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Title	Mobile technological shift from 2G to 3G : A review of scientific research activities
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Citation	年次学術大会講演要旨集, 25: 1096-1100
Issue Date	2010-10-09
Type	Conference Paper
Text version	publisher
URL	http://hdl.handle.net/10119/9479
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Description	一般講演要旨

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Mobile technological shift from 2G to 3G: A review of scientific research activities

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Abstract **-** Volumes of academic publications are the commonly accepted indicator of scientific performance. Their share can illustrate the existing status of technological players, both in terms of national capacity or industrial one. In this paper, we conducted bibliographic analysis of journal articles related to 2G and 3G mobile service implementation. We built the involvement profiles of countries and technological players (universities, public research institute and private firms).

A review of the implications of mobile technological shift from 2G to 3G is presented by taking a perspective of national and sectoral innovation system. We found that such a shift has enabled developing countries to catch up. For example, 3G's utilization of CDMA has made South Korea perform better in 3G-related research activities. The shift from 2G to 3G has also led to the convergence of various technological agenda, in which more technology developers can work in the diverse research fields. We also imply that mobile technology which is characterized by an evolutionary path, has opened opportunities for technological players to engage in the continuous research activities.

Keywords*:* Mobile technology, Innovation, R&D activities

1. INTRODUCTION

Mobile technology evolution from second (2G) and third generation (3G) has given significant changes in the society and activities of human life. The early development of 2G was designed only to support basic services while 3G has led to the deployment of various life style applications. Such a 3G mobile multimedia service has also enabled a rapid growth of subscribers. ITU statistic reported that mobile cellular subscriptions were expected to pass 5 billions in 2010 which would have been driven by advanced services and handsets development, in addition to mobile health services and mobile banking (ITU, 2010).

This paper aims to review research activities in the development of 2G and 3G mobile technologies. Scientific research activities can be used to monitor changes in the system of innovation in addition to the existing status of technological players. It can also be utilized to analyze the impact of technological change on the actors in the system.

Our research is carried out by using bibliometric analysis of mobile technologies-related journal articles. Miyazaki and Islam (2007) previously developed a framework to investigate Nanotechnology's academic research activities. We subsequently utilized the framework by focusing on answering how technical shift from 2G to 3G has given influence to the system of innovations, both from the perspective of national (Freeman, 1995) and sectoral dimensions (Malerba, 2002) (Edquist, 1997).

The paper is divided into six sections. The second section explains briefly the framework of analysis while the third section presents bibliometric analysis of 2G and 3G mobile technology development. The changes from 2G to 3G and their impacts to innovation system are analyzed in the fourth section. Conclusions are given in the fifth section by summarizing our main findings.

2. FRAMEWORK OF ANALYSIS

Evolution of mobile technology from 2G to 3G is characterized by the scientific research activities regarding mobile standard development. As part of the radio communications system, mobile technology is regulated and standardized by the International Telecommunications Union (ITU). We may argue that standardization could be used to indicate mobile technological trends. For example, the rapid development of WiMAX has enabled the technology to support 3G service requirement. It led ITU to recognize WiMAX as one of the 3G terrestrial radio interfaces despite the fact that WiMAX did not evolve from the evolutionary path of mobile system (ITU, 2007).

Fig. 1 depicts our framework of analysis. We conducted bibliometric analysis by examining 2G and 3G-related academic journal publications in English from Engineering Village database. The articles were collected from the leading science and engineering journals, e.g. IEEE Transactions on Communications, IEICE Transactions on Communications and ETRI Journal. They were retrieved through 60 specialist search strings derived from the names of mobile standards. Table 1 summarizes the main search-strings and number of relevant articles in a 19-year time-frame (1990–2009).

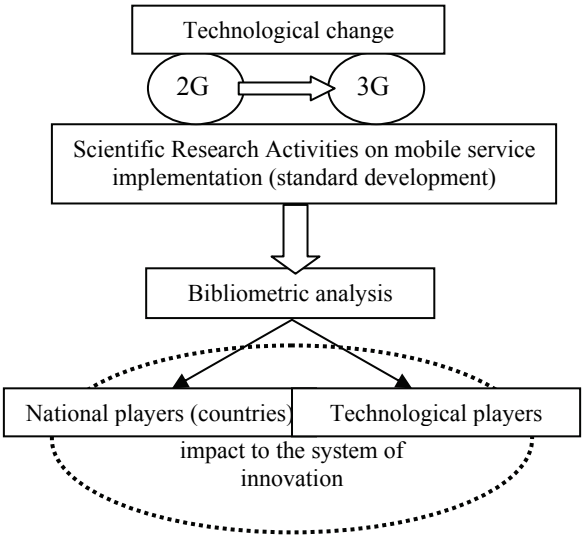

Fig.1 Framework of Analysis

Table 1 Search strings to download the mobile-technology related journal articles from *Engineering Village Database*

Stand -ards	*Some of main search strings*	*Number of relevant articles*
2G	GSM, D-AMPS, iDEN, PDC, PHS, CDMAone, IS-95, GPRS, HSCSD, IS-136, IS-54, 2G, 2.5 G	1,487
3G	WCDMA, IMT2000, CDMA2000, HSDPA, UMTS, UTRA, UWT-136, TS-CDMA, TDMA-SC, CDMA-FDD, SCDMA, DECT, IP-OFDMA, WiMAX, 3G	8,560

Bibliometric analysis has an ability to provide findings regarding the share of technological players, both from the perspective of national and sectoral innovation system. We linked the findings to the theory of technological changes, in which they would drive changes in social aspect and organizational behavior (Coombs, 1987).

Previous works have shown that technological change give significant influence to the actors in mobile telecommunications system. Suryanegara and Miyazaki (2010) showed that a shift from 2G to 3G has led to differentiation strategies of Japanese operators. In addition, backward compatibility has been one of the significant factors of 3G service diffusion as shown in the case of Japanese operators (Jonsson and Miyazaki, 2004).

3. SCIENTIFIC RESEARCH ACTIVITIES

3.1 Share of National Players

To measure the scientific performance of an innovation system, we conducted an assessment of academic publications and revealed their authors' affiliated institutions and countries. Fig. 2 and Fig. 3 show the respective involvement of countries in the scientific and engineering research related to 2G and 3G mobile standard development.

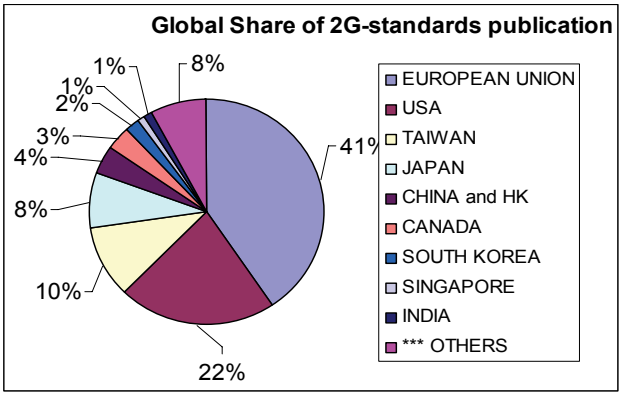

Fig. 2 Share of national players in 2G research activity

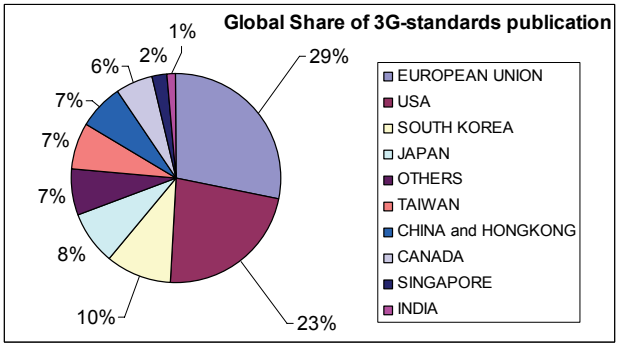

Fig. 3 Share of national players in 3G research activity

Fig. 2 shows that research activities regarding 2G standards were dominated by countries from the EU (41%) and USA (22 %) while Taiwan and Japan accounted for a relatively similar share (7 – 8 %). By looking at the keywords of publications, the finding shows that Taiwan conducted activities related to GSM and its data communications improvement. On the other hand, Japan contributed mostly on the general wireless technological agenda, without having specific association with the GSM standard.

Fig. 3 reveals that the domination of the EU and USA continued to 3G as the two most dominant standards (WCDMA and CDMA2000) were originally developed in those regions. The Asian players have

kept their global position in which South Korea was able to surpass Taiwan becoming the world's third active player. Meanwhile, China and Hong Kong were able to increase their contribution from 4% in 2G to 7% in 3G research. The overall condition has confirmed an emerging involvement of Asian countries in the mobile technologies' scientific research activities.

3.2 Share of Technological Players

Concerning the role of technological players, we differentiated authors' affiliation into universities, public research institutes and private firms (classified into service operators and technological vendors). Fig 4 exhibits the shares of authors' affiliated institutions of 2G and 3G-related journal articles.

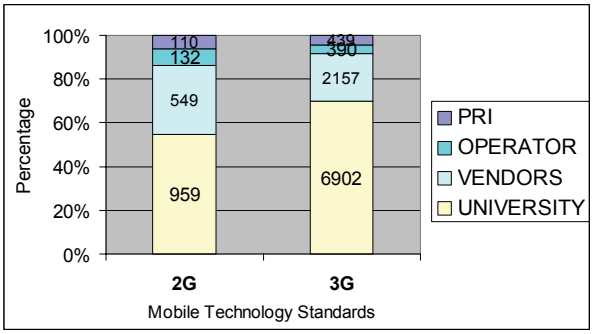

Fig. 4 Share of authors' affiliated institutions of 2G and 3G-related journal articles

Fig. 4 reveals that universities have the largest shares, complemented by private firms and Public Research Institute (PRI). We categorized the firms into service operator and vendors - including software developers, telecommunication manufacturers and handset makers. The finding shows that universities' involvement is relatively consistent by being the most active contributor, in which Universities account for 55% of 2G and 70 % of 3G articles. The intensification of Universities' role is not very surprising since journals highly emphasize on the scientific side, while industrial players focus more on technological implementation.

We note that technological vendors have taken active involvement since the preceding generations, such as Alcatel-Bell-Lucent (accounting for 7% of vendors' contribution) and other large handset makers such as Nokia, Samsung and Ericsson. The telecommunications legacy problem justifies such a perspective in which industries developed types of 3G standards to match with their 2G technologies, e.g. WCDMA was proposed by the industry to support seamless migration from GSM.

Yet, the role of operators is not as active as vendors, and is prominently led by world leading operators, in particular NTT DoCoMo and Vodafone. We may imply that operators are focusing on utilizing the knowledge for their service implementation in which links with the vendors are directed to support service diffusion.

The percentage of scientific output produced by operators has shown a reduction from 2G to 3G. The leader is NTT/DoCoMo accounting for 180 publications (46% share of operators' contribution on 3G-standard, an increase from 32% on 2G-standard). The finding also justifies company's status as the worlds' highest R&D budget operator in which DoCoMo spends 100 billions yen for R&D activities in 2008 (DoCoMo 2008). To give details on firms' involvement, Table 2 lists the operators' and technology vendors' research output of 3G-related journal publications.

Table 2. Operators' and Technology vendors' research output in 3G-related journal articles (1993-2009)

Number of Publications	Company Name	Country of origin
350	ALCATEL-BELL-LUCENT	USA
180	NTT – DOCOMO	Japan
148	NOKIA	Finland
126	SAMSUNG	South Korea
118	ERICSSON	Sweden
109	QUALCOMM	USA
85	MOTOROLA	USA
77	NEC	Japan
73	SIEMENS	Germany
49	LG	South Korea
48	NORTEL	USA
47	FUJITSU	Japan
10	KDDI	Japan

Table 2 indicates that firms originated from USA, the EU and Japan have the most contribution, nevertheless the presence of Samsung and LG reveals a rising performance of South Korean-based electronic firms. We note that South Korean companies are not telecommunications specialist suppliers but could compete with USA and European firms by developing competency on handset technologies. In the global handset shipment, the two South Korean companies have been among the top together with Nokia, Motorola and Sony Ericsson (ITU, 2009). The table also implies that Chinese affiliated firms have not yet shown significant performance, despite the country's strong involvement in scientific research activities.

4. RESULTS

Based on the data analyses of research activities, we present results regarding the implications of the technological change from 2G to 3G by taking the perspectives of national and sectoral innovation system.

4.1 Opportunity to catch up for developing country

The finding implies that a technological change from 2G to 3G has opened opportunity for emerging countries to catch up. As the emerging country, South Korea shows an obvious difference between research performance in 2G-technology (accounted for 2%) and 3G-technology (10%). The difference signifies a fact that South Korea was able to take advantage from the utilization of CDMA as a core 3G technology. We note that the Korean electronic companies were one of the main contributors of CDMA-based technology. Our statistical analysis of USPTO-granted-patent reveals that among all Korean industries, Samsung has accounted for 61 % of CDMA2000 patents and 61% of WCDMA patents. Hence, it denotes another finding that such a notable R&D performance has been fostered by the active involvement of large electronic firms.

We note that the South Korean electronic firms have utilized their basic competence to support R&D on telecommunications' specialist research field. Unlike USA or the EU-affiliated firms, they did not originate from telecommunications specialist suppliers. With a technological diversification, South Korea has generated new technological competitiveness and has been able to promote their national system of innovation.

4.2 Firms involvement on the technological convergence

Based on a comparative share of technological players' research output (Table 2), we found out that no firms dominate the industry. The situation can be explained since mobile telecommunications system is an integration of several technical modules, therefore various firms can contribute to its technological development. For example, the strong research performance of Qualcomm was mainly facilitated by the firm's capability on designing electronic chip for CDMA-based mobile infrastructure. Qualcomm fabricates the chip while firms like Nokia, Ericsson embed the chip into their handset product. Similar case applied to firms like Cisco and Nortel, which produce hardware related to data communications network, e.g. router and switch.

However, despite diverse technical fields, the technical shift from 2G to 3G has indicated a convergence between technological areas. By using Vantage Point software, we built cross-correlation map of 2G and 3G journal publications as exhibited in Fig. 5. The map shows difference of scattered position of research technological agenda (derived from keyword analysis), in which 3G research activities are more closely related compared to 2G. There are also intensifications of certain technical areas indicated by several large dominant circles on the map.

Such a circumstance may imply that more firms can participate in research activities. The source of knowledge is getting more diverse which enables new firms to engage and to contribute to the development of emerging technologies. For example, Intel has been dynamically engaged in R&D activities to develop WiMAX's chip. We point out that Intel did not actively get engaged in 2G or any CDMA-based research activities, yet, the firm tried to take opportunity from the emergence of WiMAX. As part of broadband wireless access, WiMAX could support higher users' mobility in which its technology is being added to many laptops. Hence, Intel's case also signifies an industrial response to the convergence between wireless technology and computing system.

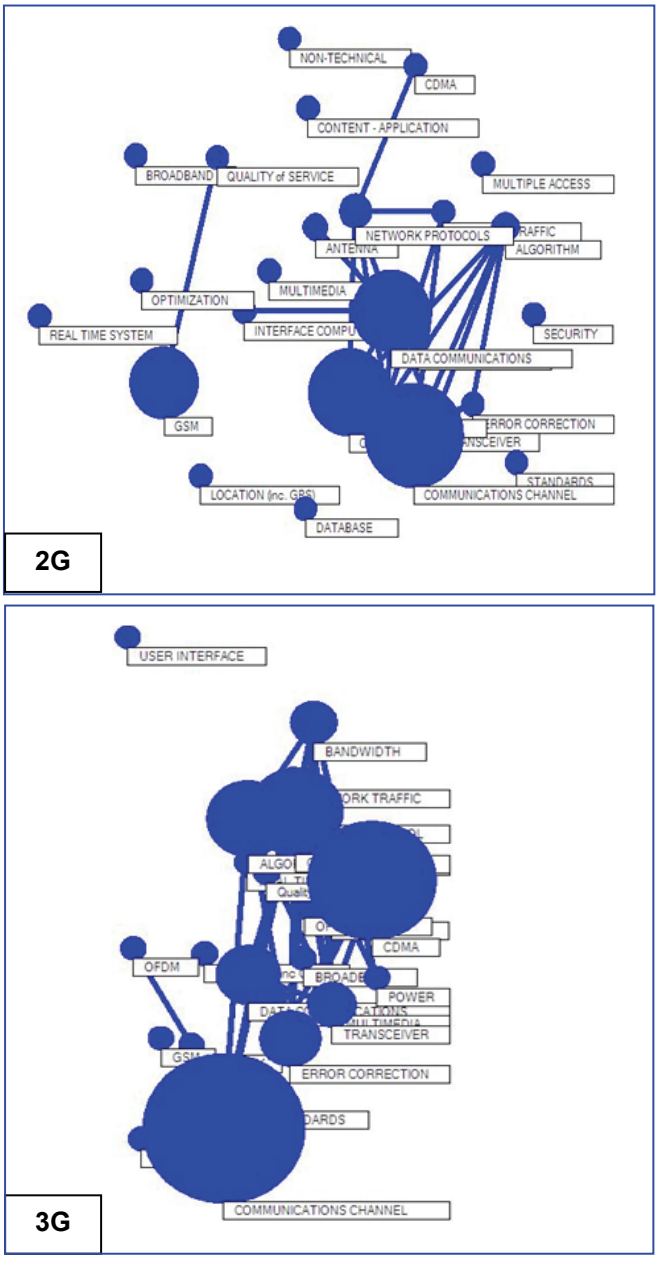

Fig.5 Cross Correlation map of 2G and 3G related journal publications

However, firms, which have participated since 2G technology development could obtain benefit from their continuous involvement. It was facilitated by the nature of mobile technology, i.e. characterized by evolutionary mechanism from one generation to another. For example, Qualcomm that has contributed to the development of 2G's CDMA platform is having commercial success because their CDMA is also used in most of 3G standards.

Taking into account the current situation, Alcatel-Lucent also shows continuous involvement in both 3G and 4G research activities. The firm is developing LTE-technology as the continuous technology of 3G-WCDMA. As technology developers, firms could submit proposals of technology standards to ITU. Hence, their involvements on preceding technologies would also give implications to the upcoming technological path.

5. CONCLUSIONS

In this paper, we have conducted bibliometric analyses of journal articles related to 2G and 3G mobile standard developments. By looking at their volumes and affiliated countries, we are able to understand the scientific performance of any national innovation system. Our work has shown that the technological change from 2G to 3G has given opportunities for developing countries to catch up. We point out South Korea, which has shown notable performance in the research activities regarding 3G through the active involvement of country's universities and large firms.

The technical shift from 2G to 3G has also made more industrial players get involved in the research activities. Our analyses revealed that 3G technologies are showing convergence while the number of technological agenda is getting diverse. Consequently, the emergence of new technologies has opened opportunity for new firms to engage and to build their competence. Yet, the evolutionary path of mobile technology development has also opened another opportunity for firms to engage in the continuous research activities. It enables firms to set the upcoming technological path by proposing relevant standards to ITU.

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