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The Making of a Sustainable Wireless City? Mapping Public Wi-Fi Access in Shanghai

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Abstract: In the context of the global information economy, ready access to the Internet is critical to a city's competitiveness, which has prompted a number of cities to launch plans to establish wireless networks. Most literature on the development of wireless cities focuses on cities in Western countries, and few have discussed how Chinese cities have adopted wireless technologies in their urban infrastructure development efforts. This paper examines recent development and spatial distribution of public Wi-Fi access in Shanghai, a leading business hub in China. We mapped Wi-Fi hotspots through the government sponsored "i-Shanghai" project and China Mobile Communications Corporation (CMCC). We find that while telecommunication providers have been proactively deploying WLAN (wireless local area network, a proxy of public Wi-Fi or wireless access) hotspots in Shanghai, neither government sponsored WLAN hotspots nor facilities established by CMCC could cover the old traditional neighborhoods in the central city and sub-districts in remote rural areas. We also address the development of a more sustainable wireless city in Shanghai with a particular focus on digital divide and social equity issues.

Keywords: Wi-Fi; wireless cities; GIS spatial analysis; digital divide; China

1. Introduction

Wireless communication technologies have emerged as a major force underlying the recent development and change of the global economy [1]. Under such notions as *digital cities* [2], *intelligent cities* [3], *mobile cities* [4], *wireless cities* [5], *ubiquitous cities* [6], and *smart cities* [7,8], new planning strategies that emphasize the adoption and adaptation of information and communication technologies (ICTs) have attracted considerable attention from scholars and policy makers. In the context of the global information economy, the usage of wireless technologies has become a key indicator of the competitiveness of a city [5,9–11]. A number of cities, such as Singapore and Taipei in Asia, Philadelphia, San Francisco and Boston in the United States, and Perth in Australia, have either expressed an intention to establish a wireless network or launched specific plans to develop wireless cities [5,12,13]. While most literature on wireless cities and the digital divide focuses on cities in Western countries, few have discussed how Chinese cities have adopted wireless technologies in infrastructure development, and even fewer have addressed the issue of digital divide in China's urban landscapes.

By the end of 2014, China's mobile Internet users had reached 649 million, as compared to 22.5 million in 2000, accounting for 19% of the total number in the world [14], among which the number of smart phone users increased to 557 million by the end of 2014 [15]. Internet development,

especially a dramatic increase in the number of smart phone users, has resulted in a booming demand for wireless access in Chinese cities [16]. In collaboration with major telecommunication operators, including China Mobile Communications Corporation (CMCC), China Unicom, and China Telecom, local governments in Chinese cities have launched plans for public Wi-Fi network access and the development of "wireless" cities. For example, since 2012, the Shanghai Municipal Government has launched a project named "i-Shanghai" (or *loving Shanghai*). The project aims to deploy over 4000 Wi-Fi hotspots by 2020, making Shanghai a large-scale wireless city.

This paper examines the development of public Wi-Fi access in Shanghai and compares the WLAN hotspots established by CMCC and those sponsored by the Shanghai Municipal Government through the "i-Shanghai" project. Notably, the total number of Internet users in Shanghai has increased by 500% during 2000–2014, among which the share of Internet users through smart phone or other mobile devices has increased from 64% in 2009 to 79% in 2013 [17,18]. We analyze the spatial distribution of Wi-Fi access at multiple scales (*i.e.*, district and sub-district levels) and in different areas (e.g., central city and suburban areas). By applying exploratory spatial data analysis (ESDA) methods, such as concentric analysis and spatial hot spot analysis, we underscore the proactive role played by telecommunication companies in shaping the Wi-Fi geographies in Chinese cities. The remainder of the paper is organized as follows: the next section briefly reviews the concept of wireless city and related literature on wireless city development and the digital divide. This is followed by the spatial distribution analysis of public Wi-Fi access in Shanghai provided by the "i-Shanghai" project and CMCC. The last section summarizes the major findings and discusses the characteristics of Shanghai's pathway towards a sustainable wireless city.

2. Background and Literature Review

Wireless cities are essentially cities completely covered by high-speed broadband and public Wi-Fi access, where the Internet can be openly accessed and used by their citizens. Wireless technologies are an important part of infrastructure development through which the efficiency and equity of governmental service can be improved [5]. Wireless network coverage is also a key step to extend fiber broadband to the public, and the access to Wi-Fi, and more broadly the Internet, is regarded as "the city's fifth major infrastructure" next to water, electricity, gas, and roads [19–21]. The impact of wireless city development is significant in many aspects, such as providing mobility values [22], changing travel behaviors [23], altering the perception of community and forming social networks in urban space [24–26]. Previous literature found that in wireless cities, transaction costs can be reduced [27] and social well-being of citizens is better off through closer social interactions [22,28,29].

Given the benefits of developing wireless networks or ready access to the Internet, a great number of cities are deploying or have plans to establish wireless broadband networks [30]. Previous literature has also documented a number of factors that determine the locations of public Wi-Fi access mostly in Western cities. Customer choice is regarded as a basic driving force behind the development of the wireless broadband market, and the layout of wireless facilities is obviously influenced by local social and economic factors [31]. Oyana [32] studied the distribution of wireless facilities in Southern Illinois, USA and identified three main factors that influence the distribution of wireless facilities: the higher educational population rate, age-specific group, and average family income. Driskella and Wang [33] examined the spatial layout of Wi-Fi access in Louisiana, USA, suggesting that the determinants of public Wi-Fi hotspot location are residents' socio-economic disadvantages in neighborhoods and their household characteristics. Grubesic and Murray [31] analyzed the distribution of Wi-Fi hotspots in four neighborhood communities in Cincinnati, USA, and reported that the degree of network access in each community was closely related to social, economic, demographic, and spatial factors, but evident differences exist between rich and poor blocks' Wi-Fi access; the network access in the inner city is concentrated in areas around commercial and office buildings.

Urban planning and government policies also play an important role in the making of a wireless city [34]. For example, through a comparative study of Singapore and Taipei, Hu *et al.* [5] suggested

that the development of the wireless city in Taipei is mainly driven by top-down government policy while such development depends more on the market-driven participation of customers in Singapore. The development of wireless city is also driven by the innovation and widespread use of smartphone technologies. In a case study of Salt Lake City, USA, Torrens [35] identified that Wi-Fi access has provided a possible solution to "last-mile" problems in the city, and Evans-Cowley [36] also addressed the influences of mobile phones on urban life.

Given the nature of Internet access as a public utility, the role of government in providing Wi-Fi infrastructure is of particular concern in the literature [30,37,38]. Ballon *et al.* [30] reviewed the public-private partnership in shaping wireless city networks in both EU and the U.S. and found that public authorities such as governments will strive for the optimal trade-off between minimizing their inputs for directly being involved in the establishment and operation of wireless city networks and maximizing the leverage for the purpose of specific policy goals such as narrowing the digital divide and so on. Girth [37] explored the variation in approaches and examined the structural factors that give rise to public-private partnerships. Some literature also have examined the role of the Asian government, China especially, in telecommunication industry development and infrastructure construction. For instance, Soh and Yu [39] analyzed the development of 3G networks in China and explained how regulatory impacts from government and domestic and foreign network operators are interdependent to each other.

Despite the positive impacts of the wireless city development, the spatial and social inequalities of information technology and its access has also drawn a lot of attention [40,41], derived from the traditional thoughts of urban sociology [42], with a particular focus on the digital divide. Moreover, this type of restructuring is often associated with a new round of social differentiation in different urban spaces [31,43]. From this perspective, the term digital divide, which refers to the fact that certain segments of the population and specific social groups may be excluded from access to the Internet, has gained considerable scholarly attention [5,7,38,44,45]. As Castells [46] pointed out, the gap between network haves and have-nots increases sources of spatial and social inequality. Combined with the historical socioeconomic divides in the city, the strong commercial bias of Internet access may strengthen an uneven geography of public Wi-Fi access [47], which can be manifested at different scales, from global to regional ones, and to neighborhoods and communities [43,48–50]. Popularized by Gray Andrew Pole, a New York Times journalist, the notion of digital divide has called for more attention in regards to equitable access to public Wi-Fi and the uneven distribution of access to the Internet within cities [35,48]. For example, Prieger [50] investigated the gaps in broadband usage for minorities and found that fewer fixed broadband options were available to Blacks and Hispanics, but they tend to have more mobile broadband providers available. These digital disparities are closely associated with social polarization and inequalities, imposing new challenges for the sustainability of families, communities, and cities in the context of the new information economy [51].

In short, despite an emerging body of literature on wireless cities and digital divide in Western countries, Chinese cities have largely escaped from scholarly attention and few work has been done to address potential digital divide in the course of the Chinese wireless city development [52]. Specifically, to the best of our knowledge, most of the previous literature on the digital divide or Internet development in China has focused on disparities or spatial distribution at the provincial, city or regional levels [53,54], the development of wireless city and digital divide at the intra-city level have rarely been researched.

3. Data and Study Region

The data used in this study was mainly obtained from the official websites of Shanghai CMCC [55] and the "i-Shanghai" project [56]. The raw data contains the attributes of each WLAN hotspot established by CMCC and the "i-Shanghai" project, including the name, address, type, located sub-district, and also the same attributes of Wi-Fi hotspots. WLAN is one of the most widely used broadband wireless technologies that provides public Wi-Fi access in China. By July 2013, the number

of WLAN hotspots provided by Shanghai CMCC had increased to 6800, as compared to less than 703 in 2009. In this study, the locations of all the CMCC and "i-Shanghai" WLAN hotspots in 2013 were geocoded. In addition, as shown in Figure 1, our study area included 18 districts and counties: Huangpu, Jingan, Xuhui, Changning, Putuo, Zhabei, Hongku, Yangpu, Pudong, Minhang, Baoshan, Songjiang, Jiading, Qingpu, Jinshan, Fengxian, Nanhui and Chongming, and 208 sub-districts/towns, which are the smallest administrative unit in China. Following Wei *et al.* [57], we divided the 18 districts and 208 sub-districts into four areas: traditional city property area (TCPA, which is composed of Huangpu and Jingan), expanded central city area (ECCA, which includes Xuhui, Changning, Putuo, Zhabei, Hongkou and Yangpu), inner-suburban area (ISA, which consists of Pudong, Minhang and Boshan), and outer suburban area (OSA, which includes Chongming, Jiading, Songjiang, Qingpu, Jinshan, Fengxian and Nanhui).

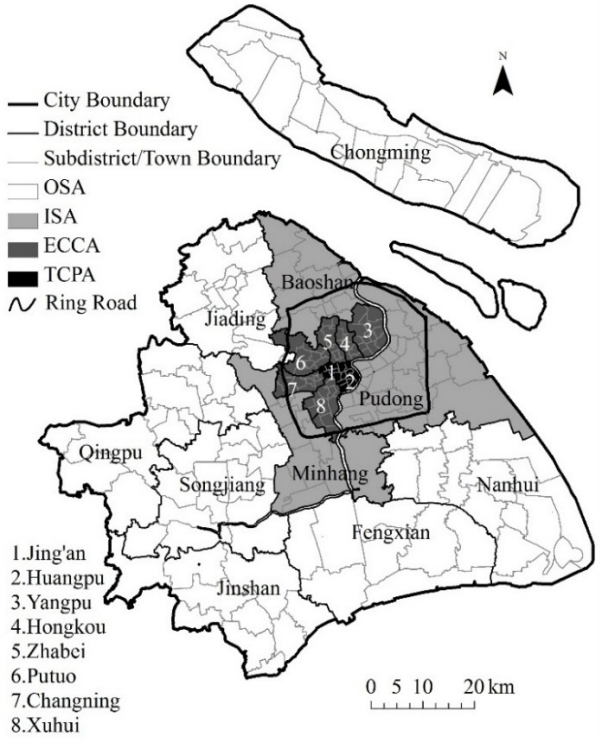


Figure 1. Administrative division and geographic structure of Shanghai. Note: TCPA = traditional city proper area; ECCA = expanded central city area; ISA = inner-suburban area; OSA = outer-suburban area.

As the largest business hub and financial center in China, Shanghai has played a leading role in developing wireless cities in China. As illustrated in Figure 2, the Internet penetration, as measured by the total number of Internet users divided by total population, increased from less than 30% before 2005 to over 70% in 2013. The number of Internet users through smartphones in Shanghai also increased from 7.47 million to 12.6 million during 2009–2013, and its shares of Internet users rose from 63.8% to 78.5% [17,58]. On par with Beijing, Shanghai is currently one of the two Chinese cities with the highest rates of Internet penetration. In fact, as early as the 1990s, Internet development was one of the items that were prioritized in the agenda of Shanghai municipal government. The theme of the 2010 Shanghai World Expo, "Better City, Better Life", reiterated the importance of developing Shanghai into a wireless city. In 2011, the Shanghai Municipal Government issued "The Shanghai's Promotion Plan for the Development of Smart City (2011–2013)", which focused on the construction of wireless city. In collaboration with major corporations in the Chinese telecommunication industry, especially CMCC, one of the goals in the plan was to build a wireless broadband network that covers over 80% of the city, with the speed of Internet of 20 Mbps.

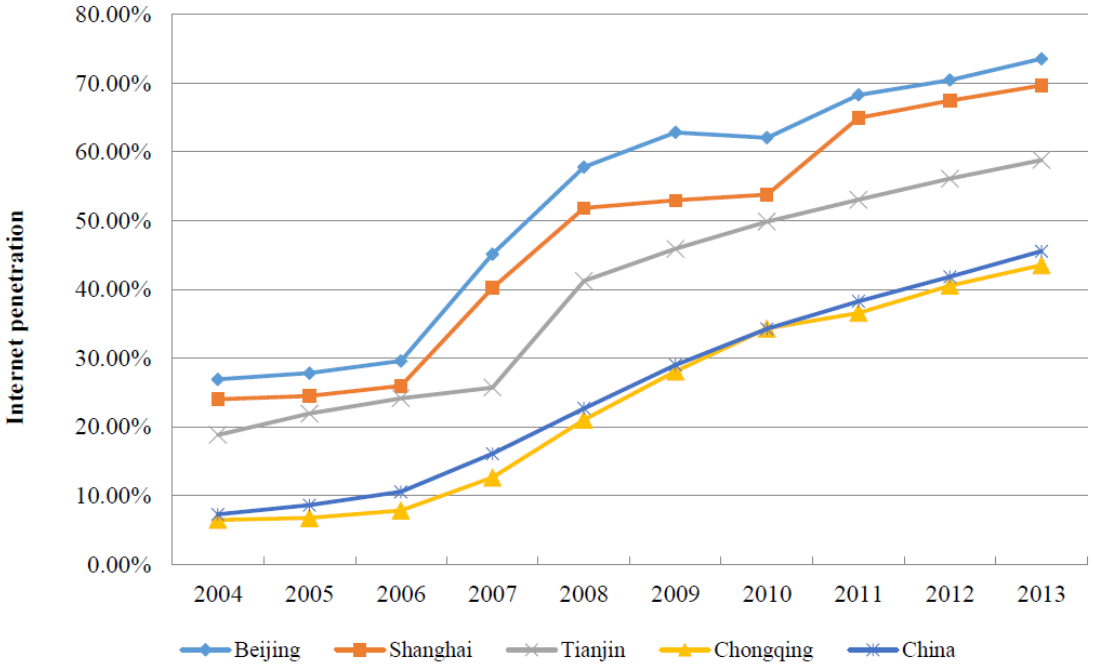


Figure 2. Internet penetration in Shanghai, as compared to China and other centrally administrated municipalities; Source: China Internet Network Information Center, 2004–2013.

4. Mapping Public Wi-Fi Access in Shanghai

This section comprehensively analyzes the geographies of Wi-Fi access in Shanghai, with an emphasis on those hotspots provided by the Shanghai Municipality Government through the "i-Shanghai" project and those established by the CMCC. CMCC has contributed significantly to the wireless city development in Shanghai. In 2013, CMCC had established more than 6000 hotspots, and the majority of these Wi-Fi hotspots are not free to access. The "i-Shanghai" project was launched in 2012, and by the end of 2013, 450 WLAN hotspots were deployed to provide free Wi-Fi access to the public. As these WLAN hotspots are free to access, a lot of benefits have been brought to those who could not afford Internet access, although the free access could only last for 2 hours.

Figure 3 describes different locations of CMCC and "i-Shanghai" WLAN hotspots in Shanghai, indicated by the type of these WLAN hotspots. CMCC WLAN hotspots are more likely to be located in commercial districts and office buildings, which accounted for 26% and 31% of all CMCC hotspots, respectively, in 2013. In comparison with CMCC hotspots, the majority of hotspots provided by the "i-Shanghai" project were placed in those areas associated with governmental and public services, especially places of interest, parks, exhibition and sports centers, and hospitals (Figure 3).

Geographically, both CMCC and "i-Shanghai" hotspots were concentrated in the areas within the outer Ring Road in Shanghai or 15 kilometer to the people's square or the city center (Figure 1). In general, "i-Shanghai" Wi-Fi hotspots were more likely to locate close to the city center (Figure 4b), and the CMCC Wi-Fi hotspots spread out more extensively to suburban districts. It should be noted that, in 2013, only eight out of 206 sub-districts in Shanghai had no CMCC WLAN hotspots and most of these sub-districts/towns were located in outer suburbs like Chongming Island, Jinshan, and Nanhui (Figure 4a). Regardless of CMCC or "i-Shanghai" WLAN hotspots, a few sub-districts/towns with a very small number of WLAN hotspots, say less than five, were located in the traditional city area of Shanghai characterized by geographical concentrations of work force communities and those neighborhoods in remote rural areas (Figure 4).

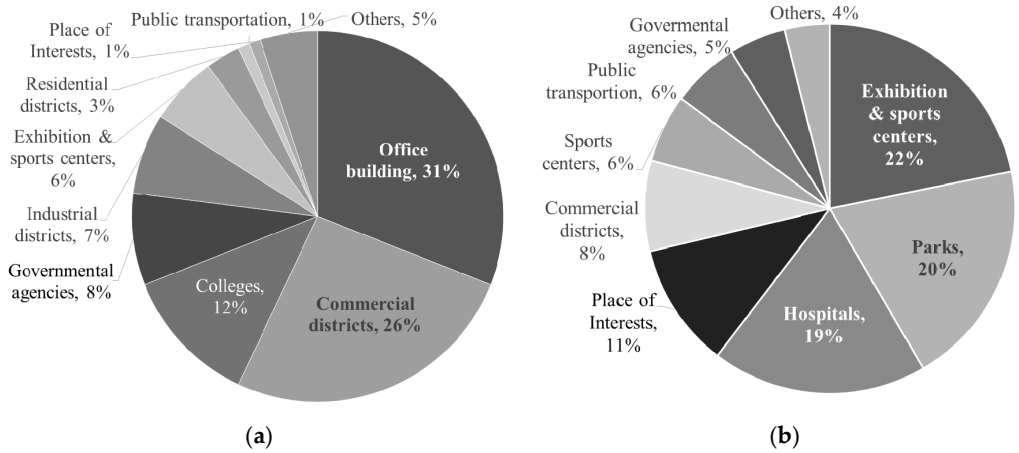


Figure 3. Types of CMCC and "i-Shanghai" WLAN hotspots, 2013. Source: CMCC and "i-Shanghai". (**a**) CMCC; (**b**) "i-Shanghai".

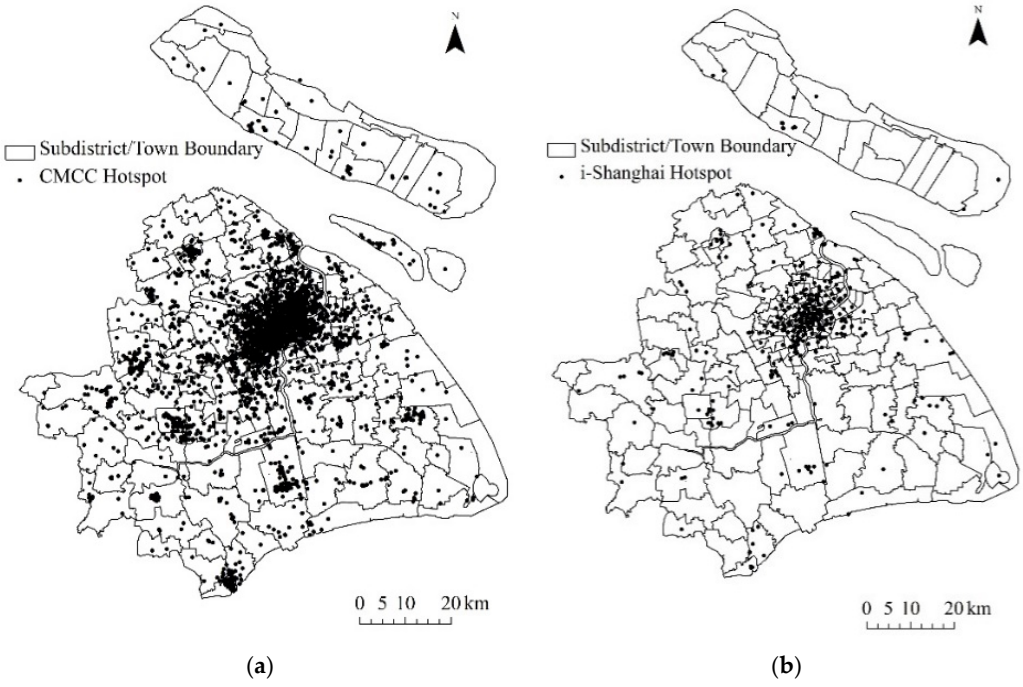


Figure 4. Spatial Distribution of CMCC and "i-Shanghai" WLAN hotspots, 2013. (**a**) CMCC; (**b**) "i-Shanghai".

Table 1 presents the top ten sub-districts/towns with the largest number of CMCC and "i-Shanghai" WLAN hotspots. Some interesting findings emerge: first, in comparison with the list of "i-Shanghai" hotspots, more sub-districts in the suburban areas were found as the top ranking sub-district/towns with the largest number of CMCC WLAN hotspots. Seven out of the top-ten ranking sub-districts were in suburban areas, such as Fangsong in Songjiang district and Jiangchuan Road in Minhang district. Second, the total number of CMCC WLAN hotspots in most of the top-ranking sub districts/towns were installed around a number of office buildings and higher education and R & D institutes, such as Xujiahui in Xuhui district and Zhangjiang in Pudong district. By contrast, the top two sub-districts with the largest number of the "i-Shanghai" hotspots, *i.e.*, Lujiazui and Huapu, were located in the inner-suburban area (ISA). Most of these places are important places of interest and locations where governmental buildings are concentrated. Overall, sub-districts with agglomerations of higher education institutes and R & D centers tend to have more CMCC WLAN hotspots, but

the "i-Shanghai" hotspots tend to agglomerate in those landmarks in Shanghai, such as the Bund, Huangpu, and Lujiazui financial district, *etc.* (Table 1).

Table 1. Ranking of China Mobile Communications Corporation (CMCC) and "i-Shanghai" WLAN (wireless local area network) hotspots in Shanghai's sub-districts/towns in 2013 (Top 10).

CMCC				"i-Shanghai"			
Rank	**Subdistrict**	**Location**	**N**	**Rank**	**Subdistrict**	**Location**	**N**
1	Fangsong	OSA	395	1	Lujiazui	ISA	16
2	Nanqiao	OSA	171	2	Huangpu	ISA	15
3	Huamu	ECCA	158	3	The Bund	TCPA	11
4	Xiayang	OSA	131	4	Chuansha	ISA	10
5	Zhangjiang	ISA	124	5	Nanqiao	OSA	9
6	Jiangchuan	ISA	123	-	Huaihai Zhong Road	TCPA	9
7	The Bund	TCPA	120	7	Jiangsu Road	ECCA	8
8	Xujiahui	ECCA	113	-	Ou-yang Road	ECCA	8
9	Huinan	ISA	102	-	Youyi Road	ISA	8
10	Zhelin	OSA	100		East Nanjing Road	TCPA	7
				10	Fenglin Road	ECCA	7
					Tianping Road	ECCA	7
					Zhoujiadu	ISA	7

TCPA = traditional city proper area; ECCA = expanded central city area; ISA = inner-suburban area; OSA = outer-suburban area.

In order to further explore the Wi-Fi geographies in Shanghai represented by the spatial distribution of CMCC and "i-Shanghai" WLAN hotspots, concentric analysis based on a 5-km radius interval and ESDA methods were used, following Wang and Gu [52]. Results of concentric analysis demonstrate that the share of CMCC WLAN hotspots within 5 kilometers from the city center (Figure 5), which is defined as the location of People's Square, was less than 20%, while its counterpart under the "i-Shanghai" project was over 35%. There were also nearly 40% of the CMCC hotspots located 20 kilometers or further from the center (*i.e.*, outer suburbs), whereas the share of "i-Shanghai" hotspots was just above 25% in the same region (Figure 5).

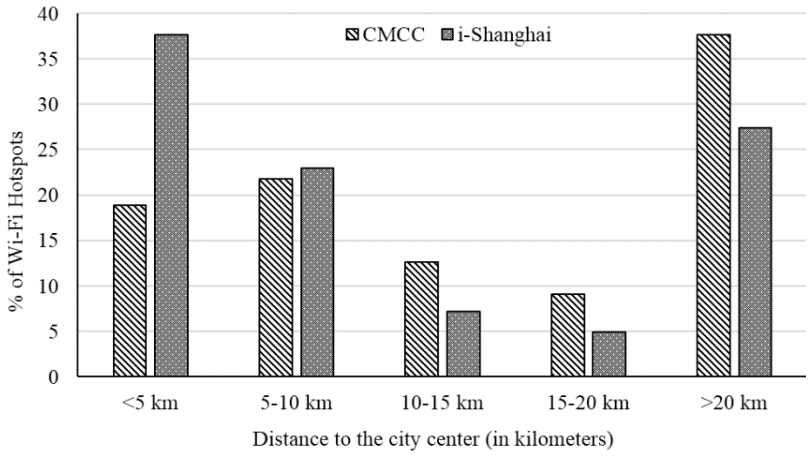


Figure 5. Spatial distribution of "i-Shanghai" and CMCC hotspots based on concentric analysis.

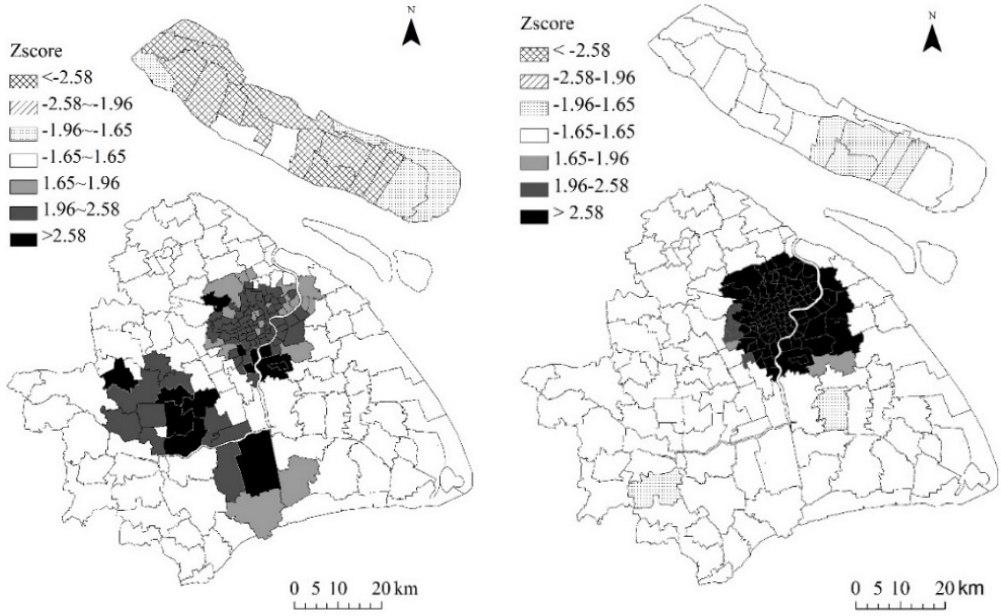
Spatial hot spot analysis (Getis-Ord Gi*), which measures the spatial association of a variable and identifies the characteristics of patterns [59], was used to further detect the clusters of WLAN hotspots at the sub-district/town level. This method detects the statistically significant spatial clusters of high values, or sub-districts/towns with large number of hotspots in this study, and identifies them as "hot spots", and the statistically significant spatial clusters of low values, or sub-districts/towns with

little number of hotspots, and identifies them as "cold spots". The Getis-Ord Gi* statistic is widely used in analyzing the distribution of geographically referenced data. The Gi* of each unit *i* could be calculated as:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}x_j - \overline{X}\sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{\left[n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}}; \quad (1)$$

where x_j is the number of hotspots in administrative unit j, $w_{i,j}$ is the spatial weight matrix, n is the number of administrative units, and S is the standard deviation of the observations. The results of hot spot analysis is essentially a z-score for each spatial unit, measuring the spatial clustering of high/low values. A statistically significant (e.g., $p < 0.05$) positive z-score implies the presence of a hot spot. By contrast, a statistically significant (e.g., $p < 0.05$) negative z-score implies the presence of a cold spot [59,60].

As shown in Figure 6b, a typical "core-periphery" structure of WLAN hotspots was found with respect to "i-Shanghai" Wi-Fi hotspots. The hot spots within the urban area (inside of the Shanghai Outer Ring Expressway) constituted the core area, indicating the clustering of "i-Shanghai" WLAN hotspots. These sub-districts/towns are mostly important commercial districts in Shanghai, such as Xujiahui, the Bund, and Lujiazui financial district. In contrast to hot spots, the cold spots were located in remote suburban sub-districts/towns, favoring less developed districts, such as Chongming Island. In comparison with the spatial pattern of "i-Shanghai" hotspots, the spatial distribution of CMCC Wi-Fi hotspots displayed a bi-center distribution. The downtown area (within five kilometers from the People's Square) remained as the core area, and what is more interesting is that another core area has emerged in the suburbs to the southwestern part of Shanghai. The new core area is where new development zones and new higher education institutes are located, including Songjiang New City, Qingpu New city, Jiangchuan subdistrict, and Nanqiao New Town. A lot of sub-districts are characterized by geographical concentrations of higher education institutes such as Songjiang University town in Songjiang New Town, Haiwan University town in Tuolin town, and Shanghai Jiao Tong University and Shanghai University of Electric Power in Jiangchuan sub-district.



(**a**) (**b**)

Figure 6. Hotspot analysis of CMCC and "i-Shanghai" hotspots in Shanghai, 2013. (**a**) CMCC; (**b**) "i-Shanghai".

In comparison with the spatial layout of "i-Shanghai" hotspots, CMCC tends to be more proactive in deploying WLAN hotspots. As shown in Figure 6a, the bi-center distribution of hot spots of CMCC Wi-Fi hotspots is greatly driven by a rapid process of suburbanization in Shanghai in recent years [61,62]. In this process, large-scale industrial enterprises extend to suburban areas first, followed by the growth of population and new housing development [63]. In addition, given the skyrocketing land price and restricted land supply in the downtown area, many business institutions and government agencies have recently moved to the suburbs in Shanghai. As a result, the rapid population growth and increased demand for Wi-Fi access have prompted CMCC to develop new cyber infrastructure like WLAN hotspots in these sub-districts (Figure 6a).

5. Micro-Scale Analysis of Three Sub-Districts

The mapping above has revealed the spatial distribution of WLAN hotspots or public Wi-Fi access in Shanghai. Contrasting Wi-Fi geographies shaped by CMCC and "i-Shanghai" WLAN hotspots were found, which highlight the proactive role of telecommunication operators in Shanghai's wireless city development. The findings motivate the concern regarding how key stakeholders, such as government, telecommunication operators, and communities, can play a role in Shanghai's wireless city development. The following section will focus on three specific sub-districts, including Nanqiao New Town, Songjiang University Town, and Pengpu Xincun, given their unique features regarding the wireless development at the community level (Figure 7).

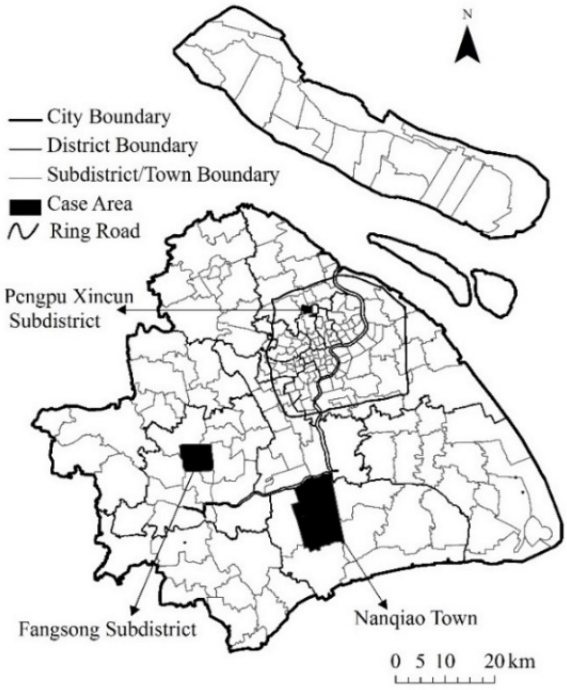


Figure 7. Locations of case studies.

5.1. Nanqiao New Town

Nanqiao is one of the top-ten ranking sub-districts that has experienced a rapid wireless development driven by the deployment of both CMCC and "i-Shanghai" WLAN hotspots (Table 1). In 2013, the number of CMCC hotspots increased to approximately 170, ranking as the second largest one in Shanghai. As shown in Figure 8a, there have been five clusters of CMCC hotspots: 1. Fengpu Commercial Street, especially those within the Fengpu Mansion, which is a commercial office building; 2. Bailian shopping mall; 3. the historical community (old town); 4. Government of the Fengxian District; 5. Nanqiao Township Government. In contrast to the spatial layout of CMCC WLAN hotspots,

the distribution of public Wi-Fi access provided by "i-Shanghai" was centered on government agencies, including the Fengxian District Conference Center and Nanqiao Township Government, and they were also located around large-scale businesses companies or the Shopping malls, namely RT-MART and LOTUS (Figure 8b).

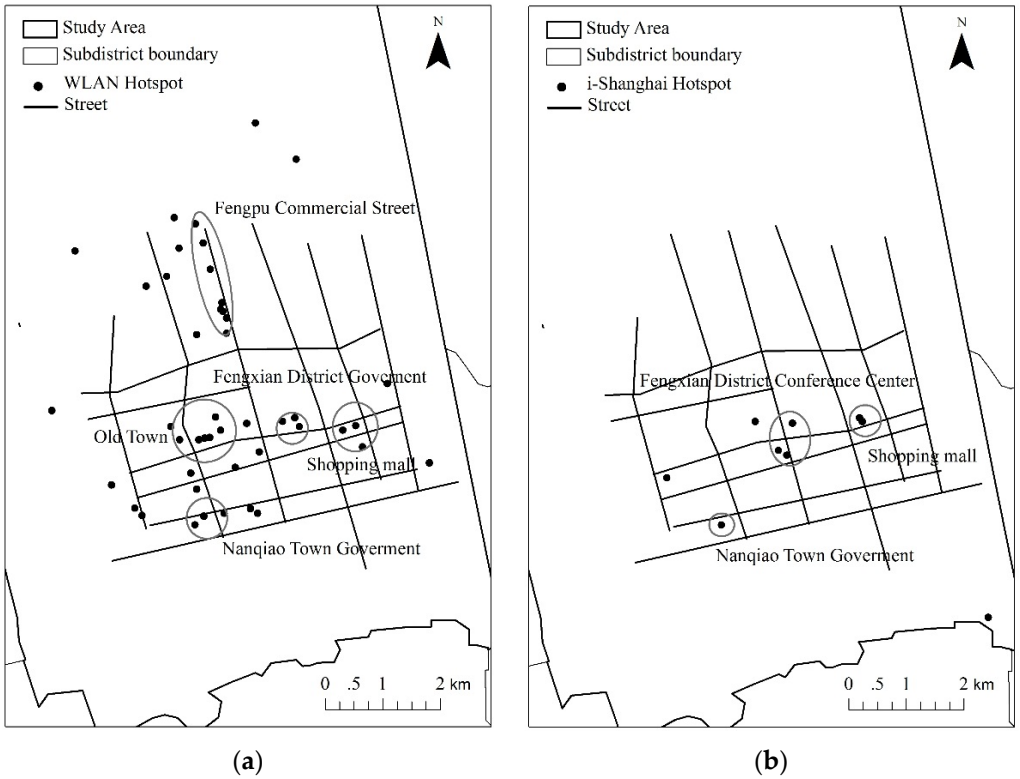


Figure 8. Spatial distribution of CMCC and "i-Shanghai" hotspots in Nanqiao New Town, 2013. (**a**) CMCC; (**b**) "i-Shanghai".

In the case of Nanqiao, the government policy and urban planning have played an important role in the expansion of public wireless access. Nanqiao New Town is the political, economic, and cultural center in Fengxian district of Shanghai, and it is also planned to be a core area providing comprehensive services for the north coast of Hangzhou Bay. As one of the three major new towns in Shanghai, the development of Nanqiao was emphasized in Shanghai's 12th Five-Year Plan [64]. Based on its development plan, new ICTs or wireless technologies were the key instrument to integrate various functions within this sub-district. These government investments aimed to provide wireless access especially in the eastern part of the Nanqiao New Town (Figure 8b). It was also designed to provide favorable development conditions for enterprises and high quality living for residents, and to promote a more competitive local business environment, with great potential demand for Internet access.

5.2. Songjiang University Town

Fangsong sub-district in Songjiang is another typical case in terms of wireless development. In comparison with Nanqiao New Town, Fangsong sub-district has achieved a rapid growth of CMCC WLAN hotspots. There have been 395 CMCC hotspots in this area whereas the number of "i-Shanghai" hotspots was four at the end of 2013. These hotspots have provided public Wi-Fi access to thousands of people especially college students. Different from Nanqiao, the wireless development was heavily driven by the establishment of Songjiang University Town. Among the 395 CMCC WLAN hotspots in 2013, about 320 were located within Songjiang University Town. In this sub-district, there are a large

number of college students and faculty in the seven higher education institutions, including Shanghai International Studies University, University of International Business and Economics, Shanghai Lixin University of Commerce, Donghua University, East China University of Political Science and Law, and Shanghai University of Engineering Science. The case of Songjiang University Town marks a more proactive role of telecommunication company, *i.e.*, CMCC, in recent wireless development in Shanghai, by particularly tracing the new demand from college students in university towns [65].

5.3. Pengpu Xincun Sub-District

Pengpu Xincun sub-district serves as a case where specific communities have been overlooked in the course of wireless city development in Shanghai. As shown in Figure 7, Pengpu is located in the downtown area. However, there has been very limited public Wi-Fi access either through CMCC WLAN hotspots or the Wi-Fi access provided by the "i-Shanghai" project. In 2013, only five CMCC WLAN hotspots, as compared to over one hundred CMCC WLAN hotspots in other nearby sub-districts in the downtown of Shanghai. Similarly, there was even no "i-Shanghai" WLAN hotspot located in this sub-district. The lagging development of wireless access in Pengpu has its own historical background. The dwelling houses in the sub-district were built for low-paid workers in previous state owned enterprises. Like other shanty towns in Asian cities [66], most buildings in Pengpu were characterized by old and small living spaces, even though the residential population in Pengpu was relatively large, about 160,000 residents in 2013. The development of Pengpu community has slowed down in recent years because of the limited space, and the unfavorable socio-economic conditions in the community have resulted in the backward wireless development in these areas. In short, the case of Pengpu reflects that even though the WLAN hotspots have been widely built up due to the efforts made by either telecommunication companies or the government, there have been many new "blind spots" in Shanghai's communities where the gap between information haves and have-nots is still evident [67].

6. Policy Implications

Our mapping of public Wi-Fi access in Shanghai has important policy implications in developing wireless cities and addressing the digital divide issue in the context of China. First, as shown in this study, the planning in China is more focused on physical dimensions and deemphasizes issues related to social equity [68], as illustrated by the digital disparities at the community and neighborhood levels in this study. More efforts should be made to address the social dimension of wireless city development in Shanghai and other Chinese cities. Second, Chinese cities are transitional cities. Local governments and market forces are collectively shaping the Wi-Fi geographies especially through the establishment of new development zones and towns in their suburban areas [69]. Hence, how to develop a mutually beneficial collaborative relationship between the government and market participants should be underscored in the future infrastructure planning. Third, although the study has been focused on the spatial distribution of public Wi-Fi access in Shanghai, the development of wireless cities should address not only the construction of hardware facilities, but also the education and supporting system that improves access to the Internet. Therefore, not only the quantity of wireless access, but also the quality of public access to the digital world, deserves attention from policy makers.

7. Conclusions

Wireless technologies play an increasingly critical element in the Chinese urban and infrastructure developments. Local governments and major network operators have increasingly embraced the notion of wireless city, as the access to Internet through public Wi-Fi has become an integral part of a city's economic competitiveness [70,71]. This research traces the recent wireless city development in Shanghai using data gathered from both the government and the telecommunication providers and several interesting findings are uncovered. First, a substantial amount of public Wi-Fi facilities has been deployed and built up, shaping Wi-Fi geographies in Shanghai at multiple spatial scales [69], and

a mix of market participants and governmental agencies has been involved in the process of wireless city development in Shanghai. Second, by mapping public Wi-Fi at both district and sub-district levels, we find that both local governments and major telecommunication companies, such as CMCC, have significantly contributed to the widespread Wi-Fi access to the Internet in Shanghai. Results also suggest that telecommunication companies, such as CMCC, have played a more proactive role in the deployment of WLAN hotspots. These findings are similar to the recent wireless development in other cities in Asia, such as Singapore and Taipei [5], while the results also pinpoint the unique characteristics of the Chinese government in the pursuit of wireless city development under rapid urban growth and economic transition. As shown in our micro-scale analysis, Naoqiao New Town, as a major new business community in Shanghai, has fueled the new wireless development by having both governmental agencies and large-size business corporations involved. Songjiang University Town presents a typical case that telecommunication operators, such as CMCC, have played a proactive role in shaping Wi-Fi geographies. In contrast, Pengpu Xingchu has exhibited a sluggish wireless development despite its advantageous location in the central area of Shanghai. Third, from the perspective of social inequalities and sustainability, despite the rapid expansion of both CMCC and "i-Shanghai" WLAN hotspots, the digital divide is still evident especially at the community level. Deployment of WLAN hotspots is obviously biased towards business centers and university campuses as well as their surrounding areas in Shanghai. Public Wi-Fi access was rarely found in poor residential areas in the inner city and remote rural areas of Shanghai. This polarized structure indicates that the problem of digital divide is far from being solved while new digital divide has been created, imposing profound challenges for making Shanghai a sustainable wireless city in the future. Finally, although we have mapped the public Wi-Fi access in Shanghai, studies of digital divide are also promising from a user or customer's perspective, especially when this type of data becomes available. In addition, as China is a country characterized by its huge size and regional differentials, more research is needed to compare the development of wireless cities in different geographical regions or across urban hierarchy in China [72].

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