Wifi Hotspots in 100 U.S. Cities and Policy Implications

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Summary

This paper argues that as our society progresses toward a ubiquitous society, our policy focus should be moved from household broadband penetration to a wider vision of broadband accessibility as measured by several broadband density concepts. Then, it shows that the number of WiFi hotspots in 100 U.S. cities is related to demographic and economic characteristics of those cities: their population, population density, household density, and household median income. This paper further visually illustrates that free or paid WiFi hotspots are by and large located in areas where low income households reside. Based on these statistical and visual analyses, this paper offers five recommendations to facilitate an effective broadband policy.

Key Words: WiFi; Broadband; Accessibility; Usability; U.S. cities

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1. Introduction

The U.K. government recently published a comprehensive communication policy report, *Digital Britain*, enumerating many policy measures to facilitate U.K.'s transition to a leading digital and knowledge based economy (DCMS & DBIS, 2009). The report aims to increase the affordability and availability of broadband service as well as citizens' capabilities of using information and communication technologies in the U.K. Affordability is associated both with household income and the cost of broadband service and terminal equipment such as a cell phone and a computer. As is also true of other governments, the U.K. government helps low-income families by subsidizing their network connections. The U.K.'s policy measures to improve broadband availability at home are twofold: one is to adopt the concept of universal service in broadband, guaranteeing at least 2 Mbps network connection in all U.K. homes by 2012 at the latest, and the other is to boost private investment in the next generation network rollout by providing subsidies. The policy measures aimed at citizens' capabilities emphasize both training to equip citizens with proper skills and strategies to motivate them to use more online services.

Even though *Digital Britain* contains well organized policy schemes based on data to support them, this report seems to be grounded on an older view that users will continue to access broadband networks primarily at their homes and office, whereas, in fact, people have already begun to use more and more wireless Internet services. Therefore, it can be said that *Digital Britain* fails to provide new perspectives that address the transition of our society into what has been termed a "ubiquitous society" defined as a society in which people can get access to communication networks anytime and anywhere.

In the United States, The FCC is also in the process of formulating a national broadband plan, for which it announced a notice of inquiry (NOI) in April 2009 that raised various policy issues to be resolved so that all US citizens can have access to broadband capabilities. In creating a national broadband plan, the FCC is trying to draw up a comprehensive and coherent roadmap to increase the accessibility and affordability of broadband services and, ultimately, to maximize the benefits of broadband access and use (FCC, 2009). In contrast to the approach taken by the U.K., the FCC raises many fundamental questions on future broadband policies. For example, it seeks comments on how to define broadband, how to measure broadband availability, and how to maintain the desired balance between the free market and government intervention.

As our society evolves toward a ubiquitous society, we need to develop new policy schemes and suggest new perspectives by exploring and researching what is currently happening in our society today. Right now, our perceptions of a world transformed by technological change greatly exceed our awareness of its consequences: we can predict that individuals will soon use Internet services in a seamlessly interweaved web of wired and wireless networks; yet we actually do not know much about current changes in our society as a result of advances in technology and connectivity, and cannot predict how our society will reshape itself in the future both because the speed of technological change precludes our ability to understand their implications systematically and their novelty leaves us unable to analyze them based on our past experiences.

This paper argues that as our society progresses toward a ubiquitous society, policy concerns should be refocused from households to individuals, from penetration to accessibility, and from affordability to usability. Specifically, this paper explores the effects of WiFi hotspots on broadband accessibility, and, from this analysis, derives policy implications useful for the formulation of a national broadband plan in the U.S. This paper focuses on WiFi hotspots because WiFi access service is provided, in part, on a non-subscription base, which can facilitate the realization of a ubiquitous society. Usability, as discussed in section 2, is a concept encompassing users' affordability of services and capability. As nations world-wide have created various policy measures to ameliorate users' affordability and capability, as stated in *Digital Britain*, this paper focuses mainly on the issue of accessibility.

The next section first defines relevant nomenclature in this area, particularly accessibility and usability, which can be useful for research and policy development. Section 3 discusses the results of a regression analysis, in which the 100 largest cities of the U.S. in terms of population size were selected and statistically analyzed to explore the relationship between the number of WiFi hotspots and several explanatory variables such as population size, household density, and median income of these cities. Through visual illustrations, Section 4 then presents the relationship between WiFi hotspots, especially free WiFi hotspots, distribution and household distribution by quintile income groups.[3] Section 5 discusses the policy implications and issues that can be drawn from the discussion in the preceding sections, and section 6 concludes the paper with a brief summary of key findings and suggested directions for further research.

2. Concepts and measurements: accessibility and usability

2.1. Concepts of accessibility and usability

Governments throughout the world are trying to increase broadband penetration rates because broadband subscription has been found to have a close relationship with economic growth and economic wellbeing of people. According to Crandall et al. (2007), for example, U.S. state GDP and employment levels are positively correlated with broadband use; A recent OECD analysis found that a simple correlation between GDP per capita and broadband penetration is 0.67 (OECD, 2008). Acknowledging the social and economic importance of broadband subscription by households, U.S. States began to gather data on broadband penetration, measured by the ratio of broadband subscribing households to total households, and publish their broadband maps, and, similarly, international institutions such as OECD and ITU (International Telecommunication Union) compare and announce nations' broadband penetration ranking.[4]

However, broadband penetration data deliver only limited information to policy makers in a ubiquitous society where the terminal point of information service moves from a home to an individual, even if the home remains the central place where individuals spend a large share of their time and use information services. Household penetration data do not fully reflect the broadband accessibility in a society that has adopted various wireless broadband services such as 3G, WiMAX, and WiFi. Especially, in a country where free WiFi hotspots are spreading, simple household broadband penetration data do not accurately represent the degree of broadband accessibility to an individual. In this period of transition to a ubiquitous society, it is therefore necessary to develop new concepts and measures that provide an accurate picture of actual information consumption.

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[3] Free WiFi hotspot means that users of wireless Internet at free WiFi hotspots are not required to pay any monetary fees or purchase any products or services. Examples are WiFi hotspots provided by cafés and retail shops in the U.S. Refer to Kwon & Yang (2008) for details.

[4] Private consulting firms like Strategy Analytics also publish an international ranking of broadband penetration rates (Strategy Analytics, 2009). According to Strategy Analytics' report, Korea ranked first and the U.S. ranked 20th out of 58 countries surveyed, whereas according to OECD (2008), Korea ranked seventh and the U.S. 15th.

While recent policy reports such as *Digital Britain* and the NOI of the FCC provide new terminologies, the terms are mostly used with regard to fixed broadband connection in the former and are not defined in the latter. Both *Digital Britain* and the NOI are focused on enhancing availability, affordability, and user capability of broadband services even though they use different terms. In measuring the degree of households' connectivity to broadband network *Digital Britain* uses the term "availability" and the NOI "accessibility." In addition, *Digital Britain* uses capability to refer to users' ability to use broadband service, while the NOI seems to use it to describe the capacity of broadband network or services provided through broadband network.[5]

In a ubiquitous society, individuals with skills to connect to a network and to use equipment and applications should be able to have access to broadband networks anywhere, using proper equipment at affordable prices. Therefore, this paper proposes two terms to describe information consumption in a ubiquitous society: accessibility and usability. In a market economy, accessibility to networks and usability of network services are determined by supply and demand conditions; in this perspective, this paper classifies the factors determining information consumption into these two categories.

From the supply side, at a minimum, a broadband connection service at a specific place should be available to individuals, leaving aside conditions for use such as rate, connection speed and technology. Therefore, this paper defines accessibility of broadband connection as the level of individuals' accessibility to networks at various locations. In other words, potential users should be able to figure out the kinds of broadband services available at locations and the conditions to use them. Broadband availability can also be interchangeably used with accessibility.

U.S. State governments or the FCC can provide broadband accessibility information to the public by adding WiFi access point information and coverage of 3G or WiMAX services to current broadband maps. For wireless service users, neither current fixed broadband connection information nor 3G or WiMAX coverage information provides as much useful information as WiFi hotspots because they are exclusively membership based services. Therefore, adding the location information of free Wi-Fi hotspots to broadband maps and providing free WiFi access

[5] The NOI actually seeks public opinion on how to define broadband capability rather than defining the concept.

point databases with a search function to the public are likely to be the first steps toward a ubiquitous society. This addition of WiFi hotspot information to broadband maps would further induce private firms to provide free WiFi connections to the public.

From the demand side, users' affordability will be determined by their income and the prices of connection services. Thus, affordability will be determined by users' income level at given market prices. However, affordability is not a sufficient condition for the use of broadband services because, even though users have the financial resources to afford these services, they will not use them, absent acknowledgement of their benefits because of lack of motivation or lack of skills. Whereas *Digital Britain* uses "capability" to describe users' motivation and skill readiness, usability in this paper refers to both users' affordability and capability.

2.2. Measurements of accessibility

When emphasis is placed on fixed broadband access, household penetration data can serve as a good measure to monitor nationwide broadband use, and provide policy makers with a broader view of broadband availability in counties, cities, and states. In a ubiquitous society, however, we need to develop other concepts and measurements to assess accessibility to broadband services.

Basically, broadband accessibility can be measured by broadband density—the number of broadband access points or the area covered by services divided by total size of an area or population of an area. Four types of broadband services currently exist: fixed broadband, WiFi, 3G, and WiMAX. Of these four, the first two services are location specific services because their area of service is limited to a small area, but one base station in each of the last two services usually covers a wider area than the first two. Therefore, given these characteristics, measuring the broadband density of an area can be conceptualized as follows:

[Fixed broadband services]

- Fixed broadband density = the number of households subscribing to broadband service/total size of a given area or total number of households in that area
- (free) WiFi density = the number of (free) WiFi hotspots/total size of a given area or the population of that area

[Mobile broadband services]

- Size of a given area covered by 3G, and WiMAX/total size of that area

In the measurements above, an area can consist of a tract, county, city, or state. If the total households of an area are used in the calculation of fixed broadband density, the measurement is the broadband penetration rate of an area. WiFi density, when calculated by the population of an area multiplied by 1000, becomes the number of WiFi hotspots per 1000 persons. The third measurement is simply the coverage of each service, which can be obtainable from service providers.

In order to understand the degree of dispersion of broadband access points, we can calculate the averages and variances of broadband densities measured at the tract or block group level. The averages and variances of free WiFi densities measured at the tract or block group level will vary across a county, a city, or a state; the average density measures the degree of free WiFi accessibility of a city, and the variance of density measures a scatter of free WiFi accessibility of a city.

3. WiFi hotspot distribution in 100 U.S. cities and its determinants

3.1. Unique features of WiFi service

WiFi service is provided in the U.S. by both network operators and businesses such as cafés, snack stores, and hotels. Network operators like AT&T provide WiFi service to their network service subscribers and to customers of retails stores through business partnerships with those stores. AT&T's provision of WiFi exemplifies only one of many different models of wireless service provision: some businesses such as cafés and bakeries provide WiFi service to customers and visitors for free; some businesses provide the service for free if customers watch advertisements; and individuals share WiFi connection with closed group members or sell WiFi connections (Kwon & Yang, 2008; Middleton & Potter, 2008).

WiFi service is based on wireless communication technologies as WiMAX service is, but its coverage is limited to small areas because the coverage of WiFi is 100 to 300 feet. Therefore, location owners can restrict their WiFi hotspot connections within their sites and combine WiFi service with their own services to increase customer visits. WiMAX is similar to WiFi but uses an exclusive spectrum band in contrast to WiFi, which uses spectrum commons. In addition, WiMAX is a subscription based service, with coverage ranging from 3 miles to 30 miles, which means that it resembles 3G service more than WiFi service. Consequently, small businesses that are using WiFi service as a marketing tool cannot consider WiMAX as an alternative. WiFi service is thus likely to exist in the future without severe competition because of its unique features.

3.2. Overview of WiFi hotspot distribution in 100 U.S. cities

According to JiWire data, as of August 31, 2009, there are 67,479 WiFi hotspots in the U.S.[6] 13,159 of those WiFi hotspots, 19.5% of the total, are in the 100 largest United States cities, in terms of population size. The population of those 100 U.S. cities was 20.1% of the total U.S. population in 2000, which shows that the share of WiFi hotspots in 100 U.S. cities is commensurate with that of the population.[7]

On average, the number of WiFi hotspots existing in these 100 U.S. cities is 132 and 0.3 per 1000 persons. New York city, with the largest population in the U.S. has the largest number of WiFi hotspots, 973, and Corpus Christi, TX, ranked 61st in population size among these 100 cities, has the fewest number of WiFi hotspots 26. In terms of WiFi hotspots per 1000 persons, Jersey city, NJ is ranked first, with 1.4 WiFi hotspots per 1000 persons and Los Angeles, CA, is ranked last with 0.05.

3.3. The model and data

In this paper, an analytical model to analyze the determinants of WiFi hotspot distribution is constructed based on demand and supply theories of economics. Demand for WiFi broadband service will depend on the population size of a city, which can be seen as a proxy variable for market size, population density, household income, and other demand determinants such as consumer preference, weather, and prices of substitutes. Demand for WiFi service will increase as population and household income rise and as the price of substitutes, such as the price of fixed broadband service, also rises. This causative chain is elementary, reflecting principles explained in undergraduate microeconomics textbooks of the effects of these exogenous variables on demand. However, in contrast, the effect of population density on demand for WiFi service is not similarly obvious because it is unclear whether population

[6] Refer to www.jiwire.com for WiFi hotspot information. JiWire data are collected based on a voluntary reporting system, so the level of data precision cannot be provided.

[7] Population data are obtained from U.S. Census Bureau (www.census.gov). The list of the 100 largest cities of the U.S. in terms of population size is based on the 2000 Census data.

density causes an increase in the number of WiFi hotspots when population size is controlled.

On the supply side, as explained above in subsection 3.1, there are two types of suppliers: network operators and businesses. In terms of network operators, network roll-out costs per line decrease with household density because as household density rises, the average length of access networks to homes becomes shorter. In addition, there will be a positive correlation between household density and business building density, so household density will be positively correlated with WiFi hotspot numbers. WiFi modem costs are not taken into account in this analysis since businesses such as cafés, bakeries, and hotels, can mount WiFi access points at their premises at a very small cost.[8]

The analytical model of this paper is presented below, and the actual regression model used in this analysis is presented in equation (1), in which I use the data currently available.

Analytical model: the number of WiFi hotspot numbers = *f*(population, population density, household density, household median income, other factors affecting the number of WiF hotspots in a city)

Regression model: $\mathrm{WiFi}_i = f(\mathrm{C}, \mathrm{PopT}_i, \mathrm{PopDen}_i, \mathrm{HousDen}_i, \mathrm{MHI}_i)$, $i = 1 \ldots 100$ (1)

where C is constant, PopT total population of a city in thousands, PopDen population density pei square miles, HousDen household density per square miles, and MHI median household income. WiFi data were obtained from the JiWire website and other data for explanatory variables were extracted from 2000 Census data. SAS version 9.1 was used to run the regression.

Table 1. Regression results: Dependent variable is WiFi

Variable	Coefficient	p-value
C	-165.92078	<.0001
PopT	0.05088	<.0001
PopDen	-0.02150	0.0242
HousDen	0.10933	<.0001
MHI	0.00412	<.0001

* F-value for the model is 65.58 and adjusted R^2 is 0.72.

3.4. Outcomes

The regression model is statistically significant as shown in Table 1, and all independent

[8] WiFi modem prices are around $100 per modem at online shopping malls.

variables are also highly significant. The signs of coefficients correspond with the initial expectations noted in subsection 3.3. The number of WiFi hotspots grows with population, household density, and median household income, but falls with population density.

The number of WiFi hotspots increases by 51 per million persons, by 4 per $1,000 increase in median household income, and by 11 per 100 households per square miles. It decreases by 22 per 1000 persons per square miles. The effect of population density on the number of WiFi hotspots is an interesting result even though it eludes logical explanation. A caveat for the interpretation of PopDen coefficient is that its negative sign is likely to be the result of the high correlation between PopDen and HousDen, i.e., it may be caused by a multicollinearity problem.[9] In fact, when HousDen is omitted, the sign of PopDen becomes positive.

To sum up, the number of WiFi hotspots in U.S. cities increases with population size, income, and household density. While the policy implications derived from the analysis are not clear-cut, one implication proffered here regarding broadband accessibility in terms of WiFi hotspots, is that more policy concern should be placed on areas where the local economy is in recession. In addition, if data on the geographical distribution of WiFi hotspots, especially free WiFi hotspots, in U.S. cities become available, it is possible to analyze how free WiFi hotspots are related to the broadband access of low income families by matching the data with household income distribution data. A study on free WiFi user characteristics is also highly advisable in order to assess whether free WiFi hotspots located near low-income families contribute to lessening the digital divide. The next subsection turns to a discussion of this issue of the relationship of WiFi hotspots and low-income families.[10]

4. WiFi hotspot and income distribution in the U.S.

It is a well-known fact of urban economics that low income households tend to live in the central area of cities as shown in Figs 1 and 3. The poverty rate of families living in the inner cities is more than twice that of suburban families (O'Sullivan, 1996). In Figs 1 and 3, the grids show tracts which usually have from 2,500 to 8,000 persons, and the two figures show the quintile

[9] Correlation coefficient between population density and household density is 0.9777.

[10] Section 4 is revised version of subsection 4.2 of Kwon & Yang (2008).

distribution of household income.[11] Figs 2 and 4 present paid and free WiFi hotspot distribution in Chicago and Lansing. The map on the left in Fig. 2, covering a more extensive area than that on the right does, presents Wi-Fi hotspot distribution, with the numbers in the bubbles depicting the available hotspots of the areas; and the map on the right, a zoomed-in image of the map on the left, shows the distribution of for-pay (blue) and free (green) Wi-Fi hotspots. By examining these two figures jointly, it can be seen that WiFi hotspots, both free and paid, are concentrated in low-income residential areas.

The reason for this overlap is that free WiFi hotspot service is provided by stores located in central business areas, which are also the areas where low-income families tend to live. Given this overlap, we can make the presumption that free WiFi services can contribute to, or, at least has the potential of contributing to, lessening the digital divide. Therefore, rather than building citywide wireless networks, city governments can better ameliorate the digital divide by encouraging or subsidizing various retail stores in the central areas of cities to provide free WiFi access. Furthermore, even when local governments try to provide free WiFi access to citizens directly, they should take into account the distribution of low-income households and free WiFi hotspots rather than simply blanketing a city with wireless networks. By doing so, they can decrease both the possibility of crowding out private provision of free WiFi hotspots and the risk of squandering public funds.

As the visual presentation of overlapping areas of low income households and free WiFi hotspots is based on quite rudimentary techniques, it would be preferable to use a more refined method of measuring the correlation between income distribution and free WiFi hotspot distribution. The problem at this point in time, however, is that location information for free WiFi hotspots is not currently available. If free WiFi hotspot numbers in each Census tract or block group become available, it would be possible to measure more precisely the relationship between free WiFi distribution and income distribution.

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[11] Figs. 1 and 3 are obtained from a U.S. Census Bureau website and Figs. 2 and 4from JiWire website.

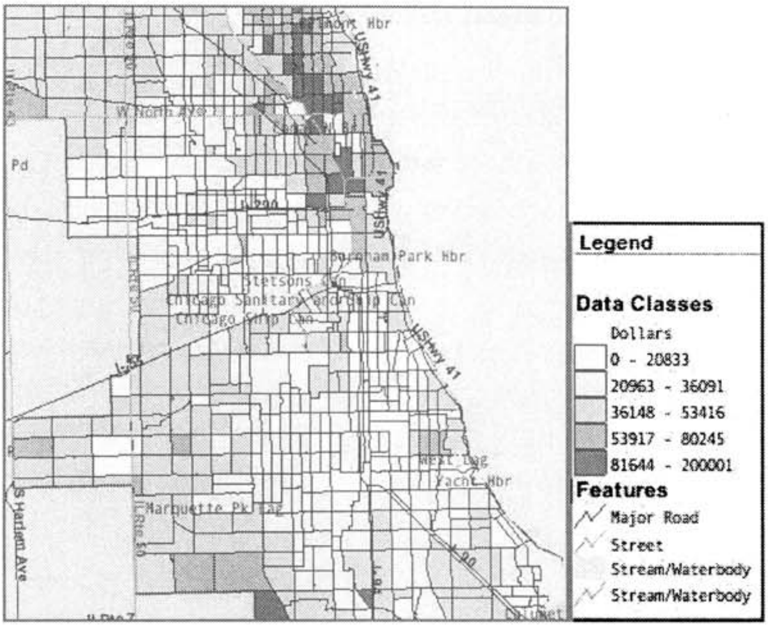

Fig. 1. Quintile household income distribution in Chicago

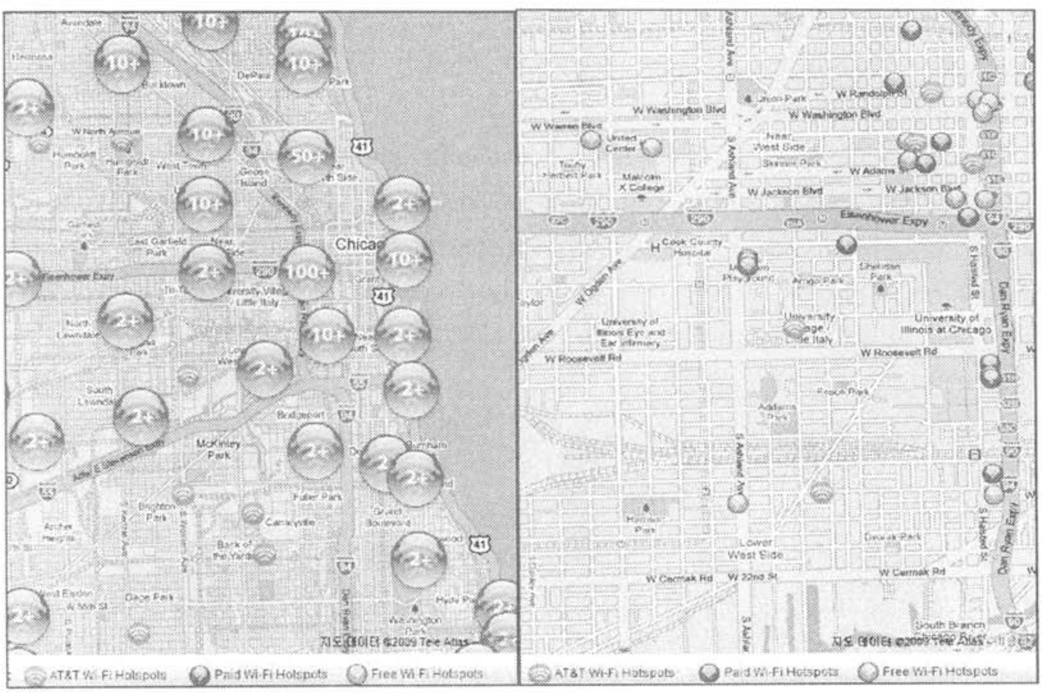

Fig. 2. Distribution of free and paid WiFi hotspots in Chicago

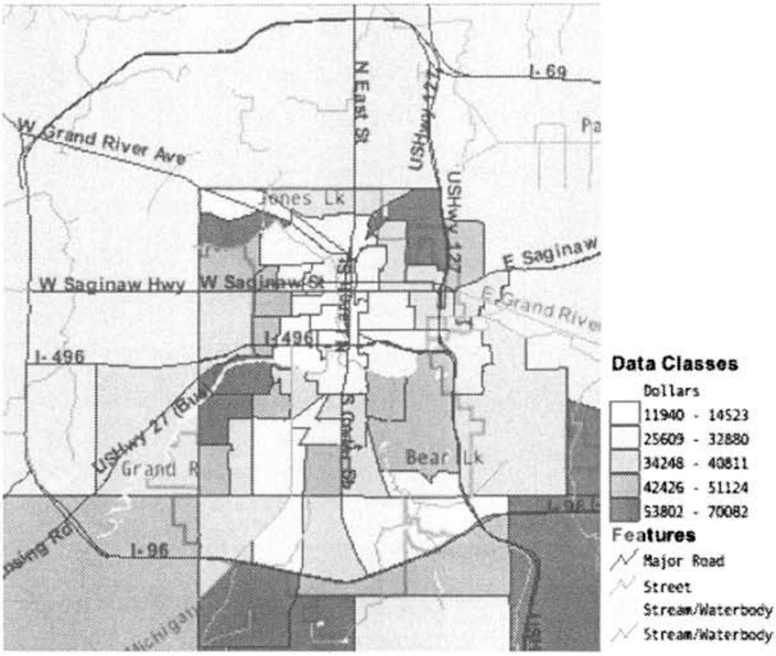

Fig. 3. Quintile household income distribution in Lansing

Fig. 4. Distribution of free and paid WiFi hotspots in Lansing

5. Policy implications and issues

5.1. WiFi hotspot location information at the Census tract level is of great value and statewide broadband maps should be supplemented with WiFi hotspot accessibility information

As places with free or paid WiFi hotspots function as strongholds for wireless broadband access, their location information as well as access conditions should be available to both users and researchers. Geographical distribution data on free or paid wireless Internet access points are far more useful than simple access point numbers. If free or shared wireless Internet access points are widely scattered in low income areas and their numbers are growing, distributing cheap or refurbished notebook computers to low income families and teaching them how to use the Internet would be far more powerful policies in reducing the digital divide than municipalities' blanketing their cities with public WiFi networks.

The U.S. Bureau of Census could include WiFi hotspot location data in the data collection pool for the Economic Census, which is repeated every five years, or, alternatively for the decennial Census Survey. WiFi density data based on the census tract or block group level would enrich our analysis of broadband issues and our ability to devise an effective overall broadband policy.

Statewide broadband maps, which currently provide only wired broadband accessibility information to the public, should also include WiFi hotspot accessibility information. If state or municipal governments followed the lead of JiWire which does provide a WiFi location search function with access conditions on the Web, it would be very useful to the public.

5.2.Given the differences between WiFi broadband service and WiMAX and the unique function WiFi can play, more policy attention should be placed on free WiFi accessibility

WiFi is similar to WiMAX in that both technologies were developed for broadband wireless connections. However, WiMAX exists basically as a subscription based service, while WiFi can be either a subscription or non-subscription based service. In addition, non-telecommunication firms, including cafés, bakeries, and retail stores, can easily combine WiFi connection service with their own services to increase customer visits because the coverage of WiFi can be confined to their small premises, the cost of mounting access points is minimal, and WiFi can be a non-subscription based service. Therefore, in formulating broadband policy, WiFi should be treated as a key technology.

5.3. Research on free WiFi user characteristics will be valuable for developing broadband policy

WiFi density data of a tract simply present wireless broadband accessibility in that area. That, as shown by this data, a large share of WiFi hotspots is located in areas where there is a concentration of low-income households has the potential to alleviate the digital divide, although that potential may not necessarily realized.

The challenges in realizing this potential stem from the fact that high accessibility does not guarantee high usability if low-income household members do not have skills and electronic equipment including notebook computers. Therefore, research on free WiFi user characteristics will be valuable for formulating overall broadband policy.

5.4. Statistical Analysis must move beyond broadband penetration statistics alone as such statistics do not capture the realities of broadband accessibility that encompass the use of wireless services.

Table 2 compares ten cities with more WiFi hotspots than the fitted numbers of WiFi hotspots with ten cities with less than the fitted number of WiFi hotspots. The first column of the table lists the ten cities that belong to the first category and the fourth column of the table lists the ten cities that belong to the second. The columns entitled *WiFi* show the actual number of WiFi hotspots in the cities of these two groups, and the columns labeled *Residual* present residuals from the regression used in subsection 3.4. New York City, which has the greatest WiFi hotspots in the U.S. and not shown in Table 2, mainly because of its population size and household density, has a negative residual, which means that its fitted WiFi hotspots are greater than the actual number.

As shown in Table 2, some cities are ahead of others in terms of wireless broadband accessibility. Even though this paper cannot compare this result with broadband penetration data for these 100 U.S. cities because such data do not exist, it is likely that broadband penetration statistics do not accurately reflect broadband accessibility for users since those statistics do not address wireless accessibility and the disparities between cities in this respect.

Table 2. Cities with more and less WiFi hotspots than fitted numbers of WiFi hotspots

City Name	WiFi	Residual	City Name	WiFi	Residual
San Francisco CA	860	305.0	Baltimore, MD	169	-55.5
Seattle, WA	487	227.5	Arlington, TX	62	-59.7
Portland, OR	290	155.0	St. Louis, MO	83	-71.2
Santa Ana, CA	211	148.0	Newark, NJ	95	-76.9
Austin,TX	254	146.3	Oakland, CA	94	-79.5
Honolulu CDP, HI	281	132.9	Garland, TX	29	-81.6
New Orleans, LA	168	124.9	St. Petersburg, FL	42	-86.3
Washington, DC	430	112.3	Detroit, MI	57	-95.3
Atlanta, GA	194	108.2	Buffalo, NY	54	-133.2
Chicago, IL	512	90.5	Los Angeles, CA	179	-136.8

5.5. Government policies that increase free or shared WiFi hotspots should be implemented

As long as WiFi access is a subscription based service, it is not different from WiMAX, 3G, and fixed broadband services. However, free or shared WiFi hotspot access requires us to reconsider existing business practices of network operators.

The Internet service providers' control of networks, in particular, is currently a subject of interest worldwide (Middleton & Potter, 2008). In Korea and other countries, network operators control only the maximum data throughput for large business customers, but control the number of simultaneous users as well when subscribers are individuals or retail stores. Adopting subscription fee schedule commensurate with data throughput can contribute to increasing shared or free WiFi hotspots in society given that, as found by Middleton & Potter (2008), "average households make use of less than 2% of the capacity of their wired broadband connections." Therefore, by adopting pricing rules commensurate with data throughput, governments can encourage individual users to share wireless bandwidth with others and small businesses to bundle free Internet access with their own businesses. While advocates for net neutrality may criticize this policy as an attempt to adopt usage pricing, it remains true that this policy can increase subscribers' welfare as well as efficiency in network usage.

Without adopting usage pricing system, network operators have an incentive to control the number of users per WiFi hotspot based not on traffic burdens but potential revenue decrease. Especially when residential units are apartment complex, several households can share one hotspot, resulting in a decrease in revenue of network operators if the number of users is not controlled. However, if usage pricing is allowed, then a network operator's revenue will not decrease because of shared use of WiFi hotspots.

6. Conclusion

This paper argues that as our society progresses toward ubiquitous society, our policy focus should be moved from household broadband penetration to broadband accessibility measured by concepts of broadband density. It shows that the number of WiFi hotspots in 100 U.S. cities is linked to their population, population density, household density, and household median income.

This paper also visually illustrates that free or paid WiFi hotspots are by and large located in areas where low income households reside and that, given this overlap, free WiFi services have the potential of contributing to lessening the digital divide. Therefore, rather than building citywide wireless networks, city governments can better alleviate the digital divide by encouraging or subsidizing various businesses in the central areas of cities to provide free WiFi access and adopting strategies to increase potential users' motivation and ability to use wireless services. Furthermore, even when local governments try to provide free WiFi access to citizens directly, they should take into account the distribution of low income households and free WiFi hotspots rather than simply blanketing a city with wireless networks. By doing so, they can decrease both the possibility of crowding out private provision of free WiFi hotspots and the risk of squandering public funds. While the visual presentation of overlapping areas of low income households and free WiFi hotspots is based on quite rudimentary techniques given the data currently available, if free WiFi hotspot numbers in each Census tract or block group become available, it would be possible to measure more precisely the relationship between free WiFi distribution and income distribution.

Based on the analyses in sections 3 and 4, this paper makes five recommendations.

- *WiFi hotspot location information at the Census tract level is of great value and statewide broadband maps should be supplemented with WiFi hotspot accessibility information. The U.S. Census Bureau may include WiFi hotspot location data in the data collection pool for its Economic Census or decennial Census Survey.*
- *WiFi broadband service is different from WiMAX and can play a unique function and,*

accordingly, more policy attention should be placed on free WiFi accessibility.

- *Research on free WiFi user characteristics will be valuable for developing a national broadband policy.*
- *Statistical Analysis must move beyond broadband penetration statistics alone as such statistics do not capture the realities of broadband accessibility that encompass the use of wireless services.*
- *Government policies should be implemented that increase free or shared WiFi hotspots.*

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