Towards Intelligent Optical Networks: The Role of Intellectual Property

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Abstract: An overview of worldwide patenting activity covering machine learning and artificial intelligence in the field of optical communication is presented. The results emphasize a worldwide growing market offering benefits for both providers and customers.

1. Introduction

For the last few years, machine learning (ML) and artificial intelligence (AI) software tools have become new enablers of efficient, reliable and flexible optical networks. They are more and more successfully applied in a myriad of tasks like configuration and operation of network devices, performance monitoring, modulation format recognition, and nonlinearity mitigation. We present an in-depth analysis of worldwide activity considering artificial intelligence in the field of optical communication using the databases of the European Patent Office (EPO) covering both worldwide published patent and non-patent literature. These statistics summarize past and present directions in optical transmission and networking where ML and AI play important roles and provide an indication of potential future trends in terms of research and development as well as market movements.

2. Methodology

One of main tasks of the EPO is to search for prior art documents, which can be any document published before the filing of a patent application, to assess novelty and inventiveness of the patent application. To ensure a high quality search, the EPO maintains daily updated databases encompassing documents containing both worldwide published patent applications [1] and non-patent literature, which includes scientific publications, conference proceedings and standards, as well as internal top-of-class search tools. We used these tools and databases to produce the statistics presented below, using ML- and AI-specific keywords and the cooperative patent classification (CPC) to filter documents pertaining to the field of optical communications.

3. Patenting activity

A. Worldwide patenting activity

The starting point for our analysis was an evaluation of the number of ML- and AI-related first publications per patent family (a patent family is a collection of patent applications covering the same or very similar technical content) in optical communications in the period between 1990 and 2018. These statistics then were compared to the number of publications in telecommunications in general and in all technical fields to get an overview of the patenting activity. The result can be seen in Fig. 1a. All three graphs show high volatility up to the year 2010, which is at least partly a consequence of the economic crises of 2000 and 2008. From 2010 onwards, however, the fields of

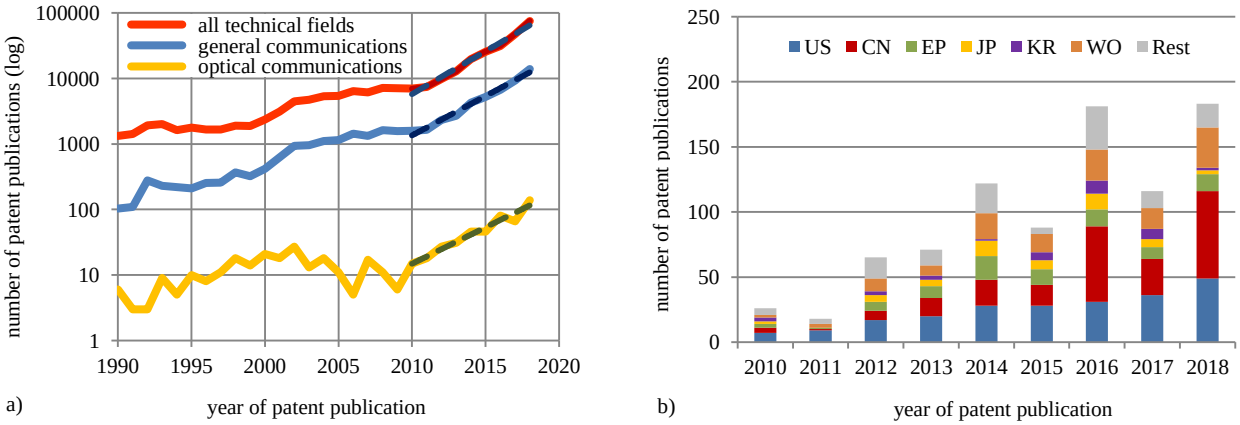

Fig. 1: Number of AI and ML-related publications per year (a) and regions in which protection is sought (b).

ML and AI exhibit exponential growth in every graph (shown by the linear dashed lines in Fig. 1a, corresponding to an exponential fit in logarithmic scale). This manifests the strategic importance of these technologies for future investment in research and development. The period of investigation for our present analysis has thus been limited to the years of 2010 to 2018. Even if the patenting activity in optical communications is only around 1% of all fields of communication related technologies and 0.1% of all technical fields (see Fig. 1a), a clear trend corresponding to a 10 fold increase of the number of publications every five years can be observed.

B. Relevant geographical regions

To get an impression which national markets are considered most valuable by the applicants, the geographical regions for which protection is sought was assessed by analyzing the number of patent publications of the most relevant publication authorities (national patent offices). Apart from the national offices, there is still another intellectual property jurisdiction, the World Intellectual Property Organization (WIPO), whose publications, identified by the code WO, refer to international application filings under the Patent Cooperation Treaty (PCT) [2]. The publication authority of a patent application is, apart from those of PCT filings, an indicator for the geographical protection claimed for an invention. From the shares of each publication authority of the total number of annual publications in AI and ML in optical communications, presented in Fig. 1b, it can be seen that the importance of protection has shifted focus from the USA (US) to China (CN) since 2016. Roughly half of the publications come from Asian offices (CN, JP, KR) and 30% from the USA, while only about 5% are filed aiming at protection in Europe. There is, however, a range of uncertainty because PCT filings are also more and more frequently used by the applicants in AI and ML fields, reaching around 20% of the annual publications in 2018 (see fig. 1b). This is an indication that more and more applicants are planning to protect their inventions in several different geographical regions at an early stage of development. Considering absolute numbers, patenting activity, which is usually linked to the investment in the concerned areas of technology, demonstrates an enormous growth in the fields related to AI and ML in optical communication technologies.

C. Origin of applicants

Next we concentrated on where the applicants are located as an indication as to where innovations come from in order to get an impression as to which countries are especially active in the field. What can be observed from the results, depicted in Fig. 2a, is the relative regional distribution of patent applicants (originating country), which differs significantly in both share and development over time to that which can be observed for the yearly publications per country in Figure 1b. While over the observed period of time an average of 75% of the applicants originate from the USA (see blue bars in Fig. 2a), the number of Chinese publications becomes disproportionately high from 2016 onwards, which indicates a significant interest in the Chinese market. A similar development but on smaller scale can be seen for European and Japanese applicants, who also extend the region where protection is sought beyond their local market. Figure 2b gives an overview of applicants who are particularly active in certain fields of optical communication.

D. Comparison with non-patent literature

For further investigation we used our non-patent literature (NPL) data bases for comparing patenting activity with scientific publication activity. As a first step, in order to verify the completeness of our internal NPL data bases, we compared our NPL search results with the ones obtained with the search engine run by Google for scientific publications: Google Scholar. Figure 3a shows a good correlation in the evolution validating our approach, even if

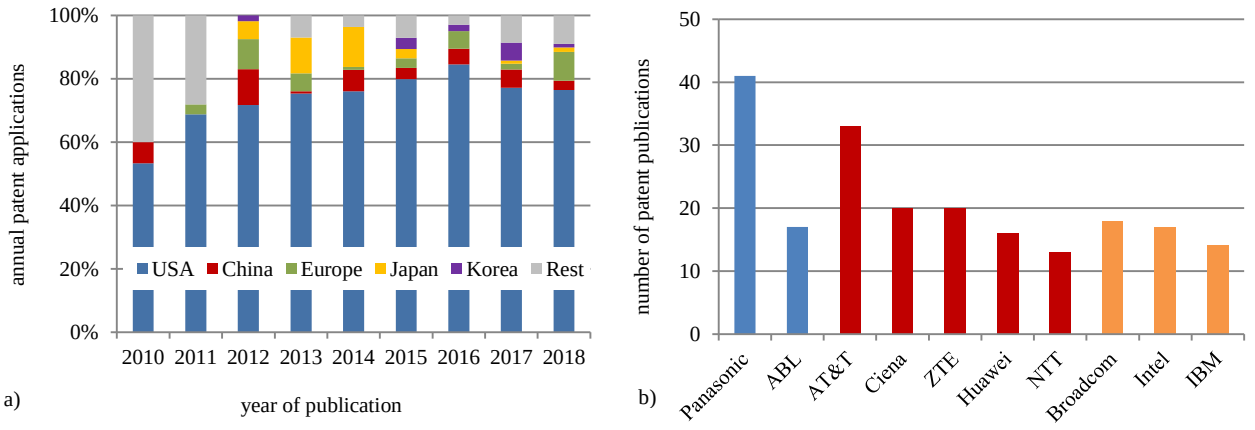

Fig. 2: Origin of patent applicants over annual patent publications (a) and number of publications per applicant (b).

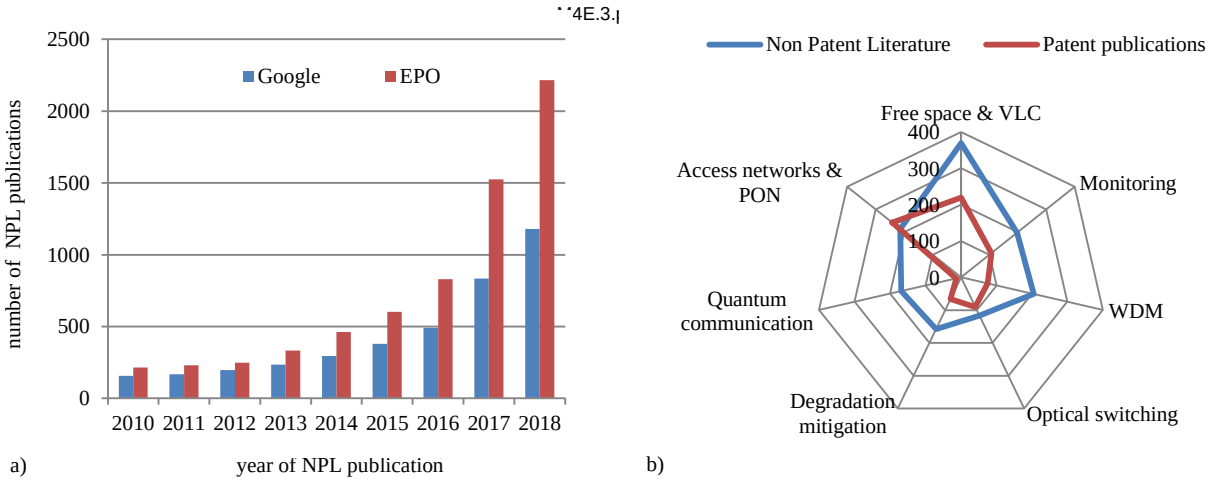

Fig. 3: Number of AI/ML-related NPL publications (a) and number of NPL and patent publications per domain (b).

our internal search results in significantly higher number of publications, explicable by cross-references and duplicated publications that our tool counts as separate hits. When comparing the evolutions of NPL-publications (see Fig. 3a) and patenting activity (see Fig. 1a), the same exponential increase of publication numbers can be seen starting from 2010, confirming that the survey of patenting activity gives a reliable indication as to where research and development are concentrated.

E. Survey of technical domains

To deepen our analysis, an extended survey with focus on main technical domains in optical communications using AI and ML has been carried out. As can be seen from the red (patent literature) and blue (non-patent literature) lines in Fig. 3b, optical wireless technologies (free space optics and visible light communication, VLC) are the most active domain which may be explained by the vast interest concerning the Internet of Things using such technology for home networking. For domains like monitoring, WDM, switching and mitigation of degradations it cannot yet be identified to which extent AI and ML will be implemented in networks but it is clear from the red and blue lines in Fig. 3b that these domains evoke great interest, although their development, measured in terms of the number of NPL publications, appears slightly delayed as compared to optical wireless technologies. While for the previously considered domains the difference between NPL publications and patent publications is more or less constant (see the distance between the red and blue curves in Fig. 3b), a significant difference can be seen between access networks and quantum communication. The unexpected discrepancy for access networks can be explained by a certain level of uncertainty when using our in-house NPL-search tool, which is merely based on keywords, wherein the publicly available search tool for patent literature [1] bases on much more accurate CPC-classes. In quantum communication, this can be explained by the fact that it is a relatively new field of research and development. This means that an increasing number of patent applications in quantum communications is to be expected in the next years, continuing to equalize the gap between NPL- and patent publications.

3. Conclusion

The present study confirms that observation of patent activity is a profound measure to spotlight market trends as well as research and development directions. The comparison of NPL publications with published patents, focused on AI-and ML-related content in optical communication, correlates well with present hot topics of the scientific world, although the demand for intellectual protection of relatively new areas like quantum communication is behind its present scientific focus. The results highlight that AI and ML in the field of optical communication is an area of fast evolution and immense opportunity for innovation and that inventors are starting to make use of the opportunities given by the national and international patent legislations to protect inventions relating to software linked to AI and ML.

4. Acknowledgement

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5. References

[1] Espacenet: Free access to information about inventions and technical developments from 1782 to today; *www.espacenet.com.*
[2] PCT – The International Patent System; *www.wipo.int.*