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Exploring 4G patent and litigation informatics in the mobile telecommunications industry

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ABSTRACT

Patent informatics are often analysed for IP protections, particularly in high-tech industries. This research develops a computer-supported generic methodology for discovering evolutions and linkages between litigations and disputed patents. The IP litigations in mobile telecommunications are used as the case study. An ontology framework representing the 4G domain knowledge is defined first. Then, a modified formal concept analysis (MFCA) approach is developed to discover the evolutionary linkages of legal cases and their disputed patents. In addition to citation-based patent analysis, this research provides a new approach in identifying legal and technical evolutions for future R&D planning and IP strategies.

1. Introduction

Intangible asset development and protection are essential to sustain the competitive advantage of enterprises [1] [2]. R&D intensive companies use patents to protect the values of their innovations [3] and often develop strategies for patent infringement litigations to actively guard their commercial interests [4] [5]. In addition to patents, companies also use a combinations of other intellectual properties (IPs), e.g., trademarks, designs, plant varieties, copyrights, and other registered properties to gain a monopoly or competitive edges on the proprietary knowledge [6]. Patents represent technological progress and provide a monopoly for commercialization for many years (e.g., 20 years from the filing dates in US or PCT) to the patent assignees [7]. Patents prevent others from using the same inventive techniques or methods and competitors must create different and improved products or techniques (or licence the technology) to compete commercially [8] [9] [10]. Patents provide royalties if licensees find that licensing patented technologies are more cost effective than creating alternative, non-infringing solutions.

For high-tech industries, such as the mobile telecommunications industry, there are owners of patents in the marketplace who buy, collect, and enforce patent rights in order to collect royalties while neither manufacturing nor distributing products. These types of IP owners are identified as non-practicing entities (NPEs) [11]. NPEs specialize in technology domains and purchase patents that have potential for negotiating royalty claims and licence fees from product manufacturers and distributors. The global mobile telecommunications industry STPI [12] reports that US has the largest number of standard essential patents (SEPs) in telecommunications. The United States also has the largest number of telecommunications patent disputes in the world. Statistics show that from 2008 to 2012 there were about four thousand IP infringement cases filed in the US. By 2013, the number of patent litigation cases exceeded six thousand [13]. There is a growing trend of patent lawsuits in the global mobile telecommunication marketplace as companies fight for market control and IPR protection [14].

This paper explores the evolution of NPE litigation and disputed patents to assist companies in the planning and development of strategic R&D decisions. The specific objectives of the research are to

(1) Use litigation and patent mining techniques to analyze the evolution of NPE lawsuits and patents.
(2) Use modified formal concept analysis (FCA) to graphically visualize the litigation trends.
(3) Cross-analyze the litigations, the disputed patents, and other essential patents to derive strategic IP protection strategies.

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(4) Recommend manufacturers to acquire or cross license related patents.

This paper is organized as follows. The first two sections introduce the research literature for patent infringement litigation, LTE/LTE-A communication technologies, the ontology concept, FCA, and text mining techniques. In Section 3, the general methodology of this study and the modified FCA method are discussed. Section 4 describes a case application to non-practicing entities, Wi-Lan technologies, and the evolution of Wi-Lan patent litigations over time. In the last section, the research results, contributions, and the recommendations for future research are provided.

2. Literature review

In this section, the literature related to the study are divided into LTE/LTE-A mobile communication networks, the concept of ontology, formal concept analysis (FCA), and patent-specific text and data mining.

2.1. 4G mobile communication networks

Long Term Evolution (LTE) was first developed by 3GPP in 2008 and is commonly known as the 3.9G communication technology standard. The communication technology standard was defined in the technical document 3GPP Release 8 [15]. The content of the standard is precisely described as "LTE communication technology enhances the user's data transmission rate and quality of service (QoS). Service is guaranteed even if the user is at the edge of the signal range where a more flexible spectrum, a simplified network structure, lower latency, and enhanced cooperation in multiple communication systems are provided" by Sälzer and Baker [16]. In 2008, the International Telecommunication Union for Radio Communication (ITU-R) required IMT-Advanced to begin implementing the 4th generation (4G) mobile communication technology and issued a formal notification [17]. In 2010, 3GPP replied to the formal notification by submitting 3GPP's Release 10, which was referred to as Long Term Evolution Advanced (LTE-A).

LTE-Advanced meets the ITU-R's definition of 4G and was the first standard recognized as a 4G mobile communications technology by the ITU-R in 2010. The specifications for LTE-A include a data rate of 3 Giga bytes per second (Gbps) for downlinks and 1.5 Gbps for uplinks, higher spectrum efficiency, and improved performance at the cell edge. Wannstrom [18] reports that LTE-A includes several key communication technologies, such as carrier aggregation, multi-input multi-output (MIMO), coordinated reception of multicasts (CoMP), and orthogonal frequency division multiplexing (OFDM).

Companies such as Qualcomm and Ericsson dominate the standard essential patent market. Some non-practicing entities (NPEs) seek opportunities to license their IPRs and often challenge the ownership and control of key technologies by filing infringement lawsuits against manufacturers or channel distributors. In order to avoid NPE patent infringement litigation and understand the patterns of NPE legal action, this research uses modified formal concept analysis to explore the evolution of patent infringement lawsuits and the disputed patents. Two modified FCA models are constructed to observe the evolution of the lawsuits over time and the relation to disputed patents. Communications manufacturers are frequently involved in patent infringement litigation due to aggressive competition and the scale of investment needed to introduce and sustain products in the global marketplace. A patent litigation trial usually takes two to three years to complete and cording to the American Intellectual Property Law Association (AIPLA) report, the average cost of a lawsuit is about $3 million USD. The impact of patent litigation on companies is time consuming and costly and often eliminates entrepreneurs from the marketplace. The announcement of a court injunction delays the launch of short lifecycle products and results in substantial losses that financially devastate companies. This study provides analytical tools to map the litigation trends, the disputed patent portfolios, and the competitors' using patents for IP protection and litigation defence strategies.

2.2. The ontology concept

The Internet provides access to a wealth of information stored in public databases available for retrieval and re-use, such as patent corpuses. Information discovery and analysis technology is needed to aid in the interpretation and synthesis of IP data trends. Ontologies are critical to this type of analysis since they are used to create a hierarchical semantic tree used to define a particular knowledge domain [19]. The concept of ontology originated from philosophy and was originally used to explore the essence of objects. The ontology is formed by a collection of terms (vocabularies), semantic interconnections, inferences, and simple logic rules to identify relations [20]. The ontology defines the domain knowledge and use standardized common terminology to efficiently share knowledge. Fensel et al. [21] refer to four key functions and their advantages of the ontology. First, the abstraction or concept using the ontology schema is easily understood. Second, the concept and limitations are precisely and explicitly defined. Third, the precise descriptions are formally represented. Finally, knowledge can be co-verified and shared by users.

2.3. Formal concept analysis

Formal concept analysis (FCA) was derived from mathematical lattice theory [22]. The prominent feature of FCA is that the relationships between objects and concepts are represented as hierarchical diagrams and the complex data structures are visually presented as lattices [23]. FCA can be regarded as a conceptual clustering technique, and is used for describing the connecting relationships between abstract concepts or data by key concepts [24]. FCA has been applied in many areas, such as psychology, biology, science, and computer science [25]. FCA is frequently applied to analyze large and complex data sets to help decision makers understand data structures and their relevance over time. The FCA procedures for constructing a concept lattice (for presenting data concepts and their relevance) are described as follows:

Step 1. Definition of the FCA notation

(1) Define a formal context K= (O, A, I), where O are objects and A are attributes, I is the relationship between O and A. The left most column of the formal context K (Table 1) are the objects (o1, o2, …, o5) and the top most row represents the attributes (a1, a2, …, a6). The expression of the relationship between O and A are written in another form $(o, a) \in I$, meaning the object o has the attribute a. A formal concept consists of two parts which are a set of attributes and a set of objects. For instance, in Table 1, a concept is formed by object o2 with the set of attributes {a3, a5, a6} and the concept is expressed as {o2; a3, a5, a6}.

(2) A formal concept of (O, A, I) is (O_i, A_j) with $O_i \subseteq O$, $A_j \subseteq A$, $A' = O$ and $O' = A$. O is the extent and A is the intent of the formal concept (O_i, A_j). Table 1 shows that Oi contains objects o3 and o5, and the related attributes of Oi are a2, a4, a5 and a6.

(3) Given a set of objects O_i and $O_i \subseteq O$, then A′ represents all attributes included in the set O_i. For instance, a set $O_i \subseteq O$ consists of o3 and o5. The set O_i is related to the set A_j consisting of the attributes a2, a4, a5 and a6.
(4) Let C1 = {o1; a1} and C2 = {o2; a2} represent the content of two objects with attributes. If a1 ⊆ a2 (equivalent to o1 ⊆ o2), then {o1; a1} is called the sub-concept of {o2; a2}. Conversely, {o2; a2} is called the super-concept of {o1; a1} and the relationship is denoted as {o1; a1} ⊆ {o2; a2}.

Step 2. Formal context presentation

Formal concepts are converted into a two-dimensional matrix using the above notation and then converted into the concept lattice [26]. As shown in Table 1, the example formal context has five objects, six different attributes, and X represents the relationship between objects and attributes. Formal context definition is necessary prior to deriving the FCA concept lattice. Given a sub-concept and super-concept, the hierarchical relationship is derived. The hierarchical relation of the concept lattice provides a visual interpretation as shown in the example graph in Fig. 1 [27].

Step 3. Concept lattice construction

The concept lattice represents a top-down hierarchical structured graph. The top node of the concept lattice is the largest sub-concept and is part of the universal set of objects known as supremum representing the general concept. The higher nodes represent more generalized concepts. The lower nodes of the lattice represent more specific concepts and are called the infimum which consists of the universal set of attributes.

The following illustrates the concept lattice construction steps. The first step is to map the sub-concept or super-concept relationships between attributes. As shown in Table 1, all objects have the a5 attribute. Hence, a5 is the most universal attribute and is equal to the universal set of objects. Therefore, a5 is placed on the top of the concept lattice. Since a5 is in the universal set, a5 is the super-concept of all the attributes. a1, a2, a3, a4 and a6 are the sub-concepts of a5 and a3 and a1 have a hierarchical relationship. a3 is the super-concept of a1 and a1 is the sub-concept of a3. Based on the sub-concept and super-concept relationship, the attributes can be sorted as follows: a5 > a2 = a4 = a6, and a5 > a3 > a1. As shown in Fig. 1, {o1, o2, o3, o4, o5; a5} is the top concept which also represents that o1, o2, o3, o4 and o5 have the same a5 attribute. All related objects of the concept are drawn on the left of the semicolon and the all related attributes of the concept are drawn on the right side of the semicolon. The concepts constituted by a2, a3, a4 and a6 are the first sub-layer concepts of the a5 concept. The concepts are labeled as follows: {o2, o5; a5, a6}, {o3, o5; a4, a5}, {o1, o2, o4; a3, a5}, {o1, o3; a2, a5}, and are plotted in the next layer of the a5 concept. Since a1 is the sub-concept of a3 and a3 is the sub-concept of a5, a1 is the second-order layer sub-concept of a5. When drawing a1, a1 must be drawn below a3 and a3 must be drawn below a5.

After defining the sub-concept and super-concept relationship, the nodes are plotted using linkages to merge the concepts and progressively narrow higher level concepts to concepts with single objects in the next layer. A concept with a single object is represented by a circle. For instance, o2 has attributes a3, a5 and a6. Therefore, a concept formed by o2 and the related attributes is a concept with a single object. The concept can be written as {o2, a3, a5, a6}. Since a3 is the sub-concept of a5, a3 inherits a partition of the concept a5. Consequently, making linkages between a2, a3 and a6 is complete and no needs linkage with a5, o2, o3, o4 and o5. Since o1 has one extra attribute (a2) than o4, the o1 concept is plotted directly under the o4 concept. Finally, concepts with single objects connect to the infimum and the drawing of the concept lattice is complete.

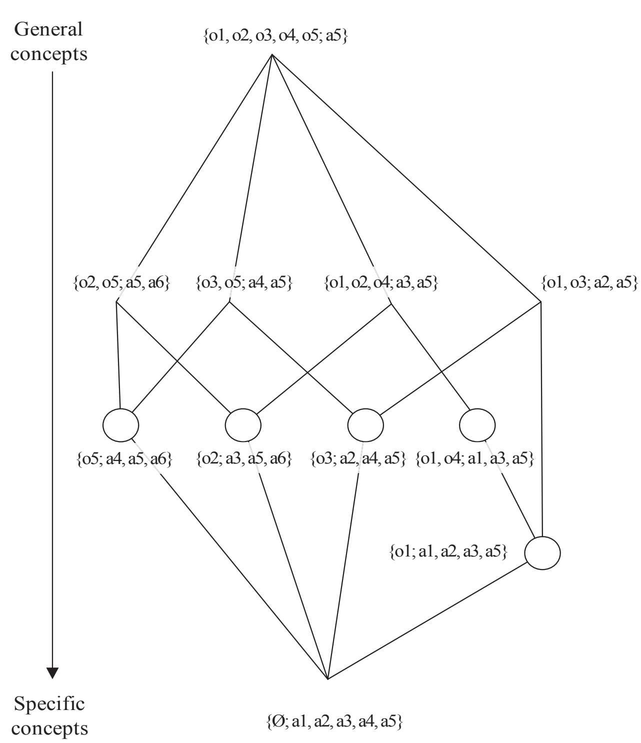

Fig. 1. An example of a hierarchical concept lattice.

2.4. *Patent text mining and data mining*

Text mining is a reductive approach used for knowledge analysis of text documents. Text mining derives previously unknown and potentially useful information from a natural language database [28]. The extracted information is converted into useful intelligence with expert assistance for refinement and verification [29]. While data mining is used to deal with structured data, text mining is used to analyze text data which is variable in length and not structured like numeric data [30]. In previous literature, Song used a key term list to represent a document [31]. Chang [7] applied the frequency of keywords in patent documents as the input data to generate a patent network graph. The analytical and algorithmic processes of a typical text mining is described by Ramasubramanian and Ramya [32].

3. Methodology

Fig. 2 depicts the general process flow of the case study. First, the court documents are downloaded from the LexisNexis Federal Intellectual Property Cases database and the disputed patents from the United States Patent and Trademark Office (USPTO). The documents are checked and organized before inputting their texts into the text mining system, where the key terms of the disputed patents and the cases are extracted. The computer-supported modified formal concept analysis (MFCA) is used to generate the evolution figures. When there are disputed patent portfolios, the disputed patents' CPC codes are used to perform the patent similarity analysis. The patent similarity analysis reveals similar patents owned by other companies and provides strategic guidance for IP cross-licensing and patent acquisition [33]. The following section illustrates the MFCA method and algorithm.

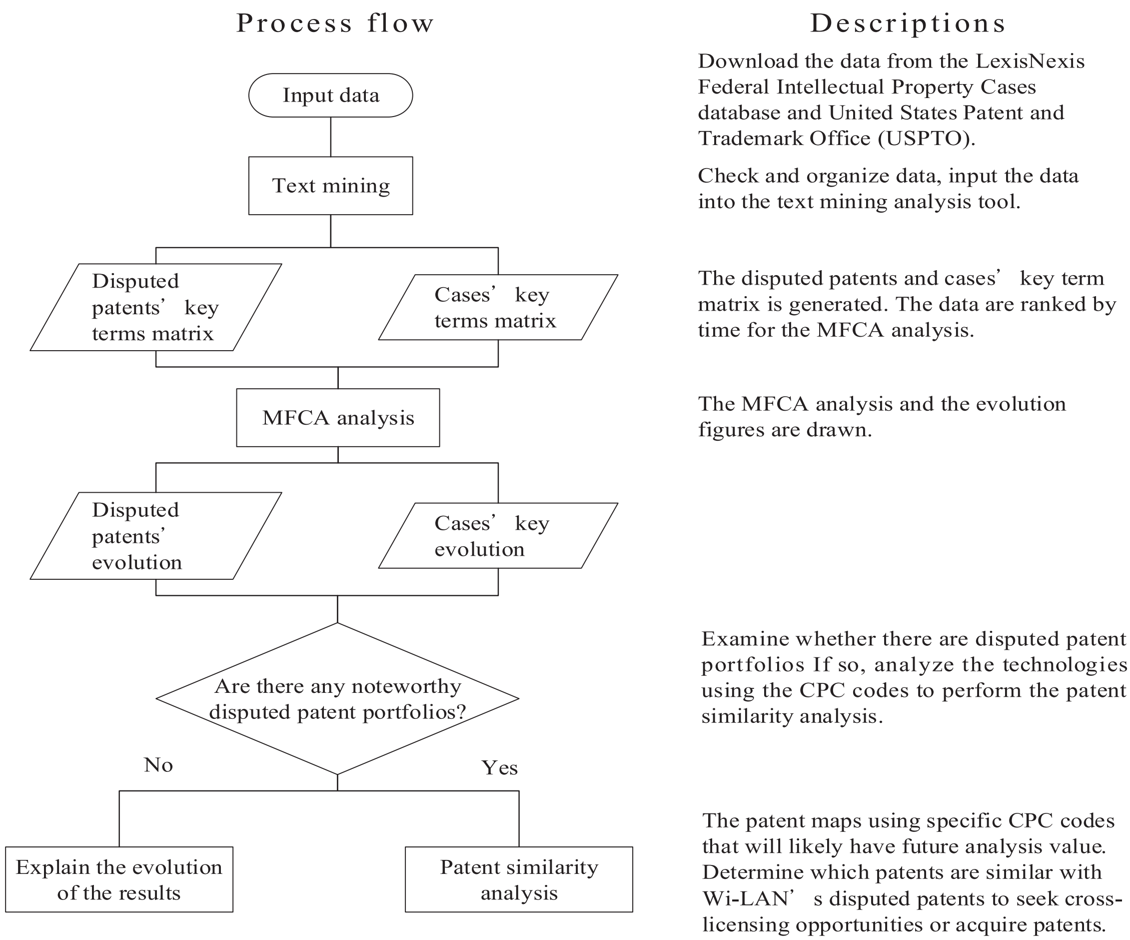

Fig. 2. The process flow of this study.

3.1. Modified formal concept analysis (MFCA)

The traditional FCA considers the relationship between the objects and the attributes and not the effect over time. Therefore, traditional FCA analysis is not suitable to monitor technology evolution over time. This research uses a modified FCA to analyze and monitor the evolution of patent lawsuits and the disputed patents. The modified FCA was first adopted by Lee et al. [34] for domain specific patent evolution but not for litigation analysis. The difference between the modified FCA and the traditional FCA is that the data are preprocessed. This study uses a horizontal dynamic lattice to depict the litigation evolution of the disputed patents and the related cross-analysis. Fig. 3 illustrates the process flow of MFCA.

Step 1. Data collection

In order to define the target and results, the litigation cases are downloaded from the LexisNexis Federal Intellectual Property Cases database and the disputed patents from USPTO. The first step is to verify the resources and check whether there are missing values. After collecting and cleaning, the data are archived in the database in the corresponding analysis field. The computer is used to perform the text mining process.

Step 2. High-frequency key terms analysis

Text mining is used to derive the key terms matrix for input into the MFCA algorithm. The normalized term frequency (NTF) values are used to rank the key terms [35]. Three hundred top ranked key terms are selected for constructing the patents versus the key terms matrix.

Step 3. Formal context

Disputed patents and litigation cases are utilized as the input of the modified FCA. For disputed patents, three fields including patent number, issue date, and high frequency key terms, are used. For litigation cases, the case number, launched date of the litigation, and high frequency key terms are used. The disputed patents and litigation cases are ordered by their issue dates. The patents versus key terms matrix is a 0–1 matrix. If the NTF value of a given key term for a given patent is greater than a threshold value, the value 1 is assigned. Table 2 is an example of a MFCA formal context with five patents (P1 ~ P5) in one dimension and seven key words (KP1 ~ KP7) in another dimension. In the matrix, 1 represents the keyword existence in the patent (i.e., NTF > than the threshold value). As noted in Table 2, the patents are sorted by the issue dates on the left hand side of the table.

Step 4. Drawing the concept lattice

The following discussion describes the MFCA algorithm. MFCA uses the formal context and the similarity matrix to draw evolution graphs. Table 3 is the similarity matrix of the MFCA formal context, derived using the cosine similarity value of given two patents, i.e., Euclidean dot product of their key-term frequency vectors [36] [37]. Using the number of keywords and the patent issued dates as vertical and horizontal coordinates, the patents are plotted in Fig. 4 accordingly. From left to right, the patents are sorted according to

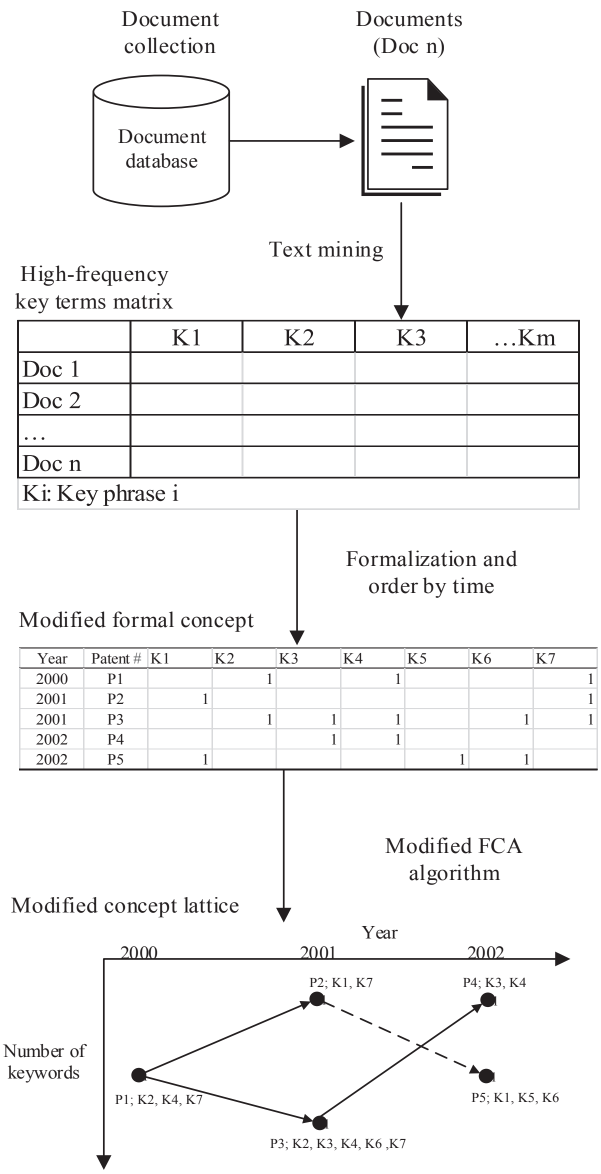

Fig. 3. The MFCA process for identifying concept linkages between patents in litigations.

Table 1
An example of formal context.

A/O	a1	a2	a3	a4	a5	a6
o1	X	X	X		X	
o2			X		X	X
o3		X		X	X	
o4	X		X		X	
o5				X	X	X

the issued dates. From top to bottom, the patents are sorted according to the number of keywords within. Patents containing fewer keywords are placed at the bottom and patents with more keywords are placed at the top. The MCFA algorithm and pseudo code are provided in Appendix I.

After deciding the position of patent node, the linkages among nodes are drawn based on the formal context and the similarity matrix. The similarity values between pair-wise patents are listed in Table 3. The similarity values of P2-P1, and P3-P1 are 0.408 and 0.775 respectively. Both values are greater than the pre-set threshold (0.3), so two solid links are created as shown in Fig. 4. P2 and P3 cannot be connected since they are both issued in the same year. The similarity values of P4-P1 and P4-P3 are greater than the threshold, but the P3-P1 evolution link has been established and P4 does not directly link to P1. Instead, P4 can only make a connection with P3, which indirectly establishes the P1-P4 connection. The type of linkage line (solid - strong or dotted - weak) is determined based on keyword occurrence. For example, if P4 possesses common keyword(s), e.g., K4, as its super-concepts P1 and P3, then a solid line is used to connect P4 and P3. Otherwise, a dotted line is used to connect the patents. The drawing of the sample dynamic lattice is shown as Fig. 4. The threshold value is pre-set by analyst and allowed changes and try-runs to assess the evolution analysis results. In our case study, the threshold is set at 0.3. If the threshold value is set too low, most disputed patents will be judged as being all related (too many linkages). If set too high, few links will be established. Therefore, a computer-assisted system can easily adjust the threshold values for numerous analytical runs.

Table 2
An example of a MFCA formal context.

Year	Patent#	KP1	KP2	KP3	KP4	KP5	KP6	KP7
2000	P1	0	1	0	1	0	0	1
2001	P2	1	0	0	0	0	0	1
2001	P3	0	1	1	1	0	1	1
2002	P4	0	0	1	1	0	0	0
2002	P5	1	0	0	0	1	1	0

Table 3
The similarity matrix of the MFCA formal context.

Year	Patent#	P1	P2	P3	P4	P5
2000	P1	1.000				
2001	P2	0.408	1.000			
2001	P3	0.775	0.316	1.000		
2002	P4	0.408	0.000	0.632	1.000	
2002	P5	0.000	0.408	0.258	0.000	1.000

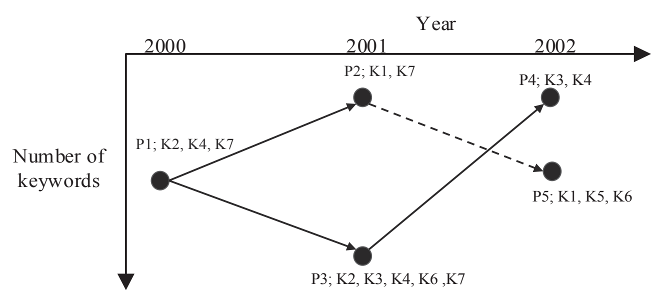

Fig. 4. The dynamic lattice representation of Table 2's MFCA context.

Step 5. Model explanation

By summarizing and integrating the results of the concept lattice, an appropriate technology development strategy is derived. In the study, the patent litigation is usually linked to a patent cluster or a patent portfolio. The approach provides information about which disputed patents are similar and the technological clusters are used to identify underlying trends.

4. Case study

4.1. Evolution of Wi-Lan litigation and disputed patent portfolios (G1-G5)

This research uses Wi-Lan litigation and disputed patents as the research target. The cases were downloaded from the LexisNexis Federal Intellectual Property Cases database. The disputed patents were downloaded from the United States Patent and Trademark Office (USPTO) database. The research identifies 16 Wi-Lan patents (Appendix II) and 28 litigation cases (Appendix III). These documents are used as case study to build the time-based MFCA models. First, the cases are categorized into five groups (G1-G5) based on the involvement of similar patent sets (Table 4). The evolution of litigation and disputed patents in all groups are illustrated in Figs. 5 and 6.

The G1 patent portfolio, consisting of five patents, has the largest number of legal cases (12) as listed in Appendix III. Wi-Lan has used this portfolio for many years in more than thirteen lawsuits. The disputed patent, RE 37,802, refers to "multi-code direct sequence spread spectrum." The patent presents a modulation scheme which is called Multi Code Direct Sequence Spread Spectrum (MC-DSSS) or MC code. MC code allows the information in a MC-DSSS signal to be decoded into a sequence of low complexity parallel operations to reduce interference. Patent US 5,282,222 is the "method and apparatus for multiple access between transceivers in wireless communications using OFDM spread spectrum," which proposes a method allowing a number of wireless transceivers to exchange voice data or video data over an OFDM system. The patent uses a processor for applying a Fourier transform to the multiplexed information to bring the data into a time domain for transmission. The patented technique enhances voice quality, saves power, and reduces the complexity of the transmission. The disputed patent is a key patent complying with the 802.11a communication standard released by the Institute of Electrical and Electronics Engineers (IEEE) in 1999. Wi-Lan specializes in the development of OFDM and OFDMA technologies and owns quite a few patents in this specialized domain. With the development of new communications technologies, many wireless communication standards and products have adopted the OFDM/OFDMA technologies including the digital subscriber line (DSL), WiFi (IEEE 802.11), and IEEE WiMAX (802.16). This observation potentially explains the numerous patent litigation cases across a variety of product types. The first case in group 1 (G1) occurred in 2007. The defendants included Acer, Apple, Atheros, Buffalo, D-Link, Westell, Research in Motion (RIM), Intel, Motorola, Utstarcom, LG Electronics, and Broadcom. The products involved in the patent infringement disputes include Wi-Fi/DSL wireless routers, notebook computers, smart phones, and many other communications products. Most companies decided to settle the cases from 2009 to 2013. The remaining defendant was Apple. The Wi-Lan versus Apple case reached a verdict on April 2, 2014 finding Apple not guilty of infringement (Case No. 27 in Appendix III).

The G2 portfolio has five disputed patents in the case of Wi-Lan versus Alcatel-Lucent, Ericsson, Sony mobile, and HTC. Wi-Lan believed that the products made and sold by the defendants infringed on their patented technologies. The United States District Court for the Eastern District of Texas dismissed the Wi-Lan case in July 2013. Alcatel-Lucent and Ericsson did not infringe patents US 6,088,326, US 6,195,327, US 6,222,819, US 6,381,211, US 6,260,168 and Sony and HTC did not infringe claims 2 and 5 of US 6,381,211. The results of further lawsuits (No. 24 in Appendix III) ended the subsequent challenges. Wi-Lan eventually sold the G2 patents to Airspan Communications in April 2014.

The G3 disputed patent portfolio is related to three lawsuits (No. 16, No. 26 and No. 28) as listed in Appendix III. The first case is Wi-Lan versus Alcatel-Lucent (Case No. 16). This portfolio involves 3GPP LTE wireless network standards. The disputed patents, US 8,027,298 and US 8,249,014, relate to the modulation signal transmission method of wireless communication systems. These two patents and the Group 4 patents belong to the same patent family. As plotted in the ontology map (Fig. 7), patents −298, −014, and −640 (the last 3 digits of US patent number) are identified in the same end-node of "communication control − signal control − allocation method" with their similarity values greater than 0.6. G3's third patent US 8,229,437 proposes pre-allocating identifiers to wireless devices for use in requesting resources over a random access channel. A wireless device having the pre-allocated codes can transmit a particular code over the channel as a request for resources. The invention reduces the probability of random access channel collisions and conserves the resources needed to support anonymous requests. The first G3 lawsuit occurred in 2013 indicating a new technology with evolving commercialization.

The G4 patent portfolio is related to the Wi-Lan versus Apple (Case No. 19 in Appendix III). This portfolio includes two disputed patents, US 8,315,640 and US 8,311,040. Patent −640, entitled "methods and systems for transmission of multiple modulated signals over wireless networks," and is an inventive method and apparatus for requesting and allocating bandwidth in a broadband wireless communication system. As indicated above, this patent belongs to the −298 patent family. Patent −040, "packing source data packets into transporting packets with fragmentation," provides a new method for transmitting packets over a communication system. The packets of information in the first format are converted to packets of information in the second format prior to transmission via the communications link. The technology packs and fragments and coordinates the information in the first format to improve data transmission efficiency. The Wi-Lan versus Apple case was filed in April 2013 and was transferred to the US District Court for the Southern District of California. This case deserve attention and close observation from companies in the industry.

The G5 patent portfolio is related to Wi-Lan versus LG Electronics (Case No.'s 7–13, Case No. 15, Case No. 17 and Case No. 21 in Appendix III). The disputed patent US 5,828,402 involves V-chip technology widely used in North America since the year 2000. All US televisions are equipped with V-chips to classify program content and to limit program selection. The patent presents the method of blocking the reception of unwanted television programming. The data of the television program are transmitted by data packets, which are detected by a blocking apparatus. Then the data packets are compared to preferences stored in non-volatile memory in the blocking apparatus. If the content of the data

Table 4
Classification result of disputed patents and corresponding litigation.

Group	Case No.	Patent No.
1	1, 2, 3, 4, 5, 6, 14, 18, 20, 22, 25, 27	US 5,369,670; US 5,282,222; US 6,192,068; US 6,320,897; USRE 37,802
2	23, 24	US 6,088,326; US 6,195,327; US 6,222,819; US 6,381,211; US6260168
3	16, 26, 28	US 8,027,298; US 8,229,437; US 8,249,014
4	19	US 8,315,640; US 8,311,040
5	7, 8, 9, 10, 11, 12, 13, 15, 17, 21	US 5,828,402

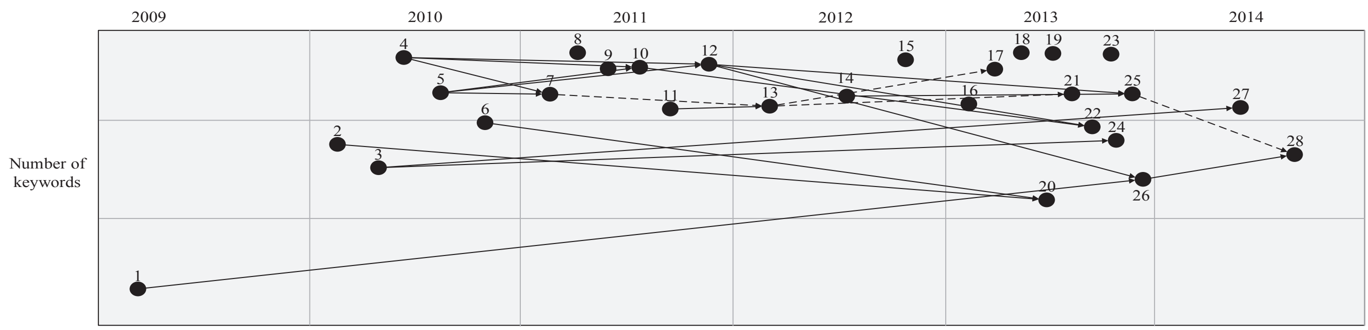

Fig. 5. The evolution of Wi-Lan litigations (refer to litigation no. in Appendix III).

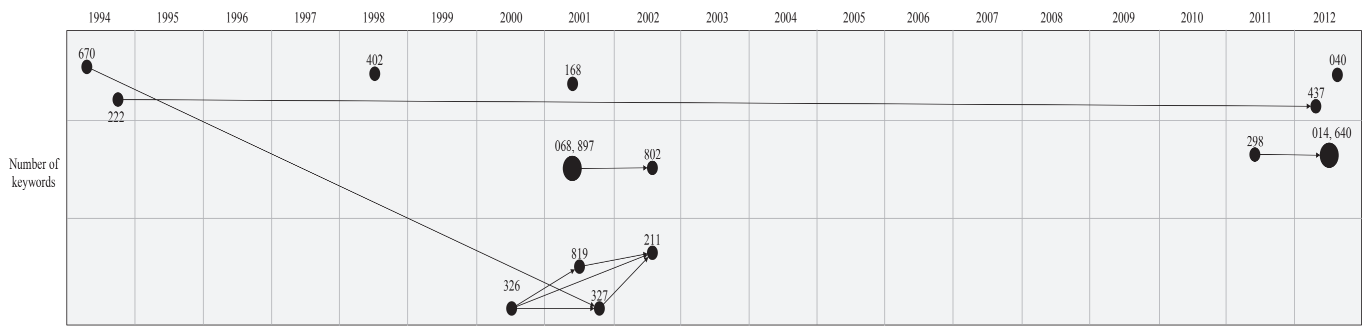

Fig. 6. The disputed patent trace (refer to the last digits of US patents in Appendix II).

packets do not match the stored preferences, then the television signal is blocked. This patent dispute involved a total of 10 cases. The results of the litigation can be seen in Case No.11 (Appendix III). For this judgment, Judge Andrew J. Peck dismissed the claim of Wi-Lan and also dismissed the invalidity claim of patent −402 by LG. Thus, patent −402 remains valid and Wi-Lan continues to appeal Judge Kaplan's summary judgment of Case No. 11 (Appendix III). The age of the disputed patent is 16 years old, indicating further legal action may not yield favorable results for the plaintiff.

As described above, Wi-Lan will likely focus on the defending its newer and more robust IPRs in LTE/LTE-A communication technologies. In summary, the evolution of the disputed patents and the litigation cases are analyzed in five groups. The G1 disputed patents belong to earlier patents (with an average age of about 17 years). Since OFDM/OFDMA is currently used in many commercial applications and products (e.g., 802.11a, WiFi/DSL, and WiMAX), patent US 5,282,222 (11 years old) may be extended with new R&D efforts and injunctions via IP litigation. Communication companies should actively pursue the development of communication standards and promote this technology as the next generation communication standard. From the evolution analysis of disputed patents, the relationship between G2 disputed patents −326, −327, −819 and −211 are very strong. Likewise, G3 and G4 patents are closely related. Patent −298, −014, and −640 belong to the same patent family with the same CPC code (H04W72/10). The patent family has a total of 13 patents that have been actively used in IPR litigation cases indicating a well formed patent barrier. Because G5 belongs to TV multimedia technology, the evolution of disputed patents shows that the relevance of patent −402 with other patents is not strong. Table 5 summarizes the suggestions for IP risk management of five the groups.

4.2. 4G LTE-A ontology and the litigation patent mapping

LTE is the mainstream wireless communication standard which focuses on enhancing wireless network data transmission capacity and data transfer speed. Since the scope of LTE technology includes many sub-technologies, it is necessary to build an LTE-A ontology to identify key domain terminologies for the patent search. Fig. 7 depicts the ontology for LTE-A technology. This study aggregates and identifies LTE-A communication technologies that are divided into data signal multiplexing, communication control, communication systems, and the core network.

Data signal multiplexing is further divided into four sub-technologies (i.e., Orthogonal Frequency-Division Multiplexing (OFDM), Single-Carrier Frequency-Division Multiplexing (SC-FDMA), Multiple Input Multiple Output (MIMO), and Code division multiple (CDM)). Data signal multiplexing and its sub-technologies are critical technologies of LTE-A since OFDM and MIMO significantly increase data transfer rates. OFDM uses special frequency division multiplexing with orthogonal subcarriers that enhance the wireless resources to provide the system with a larger and adjustable bandwidth. MIMO increases throughput by enhancing bandwidth utilization.

Communication control is divided into five sub-technologies including encoding, feedback control, signal control, dynamic adaption and flexible control, and resource management and scheduling. Communication control and its sub-technologies are related to signal transmission. When transmitting data dynamically, errors occur and when the error rate reaches a certain level, the quality of signal transmission diminishes. The communication control technologies encode the digital signal to decrease errors. These technologies are used for signal transmission process management, reference signals, and feedback techniques.

The communication system can be sub-divided into sub-technologies such as Coordinated Multipoint (CoMP), duplex schemes, cellular base stations, handover, relay, and location services. Communication system technology involves coordination between the base stations and the terminals. For instance, when mobile users make phone calls with overlapping coverage areas,

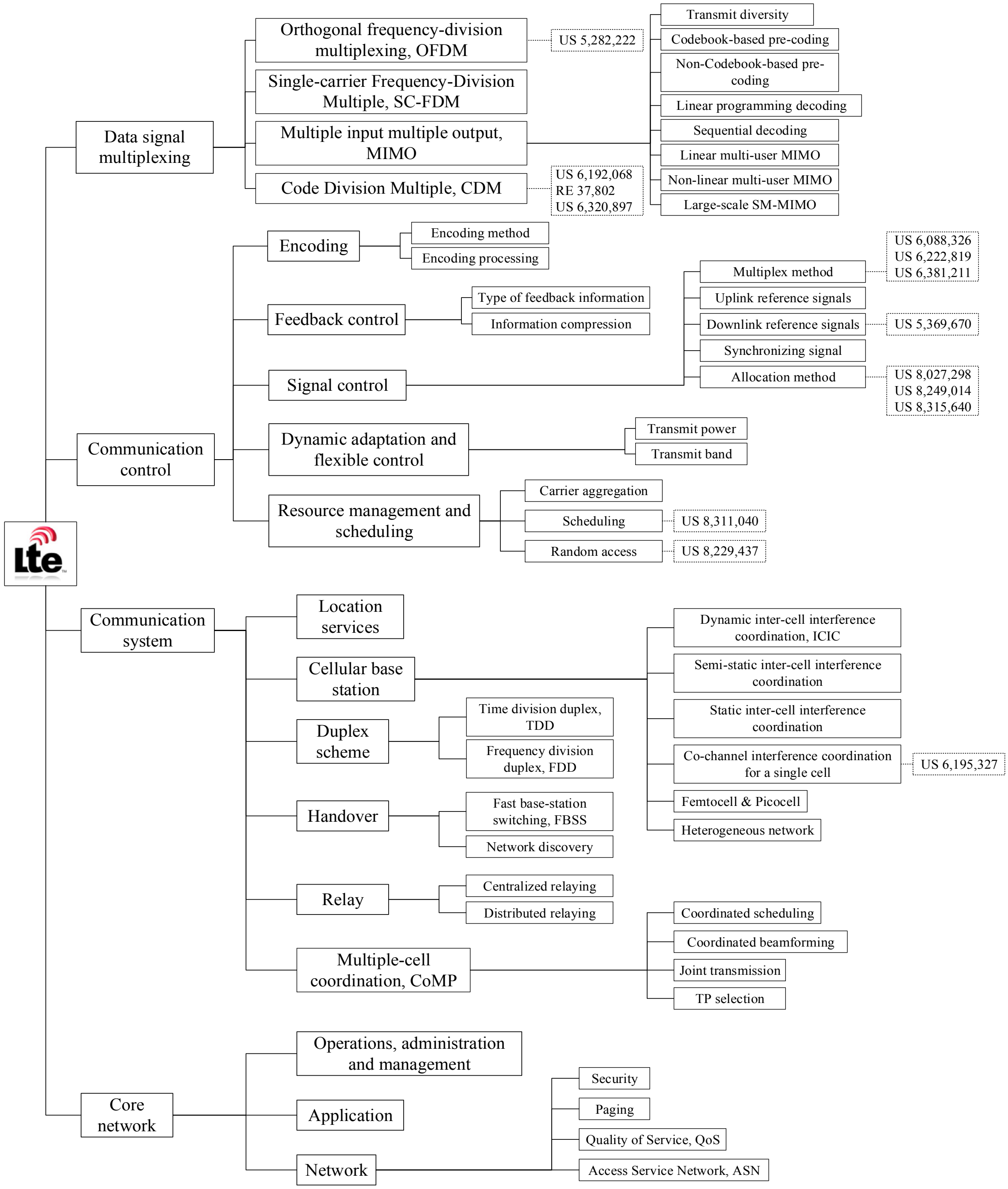

Fig. 7. The domain ontology of LTE-Advanced technologies.

then stations coordinate and complete the transmission. If the user is crossing the edge of signal coverage, the handover technique avoids broken transmissions.

The core network is divided into network, application, operation administration, and management. The network assures the quality of network services, provides information security, and access to wireless signals including LTE core network operations management techniques. This study uses the LTE/LTE-A ontology to identify specific technology domains related to Wi-Lan patent litigation cases. The ontology is used to observe the legal activity changes and technical specification trends. As shown in Fig. 7, Wi-Lan's 4G disputed patents are mapped onto the ontology schema. The end-nodes show the technology focus. Note that some disputed patents, such as V-chip and blue tooth, are out of the 4G scope and are excluded from the 4G ontology map.

4.3. Strategies for identifying defensive patents

After the litigation and patent evolution analysis and ontology mapping, the G3 and G4 patent portfolios are identified as patents for future lawsuits. This study uses the European Patent Office (EPO) patent coding systems, called Cooperative Patent Classification (CPC), to search for G3 and G4 related US patents. The related CPCs are H04W 72/10, H04W 74/0875 and H04W 28/065. H04W is

Table 5
Analysis results and recommendations.

Group	Technology development	Analysis results and recommendations
G1	Medium	- DSSS and OFDM - Because G3 evolved from G1, the emerging technologies refer to G1 for technological breakthroughs and new designs. - The lawsuit was settled on April 2, 2014. The court found that Apple did not infringe the disputed patent RE 37,802.
G2	Low	- Due to Wi-Lan's loss of this lawsuit on July 2013, the ability to sue the patent portfolio by the patent holders was very difficult. - The Eastern District Court of Texas ruled against Wi-Lan. The defendants Alcatel-Lucent and Ericsson did not infringe the disputed patents US 6,088,326, US 6,195,327, US 6,222,819, US 6,381,211 and US 6,260,168. Further, Sony and HTC did not infringe claims 2 and 5 of patent US 6,381,211. - The patents were sold on April 17, 2014.
G3	High	- G3 evolved from G1. - Analysts should further explore G3 patent technologies, find similar patents to license, and avoid ongoing litigation. - Judge Middlebrooks of the Florida Circuit Court ruled that Ericsson did not infringe the disputed patents US 8,027,298, US 8,249,014. Patent US 8,229,437 remains unresolved at the time of this research.
G4	High	- Only one litigation case is related to the patent portfolio. - Assignees whose products are similar to Apple should study all related litigation developments. - The court approved change of judicial venue to the United States District Court for the Southern District of California.
G5	Low	- TV Multimedia, V-chip technology. - These patents will expire in the year 2016. - Judge Lewis A. Kaplan supported that LG did not infringe on Wi-Lan's 5,828,402 patent (Case No.11, Appendix III).

used to group the patents related to wireless communications networks. H04W 72/10 is defined as the sub-category of local resource management of wireless communications networks including allocation of wireless resources based on priority. H04W 74/0875 represents the sub-category of wireless channel access and random access for wireless communications networks. H04W 28/065 is the sub-category of optimizing information size using assembly or disassembly of packets. This study defines the three search queries to find patents under the same sub-technologies with the same CPC classifications. Table 6 shows the search results (search date: April 13, 2015).

After defining the technical domain of the disputed patents, this study conducts the similarity analysis of disputed patents with the same CPCs. The purpose of the patent similarity analysis are:

(1) If patents with high similarity appear earlier then the disputed patents, these patents are likely to be the original patents. Patents in this category require re-examination by experts for legal defense validity analysis.
(2) Due to the high similarity of patents with the same CPC classifications as the disputed patents, these patents often have similar technical content. The communications vendors may purchase these patents or cross-license to reduce litigation risk.
(3) Even if the technical content is not completely identical, the technical content is still very similar. Therefore, high similarity patents are necessarily reviewed when creating new patents.

Table 7 lists some examples of similarity measures between patents in the 4G domain. The data indicate the similar patents owned by Wi-Lan and other global communication companies under specific CPC categories.

Using H04W 72/10 patents as an example, the cosine similarities between the similar patents are very high (7.70%). The Wi-Lan patents in the H04W 72/10 category form a patent barrier against patents US 8,027,298, US 8,929,905, US 8,787,924, US 8,462,723, US 8,249,014, and US 8,315,640 (Appendix II). When Wi-Lan initiates litigation proceedings in the technical domain of H04W 72/10, these patents will be used to defend its IPRs.

The top three patents with high cosine similarity and an age of more than 3.5 years are used to compare with corresponding patents under dispute. For example, patents US 8,027,298, US 8,249,014, and US 8,315,640 are three Wi-Lan patents in H04W 72/10 under dispute. Cisco's patent US 7,486,639 is highly similar to the disputed patent US 8,315,640. Text mining is conducted to identify the most frequently appearing key-terms (as representations of key concepts) in the disputed patents. The normalized term frequency (NTF) values are calculated to determine the list of the most frequently appearing terms in each patent document [38].

In the following paragraphs, sentences in italics show the partial content of the patent US 8,027,298. The key concepts are underlined. As shown below, patent US 8,027,298 provides a method for requesting and allocating bandwidth. The Customer Premise Equipment (CPE) sends the request messages to the base stations and is responsible for distributing the allocated uplink bandwidth.

A method and apparatus for requesting and allocating bandwidth in a broadband wireless communication system. The inventive method and apparatus includes a combination of techniques that allow a plurality of CPEs to communicate their bandwidth request messages to respective base stations.

Detect a bandwidth request in uplink (UL) data received from a subscriber unit and identify in the bandwidth request a requested amount of UL bandwidth pertaining to a UL queue established at the subscriber unit;

Determine if the requested amount of bandwidth is available; and allocate to the subscriber unit an UL bandwidth grant based on the requested amount and the bandwidth available for UL data, wherein

Table 6
Search query by the CPC classifications (Search date: April 13, 2015).

Strategy	Search query	US patent counts	Wi-Lan patents	Wi-Lan groups
1	(CPC/“H04W72/10”)	497	US 8,249,014	G3
			US 8,027,298	G3
			US 8,315,640	G4
2	(CPC/“ H04W74/0875”)	128	US 8,229,437	G3
3	(CPC/“ H04W28/065”)	330	US 8,311,040	G4

Table 7
Some similarity measures between patents in CPC - H04W 72/10.

CPC	Wi-Lan patents	Other patents	Similarity	Age	Assignee
H04W 72/10	US 8,027,298 (2009/12/23)	US 8,929,905	0.768	2	Wi-Lan, Inc.
		US 8,787,924	0.718	3	Wi-Lan, Inc.
		US 8,565,173	0.491	4	Samsung Electronics
		US 8,462,723	0.881	4	Wi-Lan, Inc.
		US 8,155,066	0.408	7	Samsung Electronics
	US 8,249,014 (2011/8/4)	US 8,155,066	0.407	7	Samsung Electronics
		US 8,189,514	0.312	10	Wi-Lan, Inc.
		US 8,565,173	0.529	4	Samsung Electronics
		US 8,654,664	0.309	4	Wi-Lan, Inc.
		US 8,929,905	0.748	2	Wi-Lan, Inc.
		US 8,787,924	0.733	3	Wi-Lan, Inc.
		US 8,462,723	0.874	4	Wi-Lan, Inc.
	US 8,315,640 (2009/12/23)	US 7,486,639	0.735	10	Cisco Technology, Inc.
		US 8,817,716	0.727	7	Ericsson
		US 8,200,234	0.609	8	Samsung
		US 8,583,157	0.648	3	Spectrum Bridge
		US 8,559,963	0.685	6	Panasonic
		US 8,462,723	0.708	4	Wi-Lan
		US 8,233,928	0.7	6	Spectrum Bridge
		US 8,219,131	0.715	7	Hitachi
		US 8,050,685	0.486	7	Samsung
		US 7,675,852	0.548	9	Rockwell Collins
		US 7,583,631	0.542	10	Digicomm
		US 7,565,160	0.483	12	Alcatel Lucent
		US 7,558,588	0.61	10	Airvana
		US 5,806,001	0.592	19	Kyocera
		US 5,978,368	0.506	17	Ericsson
		US 6,788,943	0.484	17	Nokia
		US 6,920,121	0.55	12	QPRS Limited
		US 7,035,644	0.711	18	Mitsubishi
		US 7,130,638	0.627	14	NTT DoCoMo
		US 7,233,581	0.686	14	Hitachi
		US 7,286,555	0.699	13	Alcatel Lucent
		US 7,359,349	0.515	13	NTT DoCoMo
		US 7,778,603	0.512	9	Nokia
		US 7,796,571	0.708	12	Sharp

the UL bandwidth grant is allocated to the subscriber unit for distribution. The present invention advantageously makes use of the efficiency benefits associated with each technique.

The content of Cisco's patent US 7,486,639 provides a method for dynamic bandwidth allocation within a wireless communication system. The invention facilitates the efficient use of communication channels in wireless communication systems by adapting to the uplink and downlink bandwidth requirements of the channels. The key terms of the −639 patent are extracted and underlined in the following paragraphs.

A method for adaptively duplexing transmissions between a base station and at least one CPE using a series of uplink and downlink frames of information in an adaptive time division duplexing scheme, wherein transmissions are communicated in an uplink direction during uplink time slots and wherein transmissions are communicated in a downlink direction during downlink time slots comprising:

Selecting a first service type for an uplink transmission;

selecting a second service type for a downlink transmission;

predicting an uplink bandwidth requirement that is associated with the selected first service type;

predicting a downlink bandwidth requirement that is associated with the selected second service type;

calculating an uplink/downlink bandwidth requirement ratio for a frame based upon the uplink and downlink bandwidth requirements;

Channel efficiency and data bandwidth improvements are achieved by using bandwidth requirement parameters to monitor and update the communication link time slot allocations.

The present invention can be employed to flexibly adapt the uplink/downlink time slot allocation and bandwidth once the bandwidth requirements are determined.

From the above comparison of patents with high similarity measure, their key terms and concepts are close. The sample key concepts of four patents in H04W 72/10 are listed in Table 8 for references.

5. Conclusions

In this research, the MFCA generic methodology is developed for evolution analysis of IP litigations. The mobile technology legal cases and the disputed patents are used as case examples. The research clusters the cases into five groups while each group contains a set of common disputed patents with similar sub-technologies. The evolution paths of the clustered lawsuits are systematically related to a portfolio of the disputed patents. The two-layer MFCA illustration shows the group-wise evolution paths of both lawsuits and disputed patents. Further, the evolutionary linkages of disputed patents are divided into three periods, namely the early 3G development era, the matured 3G era, and the new 4G era. Over time, there are changes in the technological processes and legal activities as discovered through the case analysis.

This research in the realm of computer-assisted IP litigation and patent analysis is critically important due to the increasing complexity, high volume documents, and high legal cost for IPR litigations. There are huge numbers of related cases and patent documents associated with each litigation case. The data and text analysis is overwhelming for companies of limited IP, R&D resources, and legal budgets to face the market challenges. Although the computer-assisted e-discovery approaches still require legal expertise to validate and verify the analytical results to alleviate the risk of making wrong judgement, the computer-assisted system

Table 8
The key concepts of four patents in H04W 72/10 (partial).

Patent No.	US 8,027,298	US 8,249,014	US 8,315,640	US 7,486,639
Key concepts (Most frequently appearing terms)	1 allocate 2 antenna 3 broadband 4 customer premise equipment (cpes) 5 detect 6 distribution 7 downlink	1 allocate 2 broadband 3 cpes 4 criterion 5 detect 6 distribution 7 downlink 8 efficiency 9 logical	1 allocate 2 broadband 3 cpes 4 efficiency 5 qos 6 quality 7 queue 8 uplink	1 allocate 2 efficiency 3 distribution 4 frequency 5 resource 6 request 7 qos 8 uplink 9 downlink

can certainly serve as a strong decision supporting tool for IPR protections and legal actions [39]. Further, there are other research, such as AmberScope, focusing on patent citation analysis for similarity analysis. Instead of investigating citation linkages among patents, this research focus on investigating the patent and litigation linkages, as a complementary decision support method.

Overall, this research provides a systematic and computer-supported process to analyze the evolution trends of the litigation cases, the patents in dispute, and the competitors' similar patents for efficiently and effectively directing R&D and IPR strategies. The methodology presented in this paper is demonstrated using the 4G case but can be applied to other domains.

Acknowledgement

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Appendix I

Modified formal concept analysis pseudo code

```
I.  Generate the sets and insert the attributes by the relationship of super-concept and sub-
    concept
      //e.g. Let a set {A, B}, A is the super-concept of B;
     B is the sub-concept of A

II.  Ranking the nodes by patent issues year
      Sort {the all of the nodes from left to right by patent issues year}

III. Calculate the cosine similarity
      Calculate cosine similarity [i][j]
      //i=number of node; j=number of node

IV. According to the cosine similarity to link each Concepts
      If (node A is the super-concept of node B or
        node A is the sub-concept of node B)

        Then make a linkage between Concept A and Concept B
          If (Cosine similarity>= Threshold)
            If (the common words of A and B are included in previous node)
                Use solid line to link A and B
            Else (the common words of A and B are not included in previous node)
                Use dotted line to link A and B
            End if
          none
      end if
```

Appendix II

Wi-Lan disputed patent list

Patent No.	Title	Issue Date	IPC code	Disputed patent Group
US5282222	Method and apparatus for multiple access between transceivers in wireless communications using OFDM spread spectrum	1994/1/25	H04L27/26	G1
US5369670	Method and apparatus for demodulation of a signal transmitted over a fading channel using phase estimation	1994/11/29	G06F17/14	G1
US5828402	Method and apparatus for selectively blocking audio and video signals	1998/10/27	H04N7/088	G5
US6088326	Processing data transmitted and received over a wireless link connecting a central terminal and a subscriber terminal of a wireless telecommunications system	2000/7/11	H04J11/00	G2
US6192068	Multi-code spread spectrum communications system	2001/2/20	H04J13/00	G1
US6195327	Controlling interference in a cell of a wireless telecommunications system	2001/2/27	H04Q7/38	G2
US6222819	Processing data transmitted and received over a wireless link connecting a central terminal and a subscriber terminal of a wireless telecommunications system	2001/4/24	H04J11/00	G2
US6260168	Paging system having optional forward error correcting code transmission at the data link layer	2001/7/10	H04L1/00	G2
US6320897	Multi-code spread spectrum communications system	2001/11/20	H04J13/00	G1
US6381211	Processing data transmitted and received over a wireless link connecting a central terminal and a subscriber terminal of a wireless telecommunications system	2002/4/30	H04J11/00	G2
RE37802	Multi-code direct sequence spread spectrum	2002/7/23	H04L 27/26	G1
US8027298	Methods and systems for transmission of multiple modulated signals over wireless networks	2011/9/27	H04W4/00	G3
US8229437	Pre-allocated random access identifiers	2012/7/24	H04W36/00	G3
US8249014	Methods and systems for transmission of multiple modulated signals over wireless networks	2012/8/21	H04W4/00	G3
US8311040	Packing source data packets into transporting packets with fragmentation	2012/11/13	H04L12/56	G4
US8315640	Methods and systems for transmission of multiple modulated signals over wireless networks	2012/11/20	H04W72/00	G4

Appendix III

Wi-Lan litigations, disputed patents, defendants, and related groups

Case No.	Case Reference	Disputed Patents	Date	Defendant	Related Group
1	Civil Action No. 2:07-CV-473 (TJW) consolidated with Civil Action no. 2:07-CV-474 (TJW)	5,282,222; RE37,802; 6,192,068	2009/6/23	Acer, Inc. et al., Westell Technologies, Inc. et al.	G1
2	Case No. 2:07-CV-473-TJW consolidated with Case No. 2:07-CV-474-TJW and Case No. 2:08-CV-247-TJW	5,282,222; RE37,802	2010/5/11	Acer, Inc. et al., Westell Technologies, Inc. et al., Research in Motion Corp.	G1
3	Civil No. 10cv859-W (CAB)	RE37,802; 5,282,222	2010/7/28	Research in Motion Corporation, Research in Motion Ltd, Motorola, Inc., Utstarcom, Inc., LG Electronics Mobile Comm U.S.A., and LG Electronics, Inc.	G1
4	Case No. 2:07-CV-473-TJW consolidated with Case No. 2:07-CV-474-TJW	RE37,802	2010/10/18	Acer, Inc. et al., Westell Technologies, Inc. et al.	G1
5	Case No. 10cv2351-WQH (BLM)	RE37,802; 5,282,222	2010/12/1	LG Electronics, Inc., LG Electronics U.S.A., Inc. Broadcom Corporation,	G1
6	Case No. 2:07-CV-473-TJW- consolidated with Case No. 2:07-CV-474-TJW-CE	5,282,222; RE37,802; 5,369,670	2010/12/30	Acer, Inc. et al., Westell Technologies, Inc. et al.	G1
7	No. 10 CV 7721	5,828,402	2011/1/18	LG Electronics, Inc., LG Electronics U.S.A., Inc.	G5
8	Case No.: C 10–80254 JF (PSG)	5,828,402	2011/2/8	LG Electronics, Inc., LG Electronics U.S.A., Inc.	G5
9	Case Number C 10-80254-JF (PSG)	5,828,402	2011/3/8	LG Electronics, Inc., LG Electronics U.S.A., Inc.	G5
10	Case Number C 10-80254-JF (PSG)	5,828,402	2011/4/26	LG Electronics, Inc., LG Electronics U.S.A., Inc.	G5
11	10 Civ. 432 (LAK) (AJP)	5,828,402	2011/8/2	LG Electronics, Inc., LG Electronics U.S.A., Inc.	G5
12	Case Number 10-mc-80254-JF (PSG)	5,828,402	2011/8/18	LG Electronics, Inc., LG Electronics U.S.A., Inc.	G5
13	10 Civ. 432 (LAK) (AJP)	5,828,402	2012/3/7	LG Electronics, Inc., LG Electronics U.S.A., Inc.	G5
14	Case No. 2:11-cv-68-JRG	RE37,802; 5,282,222	2012/6/27	HTC Corporation, HTC America, Inc., Exedea, Inc.	G1
15	2011–1626	5,828,402	2012/7/13	LG Electronics, Inc., LG Electronics U.S.A., Inc.	G5
16	Case No. 12-23568-CIV-ALTONAGA/Simonton	8,027,298; 8,249,014; 8,229,437	2013/1/28	Alcatel-Lucent USA, Inc.	G3
17	Case No.: C 10–80254 JF (PSG)	5,828,402	2013/2/25	LG Electronics, Inc., LG Electronics U.S.A., Inc.	G5
18	Case No. 2:11-cv-68-JRGCONSOLIDATEDCASE NO. 2:12-cv-600-JRG	5,282,222; RE37,802	2013/3/25	HTC Corporation et al. Apple, Inc. et al.	G1
19	Case No. 12-cv-24318-KMM		2013/4/2	Apple Inc.	G4

(*continued on next page*)

(*continued*)

Case No.	Case Reference	Disputed Patents	Date	Defendant	Related Group
		8,315,640; 8,311,040			
20	Case No. 2:11-CV-68-JRG	5,282,222; RE37,802	2013/4/11	Apple Inc.	G1
21	10 Civ. 0432 (LAK) (AJP)	5,828,402	2013/5/10	LG Electronics, Inc., LG Electronics U.S.A., Inc.	G5
22	Case No. 6:10-CV-521	5,282,222; RE37,802; 6,192,068; 6,320,897	2013/6/4	Alcatel-Lucent USA Inc.	G1
23	Case No. 12-cv-24349-DMM/DLB	6,260,168 6,088,326; 6,195,327; 6,222,819; 6,381,211	2013/6/6	Research in Motion Limited, Research in Motion Corporation	G2
24	Case Nos. 6:10-cv-521-LED, 6:13-CV-00252-LED.	6,088,326; 6,195,327; 6,222,819; 6,381,211	2013/7/11	Alcatel-Lucent USA Inc. et al.,	G2
25	Case No. 2:11-CV-68-JRG consolidated with Case No. 2:12-cv-600-JRG	5,282,222	2013/7/17	HTC Corp. et al.	G1
26	Case No. 12-23568-CIV-ALTONAGA/Simonton	8,027,298; 8,249,014; 8,229,437	2013/9/9	Alcatel-Lucent USA, Inc.	G3
27	Case No. 2:11-CV-68-JRG Lead Case No. 2:12-CV-600-JRG	RE37,802	2014/4/2	HTC Corp. et al., Apple Inc. et al.	G1
28	Case No. 2013-1485, 2013-1566	8,027,298; 8,249,014; 8,229,437	2014/8/1	Ericsson, INC., Telefonaktiebolaget LM Ericsson, Alcatel–Lucent USA, Inc., Sony Mobile Communications AB and Sony Mobile Communications (USA), Inc.	G3

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