

Recent Development Trend of Blockchain Technologies: A Patent Analysis

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ABSTRACT

Blockchain is essential for cryptocurrencies, but its use is not limited to cryptocurrency. Blockchain can be used in a wide range of applications. Recently, many blockchain inventions and applications have been proposed, which have received considerable attention from academics, industry practitioners, and the government. However, few studies have analyzed the development of blockchain technology. In this study, a patent analysis of the U.S. patents of blockchain was conducted. With an analysis of 335 patents awarded, a profile of recent blockchain technology development was obtained. The results indicated that three-quarters of the U.S. blockchain patents were originated in the United States. Half of the awarded U.S. patents are from foreign origin, and the proportion of the blockchain patent originated in the United States is more extensive, which revealed that the United States is a leader in the blockchain technology. Furthermore, 14% of blockchain patents were awarded to IBM, indicating that IBM as a technology giant in the blockchain technology. Additionally, word cloud and N-gram were used to reveal the relevant terms and phrases used in the abstracts of blockchain patents.

Keywords: Blockchain, Cryptocurrency, Patent Analysis, Word Cloud, N-Gram.

1. INTRODUCTION

With the recent development of cryptocurrencies that started from the launch of Bitcoins proposed by Nakamoto [1], cryptocurrencies have continually received considerable attention from investors, entrepreneurs, regulators, and the general public [2]. Numerous cryptocurrencies, including Bitcoins¹, Bitcoin Cash², and Ethereum³, use decentralized control architecture without a centralized authority. In the world,

¹ <https://en.wikipedia.org/wiki/Bitcoin>

² https://en.wikipedia.org/wiki/Bitcoin_Cash

³ <https://ethereum.org/>

there are more than five thousand cryptocurrencies with a total market capitalization of more than US\$ 255 billion and more than three hundred cryptocurrencies with a market capitalization more than US\$ ten million as of 2020⁴.

The design of most modern cryptocurrencies is highly based on the blockchain, which is a growing list of records called blocks or ledgers. Each block links to previous and subsequent blocks. All blocks contain a cryptographic hash of their previous blocks, timestamp, and transaction data. Blockchain is a transaction ledger because it is used to record transaction data. Decentralization is a critical advantage of blockchain that can be used to establish disintermediary peer-to-peer (P2P) transactions without mutual trust and centralized control among transaction parties [3].

The applications of blockchain are not limited to its use as the fundamental technology for cryptocurrencies. Blockchain can revolutionize industry and commerce transactions because of its abilities of immutable, transparent, secured, fast, and trustworthy functions. As an essential cryptocurrency component, blockchain is a distributed ledger that records transaction data in a verifiable and permanent approach [4]. After understanding the cryptocurrency principle, people realize that blockchain is essential for cryptocurrencies and exhibits potential for a wide range of applications, which has received increasing attention worldwide.

Blockchain can be employed for any purpose of transaction data recording. Previous studies have reported blockchain applications in various fields, such as e-government [5], food supply information security [6, 7], energy systems [8, 9], sharing economy [10], health care [11, 12], education [13], online education [14], intellectual property management [15], banking [16], personal identity [12, 17], asset ownership [12, 18], supply chains [12, 19], and the prevention of unethical business transaction [12].

Both academics and industry practitioners have paid attention to the wide range of applications of blockchain; however, the development of blockchain technology has not been thoroughly studied. The blockchain studies have mostly focused on technology issues and industry applications of blockchain. However, if the innovative applications of blockchain are not established on patent protected technology, the applications can easily be imitated. If a blockchain application is not based on any patented technology or technology secret, the first mover firm of the innovative application can only obtain a few competitive advantages because the second mover can easily launch a similar application.

Patents and business secrets are two approaches to preventing competitors from imitating innovations. However, most blockchain applications are designed for transaction purposes. Blockchain applications must be transparent to obtain the trust of transaction parties; thus, maintaining business secrets is not easy because everything should be transparent. Therefore, applying patents is a more suitable strategy than maintaining secrets to secure competitive advantages obtained from blockchain innovations.

According to the aforementioned discussion, this study focused on the development trend of blockchain technologies that are essential for decentralized online transactions. In this study, a bibliometric analysis of blockchain technology was performed using patent data. To the best of our knowledge, currently, a complete profile of granted blockchain patents by time, by countries, and by applicants (companies) is

⁴ According to coinmarketcap.com, as of January 30, 2020, there were 5,076 cryptocurrencies exchanged in 20,325 transaction markets. The total market capitalization was US\$255 billion.

unavailable. Thus, an overview of granted patents was provided to reveal the current development of blockchain technology.

2. PATENT DATA COLLECTION AND ANALYSIS

A patent data analysis was considered an essential approach to evaluate innovation [20], monitor the development trends of technologies [21-23], and forecast technologies [24, 25]. Studies have employed the patent analysis to explore the technology development of countries [26] and competitive advantage of firms in industries [27, 28].

We analyzed the granted patent of the blockchain technology to study its recent development. We contributed to the existing literature by providing a profile of blockchain development by countries and companies. Understanding the current development trend is crucial for academic or practical researchers to plan their future research strategies.

A patent is an intellectual property that provides its owners a right to exclude others from the industrial utility of their invention for a certain period. A granted patent can only provide protection to the invention in the country where the patent was granted. The invention is not protected in countries where patent applicants did not seek protection. Thus, most international mobile phone companies apply for patents in some major countries.

2.1 DATA SCOPE

The United States is the largest economy in the world. Thus, most companies first apply for patents in the United States if their invention can be used in the global market. Moreover, most blockchain applications involve online transaction records. These online transactions can be performed without geographical boundaries. Companies must apply for patents to prevent others from imitating their inventions.

The Global Patent Search System (GPSS) provided by the Intellectual Property Office, Ministry of Economic Affairs, Taiwan, was used to search patents granted from the United States Patent and Trademark Office (USPTO). The granted patents in this database can be tracebacked to January 1976. However, most blockchain patents were granted in the 2010s. Because the term of U.S. patents is 20 years from the application filing of the patent, any blockchain patent filed before 1999 was no longer effective. Thus, we focused only on patents granted between January 2000 and December 2019. We analyzed the patent trend observed in all countries worldwide during these 20 years to realize the development of blockchain technology.

2.2 KEYWORDS FOR DATABASE SEARCH

We used the terms "block chain," "blockchain," and "chain of block" as keywords to search patents in the database. However, the term "block chain" is common in many other fields. For instance, the term "block chain" was used as a snow chain device for motor vehicle tires by Gun [29] or a metal chain used for moving (tow-away) automobiles by Hoffman [30]. Furthermore, in chemical industries, the term "block chain" is used for polymers (copolymers and homopolymers). Additionally, "block chain" is used in conveyor track chains. Thus, we analyzed all the patents to remove patents that were not related to information systems.

We used the International Patent Classification (IPC) 3 code to classify the acquired patents. The IPC code provided a hierarchical system for the classification of

patents according to technology areas. The first hierarchy was employed to divide all the patents into eight categories: (A) human necessities, (B) operation performing and transporting, (C) chemistry metallurgy, (D) textiles and paper, (E) fixed construction, (F) mechanical engineering, lighting, heating, weapons, and blasting, (G) physics, and (H) electricity. Blockchain used in information systems were discussed; it should belong to electricity, category (H). Furthermore, the blockchain patent can be a part of a device. Thus, it could belong to physics, category (G). Thus, only patents that were classified into physics and electricity were considered. We searched the patents granted between 2000 and 2019 and obtained 350 granted patents. Figure 1 presents the number of blockchain patents granted in the United States by year. Most patents (335) were granted between 2017 and 2019, which contributed to 95.7% of all blockchain patents. Only 15 patents (4.3%) were granted between 2000 and 2016. Moreover, the topics of most blockchain patents applied in the 2000s were different from those of blockchain information systems. Thus, we studied the data obtained in the period range of 2017 to 2019.

The search commands used for the global patent search system (<https://gps.tipo.gov.tw/>) were “(IC=G* OR IC=H*), (ID=20170101:20191231), and ((blockchain)@AB OR (block chain)@AB OR (chain of block)@AB) NOT ((copolymers@AB), (homopolymers)@AB, or (polymers)@AB or (polyether)@AB or) NOT ((conveyor track)@AB).”

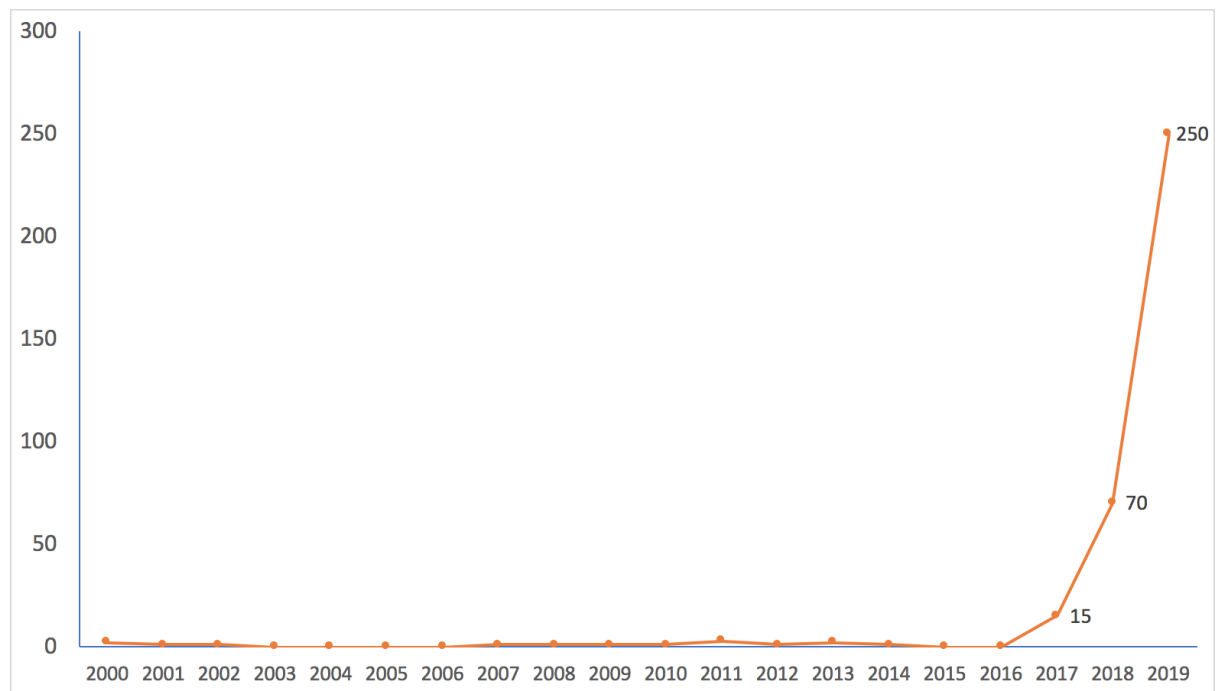


Figure 1. Blockchain patents by years.

3. RESULTS of PATENT ANALYSIS

3.1 IPC Categories

The analysis results revealed that the most blockchain patents belonged to IPC code H04L (transmission of digital information, e.g., telegraphic communication). A total of 282 patents belonged to this category, which contributed to 84.2%. The second most patents were of G06F (Electric digital data processing), which contributed to 178 patents (53.1%), which was followed by G06Q (data processing systems or methods, specially adapted for administrative, commercial, financial, managerial, supervisory, or forecasting purposes) with 112 patents (33.4%), and H04W (wireless communication networks) with 43 patents (12.8%).

Table 1. Patents by IPC classification

IPC Classification	Description	Count	Percent
H04L	transmission of digital information, e.g., telegraphic communication	282	84.2%
G06F	electric digital data processing	178	53.1%
G06Q	data processing systems or methods, specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes; systems or methods specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes	112	33.4%
H04W	wireless communication networks	43	12.8%
G06K	recognition of data; presentation of data; record carriers; handling record carriers	19	5.7%
G16H	healthcare informatics, i.e., information and communication technology [ICT] specially adapted for the handling or processing of medical or healthcare data	12	3.6%
G06N	computer systems based on specific computational models	11	3.3%
G07C	the time or attendance registers; registering or indicating the working of machines; generating random numbers; voting or lottery apparatus; arrangements, systems or apparatus for checking not provided for elsewhere	10	3.0%
H04N	pictorial communication, e.g., television	10	3.0%

Note: Any patents can belong to more than one IPC classification.

3.2 Countries

More than half of U.S. patents of all categories were of foreign origin (52.3% in 2018). However, three quarters (253, 75.5%) of blockchain patents were from the United States. Thus, the United States has the most awarded blockchain patents. Ireland has the second most awarded patents of 28 (8.4%). Other countries contribute less than patents. Some patents were awarded to tax haven countries, such as the British Virgin Islands (8 patents, 2.4%), Cayman Islands (3 patents, 0.9%), and the Bahamas (1 patents, 0.3%). The results indicated that the United States exhibits the most competence for blockchain technology.

Table 2. Patent by country

Country	Country Code	Number of Patents	percentage
United States	US	253	75.5%
Ireland	IE	28	8.4%
The British Virgin Islands	V.G.	8	2.4%
United Kingdom	G.B.	6	1.8%
Switzerland	CH	5	1.5%
China	C.N.	5	1.5%
Canada	CA	4	1.2%
Germany	DE	4	1.2%
Japan	J.P.	4	1.2%
Australia	A.U.	3	0.9%
South Korea	K.R.	3	0.9%
Cayman Islands	KY	3	0.9%
France	FR	2	0.6%
Sweden	SE	2	0.6%
Bahamas	BS	1	0.3%
Israel	IL	1	0.3%
India	IN	1	0.3%
Russia	R.U.	1	0.3%
Taiwan	T.W.	1	0.3%

3.3 Assignee

In this study, the assignees (applicants) of blockchain patents were analyzed. We found that 36.4% patents were awarded to the top five companies, and IBM was in the first place that contributed the most blockchain patents (47 patents, 14.0%), and Accenture Global Solution was in the second place with 28 patents (8.4%), which was followed by Bank of America (24 patents, 7.2%), Capital One Services (12 patents, 3.6%), and Mastercard (11, 3.3%). Table 3 presents a list of companies with two or more blockchain patents.

3.4 Term Frequency

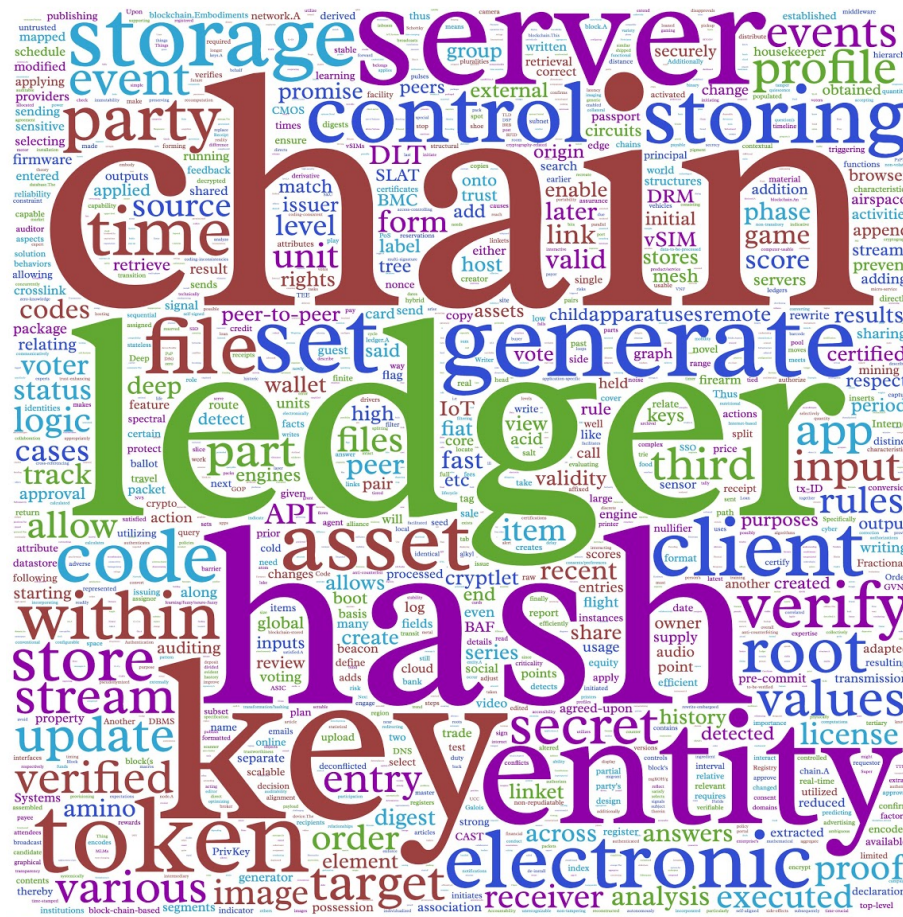
Term frequency (T.F.) is often used in the fields of text mining, natural language processing, and information retrieval to determine the frequency at which a term occurs

in a document. Studies have used term frequency to analyze the patent document to establish the critical technology concept in grand patents [31, 32].

Moreover, in this study, term frequency was used to obtain the frequently used terms in a patent abstract. Table 4 presents the terms that have been used for more than 50 times in the abstracts of 335 patents. The frequently used terms were data, blocks, systems, transactions, networks, devices, information, chain, distributed ledger, hash, key, request, smart access, digital, receiving, nodes, identity, computers, value, record, private, entity, contract, messages, public, stored, cryptographic, and tokens.

A word cloud (tag cloud) can be used to visually represent the high-frequency terms used in text data. Typically, the word cloud is employed to depict the keyword metadata or tags of websites. Studies have used the word cloud to analyze patent documents [33, 34]. We employed the word cloud to illustrate the frequently used terms in the abstract of blockchain patents (Figure 2).

In some cases, key terms were phrases rather than single words. N-gram can be used to determine new phrases that are not present in a predefined dictionary. In computational linguistics, n-gram is a contiguous sequence of n items ($n = 1$ to infinity) obtained from the given text or speech sample. N-gram can be used as an extractor to automatically determine a critical phrase used in any patent [35]. We used 2-gram and 3-gram to acquire the frequently used phrases in the abstracts of blockchain patents. Tables 5 and 6 present the results 2-gram and 3-gram, respectively.



Created by <https://www.wordclouds.com/>

Figure 2. Word Cloud of Blockchain Patent Abstract

Table 3. Patent by assignee

Applicant (Assignee)	Patents	%	Applicant (Assignee)	Patents	%
IBM	47	14.0%	Wells Fargo Bank	4	1.2%
Accenture Global Solutions	28	8.4%	Alibaba	3	0.9%
Bank of America	24	7.2%	Dell	3	0.9%
Capital One Services	12	3.6%	The Bank Of New York Mellon	3	0.9%
Mastercard	11	3.3%	The Toronto-Dominion Bank	3	0.9%
Guardtime IP Holdings Limited	8	2.4%	Verizon Patent And Licensing	3	0.9%
Madisetti Vijay K.	8	2.4%	Winklevoss I.P.	3	0.9%
Black Gold Coin, Inc.	7	2.1%	SAP	2	0.6%
Cisco	7	2.1%	Sony	2	0.6%
Acronis International	5	1.5%	Stampery	2	0.6%
Blockchain Asics	5	1.5%	Uipco	2	0.6%
Tran Bao	5	1.5%	Vmware	2	0.6%
Intel	4	1.2%	Walmart Apollo	2	0.6%
Northern Trust	4	1.2%	Wiig Rex	2	0.6%
Shocard	4	1.2%	Xage Security	2	0.6%

Table 4. Frequently used terms in blockchain patents

term	Frequency	term	Frequency	Term	Frequency
data	450	key	109	Record	84
block	372	request	104	Private	81
systems	260	smart	103	Entity	78
transaction	239	access	102	Contract	75
network	232	digital	99	Message	71
device	198	receiving	97	Public	65
information	166	node	94	Stored	65
chain	158	identity	90	Cryptographic	64
distributed	146	computer	88	Token	51
ledger	134	block	86		
hash	134	value	86		

Table 5. Frequently used phrases (2-Gram)

Phrase (2 Gram)	count	Phrase (2 Gram)	count	Phrase (2 Gram)	count
smart-contract	96	block header	21	transaction record	12
blockchain network	73	blockchain ledger	20	blockchain system	11
distributed ledger	65	mobile service	18	committed tokens	10
hash value	42	private blockchain	18	computer processors	10
blockchain transaction	35	identity verification	16	control commands	10
service provider	34	second blockchain	16	digital certificate	10
distributed network	27	central service	15	digital identity	10
computer program	26	transaction data	15	digital promise	10
mobile device	26	blockchain database	13	identification information	10
blockchain technology	24	transaction request	13	integrated circuit	10
verification addresses	24	digital meeting	12	node device	10
digital signature	22	operating procedure	12	target transaction	10

Table 6. Frequently used phrases (3-Gram)

Phrase (3 Gram)	Count
corresponding verification addresses	12
private blockchain network	22
multifactor personal identity	12
personal identity verification	12
first merged block	11

Created by <http://guidetodatamining.com/ngramAnalyzer/analyze.php>

4. DISCUSSION

The results of the study revealed the development trend of blockchain technology. The rapid development of blockchain applications has received considerable attention from both information technology giants and startup companies. Patents are essential and indispensable to acquire technology competence and a sustainable competitive advantage of blockchain innovations. We analyzed the U.S. patents granted for blockchain and concluded that most U.S. patents were awarded to US-based companies. Half of the patents are of foreign origin. A total of three-quarters of U.S. patents of blockchain are of U.S. origin. Moreover, IBM is the major patentee with a contribution of approximately 14%.

Blockchain can be used for any purpose of transaction data recording. Thus, blockchain is a high-potential technology. However, blockchain is still in the early stage of the technology life cycle. Industry practice should not consider only applications. Technical competence is the root of competitive advantage for future blockchain development. Blockchain innovations that are not based on a patented technology can be easily imitated, and the first-mover firm that develops an innovative application can obtain only a few competitive advantages because the second mover can easily imitate the application.

AUTHOR BIOGRAPHIES

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