-Rural Scotland

Although the urban–rural local authority analysis presented above provides clear evidence of an urban–rural digital divide, the fact that many 'rural' local authority areas contain sizeable urban communities (e.g. both Stirling and Perth and Kinross are predominantly rural local authority areas but include the large settlements of Stirling and Perth, respectively)

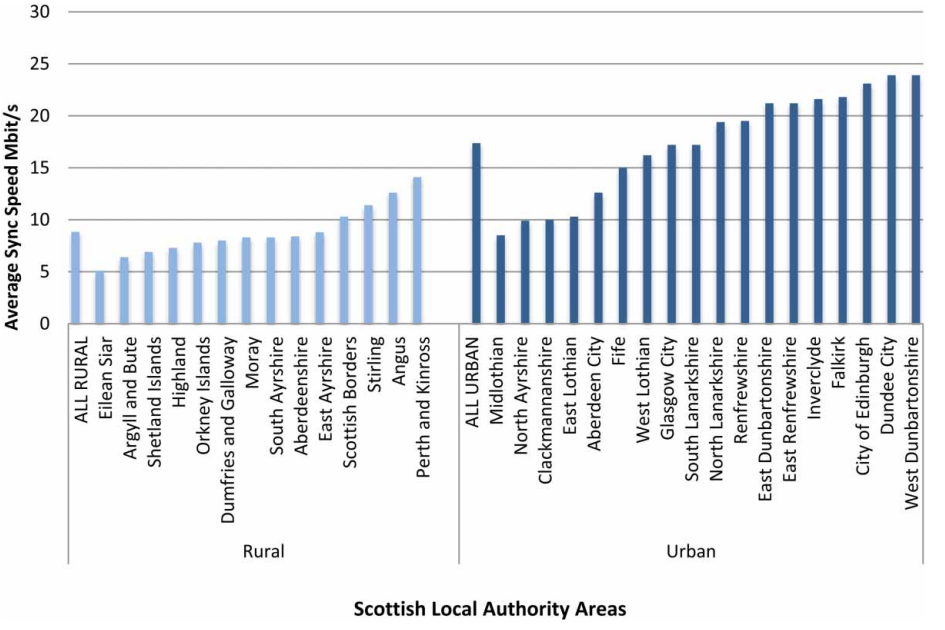
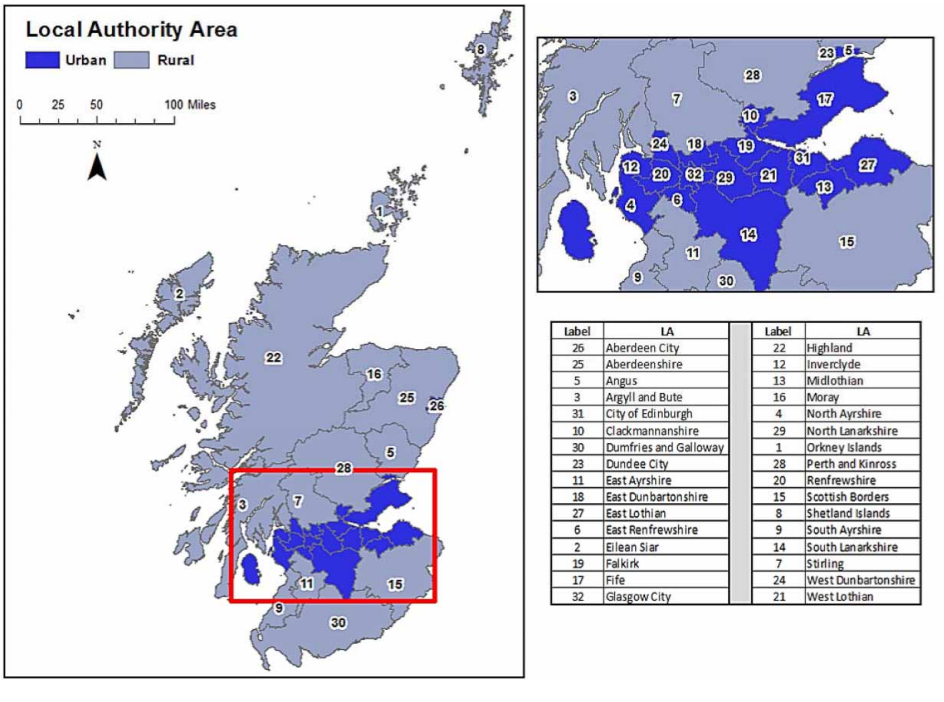


Figure 3. Average broadband sync speeds, 2013 by Scottish Local Authority Areas.
Source: Authors' analysis of postcode infrastructure data published by Ofcom, Dec 2013, available at http://maps.ofcom.org.uk/broadband/.



Label	LA		Label	LA
26	Aberdeen City		22	Highland
25	Aberdeenshire		12	Inverclyde
5	Angus		13	Midlothian
3	Argyll and Bute		16	Moray
31	City of Edinburgh		4	North Ayrshire
10	Clackmannanshire		29	North Lanarkshire
30	Dumfries and Galloway		1	Orkney Islands
23	Dundee City		28	Perth and Kinross
11	East Ayrshire		20	Renfrewshire
18	East Dunbartonshire		15	Scottish Borders
27	East Lothian		8	Shetland Islands
6	East Renfrewshire		9	South Ayrshire
2	Eilean Siar		14	South Lanarkshire
19	Falkirk		7	Stirling
17	Fife		24	West Dunbartonshire
32	Glasgow City		21	West Lothian

Map 1. Rural and Urban local authority areas in Scotland.

and 'rural' areas are found within many predominantly urban local authority areas (e.g. North Ayrshire includes the Isle of Arran, classified under the Scottish Government's sixfold urban–rural definition as remote rural), a finer grained urban–rural analysis is now presented to further interrogate the urban–rural digital divide. Unit postcode-level broadband data were geo-coded as 'urban', 'accessible rural' and 'remote rural' following the Scottish Government's urban–rural classification.[2] Postcode matching used files published by the Scottish Government (available at http://www.scotland.gov.uk/Topics/Statistics/SIMD/SIMDPostcodeLookup). Table 1 presents an overview of selected broadband infrastructure variables using this threefold classification.

An urban–rural divide is evident in all the infrastructure metrics presented in Table 1. Although connections with less than 2.2 Mbit/s are found across Scotland, they are much more likely to be found in unit postcode areas in rural Scotland than in urban Scotland (46.5% of unit postcodes in accessible rural and 41.3% in remote rural areas contained connections of less than 2.2 Mbit/s while only 28% of urban unit postcodes contained connections with this slow speed). There is negligible availability of Next Generation broadband infrastructure out with the urban areas. Although in remote rural Scotland 1.7% ($n = 254$) of unit postcodes were areas where Next Generation Broadband was available all but 2 of the 254 unit postcodes were clustered in 3 areas. These next-generation rural 'hotspots' are around Peebles and Innerleithen in the Scottish Borders, in and around Nairn in Highland and around Cumnock and New Cumnock in East Ayrshire[3]. The superfast broadband availability in rural local authority areas shown in Figure 2 must therefore be concentrated in the urban localities found within local authority areas the twofold classification defines as being rural (such as, for example, Inverness in Highland, Perth in Perth and Kinross, Dumfries in Dumfries and Galloway).

Not only is Next Generation broadband unavailable across most of rural Scotland, the average speeds and maximum speeds achievable in rural areas are much lower than those achievable in urban areas. Table 2 reports that rural average speeds and maximum speeds are both half those of urban areas. Figure 4(a)–(c) present the distribution of average speed data for remote rural, accessible rural and urban Scotland, respectively. For both remote and accessible rural areas there is a steep drop off in the proportions of connections with an average speed in excess of 8 Mbit/s; the remote and accessible rural averages are strongly influenced by a small number of high values. In remote rural

Table 1 Selected attributes of broadband infrastructure in Scotland by urban, accessible rural and remote rural areas

	urban	accessible rural	remote rural
Total number of unit postcodes	984,832	42,210	24,255
Postcodes with valid* data (%)	77.5	66.5	62.7
Postcodes with connections of less than 2.2 Mbit/s (%)	28	46.5	41.3
Postcodes where Next-Generation connections are available (%)	72.0	9.1	1.7
Average speed (Mbit/s)	18.0	8.3	7.9
Average maximum speed	24.0	12.1	11.1

Source: Authors' analysis of postcode infrastructure data published by Ofcom, Dec 2013, available at http://maps.ofcom.org.uk/broadband/.

*Ofcom do not report data for all unit postcodes. Those classified as having 'no premises', or 'insufficient' data were removed from the data-set and the analysis was conducted using only those remaining postcodes, those we describe as having 'valid data'.

Table 2 Geographic and premises coverage of mobile signals in the UK (based on predicted coverage)

	2G				3G			
	geographic coverage		premises coverage		geographic coverage		premises coverage	
	no signal from any operator (%)	signal from all operators (%)	no signal from any operator (%)	signal from all operators (%)	no signal from any operator (%)	signal from all operators (%)	no signal from any operator (%)	signal from all operators (%)
Scotland	26.2	41.7	0.7	91.9	50.5	4.9	3.4	69.8
Wales	15.7	52.8	1.2	87.0	21.9	11.5	2.3	58.4
Northern Ireland	8.0	56.5	1.5	81.0	13.3	16.7	2.6	62.9
England	4.6	72.8	0.2	95.2	6.0	32.7	0.5	82.6
UK	12.7	62.4	0.4	94.1	22.9	21.0	0.9	79.7

Source: Reproduced from data reported by Ofcom (2013, p. 47 – Figure 36).

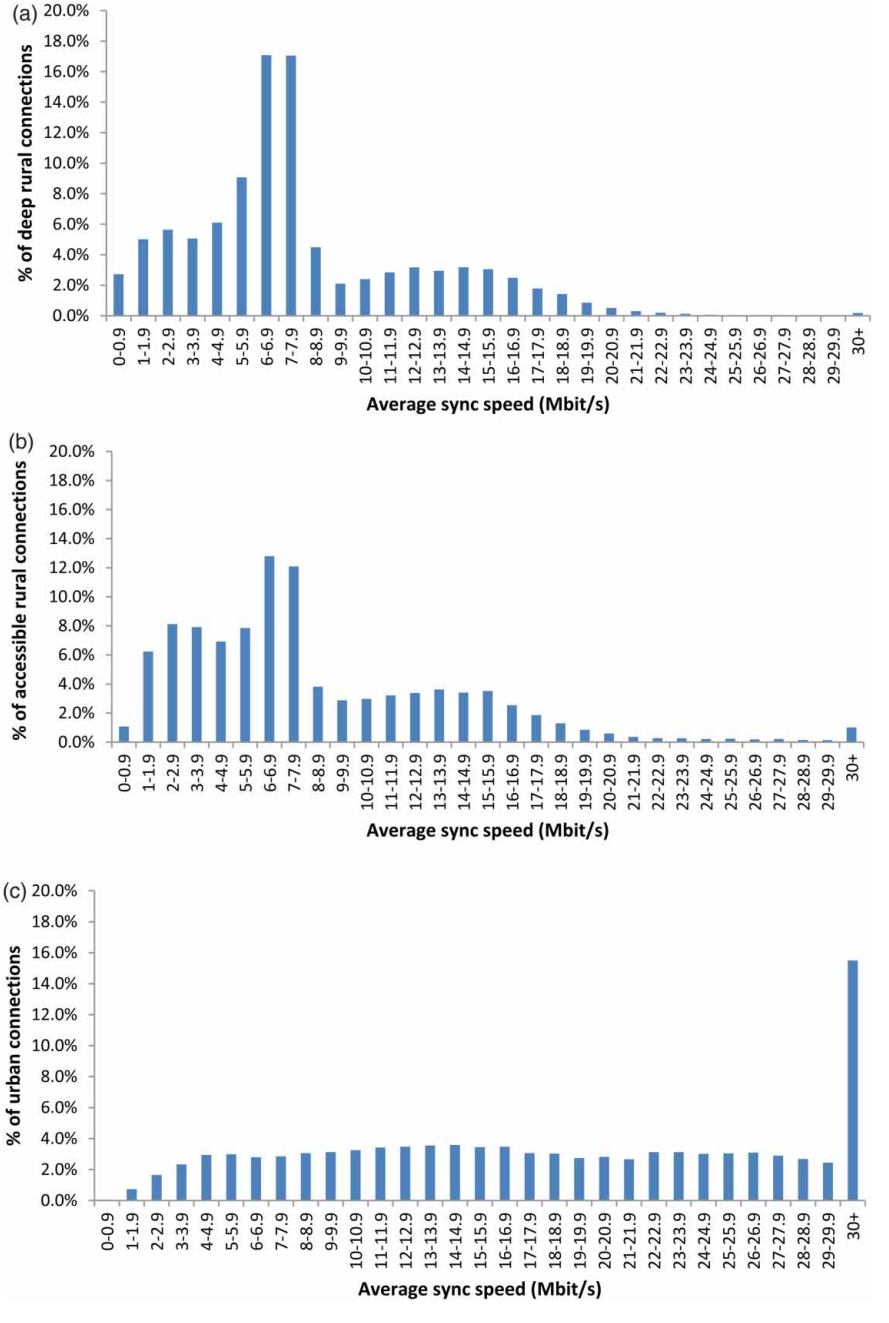


Figure 4. (a) Average sync speed in remote rural Scotland. (b) Average sync speed in accessible rural Scotland. (c) Average sync speed in urban Scotland.
Source: Authors' analysis of postcode infrastructure data published by Ofcom, Dec 2013, available at http://maps.ofcom.org.uk/broadband/.

Scotland, 68% of connections have an average speed below 8 Mbit/s, the accessible-rural proportion is 63%, but in urban areas only 16% of connections are below 8 Mbit/s.

The data presented in Figure 4(a)–(c) present clear evidence of an urban–rural, and further, an accessible-remote rural digital divide. Distinct differences in the average and maximum sync speeds available across Scotland reveal patterns of access that are advantageous to urban dwellers but which may limit the ability of rural residents and rural business to fully engage in the digital realm. Such disadvantages may, in turn, have further ramifications for the economic and social sustainability of less digitally connected places.

Our analysis accords with recognition from other national contexts that broadband speeds in rural areas tend to be lower than those in urban areas (European Commission 2013; Ofcom 2013; Rajabiun & Middleton 2013). Much has been written about the need to improve rural broadband. The European Commission (2013, p. 8) noted, for example, that bringing Next Generation Broadband services to the most rural areas 'remains the biggest challenge for broadband in the European Union'. The literature includes examples of how attempts have been made to improve provision in rural areas, and remote-rural areas in particular (such as Canadian examples presented by Scott Carson 2013 and by Rajabiun & Middleton 2013) but much still needs to be done to enable the rural broadband infrastructure to 'catch up' with that available in most urban areas.

From a UK perspective, Ofcom suggests that:

> … we have considered whether the postcodes which appear to have persistent speed problems are served by 3G mobile networks and could consider using mobile broadband. Our analysis indicates that 85% of the premises that have less than 2.2 Mbit/s and are not in the NGA [Next Generation broadband area] footprint are served by all 3G operators and 99% of these are served by at least one 3G operator. (2013, p. 22)

The implication is that if the user cannot obtain a decent fixed broadband speed they should switch to a mobile Internet service. Could deficiencies in fixed broadband provision across Scotland be mitigated by the mobile Internet infrastructure? We now turn to examine some data about the mobile telecommunications infrastructure in an attempt to answer this question. Our analysis of Ofcom's mobile telecommunications data is confined to the local authority level because these data are not published for unit postcodes.

Mobile Internet Infrastructure in Scotland

Accessing the Internet 'on the move' is now prevalent. To do so requires the user to have an Internet-enabled mobile device (smartphone, tablet, etc.) and to be physically located either in an area with a 3G or 4G signal operated by their network provider or where a public Wi-Fi network is available. 4G coverage across the UK has increased very quickly since this technology was introduced at the end of 2012 but Ofcom did not publish 2013 data for 4G infrastructure across the UK. Assumed indoor 4G coverage for Scotland was reported by the Scottish Government (2014c, p. 4) to be 59% at the end of 2014, up from 23% in 2013. However, 4G availability in Scotland is concentrated in and around the main centres of population; coverage in sparsely populated areas is negligible.

Ofcom (2013) reported that there is no mobile phone signal available from any operator across 22.9% of the land mass of the UK but, as reported in Table 2, there are considerable variations in mobile coverage across the UK. The geographical coverage of both 2G and 3G signals is much poorer in Scotland than elsewhere in the UK. A quarter of the Scottish landmass is not served by a 2G signal and across half of the Scottish land mass no 3G signal can be obtained. Premises coverage is better than geographical coverage but the proportion of premises in Scotland with no 3G signal from any operator is higher than that in England, Northern Ireland and Wales. The poor 3G coverage in Scotland limits the ability of Internet users to be online, 'on the move', across large swathes of the country.

Figure 5(a) and 5(b), based on our analysis of local authority-level data (where the 32 Scottish local authority areas have been grouped into two categories, urban and rural, as described for the analysis of fixed broadband infrastructure), shows that the percentage of geographic area with no reliable 2G or 3G signal varies considerably across Scotland. The rural local authorities fare much worse than the urban local authorities. In Scotland's urban local authority areas only 4%, on average, of their geographical area does not have a 3G signal from any operator, compared with 47% in the rural authority areas. 2G geographical coverage is worst in Argyll and Bute, where there is no signal across 37% of the territory and in Highland where geographical coverage is only 35%. 3G signal coverage from any operator is worst in Argyll and Bute (only available in 24% of the area), and in Highland and Eilean Siar (only available in 34% of both areas). As shown in Figure 6(a) and 6(b), even in the areas where a 3G signal is available, it is unlikely to be available from all operators, with implications for consumer choice and the ability of visitors/tourists to pick up a signal from their usual operator. The average geographical coverage across rural Scotland for a signal from all operators was 42% for 2G and only 3% for 3G. The urban averages were 82% and 50%, respectively. Geographical 2G coverage from all operators is worst in Argyll and Bute (21%), Eilean Siar (34%) and in Highland and the Shetland Islands (33% in both). These areas also have the slowest average fixed broadband sync speeds. The worst 3G coverage from all operators – at 0% geographical coverage – is in Highland, Shetland and the Western Isles, closely followed at 1% or less geographical coverage in Aberdeenshire, Argyll and Bute and Moray.

2G and 3G coverage by premises across Scotland is much better than geographical coverage, but there are notable spatial variations. There is reliable 2G coverage from at least one operator at 100% of premises within the urban local authorities and at 97% of premises in rural local authority areas; however, while 3G premises coverage is universal in the urban authorities, 14% of premises in rural areas have no 3G coverage at all. A similar pattern is evident for premises coverage by all operators. While 96% of premises in urban local authority areas have 2G coverage from all operators, only 76% of premises in rural areas do. 3G coverage from all operators serves 81% of premises in the urban areas compared with only 28% of premises in rural areas.

Our findings show considerable overlap between areas with the worst fixed broadband and those with the poorest 3G coverage. Ofcom's suggestion that the limitations of fixed Internet infrastructure could be overcome by consumers using mobile Internet services is thus unlikely to be a means of overcoming fixed infrastructure shortcomings across much of rural Scotland. Given the geography of Scotland, with large expanses of uninhabited and/or very sparsely inhabited areas it is perhaps unsurprising that geographical mobile

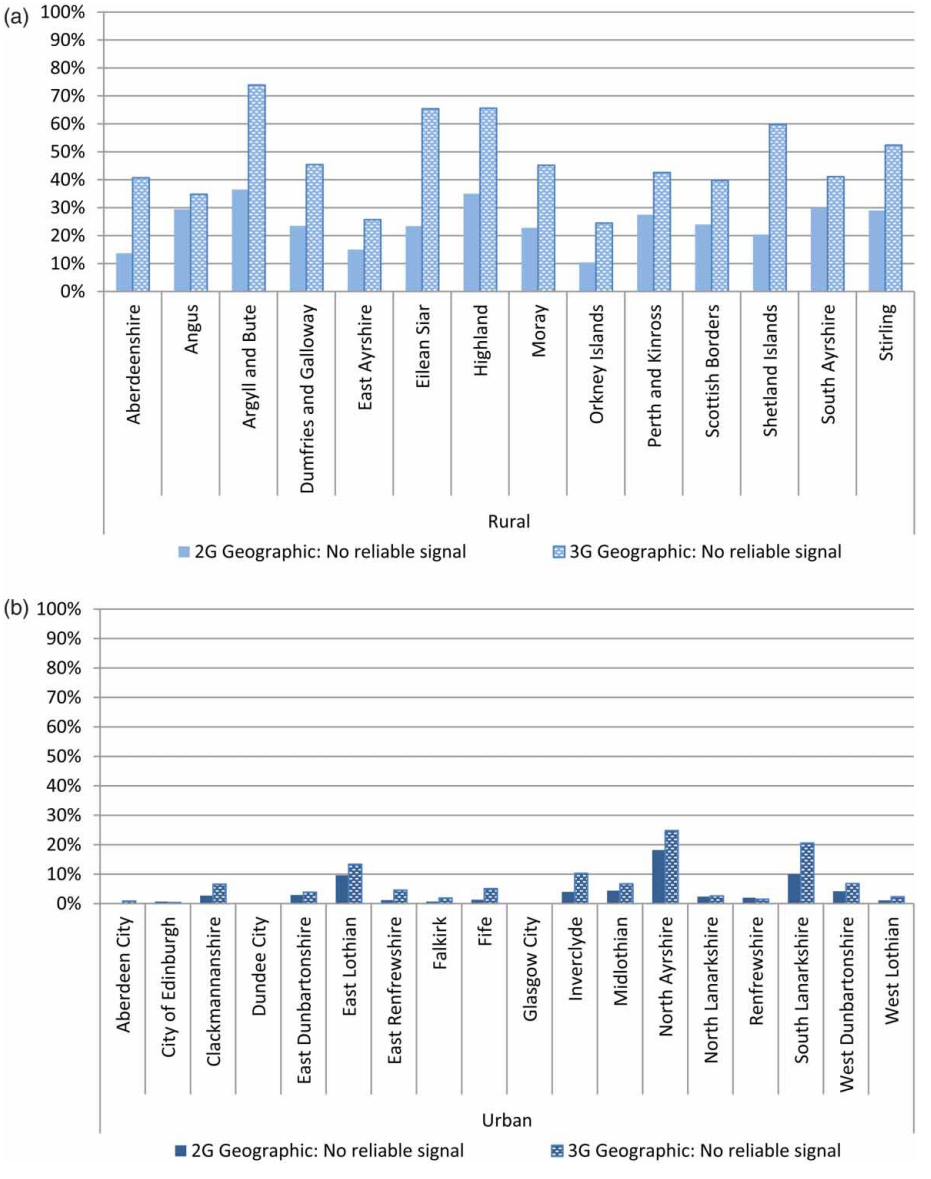


Figure 5. (a) Percentage of geographic area with no reliable 2G or 3G signal from any operator, rural Scottish local authority areas. (b) Percentage of geographic area with no reliable 2G or 3G signal from any operator, urban Scottish local authority areas.
Source: Authors' analysis of local authority-level mobile infrastructure data published by Ofcom, Dec 2013, available at http://maps.ofcom.org.uk/broadband/.

signal coverage is so poor. It is not commercially viable for the private companies that deliver mobile connectivity to install the necessary infrastructure to serve areas in which very few potential customers live. Overall, the growth in mobile ICT use has been

Figure 6. (a) Percentage of geographic area with 2G or 3G signal from all operators, rural Scottish local authority areas. (b) Percentage of geographic area with 2G or 3G signal from all operators, Urban Scottish Local Authority Areas.
Source: Authors' analysis of local authority-level mobile infrastructure data published by Ofcom, Dec 2013, available at http://maps.ofcom.org.uk/broadband/.

limited in rural areas due to the fact that the infrastructure required to facilitate adoption is lacking. 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 and effective use of mobile telecommunication opportunities.

Implications of a Two-speed Scotland for Rural Communities

People living in rural Scotland – and businesses based there – are less likely than their urban counterparts to be able to use the Internet and exploit all the advantages it offers, due to the demonstrated experience of slower connection speeds. This comparative disadvantage is particularly acute in relation to services requiring high-capacity connections, and with respect to Internet users experiencing unreliable or discontinuous connections. As noted above, there are a variety of reasons why individuals, regardless of where they live, chose not to be Internet users. However, it is not known whether or not slow and/or unreliable connections are a reason for individuals to make this choice.

We present some implications of the urban–rural digital divide below, including some illustrative quotations from interviews conducted with people who live and work in remote-rural areas of Scotland and England that were conducted for two research projects[4] associated with the RCUK dot.rural Digital Economy Research Hub at the University of Aberdeen, in which participants were asked to describe how they used ICT in their personal and business lives. The quotations were selected by the researchers who conducted the interviews and have all been anonymised. Further information about the research the illustrative quotations were drawn from is available in Ashmore *et al*. (2015) for project 1 and Williams *et al.* (2014) for project 2.

Farm businesses must comply with regulatory requirements, many of which now involve online tasks. For example, online submission of livestock registration forms, income tax and business value added tax returns is expected. A slow Internet connection makes such tasks time consuming and laborious. Not having an Internet connection is, however, out of the question:

> The farmer over there, every time he has to move sheep or cattle, he has to put it in a form. All of these forms are online these days. So if you're a farmer you can't work without broadband. (Business interview, project 1)

Multiple Internet-enabled devices are commonly owned by households today – households defined as *Next Generation Users* (Dutton & Blank 2011). In these households there is an expectation that all Internet users should be able to do what they want online, at any time, regardless of how many other household members are online simultaneously. This is especially the case in households with teenagers. Many rural households, particularly multi-generational rural households, have Internet connections that cannot support the simultaneous use of the Internet from multiple devices. An interview was conducted with a four-person family that attempts – frequently unsuccessfully – to operate two laptops, two iPads, two mobile phones, an iPod and their satellite television (recordings) off their fixed home broadband service. The demands made on their 0.5 to 1Mbit/s service repeatedly cause tensions within the household:

> 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 […]... ('Next generation user' household interview, project 2)

Reliable and high-capacity Internet access is viewed as an important or essential service by many rural dwellers yet not all households can be connected to a fixed broadband line. A

couple who had made repeated attempts to get fixed broadband installed at their home spoke of the difficulties they had faced:

> … and then they relayed the whole cable […] and it got even worse after that, after they laid new cable. And they said sorry, there's nothing we can do to get you Internet pleaser don't phone us again. (Interview with farming couple, project 2)

Broadband can provide opportunities that help to overcome accessibility and distance constraints associated with living in rural areas. Being able to use online banking services is useful, especially in areas where bank branches have closed and no mobile service is available. Online shopping offers consumers more choice and makes specialist retailing accessible. Online grocery shopping can save rural residents long round trips to a supermarket, with associated time and cost savings even when delivery charges are taken into account. For example:

> Our nearest video shops are miles away, to pick up a DVD, [but] there's plenty of stuff you could stream to your TV … . (Household interview, project 1)

With a fast, reliable broadband service increasingly being expected by the general public (and arguably having the same status as a 'normal' utility alongside, for example, a mains electricity connection), the lack of decent quality broadband infrastructure could have an effect on migration flows into and between rural areas. An interviewee in Project 1 who lived near the southern extremity of the commuter zone for Edinburgh and Glasgow observed that broadband is adding value, or improving the saleability of rural properties:

> It's number one on the housing list! And people are buying houses now, and it's the first question, you know, do you have broadband … . (Household interview, Project 1)

It is thus apparent that rural residents value a reliable Internet connection. They are aware of the benefits and opportunities it offers and want to be able to participate in online activities in the same way as people who live in other areas. Infrastructure constraints are found to be frustrating, in personal and business lives, but users persevere because of the perceived importance of being online. Rural Internet users are aware of the limitations of their connections, and feelings of being 'poorly served' and 'missing out' are common themes that have emerged across a number of research projects conducted by social scientists at the dot.rural Rural Digital Economy Research Hub.

Overcoming the Urban–Rural Digital Divide

The policy context of improving rural broadband is not straightforward. The UK Government's position is that the market should lead broadband deployment in the UK (Departments of Business, Information and Skills and Culture, Media and Sport 2010). However, interventions in the market are applied through policy instruments such as the Broadband Delivery UK (BDUK) programme. Without these interventions, commercial suppliers will not have a financial incentive to improve broadband services in areas with a small consumer base. The BDUK programme is administered and moderated by the devolved administrations in Scotland and Wales, and through contractual arrangements

with local authorities who act as agents. British Telecom has successfully bid for all the deployment contracts, but may engage other contractors to reach the 'most difficult to access' rural areas, collaborating with, for example, satellite broadband providers.

Despite policy interventions, current government commitments to roll out superfast broadband exclude as much as 10% of the UK population, mostly those who live in remote rural areas. In Scotland 10% of the population translates to approximately half a million people. Individual households and businesses may make their own arrangements for enhanced broadband, often through satellite providers, in hard-to-reach areas. Some rural communities have organised themselves and raised the funds to develop their own broadband infrastructure. Such organisation could be viewed as a political activity, a necessary standing up for 'rural rights'. Some communities feel, with reluctance, that they have no choice but to organise and develop their own broadband infrastructure: they have recognised the importance of being digitally included, have lost patience with the slow pace of commercial supplier-led roll out and feel somewhat aggrieved that they have been overlooked.

Ofcom's position is that while it expects the urban–rural digital divide in the UK will continue to widen in the short term, as fibre broadband availability in rural areas increases the divide will lessen: we expect that speeds will become more evenly matched across the UK (Ofcom 2014b, p. 4). However, this statement does not quantify how evenly matched urban and rural speeds will become. There are no published plans to date for fibre broadband, which supports the highest speeds, to be rolled out UK-wide and while the UK government has recently allocated additional funds to bring high-speed broadband to rural areas it will only extend this infrastructure to 95% of the UK (Department of Culture, Media and Sport 2015). The remaining 5%, the 'final few', will be concentrated in remote-rural areas. As mainly urban areas with high-speed broadband receive ever faster connections and 4G mobile broadband becomes available in even more locations (and a 5G mobile service has been mooted) the pace of change could result in rural areas forever having to play 'catch up'. As services such as video and High-Definition television-on-demand, and the overall quantity of data online multiplies through innovations such as the Internet of Things, the demand for reliable, higher speed connections will increase, and rural areas will continue to experience dis-association from online experience and capability.

The Pace of Change and 'Future Proofing' Digital Infrastructure

The Internet as we know it today originated in digital networks between universities, the first being the Advanced Research Project Area Network that linked the University of California at Los Angeles with the Stanford Research Institute in the 1950s. By the late 1980s/early 1990s commercial ISPs had emerged. The use of the Internet by private individuals took off once the Internet was commercialised in 1995. The pace at which use of the Internet and mobile telecommunications has increased since that time is phenomenal. The type of data exchanged online has become more diverse and the volume of data exchanged on a daily basis has increased dramatically. Cisco Visual Networking Index (2014) states that Global Internet Protocol (IP) traffic has increased more than fivefold in the past 5 years, and will increase threefold over the next 5 years and predicts that annual global IP traffic will surpass the zettabyte (1000 exabytes) threshold in 2016.

Internet applications and services are growing rapidly in their demands on connection capacities, and pressures from Big Data and, relatedly, the Internet of Things, will leave

rural broadband connection speeds trailing in their wake. Even mundane Internet activities such as voice over Internet (e.g. Skype), Internet shopping and bill-paying, animal passport registrations, job-seeking, and education and training are difficult for many at present, and other well-established uses such as video streaming are 'foreign' to large tracts of Scotland and many other rural areas worldwide. Ongoing monitoring of the patterns of urban–rural digital divides helps to provide evidence to government of the continued need for interventions in a digital market whose pace of change is such that 'difficult to reach' areas might continually be left behind. Government aspirations for a digital society and a 'digital by default' system for delivery of public services will simply not work if digital infrastructure in rural areas does not improve and keep pace with developments in urban areas.

Conclusions

This paper has set out why digital connectivity is important. In terms of fixed broadband, although some urban areas of Scotland are performing poorly, the overall picture is one of an urban–rural digital divide. When mobile telecommunications are examined a similar picture emerges: rural areas of Scotland lack the mobile connectivity now taken for granted in urban areas.

The impacts of a two-speed Scotland are many, and encompass two overlapping sets of experiences by rural dwellers and businesses. First, they cannot with certainty, or not at all, access all services that are nominally available online. If they do access Internet services they often experience slow or unreliable functionality. This, we suggest, is in itself a disincentive to use the Internet, and likely to be a particular barrier for older people and for 'digitally less literate' people whose confidence in their online ability is easily disturbed by a poor connection (rather than by their 'mistakes'). Second, rural dwellers and businesses are *relatively* disadvantaged compared with those with better connection speeds, mostly urban dwellers and businesses, and they are often paying the same price for their broadband – or more in some cases. To this extent, they are unable to take part in and reach the experiences of better connected people, and thus of wider society and economy, with all that is implied about civic and economic life opportunities.

Government and commercial ISPs are aware of the urban–rural digital divide and considerable sums of public money are being spent on initiatives designed to bring broadband infrastructure to more communities across Scotland and the UK. These initiatives will, however, not bring the most up-to-date broadband connectivity to all households in the country, and there is a risk that the pace of change is such that despite ongoing efforts to improve the rural digital infrastructure rural areas will be playing 'catch up' for the foreseeable future.

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Notes

[1] Some large private-sector organisations based in Aberdeen have their own broadband infrastructure and some exchanges in the city were upgraded under commercial deployment plans. Residential improvements have only recently got underway in many parts of the city.

[2] The threefold classification is based on the Scottish Government's 2011–12 sixfold urban–rural classification (details available at http://www.scotland.gov.uk/Topics/Statistics/About/Methodology/UrbanRuralClassification). The classifications in this paper use the Scottish Government classifications as follows: 'urban' combines 'cities' and 'other urban areas'; 'accessible rural' combines 'accessible rural small towns' and 'accessible rural areas'; and 'remote rural' combines 'remote rural small towns' and 'remote rural areas'.

[3] Innerleithen was the first town in the Scottish Borders to receive superfast broadband, in early 2012, after winning British Telecom's Race to Infinity, a competition which invited communities to register their interest in receiving upgrades to their broadband service. Superfast broadband for nearby Peebles was announced in the early autumn of 2011 and went live about a year later. Superfast broadband was introduced to Nairn in 2012 and New Cumnock benefited from the roll out of superfast broadband in late 2013. More remote rural communities were connected to superfast broadband infrastructure in 2014 and others are scheduled to benefit from further roll out scheduled for 2015.

[4] Project 1 is Fiona Ashmore's doctoral research, being undertaken at the University of Aberdeen, which explores community-based superfast broadband organisations and the extent to which superfast broadband development and use enhances rural community resilience. Project 2 is the Rural Public Access Wi-Fi Service project, again being undertaken at the University of Aberdeen, which explores innovative methods of enabling digital inclusion in rural areas. The interviews for Project 2 were conducted by Fiona Williams who, with Lorna Philip and John Farrington, comprise the social scientists working on that project. Fiona Ashmore and Fiona Williams both consented for extracts of interviews they conducted to be reproduced in this paper.

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