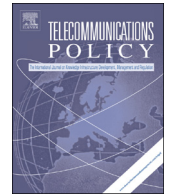




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Identifying emerging core technologies for the future: Case study of patents published by leading telecommunication organizations[☆]

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ABSTRACT

In recent years, the volume of mobile traffic has increased at an unprecedented rate and the mobile paradigm has changed. These dynamics have driven the next-generation telecommunications technologies, and the existing fourth-generation technology is reaching maturity. The pre-acquisition of promising future technologies enables firms to achieve and sustain their business growth; thus, numerous organizations in the telecommunications sector have made a huge amount of effort to develop fifth-generation (5G) technologies. Although understanding these emerging and promising 5G technologies is essential, they still remain poorly investigated. To fill this research gap, we first define the characteristics of promising technologies in the telecommunications sector, then develop a framework for identifying them based on patents. Specifically, we design three patent indices for deriving the core patents published by leading organizations in the sector. We then apply bibliographic coupling and text mining to the patents and identify their major innovation trends. We identify 21 technology fields as promising areas emphasized by the leading organizations. Theoretically, this study is one of the few attempts to examine various approaches to identify promising technologies and to suggest the most appropriate one considering the research purpose as well as the characteristics of telecommunications sector. In practice, this study can provide information about patent activities of key incumbent actors and thus offer some insights into recent technological developments towards 5G.

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1. Introduction

Considering the proliferation of smart devices and the increasing demand for multimedia streaming services, mobile data traffic volume will certainly accelerate (Fehske, Fettweis, Malmudin & Biczók, 2011). Recently, indoor traffic has received considerable attention because approximately 80% of data traffic has been generated within houses or office buildings since 2010 (Laya et al., 2014). These unexpected increases in mobile traffic volume and the changing mobile

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paradigm have driven the next-generation telecommunications technologies. Long-term evolution (LTE) systems embodying fourth-generation (4G) technology are now reaching maturity, indicating that one can only expect incremental improvements and small amounts of new spectrum (Andrews et al., 2014). Therefore, numerous organizations across the world, both public institutions and private enterprises, have been inspired to develop beyond-4G (B4G) technologies. Furthermore, the future 5G technologies are expected to evolve from locally focused technologies, while macro-based technology has occupied the mainstream of technology evolution in the telecommunications industry before release 12 (Rel-12) (Chen & Zhao, 2014). These trends indicate an opportunity to enhance market competitiveness by developing promising telecommunications technologies. For this reason, numerous organizations have redoubled their efforts to develop 5G.

To capture successful technological opportunities, particularly in the telecommunications industry, logical forecasting or prediction is necessary. Investing in a promising technology without understanding future technological directions can be very risky, as technological and market standards largely drive the technological and product/service markets in the telecommunications sector. Bekkers, Duysters, and Verspagen (2002) compared the strategies of Motorola and Philips and showed that the direction of market competition and network centrality significantly affects share or structure of a technology-intensive market. In this context, patent information might easily indicate the technological opportunity of the telecommunications sector by identifying both technological directions and relationships. In addition to providing bibliographical information, such as inventor, assignee, application date, and citations, a patent document provides detailed technological descriptions, including functional principles, technical components, and cause-effect relationships. From patent information, researchers have derived various factors such as technological strengths, weaknesses, corporate R&D efforts, technology trends, prediction of emerging technologies, and technological capabilities at individual, firm, sector, and national levels (Noh, Jo & Lee, 2015). Hence, patent analysis approaches have been widespread in studies of telecommunications (Duysters & Hagedoorn, 1998; Mu & Lee, 2005; Lee, Kim, Cho & Park, 2009a; Kang, Huo & Motohashi, 2014).

Although previous attempts to discover or forecast promising technologies have yielded valuable insight, two critical limitations remain: (1) the concepts of promising technology vary among the studies and (2) the industrial movement for developing B4G or 5G technologies has been little investigated.

Regarding the first limitation, perspectives on the promising technology depend on the characteristics of the sector or technology and the research objectives. Such variation is quite natural. However, as researchers commonly focus on only a single perspective, an in-depth understanding of the concepts of a promising technology is urgent. Regarding the second limitation, although recent literature has addressed the visions or technological specifications expected to meet the future needs of the telecommunications market (Pierucci, 2015; Osseiran et al., 2014; Rappaport et al., 2013), practical technology developmental states or technological directions towards 5G technology remain unclarified. In addition, because 5G standards are not yet officially defined, future technical standards can be better predicted by observing real technology trends than identifying target specifications. To resolve these limitations, we first attempted to organize the various concepts of promising technology through a literature review. Then, based on a concrete concept of promising technology for the future telecommunications sector, we began forecasting the directions of 5G.

Specifically, this study proposes a framework for identifying promising telecommunications technologies from patent information. The framework is then applied to understanding current technological movements towards 5G. For this purpose, we selected top organizations related to the telecommunications industry from the standard essential patent (SEP) database of the European Telecommunications Standards Institute (ETSI), and collected the latest telecommunications patents of the 30 organizations leading in the development of 4G technologies from the United States Patent and Trademark Office (USPTO). Next, we designed patent indices based on the recency, frequency, and monetary (RFM) concept and extracted the most significant patents by the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), a multi-criteria decision-making method. Then, we derived clusters of promising technologies using a bibliographic coupling and network analysis. Finally, to clarify the technological directions towards 5G, we extracted the technological keywords of each cluster by text mining.

The remainder of this paper is structured as follows. Section 2 describes the extant perspectives on what constitutes a promising technology and outlines the technological evolution of the telecommunications sector. This information was compiled through a literature review. Based on the literature review, Section 3 presents the basic approach of this study and details the processes of the research framework. Section 4 presents the study results; Section 5 discusses them. Concluding remarks, with implications and limitations, appear in Section 6.

2. Literature review

2.1. Existing approaches for identifying promising technology

The literature has used the term *promising technology* frequently and widely, but has not clearly defined it. Given that even *technology* is difficult to define in a single context, this lack of understanding is understandable. Rooney (1997), who reviewed historical definitions of technology, reported that the term *technology* must cover a wide and diffuse set of intersecting and heterogeneous contingencies. However, to support decision-making, the forecasts of a promising technology

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