ALLIANCE NETWORK AND INNOVATION: EVIDENCE FROM CHINA’S THIRD GENERATION MOBILE COMMUNICATIONS INDUSTRY

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Abstract: The evolution of a third generation mobile communications (3G) industry based on TD-SCDMA technical standard in China is explored through the lens of network analysis. We argue that inter-firm alliances help companies gain and integrate internal and external resources and foster technical innovation. We analyze alliance governance structures and governance mechanisms in particular, and show how they protect and improve network-based innovation capabilities and competitive advantages during a ten-year period. Finally we offer a theoretical model that incorporates cooperation among organizations, maturity of the industrial chain, and the accumulation of organizational knowledge and social capital, all of which contribute greatly to the development of technical innovation.

Keywords: Alliance Network, TD-SCDMA, Governance Structure, Governance Mechanism, Collaborative Innovation

INTRODUCTION

China's wireless telecom industry has experienced incredible growth since the first deployment of cellular services in 1987. The teledensity (the number of main lines per 100 persons) in China has risen from 0.38% in 1978 to more than 26% in 2008 (Yan and Pitt, 2002). By the end of October, 2010, the number of cell phone subscriptions in China has exceeded 830 million. At the same time, the wireless industry in China has been in the early phase of the diffusion of 3G technology, especially the TD-SCDMA (Time Division-Synchronous Code Division Multiple Access) technical standard, which was proposed and developed by Datang Telecom, a Chinese telecom company. It is of great importance to investigate the evolution of the 3G industry based on the TD-SCDMA technical standard in China, for wireless telecom services are critically dependent upon the creation and implementation of technical standards (Haug, 2002).

The TD-SCDMA standard was submitted to International Telecommunication Union (ITU)[1] by Datang Telecom in 1998. On January 20, 2006, it was enacted as the 3G standard of China by the Ministry of Industry and Information Technology (MIIT)[2]. And the whole process from

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[1] ITU is now an agency of the United Nations which regulates information and communication technology issues. It works to improve telecommunication infrastructure in the developing world and establishes worldwide standards. Ryan (2005) analyzed the complete evolution process of ITU since its establishment in 1865.

[2] MIIT is the department that manages and improves the development of Industry and Information Industry, and it is also the primary regulator and policy maker in this area.

laboratory-based technology to commercialization took less than ten years. At the time, there were three technical standards, TD-SCDMA, CDMA2000 (Code Division Multiple Access 2000), WCDMA (Wideband Code Division Multiple Access), in the mobile communication industry in China. The innovation and commercialization of the TD-SCDMA technical standard into 3G services required coordination among the heterogeneous actors holding specialized knowledge and resources (Yoo et al., 2005). Mobile phone manufacturers, telecom operators, telecom system equipment suppliers, service providers and other stakeholders in China, all invested huge amounts of human capital and financial resources into TD-SCDMA, especially cooperating on R&D and manufacturing, and establishing TD-SCDMA Industry Alliance (TDIA).

Given the initial weak market position of the TD-SCDMA standard, key actors were required to align their interests and collaborate effectively. Relying on organizations' specific assets and technical advantages, actors cooperated and promoted R&D and commercialization processes related to the TD-SCDMA standard and systems. The rapid commercialization of the TD-SCDMA technical standard well illustrates the behavior and interactions of organizations in the mobile communication industrial space in China, and offers a theoretical model for the promotion of technical development and industrial innovation.

The specific research questions we ask are: How did the 3G industry based on TD-SCDMA standard in China evolve? How do network structures and governance mechanisms promote technical innovation and the industrialization of technical standards? In what follows, first we provide (a) a literature review of the past research on the evolution of mobile industry in China, paying attention to strategic alliances, the emergence of an alliance network, and how they contributed to technological innovation, including a discussion of research methodology and data collection; followed by (b) an overview of the evolution of 3G industry based on the TD-SCDMA technical standard in China, from a network evolution perspective; leading to (c) a description of the evolutionary process of the TD-SCDMA industry, paying attention to how network structure and governance mechanisms played their roles; and, finally, (d) we build a theoretical model of alliance networks and collaborative innovation. At the end of the paper, we summarize our findings and make suggestions for future research.

THEORETICAL BACKGROUND

3G mobile services require integration of diverse technological and organizational resources that can not typically be found within a single firm. Van De Ven (2005) argued that the innovation in complex technology systems, such as mobile telecom services, required collective achievements. Strategic alliances or "voluntary arrangements between firms involving exchange, sharing, or co-development of products, technologies or services" (Gulati, 1995; Gulati and Westphal, 1999) can effectively mobilize and motivate the resources needed for collective innovation. Alliances can be far more than simple, one-off deals; for alliances with strong firms in an industry or with numerous firms to fulfill a variety of tasks in an industrial chain can send out positive signals to all the firms that populate an industry.

Of course, alliance formation also raises some risks because members of an alliance may violate agreements, embezzle technology, bring more competitors and increase the quantity of suppliers in a market. To counter these risks and others, governance mechanisms to protect alliances and promote innovations are needed (Jones et al., 1997), including regulations that aim to maintain long-term network relationships, promote equitable allocation of resources and incentives, and constraint the behavior of network members in appropriate ways. Network governance mechanisms work to sustain cooperation among network members and promote innovation of the alliance and every member.

Alliance structure and governance mechanisms shape economic behavior by creating opportunities and making them accessible to member firms (Uzzi, 1996). Network membership confers opportunities to work on the design, development, manufacture and sale of innovative products and services. Thus, alliance networks build direct and indirect, reciprocal, and flexible ties among science, technology and the marketplace, through the interaction of actors in various fields of activity (Imai and Baba, 1989; Freeman, 1991; Arndt and Sternberg, 2000). Whittaker and Bower (1994) found out that firms in the American pharmaceutical industry shared knowledge and other kinds of resources and developed new products by making effective use of inter-organizational alliance ties. Social capital, based on the cooperation with other organizations, can also greatly contribute to firms' technical innovation capacity (Cullen et al., 2000). Rodan and Galunic (2004) proposed that heterogeneous knowledge, gained from network interactions, had greater effect on innovation performance than the improvement of management expertise in single firms.

In high-tech industries, such as mobile telecoms, more than one technical standard can exist at the same time. A battle between technical standards to win a dominant, leading position among different technical tracks often occurs (Suarez, 2004). Morris and Ferguson (1993) indicated that a single enterprise can dominate an entire industry chain by winning and controlling technical standards. As a result, enterprises all try their best to make their technical standard to be the industry's dominant standard. Governments can also have vital influence on standards (West and Tan, 2003a, 2003b), and the success of GSM (Global System for Mobile Communications, a second generation mobile communication standard), was derived from the efforts of the European Union to set up a European uniform telecom standard.

Several studies examined the impressive growth of the Chinese telecom sector (Zhang, 2001; Zhu, 2001; Tan, 2002). Botongzhixin (2005) proposed that operators in the telecom industry should cooperate with other companies to promote the development of 3G. Whalley et al. (2009) argued that TD-SCDMA was the first case of a developing country both originating and successfully negotiating a global telecommunications standard. Tan and Lin (2006) proposed that government should contribute to the commercialization of China's 3G industry and that many factors, including political support, economic reform, market competition, and foreign direct investment had contributed to the development of China's 3G industry. Xu and Gong (2003) suggested that all of the above mentioned factors needed to work together, and formed a National Innovation System (NIS) promoting innovation and technology commercialization.

We draw upon and extend such recent studies on the role of alliance networks in the evolution of the 3G industry based on TD-SCDMA standard in China. In addition, through the use of case study, we generalize our deductions and build a theoretical model of how network cooperation promotes technical innovation and commercialization.

RESEARCH METHODOLOGY

Case Study of 3G industry in China

With the theoretical framework above, we analyze the evolution of the 3G industry based on the TD-SCDMA standard in China by means of an in-depth longitudinal case study. Eisenhardt

(1989) advocated developing new theory with the case analysis method, and case studies may be used to understand the dynamics of sole environments (Alliso, 1971), developing deep or thick descriptions (Kidder, 1982), testing theories (Pinfield, 1986; Anderson, 1983) and proposing new theories (Gersick, 1988). This paper takes the development and evolution of TD-SCDMA technology and the industrial alliance network that emerged around the technology as research objects. It will try to uncover the relationships between alliance network and innovation and propose theories modeled on both and adapted to the context of China's emerging economy.

Several reasons motivate the choice of the 3G industry based on TD-SCDMA technical standard: (a) China, growing more and more important in the international market, provides a singular context for studying organizational change (Tan and Tan, 2005) in the context of ongoing social, economic and political reform; (b) The TD-SCDMA technical standard has evolved from laboratory-based technology to commercialization, providing us with a relatively complete picture of the process of industrial development; (c) The 3G wireless industry based on TD-SCDMA technology, took only ten years to develop from laboratory-based technology, to a technical standard providing commercial service, which represents a great case study in rapid technical and industrial innovation; (d) A large number of organizations adopt different roles in the evolutionary process of the TD-SCDMA standard, building alliances with each other, and forming an elaborate alliance network. In conclusion, the evolution of the 3G industry based on TD-SCDMA standard offers a singular opportunity to study the successful innovation and diffusion of the TD-SCDMA technical standard, and how a large inter-firm network structure evolved with supporting governance mechanisms.

Data Collection

We collected data on the development of 3G services based on TD-SCDMA technical standard in China since 1997. Data came from two sources: (a) 8 interviews with key experts in the industry, who were deeply involved in the innovation and commercialization of the TD-SCDMA standard in China, including telecom operational managers and terminal manufacturers, and (b) archival data collected from various sources including the official website of TDIA, websites of its member firms, newspapers, annual reports of relevant listed companies and their archival data.

Data collection can be divided into three steps: (a) We first learned about the major firms in the development of China's 3G industry through open interviews with experts in the field and public information gathering. (b) The snowball sampling method (Laumann and Pappi, 1976) was used on archival data to identify the means and methods of cooperation between firms. In this way, we collected data on member firms and their alliances. (c) After that, we divided the longitudinal process into 7 stages (from 1997 to 2007, Appendix A), according to landmark events that occurred in the evolutionary process.

Alliances typically last for more than one year, but termination dates for alliances are rarely reported. This required us to make assumptions about alliance duration (Skilling and Phelps, 2007). We took a conservative approach. If information on alliance termination was available, we removed terminated ties from subsequent calculations. If no information was available by the end of 2007, we considered the alliance still existed between the firms in question.

Network Evolution Perspective

After data collecting and analysis, we identified 181 organizations and 310 alliances between them, relating to TD-SCDMA innovation and commercialization from 1997 to the end of 2007. The organizations and alliances formed an industry network. Then, we used network analysis software UCINET 6.0 to analyze the data. As mentioned by Skilling and Phelps (2007), firms form and maintain alliances with each other, and weave a network of relationships. Lin (2004) proposed that inter-organizational network based on cooperation can greatly enhance the internal development of member firms. An industry-level alliance network can greatly benefit the innovation performance of member firms and an entire industry (Kogut and Walker, 2001; Baum et al., 2003), especially in high-tech industries, which require complex and multiple resources and technologies that can not be found in single firm.

It is obvious that the development of an industry is a complex, dynamic and continuous process of organizational formation and technological evolution; this applies to the inter-organizational network of firms no less than the individual firms themselves. Brito (2001) proposed that industrial networks can be regarded as “living” structures in the way that firms, activities and resources react to each other in continuously changing. We adopt a network evolutionary perspective in our study of the development of the 3G industry in China based on the TD-SCDMA standard.

INDUSTRIALIZATION PROCESSES AND ALLIANCE STRATEGIES IN CHINA’S 3G INDUSTRY BASED ON THE TD-SCDMA STANDAND (Jul, 1997 ~ Dec, 2010)

As mentioned earlier, we divide the development of TD-SCDMA based alliances into 7 stages, based on how industry chains developed and evolved. Next we collect data on every stage of the development of China’s 3G industry based on TD-SCDMA technical standard, using archival data, the Internet, interviews and so on. At each stage, we discuss the entry of new firms, cooperation among them, technology breakthroughs and the increasing popularity of the standard. Finally we make some general comments on industry development (Figure 1).

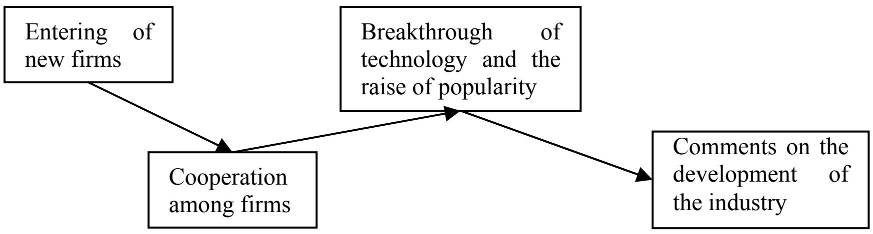

Figure 1 The Framework to Analyze the Evolution Process of the 3G Industry in China

Stage 1: R&D and Approval of the Academic Standard (Jul, 1997 ~ Aug, 2001)

In July, 1997, China’s Ministry of Posts and Telecommunication (MPT)[3] established the 3G Wireless Transmission Technology Assessment and Coordination Group. On June 30, 1998, a deadline set by the International Telecommunication Union (ITU) for collecting 3G standards from around the world, China submitted TD-SCDMA standard to ITU. At the ITU-R plenary session held at Istanbul in May, 2000, TD-SCDMA was approved as an international standard of

[3] MPT was established in 1949, regulated the post and telecommunication industry in China; in 1998, it developed into Ministry of Information Industry (MII), as the regulator of information industry; in 2008, MII merged into Ministry of Industry and Information Technology (MIIT) along with other related government agencies.

3G mobile communications, a significant breakthrough in the history of Chinese telecom industry. Then, TD-SCDMA Forum, the first nonofficial organization supporting TD-SCDMA standard, was jointly launched by 8 companies in the Chinese telecom industry[4] on December 12, 2000. It aimed at providing a platform for all stakeholders to communicate with each other on technical issues of TD-SCDMA development. On March 16, 2001, at the 11th plenary session of the Third Generation Partnership Project (3GPP)[5] held in U.S., 3GPP officially accepted TD-SCDMA as a 3G standard, symbolizing that the TD-SCDMA standard had won initial acceptance by the big telecom operators and vendors in the world.

During the process of drafting and submitting materials to establish the TD-SCDMA standard, Datang cooperated closely with Siemens, a joint partner in the development of TD-SCDMA technology. In October 1999, Datang and Siemens set up a joint R&D team to develop TD-SCDMA and, in June 2000, Siemens invested $1 billion out of a total $1.5 billion investment in Asia in the development of the TD-SCDMA standard. The cooperation between Siemens and Datang guaranteed the survival and development of the TD-SCDMA standard in the initial stages.

In the earlier stages of developing the TD-SCDMA from an academic standard to industrial standard, firms of TD-SCDMA made frequent use of alliance strategy. First, an R&D alliance between Datang and Siemens played a fundamental role in developing TD-SCDMA technical standard and in its approval by the ITU. Second, R&D institutes, universities and enterprises in China, driven by common interests and ambition, formed the TD-SCDMA Forum, an R&D alliance. TD-SCDMA Forum provided a platform for members of TD-SCDMA to communicate about common issues involving TD-SCDMA technologies and products. Third, in the certification process of TD-SCDMA by 3GPP, research institutions, industrial organizations, equipment suppliers and Chinese telecom operators formed another alliance to market TD-SCDMA. Moreover, after receiving 3GPP approval, in order to continue growing, the TD-SCDMA standard had to be made compatible with the TDD standard (Time Division Duplexing), which was owned by various Europe firms. This made the TD-SCDMA technical standard even more attractive. To view an illustration of the 3G industry collaborative network at the end of stage 1, see Appendix A, Figure 1.

Stage 2: Product R&D and Establishment of TDIA (Sep, 2000 ~ Oct, 2002)

In this stage, TD-SCDMA evolved from a technological standard to an industrial and commercial standard, giving further positive signals to members of the 3G industry or others contemplating entering the industry. In this stage, a lag in the supply of terminal devices became the bottleneck. In September 2001, Datang, together with Phillips, set up "The United Terminal R&D Center" to carry out the development of core chips for TD-SCDMA terminals.

The cooperation usually began with a sharing of personnel, technologies and funds among TD-SCDMA supporters. Commit, a terminal chip manufacturer funded by six leading domestic and foreign manufacturers[6], was established in January, 2002. Also, Datang restructured during this stage to prepare for the commercialization of TD-SCDMA; Datang Mobile was spun off from Datang Telecom (Whalley et al., 2009).

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4 China Mobile, China Telecom, China Unicom, Datang, Huawei, Motorola, Nortel, and Siemens

5 The leading 3G technological specification institution, which studied and promoted 3G technologies, WCDMA, TD-SCDMA and EDGE, in order to guarantee a smooth transition from 2G to 3G.

6 The six firms are: Nokia, TI, LG, Potevio, DBTEL and the CATT (Commit later went bankrupt due to a shortage of funding in the first half of 2008)

On October 30, 2002, TDIA was established in Beijing. Eight well-known communication enterprises (Appendix B) became the launching members. This indicated that the international mobile communication standard, TD-SCDMA, which Chinese enterprises owned the intellectual property rights had enjoyed unanimous support by the industry. With the establishment of TDIA, a TD-SCDMA prototypical industrial chain from systems to terminals was formed. Datang Telecom pledged that the TD-SCDMA technical patents would be franchised within the alliance. TDIA members contributed the necessary resources so that R&D, production and manufacturing could be carried out smoothly. More and more enterprises sought to build alliances with TDIA members, not just with leading firms, but with numerous TDIA firms at the same time. The nature of collaboration changed, from loose to close cooperation on one hand, and from accidental to self-conscious collaboration on the other. The TD-SCDMA network at the end of stage 2 is shown in Appendix A, Figure 2.

A large-scale field demonstration held in February, 2002, proved that TD-SCDMA met the requirements for a 3G Mobile Communication System raised by ITU. The TD-SCDMA standard worked well without technical barriers, and it could provide a foundation for building a national network providing 3G services. In August, 2002, 3G functions, like video calling, web surfing and mobile location services, were realized using TD-SCDMA.

In this stage, the establishment of TDIA became a founding milestone in the development of TD-SCDMA as a national and international standard. More firms joined the TD-SCDMA alliance, cooperating not only on technology R&D, but also developing terminals and systems based on TD-SCDMA standard. The commercialization of the TD-SCDMA standard progressed by means of information sharing, including technical agreements and patents. The government provided additional support for the standard. The success of the field-testing of TD-SCDMA demonstrated that it was more than just a laboratory technology.

Stage 3: Industrial Chain Alliance (Nov, 2002 ~ Dec, 2003)

The growth of TD-SCDMA industry began to show huge industrial potential once new enterprises joined the alliance network, including internationally well-known enterprises. At the end of October, 2002, Siemens, Datang's strategic partner, announced the investment of another $65.6 million in TD-SCDMA development. On November 22, UTStarcom signed a contract with Datang. Agilent, York-tech and other equipment and instrument companies also signed on. A TD-SCDMA based industry was being readied before the lauch of a Chinese 3G market.

At the same time, Datang authorized more enterprises to use TD-SCDMA patents. On January 16, 2003, STMicroelectonics, the third largest semiconductor company in the world, was permitted to use TD-SCDMA patents in developing multi-pattern, multi-media system-on-a-chip. This enhanced the R&D abilities of TD-SCDMA terminals, and sped-up the development of TD-SCDMA mobile terminals. On January 20, 2003, Datang, Phillips and Samsung jointly set up the Tianji Science and Technology Company. The company was established to provide core chips for fixed and mobile terminals. Relying on Phillips' R&D on handset chips and Samsung's overall systems capabilities, Tianji successfully skirted a bottleneck in terminal capabilities that had impeded 3G growth; Datang, Phillips and Samsung strengthened their cooperation in technology investment, personnel and market resources.

More important, a second expansion of TDIA occurred on December 26, 2003, with 6 new members (Appendix B) joining the alliance. With strong chip producers, terminal producers and an antenna merchant joining in, a more complete and commercially viable industry chain for TD-SCDMA was established. See the network at the end of stage 3, Appendix A, Figure 3.

With numerous alliances in place, TD-SCDMA gained significant ground in technology development capabilities and commercialization potential. In April 2003, TD-SCDMA handsets developed by Chongyou were able to carry on conversations with Datang's network base station. In July, the first TD-SCDMA terminal demonstration took place. At a conference on "3G in China" in October 2003, MIIT announced that a field test of MTNet for TD-SCDMA would be carried out. In August, the "TD-SCDMA International Summit 2003" was held in Beijing. The TD-SCDMA standard won strong support of the Chinese government, including MIIT, the National Development and Reform Commission (NDRC), the Ministry of Science and Technology (MST) and, at the same time, it gained approval in various other arenas, such as the China Communications Standards Association (CCSA) and the TD-SCDMA Forum.

This was a key stage in the industrialization and commercialization of the TD-SCDMA technical standard, and network alliance strategy played the leading role in bringing key actors together. A second round of TDIA expansion, which included the entrance of terminal firms in the alliance network, advanced the maturity of the industrial chain supporting TD-SCDMA. At this time, energies were focused on terminal technologies and a number of technology breakthroughs were realized. Furthermore, some well known international companies entered the TD-SCDMA space by joining in TDIA and building alliances (joint ventures, franchise agreements, etc) with existing member firms.

Stage 4: Alliance for Commercialization (Jan, 2004 ~ Jan, 2005)

The industrialization of TD-SCDMA had aroused the interests of the international telecom operators. In January, 2004, Japan deliberated the 3G plan with TD-SCDMA as one alternative. On February 13, 2004, Siemens and Huawei build a joint venture named TDTech. Then more new sub-alliances began to be built between domestic firms and well known international companies. In November, 2004, Datang and Shanghai Bell-Alcatel signed the strategic cooperation agreement, and the latter invested $350 million to promote the research, development and industrial production progresses of TD-SCDMA. During this period, Siemens, Huawei and Datang built a strategic alliance. Nortel Networks and Potevio also began to cooperate with each other, and Ericsson chose ZTE as its partner to enter the TD-SCDMA industry.

The expansion of TDIA had showed the value of alliance once again and further enhanced the maturity of the industrial chain network. On April 16, 2005, 7 enterprises (Appendix B) joined the TDIA, and the members of TDIA reached 21, comprehensively covering most links in the industry chain including chip, system equipment and handset terminal. The expansion based on standard improvement and threshold restriction had indicated the industrial influence of TD-SCDMA.

With more major cooperators and deepening of the cooperation, there is much technical breakthrough on TD-SCDMA. In November, 2004 Tianji Science and Technology successfully made the first TDD-LCR commercial telephone in the world. In December, Samsung promoted the first GSM/TD-SCDMA bi-module terminal. Datang implemented TD-SCDMA video telephone business test and international call was realized successfully based on TD-SCDMA. In January, 2005, the data card manufactured by Datang took the lead to implement the 384K data transmission service, which was the first TD-SCDMA data terminal in this field.

A succession of technology and application breakthroughs won positive appraisal and support from the government and telecom-related commercial enterprises. At the end of February, 2004, NDRC approved a R&D TD-SCDMA project, offering favorable policies and fund support. From March to August 2004, Datang delivered the first TD-SCDMA LCR terminals and PCMCIA wireless network cards in the world. In August, T3G and Spreadtrum developed a chip for TD-SCDMA terminals, and the commercialization of TD-SCDMA terminal development advanced notably. In November, the result of MTNet field test organized by MIIT was announced with TD-SCDMA passing the experiment smoothly, demonstrating its technical advantages and commercial viability.

In this stage, the TD-SCDMA alliance sought to advance the standard and develop new products, and new firms entering the alliance were those with the potential to do that. It should be pointed out that within the overall TD-SCDMA alliance network, there were many sub-alliances formed by international and domestic equipment manufacturers; the sub-alliances were geared toward providing key elements and components in the TD-SCDMA system. The competitiveness of the TD-SCDMA solution was furthered by the many sub-alliances that were formed. The TD-SCDMA alliance network dramatically upped the innovation capabilities of the 3G industry based on TD-SCDMA standard in China. To view the network at the end of stage 4, see Appendix A, Figure 4.

Stage 5: Pre-Commercialization of TD-SCDMA (Feb, 2005~ Feb, 2006)

In this stage, TDIA continued to expand, enrolling another 5 firms on November 25, 2005 (Appendix B) and further strengthening system equipment manufacturers and terminal manufacturers. A software developer joined the alliance for the first time, pushing the value chain further along toward becoming a 3G service chain of TD-SCDMA.

Commercialization of the technology and related products were gradually realized. In April, 2005, TD-SCDMA/GSM bi-module handset chips, supporting 384kbit/s data transmission, were released to the market. “The TD-SCDMA International Summit 2005” was held in April, and 20 types of TD-SCDMA handsets from 14 domestic and international manufacturers were exhibited. In July, TD-SCDMA realized multi-media service functions for the first time. Test results for TD-SCDMA equipment and terminals were satisfactory. Both Dingqiao and Datang put forward commercial system products and the TD-SCDMA industry advanced to a near-commercialization stage. Most of the bottlenecks in TD-SCDMA commercialization had been solved.

The maturation of the TD-SCDMA industrial chain along with deeper cooperation and competition within the TD-SCDMA alliance notably advanced the industry. On November 6, 2005, TD-SCDMA entered the European market. Romania decided to construct the first international TD-SCDMA experiment network with technologies and equipment provided by Chinese companies. In January, 2006, “Exposition of Great Achievements on Technical Innovation” was held in China. TDIA, together with 20 companies, demonstrated an entire TD-SCDMA system with a base station, a core network, Node B, RNC, and peripheral products, including terminals, intelligent antenna and terminal testers. Many services based on TD-SCDMA technology, like videophones, VOD (Video on Demand), WAP (Wireless Application Protocol) applications as well as HSDPA (High-Speed Downlink Packet Access) were displayed and obtained widespread attention.

On January 20, 2006, MIIT officially promulgated the TD-SCDMA standard as China’s national standard for the telecom industry. The TD-SCDMA industrial chain further advanced with various new firms, especially terminal manufacturers and software developers, joining the alliance. Bi-module chips were designed and manufactured, allowing end users to switch between 2G and 3G services freely. TD-SCDMA technology became more and more attractive to end users. The TD-SCDMA experimental network in Romania demonstrated that TD-SCDMA was attractive to international users. The TD-SCDMA system had arrived at a full and final stage of industrialization. To view the network at the end of stage 5, see Appendix A, Figure 5.

Stage 6: Commercialization: Field and Systematic Integration Tests (Mar, 2006~Feb, 2007)

A commercialization test plan for TD-SCDMA was proposed in March, 2006. Telecom operators in China, including China Mobile, China Telecom and China Netcom, began to carry out field tests in five Chinese cities, including Beijing, Shanghai, Baoding, Qingdao and Xiamen. The testing process was divided into three phases: first, the building up of telecom networks (from February to June); then, the verification and validation of the networks (from June to October); and, finally thousands of users were chosen to test network stability and performance (after November). The test mainly focused on wireless network functions, operational maintenance and different network interconnections.

At this stage, telecom operators began to play leading roles in the inter-organizational industrial network. They bought instruments from various providers, including Huawei, ZTE, Xi'an Haitian Antenna, etc, in order to build up a 3G wireless network. Inter-organizational technology cooperation and transactions increased greatly, as tests involving the whole network and various aspects of technical interdependence, especially joint testing of various linkages in the system, increased. Datang Mobile focused on terminals and systematic network solutions, building a R&D center with ShanghaiBell-Alcatel. It also established "Hong Kong TD-SCDMA Application Development Center" with Hong Kong Wireless Technology Industry Association (WTIA) and the Hong Kong Wireless Development Center (HKWDC). As the main force of R&D and industrialization, Datang Mobile actively promoted the commercialization of TD-SCDMA by building a network of alliances with other members. To view the network at the end of stage 6, see Appendix A, Figure 6.

Stage 7: Commercialization: Customer Involvement Test (Mar, 2007 ~ Dec, 2007)

From March 2007, commercialization tests expanded to another five cities, including Tianjin, Shenyang, and Qinhuangdao which would be sites of the 2008 Olympic Games. The other two were Guangzhou and Shenzhen, sites of rapid expansion of the mobile communications industry. With these tests, large scale network stability and operability became key system measures.

Inter-organizational cooperation in technology development and business were hallmarks of this stage. Telecom operators bought equipment from manufacturers to build out a network infrastructure for 3G services which, in turn, greatly promoted business transactions among alliance members. For example, China Mobile selected infrastructure vendors for a rollout of its TD-SCDMA test network in eight cities under a tender amounting to $3.81 billion. ZTE, Alcatel-Lucent and Datang all became its providers. Huawei has also begun to play a new role in the industrial network, as experiment suppliers, not only R&D sponsors.

Meanwhile, China Mobile began to test more than 20 types of TD-SCDMA handsets, and finally purchased 60,000 TD-SCDMA mobile phones from terminal manufacturers like New Postcom, Lenovo, Hisense, ZTE, Samsung Electronics and LG Electronics. At the same time, Spreadtrum became the chip supplier to New Postcom and Lenovo, MTK to Hisense and ZTE, T3G to Samsung (Whalley et al., 2009).

In this stage, the industrialization of the TD-SCDMA standard expanded, operators built TD-SCDMA physical networks in another 5 cities as well as bought and tested more terminals supporting TD-SCDMA. The focus of technology turned to actual applications. Datang Mobile became the biggest terminal supplier to China Mobile, building a "TD-SCDMA Application Development Center" together with TDIA. To view the network at the end of stage 7, see Appendix A, Figure 7.

The process of 3G industry based on TD-SCDMA standard in China displayed an evolving network structure, as mentioned above. With the standard's development, more organizations joined the network and more alliances were created among them (Figure 2).

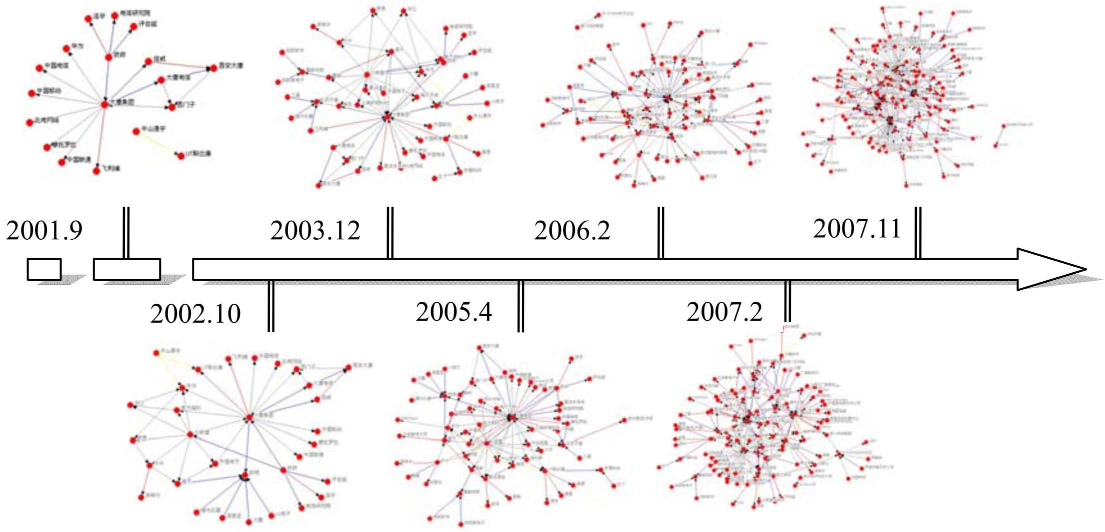

Figure 2 Evolution Process of the 3G industry based on TD-SCDMA Standard in China

TD-SCDMA based 3G Industry Today in China (Jan, 2008 ~Dec, 2010)

From July 2008 to February 2010, 30 new firms joined TDIA (Appendix B), including several international manufacturers and operators. Until then, TDIA members had reached 78. China Mobile subscribers using TD-SCDMA reached 7.69 million by March 31, 2010 (statistical data from China Mobile), and they were expected to reach 200 million in 3 years, according to Yanghua, TDIA secretary (April 22nd, 2010, Forum of TD-Chip and Terminal).

Terminal products, driven by China Mobile's "TD-SCDMA Terminal Joint R&D Fund," increased to over 300. Terminal prices decreased, making them more attractive to end users. Forty percent of the TD-SCDMA handsets were less than $300, and 20% less than $150. Handset diversity, lower prices and broadband wireless service availability contributed to the fast growth of TD-SCDMA end users. China Mobile, one of the largest telecom operators in the world, provided 3G services including VOD, Mobile TV, and video phone for the 2008 Beijing Olympic Games based on TD-SCDMA technologies and products.

The future evolution of TD-SCDMA will be TD-LTE (Long Term Evolution, 4G). 60% of China Mobile's short term investment will be dedicated to TD-LTE. China Mobile also requires that all TD-SCDMA equipment including TD-SCDMA base stations and platforms should support LTE.

INNOVATION OF TD-SCDMA BASED TELECOM INDUSTRY

In less than ten years, China's 3G industry has grown strong and prosperous. At the end of 2007, three standards, namely TD-SCDMA, WCDMA and CDMA2000, operate and compete together in the Chinese marketplace (Figure 3) in wireless broadband, video calling and mobile television applications. Three 3G standards coexist and compete at the same time. Some firms (the purple nodes in Figure 3) support all three standards and are interconnected with networks supporting each of the three standards. In particular, Datang, considered the father firm of TD-SCDMA, Huawei, and ZTE, the top two telecom equipment suppliers, have contributed greatly to the development of Chinese telecom industry.

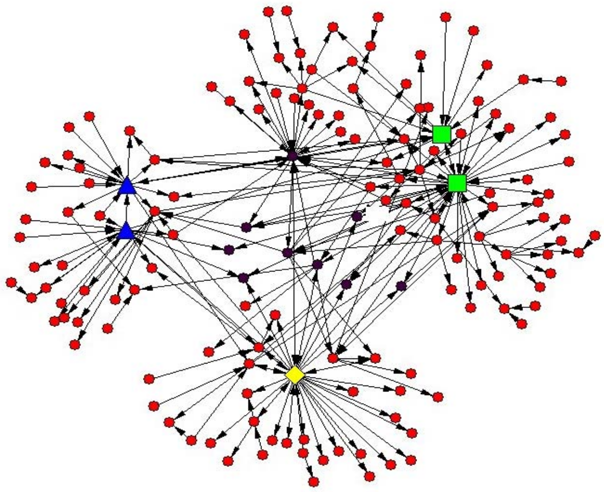

Figure 3 Three Pillars of 3G Telecom Industry Network at Stage 7 in China

Notes: (1) Green square, Datang and Siemens, support TD-SCDMA standard; Yellow diamond, Qualcomm, support CDMA2000; Blue triangle, Ericsson and Nokia, support WCDMA. (2) Tan, J. and Lin, R. H., 2006, TD-SCDMA, and the Strategic Selection in the Competition of Standards of Telecommunication Industry. Management World, 6, 71-84. (in Chinese)

ALLIANCE NETWORK AND INNOVATION

The development and commercialization of TD-SCDMA required coordination among heterogeneous actors who had specialized knowledge and resources. As Yoo et al. (2005) have proposed, interaction among key actors was the basis for understanding the development and evolution of complex technical systems. The survival, growth and development of the TD-SCDMA standard and related industry depend on the appearance of suitable alliance strategies, robust governance structures and governance mechanisms. In the next section, we will detail what they are and how they are important. Our aim is to generate theory from a case study (Yin, 1994) by making use of hermeneutic iterations between data and emerging theoretical constructs (Strauss and Corbin, 1990).

The Implementation and Evolution of the Alliance Strategies

The TD-SCDMA standard grew from a laboratory-based technology to a complete industry value chain offering a variety of commercialized services to customers. The evolutionary process was divided into 7 stages (see Table 1), and in each stage, new members (mostly playing different roles in the supply chain) joined the industry, making it more mature. Finally, after 7 stages of development, a complete industrial chain was formed (Figure 4).

Table 1 The Coverage of 3G Industry Chain based on TD-SCDMA Standard in Every Stage

Nodes / Stages	System equipment manufacturer	Intelligent antenna manufacturer	Testing instrument manufacturer	Chip manufacturer	Terminal manufacturer	Software application provider
Stage 1	●●					
Stage 2	●●●●●			●	●●●	
Stage 3	●●●●●	●		●●●●●	●●●●	
Stage 4	●●● ●●●●	●●	●●	●●●●●	●●●●●●	
Stage 5	●●●● ●●●●●	●●	●●	●●●●●	●●●● ●●●●	●
Stage 6	●●●● ●●●●●	●●●●●●	●●●●	●●● ●●●●	●●●●● ●●●●●	●●●●●
Stage 7	●●●●● ●●●●●●	●●●●●●	●●●●●	●●●●● ●●●●●	●●●●●● ●●●●●●	●●●●●

Note: (1) Siemens played an important role in TD-SCDMA, we included it in Table 1, although it did not join the TDIA; Soutec, as the first member of TDIA, went bankrupt in June, 2005, so we included it in the first 5 stages, not in stage 6 and 7. (2) Data of the first 5 stages, Tan, J. and Lin, R. H., 2006, TD-SCDMA, and the Strategic Selection in the Competition of Standards of Telecommunication Industry. Management World, 6, 71-84. (in Chinese)

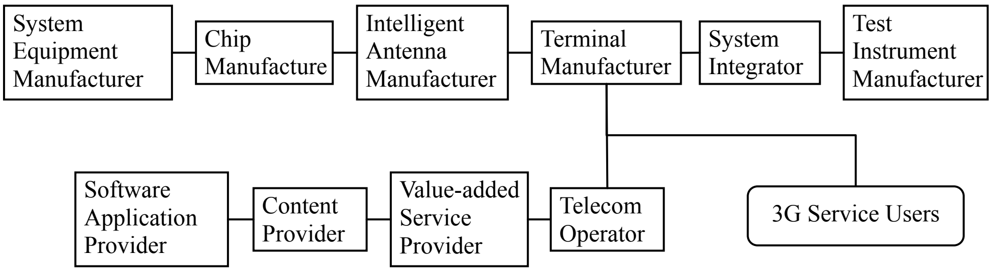

Figure 4 The 3G Industry Chain based on the TD-SCDMA Standard

In the development of the TD-SCDMA industry, TDIA and the entire industry expanded, incorporating more diverse members, encompassing more mature technologies and more complete supply chains, as seen in the development of the number and nature of technical alliances linking government regulators, enterprises and end users, shown in Table 2. Over time, the industry becomes more complete, complex and mature.

Table 2 Alliance Strategies and Maturity of the Industry Chain

Stage	Number of TDIA members	New type of alliance members	Coverage percentage of industry chain	Number of industry network members	Alliance form	Industrialization degree	Approval degree
Stage 1	2	Research institution, pioneer enterprises	16.7%	18	Enterprise research alliance	Academy standard, technical standard	Accepted by ITU, 3GPP

Stage 2	8	Domestic equipment enterprises	50%	32	Enterprise research alliance, cooperative enterprise industry alliance	Technical standard, laboratory technologies	The response of the domestic equipment firms, the ratification of the government
Stage 3	14	Joint venture between domestic firms and intl. companies	66.7%	45	Concession agreement, joint venture, industrialization base, joint lab, industry alliance	Industrialization standard and technologies	The government and international enterprises' ratification, the attention of the domestic telecom operator
Stage 4	21	Notable international enterprises alliance	83.3%	63	The sub-alliance of the total solution of the standard	Pre-commercial standard, technologies and products	The attention of the intl. telecom operators, the government's ratification, changing attitude of the intl. firms
Stage 5	26	Telecom operators	100%	69	The collaboration and competition within and outside the alliance and standard	National industrial standard, technologies and products	The ratification of the intl. telecom operators, domestic telecom operators participation in the test, the government's ratification
Stage 6	40	Software and application developers, Systematic integration and Value –added providers	100%	109	Jointly building testing network and commercialization	Commercialized Industry standard, technology, products and services	High involvement of telecom operators
Stage 7	48	End users and subscribers	100%	132	Alliance on network operation and marketing	De facto Industry standard and total solutions	Acceptance of the customers

Notes: Data of the first 5 stages, Tan, J. and Lin, R. H., 2006, TD-SCDMA, and the Strategic Selection in the Competition of Standards of Telecommunication Industry. Management World, 6, 71-84. (in Chinese)

Governance Structure of TD-SCDMA Alliance Network

1) The number, type of nodes and ties of TD-SCDMA alliance network

As the TD-SCDMA standard advanced, the number of alliance members supporting it grew. The growth of the TDIA is similar to the growth of the TD-SCDMA alliance network. In this section, we focus on the growth of the TDIA. There are 78 members in the TDIA until today, including system equipment manufacturers, intelligent antenna providers, testing instrument manufacturers, chip manufacturers, terminal manufacturers, software application developers, value-added service providers, telecom operators, and so on. The distribution of different types of members is shown in Table 3.

Table 3 Distribution of Members of TDIA

Member type	System equipment manufacturer	Intelligent antenna manufacturer	Testing instrument manufacturer	Chip manufacturer	Terminal manufacturer	Software application provider

Number	12	7	5	15	21	7
Member Type	Value-added service provider	System integrator	Content provider	Telecom operator		
Number	3	5	1	2		

The frequency and nature of inter-organizational cooperation increased with the evolution of a 3G industry based on the TD-SCDMA standard. Cooperation began with early R&D efforts, shared visions, joint testing and the signing of license agreement, to inter-investment and products providing. At the end of 2007, inter-organizational cooperation was divided into 9 types, based on the data collected, including *Collaborative Promotion*, *Purchase & Supply*, *Cooperative R&D*, *Shared Vision*, *Joint Test*, *Organizational Contacts*, *License Agreement*, *Investment*, and *Co-establishing Network*. The types are drawn from data collected on inter-organizational cooperation, as categorized in Table 4 below. Cooperation among organizations enhances the social capital of member firms, which is beneficial to the development of the3G industry.

Table 4 Types of Inter-organizational Cooperation Relationship

Style	Content
Collaborative Promotion	Working together to promote the technical standards, at the early stage of industry
Purchase & Supply	Long-term purchase between upstream and downstream firms in the industry chain
Cooperative R&D	Cooperating on R&D by co-establishing laboratories or joint R&D teams
Shared Vision	Having the common good expectation on TD-SCDMA development and showing the same intention to develop the TD-SCDMA standard
Joint Test	Cooperating to test the function and quality of telecom equipment, products or network
Organizational Contacts	Sharing the TDIA or other institutional membership related to TD-SCDMA standard
License Agreement	Sharing patents by signing agreements or other means
Investment	Investing through joint ventures or holding each others' company shares
Co-establishing Network	Building telecom network infrastructure together

2) Key nodes in the network in different stages

As described above, new enterprises entered the industry in 7 distinct stages. Initially there were two “Pioneer Firms”, Datang and Siemens, but a limited number of additional members were also very important for the development of the network, including Haitian Antenna, Spreadtrum, Huawei, and China Mobile. Datang was perhaps the most essential enterprise in the development of the industry. It proposed and advanced the TD-SCDMA technical standard; and acted as the advocate, leader and enabler of the development and commercialization processes that were crucial to industry development.

Siemens was the first international firm supporting Datang in advancing TD-SCDMA technology and funding. Haitian Antenna, focused on the R&D and manufacturing of antenna, is the only enterprise producing intelligent antenna in China and, in particular, it is the sole supplier of high-quality antennas for TD-SCDMA. Spreadtrum, a chip manufacturer, was also critical to the production of 3G cell phones. Huawei, whose scope of products covers chips, software, and terminals, played an increasingly important role in the industry. Last but not least, China Mobile, the operator of TD-SCDMA in China, was the enterprise most directly connected to end users; its vigorous participation in the TD-SCDMA industry made commercialization possible. All of these enterprises mentioned were key nodes in the evolution of the TD-SCDMA alliance network; their time, resources, knowledge, know-how, social capital and relationships were the basis for the development of TD-SCDMA.

3) Resources sharing platforms: TD-SCDMA Forum and TDIA

Funk (2002) argued that the openness of standardization committees was an important factor influencing the perceptions of potential partners. This appears to have been a major element influencing the rapid development of the 2G standard GSM. In the emergence of the TD-SCDMA standard, two institutions, TD-SCDMA Forum and TDIA, are thought to have played important roles.

TD-SCDMA Forum was an informal technical communications platform set up in 2000 by China Mobile, Datang, Huawei, Motorola and other four members. It now boasts about 400 members. Its stated goals are to explore industrialization, commercialization and internationalization processes affecting the TD-SCDMA standard and provide a mechanism for members of TD-SCDMA industry to communicate smoothly and integrate technical resources.

TDIA is a formal multilateral cooperation platform set up in 2002. Its members have grown from 8 to 78 till now. Alliance objectives include the integration and coordination of industrial resources, enabling TD-SCDMA firms to carry out effective dialogues with various levels of government, regulators and other stakeholders, enhance the fast and healthy development of the TD-SCDMA industry, and realize the application and commercialization of the TD-SCDMA standard in China and around the world. TDIA members are encouraged to freely share their resources and intellectual property with other members according to TDIA guidelines and regulations.

4) Role of Government and regulatory agencies

Tilson and Lyytinen (2006), based on a longitudinal case study of the transition to 3G of the US wireless industry, proposed that the regulatory regime set by government and institutions played a rather important role in the way wireless services were created and brought to market. Government was an important actor in the industrialization process of the TD-SCDMA standard as well, although it was not a formal member of the industry value chain.

The key contributions of government in the development of the TD-SCDMA standard include: (a) government provided crucial investments, including R&D grants, various subsidies and supportive policies in the commercialization of the TD-SCDMA standard; (b) Datang Telecom, the "Pioneer Firm" of TD-SCDMA, is a state-owned enterprise, and its operations are funded by the government. MII, MST, together with other government departments have invested a total of $120 million in Datang since the late 1990s; nearly 3,000 scientists and engineers across the country have been involved in Datang's operations (Yan, 2008).

Government's direct role may also be found in its policies and decision-making processes in support of the TD-SCDMA standard, including selection, determination and promotion of industry standards and the timing of 3G licensing. During a decade when the evolution of the TD-SCDMA standard was directly linked with Chinese national innovation system, TD-SCDMA along with CDMA2000 and WCDMA became 3G candidate standards in 2008. Finally, on Jan. 7, 2009, all of them became 3G national standards in China.

Governance Mechanisms of the TD-SCDMA Alliance Network

1) Common expectation and shared vision

China was not involved in the development of the 2G mobile communications technical standard. Recognizing this and the fast moving momentum of the communications industry, government, research institutions, telecom enterprises, and high-tech entrepreneurs converged on the opportunity of developing a 3G technical standard in China. They aimed to be favorably and advantageously situated for the coming 3G era. TD-SCDMA alliance members had confidence in the future of the TD-SCDMA standard and, hence, they collaborated to make the survival and growth of the alliance more possible. Their judgment was reasonable based on the size of China's market space (China is one of the biggest communication-developing countries), and the acceptance of TD-SCDMA as an international standard (it has been accepted by ITU and 3GPP).

2) TD-SCDMA Industry Alliance

As a formal cooperation platform, TDIA provides more opportunities for members to communicate and collaborate with each other than the informal TD-SCDMA Forum does. Under the motto of "Unity, Trust, Cooperation", TDIA members shared alliance resources, risk, and the TD-SCDMA brand. According to *The Rules of TD-SCDMA Alliance*, *Promoters Agreement of TD-SCDMA Alliance,* and *Patent Licensing Agreement of TD-SCDMA Alliance*, patents could be shared reasonably and effectively. Such agreements not only encouraged members to contribute resources for shared innovation, but also protected patents within the alliance and advanced the development of TDIA as a whole. As TDIA members grew from 7 to 78, diverse resources were integrated; market information, users and technology information were shared among them. TDIA became one of the most important mechanisms to promote the survival and growth of TD-SCDMA technical standard.

3) Support from the government

Based on government support and favorable policies, enterprises in China's telecom industry invested heavily in TD-SCDMA development. The effects of government support on the choice of telecom standards have been ever studied (West and Tan, 2003), and the success of the 2G mobile communication standard, GSM, has been attributed to the efforts of the EU to establish Europe-wide unified telecom standard (Glimstedt, 2001). In the development of the 3G telecom industry, Japanese government supported the development of 3G in Japan and the Korean government supported its national industry through the choice of 3G standards (Yoo et al., 2005). In the development of TD-SCDMA, government organizations provided different resource and favorable policies, as shown in Figure 5.

Table 5 The Role of Government

Roles	Resource	Support
• Integration of the development resources for the standard • Helping submit the standard to the ITU • Coordination of the different domestic standards • Allocation of the 155MHz un-symmetry frequency for the TD-SCDMA standard • Support MTnet field testing • Support TD-SCDMA international conference • R&D grant and fund for TD-SCDMA • Support from different governance agencies	R&D grant; National innovation project fund; Frequency resources; Policies; Time; Market chance;	Organization; Coordination; Communication; Policy making; Distribution of frequency; Grant of the licenses;

4) Mobility of the managers and professionals

Managers in different enterprises have different management knowledge and experience. The mobility of managers within an industry, especially among TDIA members, is an important motivator of industry development. For example, in November, 2004, Xiaobing Chang, the Vice Manager of China Telecom, became the president of China Union; Jianzhou Wang, the president of China Mobile, also worked in China Unicom; Caiji Zhen, the president of Datang Group, worked in MII as well as China Mobile; Huan Zhou, the president of Datang Telecom, held a part-time position as the Director of China Academy of Telecommunications Technology of MII; Daijun Zhang, who had been a project leader at Xinwei Communications and the general manager of product development of mobile terminals in Datang, is currently the CTO of Tianqi Technology.

Managers and other technical professionals are good carriers of information, knowledge and industry experience. Their mobility is an effective way to accelerate the flow of technical and managerial knowledge among alliance network members.

5) Accumulation of knowledge capital resulting from alliance network

Cooperation in the TD-SCDMA alliance network brought together diverse actors. Member firms had heterogeneous resources, such as R&D capacity, and company specific knowledge with respect to terminals, chips and software, etc. As diverse firms joined the alliance, the TD-SCDMA network accumulated more and more knowledge capital which could be deployed to promote the development of the network and provide 3G services to end users.

At the start, *shared vision* and *shared investment* were the main content of the alliance network but by the 6^{th} and 7^{th} stages, *Cooperative R&D*, *Purchase & Supply*, *Organizational Contacts* began to play important roles. The distribution and evolution of the 9 types of relationships, as mentioned above, matches the development processes of an industrial chain. However, the various sorts of relationships have different evolutionary characteristics. For example, the number of *Organizational Contacts* and *Investments* grew gradually, but the number of *Joint Tests* changed suddenly, as field testing of the TD-SCDMA standard only began in the 6th stage. Table 6 shows the co-evolution of the number and type of cooperation relationships (social capital) within the TD-SCDMA industry at different stages, indicating the importance of different sources of knowledge capital for the TD-SCDMA alliance network.

Table 6 Evolution Process of Inter-organizational Relations

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7

Collaborative Promotion	3	3	3	3	3	3	3
Purchase & Supply	1	2	2	2	6	9	37
Cooperative R&D	1	3	9	22	27	52	61
Shared Vision	7	7	8	8	9	17	33
Joint Test	0	0	0	0	0	14	18
Organizational Contacts	0	16	28	44	54	81	89
License Agreement	1	1	2	4	6	12	15
Investment	6	13	22	28	32	47	50
Co-establishing Network	1	1	1	1	1	4	4
Number of Ties	20	46	75	112	138	239	310

A Theoretical Model

During the 10-year development of the 3G industry in China, the alliance network played a pivotal role in accelerating innovation and commercialization of the TD-SCDMA standard. At first, industry actors, including firms listed in Table 3 and regulatory agencies, formed an alliance network. Under a shared vision, they interacted with each other in 9 different forms of collaboration (Table 6), and evolved and expanded along the way. The network helped firms and the industry as a whole to accumulate organizational and industrial social capital, which were potential resources for innovation.

Network organizations can effectively promote firm and industry innovation, but network structure alone cannot guarantee innovation performance. For that, network governance mechanisms are needed. For example, an industry vision helped member firms developed and shared common expectations. In addition, TDIA created mechanisms by which member firms could share technology and intellectual property. Professional meetings and conferences helped alliance members to communicate on solutions to common problems related to technological issues. The mobility of managers, engineers and professionals promoted knowledge flow among network members. Such mechanisms enhanced positive interactions around TD-SCDMA development, promoting an accumulation of knowledge, know-how and technology.

Because there are always issues of free riding and varying levels of risk tolerance in alliances and networks, a shared vision among members is critical. The role of TDIA was critical in these respects. Although the number of TDIA members has been keeping expanding, entrance into TDIA was limited according to strict criteria. This was called restrictive entrance by Jones et al. (1997). It was thought that shared vision and interactions among network members improved the basis of organizational trust. Government support was well balanced using a mix of regulatory principles and market mechanisms, such as R&D grants and regulatory policies to support firms in the industry. These helped the network to garner the visible and invisible resources that it needed, and also advanced commitment and trust among network members.

An accumulation of knowledge and social capital enlarges the likelihood of innovation and accelerates the speed with which innovation elements may be combined. Numbers of innovations rise and time-to-market is shortened. This may be why it took only ten years for the TD-SCDMA technical standard to be commercialized while the CDMA2000 and WCDMA standards took almost twenty years or more to do so. This may be explained in part by later mover or follower advantages (Perez and Soete, 1988; Amsden, 2001); however, given the detailed analysis of this case, we believe that network governance contributed greatly to the rapid development and success of TD-SCDMA. The 3G alliance network, based on the TD-SCDMA standard, produced more candidate innovative products for ITU and 3GPP technology selection, regulatory selection by China's MII, market selection by manufacturers, such as Motorola and Samsung, telecom operators, such as China Mobile, one of the largest telecom operator in the world, and, finally, end users. Processes of collaborative innovation and adaptive innovation (Lin, 2004) are shown in Figure 5.

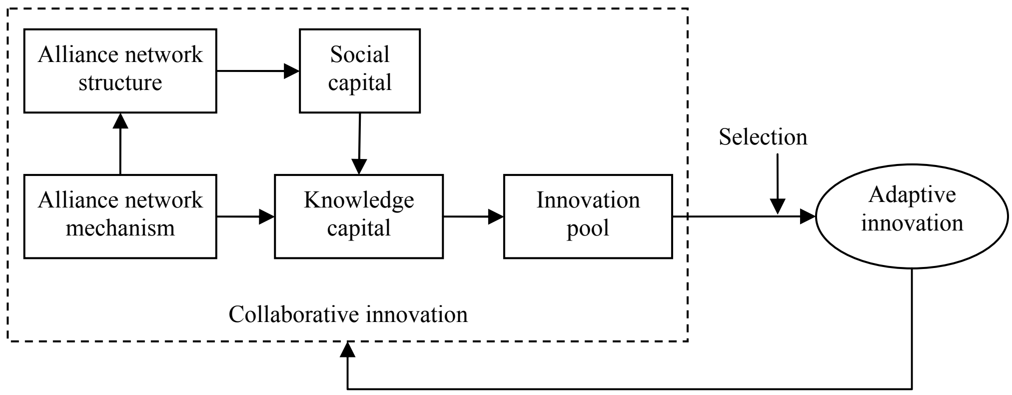

Figure 5 Processes of Alliance Governance and Collaborative Innovation in a High-tech Industry

CONCLUSIONS AND IMPLICATIONS

Conclusion and Implications for the Industry

Alliance strategies were pivotal and fully used during the commercialization of the TD-SCDMA technical standard. By using a strategy of widespread alliance formation, the strength of the TD-SCDMA standard and its industrial network grew steadily. The industry value chain developed and deepened as the alliance capabilities of the network strengthened. The successful innovation and diffusion of the TD-SCDMA standard and industry in China represent a collective achievement: numerous local and international organizations cooperated on building an alliance network which is characterized by positive feedback loops and learning.

The commercialization of the TD-SCDMA technical standard followed a typical high-tech industry life cycle model, as proposed by Eva Söderström (2004); the standard evolved by defining, developing and refining standards and through product development and commercialization. A standout feature of the development of the TD-SCDMA standard to date is the highly compressed nature of the evolutionary cycle; alliance strategies and collaborative innovations shortened the R&D, product commercialization, time-to-market cycles normally associated with high-tech industries.

The telecom industry, like many other high-tech industries, is an industry in which technologies are so complex that many different organizations, including government agencies, have to work together to provide goods and services to end users. In the case of the TD-SCDMA alliance network, members shared resources, conducted joint R&D, created knowledge and know-how, and fostered innovation up and down the industry chain. With an accumulation of knowledge capital and a furthering of the TD-SCDMA standard, organizations of many different kinds joined the industry. An effective governance structure promoted information exchange and sharing of knowledge, technology and know-how among network members. This led to an accumulation of social capital and TD-SCDMA based technical and industrial innovation. The cumulative and positive nature of network based collaboration contributed greatly to technical innovation.

Government was a central actor in the development of TD-SCDMA based 3G industry. Government actors at various levels took an important and leading part in the process, not only in terms of R&D funding but also in creating favorable policies to promote and advance the industry. This is consistent with the literature on the role of government in emerging economies.

Limitations and Further Research

Our study has several limitations. First, development of the TD-SCDMA standard successfully "locked in" industry collaborators, through a network of alliances, and forms an integrated industry chain. TD-SCDMA standard was recently adopted as a national industrial standard, and the ongoing evolution of the TD-SCDMA standard, as a national standard, for operators and end users should be further studied. Second, we focus exclusively on the development of the TD-SCDMA technical standard. However, there are three standards in China's telecom market; competition and interaction among them should be studied. This will help clarify the emergence of the TD-SCDMA standard in China's developing wireless telecom industry.

Our study provides several avenues for future research. First, alliance networks that adopted TD-SCDMA, CDMA2000 and WCDMA standards have different starting points, different technical trajectories, different levels of industry value chain development, and different evolutionary tracks and tactics. The structural and dynamic attributes of these three networks need to be further studied to uncover the relationships among network structure, network attributes and network performance. The impact of governance structures and mechanisms on performance and innovation should be studied by comparing evolutionary processes of the three networks.

Second, for a telecom industry with network effects, collaborative innovation is a highly effective way to promote industry development. More data on industry network effects should be collected in the future and, especially, the effects of network structure and behavior on innovation need to be closely examined. Simulation methods may be important in studying network dynamics. Finally, another issue for future research is to examine and analyze how specific network structures and properties, such as centrality, structural holes, network density, and average path length, affect firm and industry innovation performance.

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REFERENCE

[1] Allison, G. 1971, *Essence of Decision*, Boston Little, Brown.

[2] Amsden, A. 2001. *The Rise of "the Rest": Challenges to the West from Late-industrializing Economies*, Oxford: Oxford University Press.

[3] Anderson,P., 1983, Decision Making by Objection and the Cuban Missile Crisis, *Administrative Science Quarterly*, 28, pp.201-222

[4] Arndt, O. and Sternberg, R., 2000, Do Manufacturing Firms Profit from Intraregional Innovation Linkages? An Empirical Based Answer. *European Planning Studies*, 8(4), pp.465-485.

[5] Baum, J. A., C., Shipolov, A. V., and Rowley, T. J., 2003. Where do Small Worlds Come From? *Industrial and Corporate Change*, 12, pp.697-725.

[6] Brito, C. M., 2001, Towards an Institutional Theory of the Dynamics of Industrial Networks. *Journal of Business & Industry Marketing*, 16(3), pp.150-166.

[7] Cullen, J. B., Johnson, J. L. and Sakano, T., 2000, Social Ties and Foreign Market Entry, *Journal of International Business Studies*, 31(3), pp.443-469.

[8] Eisenhardt, K. M., 1989, Building Theories from Case Study Research, *Academy of Management Review*, 14(4), pp.532-550.

[9] Eva Söderström, 2004, *Formulating a General Standards Life Cycle*. CAiSE 2004: 263-275

[10] Freeman, C., 1991, Networks of Innovators: A Synthesis of Research Issues, *Research Policy*, 20(5), pp.499-514.

[11] Funk, J. L., 2002, *Global Competition between and within Standards: The Case of Mobile Phones*. New York, Palgrave.

[12] Gersick, C., 1988, Time and Transition in Work Teams, Toward a New Model of Group Development, *Academy of Management Journal*, 31, pp.9-41

[13] Glimstedt, H., 2001, Competitive Dynamics of Technological Standardization: The Case of Third Generation Cellular Communications, *Industry and Innovation*, 8(1), pp. 49-78.

[14] Gulati, R. and Westphal, J. D., 1999, Cooperative or Controlling? The Effects of CEO-board Relations and the Content of Interlocks on the Formation of Joint Ventures, *Administrative Science Quarterly*, 44, pp.473-503.

[15] Gulati, R., 1995, Social Structure and Alliance Formation Patterns: A Longitudinal Analysis, *Administrative Science Quarterly*, 40, pp.619-652.

[16] Haug, T., 2002, A Commentary on Standardization Practices: Lessons from the NMT and GSM Mobile Telephone Standards Histories, *Telecommunications Policy*, 26(3-4), 101-107.

[17] Imai, K. and Baba, Y., 1989, *Systemic Innovation and Cross-Border Networks: Transcending Markets and Hierarchies*. OECD Conference on Science, Technology and Economic Growth, Paris.

[18] Jones, C., Hesterly, W. S. and Borgatti, S. P., 1997, A General Theory of Network Governance: Exchange Conditions and Social Mechanisms, *The Academy of Management Review*, 22(4), pp.911-945.

[19] Joshi, A., 2006, The Influence of Organizational Demography on the External Networking Behavior of Teams, *Academy of Management Review*, 31(3), pp.583-595.

[20] Kidder, T., 1982, *Soul of a New Machine*, New York Avon

[21] Kogut, B., and Walker, G., 2001, The Small World of Germany and The Duration of National Networks, *American Sociological Review*, 66, pp.317-335.

[22] Morris, R. C., and Ferguson C. H., 1993, How Architecture Wins Technology Wars? *Harvard Business Review*, 71(3), pp.160, 163, 166-170.
[23] Perez, C. and Soete, L., 1988, 'Catching up in Technology and Windows of Opportunity', In G. Dosi, C.Freeman, R Nelson, G.Silverberg and L. Soete, (ed.), Technical Change and Economic Theory. London and New York: Pinter Publishers, 458-479.
[24] Pinfield, L., 1986, A Field Evaluation of Perspectives on Organizational Decision Making, *Administrative Science Quarterly*, 31, pp.365-388
[25] Rodan, S., and Galunic, C., 2004, More than Network Structure: How Knowledge Heterogeneity Influences Managerial Performance and Innovativeness, *Strategic Management Journal*, 25, pp.541-562.
[26] Ryan, P., 2005. *The Future of the ITU and its Standard-Setting Functions in Spectrum Management*. Standards Edge: Future Generation, Sherrie Bolin, ed., p.341, Sheridan Books.
[27] Skilling, M. A., and Phelps, C. C., 2007. Interfirm Collaboration Networks: The Impact of Large-Scale Network Structure on Firm Innovation, *Management Science*, 53(7), pp.1113-1126.
[28] Strauss, A., and Corbin, J., 1990, *Basics of Qualitative Research: Grounded Theory Procedure and Techniques*. Sage, Newsbury Park.
[29] Suarez, F., 2004, Battles for Technological Dominance: An Integrative Framework, *Research Policy*, 33, pp.271-286
[30] Tan, J. and Tan, D., 2005, Environment-strategy Coevolution and Coalignment: A Staged-model of Chinese SOEs under Transition, *Strategic Management Journal*, 26(6), pp.141-157.
[31] Tan, Z. X., 2002, Product Cycle Theory and Telecommunication Industry-Foreign Direct Investment, Government Policy, and Indigenous Manufacturing in China, *Telecommunications Policy*, 26, pp.17-30.
[32] Tilson, D., and Lyytinen, K., 2006, The 3G Transition: Change in the US Wireless Industry, *Telecommunication Policy*, 30, pp.569-586.
[33] Uzzi, B., 1996, The Sources and Consequences of Embeddedness for the Economic Performance of Organizations: The Network Effect, *American Sociological Review*, 61(4), pp.674-698.
[34] Van De Ven, A. H., 2005, Running in Packs to Develop Knowledge-Intensive Technologies, *MIS Quarterly*, 29(2), pp.368-378.
[35] West J., and Tan J., 2003a, Qualcomm in China (A), *Asian Case Research Journal*, 6(2), pp.5-99.
[36] West J., and Tan J., 2003b, Qualcomm in China (B), *Asian Case Research Journal*, 6(2), pp.101-128.
[37] Whalley, J., Zhou, Weimin, and An Xiaopeng, 2009, *Chinese Experience with Global 3G Standard-Setting, Cesifo Working Paper*, No.2537, Category 5: Fiscal Policy, Macroeconomics and Growth, February.
[38] Whittaker, E. and Bower, D. J., 1994, A Shift to External Alliances for Product Development in the Pharmaceutical Industry, *R&D Management*, 24, pp.249-259.
[39] Xu, Y., and Gong, M., 2003, National Innovation System and Its Implications for 3G Development in China, *Communications & Strategies*, 52, 155-174.
[40] Yan, H., 2008, The 3G Standards Setting Strategy and Indigenous Innovation Policy in China:

Is TD-SCDMA a Flagship? Danish Research Unit for Industrial Dynamics, Working Paper.

[41] Yan, X. and Pitt, D., 2002, *Chinese Telecommunications Policy*. Norwood, MA: Artech House Inc.

[42] Yin. R. K., 1994, *Case Study Research: Design and Methods*. Sage, Thousand Oaks.

[43] Yoo, Y. J., Lyytinen, K. and Yang, H. D., 2005, The Role of Standards in Innovation and Diffusion of Broadband Mobile Services: The Case of South Korea, *Journal of Strategic Information Systems*, 14, 323-353.

[44] Zhang, B., 2001, Assessing the WTO Agreements on China's Telecommunications Regulatory Reform and Industrial Liberalization, *Telecommunications Policy*, 25, pp.461-483.

[45] Zhu, H. B., 2001, The Impact of Industrialization Policy on Telecommunications, the Deregulation Process and Foreign Financing: China's Case, *Communications & Strategies*, 41, pp.37-61.

[46] (In Chinese) Lin, R. H., 2004, *Network Organization and Fast Growth of Enterprises*, Nankai University Press. Tianjin.

[47] (In Chinese) Tan, J. and Lin, R. H., 2006, TD-SCDMA. And the Strategic Selection in the Competition of Standards of Telecommunication Industry, *Management World*, 6, pp.71-84.

APPENDIX A

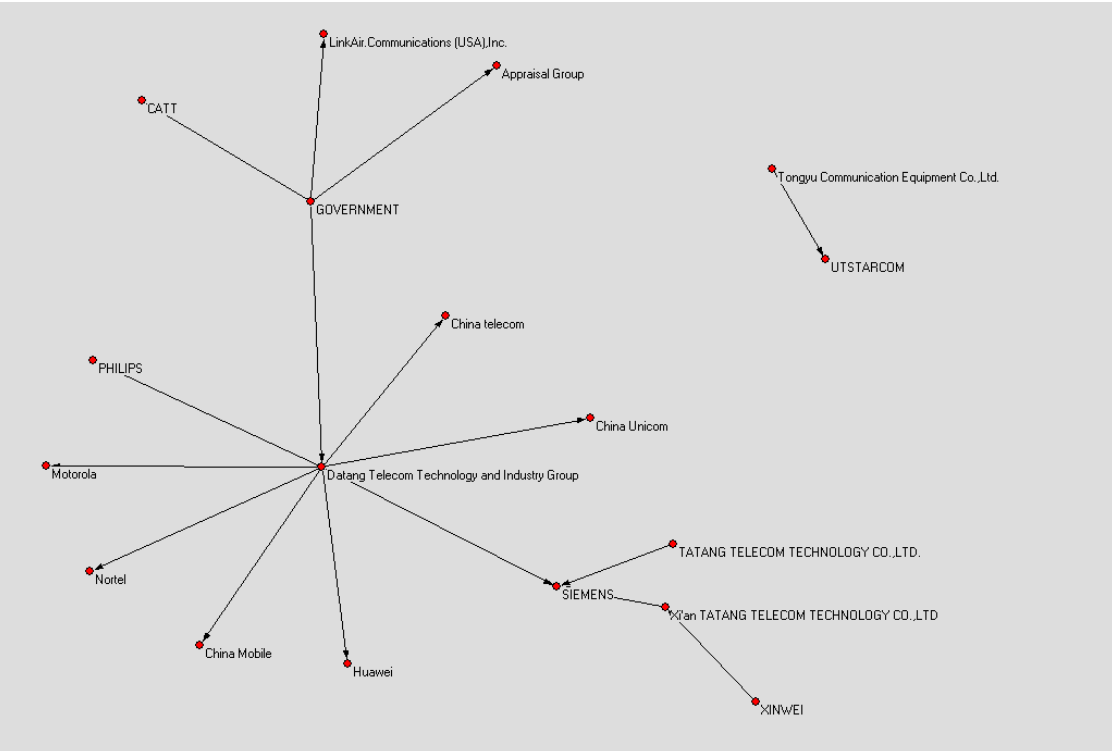

Figure 1 Network Structure at the End of Stage 1

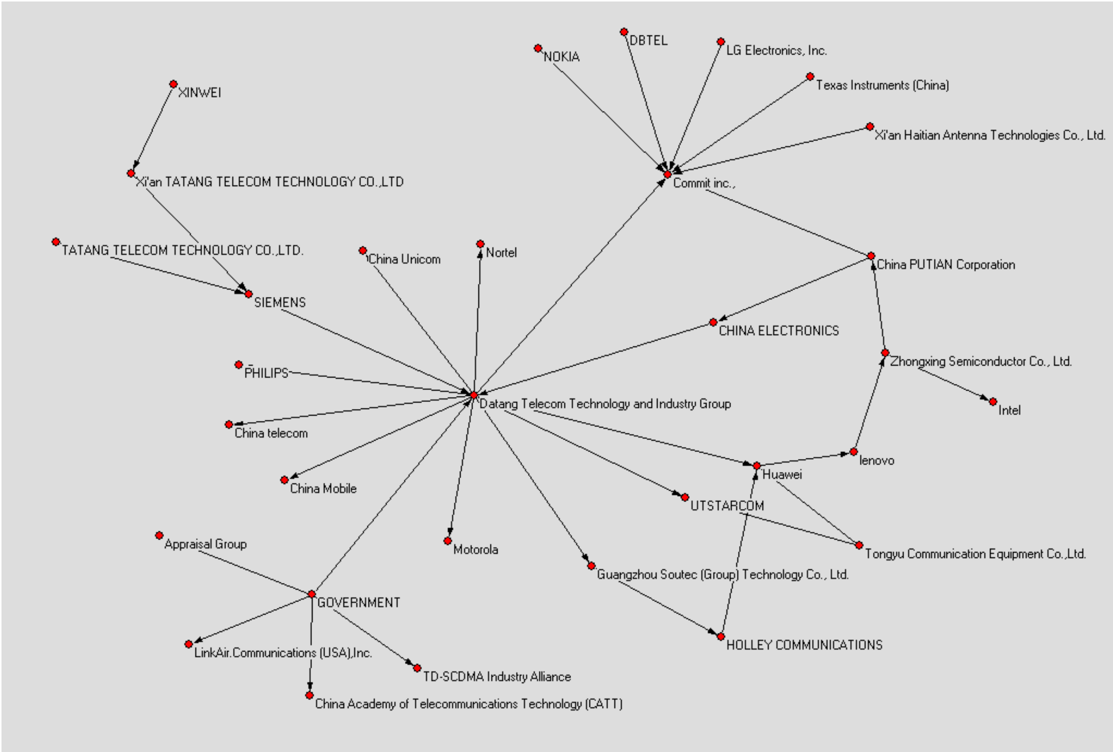

Figure 2 Network Structure at the End of Stage 2

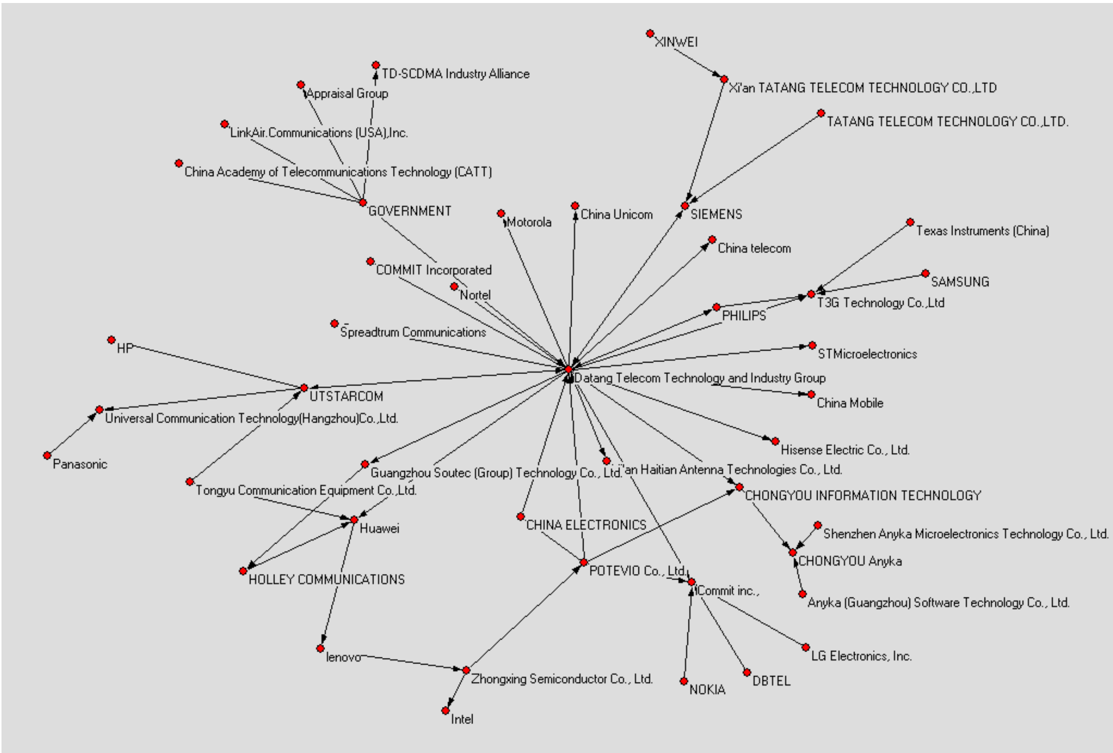

Figure 3 Network Structure at the End of Stage 3

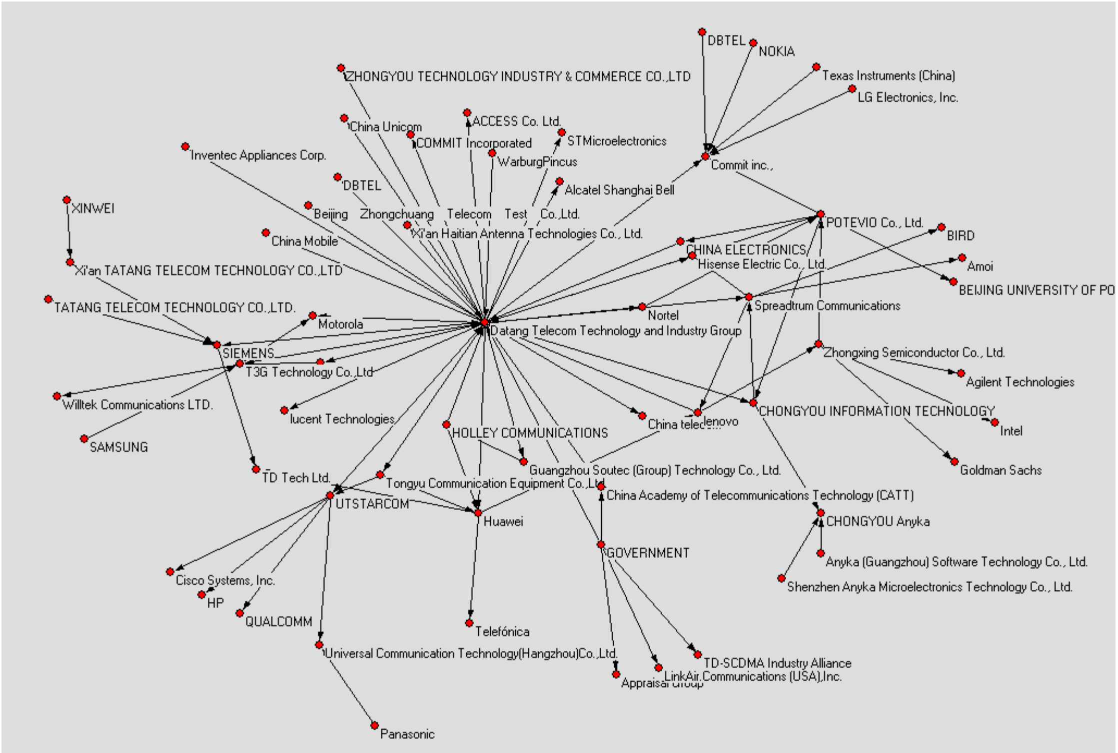

Figure 4 Network Structure at the End of Stage 4

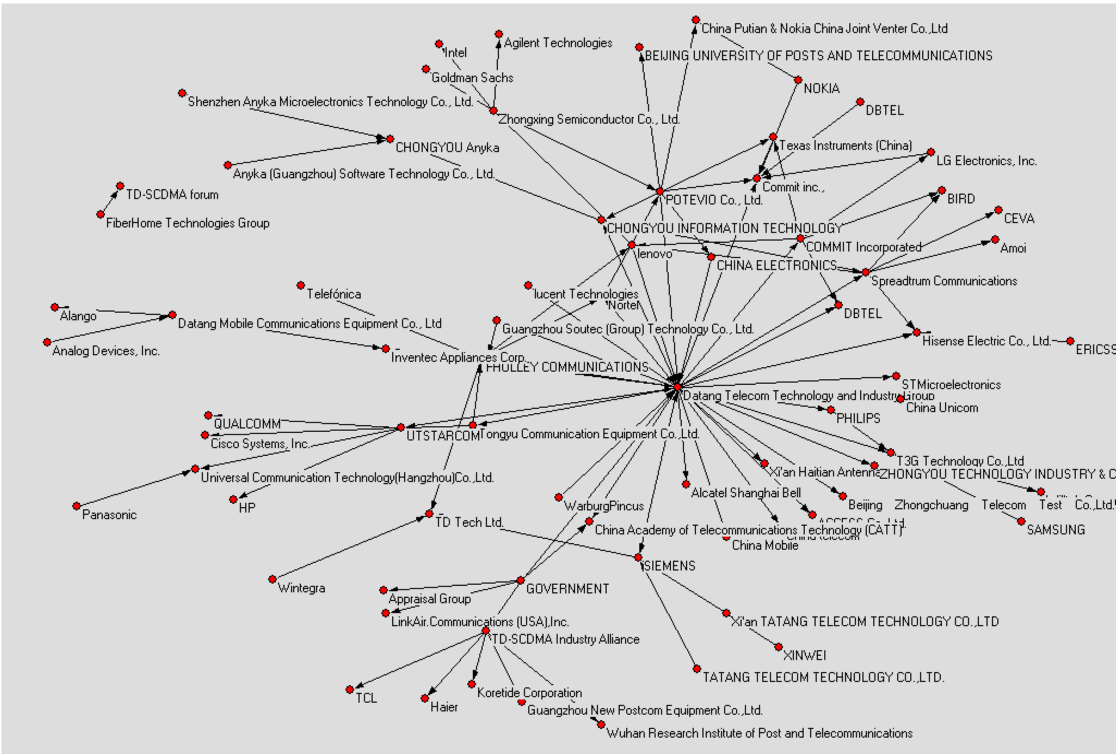

Figure 5 Network Structure at the End of Stage 5

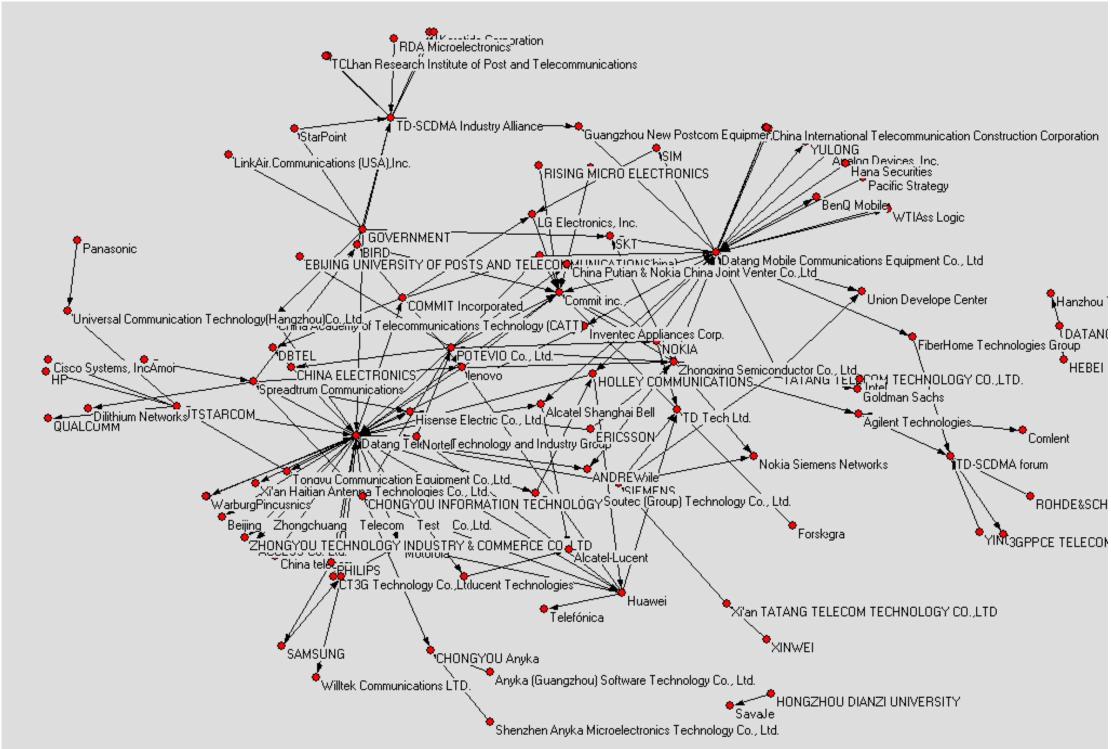

Figure 6 Network Structure at the End of Stage 6

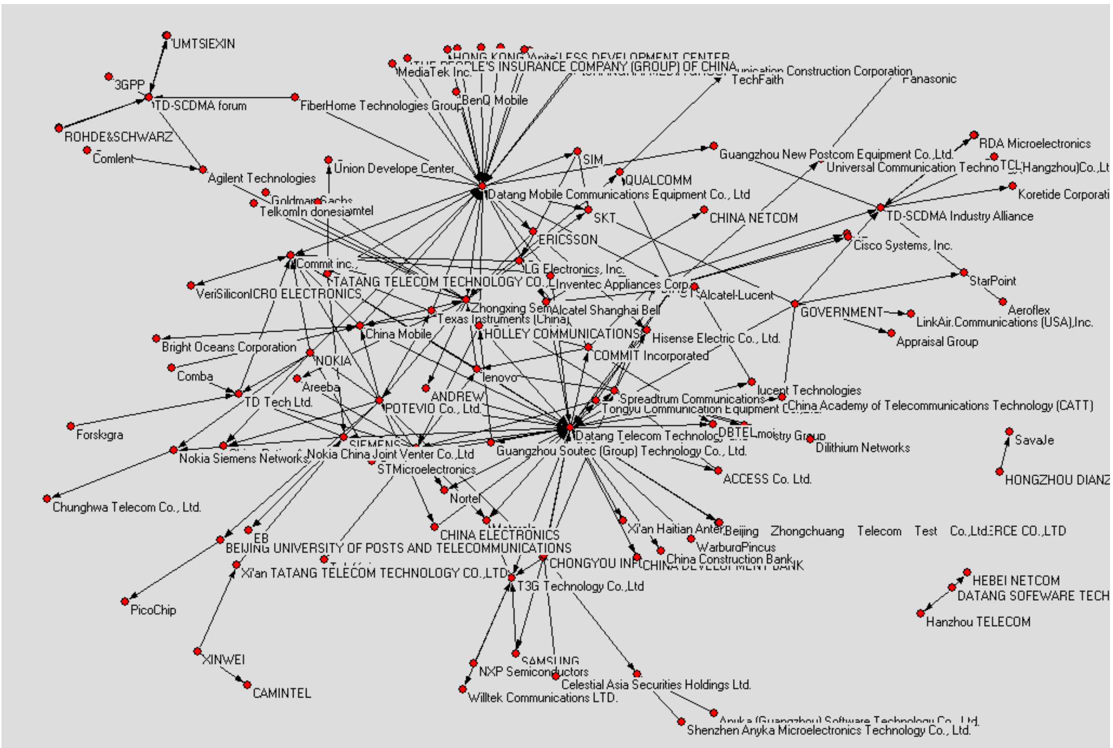

Figure 7 Network Structure at the End of Stage 7

APPENDIX B: Members of TD-SCDMA Alliance

Time	Number of Entrants	Names of Entrants
October, 2002	8	CEC (CM), Datang Telecommunication (SEM), Holley (TM), Huawei (SEM, TM), Lenovo (TM), Potevio (SEM), SouTec (TM), ZTE (SEM, TM)
December, 2003	6	Chongyou (CM), Commit (CM), Hisense (CM), Spreadtrum (CM), T3G (TM, CM), Xi'an Haitian Antenna (IAM)
April, 2005	7	DBTEL (TM), ENVADA (TM), Shanghai Bell-Alcatel (SEM, TM, SI), Tongyu Communication (TAM), UTStarcom (SEM), ZCTT (TIM), Zhongyou Science and Technology (TIM)
November, 2005	5	Kortide Corporation (SAP), New Postcom Equipment (SEM), Qingdao Haier Telecommunication (TM), TCL Group (TM), Wuhan Research Institute (SEM)
December, 2005	-1	SouTec (bankrupt)
July, 2006	4	Andrew China Telecom Equipment (IAM), Beijing StarPoint Telecom Software (TIM), Comba Telecom Technology (SAP), Shanghai Comlent Communication (CM)
November, 2006	11	Beijing ACEA Achieve Telecom Technology (SAP), Bright Oceans Telecom (SAP), LONGCHEER (SAP), Ningbo Bird (TM), NRIET (IAM), Shanghai RDA Microelectronics (CM), Shanghai SIM Technology (IAM), Shenzhen CFC Network Technology (SAP), Shenzhen Mobi Antenna Technologies (IAM), Shenzhen Yulong Computer Telecommunication Scientific (TM), The 40th Institute of China Electronic Technology Group (TIM)
June, 2007	8	Beijing Rising Technology (SEM), Flextronics China (TM), Fujian Youke Telecom Technology (SEM), Guangzhou Jinpeng Group (TM), Rising Micro Electronics (CM), Shanghai BenQ (TIM, TM), Shenzhen GrenTech (CM), Wuhan Fingu Electronic Technology (CM)
July, 2008	10	Beijing Creative Century Information Technology (SI), China Mobile (TO), Fujian Vtion Technology (TM), Hangzhou EB Information Technology (VSP), MediaTek (CM), NTS Technology (CM), PTAC (VSP), Shanghai Digimoc Telecom Technology (SEM), WINGTECH Group (TM), Wuhan Dopod Communication (TM)
June, 2009	6	AST Wireless Corporation (CM), Beijing TIMI Technologies (SI), Beijing PicoChip (CM), Borqs (SAP), Dalian Hua Chang (TM), Gionee Communication Equipment (TM)
July, 2009 to February, 2010	7	Beijing InnoFidei Technology Limited (CM), Beijing Tianyu Communication Equipment (TM), Dingli Communications (SAP), Ningbo Junper Communication Technology (SI), Sunwave Communications (SI), Wuhan Tianyu Information Industry (TM), Zhangjiagang Free Trade Zone Guoxin Communications (IAM)
February, 2010	7	Jiangsu Ronglian Technology (SEM), NetAfrique (TO), Samsung Electronics (TM), Shenzhen Tat Fook Technology (TM), Shenzhen Winhap Communications (SI), SK Telecom (CP), STELCOM Corporation (VSP)
Total Number	78	

Notes: System Equipment Manufacturer (SEM), Intelligent Antenna Manufacturer (IAM), Testing Instrument Manufacturer (TIM), Chip Manufacturer (CM), Terminal Manufacturer (TM), Software Application Provider (SAP), Value-added Service Provider (VSP), System Integrator (SI), Content Provider (CP), Telecom Operator (TO).