Briefly Review of China High Technology Networks

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Abstract. We briefly review and summarize the results in research of China High Technology Networks(CHTN), which can be composed by three levels. A weighted framework is put forward and can be used to study some similar networks. According to our idea and method, the CHTN is constructed. Then the CHTN's topological properties are investigated, including degree distribution, shortest path length, clustering coefficient, degree-degree correlation and community structure. The quantitative results can be helpful for promoting management and adjusting structures of the CHTN.

Keywords: Chinese High Technology Networks, topological properties, network science.

1 Introduction

Network Science [1,2], which is in the context of network theory and with non-trivial topology as well as dynamical features, is widely spread to many disciplines including nature science and social science, such as, economics, computer science, biology, sociology and engineering field. In the literature of economics, there are two kinds of mode to study networks. One is that one can study the industrial organization in a networked instrument. For example, in Ref [3] network effects, which are defined as the general property that the utility of a product increases with the number of users, are summarized along market structure, firm strategies and public policy. In Ref [4] the role of product development is studied while company competencies are deal as a network. In Refs [5, 6], the model is empirically tested using a database of 308 German companies. The results show that both network competence and technological competence have a significant positive impact on a company's innovation success. Furthermore, the results suggest that a company's technological strategy supports the development of both network and technological competencies. Another mode is by modeling the structure characteristic, algorithm and dynamics of a network [7-11]. For example, Refs [7, 8] study a supply chain (SC) economy and the proposed network model is built upon operation links and interface links, representing, respectively, substantial SC operations and coordination functions between the operations. It is not only important for managers to know how to optimize various elements of product development, e.g., the development process, market orientation, and top management support, but also to know which other competencies must be addressed to achieve good results.

The massive and comparative analysis of networks from different fields has produced a series of unexpected and dramatic results [12]. But it is still blank to study

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the Chinese High Technology Network(CHTN) from the view of network science. In addition, existing studies on the researches on the CHTN have few papers to its network character. After investigated the feature of the CHTN, we organize the networks of the CHTN based current Chinese National Statistical data we obtained so far. Using the new concepts and measures to characterize the topology of network, we depict the CHTN and achieve some tentative results [13-18]. The data used in this paper are taken from book [19] and annual statistical reports [20, 21] published by several governments situated in Beijing. It's difficult to access more detailed data beyond them. Here we briefly review the some interrelated results and try to give a theoretical framework to study such networks.

2 Classifying the CHTN

In order to analyze an integrated high technology network, we focused the CHTN on three levels: from the level-1 Zhongguancun Science Park(Z-park), the level-2 China Torch Program(CTP) to the level-3 China High Technology Industry(CHTI). Z-park is experimental zone of China's overall reform where the State started to implement its strategy of "Rejuvenating the Country by Science, Education and Talents". CTP is a guiding program designed to develop new and high technology industries in China. Science and Technology Industrial Park(STIP) is a major component of the CTP and now the totals of 54 national STIPs have been playing an increasingly important role in national economic growth and social development. CHTI has made remarkable progress especially since the 1990s, which has not only created the material base for China to develop international technology trade, but also has made it possible for the Chinese high technology industry to play important role in the global market and participate in world competition. The relationships among them are that Z-park is the first and leading science park of STIP in China, which become a large part of the CHTI. The CHTN Networks are more complex along the three levels.

Despite of the hierarchy of three levels' network, we try to investigate their topological properties by a unified hybrid network theoretical framework [29]. From a complex network viewpoint, the interaction between economical indicator and high technology can be described as a network whose vertices(or nodes) represent either companies or indicator related to researches, and each edge(or link) represents certain relationship between any two of them. It can be summary as following.

(1) Most networks people concerned are weighted networks. This is motivated by the fact that in most of the real cases a complex topology is often associated with a large heterogeneity in the capacity and intensity of the connections. Directed network is also studied in the STIP [17]. We also enlarge STIP to Hi-tech Park-University Science Park Joint Network(HTP-USPJN) in Ref [16] since more nodes can be considered.

(2) Node has a certain attribute in a network. It can be an entrepreneur or a company in the Z-park, or an economic indicator charactering the STIP or the CHTI. In a weighted network the value of a node i is equal to its economic indicator and can be denoted by a_i.

(3) Edge in the network is constructed according to the idea and principle of hybrid between randomness and determinateness, which is crucial differing our series models[22] from other existing model that mainly concern the randomness. Since

nodes in a province trend to be closer than in different one, they can be linked in a determinate way. And partner assistance is also occurred for the node because of regional disparity. So diverse attachment mechanisms are taken, e. g. complete graph, preference similar to BA [1], random choosing, switch through a threshold and they can be investigated in a unification organized way[13-18]. The weight(w_{ij}) of a edge connected node i and j is defined as

$$w_{ij} = \mu \frac{a_i a_j}{\sum_{i,j} a_i a_j}. \tag{1}$$

where μ is a constant to magnify the value of w_{ij} for the convenience of calculation. Also the strength(s_i) of a node i is defined as

$$s_i = \sum_j w_{ij}. \tag{2}$$

where j is any neighbor of the node i.

(4) All the networks are evolving with time. Here the time interval is year, e.g. for the Z-park network there are three periods [19]. And we collect data in several years under an economic indicator [20-21].

3 Analysis of the Data

To characterize the CHTN, we compute four important topological features in the network: degree distribution, shortest path length, clustering coefficient and degree-degree correlation. Moreover, a software tool named *CFinder*, which is based on the Clique Percolation Method(*CPM*) [23], is used to detect the network community.

3.1 Topological Properties

Degree k_i of a node i is the number of edges connected to it. In general, the importance of a node is in proportion with its degree. Fig.1 gives a slice of degree distribution $P(k)$, or cumulate degree distribution $P_c(k)$ of the networks.

Several common distributions are unfolded to us, i.e. power-law distribution in Fig.1(a) is

$$P_c(k) = A_0 k^{-\gamma}. \tag{3}$$

Exponential delay distribution of second order in Fig.1(b) is

$$P(k) = A_1 + A_2 e^{-\frac{k}{A_3}} + A_4 e^{-\frac{k}{A_5}}. \tag{4}$$

Poisson distribution is shown in Fig.1(c), and stretched exponential distribution (SED)[23] in Fig.1(d) is

$$P_c(k) = e^{-(\frac{k}{A_6})^c}. \tag{5}$$

Where A_i (i=0, 1, …, 6) is constant and γ and c is corresponding exponent respectively.

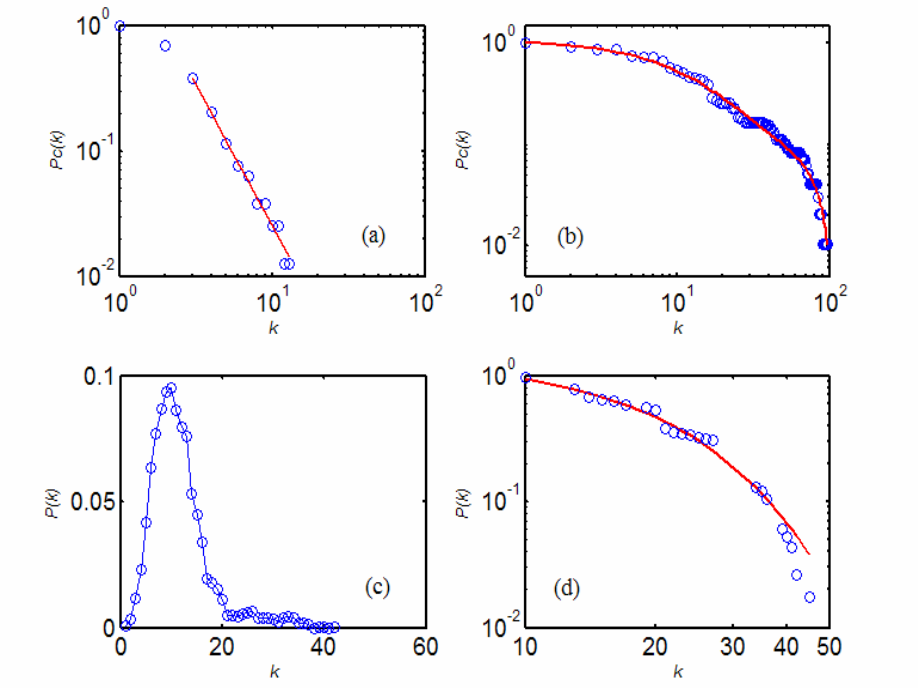


Fig. 1. Degree distributions in three levels' networks. (a)company network in Z-park with exponent γ = 2.3. (b)CHTEN-2 for sales revenue at 2005. (c)un-weighted and undirected network in STIP when p=0.001 at 2004, which is taken from Ref [17]. (d)weighted and random network in HTP-USPJN taken from Ref [16] and exponent c = 1.5. All curves are fitted results.

The cumulate distributions of node strength s and edged weight w are also obtained, and they are all stretched exponential distribution. In the Refs [14-16], empirical values of c in different networks, which is stretched exponential in SED, are shown, e.g. Fig.2 gives a snapshot of exponent c in Eq.(5) for the cumulative distributions of s and w in CHTEN and we can see that for a certain network type, c of s and w are all almost same for different years, though they are different for different network. We also found that the form of distribution of a network is similar for past few years despite network is evolving. It shows that the development of China high technology continues to forge ahead.

The average clustering coefficient(ACC) and average shortest path length(L) of a network are introduced to determine whether a network is a small-world one[1, 25]. Through numerical calculation, we give the corresponding results in Tab. 1. Almost all the networks have small APL and large ACC, which demonstrate they have small-world effect. It is also found that most of the networks tend to be disassortative r_c, which is defined by Ref[26] as $r_c<0$, and it indicates that the nodes in the network that

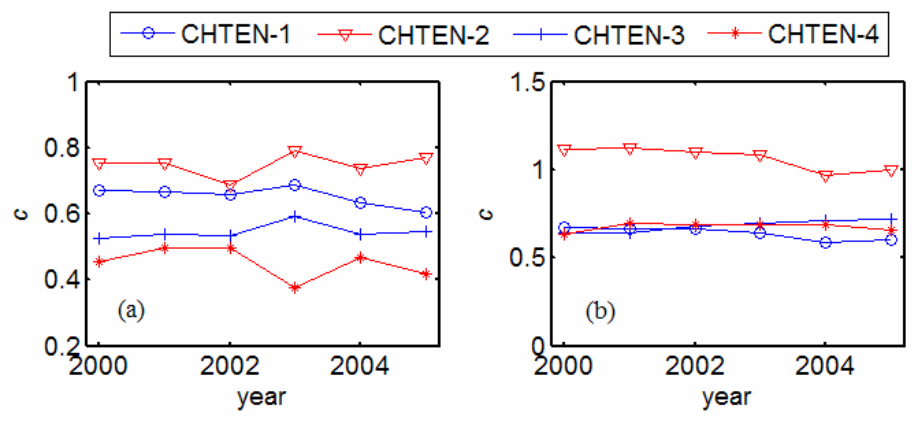


Fig. 2. Exponent c VS year in the CHTEN. (a) for the cumulative distribution of s, (b) for the cumulative distribution of w, which are all taken from Ref [14].

Table 1. *ACC*, *APL*, r_c in the three levels of CHTN

	APL	*ACC*	r_c	Ref
Z-park	4.8	0.2	<0	[13, 18]
STIP	1.4~3.2	0.25~0.7	<0	[17]
HTP-USPJN	1.7~1.9	0.9~1	>0	[16]
CHTI	1.7~2.4	0.38~0.45	<0	[14, 15]

have many connections tend to be connected to other nodes with few connections. It shows that high technology tends to expand from developed to developing area.

3.2 Network Community

Further, we analyze the evolving of network community of the CHTN based on the *CPM*, Not only four types of statistics distributions of community is obtained shown in Ref [17], but also the changing of maximum *K*-clique community shown in Refs [14, 15] where clique is maximal complete subgraph and *K* is corresponding number of the nodes.

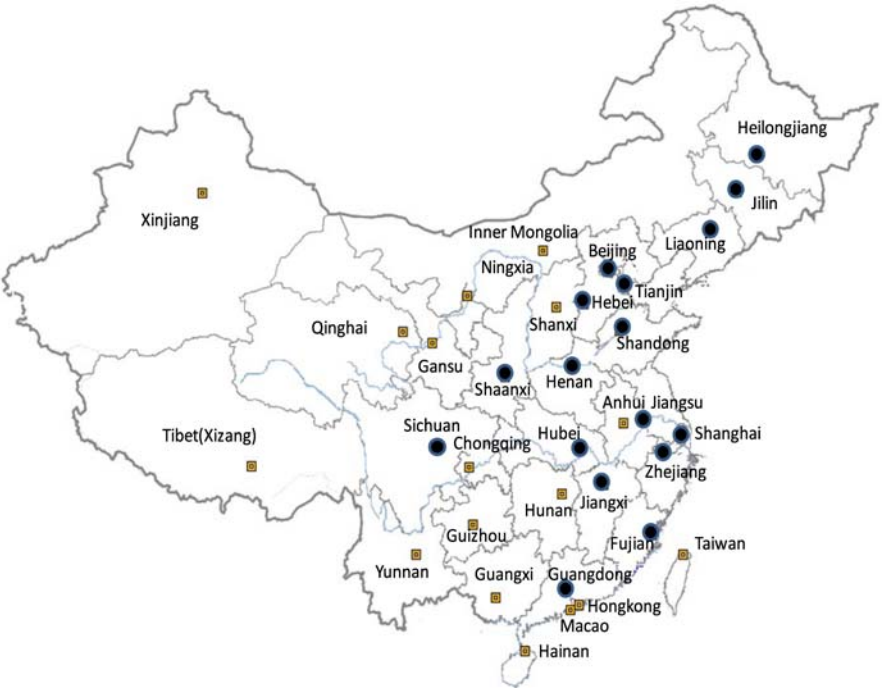
Fig.3 give the schematic maps of the community with *K*=22 in the CHTEN-2 [14,15] from 2000 to 2005 in order to explore the rule of community in the same size of *K*. Fig.3(a) is the initial community in 2000 and Fig.3(b) is the resulting one in 2005. In 2000 there are 17 provinces involved in the community and the number of industries in each province almost changes in the following five years. Recurring to the size of the dotted circle, the developing of high technology in a province is portrayed [15]. It can be clearly seen that it is more robust in the eastern regional than in the western in China. So persistent efforts should made to coordinate poverty-alleviation programs of the Chinese eastern and western regions.

In the other hand, in the CHTEN-4 by the corresponding province whose industries having the same number of cliques, some regional economic, such as Yangtze Delta, the Pearl river Delta and the areas surrounding the Bo Sea, can be reflected [14].

Further, we find that P_s, which is the ratio of the removed edges in CHTEN-2 to total edges in CHTEN-1 according to their constructive way, has exponential relationship with maximum of K, denoted with K_{max}, as Eq.(6).

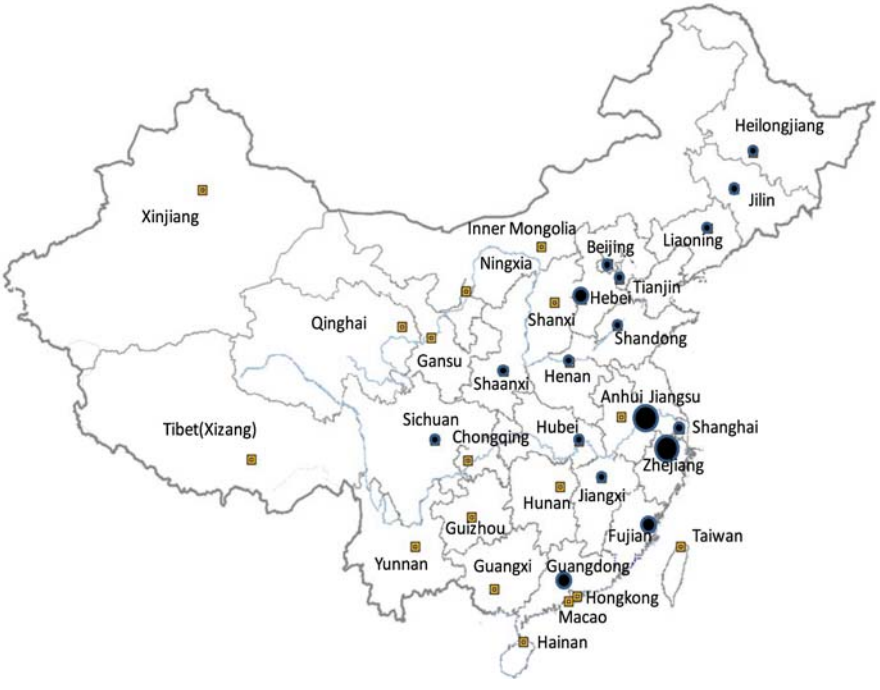
$$K_{\max} = ae^{\frac{p_s}{b}} + c \tag{6}$$

where a, b and c are all constants. And Fig.4 gives the function curve in five year for four types of network. The data fall into both sides of the curve. K_{max} and P_s are all decreasing from 2000 to 2004, but it changes in 2005. This potentially implicate that the strategy of development of the West Regions effect, and it narrows down the difference among provinces.



(a)

Fig. 3. Schematic maps of the community with K=22 in the CHTEN-2 [14,15]from 2000 to 2005. (a) map of the community in 2000, dotted circle denotes node in the community and dotted square is the province else. (b) map of the community in 2005, and smaller dotted circle denotes that a node belonging to the province is departing from the community and larger one denotes reverse, i.e. becoming a part of the community.



(b)

Fig. 3. (*continued*)

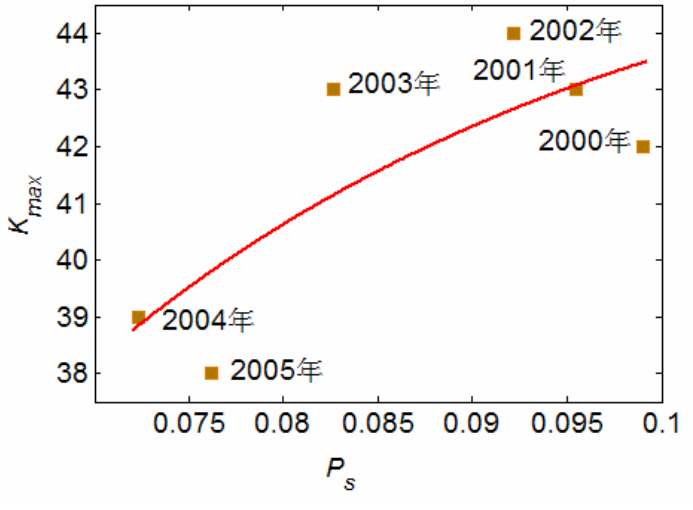


Fig. 4. K_{max} as a function of Ps for four types of network. It is taken from Ref [14].

4 Conclusions and Discussions

In summary, we have briefly reviewed main parts of our recent work on the CHTN. After classifying the CHTN, we show the interrelated results on its characteristics and community. Firstly degree distributions in three levels' networks have a variety of forms, such as power-law, Poisson, SED. Further, cumulate distributions of nodes strength and edge weight obey SED. Disassortative of the network shows that high technology tends to expand from developed to developing area and it will avail to the technical exchange. Then community structure of the network can be studied by using a software *CFinder* and by the interrelated data we potentially find some features in consistent with realities, such as the growth of high technology is uneven and the existing of the regional economic.

Besides, we present a simple evolving model [15] to embody the tendency that more nodes are involved in the CHTN. Using analysis and simulation, we study its cumulated weight distribution and determine the exponent of power-law. But it still needs to be improved. Recently we suppose that a node in the CHTN can have several attributes and they can be used to depict the interact of nodes in some way of randomness and determinateness [27]. Maybe they can be combined to discover more feature of the CHTN.

Anyway, the framework in this paper offers us an exciting way to study the networks whose relationships between nodes can not be directly obtained. Meanwhile, we also discussed several features of the China Top-100 Electronic Information Technology Enterprise Network in Ref [28]. And exploring the characteristics of the CHTN in each level not only provides a good example of the interplay between structure and economic indicator, but also offers a glimpse on the developmental situation of the high technology in each province of China.

The issue of high technology networks is not only associated with China, but also with all over whole world as well as with multi-levels for practical applications. It is still open and much more challenging for multidisciplinary researchers.

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