A FRAMEWORK FOR UNDERSTANDING MOBILE TELECOMMUNICATIONS MARKET INNOVATION: A CASE OF CHINA

Ping Gao
Institute for Development Policy and Management (IDPM)
The University of Manchester
United Kingdom
ping.gao@manchester.ac.uk

Jan Damsgaard
Center for Applied Information and Communication Technology (CAICT)
Copenhagen Business School
Denmark
jd.caict@cbs.dk

ABSTRACT

Most of the present research on the dynamics of mobile telecommunications market focuses on either technology innovation or service adoption. Drawing upon actor-network theory, we set up a framework that incorporates the two perspectives. We further apply this framework to dissect a case of China Telecom. The case study demonstrates that our model enables a systematic description on the mutual influence of infrastructure innovation and innovation adoption that moves beyond unilateral accounts. Moreover, our framework captures the interplay between mobile telecommunications market and its social network formed by the interrelated users, service providers and other related institutions. It is a useful too for the researchers to grasp a systematic understanding of mobile telecommunications development in China in particular, and in other countries in general.

Keywords: Actor-network theory; Adoption; China; Infrastructure; Innovation; Mobile telecommunications market

1. Introduction

In recent decades we have witnessed dramatic changes in mobile telecommunications technologies and services. This phenomnon raises wide research interests as the general availability and widespread adoption of advanced telecommunications technologies are linked to the economic potential of nations [Fransman, 2002]. However, research to date has largely focused on Western countries. This article analyzes mobile telecommunications market innovation in China, which has been relatively sidelined in this research term. China is the largest mobile telecommunications market in the world, which grows at one of the highest rates in the global scale. Constrained by its unique social environment, China's mobile telecommunications market has innovated in a particular way [Zhu, 2005]. For example, as we will read later in our case study in this article, in other countries the markets have changed from the second generation (2G) through the 2.5 generation (2.5G) to the third generation (3G); but in China, waiting for its indigenous 3G technologies to mature hence be used, the government has not issued the 3G licenses yet. Interestingly, we instead have seen the success of personal handyphone system (PHS), a cordless telephony technology generally treated as an extension of the fixed network. It is of practical interest to know the characteristics of mobile telecommunications market innovation in China and to disclose the driving forces to it.

Indeed, this article does not limit its focus to the description of the Chinese experience. Instead, we have a more important purpose that is to make theoretical contribution. Specifically, we attempt to propose a framework that may help us understanding mobile telecommunications market innovation in China in particular, and in other countries in general. Normally, researchers investigate the dynamics of mobile telecommunications market from two distinct perspectives, either technology innovation or service adoption [Okazaki, 2005]. As an example of innovation studies, Edquist [2003] reports the results of a collection of papers that draw upon Systems of Innovation Theory to analyze the innovation of Internet and mobile technologies. Equally, there has also been considerable research carried out to explain the user adoption of mobile services [see e.g. Bauer, Barnes, Reichardt and Neumann, 2005; Pavlou and Chai, 2002; Pedersen, 2005], for which Diffusion of Innovation Theory [Rogers, 1995], and Theory of Reasoned Action [Ajzen, 1980] as well as its extensions like Technology Acceptance Model [Davis, 1989] and most

recently the Unified Theory of Acceptance and Use of Technology (UTAUT) [Venkatesh, Morris, Davis and Davis, 2003], serve as major analytical tools.

We argue that infrastructure innovation or service adoption perspectives alone can only partly explain the innovation in mobile telecommunications market [Okazaki, 2005]. Drawing upon actor-network theory, in this article we combine the two perspectives into one framework to pursue a holistic understanding of this phenomenon [Callon, 1991]. In the literature, actor-network theory is mainly used to study the technology design as a micro issue [Walsham, 1997]. Our work extends the application of actor-network theory to a macro process of mobile telecommunications market change.

This paper is organized as follows. In the second section, we draw upon actor-network theory to primarily develop a conceptual framework for analyzing mobile market change. Section 3, 4 and 5 are devoted to further substantiating this framework. Specifically, in the third and the fourth sections, we review infrastructure innovation and technology adoption theories and their applications in studying the telecommunications market, and discuss the components of the social system underpinning this market development. In the fifth section, we finally get our framework based on these perspectives; We will also propose the research problems that this fresh framework is capable to address. In the sixth section, to justify the explanatory power of our model, we use it to dissect the case of China Telecom. The last section derives the conclusion, discusses the limitations, and suggests the future lines of research.

2. Market Innovation As A Socio-Technological Process

Our purpose is to understand the mechanism for mobile telecommunications market innovation, especially that in China. Here innovation has the same meaning as dynamics, change, transformation and development. Specifically, by mobile telecommunications market innovation, we mean that, as time moves on, new mobile technologies and networks are deployed in the market. Moreover, this innovation process often leads to changes in market structure composed by varied players, and the appearance of novel services in the market.

In understanding the mechanism for mobile telecommunications market innovation, we are informed by actor-network theory [Callon, 1991]. Actor-network theory examines the motivations and actions of actors who form elements of heterogeneous networks of aligned interests. One potential application of this theory is to investigate the process whereby the respective interests of different human and non-human elements are aligned into a social and technological arrangement or network, which in the literature usually refers to a technological design [Gao, 2005; Walsham, 1997], but in our case to the mobile telecommunications market.

The central argument of actor-network is that successful networks of aligned interests are created through the enrolment of a sufficient body of actors that inscribe their interests into the network [Walsham and Sahay, 1999]. A key feature of this theory is that actors are taken to include both human beings and nonhuman actors (or artefacts), such as a technology, which together compose one network [Callon, 1991]. The actors have been broadly defined in the applications of actor-network theory to include people, organizations, and technologies such as software, computer, and communications infrastructure. For instance, describing a classification scheme for understanding nursing work as a political actor, Bowkers, Timmermans and Star [1996] give a special example of defining the nonhuman artefact; Gao [2005] defines the telecommunications market as the non-human artefact, and demonstrates that actor-network theory can be used to study telecommunications market structure change from monopoly to competition. Similarly, in this paper, we define mobile telecommunications market as the non-human artefact, and use actor-network theory to analyze its innovation process.

As a result, we have the preliminary framework of using actor-network to analyze mobile telecommunications market dynamics, as is shown in Figure 1. Our consequent task lies in disclosing the mechanism for this innovation process (the upper block in Figure 1), and identifying mobile telecommunications market players composing the social system for this transformation (the lower block). We also need to examine the dynamic relationship between mobile telecommunications market and its social system. In the next section we will theoretically explore these issues.

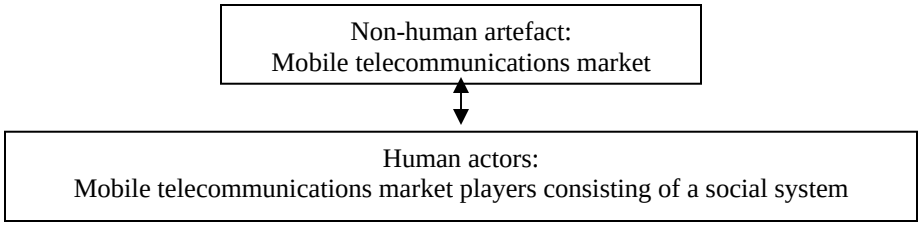

Figure 1: The preliminary framework of actor-network analysis

3. Opening the "Black-Box" Of the Market Innovation Process

Traditionally, actor-network theory has mainly served as a methodology that describes the technology design as a process of network building and social interaction. The technology is treated as a "black-box", which means people only attribute its design to the fact that the relevant social actors align their interests around it. It is a research challenge for researchers that they need to open the "black-box" in order to understand the process of actor-network formation and maintenance deeply. To address this concern, Walsham [1997] advises that we should incorporate other theories and the relevant literature with actor-network theory. In our paper, we draw upon theories in infrastructure innovation and innovation adoption disciplines to describe the process of mobile telecommunications market innovation.

As mentioned above, in the literature, there are two separate streams of knowledge in understanding the mechanism of the market change, which are adoption of innovation or infrastructure innovation. Table 1 condenses these two perspectives along with their theoretical supports. Next, we review theories and practices of both traits, and discuss the necessity and possibility of linking the two schools together so as to open the "black-box" of innovation in mobile telecommunications market.

Table 1: Infrastructure innovation and innovation adoption perspectives

	Infrastructure innovation	**Innovation adoption**
Key Drivers	Innovation of infrastructure and technology	User value
Unit of analysis	Networks of organizations, diverse communities, different institutions	Users
Viewpoint of diffusion	Longitudinal process that stretches over a considerable amount of time and space	Single point or short period
Key theoretical references	Systems of Innovation Theory [Dosi, Freeman, Nelson and Soete, 1988; Edquist, 1997]	Diffusion of Innovation Theory [Rogers, 1995; Tornatzky and Klein, 1982]; Theory of Reasoned Action [Ajzen, 1980]; Unified Theory of Acceptance and Use of Technology [Venkatesh, Morris, Davis and Davis, 2003]
Typical examples	Edquist [2003]	[Bauer, Barnes, Reichardt and Neumann 2005; Pavlou and Chai, 2002; Pedersen, 2005]

3.1 Market development as a result of innovation adoption

In the present literature, adoption and diffusion models have remained the popular means to explain the growth of mobile telecommunications market [Bauer, Barnes, Reichardt and Neumann, 2005; Pavlou and Chai, 2002; Pedersen, 2005]. More specifically, in explaining the market development as the results of the users' pull, people refer to two different sets of theories. The first one is the Diffusion of Innovation Theory (DOI). DOI identifies four elements that characterize a successful diffusion process of an innovation: 1) an innovation and its characteristics 2) that are communicated through specific channels 3) to the members of a social system 4) over time. General factors that have been found to influence adoption include: adopter characteristics, the social network, the communication process, the characteristics of the promoters, and the innovation attributes. Typical attributes include *trialability, relative advantage, compatibility, observability* and *complexity* [Rogers, 1995].

The Theory of Reasoned Action (TRA) and its extensions like Technology Acceptance Model (TAM) are another set of theories that address technology adoption [Ajzen, 1980; Davis, 1989]. Like DOI, these models predict diffusion of innovation over time and space by associating a group of variables with an adoption outcome [Wolfe, 1994].

In fact, people often incorporate DOI theory with the adoption models to find the best mix of innovation characteristics that promotes adoption. Accordingly, scholars have applied adoption models to explain diffusion with a small set of factors, like the relative advantage, compatibility, the complexity of the technology, the management support and champion of technology adoption, the market size and centralization, and the technical sophistication [Tornatzky and Klein, 1982].

Overall, the tradition of innovation adoption is founded on a desire to explain individual decisions to use particular services. The adoption population is assumed to be relatively homogeneous with well-defined boundaries. The implementation stretches over limited time, but learning is not considered as a part of the adoption process, and is seldom involved after the adoption [Lyytinen and Damsgaard, 2001].

3.2 Market development as a process of infrastructure innovation

In general, although in the past traditional adoption theories have provided many useful insights for understanding the diffusion of technology innovation, recent empirical studies of the diffusion of complex, networked information technologies, like business-to-business electronic commerce infrastructure, point out their limitations [Lyytinen and Damsgaard, 2001]. Mobile telecommunications market is built upon an infrastructure that offers services to the customers via mobile devices. The infrastructure innovation involves both radical and evolutory shifts in its underlying technologies. A radical transition usually enables new services (e.g., video streaming) but requires the users to acquire new handsets. The move from 2G to 3G, for example from GSM (Global System for Mobile Communication) to UMTS (Universal Mobile Telecommunications System), is a radical transition. Between radical shifts, the technology matures gradually. As a good example of evolution, GPRS (General Packet Radio Service) and EDGE (Enhanced Data Rates for GSM Evolution) bring about faster data connection than the GSM technology, but basically the users can use the same handsets to access these advanced networks. Therefore GRPS and EDGE are often refered to as 2.5G, in contrast to 2G technologies represented by GSM.

So far, we know that the development of mobile telecommunications market is not only a consumer matter or "user-pull". It also depends on the "technology-push" and infrastructure innovation. In studying this process we should take into account the roles of broader mobile market stakeholders, including, for example, equipment vendors, network operators, content providers, government, and intra-governmental organizations, that play their different roles in promoting the market innovation [Muller-Veerse, 2000]. The Systems of Innovation Theory is a significant tool for analyzing infrastructure innovation [Edquist, 1997]. For example, Edquist [2003] has presented a collection of articles that draw upon this theory to investigate the social network surrounding the Internet and mobile telecommunications technology.

3.3 The interrelated processes of innovation and adoption

We challenge the present work that generally treats mobile telecommunications market change from either an infrastructure innovation or a service adoption perspective. Based on specific sets of theories, both perspectives offer plausible explanations to why a complex socio-technological system diffuses (Table 1). Yet, we argue that these two fundamental perspectives are complementary, not exclusive; they are interdependent, not separate. The innovation adoption drives infrastructure innovation and vice versa. A self-enforcing spiral of mutual re-enforcement of both infrastructure innovation and innovation adoption can unfold under favorable circumstances. The investigation of mobile telecommunications market innovation has to deal with both the factors that influence the demand of potential adopters for innovation, and the supply elements for the innovation that determine the spread patterns of the innovation [Okazaki, 2005; Rosegger, 1996].

First, mobile telecommunications services are based on complicated infrastructure consisting of various components. These components need to be in place for the proper use of the infrastructure and the efficient operation of the technologies. Examples of such components are applications, services, billing systems, networks, handsets, and standards [Muller-Veerse, 2000]. The mobile telecommunications market is built upon this infrastructure. In other words, the infrastructure supports a series of technology applications and enables different sorts of services for the adoption of potential users.

From the diffusion of innovation perspective, it is clear that individual users will only adopt a technology insofar as they perceive the adoption to be beneficial to them. The judgement is based on the fit between the technology's immediate properties, like usability and accountability, and adopters' characteristics, for example, education and financial background, gender, and age, etc. [Ajzen, 1980]. In fact, the situation of user adoption of services and technologies influences the innovation of infrastructure, and requires the infrastructure enabling the provision of new, appropriate services [Abbate, 1999]. The key market stakeholders thus engage in framing the infrastructure so that it supports a certain pattern of usage [Faraj, Kwon and Watts, 2004]. The mobile telecommunications infrastructure is emergent in nature; it is not only built, but also grown [Ciborra, 2000]. As an example, in the beginning, GSM system only provids voice communications services. Later SMS (Short Message Service) function are offered. As this kind of data services are provided through the signal control channel of GSM system, which means their provision does not involve additional cost for an operator, a low price can be set for their consumption. At the same time, for customers, such services are convenient to use. Consequently, SMS services have became popular. The rapid growth of the SMS market further implies for the operators that data services will dominate the future mobile service market. As a result, they have upgraded their mobile telecommunications networks from 2G to 2.5G which is capable of providing broader sorts of data services at a higher speed. Meanwhile, the good market performance of SMS has encouraged the operators to extend the application of SMS to the business field. Consequently, as we have argued above, the change of mobile telecommunications market covers the issues of both infrastructure innovation and innovation adoption.

Network economics is the theoretical ground for understanding the interrelation between infrastructure innovation and innovation adoption. Because telecommunications services are dependent on the supporting infrastructure, the analysis of user adoption of these services must be expanded to take into account of their networked characteristics [Lyytinen and King, 2002]. For a networked technology, each individual adoption decision impacts the value for a user to use the technology. The networked feature of telecommunications technologies creates a positive feedback loop directly linked to the actual adoption, and consequently it must be incorporated into the diffusion analysis [Arthur, 1990]. The continuous growth in market size changes the properties of the services and technologies as perceived by the potential adopters. At the same time, the emergence and extension of the infrastructure lowers the knowledge threshold to adoption and reduces the complexity of the technologies to the users. It decreases the adoption risks and creates user favouritism towards the technologies. It also guarantees the stability of the promoted technologies, triggers learning and thereby reduces costs [Attewell, 1992]. Moreover, the infrastructure invites technology providers to produce standard compliant products and services. Consequently, these relationships shape the innovation's properties that are in favour of adoption. Meanwhile, from another point of view, the infrastructure that supports adoption can over time become an inertia that constrains innovation [Van de Ven, 1993]. So, whilst the mobile telecommunications market becomes firmly established, it locks the technology properties into a certain trajectory [Arthur, 1989]. Thus, the innovation is a process of path dependency and path creation. This explains why for 3G systems there are two dominant international standards existing in parallel, which are respectively based on two different 2G systems used now.

4. Market Innovation and Social System

As mentioned above, a mobile telecommunications market is socially constructed. Its development depends on the establishment of an ecological social system composed of different market players [Star and Ruhleder, 1996] or human actors [Callon, 1991]. In identifying these elements, it is necessary to consider whose interests these human candidates represent [Walsham, 1997]. According to Muller-Veerse [2000], we define the users, providers of mobile services and other relevant institutions as three groups of actors that represent the social interests in mobile telecommunications market. Here, in the light of King, Gurbaxani, Kraemer, McFarlan, Raman and Yap [1994], institutions include government and public authorities (such as regulators) as the main actors. These actors compose the social system that promotes mobile telecommunications market development, which is an interrelated process of infrastructure innovation and innovation adoption as elaborated in the last section.

Furthermore, there is an interplay between telecommunications market and its social system. Social structure and technological architecture co-evolve as technical problems are solved, and the services and products are adopted in the social domain [Tuomi, 2002]. As mobile telecommunications industry develops and this segment of market matures, it accordingly calls for varied providers to enrol themselves in the business. These actors work together to promote the market growth further [Harris, Rettie and Kwon, 2005; Sawyer, Allen and Lee, 2003]. For example, in 2G markets, network operators alone play the role. But in 3G markets, there exists a provider community consisting of manufactures, network operators, service providers, content providers, and service aggregators, etc.. Different firms will carve out their particular roles and create firm-specific value chains [Pagiavlas, Marburger, Stratmann and Young, 2005]. Depending on their specific resources and core competencies, these market players will position themselves differently, forming a specific value system [Maitland, Bauer and Westerveld, 2002]. Taking the market regulators as another example. For 2G systems, in general, the regulators enact licenses through a "beauty match" method; but for the 3G market, a lot of countries prefer competetive bidding and charge a large sum for one license [Bauer, 2003].

5. The Framework

Based on the discussion in the above sections, finally we are able to come up with the framework for investigating the socio-technological mechanism for mobile telecommunications market innovation, as shown in Figure 2.

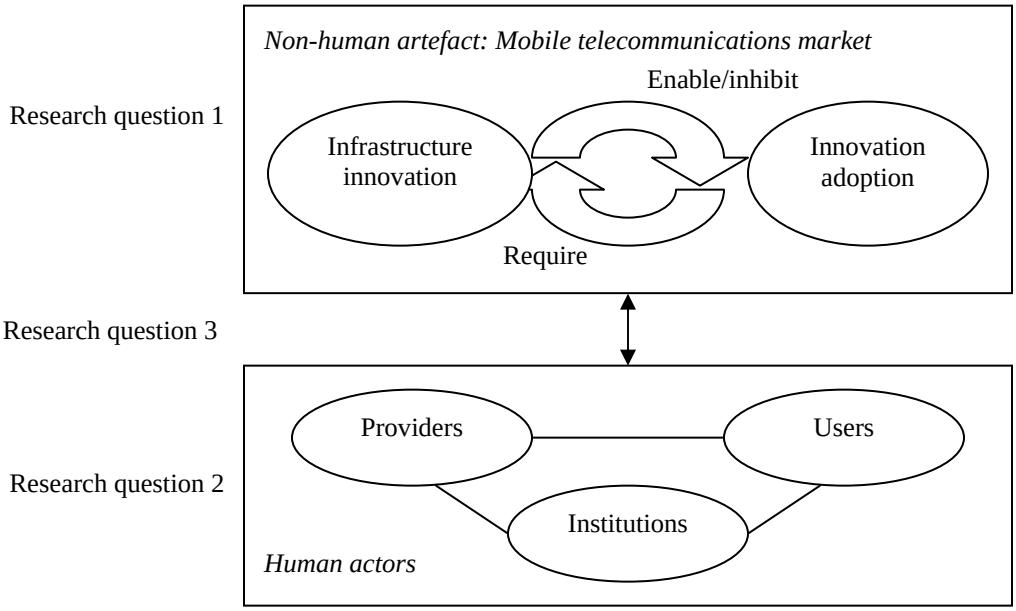

Figure 2: A framework for analyzing mobile telecommunications market innovation

In the domain of the non-human artefact, the "black-box" of mobile telecommunications market development is portrayed as the interrelated processes of infrastructure innovation and innovation adoption. In the domain of human actors, the social system is defined to consist of interrelated users, technology and service providers, and relevant institutions [Muller-Veerse, 2000]. The relationships between the human and non-human domains exemplify the ongoing struggles in promoting the transformation in mobile telecommunications market [Bloomfield, Coombs, Cooper and Rea, 1992]. Consequently, we describe mobile telecommunications market innovation as a process in which different actors participate in a social system to promote infrastructure innovation and innovation adoption as interrelated processes.

As shown in Figure 2, researchers can use this framework to address the following research questions:

Question 1: How does mobile telecommunications market transform? How do the infrastructure innovation and innovation adoption co-depend?

Question 2: In different phases of the market development, what actors are enrolled into the social system? What are the characteristics of their interactions in the social system? What are their roles in mobile telecommunications market development?

Question 3: How does the social system determine the market development, and in return how does the market development situation influence the properties of the social system?

6. Case Study

6.1 Method

Our research methodology can be labelled as case study [Holmes and Poole, 1991; Yin, 1994]. According to Glaser and Strauss [1967], researchers need to consider their theoretical purpose in selecting the case. In this article, through a case study, we attempt to demonstrate the potential that our framework in Figure 2 can be used to analyze the socio-technological mechanism for mobile telecommunications market development. Thus, in case selection, we insist the case should cover the three themes described by our framework (Figure 2), including the interrelated processes of infrastructure innovation and innovation adoption, as well as the social network around these processes. Based on these considerations, we take China Telecom as the target of analysis.

Our concern is with highly complex processes of mobile telecommunications market innovation, which take a period of time to unfold. The longitudinal case study method is well suitable for capturing the richness and complexity of these processes [Holmes and Poole, 1991; Yin, 1994]. Thus, in this paper, the case study will be organized as narratives, through which events and activities of mobile telecommunications market change in China are ordered over time.

We use both primary and secondary data. The first author of this paper ever worked in China's telecommunications administration for about one decade. In recent years after moving to academia, China's

telecommunications industry becomes his research area. For the purpose of data collection, close connections with key actors in the Chinese telecommunications market were maintained by him. In this research, this personal network has helped us collect data in different ways.

First, for the past few years, China's mobile telecommunications market has been the focus of domestic and foreign media, researchers, governments and the global information industry. We have followed key events in this market by browsing reports published in the public media. We particularly paid attention to internal reports published by Chinese telecommunications organizations. Under the help of our contact from the Ministry of Information Industry (MII), we were able to access this kind of reports. We have also conducted a thorough library study on academic outlets relevant to our research topic, for example *Telecommunications Policy* and *Communications of the ACM*. Consequently, by now, more than 100 documents were collected. They are the basis and starting point for us to collect the primary data in the next step.

Second, to verify and expand the data collected by the above method, we conducted interviews on key players concerning mobile telecommunications market innovation in China. People we interviewed include: Chief Engineer, Beijing Research Institute, China Telecom; Chairman, Advisory Committee of Information Industry Development Strategy, MII; Director, Telecommunications Policy Research Center, Beijing University of Posts and Telecommunications; Director-general, Strategy Department, China Mobile; Manager of Key Account, China Telecom; Manager of Data Communications, China Unicom. All of these interviewees were the previous colleagues of the first author. The interviews were conducted in two ways: regular telephone calls during the research and face-to-face interviews in January 2006 and July 2007.

In the following case analysis, we mainly use primary data. We occassionally refer to secondary sources, which have been verified with the primary data. For example, the articles of Chen [2006] and Kan [2005] that we will quote in the case study have been verified in our interviews with the authors who are respectively from Beijing Research Institute of China Telecom and Beijing University of Posts and Telecommunications, and other people. In regard to the method of data analysis, we code the data and dissect the case according to our framework in Figure 2.

6.2 The case: China Telecom's strategy of competition in mobile service market

In this section we present the results of our case study. Table 2, 3 and 4 give the condensed results of our analysis on the case of China Telecom, which will be deliberated next.

Table 2: Mobile telecommunications market innovation

Adoption	Customer demand influenced market development – this could partially explain China Telecom's failure in 1G (first generation) and success in PHS system deployment.
Innovation	PHS technology was improved, which guaranteed that PHS infrastructure could support services that met market demand. But, 1G system could not provide users with cheap, high quality services. In technology per se, it was impossible to innovate the 1G system.
Dynamics	In the PHS case, market demand influenced technology innovation; in turn, technology innovation pushes market growth.

Table 3: Social system and market innovation

Providers	The competition between China Telecom and mobile operators promoted mobile market innovation.
Users	Users' requirement on proper services pushed innovation in mobile telecommunications market.
Institutions	Regulators should encourage mobile telecommunications market innovation by promoting the cooperation between mobile operators and vendors. For this purpose, the regulators should also oversee the services prices, adopt a proper plan in issuing mobile network operation licenses, and effectively mandate network and service interconnection.
Interplay between social system and market innovation	Around PHS an efficient social system of innovation was formed, but not so for 1G. The interplay between market innovation and its social system was evident. In the PHS case, there was efficient cooperation between China Telecom and PHS vendors, and the government support. But for the 1G case, these key factors for successful market innovation did not exist.

Table 4: Research questions addressed

Question 1	Mobile services innovated from 1G to 2G. The market structure transformed from monopoly to duopoly. China Telecom deployed PHS as a transitional technology. Infrastructure innovation benefited users and promoted mobile service adoption.
Question 2	China Telecom and its competitor were in different positions in harnessing innovation. The regulators played an important role in a competitive market. Market demand for cheap mobile services and advanced technology pulled innovation characterized by the appearance of PHS. 1G market was a monopoly by the government. 2G technology was deployed in a duopoly market regulated by the government. China Telecom successfully participated in mobile telecommunications market by taking advantage of technology innovation, particularly PHS, and the tight control of government regulation on prices and market.
Question 3	See the last column of Table 3.

In history, the Ministry of Posts & Telecommunications (MPT) monopolized the telecommunications market in China. An interviewee from MII recalled for us that, it was as early as in 1992 when MPT began to provide the first generation (1G) mobile services. According to him, based on analogue technology, the 1G network was expensive to construct. It only provided voice services. The communications quality was poor, and roaming was not supported at all. At this time, as the Chinese economy was still in the early stage of fast growth, there was limited market demand for mobile services, especially for 1G voice services due to their poor quality and high prices. Thus, MPT did not have a strong incentive to invest heavily on 1G network. It would rather use the limited available capital resource on improving the fixed network, which was very backward and had hindered the national economic development in China. Consequently, the 1G network expanded slowly and only covered very few areas of China. In terms of our framework in Figure 2, this was due to the immaturity of 1G technology (the innovation domain) and the very limited market demand for 1G services with a bad communications quality (the adoption domain). Moreover, MPT as the key component of the social network for the 1G market did not have strong interests on it.

From 1994, the GSM system as a 2G technology was introduced into China. In contrast to the case of 1G network, the GSM market developed rapidly. Here we use our framework (Figure 2) to explain this phenomenon. First, the rapid expansion of this 2G network was supported by an efficient social system. In 1994, to remove the bottleneck position in its efforts to build a strong national economy, the Chinese government granted preferential policies to the telecommunications industry thus encouraged it to deploy advanced technologies, including the GSM system. For example, the State Council approved MPT to exact an installation fee from every telephone subscriber that equaled the construction cost of one line. In addition, MPT as the telecommunications monopoly in China was offered privileges in taxation. As a result, more than half of the entire investment capital of MPT came from these preferential policies [Gao, 2005]. Thus, the Chinese government became a critical member of the social system for GSM development. It secured MPT's investment on GSM networks. Second, from the perspective of technology innovation, GSM has significant advantage over its precursor, a 1G analogue system. As a 2G technology, GSM is based on digital technology which guaranteed the good quality for a wide range of voice and data services. Finally, on the market side, as the Chinese economy was booming, the mobile services became an important part of the social life for the normal Chinese people. There was a significant, ever-increasing demand for the mobile services. These factors together enabled GSM network and market to soar in China.

From the mid-1990s, China's telecommunications sector underwent a series of reforms. As a result, competition was introduced into the market. In 1994, the operating sector of MPT was spun off to form China Telecom. Meanwhile, China Unicom was formed, owing the licenses of operating both mobile and fixed networks. Further, in 1998, MII replaced MPT to become a neutral regulator [MII, 1999]. In April 2000, the mobile sector of China Telecom, the most profitable part of it, was devolved into an independent body called China Mobile [Gao, 2005]. Consequently, the present market structure was characterized by the competition between China Unicom and China Telecom in fixed networks, and China Unicom and China Mobile in mobile services. This market structure triggered a new round of mobile telecommunications market innovation. For China Telecom, an efficient social system was formed to promote infrastructure innovation and innovation adoption, which were interrelated processes as argued by our framework in Figure 2.

An informant of us from China Telecom explained to us the strategy of this company to challenge this market structure. At present China Telecom did not have the license to operate mobile services; however, believing that in the future the mobile services would dominate the telecommunications market, China Telecom would not give them up. In fact, China Telecom was expecting that in the near future it would get a license for operating a 3G mobile network. Instead of passively waiting for the 3G license being issued by the government for which there was not an

official plan yet, China Telecom took active strategy to prepare for this transformation. Specifically, China Telecom mobilized the formation of a social system to launch PHS services. It turned out that this initiative of China Telecom to promote mobile telecommunications market innovation benefited itself in not only getting a new point of market growth and increasing the revenue volume, but also establishing a significant user base that China Telecom might carry on to the future 3G market.

PHS is a kind of digital radio networks. It is developed from the same technology as used in cordless phones. PHS system is not a cellular network, but rather a kind of wireless technology providing access to the fixed network. Without its own switching system, the PHS technology uses relay stations to support mobile communications. Comparing with the switching system of GSM, the relay stations of a PHS network are much cheaper to construct. Thus, PHS technology per se enables comparatively lower costs for providing mobile services. PHS handsets are small and exquisite, only half size of normal cellular phones. PHS signal is much weaker than that of cellular phones, so PHS handsets are very efficient in energy consuming and their use does not involve the concern of radio radiation to human bodies, which is the case for a lot of users when using GSM services. They are not mobile telephones but more like cordless telephones operating within a radius of five hundred meters to the relay stations. Modern PHS technology allows user to use PHS phones not only in walking but also when traveling in vehicles like cars [Yuan, Zheng, Wang, Xu, Yang and Gao, 2006]. These technological characteristics of the PHS system, which are covered in the technology innovation dimension in our framework presented in Figure 2, are supportive to the rapid development of the PHS market.

Our interviewees from China Mobile and China Unicom attributed the success of PHS services in China to the fact that there was a significant market demand for them, as explained by the dimension of innovation adoption in our framework. According to a manager of key account from China Telecom, China Telecom started providing PHS services in 1997, when its mobile sector was not deprived yet. In the beginning China Telecom deployed this system only in few cities. The purpose was to provide mobile services with fixed service prices – the rates were just a fifth of that charged for normal mobile services. Most Chinese citizens rarely traveled out of their living cities. To them, cheap mobile services were useful and welcomed, but the roaming function, which was the basic function for GSM but not available in the early versions of PHS technology, did not matter. There was a huge potential market for PHS services. Thus, after its deployment the PHS network soon gained its momentum of rapid development. China Telecom won over a lot of low-end mobile users from China Mobile [Chen, 2006; Zhu, 2005]. As an explanation, a consultant to MII told us that in China the service prices were regulated by the central government, and even MII had no right to decide the basic service prices. With a two-way charge, GSM service prices were five times of that of fixed services, both set by the central government. Consequently, China Telecom gained a big advantage over China Mobile and China Unicom in market competition.

Now we move on to look at the social system for PHS market innovation. The Chinese government's attitude toward PHS was ambivalent. On the one hand, in technology PHS was not as advanced as GSM, not to say the 3G systems. MII hoped the state-owned China Telecom would move directly into the 3G market, rather than invest hugely in PHS which it believed to only have short-range benefits. On the other hand, PHS services satisfied a lot of users for their comparatively low price and acceptable service quality. Thus, in the interests of the public, MII hesitated to stop the PHS deployment. As a result, China Telecom was able to expand PHS network to most parts of China.

China Mobile strongly opposed China Telecom deploying PHS system. It claimed PHS was a mobile communications system; and without a license for operating mobile networks, China Telecom should not be allowed to provide PHS services. In response, China Telecom insisted that PHS was an extension to the fixed services, labeling PHS services as "mobile local services." Finally in 2000, MII stood on the side of customers and made a compromise. It issued Decree Number 604, which stipulated that PHS was a wireless access technology, rather than a mobile cellular technology; PHS network was an extension to fixed network, rather than a mobile network. MII agreed China Telecom to operate PHS network, but with a restriction on providing roaming services [Kan, 2005].

Comparing with GSM services, the key advantage of PHS services was the low price. In terms of our framework, there was a strong user-pull for PHS market development. As mentioned above, the GSM service prices were controlled by the central government and China Mobile could not lower them without its permission. But China was so large and in some areas the governmental regulation did not take effect. Moreover, China Mobile took flexible measures to reduce mobile service prices, like giving users bonus minutes of free calls [Chen, 2006; Zhu, 2005]. Thus, China Telecom had to update the PHS technology and improve the service quality so as to win competition with China Mobile. In fact, as the PHS market expanded fast, this became imperative. For PHS system, the communications capability of its relay stations was very limited. A relay station only supported very limited numbers of calls simultaneously. While not being a problem when there were few users, as the market grew and user size expanded the communications channels of PHS system were frequently congested, which led to very bad

communications quality and even interruption of communications when users made phone calls, especially when in fast moving vehicles [Kan, 2005].

China Telecom needed to address these challenges so as to ensure the further growth of PHS market. As advised by our framework, China Telecom worked together with PHS equipment vendors to push the innovation in PHS infrastructure. As a result, the PHS system was improved which enabled providing similar services to the GSM system. Specifically, the most significant improvement was that PHS system supported the provision of SMS, a key point of profits for the mobile telecommunications market in China, as seen in GSM operation [Yan, 2003]. Meanwhile, the PHS handset design was improved. The old type of PHS handsets had the SIM (Subscriber Identity Module) cards integrated with them. For the new models the SIM cards could be separated from PHS handsets. Thus, when a PHS user traveled to a different city he could buy a new SIM card and use the same PHS handset there. This meant that to certain degrees the roaming restrictions on PHS operation imposed by MII had been lifted [Kan, 2005].

In the beginning, China Mobile did not allow PHS users to send SMS to its GSM customers. However, in reaction to the strong objection from the public, MII stood in the line of China Telecom and ordered the obligation interconnection of the PHS network of China Telecom and the GSM network of China Mobile [Chen, 2006; Zhu, 2005]. Consequently, in the whole process of implementing PHS system, China Telecom successfully got support from the government. As a result, though met resistance by China Mobile, China Telecom formed an efficient social system that supported its initiative of pursuing mobile market innovation to succeed.

7. Discussion, Limitation And Conclusion

As Barnes and Huff [2003] have observed: though theories of technology adoption or innovation help us understand how characteristics of technology, factors underlying human behavioural norms, and industry features have driven the rapid mobile market development, we need a comprehensive framework to explain how these elements together forge this process. Our work moves one step towards this goal. Our framework integrates the adoption and innovation perspectives and hence enables the researchers to have a systematic description on the process of mobile telecommunications market development. This model calls for a dynamic description on the interrelated process of innovation and adoption. It encourages the researchers to disclose the interplay of the market transformation and its social system.

We have used a case from China to justify our framework. Specifically, we draw upon our framework to give a systematic analysis on China Telecom's initiative of promoting mobile telecommunications market innovation. In the beginning, the mobile market situation (the adoption domain in our framework in Figure 2) was that there was a huge demand for cheap voice services. Thus, China Telecom only took advantage of the traditional function of PHS network, which was to provide wireless access to the fixed networks. At this time, the PHS system was basically an improved version of the cordless telephone technology. Few years later, the hot point in mobile telecommunications market changed to be data services. Moreover, the national telecommunications reform deprived the mobile sector from China Telecom. This forced China Telecom actively to seek the formation of an efficient social system to improve the PHS network (infrastructure innovation), making it enable to provide similar services to the 2G networks dominated by China Mobile. This case presents a good example of how mobile telecommunications market development can be realized by properly handling the interrelated infrastructure innovation and innovation adoption through forming an efficient social system.

In line with our framework, the case study argues that it is the status of the dynamics between adoption and innovation, and the interplay between the market and its social system that determine the successful or failed diffusion of a technology, like 1G or PHS in the case of China Telecom. As PHS services were welcomed by customers, the operator had interests to invest in technology innovation and establish an efficient social system of innovation, which, in turn, promoted the continuous development of PHS services, for example SMS and other mobile data communications services. But such a cycle did not exist for the cases of 1G.

The Chinese experiences imply that advanced but less user-friendly, more expensive technologies like GSM are not necessarily more commercially viable than basic but easy-to-use ones like PHS [Yan, 2003]. The case of China Telecom argues that mobile operators should make effort to form an efficient social system to promote the innovation in the mobile market. This innovation should harness the power of both technology advance (technology-push) and market demand (user-pull).

The case study demonstrates that, compared with a traditional innovation or adoption theory, our model offers a higher explanatory power. It provides a tool of improving the current research. Our framework can be used to analyze the different processes of mobile telecommunications market development in varied social and technological contexts. Of practical importance, this framework allows practitioners in the telecommunications market to forecast its potential development as determined by specific social and technological elements. Further, based on our framework, a comparison of different countries can be made. Such a comparative study enables us to

draw rich cross-cultural or cross-national conclusions, and grasp a global perspective of mobile telecommunications market innovation.

Actor-network theory has gained increased attention with researchers trying to extend its applications to areas beyond technology design [Walsham, 1997]. In this paper, we demonstrate that actor-network theory is a suitable tool to analyze the macro process of mobile telecommunications market innovation. Actor-network theory examines the motivations and actions of human actors that enrol themselves into a network and align their interests around specific non-human artefacts. Yet, actor enrolment and interest alignment alone cannot fully explain the mechanism of a change. We observe that this "black-box" can be opened by properly incorporating other theories with actor-network methodology. In our paper, we combine infrastructure innovation and innovation adoption perspectives to describe mobile telecommunications market development as an interrelated process of innovation and adoption supported by an efficient social system composed of proper market actors.

This research has its limitations. To fully take advantage of our framework, we should analyze cases presenting a complete process of mobile telecommunications market development, e.g., that from 2G to 3G. Apart from this, a comparision of countries based on our framework might allow us to identify the patterns of mobile telecommunications market innovation, and conceptualize the social, technological mechanisms that influence this process.

REFERENCES

Abbate, J., *Inventing the Internet*. Cambridge, MA: MIT Press, 1999.

Ajzen, I., *Understanding Attitude and Predicting Social Behavior*. New Jersey: Prentice-Hall, 1980.

Arthur, W.B., "Competing Technologies, Increasing Returns and Lock-in by Historical Events", *Economic Journal*, Vol. 99: 116-131, 1989.

Arthur, W.B., "Positive Feedbacks in the Economy", *Scientific American*, Vol. 262, No. 2: 80-85, 1990.

Attewell, P., "Technology Diffusion and Organizational Learning: The Case of Business Computing, *Organization Science*, Vol. 3, No.1: 1-19, 1992.

Barnes, S.J. and Huff, S.L., "Rising Sun: iMode and the Wireless Internet", *Communications of the ACM*, Vol. 46, No.11: 79-84, 2003.

Bauer, J. M., "Impact of License Fees on the Prices of Mobile Voice Service", *Telecommunications Policy*, Vol. 27: 417-434, 2003.

Bauer, H.H., Barnes, S.J., Reichardt, T. and Neumann, M.M. "Driving Consumer Acceptance of Mobile Marketing: A Theoretical Framework and Empirical Study", *Journal of Electronic Commerce Research*, Vol. 6, No. 3: 181-192, 2005.

Bloomfield, B.P., Coombs, R., Cooper, D.J. and Rea, D., "Machines and Maneuvers: Responsibility Accounting and the Construction of Hospital Information Systems", *Accounting, Management and Information Technologies*, Vol. 2, No. 4: 197-219, 1992.

Bowker, G., Timmermans, S. and Star, S.L., "Infrastructure and Organizational Transformation: Classifying Nurses' Work", in *Information Technology and Changes in Organizational Work*, W. Orlikowski, G. Walsham, M. Jones and J. DeGross (ed.), London: Chapman and Hall pp.344-370, 1996.

Callon, M., "Techno-economic Networks and Irreversibility", in *A Sociology of Monsters: Essays on Power, Technology and Domination*, J. Law (ed.), London: Routledge, pp.132-161, 1991.

Chen, S.J., "Xiaolingtong, GSM and 3G Will Co-exist", *People's Post and Telecommunications*, June 16, 2006.

Ciborra, C.U., *From Control to Drift: The Dynamics of Corporate Information Infrastructures*. Oxford, UK: Oxford University Press, 2000.

Davis, F.D., "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology", *MIS Quarterly*, Vol. 13, No. 3: 319-340, 1989.

Dosi, G. and Freeman, C., Nelson, R. and Soete, L., *Technical Change and Economic Theory*. London: Pinter, 1988.

Edquist, C., *Systems of Innovation: Technologies, Institutions, and Organizations*. London: Pinter, 1997.

Edquist, C., *The Internet and Mobile Telecommunications Systems of Innovation*. UK: Edward Elgar, 2003.

Faraj, S., Kwon, D. and Watts, S., "Contested Artifact: Technology Sensemaking, Actor Networks, and the Shaping of the Web Browser", *Information Technology and People*, Vol.17, No.: 172-209, 2004.

Fransman, M., *Telecoms in the Internet Age: From Boom to Bust to . . . ?* Oxford, UK: Oxford University Press, 2002.

Gao, P., "Using Actor-network Theory to Analyze Strategy Formulation", *Information Systems Journal*, Vol. 15: 255-275, 2005.

Glaser, B.G. and Strauss, A.L. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. New York: Aldine Publishing Company, 1967.

Harris, P., Rettie, R. and Kwon, C.C., "Adoption and Usage of M-commerce: A Cross-cultural Comparison of Hong Kong and the Uniter Kingdom", *Journal of Electronic Commerce Research*, Vol. 6, No.3: 210-224, 2005.

Holmes, M. and Poole, M.S., "The Longitudinal Analysis of Interaction", in *Studying Interpersonal Interaction*, B. Montgomery and S. Duck (ed.), New York: Guilford, pp. 286–302, 1991.

Kan, K.L., "Lessons from PHS Phenomena", *Working Paper*, Beijing University of Posts and Telecommunications, 2005.

King, J.L., Gurbaxani, V., Kraemer, K.L., McFarlan, F.W., Raman, K.S. and Yap, C.S., "Institutional Factors in Information Technology Innovation", *Information Systems Research*, Vol. 5, No. 2: 139-169, 1994.

Lyytinen, K. and Damsgaard, J., "What's Wrong with the Diffusion of Innovation Theory"? in *Diffusing Software Product and Process Innovations*, M.A. Ardis and B.L. Marcolin (ed.), Boston, MA: Kluwer Academic Publishers, pp.173-190, 2001.

Lyytinen K. and King J., "Around the Cradle of the Wireless Revolution: the Emergence and Evolution of Cellular Telephony", *Telecommunications Policy*, Vol. 26: 97-100, 2002.

Maitland, C.F., Bauer, J.M., and Westerveld, R., "The European Market for Mobile Data: Evolving Value Chains and Industry Structures", *Telecommunications Policy*, Vol. 26: 485–504, 2002.

MII, *China's Telecommunications Industry over 50 Years*. Beijing: MII, 1999.

Muller-Veerse, F., *Mobile Commerce Report*. London: Durlacher Research Ltd., 2000.

Okazaki, S., "New Perspectives on M-commerce Research", *Journal of Electronic Commerce Research*, Vol. 6, No. 3: 160-164, 2005.

Pagiavlas,N., Marburger, P., Stratmann, M. and Young, S., "Mobile Business – Comprehensive Marketing Strategies or Merely IT Expenses? A Case Study of the US Airline Industry", *Journal of Electronic Commerce Research*, Vol. 6, No. 3: 251-261, 2005.

Pavlou, P.A. and Chai, L., "What Drives Electronic Across Cultures – A Cross-cultural Empirical Investigation of the Theory of Planned Behavior", *Journal of Electronic Commerce Research*, Vol. 3, No. 4: 240-253, 2002.

Pedersen, P.E., "Adoption of Mobile Internet Services: An Exploratory Study of Mobile Commerce Early Adopters", *Journal of Organizational Computing and Electronic Commerce*, Vol. 15, No.3: 203-221, 2005.

Rogers, E.M., *Diffusion of Innovations.* New York: The Free Press, 1995.

Rosegger, G., *The Economics of Production and Innovation: An Industrial Perspective*. 3rd edition, Oxford, UK: Butterworth-Heinemann, 1996.

Sawyer, S., Allen, J.P. and Lee, H., "Broadband and Mobile Opportunities: A Socio-technical Perspective", *Journal of Information Technology*, Vol. 18, No. 2: 121-136, 2003.

Star, S.L. and Ruhleder, K., "Steps toward Ecology of Infrastructure: Design and Access for Large Information Spaces", *Information Systems Research*, Vol. 7, No. 1: 111-134, 1996.

Tornatzky, L.G. and Klein, K.J., "Innovation Characteristics and Adoption-Implementation", *IEEE Transactions on Engineering Management*, Vol. 29, No. 1: 28-45, 1982.

Tuomi, I., *Networks of Innovation: Change and Meaning in the Age of the Internet*. Oxford, UK: Oxford University Press, 2002.

Van de Ven, A.H., "A Community Perspective on the Emergence of Innovations", *Journal of Engineering and Technology Management*, Vol. 10: 23-51, 1993.

Venkatesh, V., Morris, M., Davis, G. B. and Davis, F. D., "User Acceptance of Information Technology: Towards a Unified View", *MIS Quarterly*, Vol. 27, No. 3: 425-478, 2003.

Walsham, G., "Actor-network Theory and IS Research: Current Status and Future Prospect", in *Information Systems and Qualitative Research*, A.S. Lee, J. Liebenau and J. DeGross, J.I. (ed.), London: Chapman & Hall, pp. 466–480, 1997.

Walsham, G. and Sahay, S., "GIS for District-level Administration in India: Problems and Opportunities", *MIS Quarterly*, Vol. 23, No. 1: 39-66, 1999.

Wolfe, R.A., "Organizational Innovation: Review, Critique and Suggested Research Directions", *Journal of Management Studies*, Vol. 31, No. 3: 405-431, 1994.

Yan, X., "Mobile Data Communications in China", *Communications of the ACM*, Vol. 46, No. 12: 81-85, 2003.

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

Yuan, Y., Zheng, W., Wang, Y., Xu, Z., Yang, Q. and Gao, Y., "Xiaolingtong versus 3G in China: Which Will Be the Winner"? *Telecommunications Policy*, Vol. 30: 297-313, 2006.

Zhu, B., "China's 3G Puzzles", *New Fortune*, April, 2005.