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The wireless abyss: Deconstructing the U.S. National Broadband Map

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ABSTRACT

The U.S. National Broadband Map (NBM) is arguably the most complex articulation and synthesis of telecommunications data ever generated by the federal government. Drawing upon information collected by fifty U.S. states, five territories and the District of Columbia, broadband provision is tabulated at the Census block level and made available to the general public in a variety of formats (e.g., maps, tabular databases, and geographic coverages). One major policy challenge associated with deepening our understanding of wireless broadband provision in the United States is developing a methodological process for accurately rearticulating NBM wireless data collected at the block level to more meaningful economic units (e.g., Census block groups or tracts). Without this ability, policy analysis and an objective evaluation of the goals set forth in the National Broadband Plan are compromised. The purpose of this paper is to outline such a methodology, while simultaneously highlighting several consistency checks for ensuring completeness and data aggregation integrity.

1. Introduction

The National Broadband Map (NBM) is a collective effort between the National Telecommunication and Information Administration (NTIA), the Federal Communications Commission (FCC), fifty states, five territories, and the District of Columbia to provide a detailed snapshot of broadband provision in the United States. According to the FCC, broadband in the United States constitutes download (i.e., to the customer) speeds of at least 4 megabytes per second (Mbps) and upload (i.e., from the customer) speeds of at least 1 Mbps (FCC, 2010a,b). To confuse matters, the NTIA defines broadband as 768 Kbps download and 200 Kbps upload speeds. Both definitions have evolved significantly over the past decade, when as recently as 2004 the FCC defined broadband as download speeds of at least 200 Kbps (FCC, 2004). Clearly, as delivery technologies continue to evolve and improve, so too will the definition of broadband.

The NBM is a small, but significant facet of a much larger National Broadband Plan ("*Plan*") (FCC, 2010b). The *Plan* outlines a strategic agenda for both developing and enhancing broadband infrastructure because of its perceived importance to a variety of critical sectors in the U.S. economy (e.g., health care, education, energy) as well as government performance, public safety and civic engagement (FCC, 2010b). Understandably, one of the major challenges set forth in the *Plan* was to determine broadband provision levels throughout the United States. As noted by Grubesic (2012), issues of information asymmetry have plagued broadband-related development efforts in the U.S. for many years. One major reason that asymmetries exist is the lack of quality data regarding broadband provision, pricing and quality of service (QOS) at the local level (Greenstein, 2007). For example, prior to the release of the NBM, the only viable broadband provision data available to analysts was the FCC Form 477 database, which had been aggregated to the ZIP code or Census tract level. While these data were suitable for a rough snapshot of advanced telecommunications provision, their lack of spatial resolution was a significant hindrance to understanding disparities in broadband and related competitive effects. In addition, because the Form 477 data did not include pricing information, robust evaluations of the economic impact of broadband and associated telecommunications policies were difficult.

Sadly, while pricing information is still unavailable in the NBM, the spatial resolution of provision data is greatly improved. Detailed provision data are now available at the Census block level (e.g., providers, upload/download bandwidth, etc.), which is the smallest geographic unit that the Census Bureau publishes decennial survey information on. As noted by Grubesic (2012), however, there are several major problems with the NBM data. First, provider participation in the NBM varied significantly between states, ranging from 27% (Virginia) to 100% (Indiana, Illinois, and six others). Second, issues of data uncertainty for digital subscriber line (xDSL) service were not rectified, likely leading to a significant overestimation of broadband xDSL provision coverage in the U.S. Third, the NBM currently identifies thousands of zero population blocks (i.e., no residents or businesses) as having broadband. In part, these errors can be attributed to providers claiming an ability to provide service to these eligible locations within a 10 day window (NTIA, 2011), but as Grubesic (2012) notes, there is an important difference between regions that *could* have broadband and regions that *have* broadband. Finally, the sheer size of the databases associated with the NBM creates problems. For example, the wireline provider database contains approximately 12.5 million records. As a result, any

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effort to aggregate these data to alternative units for analysis is computationally burdensome, time consuming and prone to error.

Although the problems associated with wireline NBM data are fairly well understood, much less attention has been paid to the wireless NBM data. This is a notable gap because there is growing sentiment that wireless options may have a disruptive effect on the overall broadband market, making wireline options (e.g., fiber to the home) less attractive (Middleton & Given, 2011). This suggests, that now more than ever, developing an understanding of where wireless broadband options are available is critical to evaluating disparities in broadband and evaluating the relative success or failure of the National Broadband Plan over time. Unfortunately, in their current form, the NBM wireless provision data are both unwieldy and the antithesis of user-friendly. With over 50 million individual records for wireless provision, efforts to manipulate, analyze and visualize these data at a national scale are both time consuming and computationally intensive. Thus, the purpose of this paper is to provide a methodological framework for rearticulating the raw, wireless broadband provision data from the NBM to more meaningful economic units for policy evaluation, spatial econometric analysis and geographic visualization. Specifically, provision data are aggregated from Census blocks to block groups using a multistep process that leverages the data manipulation abilities of a geographic information system (GIS). A variety of data consistency checks for ensuring completeness and data aggregation integrity are also detailed.

2. Wireless broadband in the United States

Wireless broadband comes in many forms, connecting a home or business to the internet without wires, typically via a radio link between a customer's location and a facility operated by a service provider (Sawada, Cossette, Wellar, & Kurt, 2006). A simple typology to differentiate between types of wireless broadband is *fixed* and *mobile*. There are also subtle differences between platforms that use *licensed* and *unlicensed* spectrum (Sirbu, Lehr, & Gillett, 2006). Where the latter is concerned, unlicensed spectrum is shared among internet service providers, while licensed spectrum is dedicated to a single provider. For wireless platforms, fixed technologies allow subscribers to access the internet from a fixed point (while stationary), and usually require a direct line-of-sight between the wireless transmitter and receiver. *Fixed* wireless technologies include WiFi and WiMAX (Abichar, Peng, & Chang, 2006; Vaughan-Nichols, 2004) and have proven to be popular in rural and remote areas where wireline and mobile technologies are not as widespread (Zhang & Wolff, 2004). *Mobile* wireless connections provide broadband in specific geographic locations to mobile objects (cars, trucks, boats, pedestrians, etc.) using spectrum that is dedicated to an internet service provider. Mobile wireless technologies include 3GPP Long Term Evolution (LTE) and CDMA2000 (EVDO) among others (Agashe, Rezaiifar, & Bender, 2004; Dahlman, Parkvall, Skold, & Beming, 2008). Finally, it is important to note that satellite broadband technologies from providers such as Hughes, Wild Blue and Spacenet are also used throughout the United States, although the number of households subscribing to satellite services remains very small (~1 million during the first quarter of 2010) (NSR, 2010). For a brief overview of wireless broadband platforms and their associated speeds, see Table 1.

To put the U.S. wireless market in perspective, consider the recent statistics published within the National Broadband Plan (FCC, 2010b). Wireless broadband use is growing exponentially, with Cisco projecting that wireless networks in North America will carry approximately 740 petabytes per month by 2014, a 40-fold increase from 2009 (~17 petabytes). In part, this massive increase is attributable to the growing use of smart phones, but it also fueled by the use of LTE-enabled laptop computers and tablet devices. The FCC (2010a,b, 77) also notes that machine-based wireless communications will increase dramatically within the next few years, as sensor networks

Table 1
Wireless broadband overview.

Technology	Air interface[a]	Data rate (Mbps)	
		Downlink	Uplink
WiMAX	OFDM, OFDMA	75	75
UMTS-TDD	TDMA	16	16
3GPP LTE	OFDM, OFDMA	100	50
CDMA2000/EVDO	FDMA	3.1	1.8
3GPP2 ultra mobile broadband	OFDMA	275	75
MBWA	OFDMA	1	1

OFDMA = Orthogonal frequency-division multiple access.
TDMA = Time division multiple access.
FDMA = Frequency division multiple access.
Source: Kong, D.T., Liang, P-Y. and Chang, Y. (2009). *Wireless Broadband Networks*. Wiley: Hoboken, NJ.
[a] OFDM = Orthogonal frequency-division multiplexing.

and "smart devices take advantage of the ubiquitous connectivity afforded by high-speed, low-latency, wireless packet data networks."

The notion of broadband ubiquity is interesting. While there is no doubt that the number of smart devices leveraging wireless broadband networks is on the rise, the ubiquity of wireless broadband is less certain (Middleton & Bryne, 2011; Sawada et al., 2006). Fig. 1 provides some perspective on the spatial dimensions of new technology rollouts by private telecommunications providers. Specifically, it highlights locales throughout Indiana and Ohio that have access to the new wireless 4G WiMAX network built by Clear Communications.[1] This system is designed to provide average download speeds of 3 to 6 Mbps, with bursts up to 10Mbps. Although this does not reflect "true" 4G speeds as defined by the ITU (100 Mbps) (ITU, 2008), it is representative of average 4G speeds for mobile devices in the U.S. These speeds can support a variety of internet-based activities ranging from streaming audio and video to online gaming (GAO, 2010). Dark green portions of Fig. 1 denote areas with excellent coverage and high bandwidth capacities, light green areas have only partial coverage and lower available bandwidth. Areas with no green shading represent coverage gaps in the Clear Communications network. Given this information, it is evident that portions of the Cincinnati and Columbus, Ohio metropolitan areas have excellent coverage and high bandwidth capacities (dark green), but the Dayton, Ohio metropolitan area (pop. 847,502) is without any coverage (Fig. 1) from Clear Communications. Further, the second largest metropolitan area in the Midwest, Indianapolis, Indiana (pop. 1.83 million), is only partially covered and likely under-capacitated in terms of available bandwidth (light green). While early, this geographic perspective on the rollout of the much touted 4th generation network highlights underserved regions that might benefit from policy interventions if these gaps in provision persist. Granted, this is a geographic snapshot of a single provider in a mixed urban/suburban/rural region, but the notion of 4G ubiquity remains relatively far-fetched, particularly for more rural areas. Further, there are concerns that the architecture and capabilities of wired and wireless access networks will never converge, primarily because of the limitations associated with wireless spectrum availability and its associated capacity (Lehr & Chapin, 2010). That said, the FCC recently moved to open television spectrum to wireless broadband in the hope of relieving the strain on existing spectrum allocations (Benton Foundation, 2010). Regardless of one's stance on these issues, the ability to identify heterogeneities in provision between urban, suburban, rural and remote communities is critical to obtaining a better understanding of wireless broadband provision and access in the United States and supporting the National Broadband Plan.

[1] Both Indiana and Ohio have a good mix of urban, suburban and rural settings, providing a fairly representative snapshot of wireless coverage and technology for the U.S.