To appear in the May 2000 issue of *The Telecommunications Policy Journal,* Elsevier Publishers. The author would like to thank the publishers for their permission to reproduce this paper on TelecomVisions.com until the end of 2000.

Title: **Technical Innovations, Standardization and Regional Comparison**

Sub-title: **- A case study in mobile communications -**

Author's Name: Sadahiko Kano

Affiliation: Visiting Professor, Institute of Japanese-European Technology Studies (JETS), The University of Edinburgh, United Kingdom

Postal Address: 25 Buccleuch Place, Edinburgh EH8 9LN, United Kingdom

Telephone: +44 131 650 4061

Fax: +44 131 667 4340

Email: kanos@blue.ocn.ne.jp

Abstract

This paper studies the relationship between technical innovations and standardization, eliciting implications for an optimal role for standardization in the innovation processes, taking mobile communications as an example. An important role of standardization is to synchronize disjoint technical innovations into a systemic innovation, which creates a new market. A two-tiered approach to alleviate negative effects of standardization on technical innovations is discussed, to specify only the interface specifications between sub-systems and to define successive generations of standards. Finally, a regional comparison is made among Europe, Japan and USA on the standardization processes of mobile systems and their ensuing results.

Technical Innovations, Standardization and Regional Comparison

- A case study in mobile communications -

1. Introduction

Since the days of Schumpeter (1943), technology and technical innovations have played an important role in the study of economics, industrial organizations and regional development. (Dosi, Teece, Chytry 1998, Chandler 1998, Fransman 1999) However, up until 1990s, standards were regarded as a tool for technical interconnection and regulation, and not as an object of academic discipline. The author started his career in 1967 as a research engineer engaged in the research and development (R&D) activities of various telecommunication systems and networks, for example, Signalling System No.7 and ISDN (Integrated Services Digital Network), at a laboratory of a telecommunications operator, NTT, for 10 years. Then, his R&D results forced him to bring them to a standards arena, International Telecommunication Union (ITU), since 1977, so that they would be standardized before implementing them in the telecommunication networks. He has led standardization activities at ITU on Signalling System No.7 and ISDN. (Kano 1979, Kano 1991)

During the time he was involved in the standardization of ISDN in late 1980s to early 1990s, he realized that the standardization was taking on a new role, much more than just technical interconnection and regulation, though he was not quite sure what it was. Later as he was chairing a study group at ITU on the network aspects of the 3rd generation mobile systems, his realization of standardization taking on a new role became more evident. He therefore started to study the literature and noticed that, synchronizing with his realization in late 1980s to early 1990s as a practitioner, the academia has started to look at standards as an object of study. For example, Antonelli (1998) studies "the evolution of standards as economic institutions", presents a well-thought out taxonomy of standards and their various roles and effects. Fransman (1998), in his comparison on telecom paradigm and Internet paradigm, studies the innovation process in each paradigm, distinguishing between closed de jure standardization of the telecom paradigm and open de facto standardization process of the Internet paradigm. Recently, a conference was organized by IEEE in 1999 called the 1st IEEE Conference on Standardisation and Innovation in Information Technology (IEEE 1999).

This increasing interest in standards and standardization processes reflects, in the view of the author, a change occurred in mid 1980s when products and services emerged in the market as a sub-system of a total system, e.g. mobile phones as a sub-system of a total mobile communication system, computer software packages and peripheral equipment as sub-systems of a total computer system. This emergence of products in the market as sub-systems of a total system based on a certain standard rather than as stand-alone products made telecom, computer and consumer electronics industries aware of the strategic importance of standards.

This paper studies the relationship between technical innovations and standardization, thereby, eliciting implications for an optimal role for standardization in the innovation processes, taking mobile communications as an example.

First, the nature of technical innovations that have been impacting the mobile communication systems, namely, those in semi-conductor technology and in radio technology, which are continuous and predictable in nature. Based on this nature, the telecom industry collectively took an approach, in retrospect, of utilizing them in two ways: first in the way of systemic innovation, where an overall system framework is innovated at certain intervals through standardization processes as successive generations of standards, and secondly in the way of stand-alone incremental innovations, which are performed independently and incessantly by competitors in the market to differentiate their products within the framework of an overall system standard. Similar distinction as the author's between systemic innovation and stand-alone incremental innovation was made by Teece (1998) as systemic and autonomous (stand-alone) innovations, and by Nelson (1998), as change in dominant system design and incremental improvements on product design. What this paper does is to relate this distinction with the standardization.

This paper then studies the history of the systemic innovations in mobile communications, in terms of a series of successive generations of standards, namely, the 1st generation (1G) analogue, 2nd generation (2G) digital and 3rd generation (3G) multimedia standards. Defining systemic innovations by successive generations of standards, in the case of mobile communications at the interval of 5 - 8 years, is a wisdom embedded in the standardization process not to stifle technical innovations by making it difficult for new ones to be incorporated. To alleviate the negative effect of standardization to stifle technical innovations, it is observed that, in general, two-tier approach has been adopted. One is to standardize, when making a systemic innovation, only the interface specifications between sub-systems, so that stand-alone incremental innovations can be made independently and incessantly within each sub-system. The second is to define successive generations of standards, as is the case not only with mobile communications, but also with computer operating system software, to allow systemic innovations to be made at a certain interval.

From the economic and industry structure point of view, each time a new generation of standards is defined, it will create a new market, thus giving an opportunity for new players to enter the market and become major players in the new generation of systems. The incumbent players in the old market face a challenge to be locked in to the legacy systems they have invested in. Thus, the standardization of a new generation of systems gives dynamism to the market.

Then, regional comparison is made among Europe, Japan and USA on their approaches to the standardization. In standardizing 2G systems, Europe and Japan adopted a single standard by formal standards bodies, while USA allowed multiple standards to be adopted, leaving the final selection to individual operators and users in the market. Between Europe and Japan, there was a difference in that Europe's standard was made under the multiple technical leadership of competing companies, while Japan's standard was made under the single technical leadership of a dominant mobile network operator. Finally, ensuing results of the three different regional approaches are compared from several key aspects, such as market build-up and penetration, worldwide deployment, competition among standards in the market, and emerging changes toward the 3G systems.

2. Nature of technical innovations affecting mobile communications

Among many technical innovations, those in semi-conductor and radio technologies have been impacting most significantly on the innovation of the mobile systems.

In the semi-conductor technology, an empirical law is known, called the Moore's law, laid down by Gordon Moore, co-founder of Intel around 1974, which states that the capacity of semiconductor chips will double every 18 months. It has been true for the past 25 years and it is expected to hold true for at least another decade, as shown in Figure 1. Thanks to this innovation, a mobile phone, which used to occupy the whole space of the trunk of a car in 1980s, has become so small as to be put in a pocket and carried by users in mid 1990s.

The innovation of radio technology in terms of bit rates offered to a user through a radio channel is also shown in Figure 1. The first generation (1G) analogue systems, standardised in 1980s, could not carry data, but only voice. The second generation (2G) digital systems, standardized in early 1990s, normally carry data at 9.6 kb/s, although some improvements are foreseen in early 2000s to extend it to somewhere around 200 kb/s. The third generation (3G) multimedia systems, to be officially standardized in year 2000, is designed to carry data up to 2 Mb/s, about 200 times faster than the 2G systems. (Kano 1997, Kano 1999, ITU 1999)

What is unique to the innovations of these technologies is that their results are continuous and to a certain degree predictable, as shown in Figure 1, rather than being abrupt and uncertain. Of course, specific techniques used to bring these results were different in most cases, thus discontinuous and uncertain, if not unpredictable. The existence of the predictability of results played a key role for competitors in the market, in the view of the author, to synchronize systemic innovations they would like to make through standardization process, as they can predict what could be done in years to come and therefore agree to the standards for successive generations of systems in setting the target values for major system parameters. Otherwise, if the results of these innovations had been unpredictable, those who made them would most likely have developed a product on their own or in a closed cooperation with their limited partners to take full advantage of their innovations.

3. Emergence of products as sub-systems of a total system

It was in mid 1980s when products started to emerge in the market as sub-systems of a larger total system rather than as stand-alone equipment. Examples were mobile phones of the 1st generation analogue systems, computer software packages and peripheral equipment such as printers and modems, which emerged in the market in 1980s. To take a computer industry's example, Microsoft introduced its first version of Windows Operating System (OS) in 1985. As Grove (1997) pointed out, this led to the complete restructuring of the computer industry from vertical integration by IBM and DEC in 1960s and 1970s, to vertical specialization, in which specialized companies in their respective fields produced personal computer hardware, OS software, various peripheral equipment and various application software packages. These were all products that were sub-systems of a total computer system rather than being stand-alone products.

This change is mostly due to the progress in semi-conductor technology, as we have seen in Figure 1, which enabled a large amount of functions to be integrated on a single semi-conductor chip. This high integration of functions, coupled with the progress in telecom technologies, enabled products to be interconnected with each other to make a total system, which offers a whole range of new functions which stand-alone products could not offer, such as mobile phone services and Internet applications such as email and world wide web. As each sub-system generally requires totally different technical and business skills, it has become increasingly inefficient for a single company to cover and excel in all the sub-systems, which led naturally to vertical specialization.

Thus, standards, be they de jure or de facto, became important as they specified the overall system framework and the interface specifications to interconnect sub-systems. Once such standards exist, then sub-system products can innovate independently to differentiate themselves in cost, design, performance and functions to compete in the market, as long as they comply with the interface specifications with other sub-systems.

4. Systemic innovation and stand-alone incremental innovation

The emergence of products in the market as sub-systems of a larger total system led to the need of distinguishing between two types of technical innovation, namely, systemic and stand-alone. According to Teece (1998), a stand-alone innovation is one which can be introduced without modifying other sub-systems. A systemic innovation, on the other hand, requires significant re-adjustment to other sub-systems.

From the viewpoint of standardization, a systemic innovation requires a new standard, be it de jure or de facto, defining an overall framework of a new system, accompanied by a new set of interface specifications among component sub-systems. These standards are made through cooperation not only among those who complement each other, such as manufacturers of different sub-systems, but also among potential competitors, such as manufacturers of the same sub-system, to collectively create a new market and build it up as quickly as possible, as Antonelli (1998) pointed out. Systemic innovation examples in mobile communications are the successive generations of 1G, 2G and 3G systems, each of which required a new standard. Other forms of systemic innovations made through standardization are closed de facto standardization led by a single company, sometimes in consultation with its close collaborators, e.g., Windows OSs by Microsoft, or open de facto standardization by industry forums, or the emerging open de facto standardization through the use of the Internet (Fransman 1998). While Williams (1999) compares various standards setting procedures such as above, the subject is beyond the scope of this paper.

Stand-alone innovations are made in various sub-systems by competitors independently and incessantly, as stated before. Examples in mobile communications are cost and size reduction of mobile phones, improvements in their design, performance and functions, including the prolonging of their battery life-time.

5. Historical review of the mobile communication systems

5.1 First generation (1G) analogue systems

Public cellular mobile communication services were first launched in late 1970s to early 1980s using the Frequency Division Multiple Access (FDMA) technology, transmitting analogue voice signals over the radio channels between mobile phones and near-by radio stations. The analogue systems standardized and used in those days are now called the first generation (1G) systems. As shown in Table 1, they include NMT (Nordic Mobile Telephony, first launch in 1981) and TACS (Total Access Communication System, 1985) in Europe, NTT System (system developed and used by NTT, 1979) in Japan and AMPS (Advanced Mobile Phone System developed by AT&T, 1983) in USA.

In the context of this paper, the standardization of the 1G analogue systems can be characterized as follows:
(1) Since they were the first generation, there was no predecessor to them. Hence, the systemic innovation in this case was the setting up of a new standard for the first time, defining the overall framework of a system and the interface specifications among sub-systems. The overall framework included, e.g., the definition of a cell, a geographical area covered by a radio station, and the system structure composed of sub-systems such as mobile phones, radio base stations and switching network equipment to track and route a call to the location of a mobile user.
(2) From the regional comparison point of view, NTT System and AMPS were originally developed by a single company, NTT and AT&T, respectively, at a time when they were monopoly operators. In those days, the "R&D engine" resided in the Laboratories of such operators.
(3) NMT, on the other hand, was developed as a cooperative project among telecom operators and manufacturers of Nordic countries, technically led by

manufacturers such as Ericsson and Nokia, which later led to a healthy competition among them.

5.2 Role of standardization toward the second generation (2G) digital systems

To have the mobile phone sets of the 1G Systems, standardised and put into service in 1980s, were regarded more as a status symbol of a top executive, to be placed in his chauffeur driven car, than as widely deployed products in many people's pockets and handbags as we know today. In those days, the research on the 2G digital systems, carried out in various laboratories around the world in an uncoordinated way, was considered as one of those research items whose near-term practical benefits were not clearly envisaged. For example, even in 1984 at the time of its divestiture, a Senior Executive of AT&T expressed the company's view that there was little future in mobile communications[1]. Mr. Kurt Hellstrom, President, Ericsson, was quoted as saying, "When I joined Ericsson in 1984, Radio Communications was something odd happening on the outskirts of Stockholm"[2].

Technical innovations studied here and there around the world as disjoint "ripples" required a break-through to become a synchronized "wave of creative destruction"[3]. This paper argues that it was the standardization that played a crucial role to synchronize the "ripples" of uncoordinated innovations to become a "wave of creative destruction" by agreeing to a solution, toward the realization of which R&D efforts in various laboratories could be focused and coordinated. This then led to the design and proto-type manufacture of viable products that attracted the attention of the business people to seriously consider their introduction into the market.

5.3 Second generation (2G) digital systems

Two types of 2G systems were standardized and deployed in 1990s. One is the cellular mobile systems, which are more prevalent today and are characterized by the division of a geographical area into cells, typically 3-5 kilometers in radius, served by a radio station located at its center. The other is what is called the personal communication systems (PCSs), which have much smaller cells, typically 200-500 meters in radius, and supposedly more economical and better in quality. This is because of the much shorter distance between mobile phones and the near-by radio station, which reduces the power required to transmit signals from the mobile phones, improving the voice quality and increasing the data speed. However, in order to cover the same area, a larger number of cells, hence radio stations, is required, thus making it suitable to more densely populated metropolitan and urban areas.

The 2G cellular mobile systems standardized regionally are as follows: Global System for Mobile Communication (GSM) of Europe in 1992, Personal Digital Cellular (PDC) of Japan in 1993, and ANSI-136 (based on TDMA technology) and ANSI-95 (based on CDMA technology, dubbed as cdmaOne) of USA, standardized in 1993 and 1995, respectively[4]. They all use the Time Division Multiple Access (TDMA) technology, except ANSI-95, which uses the Code Division Multiple Access (CDMA) technology, the major technology to be used by the 3G systems.

The 2G Personal Communication Systems are as follows: Digital Enhanced Cordless Telecommunications (DECT) of Europe standardized in 1993, Personal Handy phone System (PHS) of Japan also in 1993, and as many as 7 standards in USA in 1990s, as shown in Table 1.

The merits of 2G systems as compared with 1G systems are:
- increased capacity to handle calls thanks to the TDMA and CDMA technology, which allows a more efficient use of the radio spectrum than the previous FDMA technology, resulting in cost reduction which enabled a wider use by the general public;
- transfer of digital data in addition to voice due to the digital transmission over a radio channel;
- improved security and voice quality;

In the context of this paper, the standardization of the 2G digital systems can be characterized as follows:
(1) 2G system standards all represent a systemic innovation, as each defines a new overall system framework and the interface specifications among its sub-systems.
(2) 2G system standards offer features that cannot be achieved by making stand-alone innovations on the 1G systems, e.g., increased capacity, transfer of digital data, improved security and voice quality.
(3) 2G system standards were adopted by formal national/regional standards bodies through cooperation among potential competitors in the future market.
(4) After the standards were completed through cooperation, fierce competition took place among the competitors within the framework of each standard by making stand-alone innovations on cost, design, performance, etc.
(4) With regard to the market build-up and worldwide deployment, each 2G standard had different results. Regional comparison is made later in this paper.

5.4 Reasons for regional standards for the 2G systems

As a person closely involved in the international standardisation in 1980s and 1990s, I can recollect at least three reasons for the standardization of the 2G systems on a regional basis rather than on a global basis, e.g., by the ITU.

The first reason was that, in late 1980s when standards work started, mobile phones were called "automobile phones" or "car telephones", as the equipment was so bulky that it could be placed only in the trunk of a car. Because cars would not easily travel across the Atlantic or the Pacific Oceans, nobody thought that an international standardization was desperately needed. However, in

Europe, cars could go easily across national borders and, therefore, regional standardization within Europe was considered necessary.

The second reason for developing regional standards was that, in late 1980s, Europe fell behind USA and Japan in what might be called the global high technology competition, as USA was leading the computer industry and Japan the consumer electronics industry. Europe needed something which would be of strategic importance to gain the lead position in the global high-technology competition. It seemed to me then that Europe had decided to focus on the mobile communication system as one of its strategic high technology projects. Therefore, standardization was done by the newly created European standards body (ETSI[5]) rather than at the ITU, which might lead to the dissemination of key strategic information to other regions, notably, Japan and USA[6].

The third reason I found in those days which I believe still applies today was the basic difference in practice and philosophy towards standardization, between Europe and Japan on one hand, and USA on the other. Europe and Japan were oriented more towards setting standards by formal standards bodies, and, wherever and whenever possible, towards a single standard for one given area. On the other hand, USA relies more on the selection through competition in the market, thereby, reducing the need for formal standards bodies to agree to a single standard.

5.5 Standardization of the third generation (3G) systems

The standardization of the 3G systems was started in earnest in late 1990s, triggered by the following factors:
(1) Envisaged needs for higher data speed for the Internet multimedia applications in early 2000s.
The 2G systems offer data speeds upto 9.6 kb/s, while the 3G systems are aimed at offering up to 2 Mb/s, some 200 times faster. This will enable a mobile terminal to run most of the envisaged multimedia Internet applications in early 2000s, including the moving picture transmission.
(2) Need for compatible mobile phones that can be used around the world
Mobile phones have become so small to be carried in a pocket and many people travelling around the world suffer from incompatible 2G standards adopted by different countries. They would like to use the same mobile phone and the same mobile phone number around the world.

The standardization work is being carried at ITU under the name of International Mobile Telecommunication-2000 (IMT-2000) since 1997. In Europe, ETSI has called it Universal Mobile Telecommunication System (UMTS). IMT-2000 has adopted the family of systems concept in 1998 to facilitate transition from the 2G systems of Europe (GSM) and of USA (ANSI-136 and ANSI-95). Japan decided not to evolve its 2G system, PDC, as a family member of the IMT-2000. The GSM evolved 3G system standard (dubbed as W-CDMA) was developed by an industry forum called the 3GPP (3rd generation partnership project) and

ANSI-136 and ANSI-95 evolved 3G standards (dubbed as UWC-136[7] and cdma2000, respectively) by the 3GPP2. The first version of the 3G standards were completed in 1999, waiting for the official approval of ITU in May-June 2000.

5.6 Interval between successive generations of standards

By comparing the years when the first version of standards was officially approved in Table 1, the following observations are made:
1) Between 1G and 2G standards, the interval is between 7 - 14 years.
2) Between 2G and 3G standards, the interval is between 5 - 8 years.

In the case of Windows OS by Microsoft, the following is observed:
1) Between the 1st version (1985) to Windows 3.0 (1990), and to Windows 95, the intervals were 5 years.
2) Between Windows 95 and 98, and then on to Windows 2000, the intervals were 3 years and then 2 years, respectively.

It can be said, therefore, that:
a) when massive deployment of hardware systems are required as with the case of mobile systems, the interval is longer than that for software;
b) the interval is becoming shorter in each case, for the current systems, it is 5 - 8 years for mobile systems, and 2 - 3 years for Windows OS.

It is worthy of note that Krechmer (1999) proposes a new standardization method, which he calls "etiquette", to allow partial systemic innovation to be made in between successive generations of systems. As he points out, it is already implemented in certain standards in the form of a protocol to identify protocols to be used between sub-systems.

6. Regional comparison - 2G systems

6.1 Different approaches to standardization

Following differences are found in the 2G mobile communications standards among the three regions:
(1) A single standard vs. multiple standards
As shown in Table 1, Europe and Japan provided a single standard for cellular mobile and for personal communication systems. In USA, two standards were adopted for cellular mobile, while, for personal communication, as many as 7 standards were approved. In the case of USA, the selection of a particular standard was left to the operators and users in the market.
(2) A single leader vs. multiple leaders
In Europe, multiple operators and manufacturers led the standards making at the ETSI. In Japan, the PDC standard was specified under the single technical leadership of a mobile operator, i.e., the mobile communication group of NTT, later to be split as NTT DoCoMo, with the cooperation of Japanese manufacturers.

In USA, each standard had multiple leaders to develop and promote it. Multiple leadership meant a more all-out competition later in the market among these leaders.

6.2 Market build-up and penetration

Table 2 shows the market build-up of the 2G systems on a regional basis in terms of subscribers at year ends 1997 and 1998[8]. Among the three regions, Western Europe has the largest number of subscribers, 93.5 million subscribers at the end of 1998. Next comes Japan, with 47.3 million, about half of Western Europe, followed by North America with only 17.9 million, about 1/5 of Western Europe and 40% of Japan, amazingly low figure for North America, which is known for its high technology propensity.

This comparison becomes more vivid when we compare the penetration of the 2G system users, namely, the number of users per 100 inhabitants, as shown in Figure 2. At year end 1998, in Japan, 37.5 people out of 100 had a mobile phone, while in Western Europe, the number was 24.2. Compared with Europe and Japan, North America again had a low number of only 9.1 people out of 100 having a 2G mobile phone.

Several explanations can be given for the slow build-up of North America such as follows:
(1) Lack of a single standard, resulting in:
- the "wait and see" attitude of operators and users to see which standard, out of the 2 cellular mobile and 7 PCS standards, would become predominant in the market;
- Poor coverage of geographical areas, as operators which adopted different standards could not complement each other to cover such a wide area as North America;
- High initial cost of mobile phones, radio stations and other network equipment, as mass production was not possible due to multiple standards.

(2) High penetration of the 1G analogue system (AMPS)
At year end 1998, there were 50.7 million AMPS subscribers in USA and Canada, its penetration being 16.9 people out of 100. This was quite a high penetration for the 1G system, compared with that in Japan, which was 3.9 people out of 100 in 1995 and that in Western Europe, which could not exceed 5.0 people out of 100[9]. Hence, North America had an extremely high penetration of the 1G system, which became a great barrier for the 2G systems to make a headway.

(3) Called-party-pays call charge arrangement
In USA, if a call is made to a mobile user, the called mobile user has to pay for the air charge. This led to many subscribers to switch off the power of their mobile phones, thus reducing the usage of mobile phones.

(4) Per call charging even for a local call
As flat rate applies to local calls in USA, users felt it expensive to pay on a per call basis for mobile local calls.

(5) The purchase of radio channels in auction depleted the financial resources of

mobile operators for some time to make significant investment in deploying the 2G mobile networks on a large scale.

Thus, the lack of a single 2G standard was not the only reason for the slow build-up of 2G mobile systems in USA, but it was a significant factor.

6.3 Worldwide deployment[10]

European GSM has the widest acceptance globally. The total number of users around the world at year end 1998 was 137.9 million, out of which Europeans were 93.8 million (68%) and the remainder is outside Europe, especially in many developing countries. China Telecom was the single largest GSM operator in the world in 1998, serving 23.6 million subscribers and growing at an amazingly rapid rate of 78.2% from 1997.

Japan's PDC is used only in Japan, although it has as many as 47.3 million subscribers in 1998, second only to the GSM. This anomaly will be discussed later.

American ANSI-136 (TDMA based) and ANSI-95 (CDMA based, dubbed as cdmaOne) were also used on a world-wide basis. The ANSI-136 had a total of 32.3 million users worldwide, out of which 20.4 million (63%) were in North America in 1998. The cdmaOne standard had a total of 22.9 million users worldwide in 1998, out of which only 6.8 million (30%) were in North America, the largest number of users being in South Korea with 14.0 million subscribers or 61% of the worldwide total.

Explanations that can be given to these differences are as follows:
(1) European GSM had the definitive advantage of a single standard in Europe supported by competing multiple manufacturers that are doing business on a global scale, such as Ericsson, Nokia, Alcatel and Siemens, later on joined by Lucent, Nortel and Motorola. This reduces the fear of telecom operators, particularly in developing countries, in selecting a wrong standard, or in being locked into a single manufacturer.
(2) With regard to the Japan's PDC, Japanese telecom operators and equipment manufacturers were too busy in satisfying the unprecedented growth in Japan (a growth of 11 to 17 million subscribers per year in years 1995-98)[11] and were not strategically poised to look at the global market. Fransman (Fransman 1995, 1999) has analyzed this propensity and dubbed it as the "paradox of the Japanese info-communication (IC) companies". The paradox lies in the fact that, although "Japanese IC companies ranked highly in the global top ten places in the three key markets of computers, telecommunications equipment and semi-conductors in terms of total sales, while at the same time failing to hold dominant or even very strong competitive positions outside Japan in many of the major sub-segments of these markets." This paradox was conspicuous when one compared it with the global presence of Japanese consumer electronics and automobile industries. What he had observed in 1995 held true again to the mobile segment, whose

market build-up was in 1995-2000. In short, because of the size and rapid growth of the Japanese domestic market, Japanese operators and manufacturers could do good business and bask in Japan and did not pay enough attention to and make enough efforts to go into the global scene. Despite the general economic depression in Japan in 1990s, its telecommunication market was making a healthy growth, as Kano (1998) pointed out.

(3) American 2G standards are doing well also outside North America. This can be explained by the fact that the high penetration of the 1G system in North America made it difficult for the 2G systems to make a headway into its own region, forcing manufacturers to look for markets outside. In addition, North American manufacturers have been aggressively globalizing their businesses after the divestiture of AT&T in 1984.

7. Regional comparison - Emerging changes for the 3G standards

7.1 Europe toward the 3G system

Europe's success in the 2G system (GSM) is indisputable. No change is foreseen at the moment on the strong propensity toward a unique standard, namely, W-CDMA to be approved by its standards body (ETSI), and its adoption by all the European Union countries directed by the European Commission.

What is changing is to make the 3G standard a truly global standard by inviting non European countries to participate in the process of standardization. In fact, when ETSI started to standardize its 3G standard, under the name of UMTS (Universal Mobile Telecommunication System), non European GSM network operators complained and requested that their voices be heard also by the standards body. As a result, the 3GPP (3G Partnership Project) was established in 1999, comprising national standards bodies whose members are planning to adopt the W-CDMA standard, such as Japan's ARIB and TTC[12] and USA's T1[13], in addition to ETSI.

7.2 Japan toward the 3G system

As we have seen, PDC, the Japan's 2G system, was developed under the single technical leadership of NTT DoCoMo and was adopted by all its competitors, Japan Telecom, DDI and IDO[14]. However, DDI and IDO announced in 1998 that, for the 3G system, they would adopt cdma2000, which is different from the W-CDMA to be adopted by NTT DoCoMo. The latter has contributed significantly to the development of the W-CDMA technology in cooperation with ETSI. The reasons DDI and IDO give for the adoption of a different standard from that of NTT DoCoMo are as follows: a) if they adopt technologies developed by its competitor, they will always suffer the time delay which the manufacturers supply new products to them after they have done so to NTT DoCoMo. This delay of 3 to 6 months have significantly disadvantaged them in the market, they claimed; b) they cannot make their own stand-alone innovations freely or in secret to differentiate their services and products, either because they do not have the "tacit" knowledge of the technology to implement them, or because of the fear that the information would be leaked to NTT DoCoMo through negotiations to use its patents, for example.

Japanese telecom standards organizations, ARIB and TTC, are therefore going to adopt two 3G standards, namely, W-CDMA, and cdma2000, which is a departure from the hitherto adhered principle of approving one standard only for a given area. Japan decided also not to pursue a 3G system evolved from their own 2G system. One can easily imagine that these decisions will change the Japanese 3G scene dramatically from that of the 2G.

7.3 USA

It seems that the basic thrust of letting the market make the final selection will not change. However, the 3G scene will differ from that of the 2G in the following two points.

(1) Three standards for the 3G rather than two for the 2G
In addition to the two 2G standards, namely, ANSI-136 and ANSI-95, GSM is also making a headway into USA. For 3G systems, three standards, namely, cdma2000, UWC-136 and W-CDMA, will be competing from the very outset. Each of the three has established an industry forum to promote its standard not only in USA but also around the world.

(2) Inviting non USA participants to the standards making
American 2G standards are being used also by non USA network operators, notably, South Korea and Japan. Hence, in parallel to European move to establish the 3GPP, an industry forum, named the 3GPP2 (3G Partnership Project 2), was established also in 1999, comprising national standards organizations such as TTA (Telecommunication Technology Association) of South Korea, ARIB and TTC of Japan, in addition to the Telecommunication Industry Association (TIA) of USA.

8. Conclusion

The main points of this paper are summarized in the following.

1. With the emergence of complex info-communication systems that are composed of component sub-systems, technical innovations can be classified into two types: systemic innovations which require a new overall framework of a system and stand-alone incremental innovations which are closed only within a particular sub-system.

2. Systemic innovations are made through various forms of standardization. This paper studied the mobile communications case, where systemic innovations are made through de jure standardization by formal standards bodies.

3. Implications for an optimal role for standardization learned from the study in this paper are as follows:

3.1 An important role of standardization in the innovative processes is to coordinate various "ripples" of technical innovations performed independently by specialist companies, and to synchronize them into a "wave of creative destruction" by giving an overall system framework, so that these disjoint innovations can work together in a systemic way to offer a useful service to the end user, thereby assisting to create a new market. When a new generation of systems create a new market, it usually destroys, in most cases gradually, a corresponding old market, thereby giving a dynamism to the industry structure.

3.2 When demands are latently existing, a single standard will create and build up a market more quickly than in the case of multiple standards. However, a single standard is not always the case for various reasons, and may not always be desirable, as it eliminates an opportunity for different technologies to compete with each other. The 3G scene will see more competition among multiple standards on a worldwide basis than the 2G scene, except in Europe. It would be interesting to see how a single-standard Europe will fare in comparison with multiple-standard Japan, USA and other nations/regions in the 3G era.

3.3 It is often asserted that standardization stifles technical innovations by making it difficult for new ones to be incorporated. Against this danger, this paper analyzes that, in general, two-tier approach has been adopted. One is to standardize, when making a systemic innovation, only the interface specifications between sub-systems, so that stand-alone incremental innovations can be made incessantly and independently within each sub-system. The second is to define successive generations of standards, as is the case not only with mobile communications, but also with computer operating system software, to allow systemic innovations to be made at a certain interval.

4. Regional comparison on standards and market build-up both on a regional basis and on a global scene highlighted the similarities and differences among Europe, Japan and USA. The differences led to the indisputable success of Europe's GSM both at home and globally, Japanese success only in their home market, and amazingly slow build-up of the 2G market in the USA. Explanations were given for these results. It will be interesting to see how 3G market will build up around the world in 2001-2010, and to compare explanations which will be given for different regional developments, if any, with those for the 2G systems given in this paper.

5. As for Japan's 3G scene, the voluntary disinheritance of its legacy 2G system and the adoption of the two 3G global standards mark a significant departure from the 2G scene, by opening up the Japanese market to two globally competing standards, the equipment of which can be supplied by any supplier, be it domestic or foreign. This should awaken the Japanese info-communication industry hitherto basking in their home market, to go out and do better on a global scene. Whether this will remedy the Fransman's "paradox" (See 6.3) is another interesting subject to observe in the 3G market build-up in 2001-2010.

Acknowledgments

The author thanks Professor Martin Fransman, Director of the Institute for

Japanese-European Technology Studies (JETS) of the University of Edinburgh, for his most valuable suggestions and comments. He thanks also an anonymous referee for the useful comments.

References

Antonelli, Cristiano (1998), "Localized Technological Change and the Evolution of Standards as Economic Institutions" *The Dynamic Firm* (Oxford University Press), pp. 78 - 100

Chandler, Alfred D. Jr., Hagstroem, Peter, and Soelvell, Oerjan, (1998) "The Dynamic Firm" The Role of Technology, Strategy, Organization, and Regions, Oxford University Press

Dosi, Giovanni, Teece, David J. and Chytry, Joseph (1998), "Technology, Organization, and Competitiveness" Perspectives on Industrial and Corporate Change, Introduction, Oxford University Press

Fransman, Martin (1995), "Japan's Computer and Communications Industry" The Evolution of Industrial Giants and Global Competitiveness, Oxford University Press

Fransman, Martin (1998), "Convergence, the Internet and Multimedia: Implications for the Evolution of Industries and Technologies" JETS Paper No.16, Institute for Japanese-European Technology Studies (JETS), The University of Edinburgh, 1998

Fransman, Martin (1999), "Visions of Innovation" The Firm and Japan, Oxford University Press

Grove, Andrew S. (1997), "Only The Paranoid Survive" - How To Exploit the Crisis Points That Challenge Every Company and Career-, Harper Collins Publishers, London

IEEE (The Institute of Electrical and Electronics Engineers)(1999), "Proceedings of the 1st IEEE Conference on Standardisation and Innovation in Information Technology" Aachen, September 15-17, 1999

ITU (International Telecommunication Union) (1999), "World Telecommunication Development Report - Mobile Cellular World Telecommunication Indicators 1999" ITU Sales Department

Kano, Sadahiko, Suzuki, Shingo (1979), "New Common Channel Signalling System No.7" Proceedings of the International Switching Symposium (ISS'79), Paris, Paper 50 A-1.

Kano, Sadahiko (1991), "ISDN Standardization" Proceedings of the IEEE Special Issue on ISDN, February 1991

Kano, Sadahiko (1997), "Trends in Mobile Communications", Proceedings of the Seminar on Global Trends in Info-Communications, Budapest, Hungary, 13-15 May 1997

Kano, Sadahiko (1998), "Telecommunication Market in Japan: Entering the Digital Era and the 2nd Phase of Competition" IEEE Communication Magazine, featuring "Telecommunication Markets, Industry and Infrastructure in Asia", November 1998, pp. 38-44.

Kano, Sadahiko (1999), "Objectives and Progress of the Standardization of the 3rd Generation Mobile System" Proceedings of the IMT-2000 Workshop, 21 June 1999, Cheju, Korea

Krechmer, Ken (1999), "Technical Communications Standards: New Directions in Innovation" Proceedings of the 1st IEEE Conference on Standardisation and Innovation in Information Technology, pp.143-148, Aachen, September 15-17, 1999

Nelson, Richard R. (1998), "The Co-Evolution of Technology, Industrial Structure, and Supporting Institutions" appearing in "*Technology, Organization, and Competitiveness" Perspectives on Industrial and Corporate Change,* Oxford University Press, pp.319-335

Schumpeter, Joseph A., (1943) "Capitalism, Socialism and Democracy" Routeledge, Reprinted in 1996, First published in 1943.

Teece, David J. (1998), "Design Issues for Innovative Firms: Bureaucracy, Incentives and Industrial Structure" *The Dynamic Firm* (Oxford University Press), pp. 134 - 165

Williams, Robin (1999), "ICT Standard setting from an innovation studies perspective" Proceedings of the First IEEE Conference on Standardisation and Innovation in Information Technology (SIIT '99), Aachen, Germany, September 15-17, 1999

Notes

1. Financial Times, February 22, 1999
2. Financial Times, July 26, 1999
3. Words of Schumpeter, Joseph A. (1943)
4. ANSI stands for the American National Standard Institute, a formal accredited standards organization of the USA.
5. ETSI stands for the European Telecommunications Standards Institute, established in 1989.
6. On this particular point, I searched for a reference or an evidence in document, but could not identify one. However, that was certainly the reactions I received from my European colleagues when I, participating in ITU activities then, tried to standardize a 2G system on a global basis at the ITU.
7. UWC stands for Universal Wireless Communication Consortium, established in 1995 to prepare standards for TDMA ANSI-136 based 3G standard and to promote its use.
8. For the sources of statistical data, see Notes on Table 2.
9. For the sources of statistical data, see Notes in Table 2. No precise statistical data was available on the value of Western European penetration of the 1G analogue systems. Hence, assuming that all the subscribers of the European standardized 1G systems (NMT and TACS) had been concentrated in Western Europe (which was not the case), the penetration would become 5.0. Hence, the penetration cannot exceed 5.0.
10. For the sources of statistical data, most are taken from International Telecommunication Union: "World Telecommunication Development

Report - Mobile Cellular World Telecommunication Indicators" 1999. They are supplemented by other sources identified in Notes on Table 2.

11. Japan's Ministry of Posts and Telecommunications: "White paper on telecommunications" 1999

12. ARIB: Association of Radio Industries and Businesses of Japan, whose missions include the standardization of radio technologies and systems.

    TTC: Telecommunication Technology Committee of Japan, a telecommunication whose missions include the standardization of non-radio related telecommunication technologies and systems.

13. T1: American National Standard Institute's Committee T1, whose mission is the standardization of telecommunication technologies and systems.

14. NTT DoCoMo - A major mobile network operator in Japan, initially 100% owned by NTT, but 67% at year end 1999.

    Japan Telecom - A new entrant to Japanese telecom market in 1985 offering long-distance, internet and mobile services. Initially a subsidiary of Japan National Railways, but in 1999, AT&T and BT have become its co-shareholders.

    DDI - A new entrant to Japanese telecom market in 1985 established by an independent entrepreneur, offering long-distance and mobile communication services.

    IDO - A new entrant to Japanese telecom market in 1985, established as a subsidiary of Toyota Motor Company, offering mobile communication services.

List of Tables and Figures

Table 1 Mobile Communication Standards

Region	1st Generation Systems (Analogue) (1980s)	2nd Generation Systems (Digital)		3rd Generation Systems (Multimedia)
		Cellular Mobile Systems	Personal Communication Systems (PCS)	
Europe	NMT (1981) TACS (1985)	GSM (1992)	DECT (1993)	IMT-2000 (2000) 3 Major Versions 1) W-CDMA (GSM evolved) 2) cdma2000 (cdmaOne evolved) 3) UWC-136 (ANSI-136 evolved)
Japan	NTT System (1979)	PDC (1993)	PHS (1993)	
USA	AMPS (1983)	ANSI-136 (1993) (TDMA based) ANSI-95 (1995) (cdmaOne: CDMA based)	7 Standards: 3 CDMA-based 2 TDMA-based 1 DECT-based 1 PHS-based	
Features	Voice only	Voice + Data (upto 9.6 kb/s)	Economical version for urban areas	Voice + Data (upto 2 Mb/s)
Radio Technology	FDMA	TDMA (+CDMA)		CDMA (+TDMA)

( ): Year when relevant specifications were first standardized.
NMT: Nordic Mobile Telephony (1st launch 1981, 4.5 million subscribers in 1998)
TACS: Total Access Communication System (1st launch 1985, 15 million subscribers in 1998)
NTT System: (1st launch 1979, peaked at 4.9 million subscribers in 1995, 0.4 million in 1998)
AMPS: Advanced Mobile Phone Service (1st launch 1983, 50 million subscribers in 1998).
GSM: Originally, Groupe Special Mobile (Later, Global System for Mobile communications)
DECT: Digital Enhanced Cordless Telecommunications
PDC: Personal Digital Cellular
PHS: Personal Handy-phone System
ANSI: American National Standard Institute
IMT-2000: International Mobile Telecommunication - 2000
UWC: Universal Wireless Communication Consortium
FDMA: Frequency Division Multiple Access
TDMA: Time Division Multiple Access
CDMA: Code Division Multiple Access

Source: ITU - World Telecommunication Development Report, 1999
ITU Press Release/99-22 "IMT-2000 Radio Interface Specifications Approved in ITU
Meeting in Helsinki, 5 November 1999

Table 2 - Market Build-up of the 2nd Generation Mobile Systems

M: million

Region	Population[3]	Number of subscribers (Year end 1997)	Number of subscribers (Year end 1998)
Western Europe[1]	387 M	GSM 46.3 M [4]	GSM 93.5 M [3]
Japan	126M	PDC 36.2 M [5]	PDC 47.3 M [5]
North America[2]	300 M	Total 5.5 M Breakdown: ANSI-136 4.0 M [6] ANSI-95 1.5 M [7]	Total 27.2 M Breakdown: ANSI-136 20.4 M [3] ANSI-95 6.8 M [7]

Notes

1. Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK
2. USA, Canada
3. Source - ITU: "World Telecommunication Development Report" 1999
4. Source - The GSM Association's Home Page <http://gsmworld.com> Press Release Archives, February 18, 1998.
5. Source - Japan's Ministry of Posts and Telecommunications: "White paper on telecommunications" 1999
6. Source - The web site of the UWCC (Universal Wireless Communications Consortium) <http://www.uwcc.org> Press Release Archive, April 6, 1998 and April 20, 1999.
7. Source - The web site of the CDMA Development Group <http://www.cdg.org> cdmaOne Worldwide Subscriber Growth Information.