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TOWARDS 4G MOBILE TECHNOLOGY: IDENTIFYING WINDOWS OF OPPORTUNITY FOR A DEVELOPING COUNTRY

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ABSTRACT
Mobile technology is continuously evolving towards the development of fourth generation (4G) cellular telephony. Many countries are anticipating such a new technological deployment while developing countries may also see it as the opportunity for catching up. Within the orientation of innovation building, 4G may act as the medium for triggering country's innovation policies. This paper aims to identify the windows of opportunity from the upcoming implementation of 4G mobile technology. The methodology is constructed based on the perspective of an innovation system in which mobile cellular is regarded as a series of technological innovations. By utilizing the relevant data of 3G and 4G standard development, we predicted the 4G implementation profile. They consist of a set of technologies which can be the main area of science and technology (S&T) as well as research and development (R&D) activities in a developing country. Policymakers may utilize such opportunities to foster the acquisition and generation of the relevant knowledge in both manufacturing and service industries.

Keywords: 4G; Developing country; Innovation; Mobile technology; Windows of opportunity

1. INTRODUCTION
The common approach for studying a developing country is concerned with the concept of windows of opportunity. However, it is commonly understood that there is a structural gap between developing and developed countries that remains and widens (Perez & Soete, 1988). To overcome the gap, developing countries execute policies concentrating on tackling investment and infrastructure matters; yet, less attention is paid to knowledge and skill constraints (Perez & Soete, 1988). It was argued that windows of opportunity can be opened by focusing on learning and catching up with new technology.

A developing country needs a growing economic system and synergy to perform fast growth based on interrelated technological dynamism. It explains why early entry into new technology systems is a crucial ingredient for the process of catching up. Therefore, the main idea is how a policymaker in a developing country could grasp the opportunities from technological innovation. In that concept, a theoretical approach of innovation system would satisfy the formulation of such an answer.

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This paper aims to identify the windows of opportunity from the upcoming implementation of 4G mobile technology. The methodology is based on the theoretical perspective of an innovation system which pays special attention to the development of scientific knowledge as the main source of technological innovation. An explanation of the underlying theories linking the theory of innovation systems and mobile technology is presented in the second section of the paper. It signifies a main concept that technological innovation is the product of processes involving the generation and the adoption of knowledge. In the context of mobile technology, 4G can be perceived as the product of continuous evolution from the preceeding generation.

The third section reviews the concept of windows of opportunity while the fourth section formulates the methodology to identify such an opportunity from the coming of 4G mobile technology. The fifth section analyzes the concept of innovation building for the developing country. A conclusion is presented in the sixth section.

2. UNDERLYING THEORIES

2.1. Innovation system and mobile technology

This section provides the understanding of the relationship between the term "innovation" and mobile technology. Starting from the ideas of creativity, entrepreneurship and capitalism evident in Schumpeter's works (1928), innovation has been regarded as the stimuli of economic growth which may lead to the formation of new economic structures. It was emphasized that the role of technology in generating new products (innovation) has made technology an indigenous factor. Subsequently, scholars have raised the importance of structuring such a perspective by introducing the term "System of Innovation".

A system of innovation can be viewed through National Innovation Systems and Sectoral System of Innovation. The "National Innovation System" was formulated as the integration of technological and social innovation perspectives, in addition to network resources. The framework of the National Innovation System subsequently leads to the identification of the policy establishment which may promote industrial activities in a country. Meanwhile, a sectoral innovation may be characterized by a specific knowledge base, technologies and inputs (Malerba, 2004). Under the dimension of a sectoral system, it should consist of heterogeneous actors which are characterized by specific learning processes.

In sum, innovation is considered as a process that involves systematic interactions among a wide variety of actors for the generation and exchange of knowledge relevant to innovation and its commercialization (Malerba, 2004). This paper adopts such a concept by linking knowledge, innovation, technology and actors in the mobile technological sector. The conceptual approach begins with initial knowledge generated by the science and technology (S&T) creators. Knowledge will contribute to the innovation process, leading to innovation in technological development. Based on that, the continuous development of mobile technology can be seen as the evolutionary process of technological innovation.

2.2. Mobile Technology Development towards 4G

The early development of mobile communications technology has accumulated knowledge from the basic science of electromagnetic theory and the technological innovation of wired telephony. The science and technology creators are the main sources of knowledge which enable the development of related technologies. Therefore, their activities give a direct impact to technological change of mobile technologies from one generation to another.

Since the first emergence in the 1980s, mobile technology has followed an evolutionary path of development which is characterized by the development of standards for each generation. 1G was designed based on an analog radio system and was initially aimed to support only voice.

1G implementation was typified by diverse technical standards in which United Kingdom and Ireland implemented Total Access Communication System (TACS), while a well-known standard - Advanced Mobile Phone System (AMPS) – was highly adopted in North America. In the early 1990s, 2G entered the market with the characterization of a digital platform. The main worldwide standards were Global System Mobile (GSM), North America's IS-95, and PDC/PHS which was implemented in Japan.

In response to the demands for broadband data communications, mobile technologies continuously evolved to third generation (3G). Most technology developers try to follow the evolutionary path, meaning that new developed standard commonly refers to the preceding ones. In the case of 3G, Europe preferred to develop W-CDMA which evolved from its 2G system in order to maintain the consistency of the GSM technology (Maeda et al., 2006). Similarly, countries were adopting the two most popular implemented standards, i.e. W-CDMA and CDMA2000, which gave seamless migration from the preceding generations.

Within the coming decade, 4G shall enter the global market with the main technological capabilities, i.e. supporting low to high mobility multimedia applications in multiple user environments. The standardization development of 4G has been particularly driven by the IMT-Advanced requirement to sustain 100 Mbit/s for high and 1 Gbit/s for low mobility (ITU, 2008). Currently, two prominent technologies have been defined as 4G standards, namely LTE-Advanced and WiMAX-2.

3. INNOVATION BUILDING AND WINDOWS OF OPPORTUNITY

Coombs et al. (1987) mentioned that technological innovations always take place between particular institutional actors, in which they can both be generating and using new knowledge as an input for their main activities. The theoretical concept denotes that the socio-institutional framework influences technical and structural changes. In the field of mobile technology, the role of national policymakers may refer to the regulator and supporting institutions. The objectives of regulatory policies should eventually lead to support the welfare of a country.

A classical concept of policies recognizes that the regulatory policies tend to be reactive to technological change (Ro & Kim, 1996). There is an explicit recognition that government is quite limited in the things they can do well, while policy should be concerned with such constraints (Nelson & Winter, 1982). Hence, for a developing country, regulatory policies would play a major role determining the ways of managing new technology. In relation to that, a regulator in a developing country can be more active by setting a managerial direction to grasp windows of opportunity.

The common condition of a developing country is lack of firms which act as technology developers. In association with that, catching up can be made within the process of technological transfer as well as innovation capacity building. One of theoretical concerns is strategic steps to create innovation capacity building (Hobday, 1995), i.e. assembly skills, reverse engineering and products, full production skills (process innovation), R&D for product and process (product innovation), competitive R&D capabilities. Consequently, the manufacturing industry in a developing country can start from the stage of assembly skills as well as reverse engineering and products. In the concept of innovation systems, windows of opportunity are linked with the orientation of innovation building. It is a framework of seeing new technology as a way to trigger the S&T activities, as well as R&D activities under the platform of the National Innovation System. Thus, the main proposition in this paper is that 4G may have technical parameters which can be utilized as a tool to initiate such activities in a developing country. The following question is then how to find such a technical opportunity?

4. IDENTIFYING 4G TECHNICAL OPPORTUNITY

4.1. The methodological concept

We use the methodology to identify windows of opportunity based on our previous work in predicting 4G implementation profile (Suryanegara & Miyazaki, 2010a). It is noted that, the work is to find out the profile of technological implementation (not the profile of technology standards), because the standards have been drawn by ITU Working Group for IMT-Advanced. The method signifies the main concept of bibliometric analysis utilizing the notion of the science pole where academic publications are regarded as viable scientific output indicators (Bell & Callon, 1994). In that concept, S&T creators are the main source of knowledge (in the form of academic publications) leading to technological innovation in mobile cellular innovation systems.

We examined the relevant scientific output of mobile technology standards-related academic journal publications from Compendex database between 1990 and 2009. Firstly, it concerns journal publications related to 3G, giving 8,560 articles from 509 journals. Secondly, we downloaded 4G-related conference publications in English from similar database giving 995 articles (Suryanegara & Miyazaki, 2010a, 2010b).

In order to focus on the details of technological research activities, we categorized the relevant technologies of mobile cellular systems, a so called technological agenda (Suryanegara & Miyazaki, 2010a). It is derived from the technical concept of a digital communications system. We looked up research articles based on several important technical phrases (such as “CDMA”, “3G”, “packet switching”) and took the most significant technological agenda. In most cases, the technological agenda has a general association with article’s keywords defined by the authors of the research articles.

After collecting the data, we plotted the diffusion trend of 3G technological agenda. The diffusion trend of the current 3G implemented technologies is used to provide understanding on how the present situation may influence the future. A diffusion trend is constructed by approaching the Gompertz’s S-curve because it can describe many natural phenomena and also fit the technological growth process, including diffusion or penetration over time (Porter et al., 1991). A study by Vanston and Hodges (2004) argued that the Gompertz curve is an appropriate mathematical model that has an ability to describe mobile technology’s typical diffusion phases, i.e. emergent, inflexion and saturation phases. Based on the observed data, an extrapolation analysis is conducted to forecast when research activities in 3G technologies shall be completely diffuse (Suryanegara & Miyazaki, 2010a).

4.2. Data analysis

Extrapolation analyses were conducted for portraying the diffusion of technological agenda in the years between 2010 and 2018. Figure 1 depicts the Gompertz diffusion model of the main technological agenda of 3G mobile standard. The x-axis refers to year while the y-axis refers to number of articles.

Figure 1 signifies the phenomenon that some of technological agenda will completely diffuse in the coming years, while some others are showing exponential growth. Based on that figure, one can identify which technological agenda would have potency to keep growing and diffusing, or would be in a state of decay in the near future. In relation to the innovation building, a policymaker of a developing country may have information about research topic which can be an opportunity to catch their technological lag. A country can focus on the growing research topic because it would be very relevant for upcoming 4G. On the contrary, a country should consider the special strategy for developing research related to the decaying topic.

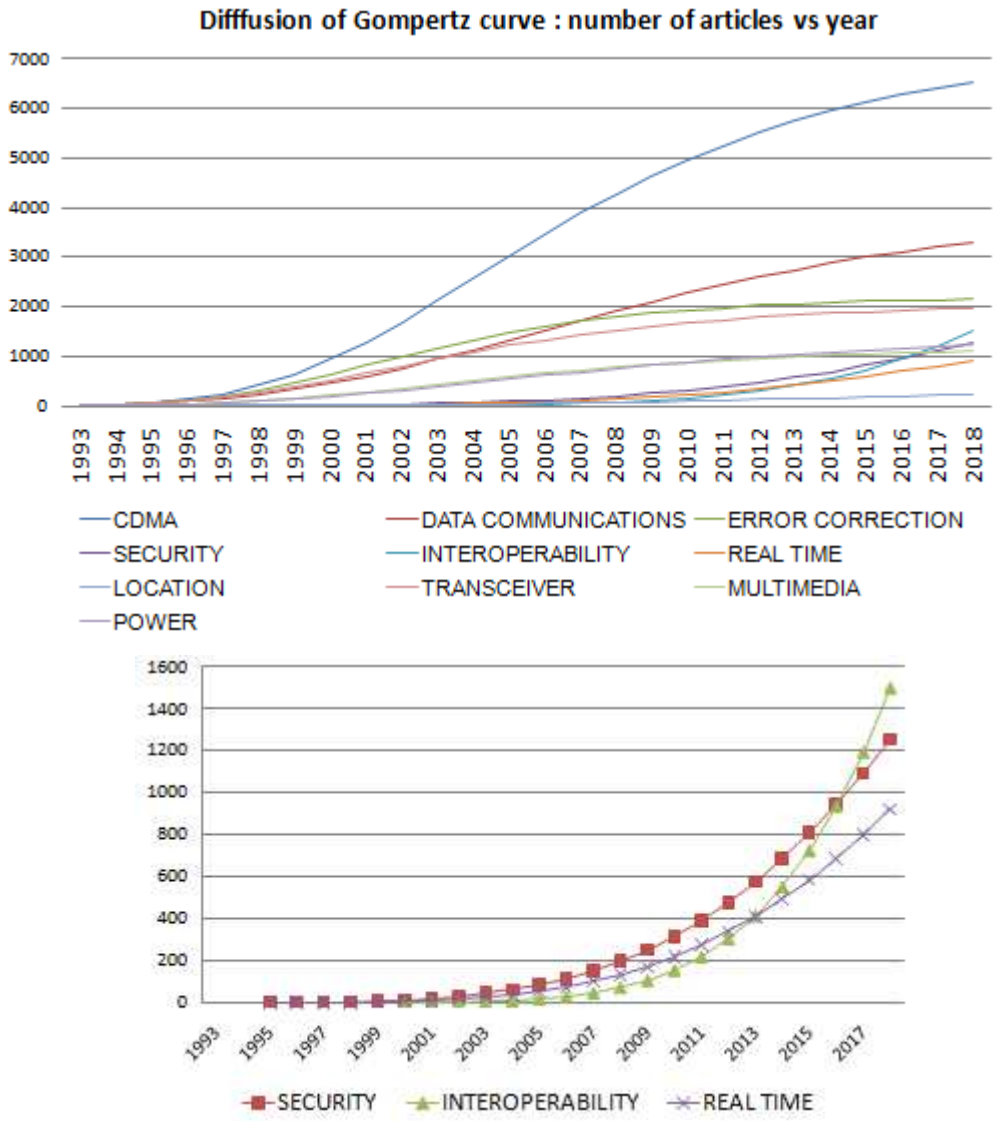

Figure 1 The S-curve of Diffusion of 3G Technological Agenda (subset is its zoom)

The diffusion growth of *cdma* implies that *cdma* has been a highly important basic research area of mobile communications. By observing the extrapolation data points up to 2018, several more years will be required to reach complete diffusion which means that the future period would be still influenced by research topic related to *cdma*. Meanwhile, the plot reveals that the research related to *Error Correction* has completely diffused indicating that the current error correction technique has given its best performance. It also implies that research activities can can be initiated to develop new techniques for the next generation mobile technology.

The figure shows that *Data Communications* technological agenda will keep growing steadily. It implies that the innovations of future technologies are still driven by knowledge generated from research activities related to packet data communications. Figure 1 also demonstrates the continuous diffusion for technological agenda of *Transceiver*, *Multimedia* and *Power*. Research activities regarding those topics are still promising and would continue to grow until they become completely diffused after 2018.

The subset of Figure 1 shows the exponential curves of three technological agenda. The exponential trend indicates that they have a potential to keep growing and may take a longer time to reach complete diffusion stage. The figure denotes that technological agenda of

Security, *Interoperability* and *Real Time* would be significant research areas in the future. By looking such a trend, we may argue that future research activities would be characterized by continuous improvements of current 3G technology. On the other hand, the growth of some technological agenda, which already reached a saturated level, may imply its fitness to existing 3G technology.

It is noted that the analysis of extrapolation graphs should be combined with scientific activities regarding 4G-related academic conferences articles. However, to portray the growth behavior, they are not in the form of s-curve, in which x-axis refers to year and y-axis refers to number of conferences articles. Figure 2 depicts several research topics that recently emerged and have grown significantly, in particular technological agenda regarding *Heterogeneous Network*, *Ad-hoc network*, *Ubiquitous Computing* and *WiMAX*. Meanwhile, by combining the trends in Figure 1 and Figure 2, it is noted that the coming of 4G would be indicated by the heterogeneous network and interoperability with other technology platforms. Consequently, new operators could offer different technologies with a comparable quality and cheaper subscription cost. As a result, competition will become more intense and efforts to retain subscribers would become more important (Suryanegara & Miyazaki, 2010b).

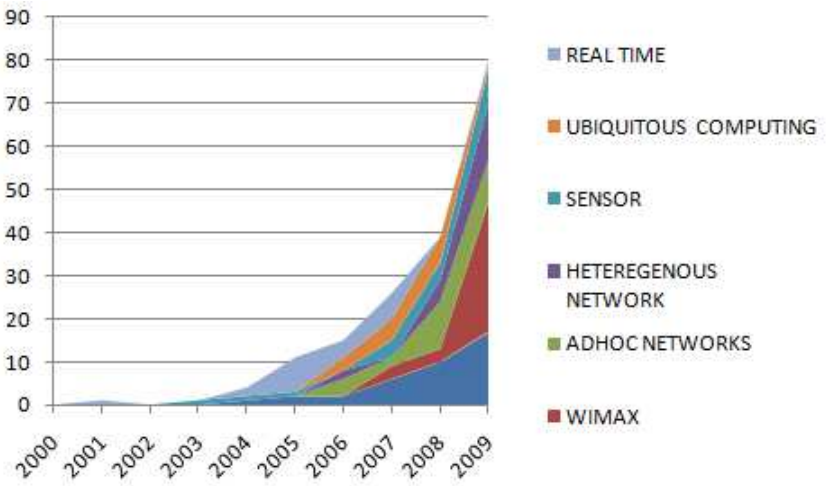

Figure 2 The growth of several important research topics related to 4G development

5. DISCUSSION

What can we infer from Figure 1 and Figure 2? Basically, the figures has given an important information for policymakers. The main idea is that a policymaker should foster S&T activities on several emerging technologies which have been shown by the figures. The main stage of unfolding innovation building strategy is to set a constructive learning mechanism from the technical opportunities offered by 4G. Concerned by the Hobday's strategic step presented in Section 3, it is argued that policymakers in developing country should not make a policy to initiate the manufacturing industry in a complete system of mobile technology. Thus, it is noteworthy to focus on several 4G technical characteristics and grab the technical opportunity leading to manufacturing industry and service developments. As shown in Figure 1 and Figure 2, several technological agenda will keep growing and emerge as important research topics in the coming decade, in particular *Security*, *Interoperability*, *Real Time, Multimedia, Ubiquitous Computing* and *Data Communications.*

The main concept follows what Perez and Soete (1988) argued that significant efforts should be made to open windows of opportunity which may be initiated from the knowledge acquisition and research activities. It implies an opportunity to develop any related technologies which may

support the service performance of upcoming 4G communications system. The regulator, together with supporting institutions should make efforts on the activation of research activities by the S&T creators. For example, a technology related to *Antenna* fabrication can be a pioneer of manufacturing industry and may contribute to future standards improvements. Meanwhile, a country can also make a contribution based on the development of specific service applications, e.g. *real time* technology that supports the performance of streaming applications.

Another issue is that 4G implementation profile has signified the emergence of service innovation and its supporting technologies. The general implication is that the advanced service applications would emerge as an integration of several technological agenda. For example, the research activities regarding *Sensor* could also support the development of mobile health applications, i.e. a sensor would be integrated in the interface between a person and a machine.

It is believed that many innovation studies concern the source of new technology (Tether & Howells, 2007). Meanwhile, one of the important principles refers to what Sotarauta and Srinivas (2006) mentioned that the concern of innovation system building is to determine not only what to do, but how to and with whom to do it, and how to create such settings so that innovation has room and the proper basis to emerge. Consequently, policymakers in developing countries should trigger the creation of such new technologies within the orientation of innovation building policies.

As an innovation system finally leads to economic performance, the national policymakers should establish industrial policy over a technological sector. It involves certain actions (including taxes, subsidies, etc) to alter the composition of national economic activities. As mentioned by McFetridge (1999), in general, the industrial policy has “the first best” objective to compensate for various perceived market failures and “second best” attempts to exploit market imperfections to benefit the domestic economy.

Finally, there should be also a supportive condition in which heterogeneous actors exist and be able to interact and mutually influence each other (McKelvey, 2002). There must be some kind of higher-level constraint and adaptation within the country’s innovation system, which motivates such a process. In this context, the country would mainly rely on S&T creators as the source of related knowledge. Therefore, a developing country should conduct a simultaneous effort by utilizing the S&T creators, in particular universities, to acquire and to generate the relevant knowledge in 4G technological implementation.

6. CONCLUSION

This paper has presented an effort to identify windows of opportunity from the upcoming 4G implementation. Methodology was built to identify a set of technological agenda, which become the pillars of innovation in 4G. It reveals several important technological agenda indicated by the extrapolation trend of Gompertz curve. A developing country may take up new opportunities since the upcoming generation will always depend on the previous platform. Based on such findings, policymakers may consider fostering research activities in relevant fields. Science and technology creators in a developing country can set up research activities on emerging topic, in particular regarding Security, Interoperability, Real Time, and Ubiquitous Computing. Finally, a policymaker should be able to exploit such opportunities leading to innovation building in the country.

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