Telecommunications Policy 40 (2016) 532–544

Contents lists available at ScienceDirect

Telecommunications Policy

URL: www.elsevier.com/locate/telpol

Crowdsourcing mobile coverage ☆

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ARTICLE INFO

Available online 15 March 2016

Keywords:
Mobile networks
Technology adoption
Digital divide
Coverage
Poverty

ABSTRACT

Mobile coverage affects social and economic communication and performance. Looking at the determinants of mobile network coverage helps highlight both operators' strategies and individual users' decisions. Subscribers often install small wireless antennas called femto-cells within buildings with poor signal. The location and density of these antennas provides information for areas with significant demand but poor coverage-areas where coverage is effectively *crowdsourced*. In contrast to the development of fixed-line networks, average income, population, geography, and education are the main drivers of both telecom and femto-cell based mobile coverage. Low-income regions are found to receive almost 15% less coverage compared to their affluent counterparts and have two fewer telecom base stations installed for equal distributions of (potential) subscribers. Base stations tend to be at least three times further from lower-income subscribers. Within poorly-covered areas, wealthier households are able to compensate by investing in femto-cells, but poorer households are often excluded from communication networks and the internet. The results of this research has implications for information policy.

1. Introduction

The digital divide is becoming a mobile divide. In 2013, 55% of American adults had a smartphone and 60% of them connect to the internet using mobile phones.[1] Mobile phones are becoming the primary device for accessing online content particularly for young and low-income Americans. Moreover, fixed-line telephony is being overtaken by mobile telephony: 40% of households had only wireless telephones in 2013.[2] Mobile networks are gradually becoming the primary infrastructure for communicating, connecting, and accessing information. As a consequence, whereas a few years ago local groups in the UK were protesting against ‘those big nasty mobile phone masts’ in their villages, they are now asking for better coverage.[3]

☆ The authors wish to thank Tim Simcoe, Tim Bresnahan, Pai Ling Yin, Chris Forman, Chrysanthi Avgerou, Tommaso Valletti, Christos Genakos and conference participants at the 3rd ICT conference Munich 2013, for extremely valuable suggestions. The authors wish to thank Berthold K.B. Horn (MIT) and Brendan Gill (OpenSignal) for data provision and valuable support throughout this project. The authors are grateful for financial assistance from the Digital Cities Exchange (EPSRC Grant No. EP/I038837/1).
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[1] Pew 2013: http://pewinternet.org/Reports/2013/Cell-Internet.aspx.
[2] CDC http://www.cdc.gov/nchs/data/nhis/earlyrelease/wireless201312.pdf.
[3] Views about mobile coverage are changing. "Whereas 10 years ago parish councils and local groups were saying 'We don't want one of those big nasty mobile phone masts in our village', now what they are saying is 'Please can we have a mast so we can get some coverage?'", (BBC, 31 January 2013, http://www.bbc.co.uk/news/uk-england-somerset-21276168).

http://dx.doi.org/10.1016/j.telpol.2016.02.005
0308-5961/

Applications, remote sensing, multimedia and voice services all depend on the quality of the enabling infrastructure. Whereas e-health and e-government applications help mitigate the digital divide by making basic services available to all citizens, poor coverage can severely limit the benefits of these initiatives (Hsieh, Rai, & Keil, 2008). For example, signal obstacles due to large buildings, hills, or valleys can result in 'patchy' coverage and incomplete hand-overs of connections between neighboring base stations.[4] This inferior quality of service has led some residential and business users to install small base stations called femto-cells (or small cells) that offer mobile network access through fixed broadband connections. As saturation levels in mobile adoption have been reached in most of the developed world,[5] actual network performance will play a crucial role in the economic and social returns from investments in devices and networks. The service provider industry shows its interest in coverage through a number of mobile signal applications for smartphones; in November 2014 Apple officially entered this market when it patented its method to detect 'dead zones' via crowdsourced information.[6]

The contribution of this paper to the understanding of these economic and information policy issues is organized in two levels: first by looking at the use of a substitute network (femto-cells) and trying to quantify the magnitude of signal exclusion; second by attempting to identify a socio-economic model of mobile signal supply. Using a unique crowdsourced dataset to identify mobile operators' network design allows us to link this information to socio-economic characteristics of the covered areas. The findings help stimulate the debate on mobile network access and performance that is now key in the digital agendas of many governments.

The paper is organized as follows: in the next section a theoretical framework of mobile coverage is outlined. Section 3 describes the data and the clustering algorithms; Section 4 presents the empirical models, results and robustness checks; Section 5 concludes.

2. Theoretical framework

2.1. Characteristics of mobile networks

Mobile networks are comprised of base stations (or cell towers) that are used to supply signal to an area. The quality of users' communication depends on signal strength that declines with distance from the base station. Distance is thus effectively a proxy for the quality of service, and due to network bandwidth restrictions, poor or patchy signal may be comparable to no signal at all. Subscribers are often unaware of the signal strength in their home or workplace. This information asymmetry can be exploited by operators to attract subscribers independent of their installed infrastructure and actual coverage.[7]

In areas with insufficient mobile coverage, users may purchase and install femto-cells. Femto-cells are network devices that can be connected to fixed broadband routers and provide mobile signal for a small radius – usually covering a household or small business. In practice, femto-cells can only serve their owners due to their limited span of coverage and the requirements imposed by operators.[8] The equipment costs of femto-cells are borne by the subscribers themselves on top of the subscriptions for typical broadband and mobile service connections that allow the device to interoperate with the associated mobile phones. In 2012 there were more than two hundred thousand femto-cells installed in the UK, and more than three quarters of them were located in rural areas (Ofcom, 2012). The location of femto-cells indicates the need for a better signal and the density of femto-cells in a region is used to highlight the extent of this need. The technical reasons for poor signal strength vary. Common examples include obstacles in the line of sight (linked to the positioning and height of the mast relatively to its surroundings), insufficient transmission power, direction of the antennae, and also buildings and surface area characteristics[9].

Telecommunications networks have consistently been found to affect local and national economic performance (Czernich, Falck, Kretschmer, & Woessman, 2011; Greenstein & McDevitt, 2011; Gruber & Koutroumpis, 2011; Katz, 2012; Koutroumpis, 2009; Roller &Waverman, 2001). Network investment and adoption rates are the usual metrics to assess a country's progress in this field. However, it is the actual speeds achieved and coverage supplied that affect the use of the

[4] Base stations are wireless antennae used to 'supply' mobile coverage.

[5] For example, 91% of adults in the United States; Pew 2013.

[6] http://techcrunch.com/2014/11/11/apple-patents-crowdsourced-tracking-of-mobile-network-dead-spots/.

[7] Operators with national licenses face regulatory targets for minimum coverage but this can be as low as 80% (see Ofcom 3G competition for the United Kingdom:

http://media.ofcom.org.uk/2013/11/07/ensuring-3g-coverage-compliance/).

Coverage measurements are probabilistic and based on median path losses for different population densities. Crowdsourced data can alleviate this lack of clarity.

(http://stakeholders.ofcom.org.uk/binaries/consultations/2100-MHz-Third-Generation-Mobile/annexes/methodology.pdf).

[8] Commercial use is not allowed, and subscribers need to disclose specific mobile devices (phone numbers/SIM cards) that will be connected through each femto-cell.

[9] In the United States, mobile coverage is covered in the Federal Communication Commission's (FCC's) universal service policies. The result of the 2011 FCC order was the Connect America Fund (CAF) with an annual budget of USD 4.5 billion and a national goal of a universal availability of both fixed and mobile broadband. The CAF provides support for both fixed and mobile broadband expansion in the most remote areas and funding to facilitate a measured transition for companies impacted by the reform (Inter-Carrier Compensation) (Calvo, 2012).