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Disruptive innovation and technology ecosystem: The evolution of the intercohesive public–private collaboration network in Chinese telecommunication industry

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ABSTRACT

Recent events involving Chinese technology firm Huawei and its role in the global 5th Generation (5G) telecommunication standard, as well as the role of the Chinese government in shaping the technology competition, have pushed the issue of public–private collaboration to the headline. To offer improved understanding about this issue of profound implication for research and practice, we trace the trajectory of a previous public–private collaboration and investigates the disruption and restructure of a technology ecosystem. The standardization of China's TD-SCDMA technology reveals that (1) a network has a more centralized structure at its inception; (2) intercohesion increases and structural folds facilitate knowledge generation and disruptive innovation in the orchestration phase; (3) in the embedded phase, the public institutions' status generally remained stable. Essentially, the government empowers various institutions to form a strategizing group, and leads this group across the disruption and reconfiguration of the industrial network.

1. Introduction

Novel forms of government engagement and public–private collaboration are increasingly becoming a commonplace to promote innovation, boost industry competitiveness, and/or provide public goods or services (Levén et al., 2014). Governments in emerging economies, in particular, often have to play a strong "visible hand" when domestic firms are reluctant to invest in technologies that can potentially disrupt the existing technology ecosystem (Wareham et al., 2014) and received retaliation from powerful multinational corporations that control the ecosystem (Back et al., 2014). The literature has identified the roles of governments in promoting technology innovation, e.g., providing initial conditions (Kshetri et al., 2011), organizing industrial networks and social capital (Xia, 2012), and empowering institutional intermediaries (Armanios et al., 2017). However, empirical results have been mixed, with some arguing that the government's long-term orientation will foster innovation, and others questioning its capability to cultivate innovation (Jia et al., 2019).

Despite the above theoretical advancements, however, the insights as recorded in the existing literature cannot adequately explain how the government of China, now the world's second biggest economy, helps domestic industries achieve breakthroughs in

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disrupting the existing technology ecosystems controlled by multinational corporations. The Chinese government presents an extreme case where the government can play a much more powerful and more involved strategizing role in disrupting technology ecosystems than what the literature prescribes, with profound impacts on industry evolution and competitive advantage (Genin et al., 2020). However, the role of the government has rarely been examined in the existing literature on disruptive innovation (for exceptions, see Dolfsma and Seo, 2013). Ruan et al. (2014) used a case study and qualitative evidences of the electric bike industry in China to show how the government shaped the development trajectory of the disruptive innovation. Yet little is known about the government's role in the industry network and how an industry network/ecosystem is structured to foster disruptive innovation.

We posit that a social network perspective adds critical value in examining the government's role. Scholars have started examining the critical roles of government in encouraging public–private collaboration in innovation and growth and the subsequent development of inter-organizational networks (Lazzarini, 2015; McDermott et al., 2009; Musacchio et al., 2015; Vedres and Stark, 2010). The public–private collaboration constitutes a network of independent but interconnected agents (Tan and Tan, 2017), and the government should be treated as a critical agent as it can act as a facilitator and a coordinator of the formation of public–private collaboration network (Giuliani, 2013; McDermott et al., 2009; McDonnell, 2017; Vedres and Stark, 2010). In particular, it has been found that the government is capable of contributing to the success of the public–private network by orchestrating collaboration and creating a cohesive network (e.g., Giuliani, 2013), or playing a brokerage role to facilitate knowledge exchange and recombination (e.g., Corredoira and McDermott, 2014). More importantly, prior research has suggested that certain network structure can foster a creative disruption in entrepreneurial activities (Vedres and Stark, 2010). This leads to the following question: *from a network perspective, how do a "visible and strong hand" of a state and self-organization of a market system co-exist and co-evolve in promoting innovations that disrupt the existing technology ecosystem in China*?

To address this research question, we conducted an exploratory social network analysis of China's 3G telecommunication technology (i.e., TD-SCDMA, Time Division Synchronous Code Division Multiple Access) standard-setting alliance network from its inception in 1997 to deployment in 2009. Although the industry has advanced rapidly to a large-scale deployment of 5G network now, the transition from 2G to 3G back then was more than a technology upgrade. It was a disruption to the industry ecosystem as it required a reconstruction of the industry's value network and the creation of a new market (Zhang and Liang, 2011). As prior research has rarely taken a network approach to investigate the Chinese telecommunication industry which, paradoxically, is an industry of a network nature (Economides, 1996; Leiponen, 2008), our study aims to examine a variety of structural features in the network of public–private institutions, and the roles played by the government and government support institutions (GSIs) that correspond to their network positions. Building upon the existing literature's recognition of the government's role in encouraging cohesion or brokerage in a network, we posit that an "intercohesive" network of public–private institutions with features of both cohesion and brokerage enhances innovation and disrupts status quo. The social network literature has acknowledged that network structure can be composed of overlapping cohesive groups (Moody and White, 2003). Intercohesion refers to mutual participation in multiple cohesive groups, and the overlap between cohesive groups are defined as a distinctive network position – structural folds (Vedres and Stark, 2010). Organizations at the intersection of cohesive groups (i.e., structural folds) have familiar access to diverse resources, enabling resource recombination and knowledge generation, as opposed to merely importing ideas or information.

Taking a coevolutionary approach (Tan and Tan, 2005), our case study uses quantitative network data and qualitative evidences to demonstrate in-depth analysis of how the Chinese government plays multiple and evolving roles with a long-term engagement in the disruption and construction of intercohesive industry networks to achieve long-term goals of establishing global technological standard over time. The case study reveals that (1) a network initiated by the government has a more centralized structure at its inception; (2) as the government-initiated network evolves into a government-orchestrated process, intercohesion increases and structural folds facilitate knowledge generation; (3) as the network evolves into an embedded structure, the government and GSIs generally maintained their status during the transformation. Overall, the government acts as a strategist with multi-roles, empowers and sponsors various GSIs to form a strategizing group, and leads this group throughout the disruption of industry ecosystem and the network transformation.

2. Theoretical background

2.1. Social network analysis of public–private collaborations on innovation

It has been widely acknowledged that governmental action can be devised to foster firms and industries. The majority of prior research in public policy has examined how the government shovels a "big push" by designing governmental policies to promote coordinated investments and public–private collaborations (Lazzarini, 2015; Tan, 2006; Tan and Lin, 2006). This line of research calls for a social network analysis of the government's role in industry network construction and evolution, as well as the interaction of public and private institutions over time. A society contains a plethora of public and private institutions, and social network analysis has been applied to examine how structural embeddedness affects entrepreneurial activities as well as performance (Salancik, 1995). In particular, some network positions such as brokerage, structural holes (Ahuja, 2000; Burt, 1992) and positions with high-centrality (Brass, 1984; Krackhardt, 1990) are found to be associated with power, influence and/or competitive advantage. These network positions are argued to provide connectivity to diverse ideas and information. Several recent studies on public–private institutions have suggested that the government and GSIs' capability to function as coordinators or facilitators is attributed to their bridging network positions with cross-cutting ties between different social and producer communities (McDermott et al., 2009). More broadly, public–private interaction and collaboration are embedded in a network of multi-layer and multi-actor relationships (Kivleniece and Quelin, 2012). By changing industry policies and building institutions, the government can alter network stability, reproduction, and reconstitution (Tan, 2006).

Such a network perspective is critical in explaining the disruptive development of the Chinese 3G telecommunications industry. Prior research has examined the Chinese telecommunications industry from various perspectives, such as the institutional approach of the government's support of the 3G standards (Kshetri et al., 2011), the intrinsic mechanisms of market behaviors (Xia, 2012), and the strategic choices of partnerships between domestic and foreign firms in the 3G market (Soh and Yu, 2010). However, to the best of our knowledge, none of them has untangled the features of the industry's network structure to examine the disruptive nature of TD-SCDMA technology development. Although it may not fit the original concept of disruptive innovation defined by Christensen (for comprehensive reviews, see Danneels, 2004; Yu and Hang, 2010), TD-SCDMA was disruptive in nature as it held the potential of disrupting the incumbent ecosystem by establishing its own. The incumbent firms, either domestic ones in China or multinational corporations, had no incentives to support but motives to sabotage the emergence of TD-SCDMA. The initiators of TD-SCDMA faced the same disruptors' dilemma, i.e., the risk of retaliation from the incumbents from whom they need support (Ansari et al., 2016). The Chinese government played a key role in helping TD-SCDMA solve the disruptor's dilemma. By occupying privileged network positions, the government and GSIs reconstructed and managed the network, and recombined resources to form a new business ecosystem.

2.2. Intercohesion and structural folds

The social network theorizations of the government's roles reflect either the logic of brokerage and connectivity with diversity, or the logic of cohesion or closure that provides a basis for trust, close familiarity, and means for coordination. For instance, Giuliani (2013) studied a wine cluster in Chile and found that cohesion effects drove the formation of new knowledge ties and were beneficial in stabilizing network relationships over time. Others have examined how public policy has shaped institutional framework and promoted the agglomeration of technology firms in Zhongguancun Science Park in Beijing (Tan, 2006) and bicycle manufacturing firms in Tianjin (Tan and Tan, 2017). Previous work assumes that the logic of brokerage and that of cohesion cannot coexist in a single network structure. However, scholars have recently challenged this assumption and developed a new concept, "intercohesion", as mutually interpenetrating, cohesive structures to account for both brokerage and cohesive effects (Vedres and Stark, 2010). Vedres and Stark (2010) suggest that a network community can be composed of multiple cohesive groups, and actors at the intersection of cohesive groups occupy a distinctive network position (i.e., structural fold). Such actors are multiple insiders who belong to more than one cohesive group, therefore have access to both familiarity and diversity, the combination of which are complementary and especially beneficial for innovation and new knowledge generation (Vedres and Stark, 2010). As opposed to channeling information flows through brokerage positions, intercohesion and structural folds provide opportunities for recombining diverse knowledge resources obtained through multiple cohesive groups, generate new knowledge through cohesive interactions within the cohesive group, and disrupt existing network configuration. Current research on public–private collaboration networks has not yet incorporated this concept in network and industry evolution analysis. Being a strategist with multi-roles entails the government's higher level and longer-term involvement in constructing and shaping the industry networks. We believe that the application of the concept of intercohesion can help us better understand the roles of a strong and dedicated government. This concept may potentially contribute to current literature by offering a new lens for investigating how the government as a strategist may structure and shape industry network to cultivate intercohesion and to render industry-level disruption.

3. Public–private collaboration in China's 3G technology

3.1. Industry background

China's homegrown 3G standard TD-SCDMA was initiated by the Chinese government in 1997, adopted three years later by the International Telecommunications Union (ITU) as one of the three international standards along with USA-backed CDMA2000 and Europe-backed WCDMA, and became a national standard for China's 3G market in 2006. China's wireless telecommunications industry had always been dominated by American and European standards (Soh and Yu, 2010). It not only had to pay billions of dollars in royalty fees, but also was largely locked out of high-value added activities such as standard setting (Yu and Tan, 2005). China's telecom industry struggled to upgrade, or risked becoming locked in a race to the bottom (Humphrey and Schmitz, 2000; Schmitz, 1998, 2004). Among various pathways of upgrading, setting a new technological standard is probably most challenging. The technological revolution from 2G to 3G offered China a rare opportunity to develop its own 3G standard. However, this ambition encountered substantial obstacles: weak enterprise R&D capabilities, relatively strong government research institutes with weak connections to industry, and a high degree of dependence on foreign technology (Suttmeier et al., 2006a, b). The Chinese industry as a whole lacked resources and capabilities to develop core technology, and this was coupled with resistance from existing standard providers who did not want to feed potential standard-setting competitors. Additionally, the existing business model – manufacturing with China's low-cost labor under foreign standards – remained highly profitable, subsequently reducing the interests of Chinese firms in risking building their own 3G standard. The entire business ecosystem made it essentially impossible for the telecom industry to develop a homegrown standard in the absence of an initial push from outside.

As the industry itself had neither the resources nor the incentive to collectively build its own standard, the Chinese government strategized to found the "initial condition" for a technology revolution (Suttmeier et al., 2006a, b). It established a 3G team with domestic R&D institutes and corporations in 1997, and orchestrated and facilitated a collaborative network with various institutions. Thereafter, both domestic and foreign firms joined in with a common agenda to promote the TD-SCDMA standard. A mixture of domestic and foreign firms is argued to generate positive knowledge spillovers in emerging markets (Li et al., 2012). In 2009, the standard-setting alliance grew to a complex network with 181 members. Various formal and informal inter-firm linkages emerged, and the network was geared to be coordinated by the government, GSIs and industry-level business associations. With an initiated “genesis”, the network became governed by an embedded process a decade later. Overall, the technological development and commercialization of TD-SCDMA was strategized by the Chinese government policy and collectively shaped by the participation of multinational and domestic firms (Tan and Lin, 2006). The old business ecosystem was disrupted and replaced. It is very unlikely that the TD-SCDMA technology would be born in the first place without the proactive intervention of the Chinese government. Later on, the Chinese government orchestrated network evolution in such a way that it spawned other organizations to form cohesive groups in the network and encouraged new forms of coordination to emerge, eventually rendering the network capable of self-organization. Taken together, the TD-SCDMA case provides us an ideal setting to examine how interorganizational network formed through government initiation brought about an industry disruption and technology development.

3.2. Data and methods

Up until 2009, nearly all firms in China’s telecom industry have participated in the process of TD-SCDMA standardization. We used multiple methods to collect and analyze the data. Starting from 2005, we conducted initial interviews with many executive managers in the TD-SCDMA industry, government officials, and leaders in business associations to obtain first-hand understanding of the TD-SCDMA standardization. Key members in this industry were also identified through the initial interviews. We then collected archives from two major business associations: TD-SCDMA Forum (TDF) and the TD-SCDMA Industry Alliance (TDIA), which also provided us a list of member organizations. Starting with this list, we collected information on alliance ties and additional organizations involved from reports in major trade journals and professional websites such as mscbsc.com, ccidnet.com, it.sohu.com, tech.sina.com.cn, and enet.com.cn, as well as archives of major TDIA members such as Datang Telecom Technology & Industry Group, ZTE Corporation and Huawei Technologies. We recorded all the alliance activities and organizations appeared in these sources until January 2009. In the study, the TD-SCDMA standard-setting network is composed of all TDIA members and key TDF members, as well as firms that have established joint ventures or other forms of alliances with these TDF and TDIA members. Additionally, since the Chinese government was directly and actively involved in the TD-SCDMA network, we “brought the state back” in the analysis plus a few GSIs (Evans et al., 1985), and included them as nodes in the network. There was a variety of ties recognized in our study, such as joint promotion, research alliance, patent licensing (see Table 2 for details). Each type of ties between two actors was recorded as one tie; multiple connections between two actors would result in multiple ties between these two nodes.

Based on data from multiple sources that have been confirmed by the key players in TD-SCDMA technology, we summarized the development of the TD-SCDMA technology during the 12-year period in Table 1: (1) the major technological and regulatory milestones, (2) types of new alliance members and forms of alliance, (3) degree of industrialization of the technology from academy technology to licensed and functional national 3G network, and (4) authorization agency that granted legitimacy to the technology (see Table 1). Table 2 presents the number and nature of ties among firms at different time during the evolution process (see Table 2).

To empirically examine the role of the government and GSIs in the construction and evolution of the industry network, we present selected measures of network characteristics as well as network indicators of key actors. We followed Stark and Vedres’ (2006) social sequential approach to analyze the network dynamics through identifying the analytical building blocks marked by major events. The sequence analysis allows us to study the historical processes in an eventual way. We calculate the network level and individual level indicators for each year with certain major events, to observe the sequential change of these indicators.

For network level indicators, we captured *network centralization*, *clustering coefficient*, and more importantly, *intercohesion* (see Fig. 1). *Network centralization* measures the degree to which an entire network is focused around, and dominated by, a few central nodes (Irwin and Hughes, 1992; Scott, 2000). *Clustering coefficient* is a common indicator to measure a network’s degree of clustering, the extent to which individual network members are embedded in highly clustered local neighborhoods (Wasserman and Faust, 1994). An increase in clustering coefficient indicates the emergence of clique-like local neighborhoods in a network (Baum et al., 2003; Watts and Strogatz, 1998).

To capture the concept of intercohesion of each milestone, we follow the approach taken by previous studies to identify cohesive groups and structural folds (de Vaan et al., 2015; Vedres and Stark, 2010). We adopted the method of Clique Percolation Method (for details on this method, see Vedres and Stark, 2010) to detect the overlapping community structure. This method improves standard approaches in social network analysis and has been recently recognized as a suitable tool for cohesive group analysis (Palla et al., 2005; Vedres and Stark, 2010). We started from a clique of 5 nodes (i.e., a 5-clique). If a 5-clique shares four members with another clique of five, they are adjacent. The 5-clique rolls along by replacing only one of the 5 nodes to form another 5-clique. If it is adjacent to the former one, both of them are included in a group. The clique keeps rolling along until the adjacency is exhausted, with all adjacent cliques forming one cohesive group. All members in this cohesive group have ties to at least four other members in the group. Within each cohesive group, members are closely tied to each other with close familiarity and higher level of trust. Meanwhile, there could be multiple cohesive groups in a complex network, and some members will possess memberships of multiple cohesive groups. The overlap between cohesive groups are defined as *structural folds*, with certain members occupying these structural folds. In contrast to Burt (1992)’s concept of structural hole, actors at the structural fold have access to multiple groups with diversity, and participate in dense cohesive ties within the groups. In other words, actors at structural folds benefit from both brokerage and closure. Therefore, they occupy strategically critical network positions.

We used CFinder to perform the intercohesion analysis and visualization (Palla et al., 2005). CFinder is a software tool developed

Table 1
Major Events and Stages of the TD-SCDMA Network Evolution.

Stage	Time	Types of New Alliance Members	Forms of Alliance	Degree of Industrialization	Major Events (Strategic, Technological, and Regulatory Milestones)	Authorization Agency
	1997	Government agency, R&D labs	Government-industry-university R&D alliance	Academic technology	Chinese government's primary role as initiator and direct resources provider.	Chinese government
Initiation	Oct 2001	Government agency, R&D labs, system equipment makers, chip and terminal manufacturers as new standard sponsors	Government-industry-university R&D alliance, interfirm R&D alliance joint venture, alliance organization	Technological standard, laboratory system	Passes first stage MTNet test, meets the requirement of 3G mobile communication system set by the ITU, capable of independent network building, breakthrough in data services. Technology standard legitimization internationally. Chinese government's primary role as initiator and direct resources provider.	Domestic equipment manufacturer, government
	Jan 2004	Intelligent antenna manufacturers	Alliance between licensing joint venture industrial bases and laboratories	Industrial standard	Successful call between UE and base station, MTNet Field test creates bandwagon effects. Chinese government acts as coordinator, representative, and indirect resource provider.	Recognition by international manufacturer, government, domestic operators
Orchestration	Apr 2005	Testing instruments manufacturers	Sub-union under the integral solution	Pre-commercialization standard	Result of 3G MTNet field test announced, proving that the TD-SCDMA has an independent commercial network capacity and outstanding technical superiority; increasing public interest motivates standard followers to "get tickets" and ally with key players in a TD alliance network.	Interest shown by foreign operators, government recognition, changing strategies by foreign equipment manufacturers
	Feb 2006	Application software developers	Cooperation & competition within the alliance and among standards	National industrial standard	UE makes an overall breakthrough; TD-SCDMA has capability to build an independent and large-scale commercial network; field test in a larger network is begun. Rapid technology diffusion.	Recognition by international operator, participation of domestic operators in the test, government approval
	Nov 2007	System integrators and value-added service providers	Promote the establishment of TD test network; Accelerate the commercial process	3G Licenses Issued Build & expand test network	TD technically fully meets the commercialization requirements of a 3G Test network extended to 10 cities, pm the eve of commercialization. Chinese government acts primarily as regulator and representative in international trade negotiations.	Domestic operators participate in pre-commercialization test
Embedded	Jan 2009	Terminal manufacture	Commercialization, provide stable service with more customers	3G Licenses Issued	3G licenses issued, and China Mobile got the TD-SCDMA license, in Jan 2009.	Customers

Table 2
The growth of the TD-SCDMA industry strategic alliance network.

Type of Ties	Nature of Ties	1997	Oct 2001	Jan 2004	Apr 2005	Feb 2006	Nov 2007	Jan 2009
Joint Promotion	Alliance members work together to promote technology standards	1	3	3	3	3	3	3
Procurement Relationship	Alliance members at different stages of the industry supply chain enter formal contracts or agreements	0	2	2	2	6	37	49
Research Alliance	Alliance members cooperate in R&D through co-establishing laboratories and other means	0	3	9	22	27	61	74
Common Vision	Alliance members all attend the TD-SCDMA technology forum and express the intention to cooperate, but there is no practical cooperation	2	7	8	8	9	33	36
Joint Test	Alliance members work together to test equipment and technology	0	0	0	0	0	18	20
Organizational Contacts	Firms officially join the TD-SCDMA Industry Alliance	0	16	28	44	54	89	108
Patent Licensing	Alliance members share their patent technologies with other alliance members	1	1	2	4	6	15	15
Joint Investment	Alliance members invest in joint ventures	0	13	22	28	32	50	65
Joint Network Building	Alliance members work together to establish infrastructures	0	1	1	1	1	4	5
	No. of Nodes	5	32	45	63	77	146	181
	No. of Ties	4	46	75	112	138	310	375

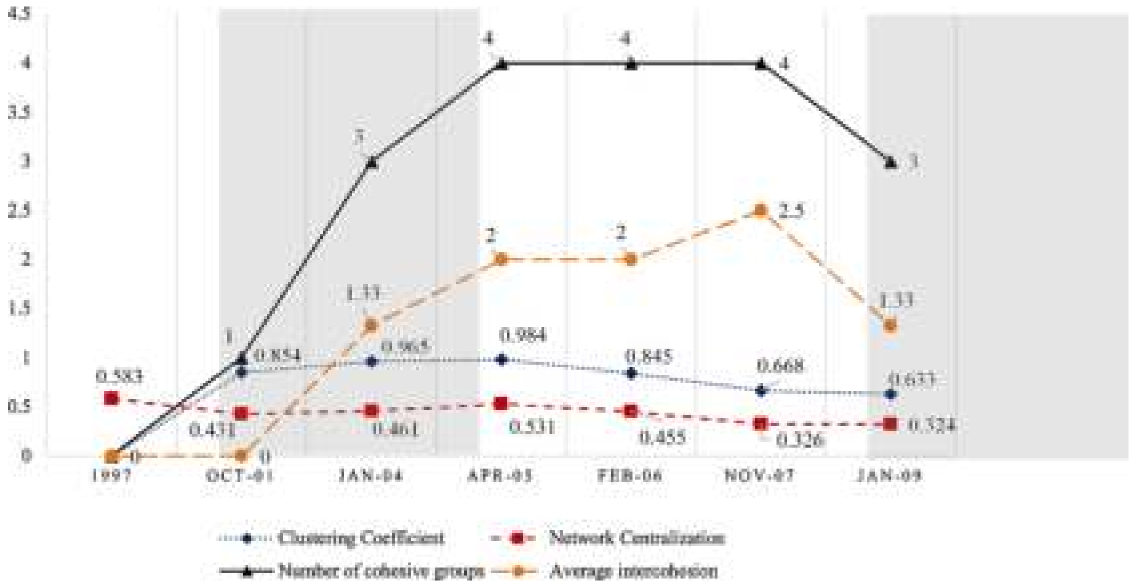

Fig. 1. Key Indicators of the TD-SCDMA Standard-setting Alliance Network, 1997–2009.

by Palla and his colleagues for network cluster detection based on the Clique Percolation Method. After identifying the cohesive groups of the network in each stage, we recorded *the number of cohesive groups, actors at structural folds,* and calculated *average intercohesion* for the industry network at each stage. We followed the work of Vedres and Stark (2010) and measured intercohesion of a given group in a given year by the number of groups with which this given group overlaps. Then we calculated the average of intercohesion across all cohesive groups in a given year.

Six actors were identified at structural folds over the ten years: Datang, Huawei, Motorola, Putian, CTSTRI, and Commit. Together with three governmental institutions (the Government, TIDA, and TDF), we calculated the following network indicators for these key actors at each stage: *degree centrality and eigenvector centrality* (see Table 3). *Degree centrality* of a network member (i.e., linkages to other members) captures the member's locational advantages in a network and is widely used as a measure of the member's social power over other members (Brass, 1984; Burt and Minor, 1983; Krackhardt, 1990; Wasserman and Faust, 1994). *Eigenvector centrality* not only considers the number of actors each node is connected to, it also takes the centrality (or status) of these actors into account (Bonacich and Lloyd, 2001). As such, an actor can exhibit low degree centrality by connecting to a limited number of other actors, yet show high eigenvector centrality if its connections possess high level of centrality. We used UCINET 6 software to analyze the TD-SCDMA standard-setting network and calculated the above three indicators of the key actors. We then employed NetDraw visualization software to illustrate the TD-SCDMA standard-setting alliance network at different points of time (see Fig. 2).

4. Empirical evidences

4.1. Overall industry development

As shown in Table 1, the trajectory of China's homegrown 3G standard evolved through several major events, from being merely an academic standard to commercialization. In 1997, the development of TD-SCDMA was initiated by Siemens and China Telecom Scientific and Technological Research Institute (CTSTRI, a state-owned R&D center), which was then an academic standard. In 1999, Datang was founded by CTSTRI as the leader of coordinating TD-SCDMA development. In 2001, TD-SCDMA was successfully adopted by ITU as one of the three international standards along with CDMA2000 and WCDMA. Throughout the development process, firms with diverse industry backgrounds joined the network, and the supply chain became increasingly mature. TD-SCDMA became an industrial standard in 2004, under preparation for commercialization. In 2006, it became China's national standard, followed by pre-commercialization testing, such as the field and systematic integration tests in 2006 and 2007. China Mobile provided 3G service for the 2008 Olympic Game in Beijing, received the TD-SCDMA license in January 2009, and started to provide 3G services to customers in China and all over the world.

4.2. Network-level indicators

4.2.1. Clustering coefficient and intercohesion

Clustering coefficient should, to some extent, reconciles with (although differs from) the results of intercohesion, as it measures the degree of network cohesiveness. In Fig. 1, we can see that clustering coefficient jumped from 0 to 0.854 in 2001, when the government constructed a cohesive 3G team. At this point, the sole cohesive group identified through community detection (See

Table 3
Network indicators of key actors.

	1997	Oct 2001	Jan 2004	Apr 2005	Feb 2006	Nov 2007	Jan 2009
	Government (F55)						
Degree Centrality	2	4	5	5	6	8	8
Eigenvector Centrality	0.5	0.05	0.071	0.065	0.08	0.064	0.063
	TDIA (F60)						
Degree Centrality	N/A	N/A	16	23	30	53	68
Eigenvector Centrality	N/A	N/A	0.219	0.218	0.229	0.206	0.227
	TDF (F73)						
Degree Centrality	N/A	8	8	8	9	16	17
Eigenvector Centrality	N/A	0.266	0.156	0.14	0.135	0.14	0.095
	Datang (F3)						
Degree Centrality	3	19	36	50	51	55	58
Eigenvector Centrality	0.653	0.484	0.438	0.478	0.463	0.374	0.339
	CTSTRI (F57)						
Degree Centrality	N/A	1	15	16	16	16	18
Eigenvector Centrality	N/A	0.005	0.207	0.197	0.2	0.177	0.164
	Huawei (F10)						
Degree Centrality	N/A	9	20	24	25	28	30
Eigenvector Centrality	N/A	0.309	0.341	0.328	0.33	0.277	0.275
	Motorola (F11)						
Degree Centrality	N/A	9	9	13	13	15	15
Eigenvector Centrality	N/A	0.309	0.189	0.228	0.218	0.176	0.139
	Putian (F16)						
Degree Centrality	N/A	N/A	18	20	24	27	27
Eigenvector Centrality	N/A	N/A	0.261	0.228	0.247	0.256	0.24
	Commit (F59)						
Degree Centrality	N/A	N/A	11	12	12	29	29
Eigenvector Centrality	N/A	N/A	0.141	0.116	0.126	0.258	0.244

Fig. 3) was the TD-SCDMA Forum (TDF) in which the founders closely connected to each other for the promotion and popularization of the new technological standard. The establishment of TDF was encouraged by the Chinese government, and composed of 8 founders: Datang, Siemens, China Mobile, China Telecom, China Unicom, Huawei, Motorola, and Nortel. The forum was established in 2000 as "the government-endorsed organizer of the yearly China TD-SCDMA International Summit, the highest level TD-SCDMA conference globally" (TDF, 2000). TDF serves as a platform or a community to enhance communication and trust within the wireless telecommunications industry. Meanwhile, as there is only one cohesive group with no condition for group overlap, intercohesion remained at the value of 0.

Later on, as more firms entering the collective development of the TD-SCDMA standard, some of them (both GSIs and non-GSIs) formed highly cohesive groups through establishing joint ventures and founding industrial associations. In January 2002, as major investors, six leading domestic and overseas enterprises (i.e., Nokia, Texas Instruments, LG, Putian, Daba, and CTSTRI) established a joint venture (i.e., Commit) in Shanghai to develop a TD-SCDMA chipset (TDF, 2000). In October 2002, the TD-SCDMA Industry Alliance (TDIA) was established by 9 GSIs and non-GSIs (i.e., Datang, CTSTRI, SOUTEC, Holley, Huawei, LENOVO, ZTE, CEC, and Putian), indicating that TD-SCDMA had obtained support throughout the industry. TDIA was born as a GSI with the mission of integrating and coordinating industry resources, improving R&D and production level, and promoting industrial application of TD-SCDMA in domestic and global markets (TDIA, 2002). In January 2003, Datang, Philips Semiconductors, Motorola, and Samsung established a joint venture, T3G Technology, to offer chipset solutions for TD-SCDMA terminal manufacturers. As a result of these cohesive collaborations, clustering coefficient climbed to 0.984 in 2005, indicating that the majority of network members are clustered in local neighborhoods. Regarding intercohesion, cohesive groups increased to 3 and later 4, and the level of intercohesion started to grow from 1.33 to 2. In Fig. 4, three cohesive groups (i.e., TDF, TDIA, and Commit) overlapped with each other, with Datang, Huawei, Putian, and CTSTRI occupying the structural folds. Each of them bridged two cohesive groups. In Fig. 5, the number of cohesive groups increased to 4 with the addition of T3G Technology subgroup, which brought Motorola to the structural fold as well. Additionally, Datang started to channel three cohesive groups.

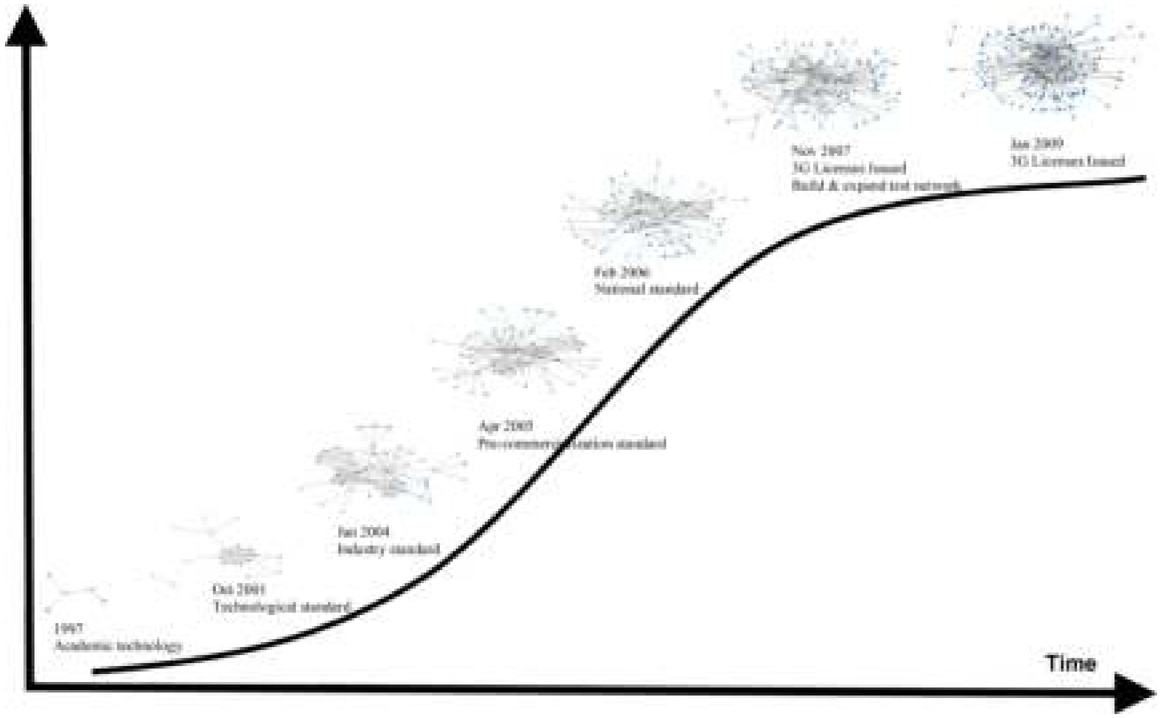

Fig. 2. Evolution of TD-SCDMA Standard-setting Alliance Network, 1997–2009.

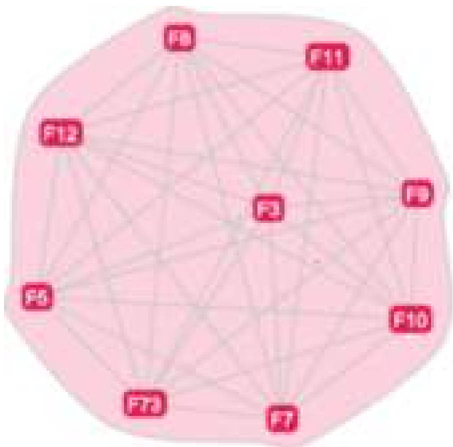

Fig. 3. Cohesive Group in September 2001.

Since February 2006, clustering coefficient started to drop to the level of 0.6, while intercohesion continued to reach its peak in 2007, indicating the operational and theoretical differences between these two measures. The decline of clustering coefficient is attributed to the influx of more enterprises entering the industry network by joining TDF, TDIA, or providing auxiliary services and equipment. However, these enterprises did not form as many cohesive network ties as other institutions did in the past, therefore yielding lower clustering coefficient. In contrast, the level of intercohesion increased to 2.5 by the end of 2007, despite that no additional cohesive group was formed. In Fig. 6, we can see that the four cohesive groups become more infused, with Commit occupying a structural fold as well, and both Datang and Putian connecting three communities. In other words, the dimension of cohesiveness remained stable whereas the dimension of brokerage increased as more network actors became bridges between communities. Therefore, intercohesion demonstrates the critical roles played by key actors. By 2009, the number of cohesive groups dropped to 3 when members of TDIA and TDF became fully connected to each other to form a larger cohesive group, and intercohesion decreased accordingly (see Fig. 7). The evolution of cohesive groups shows how the cohesion of the industry network was disrupted and reconfigured overtime.

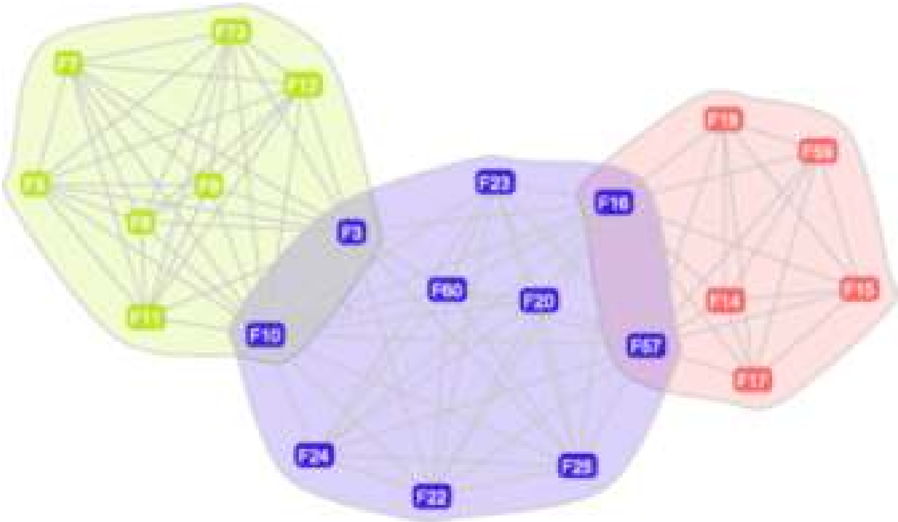

Fig. 4. Cohesive Groups in January 2004.

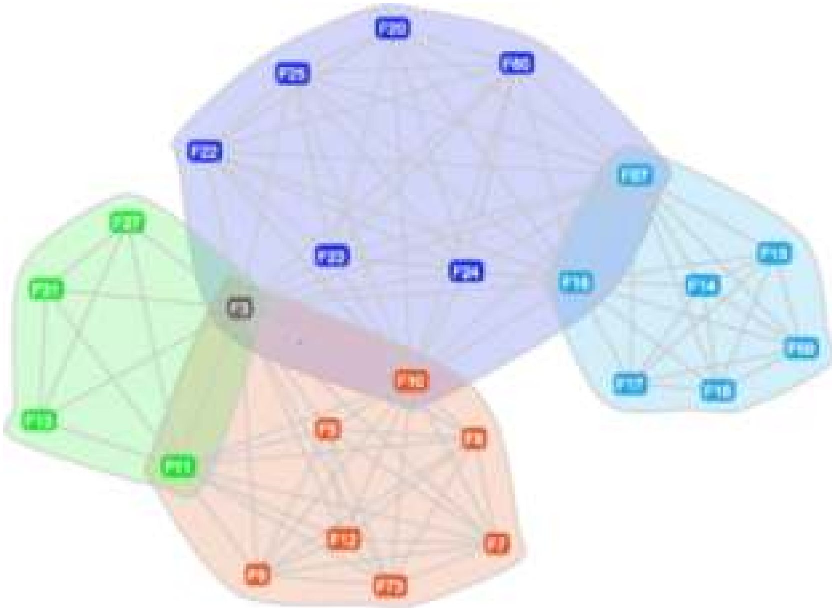

Fig. 5. Cohesive Groups in April 2005 and February 2006.

4.2.2. Network centralization

As shown in Fig. 1, network centralization was higher in early years and generally declined over the years. It was at its peak (0.583) in the beginning, when the government and GSIs (i.e., CTSTRI and Datang) dominated the construction of a 3G team. As more institutions joining the network and some of them taking important roles since 2001, network centralization slightly declined and remained at around 0.45, where a handful of GSIs and non-GSIs dominated the network structure. From 2006 on when TD-SCDMA became a national standard, technological uncertainty drastically decreased. The industry witnessed an influx of firms along various links of supply chain joining the network playing more active roles. The network centralization thus further declined to slightly over 0.3. The changes in network centralization indicate that the government and GSIs did not act as merely a centralized policy maker throughout the development process.

4.3. Network indicators for key actors

In this section, we examine various network centrality indicators of the key actors occupying structural folds, plus the government, TDIA and TDF which acted as important players throughout the period (see Table 3).

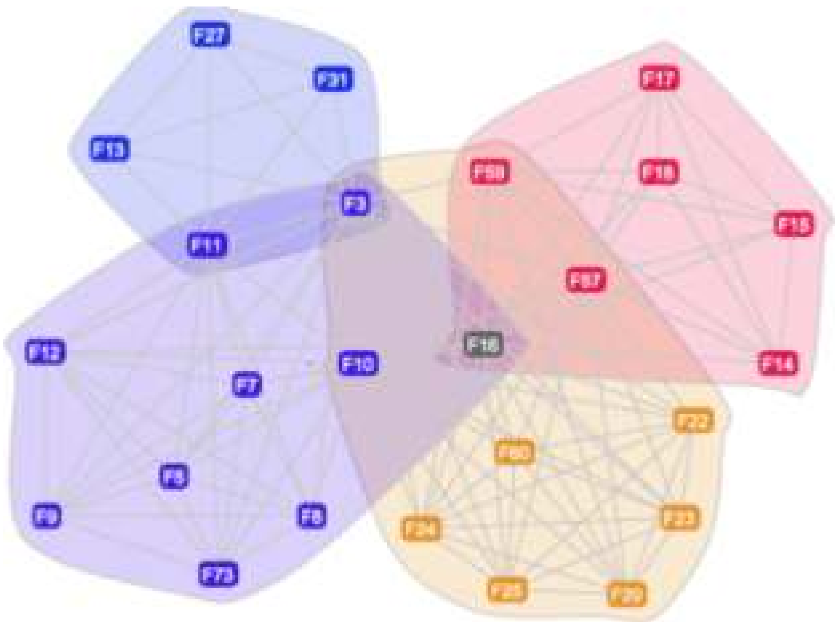

Fig. 6. Cohesive Groups in November 2007.

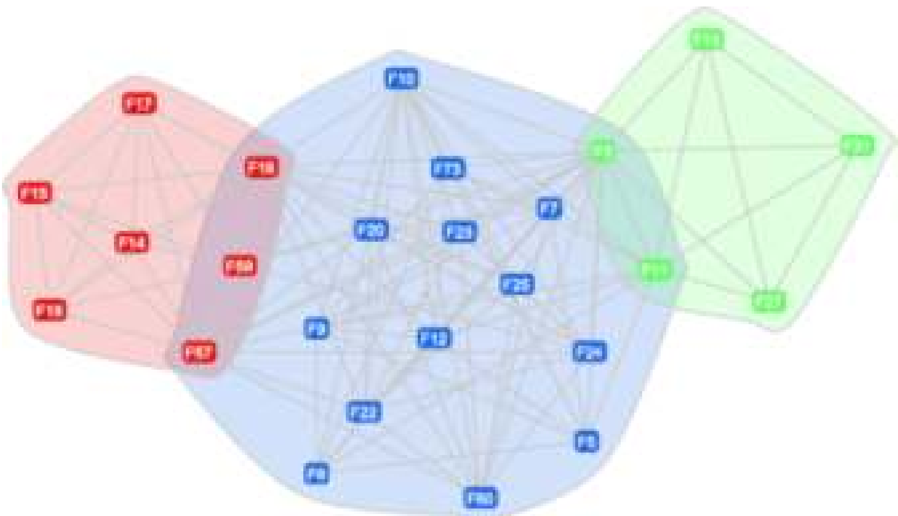

Fig. 7. Cohesive Groups in January 2009.

4.3.1. Degree centrality

Table 3 shows that in the development process of China's TD-SCDMA standard, not surprisingly, the degree centrality of key actors all increases with more and more firms joining the network. They became increasingly connected to more institutions over the years. Among the key members, TDIA and Datang as two GSIs are the most well-connected institutions with highest degree centrality. Although the government itself was not connected to a large number of other actors, the two GSIs acted as government agents and were considered the "super stars" in the industry.

4.3.2. Eigenvector centrality

The eigenvector centrality value of the government and TDIA remained fairly consistent. Eigenvector centrality is argued to be a more accurate measure of an actor's status in a network (e.g., Bonacich and Lloyd, 2001). Although the government's eigenvector centrality is not high throughout the whole evolution process of TD-SCDMA, its status or influence remained stable despite that its degree centrality became significantly lower than other key actors overtime. That is to say, although the government was not directly connected to many organizations at later stage, its connection with other key actors with high status (e.g., Datang, TDIA) enabled the government's stable status and influence. The government was able to channel its influence through two high-status GSIs. TDIA acted as an alliance association for various institutions throughout various stages of the value chain, therefore its status and influence remained stable at a relatively higher level (above 0.2). The eigenvector centrality of other GSIs (i.e., Datang, TDF, and CTSTRI) remained at a fairly higher level, then decreased since 2007. These GSIs were heavily involved in and dominated the R&D of TD-SCDMA, but less engaged in the commercialization stage, attributing to the decrease of status since 2007. Among these three GSIs, Table 3 shows that Datang exhibited particularly high eigenvector centrality (roughly between 0.45 and 0.5) before the commercialization stage, indicating that Datang was the most powerful and influential government agent dominating the technological development of TD-SCDMA. Besides GSIs, a few non-GSI private enterprises (i.e., Huawei, Putian, Motorola, and Commit) showed relatively high level of eigenvector centrality (e.g., at the level of 0.2 and 0.3), indicating a network structure where both public and private actors took part in the structuring process. In particular, Commit's eigenvector centrality increased significantly since 2007, suggesting that it played a more active role in the commercialization stage of TD-SCDMA.

5. Theoretical propositions

The network analyses presented in the above section revealed the major events throughout the industry evolution and various network structure characteristics at both the network and individual levels. The major events suggest important stages of the technology development from academic standard, to industrial and national standard, then to licensing and commercialization. Network indicators suggested a general pattern of substantial increase after 2001, and a visible decrease after 2006. Consequently, we divided the evolution of the TD-SCDMA network into three stages: initiation, orchestration, and embedded (see Fig. 1).

5.1. The initiation phase (1997–2001)

If individual organizations with low interdependence lack common interests, it is unlikely that a network will grow randomly by itself to connect individual organizations, unless a triggering entity acts as a strategist and purposefully initiates the network (Doz et al., 2000). Previous research also suggests that innovative projects are less likely to be initiated in the private sector when market or technological uncertainty is high (Jiang et al., 2010; Li and Mahoney, 2011). As found in our study, the government served as the strategist (Lazzarini, 2015); together with its research center CTSTRI and its agent Datang, they initiated the development of TD-SCDMA. As noted by the CEO of one private company in the industry, "*Domestic companies had little to gain in the development process of TD-SCDMA technology; we wouldn't have got on board if it weren't for the government's mandate.*" A president from a research institute stated that "*since the government has spoken up, we have the obligation to take part in the R&D.*" To be capable of initiating an inter-organizational network, it is necessary that the strategist has enough influence over other organizations. The influence can come from high social status, good reputation, legitimate authority, and/or access to critical resources. As a state-owned R&D center, CTSTRI submitted the initial draft of TD-SCDMA standard developed by the government-led 3G team in 1998, and founded Datang as the leader of coordinating TD-SCDMA development in 1999. The Chinese government also made sizable financial investment in Datang, and actively searched for foreign strategic partners on its behalf. Datang was legitimized as the leader of the TD-SCDMA industry through the endorsement from the Chinese government which intentionally delegated responsibilities. CTSTRI and Datang gained their status and influence through being legitimized by the Chinese government. The initiation of this new network marks the disruption of existing business ecosystem. A variety of new players entered the industry, with the aim of developing a more advanced technology and standard that would disrupt current balances.

Once the network is initiated, the strategist will also assume the responsibility of directing the functioning of the entire network, and applying rewards and sanctions when necessary. These responsibilities often reinforce the strategist's power and influence over other network members. For example, Toyota created a knowledge-sharing network of suppliers which accept Toyota's legitimacy as the key leader and follow Toyota's guidance of maintaining inter-firm relationship (Dyer and Nobeoka, 2000). Networks initiated by strategists such as the Toyota case will witness the strategist enjoying more access to the resources of the network, better coordination capability, and less dependence on other members. The entire network will have a hub-and-spoke structure, where social power and influence will be centered on the strategist and, possibly, its close allies. In our study, the government, CTRSTI, and Datang directed and dominated the network structuring in this phase. They encouraged and brought seven other enterprises on board to establish TDF in 2001, which served as a platform for information and knowledge exchange and coordinated communication. Compared to a network formed through a process where a central leader is absent, a network initiated by a strategist will exhibit high network centralization. At this point, the government and the GSIs were the hub(s) of the industry network, and network centralization was at its highest level (0.583). Therefore, we propose:

Proposition 1. In an emerging economy, the government can function as a strategist to initialize a centralized public–private collaboration network, disrupting the industry status quo.

5.2. The orchestration phase (2001–2006)

Central firms are argued to function as the network orchestrator in the growth of a network to facilitate innovation (Dhanaraj and Parkhe, 2006). Dhanaraj and Parkhe (2006: 659) define network orchestration as "the set of deliberate, purposeful actions undertaken by the hub firm as it seeks to create value". They argue that, in an innovation network, orchestration involves ensuring knowledge is shared, acquired, and deployed within the network. To enhance knowledge mobility, network orchestrators can facilitate technology combination in novel ways, reinforce a common identity among network members, and foster socialization of formal and informal linkages among network members (Brown and Duguid, 2001; Dhanaraj and Parkhe, 2006).

What remained unaddressed is how central firms orchestrate the network structure and activities for knowledge mobility and disruptive innovation. Central firms possess prominent and high-status positions. As such, new entrants and existing firms will be attracted and form more ties with central firms, progressively reinforcing the centrality and influence of prominent firms (Giuliani, 2013; Rosenkopf and Padula, 2008). Some scholars argue that central firms occupying bridging positions are capable of channeling knowledge and information sharing. Others suggest that a core/periphery structure facilitates the diffusion of technological standards (Balland et al., 2013). However, structural fold provides opportunities for recombining diverse knowledge resources through multiple cohesive groups (Vedres and Stark, 2010). Central firms may make use of their prominence, orchestrate network activities to form cohesive groups, and foster key actors occupying structural folds for both brokerage and cohesive benefits, thus further disrupting the dispersion and coordination of group members.

In a public–private collaboration network, the government and GSIs act as network orchestrators. Appealed by the GSIs' prominence (e.g., status, authority), other enterprises enter the network for collaboration. For example, in our study, shortly after TD-SCDMA was formally adopted by the ITU, Siemens committed one billion USD to co-develop TD-SCDMA with Datang. The government and GSIs' orchestration will lead to both GSIs and non-GSIs occupying critical network positions. In our study, the Chinese government, CTRSTI and Datang are network orchestrators in this phase. Commit was created as a joint venture led by CTRSTI and other enterprises to form one cohesive group in early 2002. Firms in this cohesive group focus on the technology development and commercialization of TD-SCDMA. In late 2002, another cohesive group TDIA was established by CTRSTI and Datang, along with seven other enterprises for resource integration and R&D coordination. Datang authorized other TDIA members to use the TD-SCDMA standard. In 2003, T3G technology was formed by Datang and three other foreign corporations. This cohesive group focuses on technical solutions for terminal manufactures. Together with TDF, these four cohesive groups reinforce a common identity among group members, provide group members with cohesive knowledge and information sharing. Key actors on structural folds (i.e., CTSTRI, Datang, Huawei, Putian, Motorola, and Commit) are able to access diverse knowledge and resources of these cohesive groups (i.e., R&D, equipment manufacturing, commercialization), and combine them in novel ways through cohesive interactions among themselves and other group members. In addition, TDF and TDIA are orchestrated by the government and GSIs as exchange forums and platforms to foster socialization, formal and informal communications. A Chairman of one company one the structural folds commented that "*Being part of the TDIA provides us with a platform to communicate and collaborate with industry practitioners, to promote ourselves, to get more information on market demand and industry & technological development, and get more access to pooled resources. It is a multi-functioning platform.*" Through orchestrating an intercohesive network, the government and GSIs enhance knowledge recombination and facilitate the development of the disruptive new technological standard.

Proposition 2a. In an emerging economy, GSIs will establish more network ties over time and cohesive groups will be formed around GSIs during the orchestration phase,.

Proposition 2b. During the orchestration phase, structural folds will form as cohesive groups overlap; key actors composed of both GSIs and non-GSIs will occupy the structural folds, facilitating knowledge generation and disruptive innovation.

5.3. The embedded phase (2006–2009)

After the orchestration phase, an increasing number of non-GSIs will join the industrial network, gain autonomy, and become embedded in the industrial network. Network activities will include an increasing amount of autonomous interaction and collaboration among organizations, in face of similar interests, high interdependence, or a perceived need to gain access to similar resources (Doz et al., 2000). The functioning of the embedded phase tends to rely on the interaction among all member organizations. Such a network takes on a life of its own, with minimum guidance from a triggering entity, and its growth depends not on a core leader's maintenance, but on mutual benefits continuously generated from collaboration. The network essentially 'self-organizes' itself. Self-organization refers to the network-level dynamics whereby members interact without a central planner, causing the system as a whole to display emergent and orderly patterns (Brown and Eisenhardt, 1997). Self-organization theorizes how a higher-level order emerges from interactions with lower-level system components without intervention by a central planner (Anderson, 1999; Maguire and McKelvey, 1999). The notion of self-organization powerfully explains the emergence of certain social structures. For example, it has been used, as a unifying rationale for the micro-macro linkages between individual action and network structure, to examine the emergence of a standard-setting network in the booming nanotechnology industry (Meyer et al., 2005). A network governed by an embedded phase is comprised of numerous interacting entities (both GSIs and non-GSIs) with frequent interactions, forming cliques (Watts and Strogatz, 1998), or a subgroup, within the whole network. Compared to network phases initiated or orchestrated by GSIs, the centrality of the emerging non-GSIs occupying the positions of structural folds will increase. Increasing autonomous interaction and collaboration among network members will increase the level of embeddedness of the network (Giuliani, 2013; McDermott, 2007), causing some cohesive groups to merge into larger groups. The disruption tends to settle in this stage with dominant design/standard emerged and industry network restructured. However, despite that non-GSIs continue to gain status and influence, that of GSIs will remain relatively stable throughout various phases of network structure evolution. This is because the government and GSIs are connected to not only more network members, but also more high-status network members.

In our case study, the number new members joining the TD-SCDMA network almost doubled in 2007, with another significant increase in 2009. More enterprises formed alliances and collaborations autonomously. Network members committed voluntarily to investing various resources into the development, industrialization, and commercialization of the TD-SCDMA standard, including R&

D, manufacturing, and testing of end-products. The formerly disruptive technological standard got established with 3G licenses issued. In Fig. 2, we can see that the amount of network ties significantly increased in this phase, and network members tend to be more closely connected to each other in 2009. The CEO from one of the companies that joined later commented that "*Compared to 1G and 2G's western standards, 3G has created another path in China; the telecommunication industry will see rapid development. From telecommunications operators, to equipment manufacturers, to software and content providers, we are all part of the big 'TD' family.*" TDIA and TDF merged into a larger cohesive group in 2009, due to increased network ties established between members of both associations. Commit became another non-GSI occupying structural fold, whose eigenvector centrality increased significantly. The status of the government, TDIA, and TDF remained fairly stable throughout three phases. Although Datang's status declined in this phase, it still held the highest value of eigenvector centrality in the network. It indicates that in the embedded phase, while the status and power of non-GSIs increase due to self-organization, the government as the strategist and GSIs continue to play a critical role in the network structure.

Proposition 3. In the embedded phase, non-GSIs' centrality will tend to increase, and cohesive groups will tend to merge. In an emerging economy, the government and GSIs' central status will remain relatively stable.

6. Conclusion

Economic activities have been viewed as embedded in industrial relationships and shaped by state crafting (Piore and Sabel, 1984). To uncover the paradox of the coexistence of a powerful state and a self-organizing market system, we conducted an exploratory social network analysis of the one-decade (1997–2009) history of China's TD-SCDMA technology standard setting alliance to examine the roles played by the Chinese government and GSIs in promoting disruptive innovation, and the impacts on the evolution of the industry network structure. The study aims to address this research question: how the government plays a more powerful and more involved strategizing role in disruptive innovation with profound impacts on industry evolution and competitive advantage (Lazzarini, 2015).

6.1. Theoretical contribution

First, our study contributes to the literature of public–private collaboration network by examining how the government along with its GSIs plays multi-roles as a strategist. A growing number of studies have recognized the power of governmental capability and the role of public–private institutions in emerging markets (Lazzarini, 2015; Musacchio et al., 2015; McDermott et al., 2009). However, most current research on the government's role in emerging markets considers the state a catalyzer to foster new firm capabilities (Musacchio et al., 2015), a coordinator to enable product upgrading (McDermott et al., 2009), or a facilitator to enhance knowledge recombination (Corredoira and McDermott, 2014). Our study suggests that the government, along with its GSIs, can act as a powerful strategist, play multi-roles in directing and structuring the industry network to generate new knowledge and disruptive innovation. In contrast to the "bottom-up" perspective in the literature of national system of innovation in developing countries (e.g., Arocena and Sutz, 2000; Srinivas and Sutz, 2008), our case study shows that the government first initiated the establishment of TD-SCDMA network, delegated two GSIs, then together they orchestrated the network by deliberately creating connections and collaborations with domestic and foreign enterprises across the value chain. Non-GSIs were encouraged and empowered to take central roles during network orchestration, leading to an embedded network at the end. The government and GSIs strategized the network development, however, without holding tight onto centralized power and authority throughout the process.

Second, our findings of the intercohesive network structure contributes to the literature of public–private collaboration network by offering a new lens for examining the dynamics of public–private network. Two primary logics in the network literature advocate the benefits of brokerage ties of connectivity and cohesive ties of closure respectively (Burt, 2005; Giuliani, 2013; Vedres and Stark, 2010). However, an intercohesive network offers network positions with traits of both brokerage and cohesion (de Vaan et al., 2015; Vedres and Stark, 2010). The results of our case study show that through network orchestration, on top of a bourgeoning alliance and collaboration activities among network members, four cohesive groups were formed in the industry network: TDIA and TDF as platforms for knowledge and resource communication, Commit for R&D and commercialization collaboration, and T3G for developing technical solutions for equipment manufacturing. Six key enterprises (both GSI and non-GSI) were at the intersection of these cohesive groups, accessing diverse knowledge and resources on the one hand, and infusing the knowledge and resources into cohesive network ties on the other hand. By recombining diverse knowledge and resources within cohesive communities, the collaboration between public and private institutions successfully developed the TD-SCDMA 3G standard and disrupted the 2G business ecosystem. To the best of our knowledge, our research is among the first to examine how an intercohesive network structure facilitates the collaboration between public and private institutions. In contrast to being a mere broker by bridging groups (e.g., McDermott et al., 2009) or configuring cohesive public–private network ties (e.g., Giuliani, 2013), the government can strive to foster intercohesion and create conditions for critical institutions to occupying strategic positions such as structural folds.

Third, out study explores the government's role in shaping an industry network to generate disruptive innovation. The role of the government has rarely been examined in the existing literature on disruptive innovation, even less from a social network perspective. Christensen (1997) originally coined the term 'disruptive technology' to describe those technologies that are initially inferior but replace the mainstream technologies by rapid improvements. The concept was then expanded as 'disruptive innovation' to include innovations not only in technological products but also in services and business models, and can happen in both low-end and new markets (Christensen and Raynor, 2003). This study contributes to the literature by extending disruptive innovation to an industry level and examines how structural folds enable the disruption of industry network and the establishment of new technology standard. Through the central role of the government, disruption can happen not only at business level, but also at industry level, manifested by the disruption of the industry ecosystem, the reconfiguration of the industry network, and the recombination of resources.

6.2. Practical implication

China's economic upsurge, embodied in its homegrown high-tech technology standards, challenges researchers to explain the co-existence of a market system and a "visible hand" of a state with a central planning tradition. Although our study primarily concerns public–private collaboration on innovation and network theory, it helps us understand the China paradox. A unique perspective in this study is that by taking a social network approach, we examine the state government's role in the intercohesive public–private collaboration network. We find compelling evidence that the state played a strategizing role in initiating network formation and in collaborating with state research laboratories, which later were transformed into key players in the telecommunications industries through spin-offs. Once the "initial condition," or institutional infrastructure, was established, the state orchestrated the industry network to create overlapping cohesive groups with diverse knowledge and resources. In the meantime, the participatory policy allows other enterprises act autonomously. The strategic alliance network built momentum, leading the increasingly large and complex network of firms into a state of self-organization, embedded network, driven by the strategic goals, resources, and capabilities of each individual firm. Like other organizations, the government has limited capacity in the marketplace, and is subject to similar fundamental constraints (Evans et al., 1985). As a consequence, the government delegates increasing responsibility to GSIs. However, the status and influence of the state government is still present, with GSIs working alongside the government, taking on increasing autonomy, and sharing responsibilities. Besides GSIs, several non-GSIs enterprises (usually large telecommunications firms) gained power over the years, and played important roles in network construction. As a consequence, the actions of the central government, especially with respect to the marketization of the technology standardization process, must be understood as part of the political approach empowering other organizations which are formally tied to but are becoming increasingly autonomous from the central government (Yang, 2004). The duality and changing role of external intervention and self-organization found in Chinese standard-building initiatives provides evidence that the seemingly opposing forces can co-exist and even become complementary over time.

Since the case study is based on a network initiated by the state government, it has direct policy implications to other government-led interorganizational networks. Given that government is treated as a participatory organization and a node in the network, we believe that findings from the TD-SCDMA case have practical implications to a broader audience. Either government or not, a triggering organization, after successfully initiating an interorganizational network, will probably benefit more if it orchestrates the network to empower autonomy and self-organization, rather than either tightly controlling fellow network members or reluctantly letting the network to drift without a common goal.

6.3. Limitation and future research

As in any research endeavor of this nature, certain limitations should be noted. First, as a fairly new concept, intercohesion bears significant theoretical implications and great potential of contributing to the literature of disruptive innovation and public–private collaboration networks. Future research is encouraged to conduct in-depth investigations of the dynamic and historical dimensions of intercohesive networks. Second, as this study is situated in the unique setting of the standardization of China's TD-SCDMA technology, it has strong implications to similar cases where government plays "a visible hand" in creating initial conditions for technology advancement (e.g., the heavy involvement of government in the development of 3G technology in Europe or the strong support of government in the wine industry of Argentine's emerging economy). Furthermore, we believe that findings from the TD-SCDMA case will have generalizability in settings where a network originally formed through an initiation phase evolves into an embedded phase, regardless whether the initiator is the government. However, differences between the government and for-profit organization as well as those between the emerging economies and developed economies should certainly be noticed. We encourage future research to test the generalizability of the findings in other research settings, particularly those where a for-profit firm initiated public–private collaboration in developed economies. Finally, since this study is solely based on data from one network, we did not have a large enough sample to statistically test the propositions. Future empirical research may collect data on multiple networks for quantitative evidences.

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