Diffusion of Broadband Mobile Services in Korea: The Role of Standards and Its Impact on Diffusion of Complex Technology System

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Introduction

Rapid developments in computing and communication technology have made broadband Internet service over the wireless phone networks possible. This so-called 3G (third generation) mobile services promise to usher us into an era of a seamless marriage between Internet data and mobile phone services. However, despite the much-hyped fanfare in the media, the actual diffusion of 3G services has been much slow and disappointing in most countries. South Korea has been one of one of few countries that have experienced rapid development and diffusion of 3G and the less-advanced 2.5G (two and half generation) mobile services. Given the rapid and ubiquitous penetration into everyday use in Korea, broadband mobile services in Korea offers an unique opportunity for us to examine how complex technology gets accepted in a larger scale.

In this study, we seek (a) to offer theoretical explanations for the pattern of diffusion of broadband mobile services in Korea and (b) to gain new theoretical insights on the diffusion of innovation of complex technology systems. In particular, we are interested in the role of standards and their impact on the diffusion of complex technology systems innovations. We use Anctor network Theory (ANT) as a theoretical lens to investigate the complex evolution of the broadband mobile services in Korea.

Theoretical background

Diffusion of Innovation

According to Rogers (1995), diffusion of innovation can be defined as the process "by which an innovation is communicated through certain channels over time among the members of the social systems." Typically, a sequential stage model consisting of adoption and implementation phases is assumed (Cooper & Zmud, 1990; Fichman & Kemerer, 1997). The past research has sought to explain diffusion of innovation based on the adopter characteristics, the social network in which the adopters belong to, the communication process, the characteristics of the promoters, and the attributes of the innovation itself including triability, relative advantage, compatibility, observability, and complexity (Cooper & Zmud, 1990; Davis, Bagozzi, & Warshaw, 1989; Fichman & Kemerer, 1997; Zmud, 1984). At a more macro-level, other scholars sought to explain diffusion of innovation at an industry level by looking at the characteristics of innovative firms (Dosi, 1988), absorptive capacity of individual companies (Cohen & Levinthal, 1990), or the process by dominant designs emerge (Anderson & Tushman, 1990).

Although the traditional diffusion of innovation theory has provided many useful insights to understand the adoption and diffusion of technologies in the past, recent work in the diffusion of complex technology point out its limitations (Faraj, Kwon, & Sussman, forthcoming; Lyytinen & Damsgaard, 2001; Tuomi, 2002). In particular, traditional diffusion of innovation studies treat innovation as distinct and measurable features (Rogers, 1995). Thus, the innovations are often characterized as unproblematic, complete, unambiguous objects that needs to be "diffused" as they are in a linear temporal sequence.

However, complex technologies such as broadband mobile computing service are ambiguous, problematic, messy, and malleable. Such complex technologies have *interpretive flexibility* (Bijker, 1995;

Orlikowski, 1992). As such, actors who belong to different communities construct different meanings of the innovation. Therefore, these technologies are socially constructed, and simultaneously, community shaping (Hughes, 1987).

Therefore, the study of innovation and diffusion of complex technological systems like broadband mobile computing services must cross several realms of scientific, public and economic activities ranging from observations of ideas, theories and laboratories, industrial policy and regulation, to explorations of marketing strategies and changes in consumer behavior. Most of these features are addressed separately and in isolation by lines of research. Though each issues mentioned above is useful in understanding a specific phase or aspect in the innovation and diffusion process, each one alone is inadequate to account for the dynamic evolution of complex technical systems.

Research Framework

Drawing on a framework suggested by Lyytinen and King (2002), we conceptualize the diffusion of complex technology systems innovations as dynamic interplay among actors in three different realms: innovation system, regulatory regime, and market place. Our research theoretical framework is based on the following premises. First, the evolution of broadband mobile computing service systems is critically dependent upon the specification and implementation of **standards** (Funk, 2001; Funk & Methe, 2001; Haug, 2002; Lehenkari & Miettinen, 2002). By standard we mean any written artifact, which enables effective coordination of activities between independent users of telecommunication technologies including manufacturers and service providers. There are three ways that standards set in: *de facto* standards set by markets (often proprietary) as in U.S., voluntary industry agreements, and *de jure* standard mandated like GSM (Global Systems for Mobile communications) in Europe and CDMA (Code Division Multi Access) in Korea and the US by National Standard Bodies (NSB) like government and ITU (Gandal, Salant & Waverman, 2003).

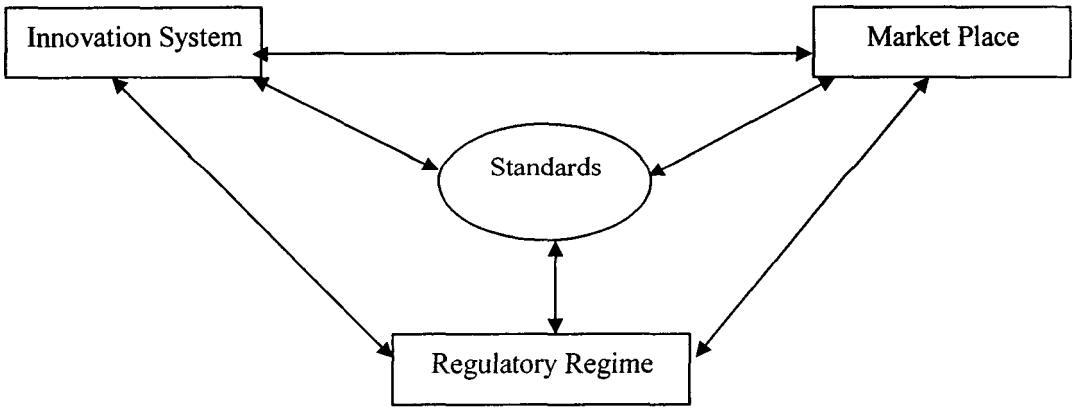


Figure 1. Research Framework

Second, according to ANT, in order to faithfully understand the development of new technology, one needs to examine interrelationships among actors, institutions, the environments, and artifacts which form *actor networks*. Thus, we argue that in order to provide a faithful and explanatory account regarding *why* and *how* the broadband mobile computing services have evolve like they have, we must analyze dynamic and critical relationships among actors in three realms. These are the *innovation system*, the *regulatory regime*, and the *market place*. These three realms of activity and their dynamic interactions establish an entity what we shall call *an innovation and diffusion system*.

By an **innovation system** we mean the interlinked network of sites, competencies, ideas and resources, which is capable over time to develop novel technologies and solutions based on research,

experimentation and development activity. The process generated by the innovation system is called here an ***innovation cycle*** (due to the continuous and path dependent nature of the activity). By a **regulatory regime** we mean any type of authority (industrial, national, international), which can influence, direct, limit or prohibit any activity in any other systems in the innovation and diffusion system including the regulatory regime itself. This right is normally endowed through the concept of statehood and public control over economic or other types of activity. The process generated by the regulatory regime is called ***regulatory cycle***, which normally results in some form of decision. A regulatory cycle includes *regulatory intervention* like licensing and frequency allocation and *regulatory monitoring* like pricing and quality assurance. Changes in regulatory regime can have fundamental impact on other regimes through measures like market liberalization and licensing. By **market place** we mean a set of actors that produce some telecommunication services or technologies (within a value chain) exploiting the technological potential defined within a telecommunication standard. These services and the interactions follow in most cases principles of economic exchange and involve exchange of goods and services between independent actors against tokens of exchange. The process generated within the market place is called a ***diffusion cycle*** which covers the willingness and propensity of the actors to adopt and utilize services and technologies enabled by the wireless standard. The concept of market place includes changes in customer behavior, introduction of new services, and sources and means of possible competition for different market segments due to the transfer and channeling of innovation in the market place.

Furthermore, we assume that each one of these systems is in a constant flux and continually interacts dynamically with the two others either through feed-forward (e.g. market and service anticipation in the innovation system), or feedback loops (exploitation of market experiences). Therefore, the framework must help in analyzing the relationships between such behaviors like: innovation and standardization, regulation and standardization, or diffusion and standardization.

Finally, we posit that these relationships are mediated through standards as boundary objects. Boundary objects are media through which different groups of actors connect. According to Star and Griesemer (1989), boundary objects are "both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (p. 393). *Plasticity*, or malleability, is particularly important if knowledge needs to be created through the interactions between different communities of practice (Henderson, 1991). Many of the existing accounts of innovation and diffusion literature do not adequately analyze the critical relationships between such behaviors – this in particular applies to relationships between innovation and standardization, and diffusion and standardization. According to ANT, *inscribing* and *translating* are two main processes by which actors and artifacts are interconnected and mobilized to transform actor networks. Inscription refers to the way technical artifacts embody patterns of use. Translations refers to a variety of ways by which actors seek to persuade others and enroll them into an irreversible alignment with a existing or prospective network. Thus, success and failure of innovation diffusion can be understood in terms of the emergence (or lack thereof) of such transformation of actor network.

These interactions and critical "episodes" of making the innovation traverse through alternative conduits in the system of three interacting elements is in our opinion a key to understanding how complex wireless services and associated standards are built and evolve. This approach assumes innovation and diffusion of complex technology system is non-linear, problematic, and uncertain process that has been neglected in previous studies in the innovation literature. Furthermore, this perspective helps us to see innovation and diffusion as intertwined on-going technical and social negotiation processes in actor networks, thus helps us overcome a simple linear evolutionary perspective that is often depicted in the literature. We, therefore, propose that for a broadband mobile computing service to become widely accepted in the marketplace, it must meet the following criteria:

1) It must embody a set of standards which enable the integration and manufacturing of complex wireless technologies and other *peripheral technologies* which at the same time embody advances in the activities of the innovation system:
2) It must overcome major barriers and "critical episodes" in all three realms of the innovative systems (key technological challenges), the regulatory regime (obtaining rights and political will to operate, license and regulate such services), and the market place (introducing successfully new service concepts, pricing, customer service and competitive differentiation). Thus, the failure of the evolution of broadband mobile computing services may occur due to failures in the innovation system (failure to develop a standard), failures in the regulatory system (failure to recognize the standard, or the service implied by it, failure to enforce the standard), or failures in the market place (failure to make users adopt the standard or services based on the standard): and,

In the world of broadband mobile services, South Korea represents as an interesting case because Korea was a latecomer in the global competition of digital mobile services in the late 1980's which was dominated by European and the US companies. Despite this late start, Korea has emerged as one of the leading countries of broadband mobile services in early 2000's. In order to understand this rapid pace of innovation and diffusion of broadband mobile services in Korea, we conducted an in-depth field study.

Research Methodology

Our field study involved 22 in-depth interviews with key actors in all three realms and extensive archival research. We sought to analyze the roles of and relationships among actors (a) during the early stage of digital mobile services development (early 1990's) and (b) during the early stage of 3G diffusion in early 2000's. The interviewees include three major mobile phone operators (SK Telecom, KT Freetel, LG Telecom), manufacturers of both handset and network equipment (Samsung Electronics, LG Electronics), leading telephone company (Korea Telecom), ETRI (Electronics and Telecommunications Research Institute), the Ministry of Information and Communication (MoIC), and content & solution provider (Witcom), and middleware provider (FEELink). Most interviews were conducted in face-to-face which were audio taped, except the interview with MoIC which was conducted via e-mail.

In addition to interview data, we analyzed to archival data related to CDMA developments in Korea from various sources including white papers, technical reports, news magazines, and congress hearing transcripts. This archival data analysis provide important information regarding the development of broadband mobile services in Korea, but also offer important insights regarding the roles of *periphery innovations* in Korea including Internet, digital entertainment industry, landline telephony, personal computers, and other mobile technologies such as wireless local area network. Following the actor-network approach (Latour, 1987), we began with the known actors (operators and ETRI), then expanded our interview list as we followed the actors in the network. The focus of our interview was examining the actors' role in the development broadband mobile services in Korea and their relationship with others. We also asked their role in the establishment of various standards for broadband mobile services. Through this, we attempted to gain an understanding the dynamic and reciprocal pattern of interrelationship among actors over time as broadband mobile services in Korean gained its momentum in the market place.

Results

We present our results in three sections. The first section provides a historical overview of the evolution of Korean mobile phone service market. The second and the third section provides a more detailed and rich description of the actors' role and their relationship for 2G and 3G (and 2.5G), respectivey.

Korean Mobile Phone Industry

Mobile phone services were first introduced in Korea in 1984 by Korea Mobiele Telcomm (KMT), a spin-off of KT. KMT enjoyed its government monopoly during the entire 1G (first generation) era utile it was acquired by SK Telecom (SKT) in 1994. During that period, all the network equipments were imported from AT&T and Motorola. In late 80's, Korea government selected mobile telecommunication as one of the nation's key strategic industries for future export began looking for ways in which they can develop internal capabilities.

After facing stiff resistance from countries who own intellectual properties on GSM for the 2G, Korean government, research institutions, and private companies began working with QUALCOMM to commercialize CDMA. Unlike European GSM standard that improves spectrum capacity by dividing each frequency channel into time slots each of which is allocated to each user (TDMA: Time Division Multiple Access), CDMA allows multiple accesses by assigning each user a pseudo-random code, which differentiates each call simultaneously carried over the same spectrum. After the Korean government announced that CDMA would be the only standard for 2G mobile services in Korea, SKT launched the world first commercial CDMA service in January 1996. Since then, Korean CDMA market saw unprecedented rapid growth. During the same time, Korean firms and research institutions also rapidly gain technical competencies in manufacturing and design of new handsets and network devices and became a significant player in the global mobile phone market.

While the Korean government adopted a single-standard policy for the 2G services, it chose to adopt multi-standard policy for the next generation 3G services. There are two different standards for the 3G services. CDMA2000 is a continuation of QualComm's 2G CDMA technology. It is known as synchronous mode because the communication between handset and base stations are synchronized based on the same time zone, set by the global position systems (GPS) satellites. On the other hand, wCDMA (wideband CDMA) is an European standard that does not require GPS satellites by the US government. In this standard, each bas station needs to have its own code and promises a global roaming which has been the trademark of GSM standard. The Korean government awarded wCDMA licenses to SKT and KT FreeTel (KTF) in July 2000, and in August 2001, a CDMA2000 license was awarded to LG Telecomm (LGT). Table 1 summarizes the evolution of wireless service operators in Korea and Table 2 shows their relative market shares. As the table shows, SKT has been a leading service operator in the CDMA domain.

Table 1. Evolution of Wireless Service Operators in Korea

	1G	IS-95a CDMA	IS-95b CDMA	CDMA 2000 1x	CDMA 2000 1x EVDO
SKT	July, 1988	January, 1996 (World first)	August, 1997 (World first)	October, 2000 (World first)	November, 2002
KTF	April, 1984	October, 1997	July, 1999	May, 2001	May, 2002 (World first)
LGT	N.A.	October, 1997		May, 2001	N.A.

Table 2. Market share of operators (in terms of the number of registers)

2002		2001		2000		1999	
SKT	53.2%	SKT	40.9%	SKT	40.8%	SKT	43.1%
KTF	31.9%	KTF	33.0%	KTF	19.7%	KTF	18.2%
LGT	14.8%	LGT	14.7%	LGT	14.7%	Shinsegi	13.8%
		Shinsegi	11.4%	Shinsegi	13.1%	LGT	13.2%

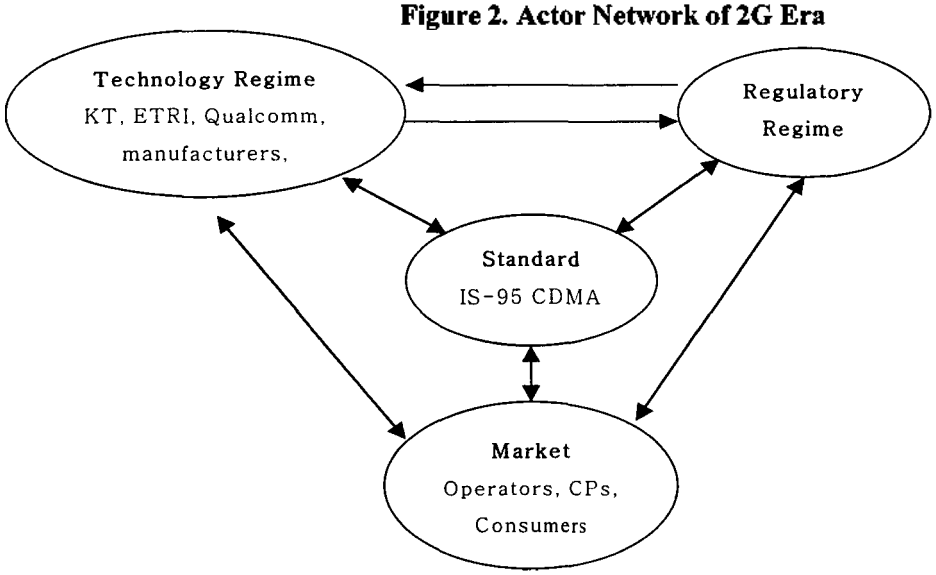
				KTM.com	11.7%	KTM.com	11.7%

KTF acquired KTM.com in 2001 and SKT acquired Shinsegi in 2002.

2G Era (1989 – October 2000)

This era can be characterized with a close collaboration among government, research laboratories (both private and government-funded), and operators in commercializing CDMA which was still in its conceptual stage. Figure 2 shows the actors and their relationship during this era.

Figure 2. Actor Network of 2G Era



Technology Regime

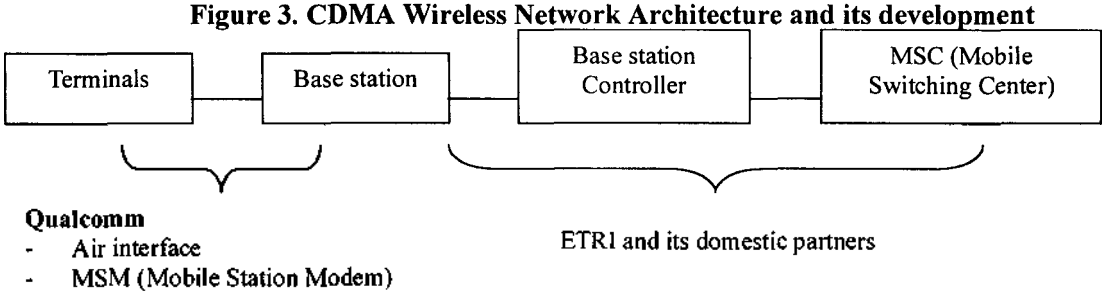
CDMA began to be developed since 1989. The first phase was launched in 1989 (through 1992) under the supervision of ETRI with the total amount of 4.5 billion won and 63 researchers. The second phase proceeded through 1990-1996 with the budget of 44.1 billion won and 608 researchers. Qualcomm was invited to join the project in 1990 with its own investment of USD 16.95 million). Between 1990-1995, four other companies joined the project as DM (Designated Manufacturers): Samsung Electronics, LG IC (later changed to LG Electronics), Hyundai Electronics, and Maxon. The first three companies each invested US$ 8.5 million for developing infrastructure and terminals in this project (also promised 6.0% and 6.5% royalties to Qualcomm for domestic and foreign sales, respectively). Meanwhile, Maxon invested US$3 million (with the promise of 5.25% and 5.75% royalties to Qualcomm for domestic and foreign sales, respectively) to focus only on terminal. Meanwhile, the foreign manufacturers did not participate in this consortium because they focused on the GSM market.

In all phases, KT played a significant leading role since KT had experience of managing large scale development and commercialization telecommunication technologies in the past. KT dispatched its researchers to ETRI, and managed the project at ETRI related to CDMA development. It was also involved in the system architecture design and the dealing with Qualcomm for the contracts.

Qualcomm developed the core technology for CDMA standard. By late 80's they already had 53 patents on radio air protocol and MSM (mobile station modem). On the other hand, ETRI, and its domestic partners, brought their experiences of developing domestic TDX exchange systems during mid 80's.

They focused on modifying existing TDX architecture in order to deploy CDMA network in a large scale. Figure 3 shows the simplified representation of the architecture of CDMA network and the roles of Qualcomm and ETRI. The resultant standards are known as a family of IS-95 CDMA standards, or also known as cdmaOne.

Figure 3. CDMA Wireless Network Architecture and its development



Operators, in particular SKT, also played significant roles in the development process. SKT organized a special taskforce for CDMA in order to conduct various field tests that provided critical feedback to the commercialization processes. Samsung Electronic developed a tight relationship with SKT by offering its latest handset models only to SKT.

Regulatory Regime

Korean government played significant roles in the early stage of CDMA development in several different ways. First, the Korean' government shaped the Korean telecommunication industry through its strong industrial policy. By the end of the 1970's, telecommunication services in Korea had been strictly controlled by the Korean government for national security due to the ideological and political standoff with North Korea. However, by the late 1980's, the South Korean government officials began to recognize the potential of telecommunication technology as a means of economic value creation (Kim, 2003a). This is reflected in the transformation of the Ministry of Post and Telecommunication, which used to regulate postal and telephone service, into the Ministry of Information and Communication in 1994 (Chang, 2003). Government, thus, significantly invested to modernize telecommunication infrastructure by spending an annual average of 1 trillion won between 1982 and 1986. The government has already set up ETRI, a research institute in 1976. Through the government funding, ETRI developed TDX technologies and licensed them to all major domestic telecommunication equipment manufacturers. As noted earlier, this capability of TDX domestication was proven to be critical in the development of CDMA technologies. Furthermore, the TDX infrastructure paved a way of more advanced digital data network infrastructure. In January 1989, the Korean Government chose the digital mobile communication as one of the national industrial project priorities.

A second, and perhaps most controversial policy decision, was the Korean government's decision to adopt CDMA over European GSM standard in November 1993. Since GSM was adopted by European countries in 1987 as a standard and it offers a global roaming capability, some operators and manufactures in Korea preferred GSM (Song, 1999). However, the government pushed the adoption of GSM for the apparent possibility of large call volume that CDMA can handle and the Qualcomm's willingness to share technology with Korean firms. On the other hand, by the late 1980's, the GSM community was established and had little incentive to share intellectual property with an outsider who did not have its own to share with the existing members. This became an important incentive for Korean government to pursue an alternative technology for 2G mobile services. The decision to standardize with

CDMA helped Korean operators and manufactures avoid problems that the U.S. firms faced with multiple standards (Chang, 2003; Funk, 2002).

Third, the Korean government provided an important role in the development and commercialization of CDMA technologies by working closely with industry partners. Government set up a research fund for CDMA technology from the license fee collected from the five operators based on the market share. The fund was managed by IITA (Institute of Information Technology Assessment) whose board consists of executives from operators, except one member. The government played a key role by arranging the collaboration between SKT, ETRI, KT, and manufacturers from the beginning so that the time lag between the technology development and commercialization can be minimized. The government also encouraged the synergy between operators and manufacturers by allowing a scheme called Vental (vendor and telecom operators) in which operators are allowed to run own business units for equipment manufacturing. Such a partnership has been proven to be very important in telecommunication industry (Steinbock, 2003)

Finally, the Korean government introduced deregulation of communication services, particularly in wireless phone and broadband internet services. As noted earlier, in 1991, the KMT was privatized and later became SKT. In 1996, had an auction for the four additional operators. As a result of introducing five operators in a relatively small and new market, the government set the stage of fierce competition in the market place as noted below.

Market

There were five operators chosen by the Korean government for the 2G services. Three operators were selected for PCS services (KTF, LGT, Hansol) and two operators for cellular services (SKT and Shinsegi). In January of 1996, SKT successfully launched the world first commercial CDMA services. The second operator (Shinsegi Telecom) began offering commercial service in April 1996. Within seven months, they reached 100,000 subscribers and within a year a half million. Three more operators (KTF, LGT, and Hansol) provide PCS service began offering their services in October 1997. All operators added data service function in the late 1998 (14.4kbps), and upgraded the network to IS-95b CDMA in 1999 (64kbps).

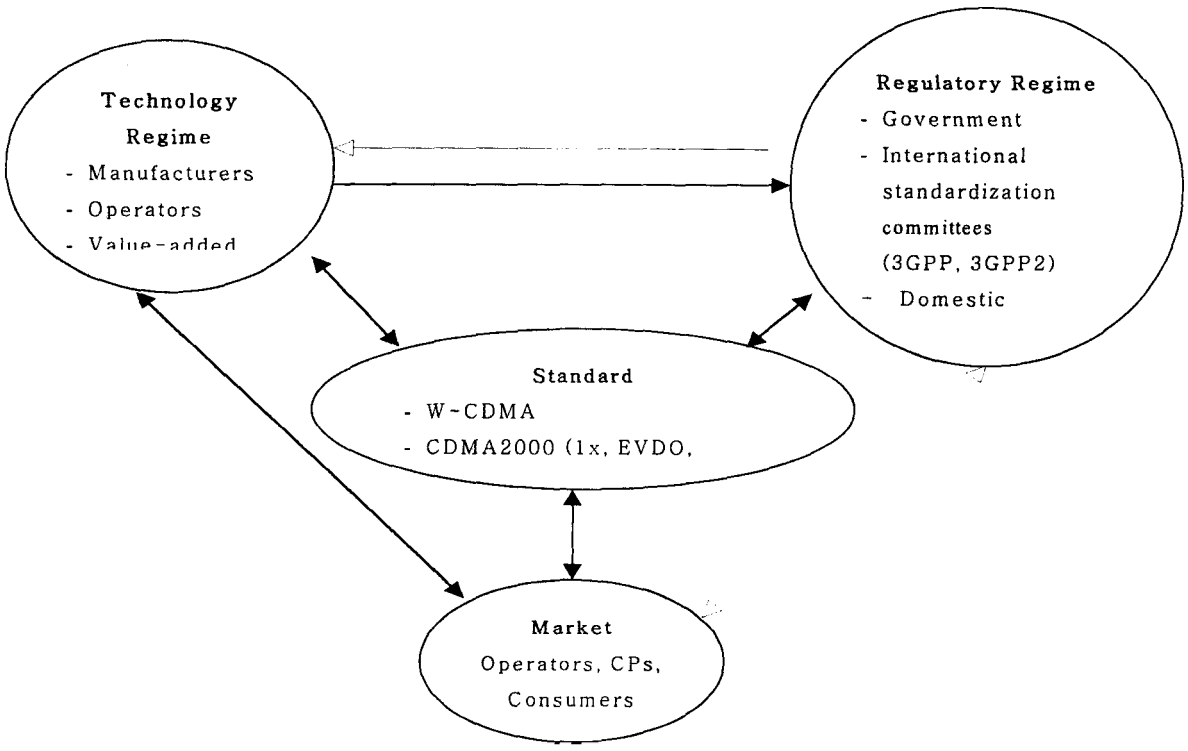
The relatively small market size and the large number of operators created fierce competition among them. The competition, however, facilitated the rapid market penetration of CDMA services through the price competition. For example, all the operators aimed at the first mover advantage, and subsidized the consumers with the almost full cost of handset purchase.

During this period, the killer contents were short-messaging services (SMS), VSM, and Caller ID. Unlike foreign operators, Korean operators collaborated in developing content services in order to expand the market size. Typically, when a new content provide comes up with a new data service idea, the operators had exclusive rights to offer the service for three to six months before the content operators could provide similar services through other operators. For example, Catch Call service (that retains the caller-number while the receiver-phone is off) was first launched with KTF. However, it soon became available to other operators. The key reason behind this is that non-interoperable services across operators were not popular among subscribers. The explosion of SMS services which dated back when three operators interoperated their SMS services in 1998 is another example of the importance of interoperability.

2.5G and 3G Era (October 2000 --)

SKT opened the era of broadband mobile services in the form of 2.5G services in October 2000 by began to use CDMA 2000 1x for the first time in the world[1]. Soon, KTF and LGT followed the suit by offering their own 2.5G services in May 2001. As broadband mobile technologies continue to evolve, this era shows radically different network of actors. Figure 4 shows the summary of the relationship among key actors during this era.

Figure 4. Actor Network of 2.5G and 3G Era



Technology Regime

As the bandwidth of 2G was proven to be insufficient to support high-volume data transmission for the multimedia broadband internet services over the mobile phone network, new standards for 3G began to emerge. International Mobile Telecommunication-2000 (IMT-2000) is the global standard for 3G wireless communications, defined by a set of interdependent ITU (International Telecommunication Union) recommendations. Both wCDMA and CDMA2000 are officially included in thi IMT-2000 family. In Korea, manufacturers preferred wCDMA because leading European countries chose it. Since wCDMA is incompatible with both GSM and CDMA2000, they predicted that there would be substantial size of new markets for both the network and terminal equipments (Gandal, Salant & Waverman, 2003).

During the previous era, Korean manufacturers significantly added their own technical innovation capability. For example, Samsung became the world largest CDMA handset manufacturer and the second player in the global market only next to Nokia. Similarly, LG Electronics also gained substantial footing in the global handset area. Combined, Korean firms occupy over 60% of the global CDMA handset market. While they still rely on core technology developed by Qualcomm, they often lead innovations in

[1] The world first commercial 3G service was offered by Japanese DoCoMo in the form of FOMA, a variant of wCDMA standard in October 2001.

new features, such as multimedia and new display screens, as a result of their tight collaborations with domestic operators who constantly try new types of services. Also important to note is that domestic manufactures dominate the domestic market for both handset and network equipments. For example, in 1995, Motorola had a dominant position of 52% in Korean handset market. However, by 1999, domestic manufacturers took over more than 90% of market share. Another significant change is that Samsung developed its own CDMA 2000 chipset in early 2003. Taken together, Korean firms have shown dramatic increase in their innovation capability in CDMA area and increased their influences in the market.

On the other hand, a number of dominant players of 2G have lost their influences. For example, KT invested 10.5 billion Korean won in various 3G development projects. KT also acquired the 3G business license from the government, and launched KT ICOM for 3G business, which was later acquired by KTF. However, KT never played such a significant leading role in this era as it did during the previous era. Foreign manufacturers (Ericsson, Motorola, and Nokia), who did not participated in the development and commercialization of 2G CDMA services in Korea, invested for IMT2000 initiatives. However, they have not been able to capture any significant portion of the market during this ear.

Two most important actors whose roles were significantly decreased are Qualcomm and ETRI. While Qualcomm was still a dominant player in CDMA2000 domain, a number of its competitors began producing compatible chipsets including Samsung as noted above and Nokia, among others. Furthermore, Qualcomm was at odd with some of operators in Korea in terms of the evolutionary path of CDMA2000. While Qualcomm preferred to follow the evolutionary path of CDMA2000 1x → CDMA 1x EVDO → CDMA 3x, LGT planed to skipped CDMA 2000 1x EVDO and wants to implement CDMA 2000 1x EVDV, which was opposed by Qualcomm. Simiarly, the role ETRI, who played a vital leading role in the development and commercialization of 2G CDMA, diminished significantly in this era. It only played a supporting role in developing 3G.

A key technology obstacle for the successfully implementation of broadband mobile data service was the standard for mobile internet data platform. In 2G, WAP (Wireless Application Protocol) and iMode were two standards. As service providers and content providers begin to offer more advanced data services, three major operators in Korea implemented their own platforms to run various internet-based applications on mobile handsets. Table 3 shows the five different platforms that three operators offer.

Table 3. Proprietary Mobile Internet Platforms for Broadband Data Services

Service Providers	Mobile Internet Application Platform
SKT	GVM
	SK-VM
KTF	BREW
	MAP
LGT	KVM

However, since these platforms did not offer interoperability across operators, the three major operators, TTA (Telecommunications Technology Association) and ETRI developed a standard for mobile internet called WIPI (Wireless Internet Platform for Interoperability). This was adopted as a part of wCDMA standards by 3GPP (the 3rd Generation Partnership Project), which is an international forum to establish wCDMA standards in may 2002. This is another significant sign that Qualcomm's influence was diminished given that Qualcomm was promoting its own BREW (Binary Run-time Environment for Wireless). Also, the prominent role that TTA, which is an association of private sector companies, in the development of WIPI was an evidence of the shift of the center of the technology innovation activities from Government-led research initiatives to private sector in Korean mobile service industry.

An important group of actors that emerged in this era is the value-added solution providers for various form of multi-media contents. They connected contents providers to mobile operators' network. While operators wanted to maintain exclusive relationship with these solution providers, most of them deals with all three operators, which reflects their growing bargaining power in the network.

As the deployment of much-hyped wCDMA was delayed and the cost of multimedia data service through 3G proved to be too expensive, a group of actors began exploring an alternative broadband mobile internet technology called Portable Internet (PI) utilizing 2.3Ghz spectrum. It was primarily pushed by landline operators and broadband service providers including KT, Hanaro Telecom, and Dacom as well as ETRI. They were collaborating with two U.S. partners – Flarion and ArryComm—who own core technologies. It is interesting to note that these are actors who were not active in the 3G actor network.

Regulatory Regime

During the 3G era, the Korean government turned to multiple standard policy, adopting both wCDMA and CDMA2000 1x. Govern gave licenses for wCDMA to SKT and KTF, and for CDMA 2000 to LG Telecom.

The Korean government's continuing deregulatory telecommunication policy toward landline telecommunications facilitated the rapid penetration of broadband Internet service in Korea. The government selected Hanaro Telecom as the second local phone service provider who focused on broadband service in order to gain market recognition. KT had to react to this strategic threat by offering its own broadband services. The government deregulation policy also encouraged from other industries such cable network companies and power utility company offering their own broadband services. Consequently, the consumers who were used to high-speed Internet access through landline began to expect similar experiences in the mobile Internet domain, which formed an important market factor behind the rapid diffusion of 3G services in Korea as we will note below.

An important changes in the regulatory regime is that emergence of the standardization organizations, both domestic and international. Domestically, TTA became an important institution for the development of IMT-2000 standards. As noted above, TTA played an important role of WIPI along with other 3G-related standard specifications. Internationally, 3GPP and 3GPP2 (The 3rd Generational Partnership Project 2) were established as official international standardization bodies for wCDMA and CDMA 2000, respectively. TTA represented Korea for both organizations. This is a significant change in their negotiation position compared to the 2G era.

Market

All three operators successfully implemented 2.5G by May 2001 using CDMA 2000 1x. KTF offered world first CDMA 2000 1x EVDO service, beginning the era of 3G services in Korea in May 2002, followed by SKT in November 2002. While both of them received licenses for wCDMA, they postpone the actual deployment due to the uncertain business environments. KTF's FIMM (First in Multi Media) and SKT's June were their EVDO services. By the end of May 2003, SKT had 800,000 subscribers for June service out of 17 million users, while KTF had about 470,000 out of for FIMM service. Furthermore, during the same time period, about 40 per cent of new handsets being sold were camera phones (Kim, 2003b). In the first quarter of 2003, SKT made 9 per cent of its revenue from multimedia data services though EVDO.

Typical popular applications include: Multimedia Messaging Service (MMS), downloading ring-tone and animation characters, downloading music and video clips, and location-based service.

Discussion

Our study suggests that CDMA (Code Division Multiple Access) standard played an integral role as boundary object that enable the alignment of interests of multiple actors during the early stage of its commercialization. During the early stage of CDMA development and commercialization, key actors interests were aligned around CDMA standards. Qualcomm, who owned the core technologies needed partners to test and commercialize its yet unproven technology. Korean government needed a partner who would transfer key know-how in digital wireless communication technologies. When they faced a high entry barrier into GSM camp, CDMA standards emerged as an effective alternative. ETRI and KT brought their experiences and expertise in TDX development, complementing Qualcomm's core knowledge in air-radio interface. Korean manufacturers were also eager to acquire new technology and expand into new business area through CDMA. Taken together, this shows that CDMA standards became an obligatory passage point of an actor network for broadband mobile services in Korea.

In this process, the meaning of innovation of 2G mobile services constantly evolves and transforms, with inherent uncertainty and interpretive flexibility among different actors. This view offers a stark contrast to the traditional diffusion of innovation perspective, which often characterizes innovation as an unproblematic object that needs to be diffused among users. Instead, innovation is *in-making* as it traverses in the actor network, gaining different interpretations and being transformed as new actors were enrolled into the network. The diffusion of CDMA into Korean market was possible as a result of enrolment of key actors, through which the innovation itself was transformed. In this regard, *diffusion* of CDMA into Korean market was *innovation*. Thus, we suggest a duality, instead of dualism, of innovation and diffusion.

Second, we also found that standard both enables and constrains innovation. Compared to the European standard, GSM, CDMA standard is a weak form of standard that only specifies air radio interface. Therefore, it provides much larger room for local innovations and experiments with new service models and ideas. Especially after the successful commercial deployment of 2G network, many content providers, operators, and middleware solution providers began experimenting with many new service models as later versions of CDMA standards began providing enough bandwidth. These experiences in turn provided useful information to the operators, who then became important voices in the standardization body (3GPP and 3GPP2) for the service level interface specifications.

This offers an interesting perspective regarding the path-dependency. In economics literature, path dependency is often used to understand the lock-in effect (Arthur, 1989; David, 1985). In our study, however, the path-dependency of operators on CDMA standard enabled them to innovate for new service models and technologies in preparing 3G services. Thus, future research on standards and standardization needs to study the different path-dependency effects of different types of standards in the innovation process.

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