Technological Alliance Networks Analysis under Complex Network Perspective——Case of China's TD-SCDMA Industry

Liang Mei
School of Public Administration
Zhejiang University
Hangzhou, 310027, China
E-mail: meiliangzju@163.com

***Abstract*—This paper discusses the structure characteristics of China's TD-SCDMA industry alliance from complex network perspective. We use the basic two parameters——average path length and clustering coefficient to do the analysis. Results show that comparing to the different types of complex network, China's TD-SCDMA industry alliance has relatively high clustering coefficient and low average path length, implicating the obvious "small-world" characteristic.**

Keywords-complex network; average path length; clustering coefficient; China's TD-SCDMA industry alliance

I. INTRODUCTION

In the globalization and network economy era, with the complexity of technology, high risk of innovation, a single company becomes difficult to have all the possible resources of the innovation activity. As no organization is an island [1], networks of collaborative relationships among firms and other institutions are widely recognized as an important organization form of innovative activities [2], and inter-organizational relationships are seen as long-term oriented arrangements between organizations (firms, institutions, agencies, etc) [3]. Thus, the research of innovation begin to focuses topics on innovation networks ——networks emerging from firms' decisions to form strategic alliances aimed at learning and producing new knowledge [4], and inter-organizational cooperation which can be extremely effective in increasing the circulation of tacit knowledge, and in creating possibilities for a firm to acquire knowledge outside its boundaries [5]. Researches in strategy and organizational fields are making use of perspectives like resource dependence theory, transaction cost economics, game theory, and social network theory, this paper analyzes innovation networks on the basis of complex network perspective, and take one of most typical technological alliance networks case——China's TD-SCDMA Sector as an example. The analysis results show the characteristics of China's TD-SCDMA Industry alliance and provide implication of proposals for the development of alliance networks.

II. THEORY BACKGROUND

A. Complex Network Theory

With the development of society and information revolution, the complex network behavior of artificial and nature networking needs more and more comprehension. Nowadays, researchers spend efforts to seek the general characteristic of networks in different fields such as telecommunication network, electric network, biology network, and social network, and the complex network theory provides a suitable analysis perspective [6]. Table I summarizes the brief history of the development of complex network theory.

TABLE I. BRIEF HISTORY OF COMPLEX NETWORK THEORY

Time (year)	Figure	Events
1736	Euler	Konigsberg seven bridges
1959	Erdos & Renyi	Random graph theory
1967	Milgram	Milgram's small-world study
1973	Granovetter	Weak ties strength
1998	Watts & Strogatz	Small-world model
1999	Barabasi & Albert	Scale-free networks

Source: Wang Xiaofan, Li Xiang and Chen Guanrong. Complex Network and Its Application. Beijing: TsingHua University Press.

But networks are inherently difficult to understand, the complexity of network systems is composed of structural complexity, network evolution, connection diversity, dynamical complexity, node diversity, and meta-complication [7]. Particularly, the most basic issues refer to the topic on structural with two parameters: average path length and clustering coefficient.

1. Average path length

The average path length (which is the same as characteristic path length) is related to the nodes and sides of a network. The distance (geodesic) of two nodes i and j in a network is defined as the number of sides in the shortest path that links these two nodes. Thus, the average path length L is defined as the average value of reciprocal distances to every two nodes in a network, see formula (1), that N represents the number network nodes.

$$L = \frac{1}{\frac{1}{2}N(N+1)}\sum_{i \geq j} d_{ij} \tag{1}$$

2. Clustering

In a network, suppose one node i connects the other ki nodes which are called the neighbors, and these nodes are composed of a cluster. Among the ki nodes, the maximum number of possible sides is equals to $k_i(k_i-1)/2$. The rate of actual number of sides among the ki nodes (Ei) and

the maximum number of possible sides is defined as the clustering coefficient, represented by formula (2).

$$C_i = 2E_i/(k_i(k_i-1)) \quad (2)$$

From the geometry characteristic, the formula above equals to formula (3) which is the standard weighted overall clustering coefficient measure [8], [9].

$$Clustering_w = \frac{3*(number\ of\ triangles\ in\ the\ graph)}{\text{number of connected triples}} \quad (3)$$

This paper utilizes the two basic characteristics of complex network measure——average path length and clustering coefficients to analyze the technological alliance networks.

B. *Strategic Alliance*

Strategic alliances are voluntary arrangements between forms involving exchange, sharing, or co-development of products, technologies, or services [10]. Researchers have already discussed alliances in various kinds of sectors such as textiles sector [11], semiconductor sector [12], biotechnology sector [13], [14], pharmaceutical sector [15], steel sector [16], and chemicals sector [17]. As a unique organizational form of networks, organizations in alliances are already embedded in their broader "network" of economic and social relationships [18]. There are two complementary perspectives of researches in alliance network analysis, namely actor level and network level, see table II [19].

TABLE II. A TYPOLOGY OF INTER-ORGANIZATIONAL NETWORK RESEARCH

	Dependent Variable or Outcome Focus	
Independent Variable or Input Focus	Individual Organizations	Collectivities of Organizations
Organizational variables	Impact of organizations on other organizations through dyadic interactions	Impact of individual organizations on a network
Relational or network variables	Impact of a network on individual organizations	Whole networks or network-level interactions

Complex network analysis is one of typical perspectives in analyzing the relationship of alliance members and structure of alliance network Melissa Schilling (2007) studies the 11 alliance networks of sector-level and concludes that firms embedded in alliance networks that exhibit both high clustering and high reach will have greater innovation output than firms in networks that do not exhibit these characteristics [20]. This paper focuses on the China's TD-SCDMA sector alliance, one of typical sector alliances of China's telecom-equipment industry, and utilizes the Melissa Schilling analysis perspectives from two parameters——average path length and clustering coefficient in complex network to discusses the structure characteristics of alliance.

III. TECHNOLOGICAL ALLIANCE NETWORKS OF CHINA'S TD-SCDMA IDUSTRY

A. *Industry Context*

The development of China's TD-SCDMA industry is followed by the rise of China's telecommunications equipment manufacturing industry. See figure 1.

In years of development, the telecommunications equipment manufacturing industry has always highlighted the importance of leveraging indigenous innovation capability, implementing the national innovation strategy, gradually improving the industrial sector structure, and upgrading technology. At present, China's telecommunications equipment manufacturing industry has emerged a number of big companies with international competitive advantage such as Huawei, ZTE and other enterprises. Their development is based on innovation and present business innovation model of China's telecommunications equipment manufacturing industry. See figure 2.

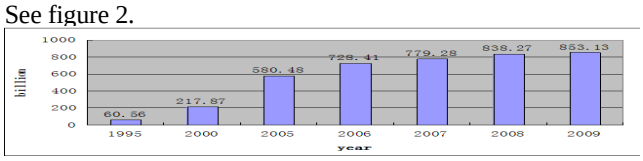

Figure 1. Industrial output value of China's telecommunications equipment manufacturing industry

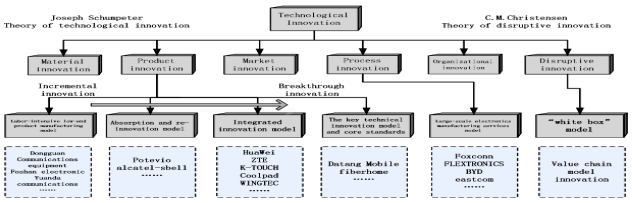

Figure 2. The technology innovation theory and "5+1" business model of communications equipment manufacturing

In April 1997, the International Telecommunications Union (ITU) sent 3G technological standard collection letter to countries, and determined the schedules and formation steps of international three generation wireless communication standards. All proposals must be submitted before June 30th, 1998. In this international context, Chinese government paid high attention to this for participating the international competition, and established 3G Wireless Transmission Technology Assessment and Coordination Group composed of experts in the field of wireless communications. Datang Group, leading the drafting of a combination of WCDMA and CDMA2000 technology merits, raised the TD-SCDMA technology standard. Under the driven by China Standards Committee, TD-SCDMA technology standard are authorized as one of three international standards by the International Telecommunication Union in May 2000. Thus, relying on international standards certification, on October 30th, 2002, TD-SCDMA Industry Alliance Conference was held in Beijing. Datang Group, Soutec, Holley, Huawei, Lenovo, ZTE, China Electronics, China Putian, eight companies as sponsor, co-signed a commitment "promoter agreement" to the development of TD-SCDMA industry, achieving the first country's international standards with independent intellectual property rights [21]. With 10 years development, China's TD-SCDMA industry experiences high speed development.

B. *The evolution of core technology of TD-SCDMA*

Technical standards for industry and international competitiveness have become increasingly important. Relying on a strong market, China also plays an increasing

important role of technical standards for international competition. These attempts include Enhanced Versatile Disc (EVD), Intelligent Grouping and Resources Sharing (IGRS), Audio, Video Coding Standard (AVS), and Time Division Synchronous Code Division Multiple Access (TD-SCDMA) standards [22]. Standards have positive economic effects. They include promoting market efficiency and expansion, fostering international trade, encouraging competition, lower barriers to market entry and faster diffusion of new technologies, protecting consumers from unsafe or unsubstantiated products, and enabling interoperability among products [23]. Standardization is often a process of building an alliance surrounding a particular technology, especially at the international level. The generation of TD-SCDMA has experienced the development and evolution of technical standard, and now it becomes an important part of technical standards for international communications industry, figure 3 describes main 3G standards evolution of international communications industry.

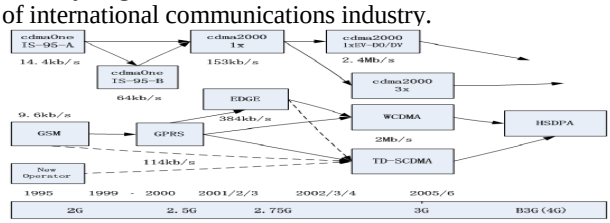

Figure 3. main 3G standards and their evolution

TD-SCDMA, standing for Time Division-Synchronous Code Division Multiple Access, is one of the three main international communication standards (the other two are WCDMA and cdma2000). TD-SCDMA integrates the technical advantages of CDMA, TDMA (FDMA), and show superiority about high spectrum efficiency, low power control, and multiple communication interfaces. These help TD-SCDMA standard achieve full application of the signal frequency, the coordination of symmetrical and asymmetrical data channel, the reduction of multi-interference, and high-frequency signal transmission dynamics.

IV. NETWORKS ANALYSIS OF CHINA'S TD-SCDMA INDUSTRY

A. *Network Structure*

In a very general way, a network is a set of nodes and the set of ties representing some relationship, or lack of relationship, between the nodes [24]. Up to the year 2010, China's TD-SCDMA industry alliance has absorbed 78 organization members, covering the whole industry chain. Among them, Datang Mobile, Holley Group, Huawei, Lenovo, ZTE, Potevio, China Electronics Corporation, and China Mobile are alliance board members. Table III summarizes the alliance members according to the industry chain positions.

TABLE III. NETWORK MEMBERS OF TD-SCDMA INDUSTRY ALLIANCE

Industry chain position of TD-SCDMA.	Company.
Equipment manufacture	Datang Mobile, ZTE, Potevio, TD Tech Ltd, Utstar, alcatel-sbell, fiberhome, postcom, CFC, GRENTECH, FINGU, JinPeng, EB, digimoc, NTS.
Chip.	Datang Mobile, COMMIT Incorporated, T3G, CYIT, spreadtrum, comlent, rdamicro, MediaTek, digimoc, NTS.
Terminal.	Datang Mobile, Holley Group, HuaWei(HW), Lenovo, ZTE, CECW, Hisense, COMMIT, T3G, Utstar, alcatel-sbell, Envada, dbtel, koretide, TCL, haier, postcom, BIRD, BOCO, yulong, SIM, LONGCHEER, BENQ, FLEXTRONICS, RME, CHINA MOBILE, PTAC, doped, vtion, EB, WINGTEC, CCIT.
Testing.	Datang Mobile, ZY, ZCTT, StarPoint, CETC41, Rising Technology.
Antenna.	HTAT, tycc, andrew, comba, CETC14, MOBI.
Operating system.	Datang Mobile, koretide.
Repeater .	Datang Mobile, ZTE, comba, ACE, CFC, youke.

We then describe the network structure of China's TD-SCDMA industry alliance by using social network software UCINET6.0. Nodes represent alliance members and links represent relationships. We define that two nodes have direct links if one node publishes or notices the relationship on website or written materials. By collecting data from each company's website, two biggest search engines in China—baidu and google, and China's TD-SCDMA industry alliance's website, we get links referring to technology transfer agreement, strategic cooperation agreement, equipment supplier agreement, intellectual property sharing agreement, joint R&D activity product tender agreement, project cooperation agreement, OEM agreement and company affiliated relationship, terminal application agreement, business merger contract. All the data collected refer to the year 2002 (China's TD-SCDMA industry alliance established) to 2010, and information of members joining in year 2009 and 2010 are eliminated because of the time lag of secondary data. The network alliance is seen in figure 4.

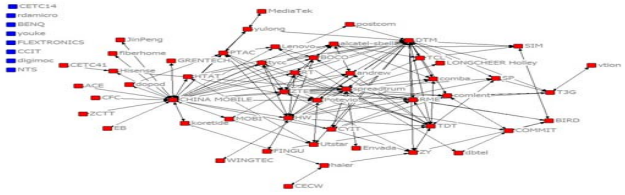

Figure 4. TD-SCDMA industry alliance network

Under the description of Fig.4, China's TD-SCDMA alliance are composed two parts with most of members participating in the core component and the other 8 members are isolated with few alliance activities. Equipment manufacturers like DTM, TDT and Potevio, terminal companies like CHINA MOBILE, HW, PTAC, alcatel-sbell have more links in alliance meaning that these organizations are more active in cooperation and participation. Other members are all joining in the alliance network at different extents.

B. *Network Characteristics Analysis*

1. Average path length

We use UCINET software to calculate the index of average path length according to the formula (1). Table IV shows the results. The average distance of China's TD-SCDMA industry alliance is 2.344 which is very small comparing to the different types of complex networks listed in literature [25] of Newman's research.

TABLE IV. INDEX OF AVERAGE PATH LENGTH

Index	Value
Average distance (among reachable pairs)	2.344
Distance-based cohesion ("Compactness")	0.475
range 0 to 1; larger values indicate greater cohesiveness	
Distance-weighted fragmentation ("Breadth")	0.525

2. Clustering coefficient

We calculate the index of clustering coefficient according to the formula (2), (3). Table V shows the results. The clustering coefficient of overall graph of China's TD-SCDMA industry alliance is 0.402 which is very relatively large comparing to the different types of complex networks listed in literature [25] of Newman's research.

TABLE V. INDEX OF CLUSTERING COEFFICIENT

Index	Value
Overall graph clustering coefficient	0.402
Weighted Overall graph clustering coefficient	0.232

In addition, we calculate the node clustering coefficients of some board members of alliance and the results are shown in table VI.

TABLE VI. INDEX OF CLUSTERING COEFFICIENT

Company	Clustering Coefficients	n-Pairs
Datang Mobile	0.197	325
Huawei	0.308	91
Lenovo	0.300	10
ZTE	0.208	120
Potevio	0.361	36
China Mobile	0.112	378

V. CONCLUSION AND IMPLICATION

From complex network perspective, this paper analyzes China's TD-SCDMA industry alliance network. By establishing the network structure of members (nodes) and their relationship (links), we analyzes the two basic characteristics — — average path length and clustering coefficient of complex network. The average path length of China's TD-SCDMA industry alliance is 2.344 and the clustering coefficient of overall graph of China's TD-SCDMA industry alliance is 0.402. By comparing to the different types of complex networks listed in literature [25] of Newman's research such as scientists cooperation network, WWW network, internet network, traffic network, neural network, protein network, and so on, China's TD-SCDMA industry alliance has high clustering characteristic and low average path length. According to the complex network theory, the small-world characteristic of China's TD-SCDMA industry alliance is obvious, and it facilitates the information flowing, knowledge transferring and innovation spillover in the whole industry alliance.

REFERENCES

[1] Payjak, SD, Day, JM, Nair, A, Sawaya, WJ & Kristal, MM 2007, Complexity and adaptively in supply networks: building supply network theory using a complex adaptive systems perspective, Decision Sciences, vol. 38, no., pp.547-561.

[2] L.Orsenigo, F.Pammoli, Massimo Riccaboni. Technological change and network dynamics Lessons from the Pharmaceutical industry. Research Policy 30(2001): 485-508.

[3] Thomas Ritter, Hans Georg Gemunden, "Network competence: its impact on innovation success and its antecedents," Journal of Business Research, vol 56, issue 9, 2003, pp: 745-755.

[4] Joel A. C. Baum, Robin Cowan, Nicolas Jonard. Network-Independent Partner Selection and the Evolution of Innovation Networks. Manage Science, vol. 56, No. 11, 2010, pp.2094-2110.

[5] Robin Cowan, Nicolas Jonard, Jean-Benoit Zimmermann. Bilateral Collaboration and the Emergence of Innovation Networks. Management Science, vol.53, N0.7, 2007,pp:1051-1067.

[6] Wang Xiaofan, Li Xiang and Chen Guanrong. Complex Network and Its Application. Beijing: TsingHua University Press.

[7] Steven H. Strogatz. Exploring complex networks. Nature 410, 268-276 (8 March 2001).

[8] Borgatti, S. P., M. G. Everett, L. C. Freeman. 2002. Ucinet for Windows: Software for social network analysis. Harvard, Analytic Technologies.

[9] Newman, M. E. J., S. H. Strogatz, D. J. Watts. 2002. Random graph models of social networks. Proc. Natl. Acad. Sci. USA 99, 2566-2572.

[10] Ranjay Gulati, "Alliances and networks," Strategic Management Journal, vol 19, issue 4, 1998, pp: 293-317.

[11] B. Uzzi, "Social structure and competition in interfirm networks: the paradox of embeddedness," Administrative Science Quarterly, vol. 42, NO 1, 1997, pp: 37-69.

[12] Stuart, T.E., "Network positions and propensities to collaborate: an investigation of strategic alliance formation in a high-technology industry," Administrative Science Quarterly vol. 43, issue 3, 1998, pp:668-698.

[13] Walter W. Powell, Kenneth W. Koput and Laurel Smith-doerr, "Interorganizational collaboration and the locus of innovation: networks of learning in biotechnology," Administrative Science Quarterly, vol 41, No.1, 1996, pp: 116-145.

[14] Joel A.C. Baum, Tony Calabrese and Brian S. Silverman, "Don't go it alone: Alliance network composition and startups' performance in Canadian biotechnology," Strategic Management Journal, vol. 21, issue 3, 2000, pp: 267-294.

[15] Victor Gilsing, Bart Nooteboom, Wim Vanhaverbeke, Geert Duysters, Ad van den Ood, "Network embeddedness and the exploration of novel technologies: Technological distance, betweenness centrality and density," Research Policy, vol. 37, issue 10, 2008, pp:1717-1731.

[16] Rowley, T., D. Behrens and D. Krackhardt, "Redundant governance structures: an analysis of structural and relational embeddedness in the steel and semiconductor industries," Strategic Management Journal, vol. 21, issue 3, 2000, pp: 369-386.

[17] Ahuja. G., "Collaboration networks, structural holes and innovation: a longitudinal study," Administrative Science Quarterly, vol.45, NO. 3, 2000, pp: 425-455.

[18] Granovetter, M. 1985. Economic action and social structure: The problem of embeddedness. American Journal of Sociology, 91(3): 481-510.

[19] Keith G. Provan, Amy Fish, Joerg Sydow. Inter-organizational Networks at the Network Level: A Review of the Empirical Literature on Whole Networks. Journal of Management, vol. 33, No.3, 2007, pp: 479-516.

[20] Melissa A.Schilling, "Interfirm collaboration networks: the impact of Large-scale network structure on firm innovation," Management Science, vol. 53, No. 7, 2007, pp: 1113-1126.

[21] Xudong Gao. ZHONGGUO 3G. Beijing: Intellectual Property Rights Press, 2010, pp.007-009.

[22] Lee, H.& Oh, S. A standards war waged by a developing country: Understanding international standard setting from the actor-network perspective. Journal of Strategic Information Systems, 2006, 15(3): 177-195.

[23] Hemphill, T., Technology standards development, patent ambush, and US antitrust policy. Technology in Society, 2005, 27, 55-67.

Bo, L., Dongliang, X. & Shiduan, C.et al. Recent advances on TD-SCDMA in China. Communications Magazine, IEEE, 2005, 43(1): 30-37.

[24] Brass, D. J., Galaskiewicz, J., Greve, H. R., and Tsai, W, "Taking stock of networks and organizations: A multilevel perspective" Academy of Management Journal, vol. 47, No.6, 2004, pp: 113-151.

[25] Newman M E J. The structure and function of complex networks. SIAM Review, 2003, 45: 167~256.