Moving Integrated Product Development to Service Clouds in the Global Economy
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Strategic Development of LTE Mobile Communication Technology Based on Patent Map Analysis

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Abstract. Information, communication, optoelectronic, and semi-conductor industry are major industries in Taiwan. In mobile communication industry, the 4th generation (4G) can be categorized into two major techniques, i.e. Long-Term Evolution (LTE) and Worldwide Interoperability for Microwave Access (WiMAX). Many 4G related patents were filed and granted globally, particularly in major markets such as US, Europe, and China, in recent years. When comparing LTE and WiMAX, LTE gradually dominates the technology landscape in 4G telecommunication development. This research depicts the LTE technology development trend and also chooses Wi-LAN Inc. as the major assignee for detailed patent map and its intellectual property rights (IPRs) analysis. The LTE patent documents in the United States Patent and Trademark Office (USPTO) database are searched. And, the research identifies 62 Wi-LAN patents as major target patents. These patents are analyzed with various patent statistic views (also called patent maps), which include the statistics of patent counts based on International Patent Classification (IPC), forward citation counts, patents in quality levels, and patents categorization in technology-function matrix. Patents are evaluated to find the high quality patents, which may lead to the litigation in the future. Finally, the technology-function matrix indicates Wi-LAN R&D focuses of the key technologies, i.e., to improve efficiency and stability of 4G transmission. Consequently, a competitor of Wi-LAN can develop new technologies and file new patents to avoid infringing upon existing IPRs. Companies can also increase their cross-licensing opportunities when more patents were granted to them in essential and/or complementary sub-technologies. Thus, this research provides critical intelligence to the LTE-related companies for enhancing their R&D and patenting strategies.

Keywords. Long Term Evolution (LTE), Patent Analysis, 4G, USPTO

Introduction

In a competitive global market, patents are useful in protecting intellectual property right (IPR) or defend against infringement threats from other enterprises. Generally speaking, patents are viewed with many aspects, e.g., profit from goods protected by patents, patent quality and patent commercial values. In the mobile communication industry, superpowers, such as Qualcomm and Ericsson, dominate the industry with

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essential patents. Meanwhile, some non-practicing entities (NPEs or patent trolls) seek opportunities to license their IPRs or challenge improper usages of the IPRs. Hence, this research analyzes LTE patents of relevant technologies to assist companies in making R&D strateges and to foresee or avoid potential patent traps.

Information communication technology, semi-conductor, consumer electronics, and mechanical industries are the top ranked industries account for inventions and utility patent applications in Taiwan [1]. In mobile communication industry, fourth generation (4G) mobile networks rapidly becomes the mainstream protocol and de facto standard. There are two main technology standard bodies in this domain. They are Long Term Evolution (LTE) and Worldwide Interoperability for Microwave Access (WiMAX) respectively [2]. LTE, supported by many telecom-operators, is gaining its lead becoming a dominant technical standard in the landscape of wireless mobile communication industry. There are over 3,000 LTE patents in 2010. Qualcomm is one of the leading companies in LTE technology development. However, LTE patents, unlike its predecessor WCDMA core and related patents, are no longer just held by few companies [3]. For instance, China and South Korea telecommunication companies are applying LTE patents in recent years that surpass their global competitors.

This research reviews recent LTE patent lawsuits and finds that Wi-LAN, which is an IP licensing NPE, files many lawsuits against global mobile communication companies (e.g. Apple, Ericsson, LG Electronics, and hTC) as shown in Figure 1. This paper starts on two patent-infringement cases filed by Wi-LAN accusing hTC infringing upon Wi-LAN's 3GPP patents, i.e. US 8315640 and US 8311040 [4]. This research analyzes Wi-LAN 3GPP LTE patents with key terminologies and IPCs for constructing systematic patent maps. Furthermore, higher quality Wi-LAN patents are identified to build the technology-function matrix. The research intends to assist companies to avoid potential infringement lawsuits and identify cross licensing opportunities.

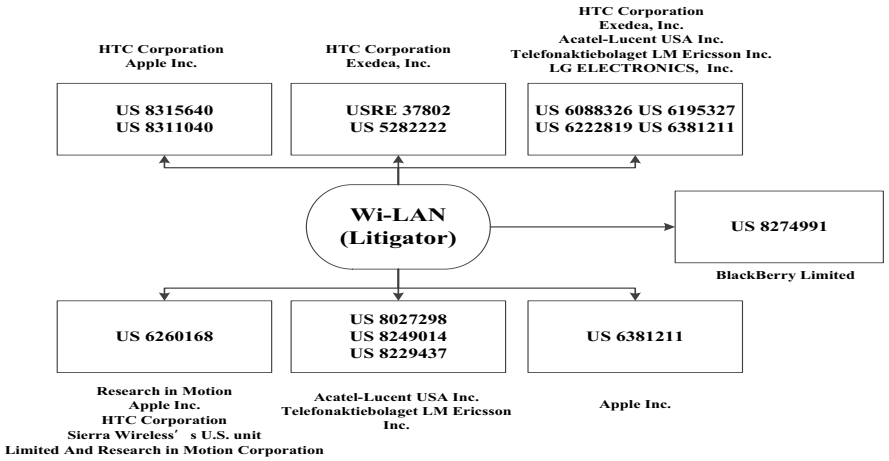

Figure 1. Recent patent legal cases filed by Wi-LAN

1. Literature Review

1.1. 4th Generation Mobile Communication Networks

International Telecommunication Union (ITU) defines 4G, the 4th generation mobile communication network, must enhance peak data rates of 100 Mbit/s for high and 1 Gbit/s for low mobility to support advanced services and applications [5]. Long-Term Evolution Advanced (LTE-A) is the first batch technology ITU recognizes as 4G standard, launched by 3rd Generation Partnership Project (3GPP). The specifications of LTE-A can be referred to as the 3GPP release 10 and 11. As to the original LTE technology, which has been commonly adopted by most telecommunication companies, should not be classified as 4G. It can only be called Beyond-3G or Pre-4G technologies, because the peak data rates do not achieve the specified 4G standard. The specification of the standard LTE can be referred to as the 3GPP release 8 and 9 [6].

WiMAX was supported by Intel. In early 2000s while mobile communication and WiMAX technology were largely aiming for the applications of PC notebooks (laptops). However, the growing popularity of smart phones and tablet PCs has changed the trend of mobile communication rapidly. Hence, this phenomenon has weakened the position of WiMAX initiatives. Moreover, LTE technologies only require telecommunication companies to upgrade their base stations to comply with LTE-A. It saves vast amount of capital investment for re-constructing the whole new base station systems. With these reasons, LTE technologies have overtaken the WiMAX gradually.

Further, multiple access technique is the key technology used to control the limited bandwidth of wireless and mobile communication systems. The bandwidth needs to be distributed to satisfy numerous end-users. There are three major multiple access techniques, i.e., Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), and Code Division Multiple Access (CDMA). These techniques use different frequencies, time slots, and codes to distinguish different users for limited bandwidth sharing at the same time [7]. LTE uses single carrier (SC) – FDMA as its uplink technique [8]. It also uses Orthogonal Frequency Division Multiple Access (OFDMA) as its downlink technique. These techniques enable LTE and LTE-A with faster data transmission capabilities and effective bandwidth sharing.

1.2. Trend of United States Patents

According to the report from WIPO [9], the number of worldwide patents is approximately 8.66 million. USPTO has the highest number of patent counts when comparing to other countries' patent corpuses. Meanwhile, WIPO report also indicates the growth of patent applications in USPTO is faster than patents filed in other countries' patent offices, with only exception being the IP office of China (SIPO) [10]. Hence, most of patent litigation cases occur in the United States involving in infringement disputes of US patents. That is the reason that we focus on discovering the LTE patent trend of USPTO. US patents are divided into three types. They are utility patents, design patents, and plant patents. From 2000 to 2009, the top 4 main countries, which applied most US patents, are Japan, Germany, South Korea, and Taiwan. However, China has the fastest growth rate of applications [11].

As to the LTE related patents issued in USPTO in 2012, Qualcomm owns most patents. The second ranked assignee is InterDigital. The followings are few companies

in China, South Korea, and Taiwan. Using IPC to classify these LTE patents, most of them are classified into H042 72/04 (i.e., allocation of wireless resource). And the second largest category is H042 36/00 [12].

1.3. Patent Analysis

With the meta-data variables, e.g., the applicants, the inventors, and the IPCs, patent map analysis is conducted to create general summary in order to integrate the patent maps with technology roadmap. Cumulative patent counts show the development stage of particular technology, which assist companies in forecasting technology lifecycles, future trends, and predict market saturation levels [13]. The technology and business intelligences lead decision makers to focus on the critical R&D directions.

In the first stage, the patent analysis focuses on the status of times, numbers, regions of patent applications, inventors, and assignees. Using text-mining techniques to analyze the independent claims on patent specification can provide micro-, technical-specific insights for industries [14]. Text mining can extract the most important description, independent claims, and images from patent specification to form a new summary text. Mani and Maybury [15] said summary text is a brief text which is extracted from the most important part of source text and based on user's needs. Hence, it can help patent engineering and experts read patent efficiently. Furthermore, we can do patent quality analysis to identify critical patent. Usually, high quality patents contain wider and more general claims and may refer to fewer prior arts [16]. High quality patents are effective in defending themselves against patent trolls and also can be applied to commercial products and productions with high profit potentials.

2. Methodology

2.1. Patent analysis flow

Figure 2 is the proposed ontology-based patent analysis process. This paper follows the process flow to analyze the LTE patenting trend and landscape. This research first builds the ontology of wireless communication to outline the scope of technology and related key phrases. In addition, through the ontology, this research searches the patents by the key phrases and the searching result is more precisely related to the domain of interests. Second, this study will use patent map analysis to realize the trend or strategy between different countries and industries. The analysis provides macro view of patent strategy. After the patent map analysis, this research analyzes the quality distribution of Wi-LAN patents. The LTE technology-function matrix is depicted to classify detailed techniques and functions that Wi-LAN patents belong to. Simultaneously, we also identify the technical vacancies with patenting potentials.

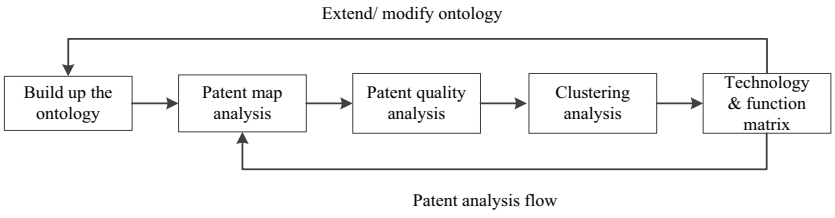

Figure 2. Analysis process

2.2. Ontology of Mobile Communication Technology

The ontology formally represents knowledge as a hierarchy of concepts within a given domain, using common vocabularies to denote the types, properties and interrelationships of the domain concepts [17]. Figure 3 depicts the domain ontology of the wireless communication technologies. The ontology can be divided into two dimensions. One is the "generations" and the other is the "technology clusters." The generations are divided into 3.9G and 4G. The technology clusters are divided into duplex method, circuit switching, and multiple in multiple out (MIMO). This study focuses on the latest communication technology to ensure that the research outcomes are relevant and valuable to the current communications industry. Thus, this research focuses on 3.9G ~4G communication technologies because older communications technologies are mostly obsolete for current applications.

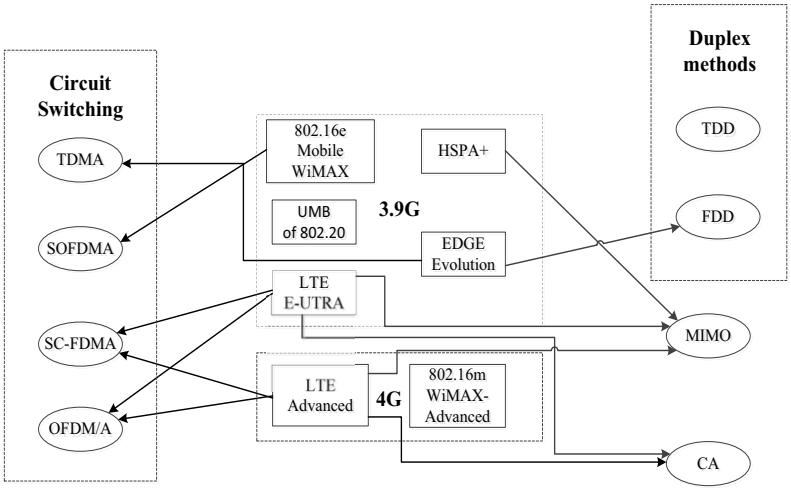

Figure 3. The domain ontology of wireless communication technologies

2.3. Patent map analysis

Patent map is a graphical display approach to present patent information. There are many dimensions contained in a patent map. For instance, patent number, countries, classifications, times, inventors, and so on. This research depicts the trend of LTE technology development and chooses Wi-LAN as the assignee for detailed patent and IPR related analyses. This research searches patents in USPTO database. First, we understand key phrases by the patent ontology of wireless communication (Figure 3), such as carrier aggregation (CA), multiple input multiple output (MIMO) and orthogonal frequency-division multiplexing (OFDM, OFDM/A). The technology of E-UTRAN is the wireless structure of LTE, including user equipment and evolved node. As shown in Table 1, the search date is at March 4, 2014. And, this research considers every possible key phrase, including its full name and abbreviation. Finally, we use these key phrases appeared in patent as search conditions to find relevant patents. One hundred and forty-two patents are found with the given search conditions.

Table 1. Patent search conditions

Key phrase	OFDM, FDMA, e-utra, CA, MIMO
Database name	USPTO
Search year	To 03/04/2014
Analysis date	Patent issued date
Patent search condition	((AN/Wi-LAN$ or AN/"wi lan" or AN/Wi-LAN) and (OFDM or FDMA or e-utra or CA or MIMO or EUTRAN or WCDMA or "Carrier Aggregation" or "Multiple Input Multiple Output" OR "Orthogonal Frequency-Division Multiplexing"))
Patent number	142

Figure 4 is the patents publication trend per year. The figure shows that Wi-LAN patents were published in early 2001 and reached the peak counts (50 patents) in 2012. Wi-LAN takes most of its infringement legal actions between 2011 and 2013. Besides, many published patents of Wi-LAN's will likely be granted by USPTO in the near future. It is reasonable to predict that LTE patent wars will go on for some years while the mobile wireless communication market grows rapidly and the profits are at the stakes.

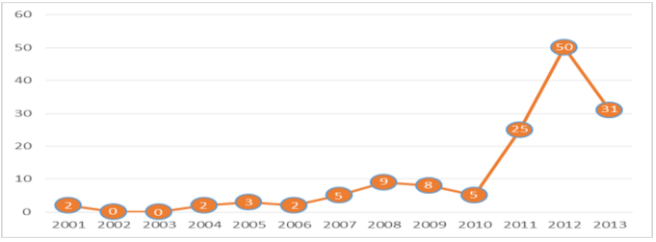

Figure 4. Trend of Wi-Lan patent publications in USPTO

The top five IPCs (in fifth-order classification) that LTE patents belong to are H04L1256, H04W0400, H04W7204, H04L1228 and H04W2806 as shown in Figure 2. H04L1256 is mainly about the packet switching systems. The technology is to increase the effect of receive/transmit data through improving switching system. H04W0400 means services or facilities specially adapted for wireless communication networks. H04W7204 is the technology of wireless resource allocation. H04L1228 is about the technology of path configuration. H04W2806 is the technology of optimizing. Figure 2 shows that most of patents are located in H04W and H04L. Thus, Wi-LAN focuses its previous patenting efforts on the technology wireless communication network (H04W) and the transmission (H04L). Other companies should review their own patents overlapping in the above two fields to avoid potential infringement issues.

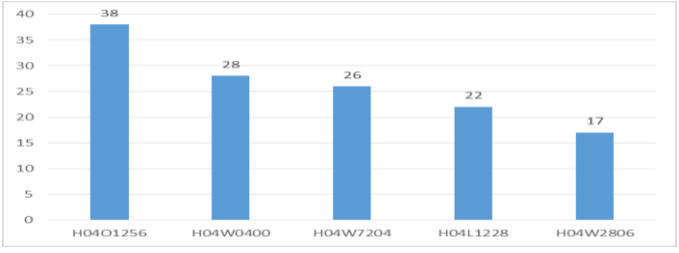

Figure 5. The top five IPC patent numbers most LTE patents belong to

2.4. Patent quality analysis

Patent validity is the basis of patent quality. A defective patent, though it has been granted, can be easily refuted in a patent litigation. As Barney [18] noted, the quality of a patent affects the market value of a patent. Thus, many additional conditions of a patent specification can be regarded as factors influencing patent value, such as claims, average number of words used in each claim, average number of words used in description, number of claims, and times cited by other patents. Therefore, it is clear that many attributes and aspects of a patent can impact its quality. The quality distribution of target patents is shown in Table 2 with total patent counts being 142. All 142 patents are between level 3 (lower quality) and level 7 (higher quality). Table 3 indicates that Wi-LAN holds a good number of high quality patents.

Table 2. Quality levels 3 (low) to 7 (high)

Patent quality	Counts
Level 3	5
Level 4	24
Level 5	71
Level 6	35
Level 7	7
Total	142

2.5. Technology-function matrix

A technology-function matrix is constructed to depict patents and IPs Wi-LAN owns with respect to specific technologies and functions. The reason why we need to build the matrix is that, if we understood the competitor's IPR and patenting status, we can then identify our future R&D and patenting strategy to counteract against the competitor. This matrix contains two main axes which represent functions and technologies. The horizontal axis represents technology, and we decompose the process of wireless communication into six major technical sub-areas. Selection represents the selection of radio frequency (RF). Packets represents the approaches how to fragment into packets and insert them into streams. Control represents the allocation of resources and setting of transmission parameters. RF transceiver represents the approach to sending or receiving analogy signal. Channel represents the channeling technique enabling signals be transmitted from base stations to user equipment. Most of technologies are dealing with the issues of controlling or allocating resources, bandwidth, parameters, and method of transmission. As for vertical axis, it represents the functions intending to be achieved (or improved) by above technologies. We define four key functions, i.e., decreasing the complexity of system, increasing the efficiency, increasing the stability, and increasing the ability of transmission. Specifically, these technologies can enhance the ability of peak data transmission, improve the ability of mobility and coverage, enhance the flexibility of bandwidth usage, and strengthen the compatibility of other 3GPP wireless access technology.

This paper picks patents with quality levels of 6 and 7 (total of 42 patents) to analyze and classify into the technology-function matrix, as shown in Table 3. The table preliminarily depicts that Wi-LAN focuses on the technology of selection, control and OFDM. In the region of selection, they put their most effort on increasing the efficiency. As for control, they focus on increasing the stability. Meanwhile, these two functions are Wi-LAN endeavors mostly. However, there are some vacant regions of

technologies, where the patent count on this matrix is zero. It indicates that other competitors can make effort on these areas or can develop on some field that Wi-LAN just holds one or two high quality patents for cross-licensing. The competitors can decide the patent strategy to avoid the potential lawsuits or issue patents for seizing the initiative by this method.

Table 3. The technology and function matrix of LTE patents

Function / Technology	Decreasing the complexity of system	Increasing the efficiency	Increasing the stability	Increasing the ability of transmission	total
Selection	1	6 ★	4	1	12
Packets	0 ⊙	2	1	1	4
Control	0 ⊙	2	6 ★	2	10
OFDM	5 ★	3	1	0 ⊙	9
RF transceiver	1	2	1	1	5
Channel	1	0 ⊙	1	0 ⊙	2
total	8	15	14	5	42

Note: ★ Potential patent trap; ⊙ Potential technology vacancy

With the patent map analysis, this research identifies the patenting and the R&D trends of Wi-LAN in macro view and also depicts the patent qualities and technology-function matrix in micro view. The result indicates that Wi-LAN patents are published with accelerative rates recently. We also reveal the main technical fields of interests in the patent maps. Meanwhile, we points out the potential threats and patenting or cross-licensing opportunities. All of the described analyses can provide companies in the industry a decide support of their future R&D and patenting strategies.

3. Conclusion

Currently, many patent lawsuits are filed by NPEs, which are costly to the smaller companies without sufficient IPR protection. This research provides a solid approach to analyze NPE patent portfolio, using Wi-LAN as case example. Due to the LTE market is a new and important target for mobile communication technology industry and the scope of mobile communication patents is widespread, it is important to have essential or complementary patents in early stage of technology development. Qualcomm is a successful example, which we will study in our future works. Furthermore, 4th Generation (4G) Mobile Forum defines the game-rule in wireless industries. It claims that a first-class company owns the standards; a second-class company owns the brands and IPR; and the third-class company owns technologies. Fourth-class company owns products. Nowadays, most of Taiwan companies only stay in third or fourth class, because they used to be Original Equipment Manufacturers (OEMs). Some of them have their own brand, but their patent strategies are far behind than 3G/4G global leaders and NPEs. Hence, how to improve and strengthen these companies' IPR through patenting or cross-licensing strategies are of critical issues.

This paper uses ontology to describe a comprehensive LTE technology domain. Afterward, key phrases are identified for technology classes. The research also identifies high quality patents for further analysis. Finally, we draw a technology-function matrix to reveal current patent landscape and future patenting strategies in mobile technology industry.

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