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# Essential patent portfolios to monitor technology standardization strategies: Case of LTE-A technologies

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ABSTRACT

Patent portfolio analysis can be a useful approach to understand the characteristics of an industry and competitors in terms of their standard-setting activities. Despite its potential, however, little attention has been given to portfolio analysis, especially for essential patents. Therefore, this study aims to develop five patent portfolio maps that can be used to analyze essential patent strategies from various perspectives: 1) concentration, 2) activities, 3) diversity, 4) quality-breakthrough, and 5) quality-impact. Then, a case study is conducted on LTE-A technologies in the telecommunications sector, where technology standards are essential to establish technology strategies.

## 1. Introduction

In the field of compatibility standards, an increasing number of companies claim to own so-called essential patents, which are indispensable for designing and manufacturing products conforming to standards (Bekkers et al., 2011) and, thus, have been attracting much attention lately (Bekkers and West, 2009). Although all patents provide technological information, essential patents are different in that they contain information about technology standards. Technology standards reduce technological uncertainties, especially in a high-tech market, such as mobile communication industries, by setting a specification such that all implementations of the same standard are expected to be interoperable. Accordingly, companies can avoid wasting resources that would have otherwise been spent through uncertainties and, thus, increase their R & D efficiency by establishing a technology standard. If a technology standard is embodied in a patent claim, it becomes an essential patent; it has one or more claims that are infringed by the implementation of a specification for a technology standard. Considering the importance of technology standards for innovation and long-term growth, it is necessary for companies to understand how competitors strategically use essential patents to protect their technology standards. Apart from these needs, essential patents have more citation counts than do other patent documents (Rysman and Simcoe, 2008), indicating that they are likely to have a significant impact on subsequent technologies and, therefore, are worth investigating in detail.

Among the various methods available to analyze competitors' patenting activities, one of the most commonly used is a patent portfolio, which allows the complex information in patent documents to be understood easily and effectively by summarization and visualization (Yoon, 2010). A patent portfolio can be a means of integrating a patent strategy to shape the overall business strategy. Moreover, it enables a company to identify its technological positions, provide information about benchmarking, and, ultimately,

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help to effectively manage the allocation of R & D resources (Ernst, 1998). Recognizing these utilities, a number of previous studies have suggested various types of patent portfolio maps and applied them for practical use (Lee et al., 2008). Particularly in the information and communication technology (ICT) industries, patent analysis has been one of the most frequently used approaches to analyze industry trends (Noh et al., 2016), national-level strategies (Lee et al., 2009a), and company-level strategies (Kang et al., 2014). Nevertheless, few previous studies have focused on essential patent strategies, especially patent portfolio maps peculiar to essential patents, which are critical to understanding the characteristics of an industry and competitors, in terms of their standard-setting activities.

Recognizing these needs, we focus on the following research question; how technological strategies in a standard setting can be comprehensively identified at the firm level by means of patent portfolio maps? To answer it, this study suggests five patent portfolios maps that can be used to analyze essential patent strategies from various perspectives and, then, conduct a case study on Long-Term-Evolution-Advanced (LTE-A) technology in the telecommunications industry, where technology standards are essential to establishing technology strategies. For this purpose, first, we designed five patent maps that can offer valuable insights into essential patent strategies and, then, developed ten patent indicators for the maps, which can indicate the characteristics of essential patenting activities in each company. Finally, we collected patent data on the LTE-A technologies focusing both on general and essential patents. Restricting our focus to the 10 major organizations with the most essential patent applications, we applied our approaches to analyze their essential patent strategies. This is one of the earliest attempts to develop an analytical tool for corporate strategies on technology standards, especially emphasizing the importance of essential patents. The proposed tool can be valuable in analyzing essential patent strategies to support R & D planning and competitor benchmarking, in addition to understanding the industry. In practice, the case study results will be useful for those who are in charge of technology planning in the telecommunications industry.

The overall structure of this paper is as follows. Section 2 examines the existing studies on essential patents and patent portfolio analysis. Section 3 explains our methods, followed by the detailed perspectives to apply the methods in Section 4. After LTE-A technology case study is presented in Section 5,we conclude this study and offer relevant contributions and limitations in Section 6.

## 2. Literature review

### 2.1. Importance of essential patents

An essential patent is defined as “a patent that protects technology essential to a standard” (European Commission, 2014, p. 2). This type of patent is related to a standard that was established by a standards institute, such as the International Organization for Standardization, International Telecommunication Union (ITU),and European Telecommunications Standards Institute (ETSI), when a standard references a technology protected by a patent (Essential Patent Center, http://www.epcenter.or.kr/).

The reasons for emphasizing the significance of essential patents are three-fold. First, essential patents help a company to gain financial benefits, access necessary resources, and, ultimately, increase competitiveness. These patents are known to have higher quality and, thus, produce more technological value than are other types (Carpenter et al., 1981). Indeed, they have more forward citations than do other types (Rysman and Simcoe, 2008). In addition to their technological value, the recent trends of patent licensing have addressed the importance of essential patents. Cross-licensing is a main approach to accessing the necessary technologies and has been actively applied to essential patents, which indicates that a company having essential patents may have strong bargaining power when it needs to acquire technology from other companies. Moreover, essential patents are really *essential* to offering standards-compliant products or services (Bekkers et al., 2009). In a standards-based industry, companies have to use technologies covered by essential patents to make their products or services compliant to the standards. For such products and services, it is impossible to have an alternative solution that does not infringe an essential patent. Therefore, for a company, essential patents are its sustainable and inimitable assets. That is, even companies with original and fundamental technologies may need to pay a great amount of loyalty to their competitors if they do not have the necessary essential patents to do their business (Korean Intellectual Property Office, 2012).

Second, globalization has led to technology standardization, which is likely to increase the frequency of the use of essential patents. In the era of the World Trade Organization (WTO) and Free Trade Agreement, setting standards has become an important issue for free trade. For example, the WTO states, “The Technical Barriers to Trade (TBT) Agreement aims to ensure that technical regulations, standards, and conformity assessment procedures are non-discriminatory and do not create unnecessary obstacles to trade” (WTO, https://www.wto.org/english/tratop_e/tbt_e/tbt_e.htm).

Technology competition to acquire essential patents will continue to intensify. According to the ITU, essential patents can be classified into three categories based on the periodic relationships between patent-filing and standard-setting. Further, standard-setting has preceded technology development for 57% of essential patents, while, for 14% of essential patents, a patent was filed after its technology had been included in a standard (Park, 2011); for the remaining essential patents, a patent was filed during a standardization meeting. These statistics imply that corporate efforts have been directed and continue to be directed toward filing an essential patent after a new standard is released.

Finally, the emergence of non-producing entities (NPEs), especially those who enforce the right of their patents, usually bought from the original inventors, to make a profit by suing others for patent infringement, has necessitated the pre-securement of essential patents (Jeong and Yoon, 2011). Patent Freedom reports that NPEs have focused more on high-tech inventions than on others (Chien, 2009). In a narrow sense, an NPE, also called a patent troll, is a person or company who acquires the ownership of a patent but never intends to use the patent for producing a product. Instead, they use the patent rights to sue others who use the patents without permission (McDonough, 2006). Therefore, the activities of NPEs can seriously threaten and interrupt the continuation of the current business of an ordinary firm.

In order to defend and enforce technology rights, companies increasingly find it strategic to use essential patents. Recognizing the significance of these patents in this globalized and knowledge-based economy, there exist several recent attempts to analyze essential patents. For example, Kang et al. (2014) have analyzed essential patents to compare Chinese and Korean companies in ICT global standardization. Contreras (2014) has investigated the patterns of engagement in the standardization of the Internet, where not only patenting, but also two other measures—participation and leadership—are introduced to examine the different patterns among Japan, Korea, and China. In line with such attempts, this present study aims to develop a method that can help a company to monitor its competitors' strategies as well as to identify its position with regard to essential patents.

### 2.2. Portfolio for patent strategy analysis

R & D investment is one of the essential decisions related to technology management. Management needs to decide which technology a company should target for investment, and how many resources and how much funding it should invest in the technology. A portfolio was first suggested to support this kind of decision-making (Ernst et al., 2004). Moreover, a portfolio has an advantage in that it enables a decision-maker to visually structure a complex problem. In particular, a patent portfolio helps a company to understand its technological strengths and weaknesses, compared to its competitors, from an objective perspective. Further, it provides valuable information for strategy-making on R & D investment; for example, it has been used to help determine the amount of R & D funding for different technology areas (Ernst, 2003) and identify licensing opportunities. As a patent portfolio represents only a limited amount of information that is critical to decision-making, it enables the efficient use and delivery of information (Ernst, 2003).

Accordingly, many previous studies have attempted to support decision-making using patent portfolios, which can be largely divided into two research streams. The first stream concerns the studies that have applied a patent portfolio to a particular industry, aiming to gain useful insights on the industry with a particular focus on industry-specific characteristics and competition analysis. Thus, the targets for analysis are mainly emerging or revitalizing industries via breakthrough technologies, such as the cloud computing (Huang, 2016), wind (Kapoor et al., 2015), automobile (Bakker, 2010), and fuel cell vehicle (Ha et al., 2015) industries. The second research stream is related to elaborating patent portfolio approaches. These studies have suggested a new approach that can better support decision-making based on patent analysis by developing a novel patent index to expand the applicability of patent portfolios, proposing an organization-specific portfolio analysis, and combining portfolio analysis with other methods to promote its effective use. As a result, patent portfolios have been applied to various areas such as supporting new product development (Lee et al., 2008), technology roadmapping (Lee et al., 2009b), investigating technology convergence (Geum et al., 2012), discovering new market and technology opportunities (Fabry et al., 2006; Lee et al., 2009c), and searching for potential R & D partners (Song et al., 2016). Further, there has been a continuous effort to help companies effectively adopt and use patent portfolios, trying to valuate a corporate patent portfolio (Grimaldi et al., 2015) or customize a portfolio method especially for small- and medium-sized enterprises (Littmann-Hilmer and Kuckartz, 2009).

Despite the valuable contribution of existing studies, however, few have considered the differences in types of patents; patents are classified into several categories—utility, design, business model, and essential—each of which protects different aspects of innovation. Of course, some studies focused on the diversity of patent portfolio considering these types, that is, whether it is diversified with even or uneven distribution of utility, design, business model and essential patent or not, arguing that such diversity is beneficial to leveraging firm performance (Lin et al., 2006; Srivastava and Gnyawali, 2011). In contrast, others questioned the value of holding diverse patents, emphasizing the benefits of specialization (Parchomovsky and Wagner, 2005), which may bring the potential paradox of diversification. Despite this conflict, the previous studies have seldom deliberated such a diversity of patents in developing a patent portfolio method; little effort has been put in designing a patent portfolio specifically for a particular type of patents. To overcome this limitation, this study restricts its focus to essential patents, and designs a patent portfolio for such patents, so that the portfolio can be used to investigate organizational technology and standardization strategies. Furthermore, these strategies, defined as filing behaviors (Berger et al., 2012), can cause significant distortions in a firm's technological strategy; thus, they must be further clarified due to the restricted focus of the current study (Lerner and Tirole, 2015).

## 3. Methodology

### 3.1. Overall research process

The overall process for this study consists of five steps (see Fig. 1). First, key areas for investigation were identified (Step 1), based on which five patent portfolios and corresponding ten patent indexes were developed (Step 2). Then, the portfolio analyses suggested in this study were applied to LET-A technology with a particular focus on essential patents to ensure in-depth analysis of organizational standard-setting activities. For this purpose, the list of essential patents corresponding to LTE-A standards was obtained from the ETSI database. All essential patents in the LTE-A technology field could be identified from this database, as the ETSI is in charge of approving essential patents in the telecommunications. Then, the bibliometric information for the essential patents was collected from the WIPS database (www.wipson.com) (Step 3). We also identified the top 10 organizations in terms of the number of essential patent applications and gathered data on all their non-essential patents for telecommunications technology. From the analysis results, patent strategies for the 10 leading organizations in the telecommunications industry were examined (Step 4), and methodological and practical implications could then be derived (Step 5).

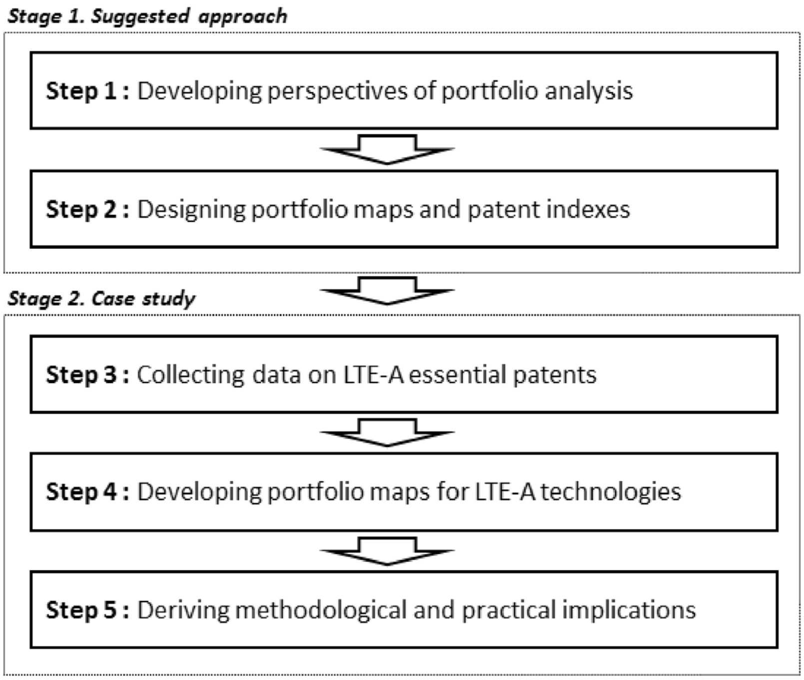


**Fig. 1.** Overall research process.

### 3.2. Case study background

LTE-A technologies in the telecommunications industry have been selected as a case example to apply the suggested approach. The rationales of choosing these technologies together with the data collection methods are explained in the following subsections.

#### 3.2.1. Rationales of technology selection

Setting an industry standard exerts a significant influence on competitiveness in the industry; such a standard enables the reduction in the uncertainty in a market and cost of products (Funk and Methe, 2001). Due to this significance, the process of standard-setting has been empirically investigated in a number of previous studies, among which David and Steinmueller (1994) claimed that standardization in the telecommunications industry is one of the most typical examples of standard-setting in a technological system. The particular focus of this study is on LTE-A technologies, which are the fourth-generation telecommunications technologies that were created to advance the LTE technologies managed by the 3rd Generation Partnership Project (3GPP). These technologies are compatible with LTE technologies and need to meet the International Mobile Telecommunications requirements of the International Telecommunication Union's Radiocommunication sector (ITU-R); they started to become standardized by 3GPP Release 10, as the early fourth-generation telecommunications technologies (Parkvall et al., 2011; Ghosh et al., 2010). At the same time, the LTE system has now reached its maturity stage (Andrews et al., 2014) and fifth-generation telecommunications technologies are expected to overcome the limitations of the LTE system (Boccardi et al., 2014; Chen and Zhao, 2014). Consequently, the size of essential patents for LTE-A technologies is large enough to derive meaningful implications from their analysis. Furthermore, it is timely to examine the technology standardization strategies for leading companies in the telecommunications industry with respect to their fourth-generation technologies, when technology standards for the fifth generation need to be established.

#### 3.2.2. Rationales of database selection

We obtain the entire list of essential patents for LTE-A technologies from the ETSI database. In 3GPP, technology specifications for LTE-A were identified in and after 3GPP Release 10. Therefore, the LTE-A essential patents are collected from 3GPP projects released after 3GPP Release 10. We also collect bibliometric information regarding the essential patents from the WIPS database, together with telecommunications-related non-essential patents published by the top 10 organizations. The patents for analysis are restricted to four patent databases—the United States Patent and Trademark Office (USPTO), European Patent Office (EPO), Japanese Patent Office (JPO), and Korean Intellectual Property Office (KPO) databases. The largest number of patents is published in these patent offices and their patents account for most technologies; the patent trends and technological characteristics can be identified from these four databases, which verify their use for this study. We also limit the patents published from 2008 to 2014 as the target, stressing their recent R & D activities and technology standardization efforts, as March 2008 is the month in which the LTE-A standards began to be established.

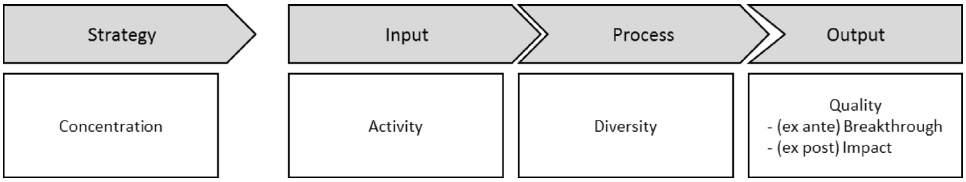


**Fig. 2.** Perspectives to investigate essential patent strategies.

## 4. Suggested approach

### *4.1. Develop perspectives of portfolio analysis*

In general, an integrated portfolio, which is regarded as a set of portfolios, is considered more powerful than an individual portfolio, as synergistic effects among different portfolios are expected (Lin et al., 2006). Hence, taking a multi-perspective approach is worthwhile to designing a patent portfolio and,accordingly, an input-process-output (IPO) model is adopted to examine the essential patent strategy from such a perspective. First, from the *input* perspective, the main focus is the degree of activities related to the essential patents filed by an organization (*activity*), as an input for patenting activities. Second, from the *process* perspective, the degree of diversity in technologies on which the organization is working (*diversity*) is considered a detailed process attribute for patenting activities. Finally, from the *output* perspective, the target for analysis is the quality of essential patents, as an output for patenting activities (*quality*). On the other hand, all of these activities will be affected by organizational strategies and, thus, an additional perspective of *strategy* is added to the basic IPO model in order to help understand the general organizational strategies toward essential patents, with respect to the degree of emphasis on essential patents compared to non-essential ones (*concentration*).

Here, it should be noted that the *quality* is measured in two ways—*breakthrough* and *impact* to consider various aspects of quality. According to Arts et al. (2013), technological inventions (i.e. patents) have been measured largely using two types of indicators—ex ante and ex post; the former measures the nature of technology (e.g., novelty), while the latter considers the impacts of technology (e.g., subsequent usage). They also demonstrated that using various indicators complementarily increases the likelihood of capturing a significant technological innovation. The quality for standard technologies can also be examined using both types of indicators to provide complementary insight. Fig. 2 represents the four perspectives suggested in this study to analyze essential patent strategies.

### *4.2. Designing portfolio maps and patent indexes*

Based on these perspectives, five maps are proposed to analyze the degree of concentration on essential patents, degree of activities in filing essential patents, diversity of technologies regarding essential patents, and quality (breakthrough and impact) of essential patents. As two indexes are required to construct each portfolio map, a total of 10 indexes are designed based on previous studies, as shown in Table 1.

#### *4.2.1. Concentration*

The purpose of a *concentration* map is to show the degree of emphasis an organization places on the development of standard technology from the strategy perspective. This map consists of two axes—the *X*-axis, indicating *technological strength* (TStr) in the industry of concern, and *Y*-axis, signifying the *emphasis on technology standard* (EmTStd) in that industry (see Fig. 3). For EmTStd, the number of patents is employed because it is one of the most frequently used proxies to measure organizational R & D activities (Ernst, 1998). On the contrary, the EmTStd is measured by the ratio of essential patents to total patents in the industry of concern, so that we can see the emphasis on an international standard regarding the overall patents filed by a company

Thus, the companies in the first quadrant, referred to as *dominant*, are those that have great technological strength in the industry and pay great attention to the industry standards; these can be regarded as technology leaders in the industry. On the other hand, companies in the second quadrant have relatively weak technological capabilities in general, but focus greatly on technology standards; a relatively large share of their technologies corresponds to standard technologies and, thus, they are referred to as *essential-intensive*. Moreover, companies in the third quadrant have neither strong technology capabilities, nor a large number of standard technologies; they are likely to have competitive advantages other than technologies, and are referred to as *latent*. Finally, the fourth quadrant includes companies with a great number of patents with relatively little focus on essential patents; these companies seem to have technology leadership in the industry, but not with regard to standard technology and, thus, are referred to as *general-focused*.

#### *4.2.2. Activity*

The *activity* map is a patent portfolio that visualizes the general R & D activities in standard technologies from the input perspective. It is different from the concentration map in that it limits its analysis to only standard technologies. In this map, companies for analysis are classified into four categories according to two criteria—*standard technology strength* (STStr) for the X-axis and *standard technology recency* (STR) for the *Y*-axis (see Fig. 4). STStr indicates the relative technological strength in terms of standard technologies, while STR represents the recent efforts in acquiring such technologies. Specifically, the STStr is evaluated by the number of essential patents an organization possesses in the industry of concern, while the STR is measured by the ratio of recent

**Table 1**
Operational definition of indexes.

| Portfolio | Indexes | Operational definition |
|---|---|---|
| Concentration | TStr_*i* | Number of patents granted by company i |
| | EmTStd_*i* | $\frac{\text{Number of essential patents granted by company } i}{\text{Number of patents granted by company } i}$ |
| Activity | STStr_*i* | Number of essential patents granted by company i |
| | STR_*i*(*t*) | $\frac{\text{Number of essential patents granted by company } i \text{ during recent } t \text{ years}}{\text{Number of essential patents granted by company } i}$ |
| Diversity | STVar_*i* | Number of different IPC subclasses in essential patents granted by company i |
| | STBal_*i* | $\sum_{j=1}^{VR_i} {p_j}^2$ where $p_j$ is individual share of IPC subclass $j$ against all the IPC subclasses of essential patents in company $i$ |
| Breakthorugh | STN_*i* | Number of essential patents of company i which have more than 0 novelty score. Where novelty score of patent $k$ is $\frac{\text{Number of novel subclass pairs of essnetial patent } k}{\text{Number of subclass pairs of essential patent } k}$ |
| | STF_*i* | $\frac{1}{Ststr.i} \times \sum_{\text{essential patent k of company } i} \sum_{\text{all patent } j \text{ applied before patent } k} \left[ \{\text{patent } j \text{ uses subclass } m\} \times e^{-\left(\frac{\text{application year f patent} k - \text{application year of patent} j}{\text{time constant of knowledge loss}}\right)} \right]$ |
| Impact | STEI_*i* | $\frac{\text{Number of patent families for essential patents granted by company } i}{\text{The number of essential patents granted by company } i}$ |
| | STTI_*i* | $\frac{\text{Number of cited frequency of essential patents granted by company } i}{\text{Number of essential patents granted by company } i}$ |

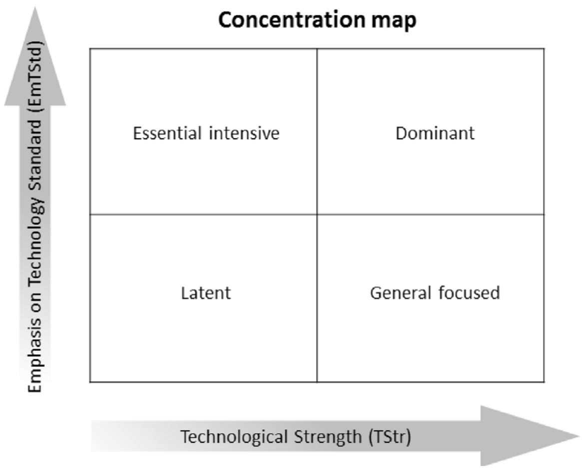


**Fig. 3.** Concentration map for standard technologies.

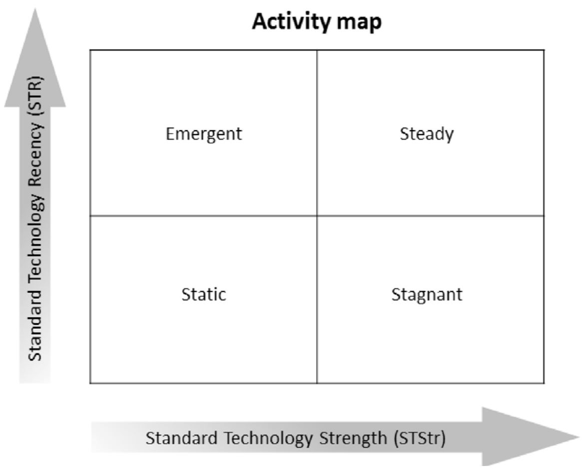


**Fig. 4.** Activity map for standard technologies.

essential patents (for the most recent *t* years) to total essential patents an organization has in the industry of concern, by borrowing the concept of revealed technological advantage (e.g., Havrila and Gunawardana, 2003).

Therefore, companies in the first quadrant are characterized by relatively steady R & D in standard technologies and constant efforts on technology standardization, referred to as *steady*. In the case of the second-quadrant companies, they show less R & D in standard technologies, but most of their R & D activities are recent and, thus, they are regarded as *emergent*. The third-quadrant companies have relative weakness in technology standardization, as they neither show intensive R & D activities for standard technologies, nor have been recently active; they are referred to as *static*. Finally, companies in the fourth quadrant present active involvement in developing standard technologies, but their R & D activities for such technologies have recently decreased; their interest in technology standardization seems to have decreased and, thus, they are referred to as *stagnant*.

#### 4.2.3. Diversity

The *diversity* map (see Fig. 5) shows how widely an organization's essential patents are distributed across different technologies as well as main technologies in the industry, from the process perspective. When filing its essential patents, the organization may choose a centralization strategy by focusing only on a particular technology, or adopt a diversification strategy by widening its scope of patent application. According to Stirling (1998), the concept of diversity can be defined in three ways: variety, balance, and disparity. Variety indicates the number of categories and balance refers to the appointment to categories, while disparity signifies the differences between the categories. Among these concepts, we focus on variety and balance to construct the diversity map given that patents for standard-setting are likely to have technologically similar characteristics, indicating that disparity might not be a main concern. In addition, as a unit of analysis for a portfolio map is generally an organization that has a set of patents, the technological disparity of the unit is somehow decreased, weakening the value of disparity analysis. Hence, in this map, the *X*-axis is designed to indicate the degree of diversification in technology areas for essential patent application—*IPC variety* (STVar)—while the Y-axis is the degree of R & D concentration in technology areas for essential patent application—*IPC balance* (STBal). In practice, technological

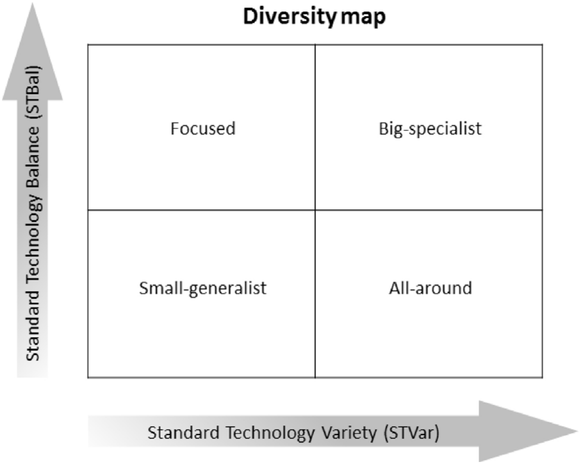


**Fig. 5.** Diversity map for standard technologies.

diversity in patents has been commonly evaluated using IPC (e.g., Kim and Lee, 2015). If the patents in an organization cover more IPCs and are more evenly distributed across the IPCs, diversity increases. In this study, STVar is measured by the number of IPC subclasses to which the patents an organization possesses belong. Here, it should be noted that there exist major technological areas, in which a relatively large number of patents are filed, and minor technological areas, in which only a few patents are filed. To see whether the technologies that an organization possesses are specialized in a few major areas or diversified over a number of areas, STBal for an organization is measured using the Hirschman–Herfindahl index (HHI) of IPC subclasses.

Therefore, companies in the first quadrant have developed various standard technologies, concentrating on limited areas, and are referred to as *big-specialist*. On the other hand, those in the second quadrant have developed standard technologies across less number areas, again focusing only on a few areas as big-specialist, and thus are referred to as *focused*. Companies in the third quadrant are the opposite of those in the first, as their standard technologies cover only limited areas but are evenly distributed across them; they are named as *small-generalist*. Finally, companies in the fourth quadrant have developed various standard technologies across large number of areas but instead of focusing only on a few standard areas, their interest spans a considerable range of areas evenly; they are referred to as *all-round*.

#### 4.2.4. Quality-breakthrough map

To design the *breakthrough* map (see Fig. 6), we follow the conventional viewpoint that considers a technological invention as an evolutionary recombinant search process (e.g., Schumpeter, 1939; Mokyr, 1990; Basalla, 1988; Arts and Veugelers, 2014). Under this viewpoint, technological innovation is achieved when the following two conditions are satisfied: technological components are familiar with existing technologies (i.e., component familiarity (CF)); and combinations among technological components are novel (i.e., novelty component (NC)) (e.g., Fleming, 2001; Arts and Veugelers, 2014; Verhoeven et al., 2016). Therefore, as ex ante indicators, NC and CF are adopted, respectively, for the *X*- and *Y*-axis of the breakthrough map. Specifically, we borrowed the two indexes from Arts and Veugelers (2014), but modified them to fit the portfolio concept; their values are obtained using only essential

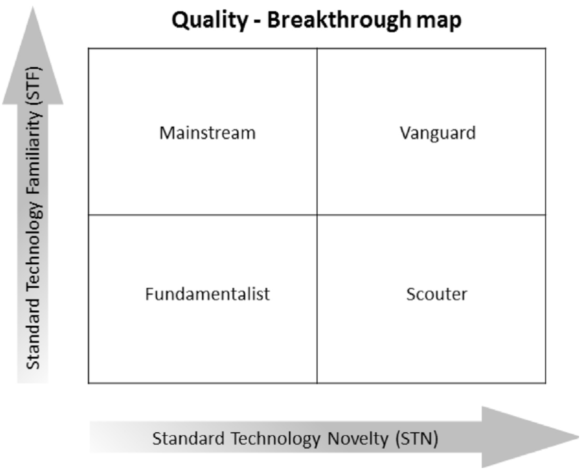


**Fig. 6.** Quality-breakthrough map for standard technologies.

patents and aggregated at a firm level, being renamed as standard technology familiarity (STF) and standard technology novelty (STN).

To construct NC, first, all unique subclass pairs of each patent in an overall dataset are identified. Then, among target patents, we discover which of these subclass pairs appear for the first time in the database. Finally, the novelty score is calculated by a focal patent's number of unprecedented subclass pairs divided by its total number of subclass pairs. Therefore, the novelty score to measure recombinant newness is between 0 and 1 (e.g., Fleming et al., 2007). Then, NC is the number of a company's patents that have a novelty score higher than 0. Further, to identify CF, we use the average value of an individual patent's familiarity scores. If a subclass in a patent was observed from prior patents recently, then the familiarity score of the patent would be increased (e.g., Fleming, 2001; Kaplan and Vakili, 2015). As such, the familiarity score (FS_*i*) for a single patent (patent *i*) is calculated as follows.

$$FSi = \sum_{\text{all atent } k \text{ applied before patent } i} \{\text{patent } k \text{ uses subclass } j\} \times e^{-\left(\frac{\text{application year of patent } i - \text{application year of patent } k}{\text{time constant of knowledge loss}}\right)}$$

For the time constant of knowledge loss, five years is used (i.e., a yearly knowledge loss of 18%) in line with prior research (Katila and Ahuja, 2002). For both NC and CF, we use IPC subclasses because of the following reasons. First, an IPC system is more comprehensive and internationally widely accepted compared to the USPC system. Second, IPC is assigned based on the technological information, while USPC is assigned from the perspective of legal protection (see Gruber et al. (2013) for details). Third, as subclasses in the USPC system are quite diverse within an overly disaggregated level of classification (about 160,000 subclasses), it is highly likely that a patent with high NC is too frequently observed (see Strumsky and Lobo (2015) for details). Finally and most importantly, essential patents used for analysis in this study cover not only those published in the US but also in other countries; the use of IPC is more appropriate than the use of USPC.

The first quadrant achieves both high technological novelty and high familiarity, indicating creative expansions of the technological standard domain. Thus, in standard-setting, companies in this quadrant can be considered the *innovator* of technology standard. The second-quadrant companies have essential patents with low novelty, but high familiarity, meaning that the latest technological trends are reflected in their patents. Despite their comparatively low novelty, the inventions of second-quadrant companies may ensure high compatibility due to high technological familiarity. Therefore, companies in this quadrant can be regarded as the mainstream of standard-setting but as *follower*. The third quadrant has relatively low novelty and familiarity. Considering that a standard tends to change over time, companies in the third quadrant possibly focus on basic and conventional technological components that used to be necessary in the past, but are rather far from the latest changes for the new standard. Or they may have focused on niche areas. Hence, we label the third quadrant as *outsider*. Finally, for the fourth-quadrant companies, they possess inventions of relatively high novelty, but low familiarity. These companies are experimentally innovative and comparatively far from the trajectories of current technology, being considered as *inventor*.

#### 4.2.5. Quality-impact map

The *impact* map (see Fig. 7) judges the degree of superiority for standard technologies in terms of economic and technology values. The *X*-axis designates the degree of economic value for essential patents, measured by *economic impact* (STEI), while the *Y*-axis indicates the degree of technology value for such patents, measured by *technological impact* (STTI). Since high-quality patents are known to have significant positive effects on organizational performance (Ernst, 1995), considerable efforts have been made to evaluate patent quality; they have suggested such approaches as the number of claims, similarity with prior art, and applicability to measuring patent quality (Trappey et al., 2012). Among the possible alternatives, this study adopts the use of patent family and patent citation information. The size of the patent family denotes the global coverage of the patent (Harhoff et al., 2003), and STEI is measured by the average size of the patent family for essential patents filed by an organization; the organization grants a patent right

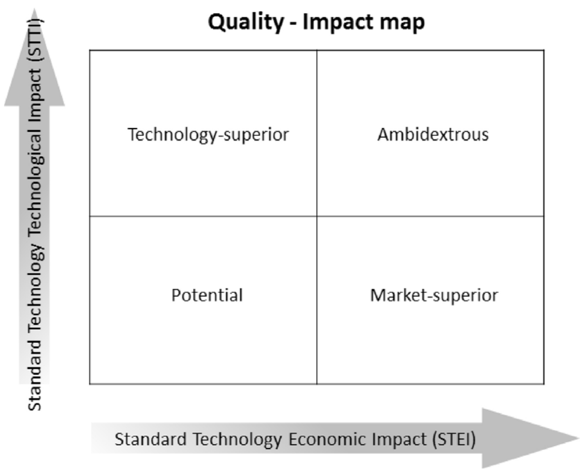


**Fig. 7.** Quality-impact map for standard technologies.

**Table 2**
Number of essential patents per patent office by year (whole dataset).

| Year | Patent office | | | | Total |
|---|---|---|---|---|---|
| | USPTO | KPO | JPO | EPO | |
| 1980s | 0 | 0 | 0 | 1 | 1 |
| 1990s | 78 | 3 | 5 | 56 | 142 |
| 2000 | 8 | 0 | 1 | 30 | 39 |
| 2001 | 35 | 4 | 2 | 21 | 62 |
| 2002 | 50 | 1 | 0 | 24 | 75 |
| 2003 | 64 | 1 | 7 | 32 | 104 |
| 2004 | 68 | 1 | 4 | 41 | 114 |
| 2005 | 88 | 1 | 5 | 53 | 147 |
| 2006 | 103 | 1 | 11 | 63 | 178 |
| 2007 | 113 | 0 | 9 | 42 | 164 |
| 2008 | 131 | 1 | 11 | 48 | 191 |
| 2009 | 216 | 37 | 64 | 68 | 385 |
| 2010 | 212 | 85 | 133 | 58 | 488 |
| 2011 | 271 | 73 | 65 | 58 | 467 |
| 2012 | 202 | 31 | 32 | 27 | 292 |
| 2013 | 106 | 14 | 9 | 4 | 133 |
| 2014 | 49 | 0 | 9 | 1 | 59 |
| Total | 1716 | 250 | 362 | 570 | 3041 |

in a country only when it can expect great economic benefits there due to the high cost of patent registration. In contrast, STTI is measured by the average number of patent citations for essential patents filed by an organization; a patent more frequently cited by other patents is more likely to significantly affect subsequent technologies (Lin et al., 2006).

The first-quadrant companies possess both economically and technologically high-quality standard technologies, and are referred to as *ambidextrous*. Moreover, these companies are likely to have a strong will to expand their business to global markets, and their standard technologies have likely been continuously used for next-generation technologies. Unlike these companies, those in the second quadrant are characterized more by technological value, rather than economic value, for their standard technologies; they are referred to as *technology-superior*. Companies in the third quadrant possess relatively low-quality standard technologies, both technologically and economically; these companies are referred to as *potential*. Finally, the fourth-quadrant companies have standard technologies available for global markets, but these technologies have only minor impacts on next-generation technologies; these companies are referred to as *market-superior*.

## 5. Case study: LTE-A technologies

### 5.1. Data collection

Based on the entire essential patents list for LTE-A standard-setting, we collect the bibliographic information for all of the patents. Consequently, starting with the patent applied in 1988, a total of 3041 essential patents are obtained, as shown in Table 2.The table shows that some of the patents applied far before their declaration as standards. The number of patents granted in the USPTO is dominating, followed by EPO, JPO, and KPO. Moreover, the number of essential patents tends to decrease from 2011, partly because of the technological changes from the fourth to fifth generations, and partly because of the time gap between patent application and registration. The data were collected in January 2015 when there were still numerous patents, which were applied for between 2012 and 2014, waiting to be granted.

When focusing on the essential patents applied for since March 2008, there are 1987 essential patents (65.34%) among the total 3041 essential patents for the LTE-A. The distribution of patents across IPCs is presented in Table 3. A total of 1974 patents (99%), of the 1987 applied for since March 2008, have one or several of the following five IPCs:electric communication technique (H04); computing, calculating, counting (G06); musical instruments (G10); signaling (G08); and basic electronic circuitry (H03).All patents published in JPO and KPO have at least one of these five IPCs.

As such, further analysis is conducted at the IPC subclass level and the results are summarized in Table 4. They indicate that the top five subclasses in the number of essential patents include wireless communication networks (H04W), transmission of digital information (H04L), transmission of information-carrying signals (H04B), multiplex communication (H04J), and electric digital data processing (G06F). Again, 1891 patents of all 1974 (95%) have at least one of these subclasses. Interestingly, four subclasses are involved in electric communication technique (H04), whereas only one is involved in computing, calculating, counting (G06). The scope of technologies for essential patents in the telecommunications industry is quite narrow and limited to wireless communications networks, as can be easily imagined.

As the top five subclasses include most of the technologies, further analysis is conducted at the main group of IPCs, except for the breakthrough map, which is a one-step-lower level of the subclass level. At the main class level (see Table 5), a total of 3596 main groups (including redundancies) are observed in the 1987 patents, out of which the top 10 main groups appear 2141 times (including redundancies).

**Table 3**
Number of essential patents of the target companies per patent office by year (top 10 companies).

| Year | USPTO | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | LG Electronics | BlackBerry | Apple | NTT DOCOMO | Motorola | Nokia | Ericsson | Qualcomm | Sharp | Kyocera |
| 2008 | 7 | 21 | 17 | 0 | 4 | 13 | 21 | 8 | 1 | 0 |
| 2009 | 33 | 18 | 24 | 0 | 36 | 19 | 18 | 26 | 3 | 0 |
| 2010 | 26 | 49 | 17 | 0 | 29 | 7 | 27 | 20 | 5 | 0 |
| 2011 | 17 | 42 | 25 | 0 | 46 | 8 | 23 | 40 | 1 | 2 |
| 2012 | 33 | 27 | 47 | 0 | 11 | 5 | 19 | 8 | 3 | 3 |
| 2013 | 15 | 5 | 32 | 0 | 0 | 4 | 7 | 6 | 1 | 0 |
| 2014 | 4 | 0 | 36 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Total | 135 | 162 | 198 | 0 | 126 | 56 | 116 | 108 | 14 | 5 |
| Year | EPO | | | | | | | | | |
| | LG Electronics | BlackBerry | Apple | NTT DOCOMO | Motorola | Nokia | Ericsson | Qualcomm | Sharp | Kyocera |
| 2008 | 1 | 13 | 0 | 1 | 5 | 12 | 1 | 0 | 0 | 0 |
| 2009 | 12 | 13 | 0 | 0 | 2 | 28 | 2 | 1 | 0 | 0 |
| 2010 | 11 | 14 | 0 | 0 | 3 | 14 | 0 | 0 | 0 | 0 |
| 2011 | 29 | 4 | 0 | 3 | 0 | 10 | 0 | 0 | 0 | 0 |
| 2012 | 17 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| 2013 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| 2014 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Total | 75 | 44 | 0 | 4 | 10 | 67 | 6 | 1 | 0 | 0 |
| Year | JPO | | | | | | | | | |
| | LG Electronics | BlackBerry | Apple | NTT DOCOMO | Motorola | Nokia | Ericsson | Qualcomm | Sharp | Kyocera |
| 2008 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 1 | 0 |
| 2009 | 0 | 0 | 0 | 32 | 0 | 0 | 0 | 0 | 21 | 10 |
| 2010 | 2 | 0 | 0 | 63 | 0 | 0 | 0 | 0 | 32 | 36 |
| 2011 | 0 | 0 | 0 | 20 | 2 | 0 | 0 | 0 | 16 | 27 |
| 2012 | 1 | 0 | 0 | 17 | 1 | 0 | 0 | 0 | 12 | 0 |
| 2013 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 0 |
| 2014 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 |
| Total | 5 | 0 | 0 | 138 | 3 | 0 | 0 | 0 | 94 | 73 |
| Year | KPO | | | | | | | | | |
| | LG Electronics | BlackBerry | Apple | NTT DOCOMO | Motorola | Nokia | Ericsson | Qualcomm | Sharp | Kyocera |
| 2008 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 2009 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2010 | 51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2011 | 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2012 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2013 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2014 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 140 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Sum | 355 | 206 | 198 | 142 | 139 | 124 | 122 | 109 | 108 | 78 |

**Table 4**
IPC distribution in LTE-A essential patent by patent office – class level.

| No. | IPC | Description of IPC | KPO | USPTO | EPO | JPO | Total |
|---|---|---|---|---|---|---|---|
| 1 | H04 | Electric communication technique | 241 | 1107 | 248 | 322 | 1918 |
| 2 | G06 | Computing,calculating, counting | 0 | 32 | 1 | 0 | 33 |
| 3 | G10 | Musical instruments | 0 | 5 | 3 | 0 | 8 |
| 4 | G08 | Signaling | 0 | 8 | 0 | 0 | 8 |
| 5 | H03 | Basic electronic circuitry | 0 | 7 | 0 | 0 | 7 |

**Table 5**
IPC distribution in LTE-A essential patent by patent office – sub-class level.

| No. | IPC | Description of IPC | KPO | USPTO | EPO | JPO | Total |
|---|---|---|---|---|---|---|---|
| 1 | H04W | Wireless communications networks | 63 | 704 | 106 | 287 | 1160 |
| 2 | H04L | Transmission of digital information | 39 | 180 | 93 | 4 | 316 |
| 3 | H04B | Transmission systems for measured values, control or similar signals; coding, decoding, code conversion; broadcast communication; multiplex systems; secret communication; transmission of digital information | 86 | 120 | 26 | 1 | 233 |
| 4 | H04J | Broadcast communication | 53 | 46 | 21 | 30 | 150 |
| 5 | G06F | Electrical digital data processing | 0 | 31 | 1 | 0 | 32 |

**Table 6**
IPC distribution in LTE-A essential patent by patent office – main class level.

| No. | IPC | Description of IPC | KPO | USPTO | EPO | JPO | Total |
|---|---|---|---|---|---|---|---|
| 1 | H04W-072 | Local resource management (e.g., selection or allocation of wireless resources or wireless traffic scheduling) | 36 | 299 | 45 | 136 | 516 |
| 2 | H04B-007 | Radio transmission systems (i.e., using radiation field) | 159 | 137 | 68 | 29 | 393 |
| 3 | H04J-011 | Orthogonal multiplex systems | 91 | 15 | 29 | 92 | 227 |
| 4 | H04W-024 | Supervisory, monitoring or testing arrangements | 22 | 111 | 13 | 66 | 212 |
| 5 | H04W-036 | Handoff or reselecting arrangements | 9 | 97 | 18 | 38 | 162 |
| 6 | H04L-027 | Modulated-carrier systems | 47 | 71 | 22 | 10 | 150 |
| 7 | H04W-004 | Services or facilities specially adapted for wireless communications networks | 4 | 125 | 6 | 6 | 141 |
| 8 | H04W-052 | Power management (e.g., TPC | 19 | 50 | 18 | 35 | 122 |
| 9 | H04L-001 | Arrangements for detecting or preventing errors in the information received) | 39 | 23 | 46 | 7 | 115 |
| 10 | H04W-016 | Network planning (e.g., coverage or traffic planning tools); network deployment (e.g., resource partitioning or cell structures) | 2 | 8 | 6 | 87 | 103 |

Despite the numerous organizations that declared the essentiality of their patents, the top 10 companies occupy 79.57% of essential patents, which were applied for since March 2008 (1581 patents), as described in Table 6. As most of the essential patents are held by those top 10 companies[1]—LG Electronics (355 patents), BlackBerry (206 patents), Apple (198 patents), NTT DOCOMO (142 patents), Motorola (139 patents), Nokia (124 patents), Ericsson (122 patents), Qualcomm (109 patents), Sharp (108 patents), and Kyocera (78 patents)—after establishing the LTE-A standard, we focus on these patents as the target to examine the strategic patenting of essential patents by means of the portfolio approach.

The individual IPC distributions of every target company are highly skewed. LG Electronics holds 185 essential patents within H04W (52.11%) followed by H04B (173, 48.73%) and H04L (113, 31.83%). For BlackBerry, 110 essential patents are involved in H04W (53.40%) and, subsequently, in H04L (55, 26.70%) and G06F (18, 8.74%). Apple is similar to LG Electronics because it holds 118 essential patents within H04W (59.60%), followed by H04L (53, 26.77%) and H04B (50, 25.25%). NTT DOCOMO has 138 essential patents with H04W (97.18%), followed by H04J (41, 28.87%) and H04B (19, 13.98%). Regarding Motorola, 98 essential patents are applied for in H04W and, subsequently, in H04L (31, 22.30%) and H04B (24, 17.27%). Nokia, Ericsson, and Qualcomm are also similar to Apple and LG Electronics with respect to major IPCs. Nokia takes 83 essential patents for H04W (66.94%), followed by H04L (38, 30.65%) and H04B (11, 8.87%). Ericsson holds 85 essential patents within H04W (69.67%), followed by H04L (22, 18.03%) and H04B (14, 11.48%). For the Qualcomm, 70 essential patents are assigned in H04W (64.22%) and, subsequently, in H04L (24, 22.02%) and H04B (17, 15.60%). Sharp holds 97 essential patents within H04W (89.81%), followed by H04J (55, 50.93%) and H04L (17, 15.74%). Finally, regarding Kyocera, it has 76 patents, which are applied for as having H04W (97.44%), followed by H04B (8, 10.26%) and H04J (4, 5.13%).

### *5.2. Portfolios for LTE-A essential patents*

Referencing the operational definition in Table 1, index values for all 10 organizations are obtained (see Table 7). When calculating the STR_$i(t)$ value, $t$ was set to 4 because LTE-A technologies were practically commercialized in 2011, indicating that patents applied for in and after 2011 are regarded as recent patents.

A patent portfolio is especially useful for monitoring competitors and strategic positioning (Ernst, 1998). It helps to identify leading companies (Ernst, 2003) and even predict future leaders (Siebert and Von Graevenitz, 2010). Likewise, as comparative analysis is one of the key benefits of using patent portfolio, comparative values are adopted in this study. That is, observed maximum and minimum values are assigned to the maximum and minimum values for portfolios, respectively; the median values are used to

[1] For the top 10 organizations, we identify them based on the *declaring companies* in the ETSI list. This means that the actual owner of a patent is considered rather than assignee information, which is written when the patent is filed. In addition, different names for the same company are adjusted. Specifically, three companies required such adjustment. First, "Research in Motion Limited" and "Blackberry" are regarded as the same company, "BlackBerry." Second, "Nokia" has three different names that are identified as "Nokia Networks Oy," "Nokia Networks," and "Nokia Corporation". Third, "MML" and "Motorola Mobility"are considered the same company, "Motorola."

**Table 7**
Index values for the 10 leading companies.

| Company | TStr | EmTStd | STStr | STR | STVar | STBal | STN | STF | STEI | STTI |
|---|---|---|---|---|---|---|---|---|---|---|
| LG Electronics | 13,569 | 0.026 | 355 | 0.518 | 13 | 0.253 | 7 | 431.249 | 25.116 | 0.882 |
| BlackBerry | 1787 | 0.115 | 206 | 0.379 | 9 | 0.292 | 1 | 281.361 | 15.777 | 2.748 |
| NTT DOCOMO | 4689 | 0.030 | 142 | 0.296 | 7 | 0.447 | 2 | 388.541 | 9.451 | 0.296 |
| Motorola | 3452 | 0.040 | 139 | 0.432 | 10 | 0.357 | 1 | 331.431 | 7.022 | 4.576 |
| Nokia | 3694 | 0.034 | 124 | 0.242 | 12 | 0.388 | 3 | 252.525 | 6.815 | 1.952 |
| Sharp | 1882 | 0.057 | 108 | 0.417 | 6 | 0.378 | 1 | 455.666 | 9.361 | 0.472 |
| Qualcomm | 9491 | 0.012 | 109 | 0.495 | 10 | 0.333 | 0 | 340.494 | 28.762 | 5.780 |
| Apple | 732 | 0.271 | 198 | 0.707 | 17 | 0.288 | 5 | 460.014 | 19.394 | 2.748 |
| Ericsson | 5460 | 0.022 | 122 | 0.434 | 13 | 0.406 | 3 | 329.531 | 9.402 | 3.320 |
| Kyocera | 1881 | 0.042 | 78 | 0.410 | 8 | 0.664 | 2 | 369.763 | 5.680 | 0.077 |

*Notes*: TStr = technological strength, EmTStd = emphasis on technology standard, STR = standard technology recency, STVar = standard technology variety, STBal = standard technology balance, STN = standard technology novelty, STF = standard technology familiarity,STEI = standard technology economic impact, and STTI = standard technology technological impact.

divide the map into four sections.

Fig. 8 shows the *concentration map* for the 10 leading companies in LTE-A technology standards. All companies are positioned in the second and fourth quadrants; five are in the second quadrant (essential-intensive), while the other five stand in the fourth quadrant (general-focused). This result provides us with very interesting insight that none of the companies dominates both LTE-A standard and non-standard technologies. Moreover, as no companies exist in the third quadrant (*latent*), we can also understand that leading companies have technological capabilities either in standard or non-standard LTE-A technologies. If we expand the scope of the target companies to those with less essential patents, the positions of companies might spread in all quadrants. To recap, among the 10 leading organizations, there are only two categories: one group strongly focuses on the LTE-A standard, while the other might further extend its concerns on other telecommunications technologies. In particular, two companies, Apple and BlackBerry, are worth further investigation *(essential-intensive)*; they have put much stress on standard technologies, having a relatively large number of essential patents, when compared to their competitors. In contrast, other companies, such as LG Electronics and Qualcomm, have strong technology capabilities in the telecommunications industry, while focusing less on focal standard technologies, when compared to others (*general-focused*).

Fig. 9 presents the *activity map* for the 10 leading companies in LTE-A technology standards. Three companies (Apple, LG Electronics, and Motorola) are positioned in the first quadrant (*steady*), and two companies (Ericsson and Qualcomm) belong to the second quadrant (*emergent*). Three companies (Kyocera, Nokia, and Sharp) stand in the third quadrant (*static*), while the remaining two companies (BlackBerry and NTT DOCOMO) are in the fourth quadrant (*stagnant*).Based on this result, we can understand that three companies in the first quadrant, Apple, LG Electronics, and Motorola, want to fortify their LTE-A standard-leading positions, while two companies, BlackBerry and NTT DOCOMO, might move their focus to the next standard. Thus, further comparative investigation of patents for those aforementioned five companies (Apple, LG Electronics, and Motorola versus BlackBerry and NTT DOCOMO) can provide us with a lens to identify different characteristics between the LTE-A standard and a future standard. Further,

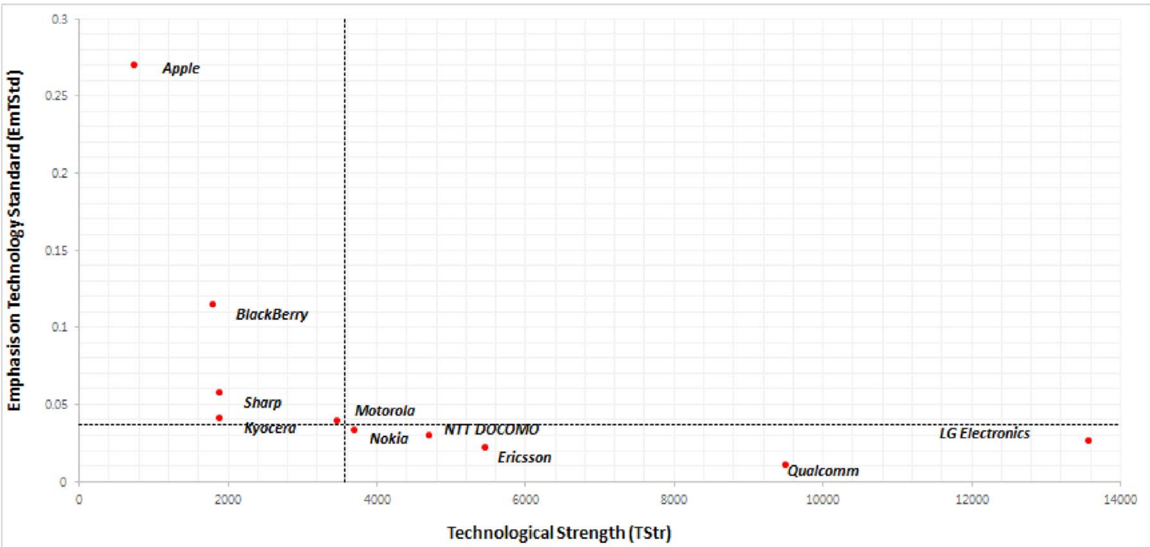


**Fig. 8.** Concentration map for LTE-A.

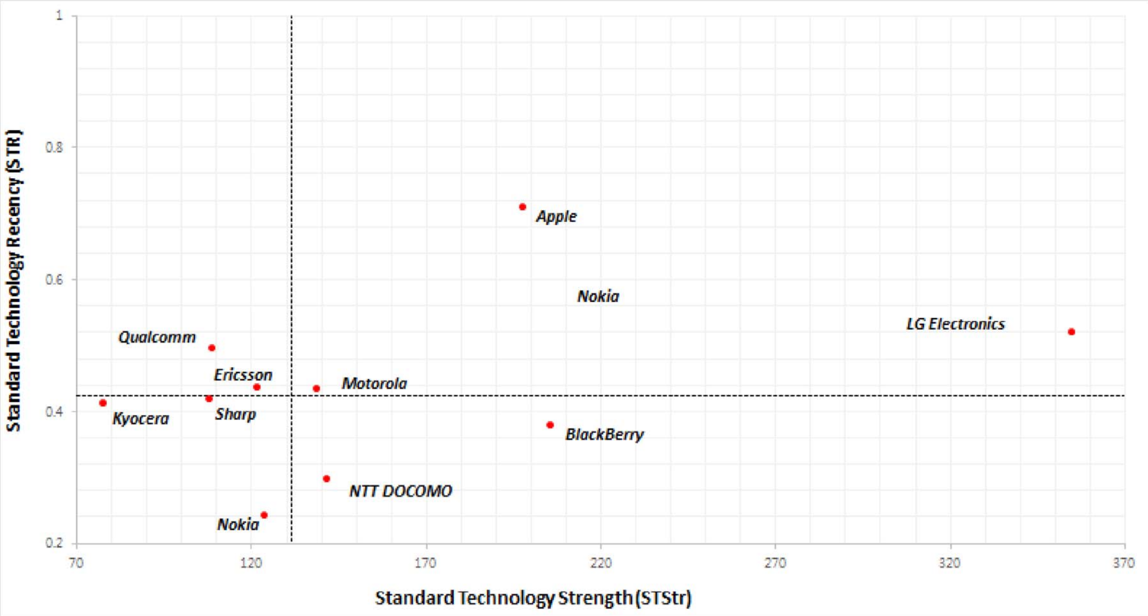


**Fig. 9.** Activity map for LTE-A.

although the absolute number of essential patents is small in companies, Qualcomm and Ericsson, which are new and late entrants into this market, have made enormous recent efforts to acquire such patents.

Fig. 10 shows the *diversity map* for the 10 leading companies in LTE-A technology standards. In the map, the majority of the companies (i.e., Apple, Kyocera, LG Electronics, Motorola, NTT DOCOMO, Qualcomm, and Sharp) are positioned in the second and fourth quadrants (*focused* and *all-around*, respectively). This signifies that the technological scope of individual companies can be largely divided in two ways: professionally focusing on certain technological areas and covering broad technological areas with a relatively even distribution of attention. Two companies, Ericsson and Nokia, are included in the first quadrant, indicating that these companies can deal with technological areas broadly, but emphasize their main interests (*big-specialist*). In contrast, BlackBerry has a distinguishing patenting strategy with respect to the technological scope, when compared to other firms (*small-generalist*).

Fig. 11 describes the *breakthrough map* for the 10 leading companies in LTE-A technology standards. Four companies (Apple, Kyocera, LG Electronics, and NTT DOCOMO) are included in the first quadrant (*innovator*); their patents meet the LTE-A standard specifications with breakthrough approaches. In contrast, three companies (BlackBerry, Motorola, and Qualcomm) are positioned in the third quadrant (*outsider*); having small novel patents with low familiarity, these companies seem to possess technology standards in niche areas. In the second quadrant (*follower*), only one company (Sharp) exists, indicating that current technological progress is

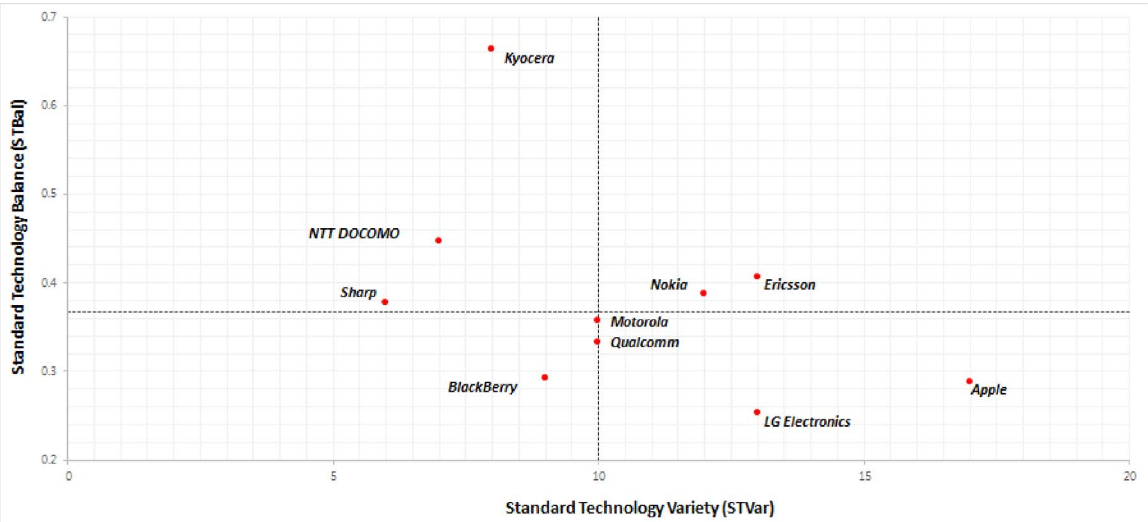


**Fig. 10.** Diversity map for LTE-A.

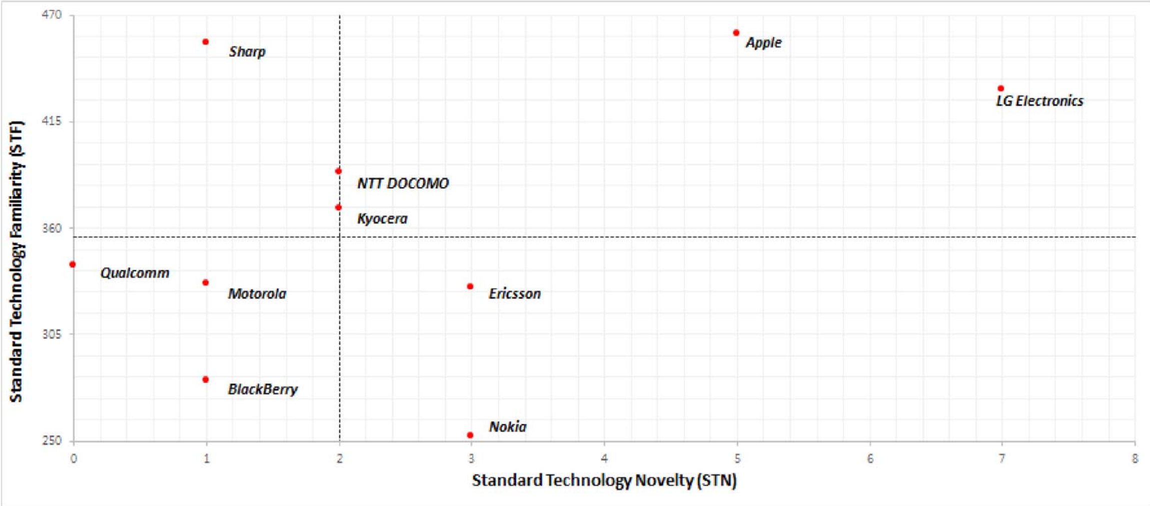


**Fig. 11.** Quality-break through map for LTE-A.

well reflected in its essential patents. On the other hand, Ericsson and Nokia stand in the fourth quadrant (*inventor*); given that these two companies belong to *all-around* in the diversity map, their strategies seem somehow pioneering, producing early-stage technology standards.

Fig. 12 indicates the *impact map* for the 10 leading companies in LTE-A technology standards. Here, LG Electronics and NTT DOCOMO show distinctive features (*market-superior*). The economic impacts of their essential patents are relatively high compared to those of other companies; however, their technological impacts are not as high as their economic impacts. These companies have aggressively tried to expand their market shares in the global market. Qualcomm is the strongest company in its standard technologies, from the perspective of both economic and technological impacts (*ambidextrous*). Actually, the company has dominated a global market share in the fields of application processors, modems, and radio-frequency chips. On the other hand, the standard technologies of Motorola have strong technological impacts on subsequent technologies, although they have only limited coverage in the global market.

### 5.3. Implications

Based on the results of portfolio analysis for the LTE-A standard, this section describes the notable companies and future opportunities. In addition, the discussible topics are presented.

#### 5.3.1. Notable companies

The companies that were nominated both in the UK Brand Finance 2015 (top brand values) and Fortune Global 500 include LG

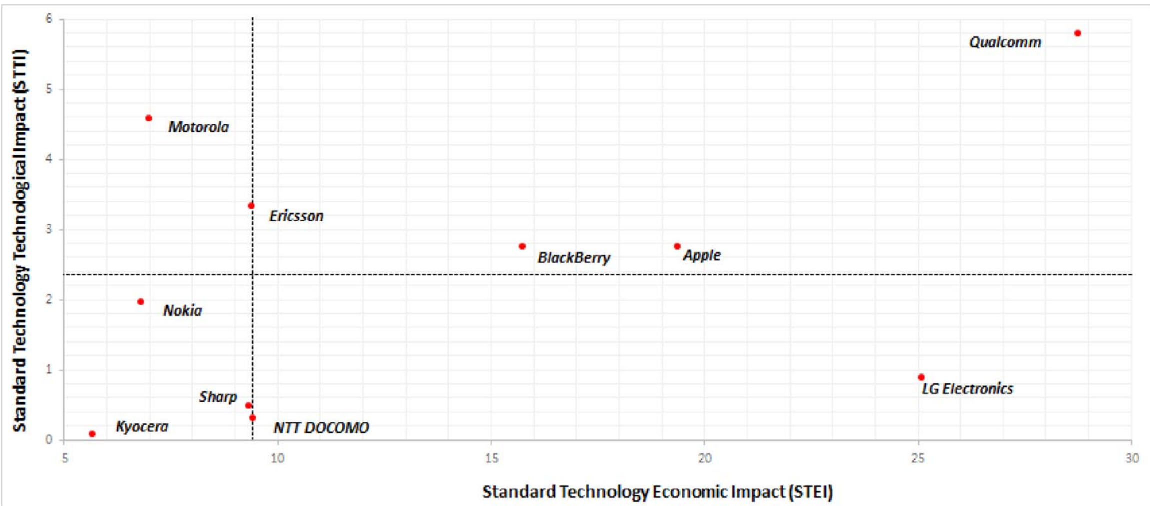


**Fig. 12.** Quality-impact map for LTE-A.

Electronics, Apple, and Ericsson. According to the five portfolio maps, these three companies have adopted distinguished technology standardization strategies in terms of essential patents, when compared to the other seven leaders. However, each of the three has shown differences in such strategies. When considering only recent essential patents that were published in and after 3GPP Release 10, LG Electronics has the most remarkable number (355). On the other hand, Apple has advantages under LTE-A standard-setting, having the highest values of EmTStd, STR, STVar, and STF, even among the 10 leading companies. In practice, Apple has shown far superior performance in brand values and total sales than have the others; in 2015, it was the top revenue-generating company in the telecommunications sector, gaining three-times more revenue than that of the second top-revenue-generating company.

Regarding the concentration strategy, all three companies show completely different patterns. LG Electronics has a relatively moderate share of essential patents, despite its notable number of LTE-A patents. Nevertheless, it has the highest number of essential patents among the 10 companies of concern in this study. It is more rational to say that it has exceptionally strong technology capabilities in general LTE-A technologies, rather than to say that it is concentrating very little on technology standardization. In the case of Ericsson, its degree of emphasis on standard technologies is similar to that of LG Electronics, although its technological capabilities show a significant gap. Compared to LG Electronics and Ericsson, Apple has stressed standard technologies greatly, although its technological capabilities are not that strong.

Regarding the activity strategy, LG Electronics has acquired the most essential patents and continues to focus on them. However, a more notable company is Apple, which has shown intensive recent efforts in technology standardization. Indeed, the essential patents acquired by Apple are mostly recent ones. Further, Ericsson has similar activity patterns as do the remaining seven companies.

The diversity map shows that the relative diversity values for all three companies are similar, which means that the main areas for standard technologies developed by the leading companies are likely to be similar to one another. However, Apple has the most diverse standard technologies followed by LG Electronics and Ericsson, as is easily expected considering its numerous essential patents.

Finally, in terms of the quality strategy, the standard technologies developed by LG Electronics and Apple are expected to have both the highest degree of breakthrough and greatest economic impact, while those by Ericsson are relatively low. Nevertheless, for all three companies, the technological impacts of their standard technologies are fairly modest. As LG Electronics has published a relatively large number of patents, it is more likely to have both high- and low-quality essential patents. Moreover, technological quality evaluated by expected impacts on subsequent technologies does not seem to be related to corporate financial performance.

When restricting the focus to Apple, which is the top company in this sector, we find that it has recently intensified its efforts in technology standardization, producing a high ratio of essential to general patents in LTE-A technologies. As a late market entrant, the company has strengthened its technological capabilities by concentrating its essential patents in the main telecommunications technology areas. Of course, corporate financial performance is determined by a complex interaction of a number of factors, of which a technology standardization strategy is only one. Still, technology standardization strategies pursued by leading companies are worth analyzing; the results will help a company to understand its technology advantages and establish its strategies to acquire essential patents.

#### 5.3.2. Discussions and future research opportunities

In this study, we suggest five maps and 10 corresponding indexes to construct the portfolios. Although our portfolio results provide the strategic patenting of companies in a broad way, from the technological standard perspective, some topics still remain as future opportunities.

First, portfolio analysis should be deliberately designed. If two indexes for a portfolio are not appropriately adopted, then the insights from the portfolio can be possibly distorted. In this vein, the breakthrough map should be carefully interpreted. In this map, we basically borrowed the concept of both recombinant novelty and technological component familiarity from Arts and Veugelers (2014) in order to reflect the recent development of patent indicators with respect to their radicalness or innovativeness. Despite contributions of these concepts, the concept of recombinant novelty (written as the novelty score in this study) has no choice but to be minimal for essential patents. Since a technological standard literally refers to an established norm or requirement with respect to technical systems, radicalness or innovativeness is rather far from its own definition. Hence, among the 1581 essential patents of the 10 leading organizations, most of them, except for only 29 patents, have novelty scores of 0. Nevertheless, if a company filed a patent with recombinant novelty, then we can identify companies introducing relatively novel technological approaches to satisfy technological standard specifications. This is why we set the STN as the number of essential patents with novelty scores higher than 0. However, when we look into the details of recombinant novelty at the patent level, an order of the target companies can be changed. The average novelty scores for each company are 0.68 for Apple, 0.33 for BlackBerry, 0.44 for Ericsson, 1 for Kyocera, 0.49 for LG electronics, 0.2 for Motorola, 0.6 for Nokia, 0.66 for NTT DOCOMO, 0.2 for Sharp, and 0 for Qualcomm. Here, Kyocera is on the top of the novelty followed by Apple and NTT DOCOMO. These analysis results show that different operationalization of indexes may lead to different results. In our case, we want to see in the breakthrough map is not the quality of patents on average, but the competency of an organization as a bundle of valuable patents at its disposal; thus, we focus on the number of novel essential patents in an organization. Similarly, a portfolio analysis should also be designed carefully to achieve the main purpose of the portfolio. Therefore, clarifying an objective or framework, such like *developing perspective of portfolio analysis* (Fig. 2), of this study should be preceded before developing a portfolio.

Second, the company that declared an essential patent may not be the original inventor of the patent. Since patents are tradable rights, in some essential patents, declarers (current owner of a patent) are not identical with assignees (inventor of a patent). Moreover, there may exist a time gap between patent application and declaration as standard essential. For example, the patent, EP19980203362, which was applied for in 1988 and declared by Microsoft, is included in the LTE-A standard that began being established in 2008.These unique characteristics of essential patents need to be considered in designing and interpreting portfolio analysis for essential patents. In particular, if the total patents of a company that were previously applied for and later are declared as essential patents are considered for designing a portfolio, more interesting analysis can be done, investigating the relationships between essential and non-essential patents; the only difference between essential and non-essential patents is whether a patent, which has a claim to meet international technological standard specifications, is declared and recognized. In this case, a retrospective study can be employed to understanding the current phenomenon with respect to strategic patenting in order to acquire the standard essentiality.

Third, incorporating various types of patents in portfolio analysis is expected to provide other meaningful implications. All patents have their own value, whether essential or not. Different types of patents present different aspects of technology strategies. Thus, to take a holistic approach to patent portfolio, it is worth considering all patents regardless of their types. Although the concentration map in this study aims to examine a company's position between overall relevant patents (TStr) and the ratio of essential patents (EmTStd),a more systematic approach is needed to reflect the diversity of patent types. At the same time, a patent portfolio customized to each type of patents is also requires more attention.

Finally, as standard-setting in a certain domain is continuously evolving with the ever-changing market demands, the strategic standard-setting activities of companies can be more precisely monitored using on a dynamic framework. For instance, a company with a small number of essential patents in the LTE standard can have a relatively remarkable amount of essential patents in the LTE-A standard. Though the portfolio analysis is a static snapshot approach to identify the positions of each entity in several pre-defined quadrants, comparing several portfolios constructed with the same indexes, but within different standard setting in a certain domain, can provide us with more insight. In a similar vein, a time-series approach can also offer useful insights regarding a company's fluctuating positions in the same portfolio window. Figs. 13 and 14 represent the dynamic analysis results for activity and diversity portfolios. In these figures, significant changes in the position of companies are observed over time. For example, in the activity maps ($t = 2$), the emphasis has been increasingly put on standard technologies in Apple, while the opposite trend is seen in Motorola. In the diversity maps, Apple and LG Electronics have moved towards increasing diversity of technologies, whereas Qualcommand Nokia have decreased the diversity, being specialized in a few areas. These dynamic analyses enable to understand the evolution of strategies in the 10 leading companies regarding LTE-A standard technologies, enriching the portfolio analysis.

## 6. Conclusion

This study aims to develop a patent portfolio map to help analyze competitors' strategies regarding technology standardization by analyzing essential patents. Four types of portfolios—concentration, activity, diversity, and quality—were developed to provide competitive intelligence in an industry where technology standards play a significant role in providing products or services. The suggested five maps are applied to LTE-A technologies, focusing on the 10 companies most active in granting essential patents for standard technologies. Then, the maps are used to understand the essential patent strategies of the leading companies from various perspectives.

Theoretically, the results of this study can be understood under the knowledge-based view that conceptualizes the firm as an institution for integrating knowledge. A set of portfolios suggested in this study simply visualizes the strategic activities of target firms in the technological standard context. Though patents have long been regarded as a valuable resource that can reflect the technological knowledge of an organization, the role of essential patents for innovation in technology standards has received relatively little attention. Considering that winners in ICT industries establish platforms that convince other players to build on these platforms, this study contributes to providing a tool (i.e., patent portfolio) for identifying companies' knowledge assets, aligned with the knowledge-based view.

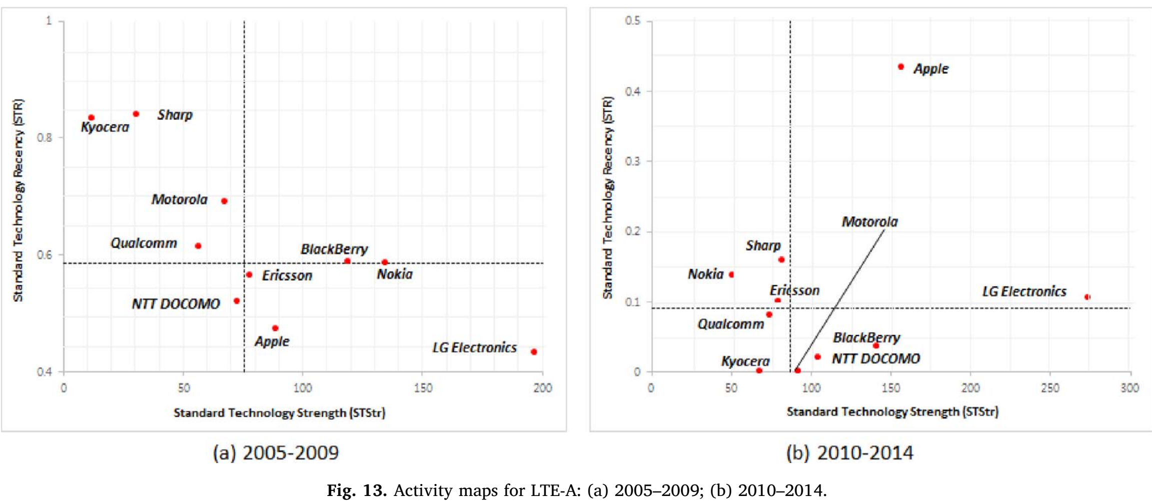


**Fig. 13.** Activity maps for LTE-A: (a) 2005–2009; (b) 2010–2014.

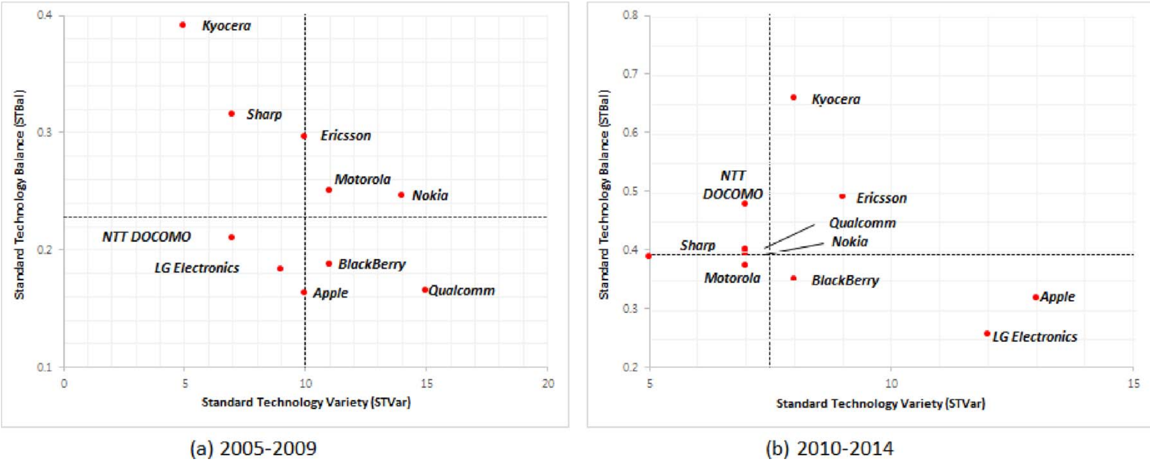


**Fig. 14.** Diversity maps for LTE-A: (a) 2005–2009; (b) 2010–2014.

Regarding practical implications, the portfolio maps suggested in this study can be helpful as a strategic decision-making support tool for firm managers. Particularly, in the telecommunications industry, where the pace of technology change has been accelerated and range of technologies protected by patents is wide, patent analysis can be one of the most effective methods to monitor technology and competitor trends. Moreover, considering the importance of technology standards for gaining competitive advantage in the industry, the analysis results on LTE-A technologies will offer systematic information to scrutinize competitors' strategies in relation to their technology standardization for the fourth generation of technologies, as well as invaluable insights to establish a company strategy for the fifth generation of technologies. Methodologically, this is one of the earliest studies to suggest a patent map focusing on a particular type of patent and, thus, it is expected to contribute to the evolution of patent portfolio approaches.

Despite its useful contribution to the extant literature, this study has several limitations. First, it suggests only four types of portfolios; however, more diverse portfolio maps can be designed to achieve implications that are more meaningful. In a similar vein, taking into account that there exist lots of patent indices proposed for patent analysis, either additional patent indexes, customized to analyze essential patents, can be developed, or the patent indexes used in this study can be elaborated. Second, and more importantly, although the five maps in this study provide meaningful insights for competitor intelligence, they are isolated from the actual organizational decision-making processes. As this study aims to shed light on the feasibility of an essential patent portfolio as a tool to identify competitors' strategies regarding technology standardization, further case study is needed to find the way in which to use these maps most effectively. Further analysis can start by identifying the decision-making issues raised when technology standardization strategies are established. Then, by linking these issues with the patent portfolio maps, the usability of the suggested approach can be significantly enhanced.

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