

THE NETWORK ADVANTAGE OF CITIES: THE EVOLVING URBAN GEOGRAPHY OF INTERNET IN CHINA

MINGFENG WANG

East China Normal University, Center for Modern Chinese City Studies

ABSTRACT

Advanced information and telecommunication technology has brought human being into a new information age, with the emerging of a global, informational, and networked society. In the 1990's, the rapid growth of the Internet has not only had strong impacts on our social system and economical structure, but also restructured the organizations of global physical and virtual spaces. In recent years, the academic research on Internet has been becoming popular in geography and planning in the western countries. In technical and economic perspectives, this paper provides an analysis of the geography of Internet in a developing country. Based on domain name measurement, it analyses the spatial uneven development of Internet in China. Furthermore, we described the spatial organization of backbone networks and ranked the Internet cities. The investments in infrastructure are already rewriting the map of competitive advantage of cities. An urban network of the network cities is emerging in which the geographical factor plays an important role.

INTRODUCTION

Advanced information and telecommunication technologies have brought human being into a new information age, with the emerging of a global, informational and networked society (Castells, 1996). The rapid growth of Internet, in 1990's in particular, has not only had strong impacts on our social system and economical structure, but also restructured the organizations of physical and virtual spaces across the world (Mitchell, 1995; Graham and Marvin, 1996). Negroponte (1995), in his book *Digital Living*, has stated that: "[T]he post-information age will remove the limitations of geography. Digital living will include less and less dependence upon being in a specific place at a specific time, and the transmission of place itself will start to become possible." (p. 165)

Undoubtedly, information revolution has gradually made the global economic activities footloose. Therefore, some researchers claim in surprise "the end of geography" (O'Brien, 1992) and "the death of distance" (Cairncross, 2001). Though, the claim is in a sense related to the technological determinism, it still stimulates spatial economists and economic geographers to begin to cast much light on information activities. In western countries, researches on advanced information and communication technology (ICT) have been the hot fields for many subjects, and studies on the Internet in a geographical perspective prosper in recent years (Aoyama and Sheppard, 2003; Wang and Ning, 2002). However, all literature focuses on the developed countries and China still has few research of this sort. To fill up the gap, this paper tries to understand in the spatial dimension the impacts of Internet on the urban and regional development in today's China.

CITIES AND CYBERGEOGRAPHY: A LITERATURE REVIEW

The rapid growth of advanced telecommunication networks generated electronic information spaces collectively referred to as cyberspace which emergence is indeed beginning to generate a new geography within the wider structure of our social and economic grounds (Batty, 1993). In the broadest sense, cybergeography is "the study of the nature of the Net through the spatial perspectives of geography and cartography" (Dodge, 2001, p. 1). Interestingly, notions of the city hold an important place in the current research and debate surrounding cyberspace and the Internet.

CITIES IN AN INFORMATION AGE

There has long existed a utopian prediction about the social and political impacts made by the technological changes. Urban meeting places, markets, entertainment, etc. will give way to net-meeting, e-commerce, electronic data interchange (EDI) and virtual entertainment (Mitchell, 1995). With the growth of communication ability and the fast decline in cost, e-communication which occurred only in the central areas before may replace the face-to-face interaction that decides the existence of CBD (Moss, 1998). Nowadays this view of urban decentralization has been widely accepted in the political, media and academic fields.

However, this kind of recognition is receiving more and more challenges from researchers who believe that the application of new technology and information complements the face-to-face communication, not substitutes (Gasper and Glaeser, 1998; Kolko, 2000). And that is the case. Existing literature in economic and urban geography has provided a rich base of empirical evidence linking communications and human settlement patterns. In 1960s, some geographers had begun to have interest on the geography of information, especially the spatial structure of information flows (Hepworth, 1989). Jean Gottman's *Megalopolis* (1961) contained maps of telephone traffic alongside that of interstate trade and travel to highlight the vital role of telecommunications in binding cities and regions to one another. Mitchelson and Wheeler (1994) mapped another form of telecommunications - the flow of overnight delivery packages - at a national scale, showing how global information flows impacted on urban system and concentrated in several node cities in United States. Similarly, recent researches indicate that newer communications forms such as the Internet also have the 'urban bias' on the spatial dimensions (Gorman, 2002). Although physical distance doesn't interfere when people use Internet for e-business, the distribution of Internet, for the purpose of profits, still takes into consideration geographical factors (Leamer and Storper, 2001), which inevitably put network infrastructure as close as possible to information centers and consumption centers, and then gradually coordinating the infrastructure construction scales with that of the centers. Owing to urban agglomeration economies of human social and economic activities, the distribution of Internet infrastructure is destined to follow suit.

WORLD CITY NETWORK IN A SPACE OF FLOWS

In the age of globalization and urbanization, locations for economic activities cannot avoid aggregating to some major large cities. Therefore, some world cities that act as global policy-makers and command and control centers tend to be global centers for information production and consumption (Friedmann and Wolff, 1982; Knox and Taylor, 1995). Castells (1996) also believes that megacities dominate all forms of international information exchange, specifically those conducted on new telecommunications networks such as the Internet. In fact, "the logic of the emerging electronic infrastructure is to follow directly the global city networks, through direct global-local interconnection" (Graham, 1999, p. 947).

Castells' (1989, 1996) famous term of "the space of flows" best grasps the new dynamic spatial form in the network society. The new space is "the material organization of time-sharing social practices that work through flows" and consists of at least three layers or dimensions: the technological infrastructure of telecommunications networks which are integrating the world; the material networks constituted by its nodes and hubs, through which commodities, information, labors and knowledge are circulated; and the dominant, managerial elite networks of work, rest and play (Castells, 1996, p. 412-415). The middle layer of theory is particularly useful to understanding the world city network, which is arguably the most important case of the material circulation. Although emphasized the flows of knowledge and information at the global scale for world city network, few existing researches are based on precious data of actual flows themselves. The reason is a lack of data on not only data transfer volumes but also time spent in communication. Maybe it is easier and better way to grasp the world cities and their interactive relations by analyzing the information infrastructures. The literature of world cities note a handful of dominant financial services centers what Sassen (1991) calls global cities, have dominated past international telecommunications networks. Furthermore, Malecki (2002) documented empirically a global bias of fiber-optic backbone networks toward world cities by analyzing global data for Internet backbones and metropolitan data on telephone switch capabilities.

While the global cities hypothesis offered a number of useful concepts and predictions for understanding the emerging structure of digital networks, more and more researchers doubt the interactive relationship between Internet and the existing global city systems, holding that information exchange among cities will result in a more complex system. As Townsend (2001a) argues, "for the first time in history, technological innovation is no longer the monopoly of global city institutions." Using a combination of domain names and user counts, Zook (2001) provided an assessment of the global distribution of Internet content creation at the urban level. He asked one question in the end with that no clear answer given: shall the Internet city system be "old hierarchies or new networks?" From a different perspective, Townsend (2001a) found that some new "networked cities" were springing up, after analyzing the spatial structure and accessibility to global Internet backbone networks. The international linkages among cities prompted by new communication technology differed from the previous one dominated the global cities, connecting more cities in more varied ways.

AN EVOLVING URBAN GEOGRAPHY OF INTERNET

Maybe at a national lever, we can comprehend more clearly the emergence of urban system of Internet. However, the current researches focus on the developed countries, especially in United States. As the origin of Internet technology, American Internet cities have a history of more than thirty years. In general, the development of the Internet in a city depends on a mixture of urban characteristics and various correlative factors (Moss and Townsend, 1998; Sternberg and Krymalowski, 2002).

First, Cities traditionally important in transportation networks and information flows are near the top of the urban hierarchy of Internet (Wheeler and O'Kelly, 1999). Second, the local economic characteristics of a city or region play an important role in supporting the development of commercial Internet (Grubestic and O'Kelly, 2002; Zook, 2000). In particular, high-technology regions exhibit high levels of Internet utilization (Sternberg and Krymalowski, 2002). Third, the network city is "typically a medium-sized city with excellent access to high-capacity Internet backbone networks and possessing a broad-based diffusion of Internet activity throughout its highly educated population" (Townsend, 2001b, p. 54). Wheeler and O'Kelly's (1999) statistics suggest there is not a strong positive relationship between Internet activities and city size. Fourth, geographical location is also a crucial factor in the history of Internet cities (Malecki and Gorman, 2001; Moss and Townsend, 1998; Townsend, 2001b). Geographic location of a city plays a more important role in the accessibility hierarchy of Internet (Grubestic and O'Kelly, 2002; Wheeler and O'Kelly, 1999).

In addition, Internet spatial pattern is a continual evolving and changing urban geography. Using domain

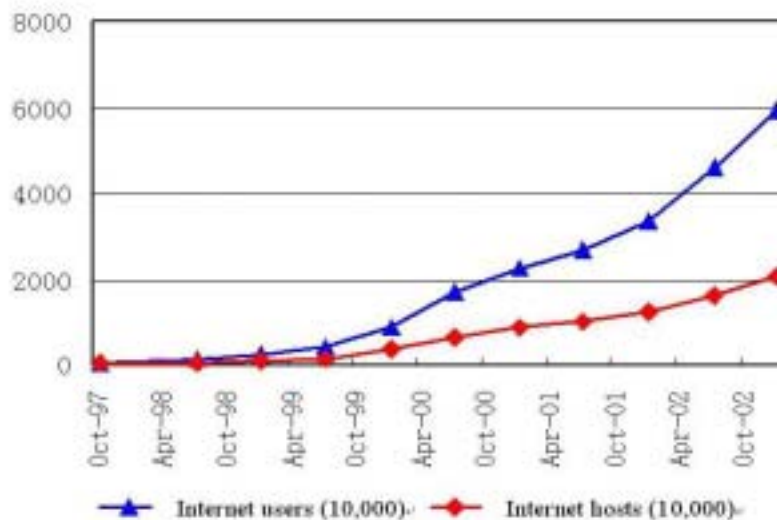
name measurement by growth rates from 1994 to 1997, Moss and Townsend (1998) identify four categories of US Internet cities: 1) the two global information centers in San Francisco and Manhattan, 2) mid-sized information cities which grew at 4 to 5 times the rate of the nation, 3) a mixed group of regional centers which grew at 2 to 3 times the national rate, and 4) several world cities which grew from 1 to 2 times faster than the national average. On the other hand, the location of network hardware is relatively fixed and stable (Gorman and Malecki, 2002). As a group, the most seven accessible cities (San Francisco, Washington, D.C., Chicago, New York, Dallas, Los Angeles, and Atlanta) on the U.S. commercial Internet have changed very little in current years (Grubestic and O'Kelly, 2002; Moss and Townsend, 2000; O'Kelly and Grubestic, 2002). However, rapid increases in domain registrations certainly suggest an increasing presence of Internet-based activity and market demand for bandwidth (Gorman, 2002; Moss and Townsend, 2000; Zook, 2000). Therefore, the hierarchy of Internet cities will still continue to change categorically and geographically in the future (Grubestic and O'Kelly, 2002).

GEOGRAPHY OF INTERNET DOMAIN NAMES

In late 1990s, more and more families began to use Internet in China. Internet users and hosts have been sharply increasing with recent years, as is shown in Figure 1. The number of China's Internet users² has taken the second place in the world, just behind USA. By the end of 2002, CNNIC reports place the total number of China's Internet hosts is 20.83 million: 19.3% are the hosts of LAN that connects the Ethernet, 71.1% are the dial-up connection and the rest are by other ways. On the other hand, Internet users who adopt multiple accessing methods totally have 59.10 million, including leased lines for 20.23 million, dial-up for 40.80 million, ISDN for 4.32 million and broadband connection for 6.60 million³. Although most people use the Internet at home by dial-up connection, broadband users increase faster. Besides computers, 1.53 million Internet users use other facilities (mobile terminals, information appliances). It shows that Internet accessing methods are more diversified in China (CNNIC, 2003).

Figure 1. THE GROWTH OF INTERNET USERS AND COMPUTER HOSTS IN CHINA.

Source: Author



DOMAIN NAME AND DATA SOURCE

Because Internet is a highly structured and organized system, its activity cannot be easily measured, especially when it comes to comparing the utilization of Internet in different geographical regions. As mentioned in above section, some researchers started to use Internet domain names to study the diffusion of Internet and made some progress in the end of 1990s. In Domain Name Systems (DNS), each domain responds to a single bill address, standing for the geographical location of the organization that possesses the domain name. Many studies use domain names as an index to measure Internet content providers (ICPs), which, besides, is also a common method taken to analyze the new economy and the competitiveness of cities and regions (Sternberg and Krymalowski, 2002). The registration and management of CCTLDs in each country are under their own organizations, in China that is China Internet Network Information Center (CNNIC) in Beijing.

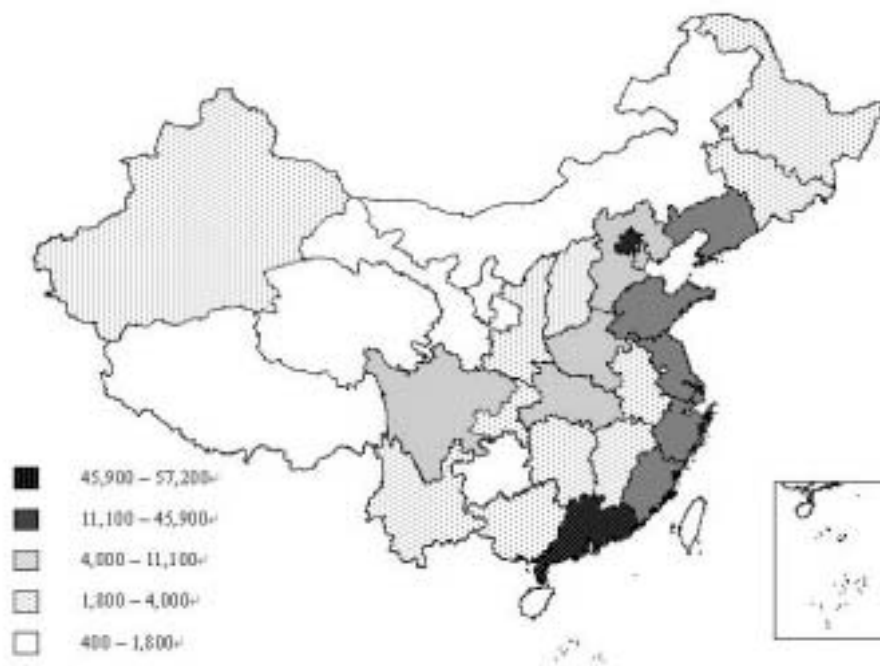
CNNIC has published statistical reports on the Internet development in China every half a year since 1997 (CNNIC, 1997-2003), which includes the provincial data of China's Internet domain names. According to CNNIC's statistics, domain names ending in CN have come to nearly 17,950 thousand by 2002. And domain names starting with WWW in China amount to 37,160 thousand. WWW web sites are web sites with an independent domain name beginning with WWW4, including CN and some other top-level domains. Since WWW domains prevail in China's web sites, it is practical to make an overall analysis on China's Internet development by the number of WWW web sites.

SPATIAL PATTERNS

Production of network information in China has clear regional differences. According to the statistics of CNNIC in January 2002, WWW domain names are mainly registered in Beijing, Guangdong and Shanghai, respectively 571,38, 45,951 and 29,819, each accounting for more than 10% of China's total, with different percentages of 20.62, 16.58 and 10.76 adding up to almost 50% in all. Other comparatively more important regions are Zhejiang for 8.11%, Jiangsu for 6.59%, Fujian for 6.31%, Shandong for 4.32%, and Liaoning for 4.03%. It shows that coastal areas in the east are the main production areas of China's web sites, the middle few and the west even fewer, as could be seen in Figure 2.

Figure 2. THE GEOGRAPHY OF INTERNET DOMAIN NAMES IN CHINA, JAN 2002.

Source: Author



A sharper contrast will be revealed if the economic production scales are taken into consideration. In the light of DES index (domain to employment specialization index, i.e., the number of domain names possessed by every ten thousand employers), the max is Beijing (for 91.85), 168 times the minimal Guizhou (for 0.55). The DES index in Beijing and Shanghai are respectively 91.85 and 44.30, far higher than other regions, and Guangdong, Fujian, Tianjing, Zhejiang with an index about 10, also comparatively higher. It is apparent that network information produces in larger scales in coastal areas in the east, especially southeast, as is the same with its level of Internet development.

Combining the two parameters mentioned above and the current situations, 31 provinces⁵ in China can be divided into three spatial levels after being standardized and clustered (Figure 3):

The first level is the information pole, including Beijing, Shanghai and Guangdong. Both indices in these three regions are obviously higher than that in others. Therefore, they are the aggregate regions of China's Internet activities.

The second level are the developed regions, including Zhejiang, Fujian, Jiangsu, Tianjing, Shandong and Liaoning, with at least one index higher, that is, the outcome after being standardized is beyond one.

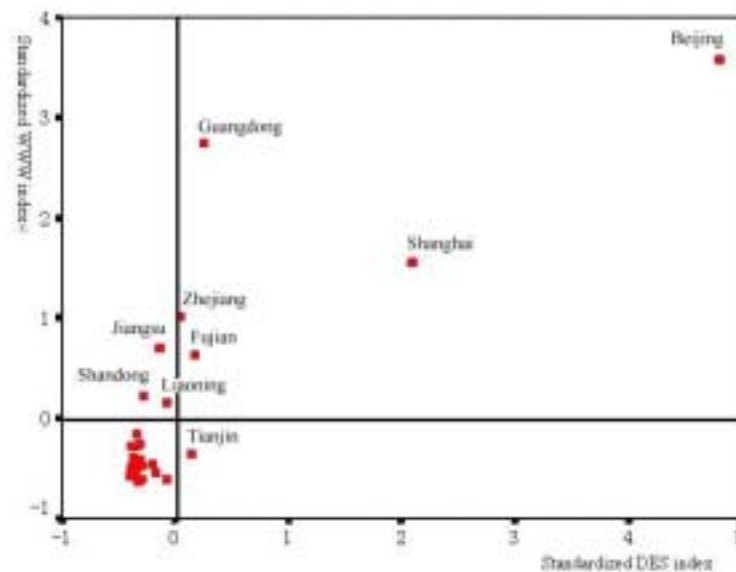
In China these regions are advanced in Internet development.

The third level are the under-developed regions, including regions not mentioned at the above two levels. Both indices of the total and the average are under the national average in these regions.

So far, China's Internet domain names mainly distribute in the coastal areas, especially three metropolitan agglomerations: Beijing-Tianjin metropolis, the Yangtze River Delta and the Pearl River Delta, which indicates the preference that geographical distribution of Internet domains have to large cities to some extent. Moreover, compared to western countries (e.g. the U.S.), geographical concentration or in other word, preference of Internet domain names to mega-cities seems more obvious in China.

Figure 3. A COMPARATIVE ANALYSIS OF INTERNET DEVELOPMENT BY PROVINCE IN CHINA, JAN 2002.

Source: Author



URBAN GEOGRAPHY OF INTERNET INFRASTRUCTURE

Network Topology and Cities

In the computer networks, we call network units such as stations, servers etc. in the abstract “nodes” and call communication media like cables in the networks “lines”. Therefore, in terms of topology, computers and the network system are geometric graphs composed of nodes and lines. It is in this way that we abstract the specific structure of the network system, which we call the topologic structure of the computer networks. The common topological structures of computer systems usually fall into the three categories: centralized networks, decentralized networks, and distributed networks (Baran, 1964).

Evolving from graph theory, topology is to research the characteristics of nodes, lines and structures that have nothing to do with their sizes and shapes. If we abstract cities as nodes and the major links connecting cities as “lines”, we can start researches on the urban network based on Internet by means of topology. The current information infrastructures and the national communication backbone networks are the outcome of decades of development in the communication network. In the early stage, Internet was designed to be a distributed network intentionally, but the collective behaviors of backbone network providers that came into being subsequently led to a highly organized system (Moss and Townsend, 1998). Therefore, Castells (2002) believes that the global network has no centrality, but nodality. Graham and Marvin (1996) have held a different idea that these networks are in fact not distributed, but share a decentralized hub-spoke structure. Certainly, with the help of the efficient transportation and telecommunication network, Internet is keeping integrating and connecting specific urban complex beyond borders. Theoretically, if one node or city gets connected to one of the backbone networks, it can reach all the nodes or cities in other networks, however, as a matter of fact, it is rather crowded in the concentrators and rendezvous points. As a result, cities that have more accesses to backbone networks in the global market will have much quicker and more reliable approach to the global information network.

Because it is hard to obtain detailed and complete data in China due to the lack of related statistics, it is rather difficult to make geographic analysis on communication networks. What's more, the structures and capacity of network keep changing. Case study is therefore a practical solution to solve the problem. This paper studies the positions of urban nodes in different networks and the relations between them in the historical viewpoint of China's commercial backbone network development.

SOME CASE STUDIES

The first two backbone networks (CSTNet and CERNET) are non-profitable and for the public benefits, mainly applied to academic, educational and research activities. Accompanying their establishment, China's commercial network was being under construction. By 2001, China had constructed ten backbone networks, as is shown in Table 1, in which CHINANET, CHINAGBN, UNINET, CNCNET, CMNET and CRNET are units operating Internet business. Among them, CHINANET with a capacity of 2.5G core bandwidth and 6032M international bandwidth is China's largest backbone Internet, bearing 80% of the total data flow in China. Comparatively speaking, there exists a long way for other networks to go to catch up with CHINANET in terms of the coverage and the bandwidth.

Table 1. THE NATIONAL INTERNET BACKBONES IN CHINA, 2001

Source: CNNIC (2002); websites of the Backbones.

Backbone	Date of opening	Number of city nodes	International bandwidth (MBps)
CSTNet	Apr 1995	45	55
CHINANET	Jan 1996	269	6032
CERNET	Dec 1995	160	257.5
CHINAGBN	Sep 1996	118	168
UNINET	Jul 2000	247	418
CNCNET	Oct 2000	17	465
CIETNET	na	97	2
CMNET	Dec 2000	na	200
CGWNET	May 1998	30	—
CRNET	Apr 2001	36	—

CHINANET was established in 1994. Beijing and Shanghai, as the first two cities constructing nodes, finished their initial linkage with the international network and the civil public database. In November 1995, the construction of CHINANET's key network started in an all-round way. The first stage included the construction of Network Operation Center (NOC) and Network Information Center (NIC) of CHINANET, as well as the nodes of 32 provincial capitals (including Hong Kong) except Taiwan. So it is evident that the distribution of China's early commercial network was rather diffuse, which had something to do with the nation's monopolized operation and the overall planning at that time. Therefore, compared with other countries, the development of network in China enjoys a more balanced geographic distribution⁶. The network adopted a partial-mesh structure shown in Figure 4(a), consisting of the core layer, district layer and access layer. Among them, the first layer includes Beijing, Shanghai, Guangzhou, Wuhan, Nanjing, Shenyang, Chengdu and Xi'an, totally eight core nodes. This node system is the same as that of CERNET and their geographic divisions share the complete similarity. It showed that in the initial development of China's networks, state-owned backbone networks tended to show consistency in policy-making although there is much room left to evaluate the rationality of the geographic division.

From July 1998 to early 1999, the backbone CHINANET entered into its second phase of expansion, covering more than 200 cities all over the country and establishing a unified nationwide network management center (NMC). However, the network still shows an incompletely connected structure of multiple levels. As shown in Figure 4(b), the differences between the first phase and the second phase are:

The latter one adjusted the former partial-mesh structure on the core layer to a triangular structure with Beijing (north China), Shanghai (east China) and Guangzhou (south China) as the super core nodes. Other five core nodes are linked to these three centers through two high-speed ATM links.

The second phase regulated its former low-speed interlines of 2M on the core layer to high-speed ATM ones, the speed of which among Beijing, Shanghai and Guangzhou is 155M while others are 155M or 34M.

It also upgraded some lines on the district layer to high-speed ATM links, the speed of which is between 2M and 155M.

In addition, NOC and NIC are still set in Beijing while their functions have been further perfected. That is to say, besides two links connecting NOC with Beijing and Shanghai through routers on the core layer, another link to routers in Guangzhou on the core layer was added in order to improve the management of the core and international node - Guangzhou.

In the second half of 2000, China Telecom carried out again a large-scale project of expanding the volume of CHINANET to build it into "a backbone of the broadest bandwidth, the largest coverage, the most stable performance, the richest information and the most advanced functions in China"⁷. The volume of bandwidth among nodes of CHINANET was upgraded from 155M to 2.5G, which is 16 times of its former speed. The whole net bandwidth comes to 800G, its physical nodes cover more than 200 cities in 31 provinces all over the country, and its business reaches out where the telephone exists. In this project, there are no big changes in the topologic structure of the backbone network, which still consists of 8 nodes on the core layer. Of the 8 nodes, three super core nodes adopt triangular whole-connection structure and 5 other ordinary ones were connected with them. As for the quantity of convergent nodes on the access layer, most provinces and regions have two, which are connected with core nodes or other joint points through dual-linkage, while some remote districts have only one. There are totally 54 convergent points on the access layer connecting each province to the backbone network and serving as providers for new business.

Figure 4. THE BACKBONE NETWORK OF CHINANET, 1996-1999

Source: Author

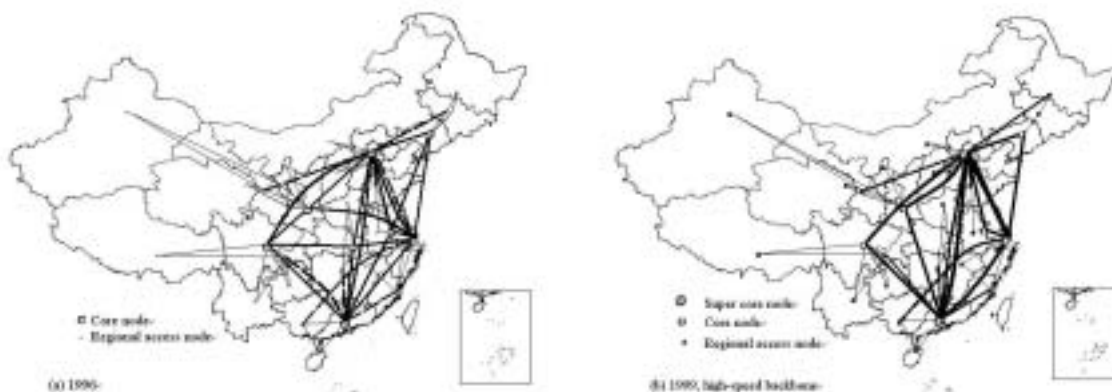
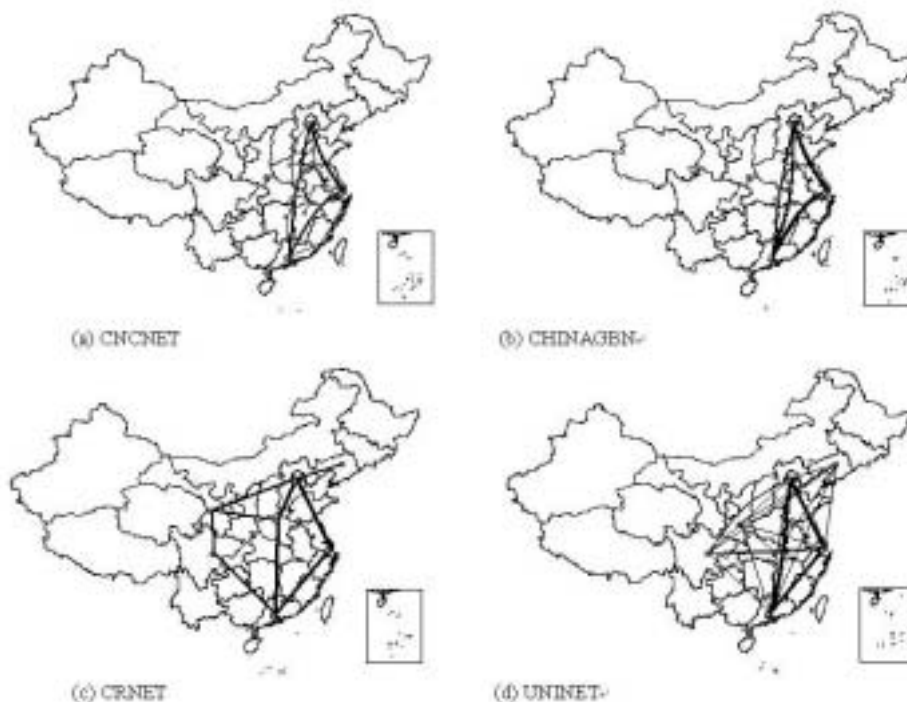


Figure 5. OTHER FOUR BACKBONE NETWORKS, 2001

Source: Author



China's telecom reform started from 1994 has brought an end to China Telecom's monopoly of the Internet access. As Table 1 shows, many new backbone networks were put through after the year 2000. Different from the early development of CHINANET, recently-established or restructured backbone network nodes are mainly distributed in eastern areas, especially in those coastal cities. In Figure 5(a), the first phase of CNCNET run through 17 cities in southeast China including Beijing, Tianjing, Ji'nan, Nanjing, Shanghai, Hangzhou, Ningbo, Fuzhou, Xia'men, Guangzhou, Shenzhen, Changsha, Wuhan, Zhengzhou, Shijiazhuang, Hefei and Nanchang. The total transmission bandwidth is up to 40Gbps. CHINAGBN established a whole-connected ATM backbone network among Beijing, Shanghai, Wuhan, Guangzhou and Shenzhen shown in Figure 5(b). It also built up backbone network nodes in large cities such as Dalian, Qingdao, Shengyang, Chongqing, Changchun, Tianjin, Hangzhou, Xia'men, Dongguan, Ningbo and Nanjing, with large-scale intranet in each city. Obviously, urban economy in the east enjoys a higher level and in turn shows a larger demand for Internet. Therefore, each backbone network always takes eastern areas into their first consideration when constructing the infrastructures.

Different from UNINET, the expanse of CRNET is faster because it is established on the basis of its former intranet. According to Figure 5(c), CRNET has completed and put through a wide-band and speed fiber optic loop in Beijing, Shanghai and Guangzhou, which is, in China, the most advanced and in Asia, the largest loop of 400G, covering 36 cities with 37 nodes (two in Beijing). UNINET (Figure 5(d)) has already spread all over the country and began business of Internet inlet in 247 cities and districts. UNINET's backbone network, made up of the access layer and the district layer, also adopts a multiple-level structure⁸. But unlike CHINANET, there are only 7 core nodes for UNINET, respectively Beijing, Shanghai, Guangzhou, Shenyang, Xi'an, Wuhan and Chengdu excluding Nanjing. This phenomenon has something to do with the regional division of information mentioned above.

URBAN HIERARCHY OF INTERNET

Table 2. RANKS OF CITY NODES OF INTERNET IN CHINA, 2001

Source: Author

Rank	City	CHINANET	CHNIAGBN	UNINET	CNCNET	CRNET	CERNET	Score
1	Beijing	5	4	4	4	5	4	26
2	Shanghai	4	3	3	3	4	3	20
=	Guangzhou	4	3	3	3	4	3	20
4	Wuhan	3	3	3	3	2	3	17
5	Nanjing	3	2	2	2	2	3	14
=	Shenyang	3	2	3	0	3	3	14
7	Chengdu	3	1	3	0	3	3	13
8	Shenzhen	2	3	2	2	2	2	13
9	Xian	3	1	3	0	2	3	12
10	Tianjing	2	2	2	2	2	2	12
=	Hangzhou	2	2	2	2	2	2	12
=	Xiamen	2	2	2	2	2	2	12
13	Jinan	2	1	2	2	2	2	11
=	Fuzhou	2	1	2	2	2	2	11
=	Zhengzhou	2	1	2	1	3	2	11
=	Changsha	2	1	2	2	2	2	11
17	Shijiazhuang	2	1	2	1	2	2	10
=	Nanchang	2	1	2	1	2	2	10
19	Dalian	2	2	2	0	2	2	10
=	Changchun	2	2	2	0	2	2	10
=	Qingdao	2	2	2	0	2	2	10
=	Chongqing	2	2	2	0	2	2	10
=	Lanzhou	2	1	2	0	3	2	10
=	Kunming	2	2	2	0	2	2	10

Notes: the way of evaluation is: the nodes in the lowest layer are given 1 mark, and one more mark is added for each higher layer. Take CHINANET for example, nodes on the ordinary layer are marked one, nodes on the district layer 2, nodes on the ordinary core layer 3 and super keys 4. Beijing as the NOC and NIC plus one comes 5. The final score for each city is the sum of marks received from different networks.

Table 2 ranks the major urban nodes in China's network. Because the higher level the nodes enjoy, the better connectivity they possess, marks in this figure to some extent, reflect the channel fluency of cities in the network. Generally speaking, eastern cities play a more important role than those western cities. This imbalance is not rare in the last 20-year development of major cities in China. Namely, there is a telling regional difference in the development between coastal and inland major cities (Ning and Yan, 1993). Evidently Beijing is the national center of China's network because almost all NOCs and NICs are located there. Next to Beijing, Shanghai and Guangzhou share equal significance. Thus these three cities build up a mega-triangular connection, which functions as the core of China's backbone network. Wuhan is also distinguished in the network due to its geographic features. In Figure 4(a) it can be easily discovered that Wuhan plays an important role in connecting the north with the south and the east with the west.

Table 2 also reveals that some cities are of higher position in the network. For instance, Nanjing's ranking 5 and acting as a center in the northern part of east China lies in its importance in China's educational and research fields. Shenzhen as a rising city also holds a significant place on the information network. Hangzhou and Xia'men, compared with their former urban status, shows an upward tendency as well. And these two cities, as nodes on the district layer, do not enjoy a high place on each single network, but share the same vitality to every network. In a word, channel fluency of these two cities is more preferable. Zhengzhou ranks 13. Being the intersection of China's rail artery, JingGuang Line and LongHai Line, Zhengzhou is bound to occupy a key position in backbone CRNET, which developed on the basis of former exclusive railway network belonging to the Railway Department.

On the other hand, some cities hold comparatively low positions in the network. Tianjing and Chongqing, as municipality directly under the Central Government, ranks 10 and 19. Geographically Tianjing is on the vicinity of Beijing, usually being treated as an ordinary provincial node. Because Chengdu - the political center and the provincial capital - takes more advantages at the beginning of network construction and becomes the network center in southwest China, Chongqing which has just been set up as a municipality directly under the Central Government could only work as a provincial node. Similarly Kunming and Harbin descend a lot as well. Harbin is even excluded from the first 25 cities. As remote provincial capitals, their geographic isolation decides their low-level connectivity. Hence, even in the cyber age, geographical locations still weigh much to the development of cities.

THE RISE OF INTERNATIONAL NETWORK CITIES

As was mentioned above, Internet develops rapidly in China in the last years, and there have been ten backbone networks and various Internet service providers (ISPs) competing in the market. In the beginning, the mutual visits of domestic networks must occupy the limited international outlet resources and backbone network bandwidth because of the comparative independence of each big network, which brought about the problems of low speed and efficiency and also disadvantaged the network safety. Actually, only when more than two networks are connected can the externality of networks be truly presented. That means users of one network can correspond with users of another, or can have access to the information services of another through interconnection to realize cyber correspondence and resource-sharing in the right sense.

Interconnection can be achieved by two means. One is to put through directly two networks and make their business interpenetrating; the other is that two networks interpenetrate their business through a third network's transmission. Interconnection between backbone networks of one nation usually takes the latter way, which has to build up network access points (NAPs). There have been over 300 NAPs set up globally up to now, which mainly locate in big cities where cyber citizens reside densely. Because networks in each country differ in the development and geographical scales, the number of NAPs each country owns also has clear difference. Countries and regions that advance in the Internet development usually possess more NAPs and some small countries often have one single. In United States, big cities like New York, Washington, Chicago, San Francisco, Dallas, Los Angeles and Houston have set up NAPs (see Townsend, 2001b). Hence, each network interlinks with others through some NAPs and cyber users can choose the closest transmission path to visit other webs.

Beijing, Shanghai and Guangzhou being the domestic NAPs and the joint points which connect domestic networks with the international ones, are commonly called Internet exchange points (IXs). TeleGeography (<http://www.telegeography.com>) has built up an IX directory on the global and provides on-line inquiries. It can be found that the geographical distribution of IX points is extremely uneven. However, almost all world cities come to be first listed in the mention of the locations of IX points. The location of these nodes is a response to the current or the future networks, surely which can be done to aim at acquiring the forward advantages in some region as well. Beijing, Shanghai and Guangzhou

function as China's IX points, indicating the significant positions the three cities occupy in the domestic networks and the important evolvement of them rising to be world cities. It is certain that the three cities are bearing changes of comparative importance.

Table 3. THE BANDWIDTH OF LEASED INTERNATIONAL CONNECTIONS (MBPS) IN CHINA'S IX, JULY 2001

Source: CNNIC (2001).

Backbone	Beijing	Shanghai	Guangzhou	Total
CSTNet	55	—	—	55
CHINANET	863	867	657	2387
CERNET	117	—	—	117
CHINAGBN	51	49	51	151
UNINET	—	47	53	100
CNCNET	—	200	155	355
CIETNET	2	—	—	2
CMNET	45	—	45	90
Total	1133	1163	961	3257

Figure 3 shows the leased international bandwidth three cities possess. In terms of the total number, Shanghai hits first, Beijing runs second and Guangzhou goes to the third, whereas the distance is not great. Because Beijing has the earliest international IX point in China, early-operated networks all make Beijing the outlet. For instance, CSTNet and CERNET have not yet established international connections in other cities till now. Shanghai and Guangzhou respectively built international connections in 1996 and 1997 with a following rapid development. Some big networks that were founded after 2000 mainly use these two cities as outlet. In particular, CNCNET and UNINET even built no outlets in Beijing. Shanghai, whose geographical location provides distinguished advantages for its vital position in the international network of optic fibers, has always been the landing spot of the international communications submarine cables which china has joined forces to construct. And Guangzhou acts as a key node for information exchange between indoors and outdoors due to its close vicinity to Hong Kong - Asia's biggest IX point. It can be anticipated that Shanghai and Guangzhou will keep their superiority in the future development.

CONCLUSIONS

Internet is an extremely bulky and complex system made of elements such as nodes, junctions, routers and so on. It is a tough task to analyze and describe its spatial structure. But technology advances in Internet have indeed exerted great influence on the development of cities and regions. Therefore, it is necessary to further the study on the spatial dimension of Internet. This paper, mainly focusing on domain names and infrastructure, is a basic analysis on China's Internet in a geographical perspective. The followings are conclusions:

First, there is no more doubt that Internet technologies geographically spread unevenly. Although Internet technologies have overcome geographical barriers to a great extent, the growth of new technologies has not led automatically to the expansion of economic activities. The great difference in space is a major sign of Digital Divide faced by the world. Either seen from the number of domain names or the infrastructure's bandwidth, the spatial distribution of Internet shows a great preference to mega-cities. The clustering of information industries has a close relationship with the physical and virtual infrastructures of telecommunications. Even though there is no evident proof that access infrastructures only can boost economy, they at least provide necessary conditions in the regional competition to attract and foster new industries.

Second, urban and regional development in the information age has already been adapted to a networked logic. Internet, as a network of networks, makes the growth of networked cities and urban networks in China that are restructured by new communication technologies. Data analysis in the paper reveals that the network connecting Beijing, Shanghai, Guangzhou and Wuhan forms the core layer of long-distance communications in China. Similar to developed countries, backbone networks in their early phase of development were specially designed to be distributed, but the collective behaviors of late-emerged backbone providers jointly produce a highly organized system, taking on an axis-amplitude decentralized look. Nowadays networks in China usually adopt a hierarchical management. Besides the four central nodes mentioned above, Nanjing, Shenyang and Chengdu also serve the function as nodes at the core layer and the centers in the regional network.

Third, there still exist differences in the network expansion between China and the western countries, North America in particular. United States is the origin of information technology and Internet development is an original diffusion. Therefore some geographical sources of important technological innovations occupy a crucial position in the new urban system and thus make great influence on the previous system. However, China as a developing country, mainly receives Internet novelties from the outside world, and its expansion follows the former urban system, consequently forming a networked urban system similar to the original.

Fourth, although Internet changes the urban and regional competitive advantages, geographical locations still mean much. At present, the media for long-distance data transmission is changing from telecommunication satellites to optic fiber networks, pushing geographical factors to play a positive role in the decision-making of infrastructure constructions. Such cities of central geographical locations as Wuhan, Zhengzhou, establish themselves to be core nodes on the district layer in the domestic networks, rather similar to their situation in other transportation systems.

In general, previously built networks of infrastructures like seaports, railway pivots and airports etc. shaped urban systems in the early phase. So what kind of urban systems will the new optic fiber network and mobile Internet bring us? More researches are needed to further the study to face the challenges.

ENDNOTES

1. We would like to acknowledge National Natural Science Foundation of China for funding this research project (No. 40171030).
2. CNNIC defines the Internet user as a Chinese citizen who uses the Internet at least one hour a week.
3. See CNNIC (2003), Internet users who adopt multiple accessing methods are re-counted, so the summation of different type of users exceeds the total number of the Internet users.
4. Refers to the web site that has an independent domain name (under .CN and gTLD). The independent domain name adoption refers to the situation in which one domain name matches not more than one website. For example, "sina.com.cn" has only one website - www.sina.com.cn, other relatives such as news.sina.com.cn and mail.sina.com.cn are different channel of www.sina.com.cn.
5. Due to the lack of data, Taiwan, Hong Kong and Macao are not included in the research.
6. See Foster and Goodman (2000), who use six indexes of pervasiveness, geographic dispersion, sectoral absorption, connectivity infrastructure, organizational infrastructure and sophistication of use to assess the Internet development in different countries. From 1994 to 2000, geographic dispersion of Internet in China has topped one in the six parameters and it also shows a higher level when compared to other developed countries.
7. See "China Telecom grew 15% in 2000", China InfoWorld , No. 991, January 18, 2001 (In Chinese). Available at <http://media.ccidnet.com/media/ciw/991/b0302.htm>.
8. For more details see the firm website of UNINET, <http://www.cnuninet.com>.

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