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Broadband speed equity: A new digital divide?

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A B S T R A C T

The availability and performance of broadband connectivity is becoming an increasingly important issue across much of the developed world as the prevalence of richer media services and growing populations have generated increasing demands on existing networks. The heterogeneous geography of broadband infrastructure and investments results in variable service provision, and as such, there exist large disparities in access and performance within different spatio-temporal locations. This paper presents analysis of 4.7 million crowdsourced Internet speed test results that were compiled between 2010 and 2013 alongside various indicators of socio-spatial structure to map disparities in English broadband speed between and within urban areas. Although average speeds have improved over time, inequity is shown to emerge between different societal groups and locations. Short-term dynamics also reveal that in areas of different density, speeds can fall dramatically during peak hours, thus influencing the availability of services. The apparent disparities in access and performance represent a major issue as Internet use becomes increasingly ubiquitous in our everyday lives, with inequalities evoking social and economic disadvantage at local and national scales. This work resonates with UK government policy that has stimulated considerable investment in improving infrastructure, and presents analysis of an expansive crowd sourced "big data" resource for the first time.

Broadband and the Internet

Within developed countries, access to the Internet in urban areas is predominantly available in the home (Dutton & Blank, 2013) and enabled through wired broadband infrastructure. This availability reduces traditional constraints on communication such as time and cost, enables the consumption of rich media services (e.g. video chat, streaming movies or music) and most importantly, enhances access to a plethora of online information and services that engender benefits for economic development, education, health and wellbeing (Broadbent & Papadopoulos, 2013; Kraut et al., 2002). Particular emphasis has been placed by governments on the link between the provision of broadband infrastructure and economic growth (Freund & Weinhold, 2004; Picot & Wernick, 2007; Xavier, 2003; Yiu & Fink, 2012), leading to promotion and investment in these technologies as part of national infrastructure plans. In the USA, the National Broadband Plan, developed by the Federal Communications Commission (FCC) aims to promote broadband availability through ensuring robust competition and universal service, as well as maximising the benefits of broadband in government influenced sectors (Federal Communications Commission, 2011). Similarly, UK government response has come in the form of the Digital Britain Report, which outlined a nationwide Universal Service Commitment (USC) to be achieved by 2012 (DCMS, 2009). The importance of such investments have been widely cited, with previous studies estimating that broadband infrastructure accounted for 9.53% of the United Kingdom's GDP growth in the period 2002–2007 (Koutroumpis, 2009). Investment in developing countries has also increased in recent years, with heavily subsidised rollout of high-bandwidth infrastructure across much of the global south (Graham & Mann, 2013), although not necessarily fixed line connectivity. For example, some private sector funded projects aim to provide widespread Internet access through the launch of medium orbit satellites (O3B, 2013). Other projects, such as the One Laptop Per Child program (OLPC), have aimed to promote the distribution of inexpensive computing equipment with wireless connectivity to children (Graham, 2011).

Early research into Internet inequalities was concerned with disparities in connectivity between developed and developing countries, and what social impacts these differences would likely engender. Within this context, the term 'Digital Divide' was introduced in the late 1990s (Norris, 2001) to describe differences between the 'haves' and 'have-nots'. Although a valuable concept at the time when the Internet was first developing, as the access divide narrowed (Kyriakidou, Michalakelis, & Sphicopoulos, 2011;

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Peter & Valkenburg, 2006), more recent discussion has diversified this binary concept, adopting instead the term 'Digital Differentiation' (Hargittai, 2002; Longley, Webber, & Li, 2008) to signify those new complexities that have emerged in differentials of Internet access. The digital differentiation approach aims to depict more nuanced differences between societal groups in terms of use and engagement patterns, that are evident especially within those countries with more developed Internet infrastructure (Longley, 2003). Such differentiating factors explored by this research have included age (van Dijk & Hacker, 2003; Lenhart, Madden, & Hitlin, 2005; Livingstone & Helsper, 2007; Loges & Jung, 2001), gender (Bimber, 2000; Cooper, 2006), rurality (Pigg & Crank, 2005; Prieger, 2013) and ethnicity (Fairlie, 2004; Prieger & Hu, 2008). Most recently, research has diversified to utilise crowdsourced information generated through location-based social media and Internet use to better understand the complex emerging geographies linked with the built environment (Arribas-Bel, 2014; Sui & Goodchild, 2011). Manifest from digital differentiation are patterns of digital exclusion where individuals will have varying degrees of engagement with the Internet (Bunyan & Collins, 2013). The complexity of such patterns has been discussed elsewhere (Longley, 2003), and have been shown to emerge between the intersections of traditional concepts of material deprivation (Longley & Singleton, 2009). Thus, you may have urban areas with populations that are typically digitally engaged, yet materially deprived, or inversely, urban areas with low digital engagement, but also low levels of material deprivation. Within a UK context, overall levels of digital exclusion have declined steadily in recent years (Dutton & Blank, 2013; Lane-Fox, 2009), albeit, a significant proportion of the population still remain digitally excluded. In 2013, this equated to around 11.4 m people having never used the Internet (18% of the UK population) (Dutton & Blank, 2013). Although these differentials are part of a wider complex of influences (Parayil, 2005), in part, these inequalities will relate to the provision of infrastructure enabling access to the Internet, and as such, underpin a UK government aim to ensure that a minimum threshold of Internet speed is enabled for all of the populations. The Universal Service Commitment outlined in the government's Digital Britain Report set a nationwide minimum connection speed of 2 Mbps to be delivered by 2012. It was stated that this target "would allow virtually everyone to experience the benefits of broadband, including the increasing delivery of public services online" (DCMS, 2009, p. 27).

Geographic disparities in access and performance exist in part due to the physical structure of broadband networks. In particular, performance is affected by the distance (or line length) between a customer's home and the nearest telephone exchange. Such is the effect, that distance to the nearest exchange is often used as a proxy for deliverable speed (Ofcom, 2012). Within rural areas, distance has a vastly limiting effect on service provision due to sparse distribution of both populations and core network infrastructure such as exchanges and backbone networks; as such, large disparities in broadband performance exist between urban and rural areas. Similar limitations of cellular networks also exist as a result of rurality, with mobile broadband coverage being often poor in isolated areas. However, although relevant to the wider field of research, disparities in mobile broadband access fall outside the scope of this paper. Advances in communications technology, such as the use of fibre optics to supply domestic broadband services, aim to increase broadband speed in locations disparate from telephone exchanges. Fibre to the Cabinet (FTTC) connections link street cabinets that supply small neighbourhood areas to a local telephone exchange with a dedicated fibre link: this allows for much faster transmission of data. FTTC connections (where available) can currently deliver speeds of up to 76 Mbps to homes in the UK (BT PLC, 2013). By contrast, Fibre to the Premises (FTTP) connections (often utilised by businesses) supply a direct fibre link to a site, allowing for large volumes of data to be exchanged rapidly. FTTP connections to domestic properties, offering speeds of up to 300 Mbps are currently only available in a small number of areas and as such are very much in their infancy. Within this context, this paper explores how provision and performance of connections to broadband infrastructure within England are both temporally and socio-spatially differentiated; evoking a complex geography of connectivity both between and within urban areas. For the first time, this study utilises a large dataset of crowdsourced Internet speed estimation tests for England, supplied by the company Speedchecker Limited (broadbandspeedchecker.co.uk), and pertaining to 4.7 million test results, with geographic attribution at the level of the unit postcode (zip code). An extract comprising two time periods was provided, covering 1/1/2010 to 31/1/2011 and 1/4/2012 to 31/5/2013.

Measuring broadband connectivity and access

Data were supplied by Speedchecker Limited, who are a provider of a Web-based application (broadbandspeedchecker.co.uk) that enables users to test their Internet connection speed. When users visit the website, a page is loaded with an embedded testing application that when run provides a small file (of known size) that is automatically downloaded and uploaded, thus enabling speeds to be estimated (i.e. size/time). After running a speed test, users are requested to supply a unit postcode and to confirm details of the connecting Internet company/package. The unit postcode details enable speed test results to be geo-located, and the website displays the test outcome within the context of other results proximal to the supplied postcode. All results derived through the website are stored by Speedchecker Limited as part of their terms of use. The geographic resolution of the geo-located speed tests is therefore high, with postcodes relating to on average around 13 households. It is important to note that these tests differ from "official" speed tests in the UK, which are collated on behalf of the industry regulator Ofcom (http://www.ofcom.org.uk) by SamKnows (www.samknows.com), who are an organisation that provide information about broadband performance, providers and usage. The crucial difference between SamKnows data and the data supplied by Speedchecker Limited is the collection method. Rather than relying on users to run speed tests through a Web application, SamKnows supply hardware in the form of a small testing box that sits between participants' existing routers and the rest of their network. Boxes are supplied to a representative sample of Internet users nationwide. In 2010, Ofcom's UK broadband performance report utilised data collected from 1506 testing boxes. The boxes automatically ran speed tests on a user's connection, but only when there was no other network activity. Conversely, data supplied by Speedchecker Limited is much larger, but there are no restrictions to prevent users from performing tests when there is other network activity ongoing (e.g. multiple users online within a property, or a background update being downloaded). As such, the data presented here could be interpreted as those actual speeds people attain when using a service, taking into consideration local constraints related to router configuration, WiFi coverage or coincident household usage. This said, comparison between the regulator estimates and the derived Speedchecker Limited estimates revealed very similar figures. Our data sample suggested a nationwide average download speed of around 4.8 Mbps in 2010, close to that estimated by Ofcom/SamKnows at 5.1 Mbps (Ofcom, 2010).

The data used for this study can be considered as 'Volunteered Geographic Information' (VGI) (Goodchild, 2007; Haklay, Singleton,