

Review Article

An Overview of the 5G Patent Landscape

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ABSTRACT

The fifth generation of mobile networks (5G) is the most recent iteration in cellular technology. To develop and implement new technologies, remain competitive, and maintain their market position, 5G patents are essential for businesses in the telecommunications industry. Examining 5G patents offers important insights into the industry's overall environment and technological development. This study aims to comprehensively analyze the 5G patent landscape by simultaneously examining technological, scientific, and financial aspects. The analysis was conducted using Questel's Orbit Insight patent research software. The analysis of 5G patents reveals significant patterns in patent applications, notable industry participants, and consequences for technological standards and market competition. 5G patents will continue to drive innovation and have a significant impact on market dynamics, shaping future industrial competitiveness and technological standards. Businesses and legislators must carefully analyze their patent strategies to successfully traverse the rapidly changing 5G ecosystem. Subsequent investigations into 5G patent analysis could also explore the effects of emerging technologies and legislative advancements on patent portfolios while also monitoring the evolution of 5G patent trends and their influence on industry dynamics.

Keywords: 5G, patent analysis, research and development (R&D), strategy, technology landscape, telecommunications industry

ARTICLE INFO

Article history:

Received: 16 May 2024

Accepted: 18 November 2024

Published: 21 February 2025

DOI: <https://doi.org/10.47836/pjst.33.2.08>

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INTRODUCTION

5G is the most recent iteration in cellular technology. Compared to earlier wireless standards, 5G was designed to significantly boost wireless network speed and bandwidth while lowering latency (Gillis & Gerwig, 2024). While the primary goal of technological advancements in 2G, 3G, and 4G has been to improve user experience, 5G

and any further developments will profoundly revolutionize our daily lives and commercial operations (Ericsson, 2024).

This new generation of international wireless standards will affect a variety of devices that millions of people use daily. While mobile phone users were the main beneficiaries of 3G and 4G, 5G links additional devices within a network, including drones, electric cars, and virtual reality (VR) technologies. Producers of these products will be obliged to depend on 5G standards for connectivity, which are protected by standard essential patents (SEPs). Having SEPs in the field of 5G technology will make it more difficult to monetize and enforce a patent portfolio, underscoring for the business community the significance of putting an intellectual property strategy in place (Spohr, 2024).

The development and commercialization of 5G technology have resulted in a significant increase in patenting activities related to high-speed, low-latency communication systems that facilitate the interconnection of all things (Xu, 2022).

Patent analysis in the 5G domain is critical for assessing technological progress and innovation activities. It provides valuable insights into the competitive landscape, enabling companies and countries to evaluate their positions in various technological domains (Rita et al., 2023). For instance, patent statistics can be utilized to identify leading innovators, track technological trends, and inform strategic decision-making in research and development.

The significance of 5G patents extends beyond mere technological advancement. They play a crucial role in shaping industry dynamics, influencing market competition and driving economic growth. Patent analysis in this field can reveal innovation patterns, technologies' evolution, and potential areas for future development (Lee & Lee, 2013).

5G patents and their analyses are instrumental in comprehending the technological landscape, guiding innovation strategies, and fostering competitiveness in the rapidly advancing telecommunications sector. As 5G technology continues to mature and find widespread applications, the strategic utilization of patent intelligence will become increasingly crucial for businesses and policymakers alike (Wang, 2011).

Archibugi and Planta (1996) noted that the complexity and heterogeneity of technological change make it challenging to identify metrics that adequately capture the scope, intensity, pace, and direction of inventive activities. Ernst (2003) highlights the importance of patent information in influencing corporate decision-making processes and strategic technology management. Owing to its extensive coverage, variety of information, and database accessibility, patent information is essential for analytical tasks.

Thorough awareness of the entire patent landscape and the most pertinent patents is fundamentally necessary to facilitate the smooth implementation of 5G, maintain profitability, and safeguard the capacity to market new goods and services with sufficient access to the required third-party patent rights. Companies that intend to leverage 5G

technology to enhance their offerings and operational efficiency must consider the potential impact of constantly growing collections of pertinent patents on their operational viability (Deloitte, 2021).

Investigating 5G patents is essential owing to their profound technological advancements, economic implications, and strategic significance. This field offers insights into the latest innovations and future trends as companies invest heavily in 5G, spurring a competitive race for patent superiority. Patents are pivotal in standard-setting processes and influence global competition. This multidisciplinary research area encompasses electrical engineering, computer science, and telecommunications and provides valuable perspectives across technology, economics, law, and policy.

Analyzing 5G patents reveals broader innovation trends in hardware, software, and applications and informs legal and policy discussions on intellectual property rights, licensing, and the balance between innovation and competition. Identifying emerging core technologies through patent analysis offers foresight into future technological advancements, which are particularly pertinent for 5G, given the rapid development and integration of new technologies. Patent analysis helps pinpoint which innovations are likely to become foundational in the near future (Noh et al., 2016).

Examining 5G patents provides a comprehensive understanding of the technological, economic, legal, and geopolitical elements shaping the future of global communication. The uniqueness of studying 5G patents lies in grasping cross-country knowledge exchange and innovation trends and offering insights into the collaborative and competitive nature of modern technology development. It allows researchers and stakeholders to better navigate the complex and evolving 5G landscape. Analyzing patent data reveals how various countries contribute to and benefit from 5G innovations, aiding in the understanding of the global distribution of technological progress and the interaction between national innovation systems (Xuan et al., 2023).

Innovative approaches, such as the integrated bibliometric-textmetric approach, can be employed to study 5G patents. This method combines data and text analysis to identify emerging trends and core technologies more effectively, providing fresh insights into the evolution of 5G (Mendonça et al., 2022). This research adopts a method comparable to the integrated bibliometric-textmetric approach, providing a comprehensive and balanced insight into the influence and substance of patents. Additionally, this method is particularly effective for reviewing patent literature as it merges the quantitative evaluation of patent citations, trends, and collaborations with the qualitative examination of patent document text. It facilitates the identification of various patents and the comprehension of the technical content, innovations, and themes they entail.

This study attempts to comprehensively analyze the 5G patent landscape by simultaneously examining technological, scientific, and financial aspects. This analysis

can provide valuable insights for policymakers, industry stakeholders, and researchers to guide future developments and investment strategies in 5G technology. Furthermore, it may reveal emerging subfields within 5G technology and highlight areas of intense competition or collaboration among patent holders. Some key points regarding the novelty of this approach are as follows:

1. **Holistic perspective:** This study takes a more holistic and diversified approach by covering the technological, scientific, and financial aspects of 5G patents simultaneously rather than aiming at just one dimension.
2. **Use of advanced patent analysis software:** The analysis utilizes Questel's Orbit Insight patent research software, which allows for a thorough and multi-faceted examination of patent data.
3. **Comprehensive search query:** This study combined three search queries to achieve more relevant, accurate, and meaningful results in identifying 5G-related patents.
4. **Multi-dimensional analysis:** Beyond patent counts, this study examines various aspects, such as technological concepts, application areas, investment dynamics, innovation cycles, collaboration networks, and geographic distribution of patents.
5. **Integration of scientific literature:** The analysis incorporates scientific publications related to 5G, providing insights into research trends, academic contributions, and patent data.
6. **Global perspective:** This study adopts a worldwide view of 5G patents, avoiding concentrating on any single country or region.
7. **Inclusion of startups:** This analysis considers the role of startups in the 5G ecosystem, not just established companies.
8. **Forward-looking insights:** This study aims to provide insights that can help stakeholders navigate the rapidly evolving 5G landscape and inform future research directions.

By combining these elements, this study seeks to provide a unique and comprehensive overview of the 5G patent landscape that goes beyond traditional patent analysis approaches.

This investigation specifically aims to examine 5G patent ownership and distribution among prominent international establishments and its implications for market competition and technological advancement. Moreover, this holistic analysis can help identify emerging trends, potential collaborations, and areas of untapped opportunities within the 5G ecosystem.

The examination of 5G patents offers important insights into the overall environment and technological developments in the telecom industry. Furthermore, the analysis of 5G patents can provide valuable insights into licensing and litigation strategies, which in turn can shape the future of 5G patents and their ability to spur innovation in the relevant sectors.

This study seeks to divulge its own patent analysis by taking a more holistic and diversified approach to analyzing the 5G patent landscape, covering technological, scientific, and financial aspects. Zhang et al. (2021) emphasize that such studies should optimize patent search terms, gather patents from major worldwide patent databases, eliminate duplicate patents, and locate trustworthy patent data to improve the research's enterprise and academic values.

Based on this foundation, the subsequent analysis delves into the intricate landscape of 5G patents, offering a comprehensive examination of their technological, economic, and strategic implications. This exploration is crucial for understanding the current state and future trajectory of 5G innovation. By scrutinizing patent data, we gain valuable insights into the key players, emerging trends, and potential challenges in the 5G ecosystem. The analysis will furnish observations of how patent portfolios shape competitive dynamics, influence standardization processes, and drive technological advancements. Furthermore, it will provide a nuanced perspective on the global distribution of 5G innovation, highlighting the interplay between different countries and organizations. This in-depth examination of 5G patents contributes to academic discourse and offers practical implications for policymakers, industry leaders, and researchers navigating the complex and rapidly evolving 5G landscape. To fully appreciate the significance of this patent analysis, it is important to first understand the fundamental concepts and rapid development of 5G technology.

BACKGROUND

An Outline of 5G

The rapid progress in cellular technology has resulted in a considerable rise in the global adoption of 5G networks. This pattern reflects the growing need for faster and more dependable mobile connectivity. By the end of 2023, there were 1.5 billion 5G smartphone subscriptions globally; by the conclusion of this year, the subscriptions will soar to over two billion (Richter, 2024). The impressive surge in 5G adoption is due to swift advancements in telecommunications technology, the broader availability of 5G infrastructure, and the rising demand for fast and reliable mobile internet services. As additional countries and regions expand their 5G networks, the number of subscriptions is expected to grow exponentially. This number is expected to surpass five billion by 2029, signifying a global and nearly omnipresent adoption of 5G technology. This proliferation of 5G will transform personal and business communications and pave the way for innovations in various sectors. Thenceforward, the beginning of the 6G era is anticipated, and the next generation of cellular networks will gradually supersede 5G. Figure 1 depicts the 3G, 4G, and 5G adoption trends from 2012 until 2029. It particularly shows the rapid growth and adoption of 5G, depicting its growing prominence in mobile communication technology over time. It offers a distinct projection of 5G's expected widespread availability and near-ubiquitous

presence by the end of the decade. As 5G networks continue to expand globally, they are expected to revolutionize industries, drive innovation, and significantly impact the technological landscape.

5G technology is set to revolutionize the way we interact with the digital world. Despite its benefits, the journey toward widespread 5G adoption has been smooth. Although 5G is the preferred option for connecting mobile phones and other devices worldwide, it is still met with skepticism in business. There have been some hiccups in the rollout of 5G, and businesses have not taken off this technology. Infrastructure challenges, high deployment costs, and security concerns have contributed to many enterprises' cautious approach. Nevertheless, industry participants predict that this year's commercial rollouts of 5G or 5G-Advanced networks will change this situation (Yu, 2024). As the initial release of 5.5G standards (3GPP Release 18) has frozen in the first half of 2024 and related technologies have been thoroughly established, the 5.5G industry is anticipated to expand rapidly (The Star, 2023). This anticipated growth is expected to address many of the existing concerns, provide more reliable and efficient solutions for businesses, and pave the way for a new era of digital transformation.

While 5G technology has faced some obstacles in its initial rollout, including infrastructure challenges, high costs, and security concerns, the landscape is poised for significant changes. The cautious approach adopted by businesses thus far may soon give way to increased adoption and implementation. The evolving 5G ecosystem is expected to address current limitations and unlock new possibilities for digital transformation across various industries.

As industries and consumers worldwide anticipate full-scale deployment of 5G networks, it is essential to understand the foundational principles that underpin this transformative technology. The classification of 5G applications is indicated by the 3rd Generation Partnership Project (3GPP)-approved 5G triangle. Figure 2 shows the three primary benefits of 5G deployment, namely Ultra Reliable Low Latency Communication (uRLLC), Massive Machine Type Communication (mMTC), and Enhanced Mobile Broadband (eMBB). This structure catalyzes 5G's novel applications, yielding multiple advantages of 5G over its predecessor generations.

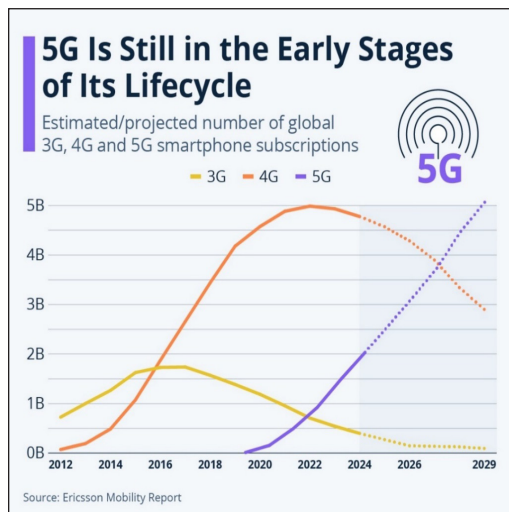


Figure 1. Forecast of 5G subscriptions worldwide (Richter, 2024)

According to Miller and Cavazos (2022), Enhanced Mobile Broadband (eMBB) refers to improved peak and average data speeds, capacity, and coverage of 5G compared to traditional mobile broadband. eMBB is a 5G specification that allows for a maximum download speed of 20 gigabits per second (Gbps) and a maximum upload speed of 10 Gbps. Massive Machine Type Communication (mMTC) refers to the capability of 5G networks to enable the Internet of Things (IoT) to use cases involving many linked devices and sensors, numbering in billions.

This case encompasses devices with low data rates and bandwidth transmitting only sporadically. These devices also require a long battery life. In addition, it includes devices that have very high bandwidths and data rates. Ultra-Reliable Low Latency Communication (uRLLC) refers to a type of extremely dependable communication with minimal delays. uRLLC is specifically designed for applications that require highly reliable real-time communications. Autonomous vehicles, smart grids, industrial Internet, infrastructure security, and intelligent transportation systems are a few examples. By introducing these concepts, the stage is set for a precis of how these technologies shape the future of connectivity and enable a wide range of innovative applications across various industries.

5G technology differs from its predecessors in a number of important features and advantages, as shown in Figure 3. The 11 features highlighted in Figure 3 are the translation of the 5G triangle into its corresponding applicable domains. By understanding these practical applications, we can better appreciate the transformative potential of 5G technology and its role in influencing the course of connectivity, innovation, and economic development. All these characteristics culminate in a digital ecosystem that is more sophisticated, efficient, and interconnected. Although 5G technology is still in its infancy, it has the potential to revolutionize both our personal and professional lives by opening a world of inventive applications that were previously unattainable with earlier iterations of mobile networks. Building upon these key features and applications, the impact of 5G technology extends far beyond faster internet speeds for mobile devices. As 5G networks continue to evolve and mature, they are likely to unlock new possibilities for innovation and economic growth, paving the way for a more interconnected, technologically advanced era.

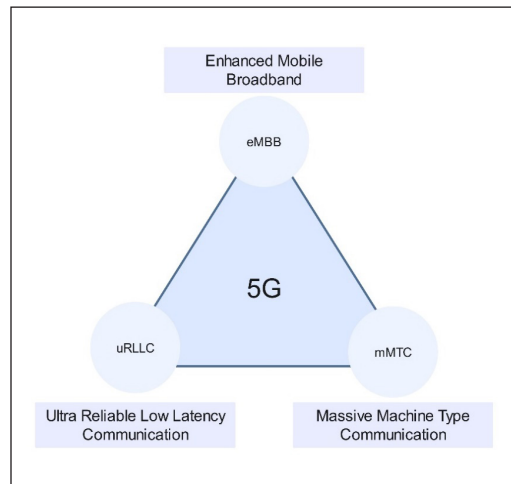


Figure 2. The trilateral classification of 5G applications. Own work

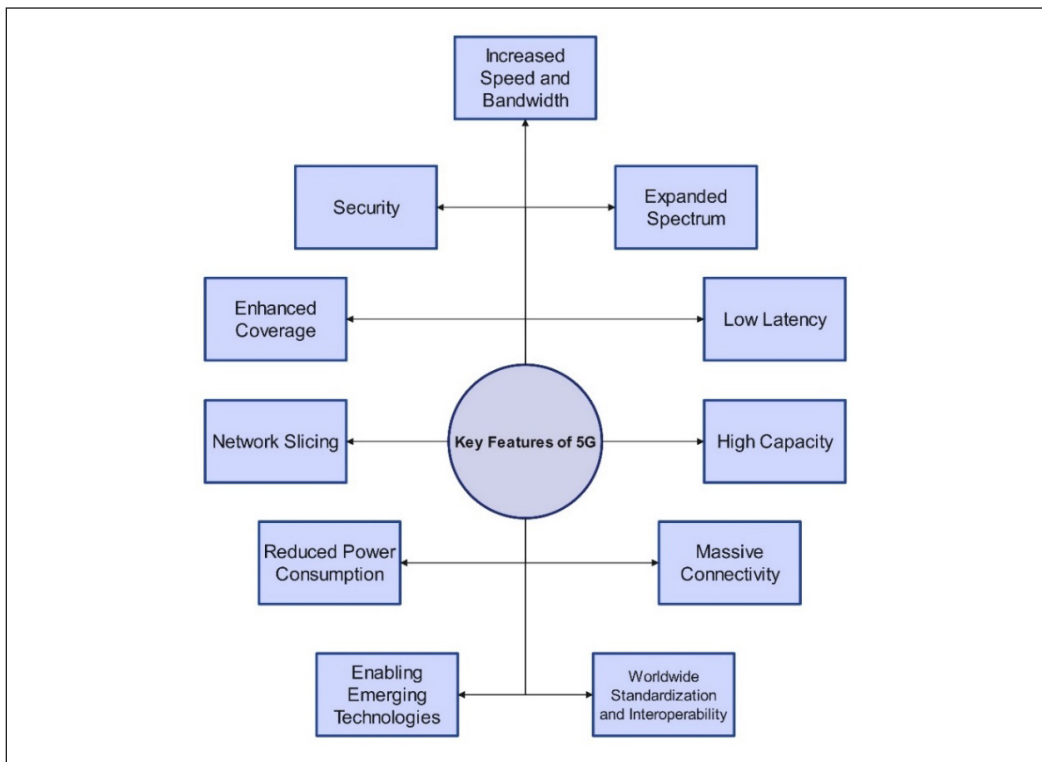


Figure 3. Key features of 5G technology. Own work

An Outline of 5G Patents

The rapid evolution of 5G technology has revolutionized the telecommunications industry, ushering in a new era of connectivity and innovation. As companies strive to establish their dominance in this competitive landscape, the strategic importance of 5G patents has become increasingly apparent. To develop and implement new technologies, remain competitive, and maintain their market position, 5G patents are essential for businesses in the telecommunications industry. In addition to safeguarding intellectual property, these patents encourage innovation and open doors for industrial partnerships and collaborations. Through an analysis of the impact of 5G patents on telecommunications, this study attempts to shed light on the strategic significance of patents in this context. A crucial aspect of understanding the landscape of 5G patents is the concept of a patent family. A patent family refers to a compilation of published patent documents pertaining to the same invention or multiple inventions that share a common characteristic and were issued at different points within the same nation or in different nations or regions (<https://iamip.com/wiki/patent-family/>). Based on extant research on 5G patents, as of September 2021, the Chinese company Huawei holds the highest number of 5G technology patent families globally,

with ownership of more than 5600 patent families. Among the remaining owners of 5G patents, Qualcomm Incorporated, an American company, held the second-highest number of patent families, with a total of 4133 (Taylor, 2023). Table 1 is a list of global patent ownership acquired through the existing literature dating to 2021. The table, which lists the top 30 worldwide holders of 5G patents, reveals diverse international distribution. Chinese companies dominate, with nine entries, followed by six from the United States. Five companies represent Japan, whereas South Korea has four. Taiwan contributed three companies to this list. The remaining entries were one company each from Finland, Sweden, and Canada.

Understanding the intricate dynamics of patent families is essential for understanding the landscape of technological innovation, especially in rapidly evolving fields such as telecommunications. A patent family comprises an assembly of patent applications that pertain to technical content that is identical or comparable. Priority claims establish a connection between applications within the same family, signifying a common groundwork for inventive ideas and innovations (<https://www.epo.org/en/searching-for-patents/helpful-resources/first-time-here/patent-families>). The foundational understanding of patent families is crucial when considering the global distribution of 5G patents. Statista

(2023) indicates that as of February 2021, Huawei possessed the largest proportion of 5G patent families globally, with 15.39% of all 5G patent families. Qualcomm secured the second position with ownership of 11.24% of all patent families related to 5G, as

Table 1
5G patents held by leading companies worldwide as of 2021 (Taylor, 2023)

Ownership of 5G patents worldwide		
Ranking	Company	Country
1	Huawei	China
2	Qualcomm	United States
3	Samsung Electronics	South Korea
4	ZTE	China
5	LG Electronics	South Korea
6	Nokia	Finland
7	CATT Datang Mobile	China
8	Ericsson	Sweden
9	Oppo	China
10	Sharp	Japan
11	Vivo	China
12	NTT Docomo	Japan
13	Xiaomi	China
14	Apple	United States
15	Intel	United States
16	InterDigital	United States
17	Lenovo	China
18	FG Innovation	China
19	MediaTek	Taiwan
20	NEC	Japan
21	ETRI	South Korea
22	Shanghai Langbo	China
23	Motorola Mobility	United States
24	Panasonic	Japan
25	BlackBerry (BlackBerry Limited)	Canada
26	Fujitsu	Japan
27	ASUSTeK	Taiwan
28	KT	South Korea
29	Google (Alphabet Inc.)	United States
30	HTC	Taiwan

Note. Data as of 2021

shown in Figure 4. This figure represents the distribution of patent family ownership among the 21 companies, shown as a percentage of their respective ownership types. Huawei dominates the 5G patent landscape, accounting for 15.39% of all patent families and demonstrating significant investment in research and development. This portfolio provides Huawei with a strategic advantage in licensing and cross-licensing agreements. Qualcomm, holding 11.24%, follows closely behind, indicating a competitive innovation ecosystem. The distribution of patents among companies can influence the development, implementation, and standardization of 5G networks worldwide, potentially impacting consumer devices, industrial applications, and smart city infrastructure. The implications of this patent ownership structure make it crucial to consider how it affects intellectual property schemes, market competition, global standardization efforts, and the potential for collaborative innovation.

In the field of advanced telecommunications, analyzing the financial investments of major corporations offers crucial insights into the industry’s technological capabilities and market preparedness. Technological strength and market maturity can be effectively assessed by examining the expenditure levels of the primary players in the industry.

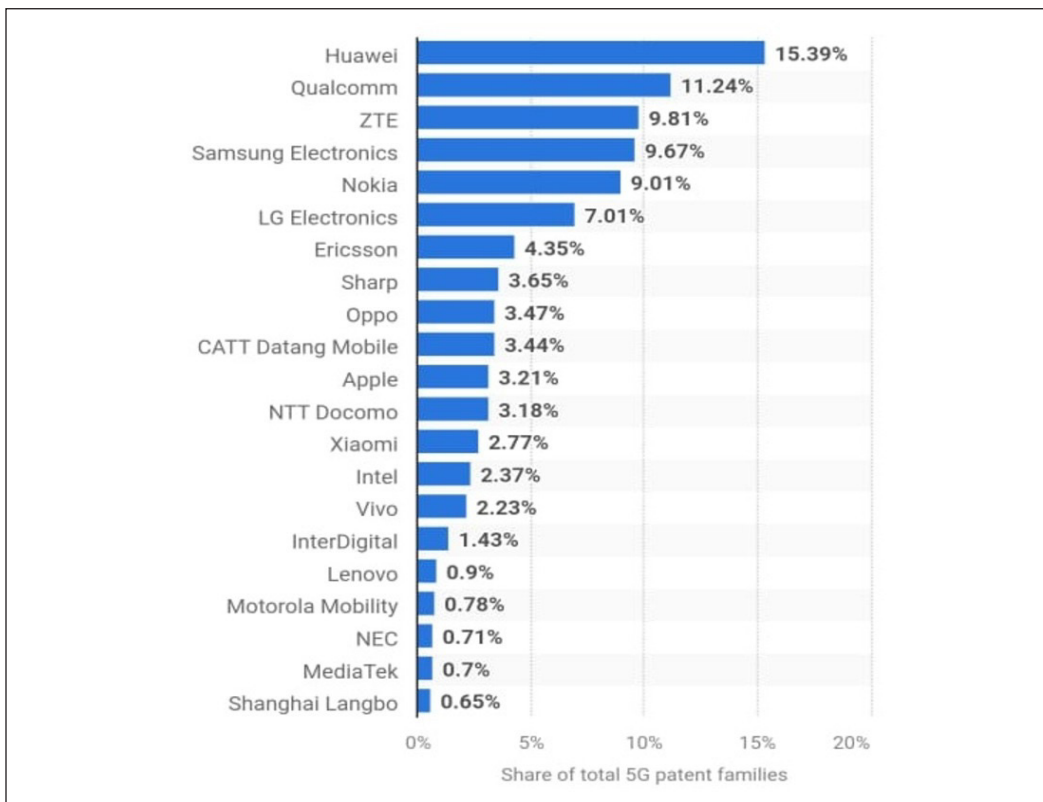


Figure 4. Percentage of 5G patent family ownership by leading companies in 2021 (Statista, 2023)

Generally, a higher volume of spending indicates greater market demand. The 5G IP market is a substantial market, with an estimated value of approximately \$3 billion. As shown in Figure 5, this significant market size underscores its substantial impact and potential within the industry. This market attracts established and emerging companies owing to its significant economic impact and potential for further growth. Significant investments reflect the growing demand for innovative solutions, indicating a market's readiness for technological development.

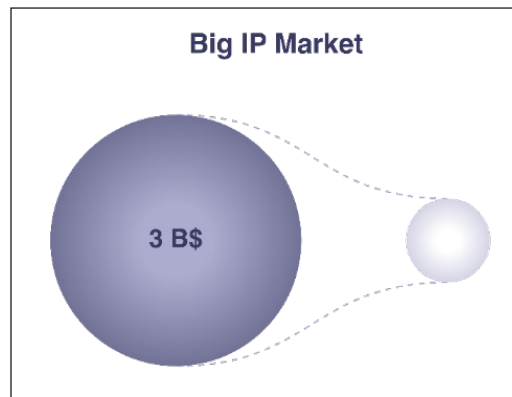


Figure 5. 5G Intellectual Property market value
 Note. The figure is retrieved from Orbit Insight

The substantial market size of the 5G IP industry implies several key points:

1. Significant industry growth potential: The large market value suggests considerable room for expansion and innovation in 5G technology.
2. High level of competition: A market of this size is likely to attract numerous players, leading to increased competition and potentially faster technological advancement.
3. Substantial investment opportunities: A sizeable market indicates attractive prospects for investors and venture capitalists interested in the 5G sector.
4. Increased research and development efforts: Companies will likely allocate significant resources to R&D to maintain their competitive edge in this lucrative market.
5. Potential economic impact: The large market size suggests that 5G technology could have far-reaching effects on various sectors of the economy, potentially driving job creation and economic growth.
6. Consumer benefits: As the market matures and competition intensifies, consumers may benefit from improved 5G services and lower costs over time.
7. Geopolitical effects: Given the strategic importance of 5G technology, a substantial market size may lead to increased international competition and potential government policy interventions.

Considering the strategic importance and sizable economic value of 5G technology, a methodical approach to examining patents is crucial for understanding the present landscape of 5G patents.

PATENT ANALYSIS STRATEGY

Patent analysis involves multiple stages, including gathering data, analyzing it to identify trends, and presenting findings (<https://www.wipo.int/web/patent-analytics>). This study performed a thorough data analysis by utilizing patent research software called Orbit

Insight by Questel (<https://insight.orbit.com/>). The Software Suite is a streamlined collection of specialized solutions that can address the specific stages of the innovation process from start to finish. The Insight portfolio connects the entire innovation ecosystem. It continuously monitors and analyzes over 500 data sources, totaling over 125 million pieces of information. Insight’s AI engine requires only a search term or a list of relevant industry organizations to generate a comprehensive overview of the technology field. Patent activity, academic research, mergers and acquisitions (M&A) activity, and a variety of other indicators are used to assess maturity, the stage of the innovation cycle, the most active players, and opinion leaders. This solution is completely automated and constantly updated. A screenshot of Orbit Insight’s homepage is shown in Figure 6, which displays where the search for patents begins and what functionalities are available. AI-driven analysis extends beyond raw data collection, offering valuable insights into emerging trends and potential disruptors within the industry. It also allows organizations to make informed decisions about their innovative strategies and resource allocation. The automated nature of the platform ensures that users have access to the most up-to-date information, enabling them to make informed decisions and stay ahead of the competition.

The patent search query for this study consisted of a combination of three different sets of queries to achieve the most relevant, accurate, and meaningful results. The queries were as follows:

- 5G
- 5G Network **OR** 5G Communication, 5G Cellular Network, 5G Mobile Network, Radio Access Network, 3GPP, Mobile Broadband

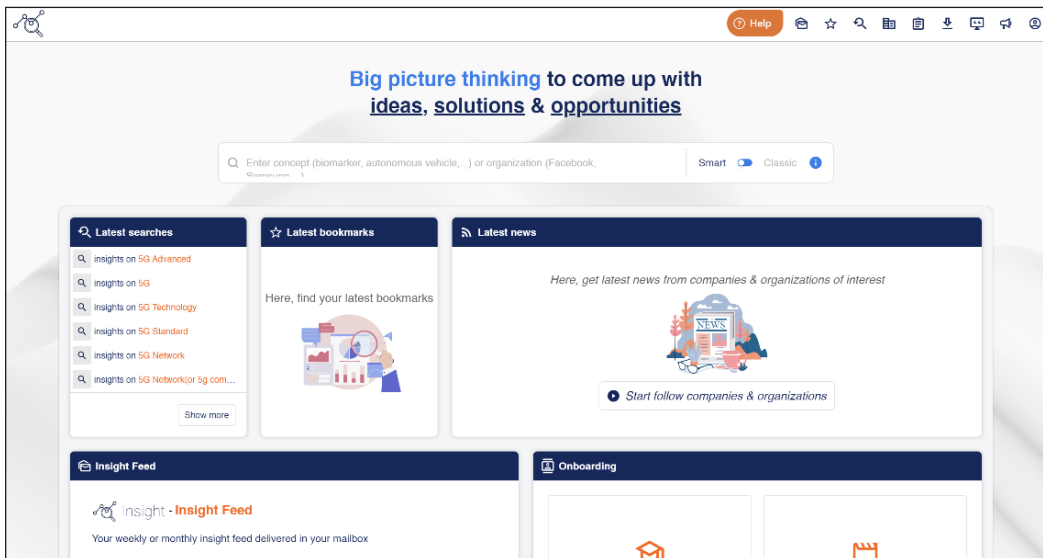


Figure 6. Orbit Insight homepage (<https://insight.orbit.com/>)

- 5G AND 5G Network OR 5G Communication, 5G Cellular Network, 5G Mobile Network, Radio Access Network, 3GPP, Mobile Broadband

The data range was from the last 10 years, and the location of the data source was worldwide. The aggregation of all three of the above queries served as the basis for performing this study. The selected search terms were formulated to cover a wide range of 5G-related advancements, spanning from technological to financial aspects. However, this broad approach might incorporate patents that are nonessential to the core 5G concepts. To address this potential limitation, we sought to mitigate this impact by meticulously examining and classifying the retrieved patents.

Having established the patent analysis procedure, including the comprehensive search query and data parameters, the attention of this study turns to the patent landscaping phase. This crucial step will provide a visual representation of the 5G technology landscape, offering insights into key players, technological trends, and areas of innovation concentration. Analyzing the patents identified through carefully constructed queries aims to uncover patterns and relationships that will inform strategic decision-making in the rapidly evolving 5G domain. The following patent landscaping analysis will leverage the data collected to present a clear and actionable overview of the current state and future directions of 5G technology development.

PATENT LANDSCAPING

Technology Landscape

While standing on the cusp of a new technological frontier, it is imperative to examine the key indicators shaping this potent field’s landscape. This analysis provides insights into the current state of wireless technology and offers a glimpse into its future trajectory. Patents serve as a window into cutting-edge developments and widely adopted technologies driving the industry forward. They are critical indicators of prevailing trends and widely adopted technologies in technological innovation. By examining the key terms frequently found in patents within the studied field, it is possible to identify the most widely adopted technologies. This study’s analysis of 5G patents reveals that the predominant concentration is on wireless communication, base stations, and user equipment, as shown in Figure 7. This figure shows the most significant 5G technical concepts through a word cloud consisting of 10 concentration areas. This suggests that these areas are at the forefront of innovation in

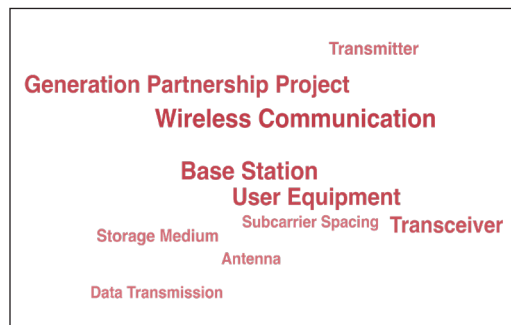


Figure 7. 5G technical concepts
 Note. The figure is retrieved from Orbit Insight

the telecommunications sector. The emphasis on these specific components indicates that industry efforts are largely directed toward improving the network infrastructure and enhancing the capabilities of end-user devices. Such findings can be instrumental for industry stakeholders, including researchers, investors, and policymakers, as they make decisions about resource allocation, research priorities, and strategic planning in the rapidly evolving landscape of wireless technology.

In the rapidly evolving world of technology, understanding primary technological areas is crucial for steering innovation and identifying potential applications for new inventions. Principal technological areas serve as excellent resources for identifying potential applications for new inventions. By inspecting the domains in which other patents within the same field are classified, it becomes possible to gain valuable insights into the intended applications and purposes envisioned by both examiners and applicants. The primary utilization areas for 5G technology are telecommunications, digital communication, and computer technology, as illustrated in Figure 8. All six leading utilization areas in this figure reflect the transformative nature of 5G. These areas highlight the broad implications of 5G, extending beyond traditional mobile communications to encompass a wide range of applications in various sectors. For instance, integrating 5G with computer technology suggests its potential to revolutionize edge computing, Internet of Things (IoT) devices, and artificial intelligence applications. Similarly, digital communication points to 5G’s role in enabling more sophisticated

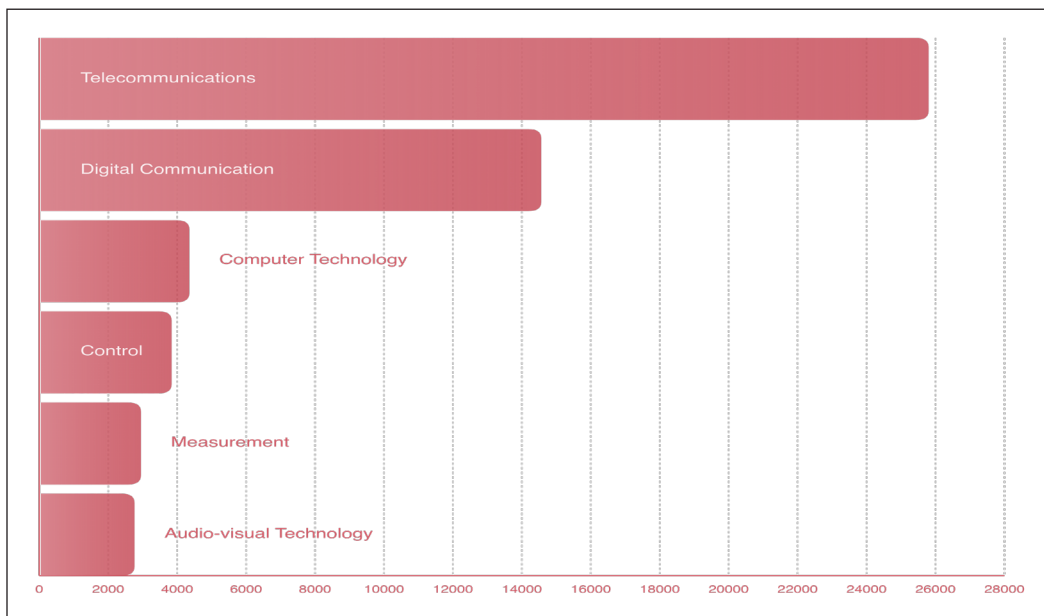


Figure 8. 5G main applications
 Note. The figure is retrieved from Orbit Insight

and efficient data transfer methods, which could have far-reaching effects on industries ranging from healthcare to smart cities and autonomous vehicles.

When industries rapidly evolve, and new technologies emerge, companies and researchers constantly seek ways to establish their presence and secure their position in the market. It leads to an increased accent on intellectual property rights and the strategic use of various tools to protect and leverage them. Strategic publishing, patents, and standard contributions are critical for technological development because they provide fresh scientific knowledge, foster the growth of ideas, and offer companies a competitive edge (Buggenhagen & Blind, 2022). 5G patents expose significant patterns in patent applications, noteworthy industry participants, and implications for technology standards and market competition. Understanding the 5G patent landscape is essential for businesses to formulate successful strategies in this rapidly evolving environment.

The temporal distribution of patent filings and institutional investments provides a foundation for understanding the strategic positioning of key players in the 5G ecosystem. It will highlight the significant growth in patent investments and institutional funding, offering a quantitative perspective on the industry’s expansion and prospects.

There has been an increase in 5G patent and institutional investments since the rollout of technology at the start of the decade. Patent investments peaked during the years 2020 and 2021, while institutional investments reached their apex in 2022. Both types of investments are experiencing an upward trend and are likely to continue until the latter stages of this decade. The potential of the industry is further illustrated in Figure 9. This figure displays a 12-year period of 5G patent investment, with a notable increase of 41.42% happening from

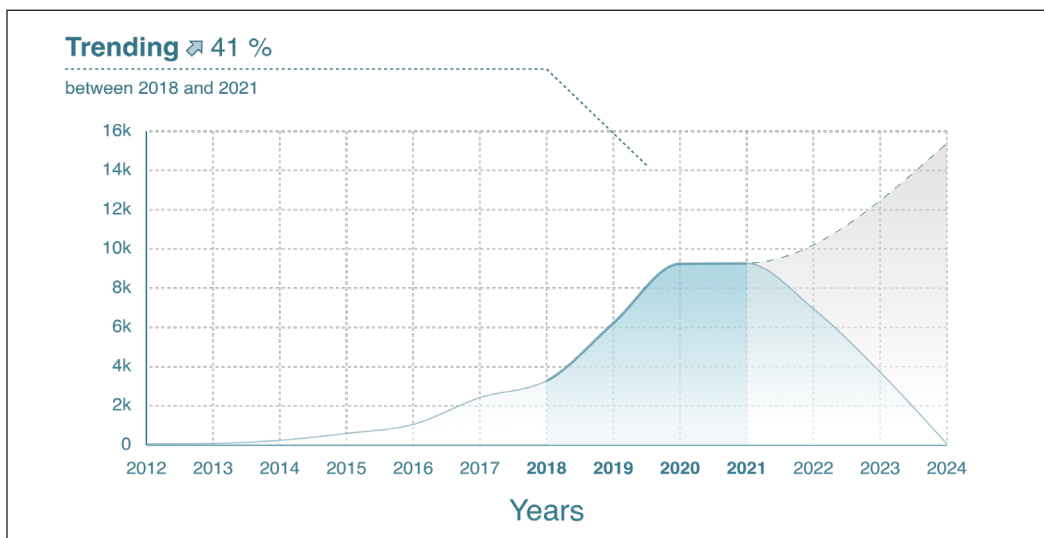


Figure 9. 5G patent investment dynamics

Note. The figure is retrieved from Orbit Insight

2018 to 2021. This substantial growth in patent filings reflects the competitive landscape of 5G development and hints at the diverse range of technologies and solutions being explored to fully leverage the capabilities of 5G networks.

In an era where technological advancements drive global progress, assessing whether technology is at the forefront of government or public institutional investment can be done by examining the funding of institutional projects. Some technologies are deemed significant at a national or international level due to their potential impacts on economic growth, national security, or societal advancement. In the case of 5G, a comparison of institutional investments in this technology between 2019 and 2022 shows that it received moderate funding of \$33.95 million, with an investment growth rate of 167.91% during this five-year interval, as shown in Figure 10. While countries and organizations continue to recognize the transformative power of 5G, it is likely that investments will continue to grow, centering on infrastructure development, security enhancements, and the exploration of new applications that can leverage this advanced communication technology.

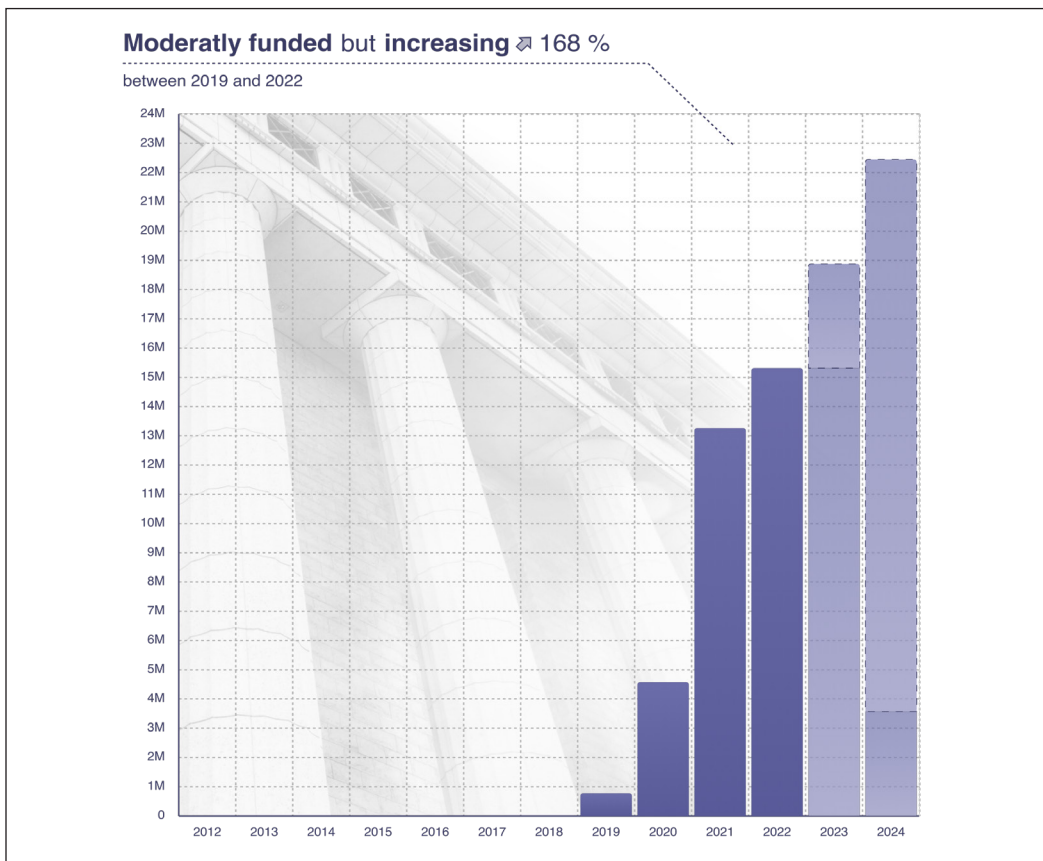


Figure 10. 5G institutional investments

Note. The figure is retrieved from Orbit Insight

Understanding the nuances of the innovation process is crucial for identifying challenges, efficiently allocating resources, and fostering a culture of continuous improvement. It helps individuals and organizations navigate obstacles, find creative solutions, and stay ahead of competition in a rapidly changing world. Excelling the complexities of the innovation process can lead to more successful outcomes, driving growth and progress in various fields. The innovation process for this technology is primarily gradual, with an originality rate of 70.7%. When assessing the distribution of portfolios, it becomes evident that the pace of the 5G innovation cycle is decelerating. This slowdown can be attributed to various factors, including market saturation, the complexity of further advancements, and potential regulatory hurdles. Figure 11 displays the current state of 5G technology, suggesting that while innovation continues, it is occurring at a more measured rate compared to prior periods of rapid development. This shift suggests that technology may enter a phase of refinement and optimization rather than radical transformation. As the industry navigates this evolving landscape, emphasis may shift towards enhancing efficiency, addressing specific use cases, and overcoming implementation challenges rather than pursuing dramatic leaps in capability. This measured approach could lead to more stable and reliable 5G solutions, albeit at the cost of rapid progress observed in technology’s infancy.

Examining the intellectual property players in the 5G landscape is crucial based on this understanding of the innovation process. Maintaining a competitive edge in the fast-paced world of modern technology necessitates a thorough understanding of major players and their strategic actions. Analyzing the key participants in the field provides valuable insights into the innovation capabilities of the most active competitors and their efforts to protect their legal rights. Even if these competitors do not currently sell products in the relevant market, they may still pose a significant potential challenge. Their innovative prowess and proactive legal strategies suggest that they are preparing to enter new markets or disrupt existing ones. With a portfolio of 6136 inventions, Samsung Electronics is the dominant player in this field. This substantial number of inventions demonstrates Samsung’s R&D capability and positions the company as a leader in shaping industry trends and standards. The sheer volume of inventions suggests diverse technological applications spanning various

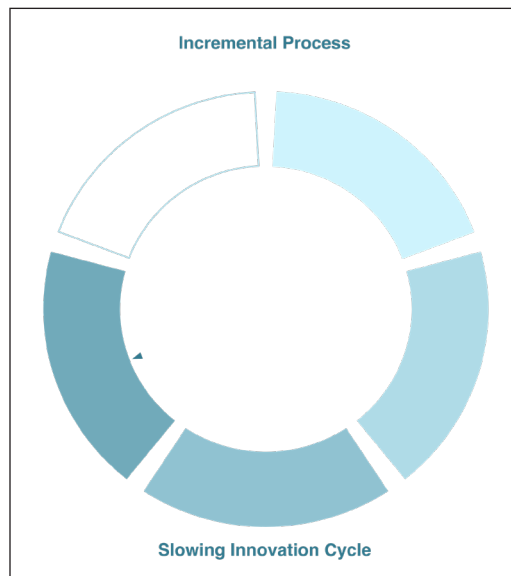


Figure 11. 5G innovation cycle
 Note. The figure is retrieved from Orbit Insight

electronics industry sectors. In conjunction with each other, four key companies, Huawei, LG Electronics, Qualcomm, and Ericsson, along with Samsung, comprise 27.16% of the Top 100 5G IP players, as shown in Figure 12. This concentration of innovative power among a relatively small group of companies highlights the industry’s competitive nature and the importance of maintaining a strong patent portfolio. It also suggests that these key players are likely to have a considerable influence on future technological development and market dynamics within their respective sectors.

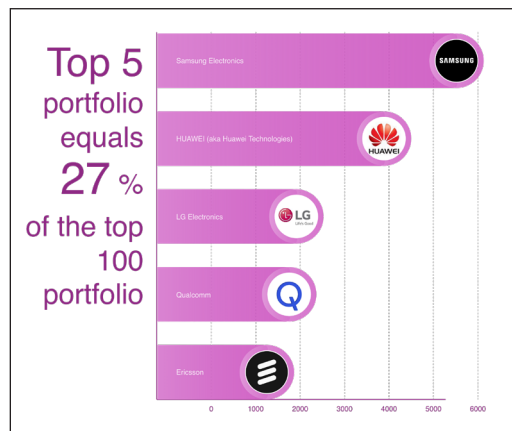


Figure 12. 5G IP players

Note. The figure is retrieved from Orbit Insight

While individual companies play significant roles, the 5G ecosystem thrives on collaboration. The importance of collaboration cannot be overstated in an increasingly interconnected world of R&D. Synergy between various entities, ranging from academic institutions to private companies and research labs, drives innovation and progress. The worldwide 5G collaboration network is heavily mutualized between academics (222) and companies (228), resulting in a total of 450 linkages. This collaboration extends beyond just academics and companies, with additional clusters (4), networks (23), and institutions and R&D labs (23), all of which play a vital part in the global network. There are 50 connections among these entities, demonstrating the deep and diversified level of collaboration within the global collaborative landscape, as shown in Figure 13. This figure reveals a multi-faceted collaborative landscape in which astuteness flows through various channels. This intricate web of relationships fosters innovation and ensures that advancements in 5G technology are approached from multiple perspectives, potentially leading to more comprehensive and widely applicable solutions. The global nature of this collaboration network also suggests that 5G development is an international effort, with expertise and resources being shared across borders to accelerate progress in this critical technological domain.

After examining the collaboration network, it is important to identify specific entities driving 5G innovation within this network. By scrutinizing this network and different interactions within the 5G ecosystem, companies, researchers, and startups that proactively contribute to 5G initiatives can be identified. This comprehensive analysis helps pinpoint the key players who are making progress in this cutting-edge field.

One group of major players are organizations that play a critical role in fostering innovation, advancing the development and uptake of new technologies, and revolutionizing markets and society. They interact with other organizations to share knowledge, coordinate

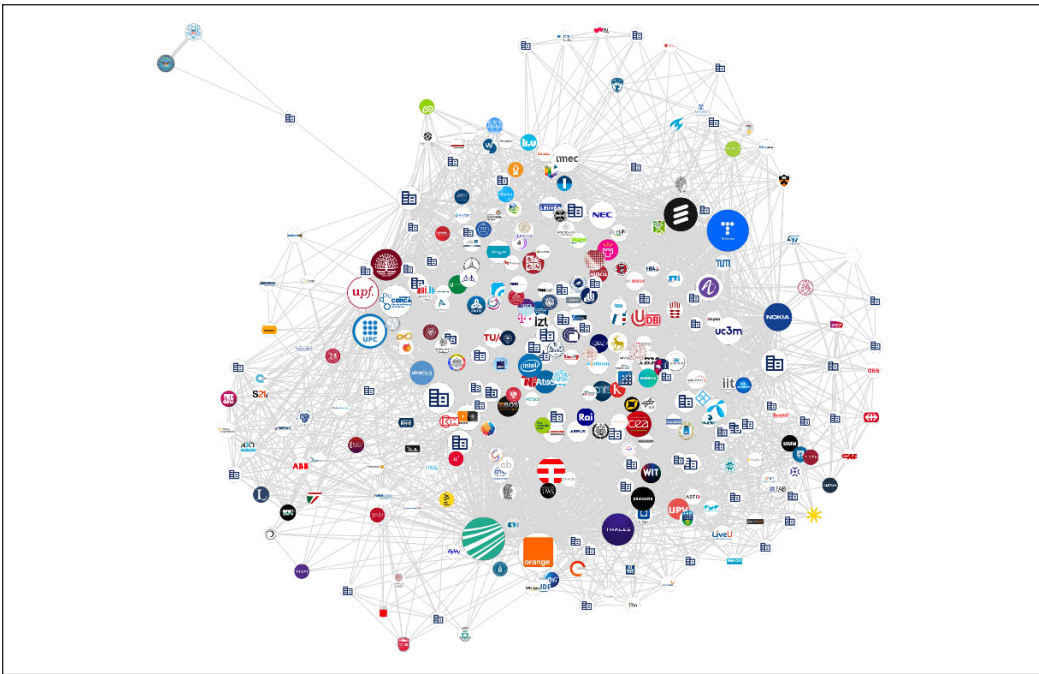


Figure 13. The 5G collaboration network
 Note. The figure is retrieved from Orbit Insight

activities and offer the infrastructure, resources, and expertise needed to develop and test innovative technologies. Organizations also set best practices and standards, offering advice on matters such as data privacy, cybersecurity, and environmental impact to guarantee the ethical, sustainable, and safe use of emerging technology. Figure 14 displays the names, types, and countries of 18 upper-echelon organizations involved in publishing, patenting, and standardizing 5G, which suggests that patent-heavy businesses maximize their influence on 5G technology development. Organizations that invest in 5G research and development are crucial for economic growth and competitiveness in the global technology landscape. Their investments create high-skilled job opportunities, stimulate technological entrepreneurship, and attract foreign investments. The innovations they generate can revolutionize manufacturing, healthcare, transportation, and entertainment sectors, unlocking new business models and revenue streams. They also shape the public policy and regulatory frameworks around 5G technology, advocating policies that support innovation while addressing societal concerns. This proactive approach creates a balanced regulatory environment that fosters technological progress while safeguarding the public interest. As the 5G landscape evolves, these organizations will continue to drive innovation, set standards, and shape the future of telecommunications, paving the way for the next generation of wireless communication systems.





































Organizations				View all: 2473 organizations
<input type="checkbox"/>	NAME	CLASSIFICATION	TYPE	COUNTRY
<input type="checkbox"/>	 Samsung Electronics		Company	 South K..
<input type="checkbox"/>	 Ericsson		Company	 Sweden
<input type="checkbox"/>	 U.S. Department of Defense		National/Govern...	 United S..
<input type="checkbox"/>	 Qualcomm		Company	 United S..
<input type="checkbox"/>	 Intel		Company	 United S..
<input type="checkbox"/>	 Deutsche Telekom AG		Company	 Germany
<input type="checkbox"/>	 Fraunhofer-Gesellschaft		National/Govern...	 Germany
<input type="checkbox"/>	 Telefonica		Company	 Spain
<input type="checkbox"/>	 Orange SA		Company	 France
<input type="checkbox"/>	 U.S. Department of Health & Human...		National/Govern...	 United S..
<input type="checkbox"/>	 Polytechnic University of Catalonia		University	 Spain
<input type="checkbox"/>	 United States Coast Guard		Government	 United S..
<input type="checkbox"/>	 National Science Foundation		Government	 United S..
<input type="checkbox"/>	 Huawei Investment & Holding Co., Ltd		Company	 China
<input type="checkbox"/>	 Thales Group		Company	 France
<input type="checkbox"/>	 NEC Corporation		Company	 Japan
<input type="checkbox"/>	 imec		Research Institute	 Belgium
<input type="checkbox"/>	 Apple		Company	 United S..

Figure 14. Organizations participating in the 5G locale

Note. The figure is retrieved from Orbit Insight

Smaller and more agile companies play a crucial role in this landscape. They often bring innovation, flexibility, and niche expertise that larger corporations may struggle to provide. Startups are another significant entity, critical to the development of breakthrough technologies, and typically established by enterprising individuals who recognize market deficiencies and are motivated by a determination to address challenges or introduce new solutions. Startups are integral to the technological ecosystem, as they stimulate innovation, challenge limits, and contribute to the progress of technology, ultimately enhancing people’s lives in various ways. On the one hand, 5G technology allows companies to deliver faster and more dependable services to their clients, leading to enhanced customer happiness and greater brand loyalty. On the other hand, it also presents fresh prospects for companies to create inventive, previously unattainable products and services. The startups shown in Figure 15 are creating inventive and cost-effective 5G solutions that have the potential to enhance accessibility to 5G for users across various countries. This increased accessibility has the potential to bridge the digital divide and foster economic growth in

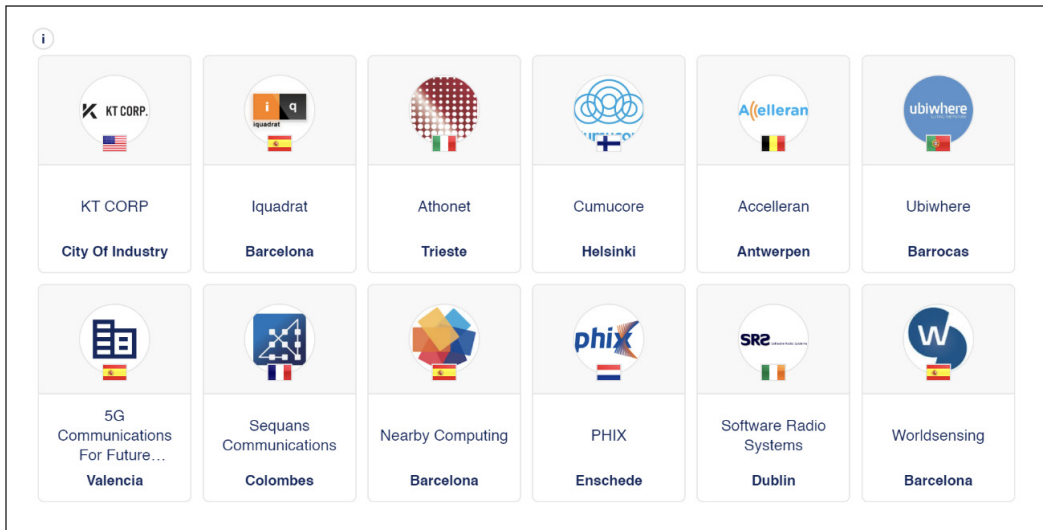


Figure 15. Startups participating in the 5G locale
 Note. The figure is retrieved from Orbit Insight

previously underserved regions. Moreover, competition and innovation driven by these startups contribute to the overall maturation of the 5G ecosystem, encouraging established players to adapt and improve their offerings. As a result, the entire technological landscape benefits from the fresh perspectives and disruptive ideas that startups bring to the table, ultimately accelerating the widespread adoption and utilization of 5G technology. Figure 15 lists the 12 startups in the foreground of 5G innovations.

Inventions

The activities of these key players and startups culminate in a rich landscape of intellectual property. The landscape of intellectual property in the realm of 5G technology is dynamic and evolving. Understanding the status of inventions is crucial to gauging the progress and competitiveness of various establishments in this domain. The following provides a comprehensive overview of the current state of 5G inventions, highlighting the legal status of these innovations: Running a search on the patent database yielded 105100 inventions. Out of all the inventions, 84.76% are still active, while just 463 have reached their expiration. The countries with the highest level of protection are China, the United States, and South Korea. The first-filing countries are China, the United States, and South Korea. As for the writing of this research paper, there have been 49,900 awarded innovations, 39,215 pending inventions, 11,937 lapsed inventions, and 3,585 revoked inventions. These numbers represent a broad ratio of 5G patents' legal status, indicating that the majority of 5G patents are either granted or pending, with less than 15% of the filings being lapsed or revoked. The statuses divided into granted, pending, lapsed, revoked, and expired are

visually represented in Figure 16. This overall distribution paints a picture of a thriving and competitive technological landscape where most of the statuses are being granted, and many are pending approval for upcoming purposes.

Geographic Protection

While the legal status of inventions provides one perspective, examining their geographic distribution offers another extent of insight. By examining the countries in which patent families are protected, as shown in Figure 17, it is possible to identify the main markets utilizing this technology. This figure includes the number of inventions split into protected patents and first filings by country and countries that have had the best acceleration in 5G patent filings. This analysis reveals regions where technology is thriving, absent, or declining. Unexploited regions will also become evident through this process. Most companies file their initial patent applications in the countries where they conduct their research and development. Studying these initial filings makes it easy to spot key countries. Therefore, ensuring robust patent protection in these critical regions is essential. By doing so, companies can safeguard their intellectual property, maintain a competitive edge, and capitalize on licensing opportunities in emerging markets. Additionally, these data can help identify potential gaps in the global 5G landscape, which may present new opportunities for market expansion.

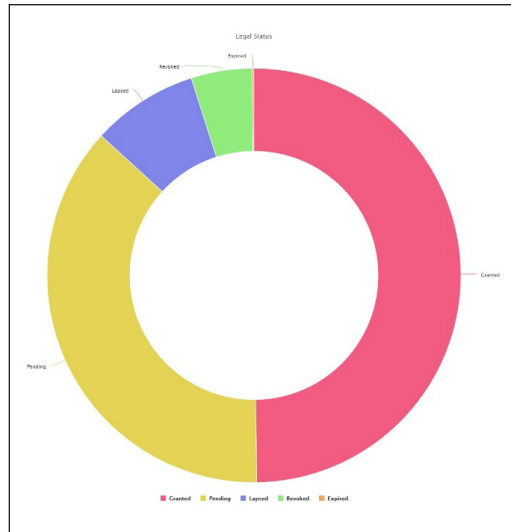


Figure 16. 5G inventions legal status
 Note. The figure is produced by inputting data into RapidMiner Studio

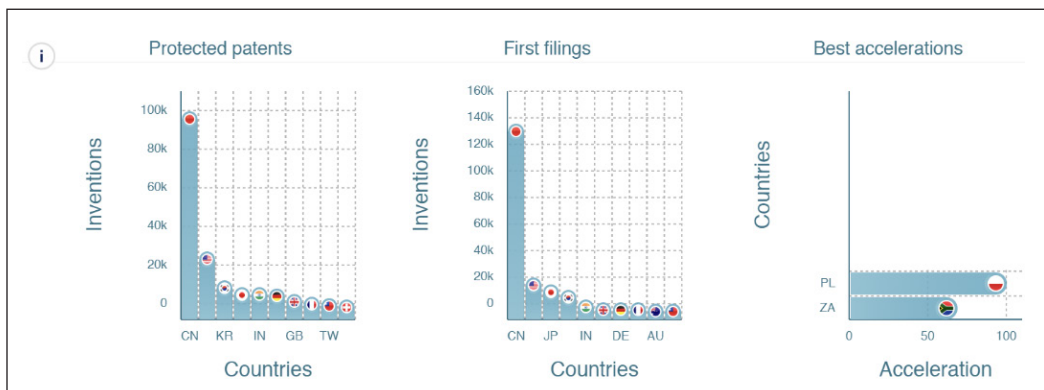


Figure 17. Geographic distribution of 5G patents filings
 Note. The figure is retrieved from Orbit Insight

SCIENTIFIC WORKS

Scientific research plays a vital role in advancing 5G technology, complementing the patent landscape. In view of scientific production (articles, theses, conferences), intellectual property (IP), networks, projects, clinical trials, and web exposure in conjunction with numerous involvements in the ecosystem, a total of 495 academics, 673 companies, and 500 startups were found to match the search. The non-patent literature (NPL) database search produced 32209 scientific activities that are related to 5G. Most of the scientific works are journal articles.

Figure 18 depicts the top countries in terms of scientific outputs pertaining to 5G, while Figure 19 illustrates the publication types of scientific works. Figure 20 delineates the number of scientific productions associated with 5G over time.

Figure 18 includes the volume of scientific work among 20 countries. It reveals the growing interest and accelerated research efforts in 5G technology over recent years, coinciding with its increasing importance in global telecommunications and digital infrastructure development. China, the United States, France, and India have led the pack, while the other countries have contributed a decent amount of scientific work.

Figure 19 presents the sum of scientific works based on publication type. Journal articles and conference proceedings articles have the greatest proportion of publication types, with book chapter abstracts separating themselves from the rest, followed by journal and conference proceedings articles. In addition, the X-axis is reversed in Figure 19, with the highest ranking toward the summit of the chart and the lowest ranking toward the bottom.

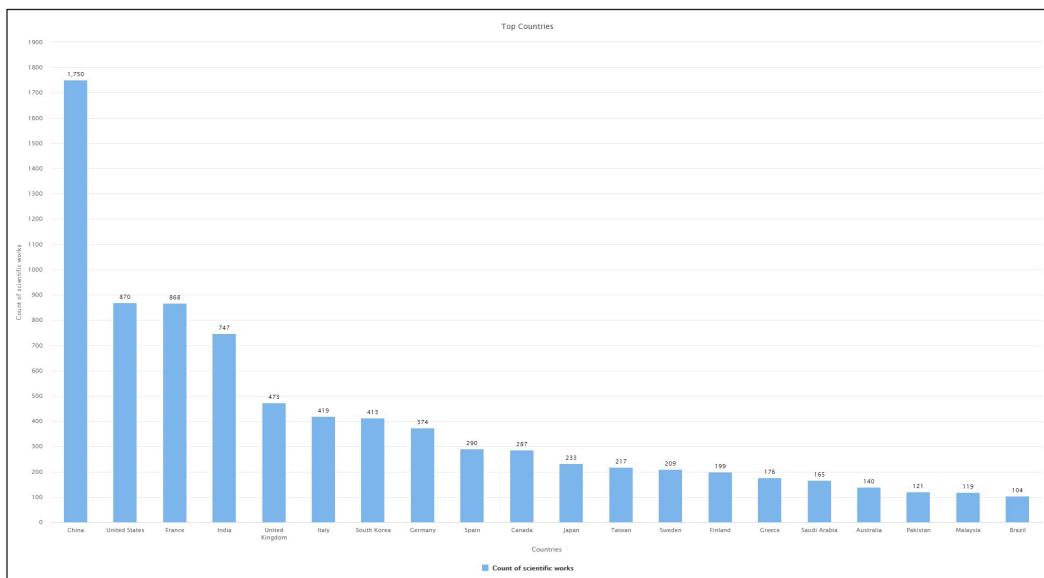


Figure 18. The top countries contributing to 5G in terms of scientific works

Note. The figure is produced by inputting data into RapidMiner Studio

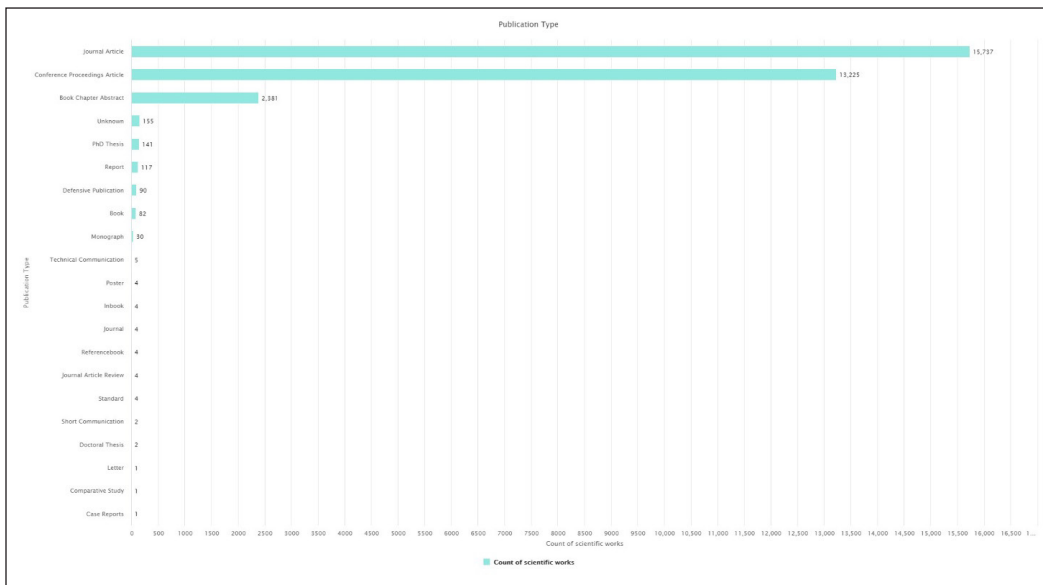


Figure 19. The count of 5G publication types

Note. The figure is produced by inputting data into RapidMiner Studio

Figure 20 displays scientific works related to 5G over a 20-year period, starting from 2004 to 2024. Since 2019, these scientific studies have witnessed a steep rise and remained at high levels until 2024, which will only be accurately measurable when they have been concluded. It is expected that 2024 will maintain a strong tally for 5G-related scientific works.

Examining the role of academia is essential to fully appreciate the scientific contribution to 5G. The intersection between academia and technology is a key driver of innovation and progress. Academic institutions serve as the foundation for technological advancement through their research initiatives and educational programs. Their collaboration with industry partners pushes the boundaries of current technology and prepares the next generation of professionals to tackle future challenges. This dynamic is particularly evident in the context of 5G. Strategic investments by universities and research centers can yield significant benefits in terms of attracting talent and securing research funding. Academic institutions, such as universities and research centers, play a pivotal role in technological progress through their research, formulation of new theories, and education of future professionals. By collaborating with industry partners, they contribute to advancing technology standards and preparing the workforce for upcoming challenges. The academic community has shown careful consideration in its approach to investing in 5G technology. Institutions that embrace this technology may gain an advantage in attracting students, instructors, and research funding. Figure 21 depicts a dozen prominent academics participating in 5G. Institutions in Spain, Finland, Sweden, the United Kingdom,

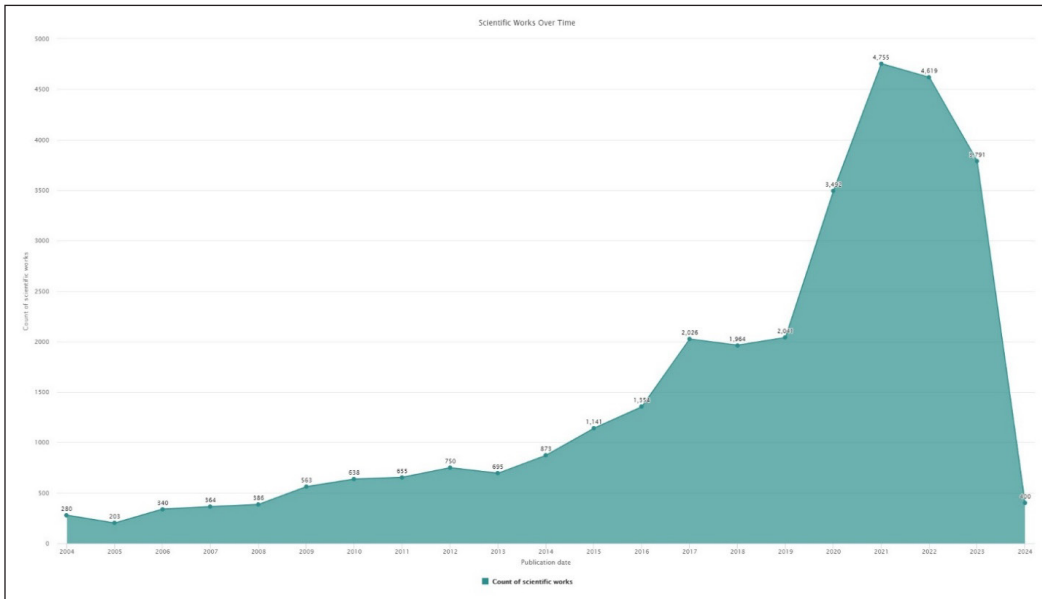


Figure 20. 5G-related scientific works overtime

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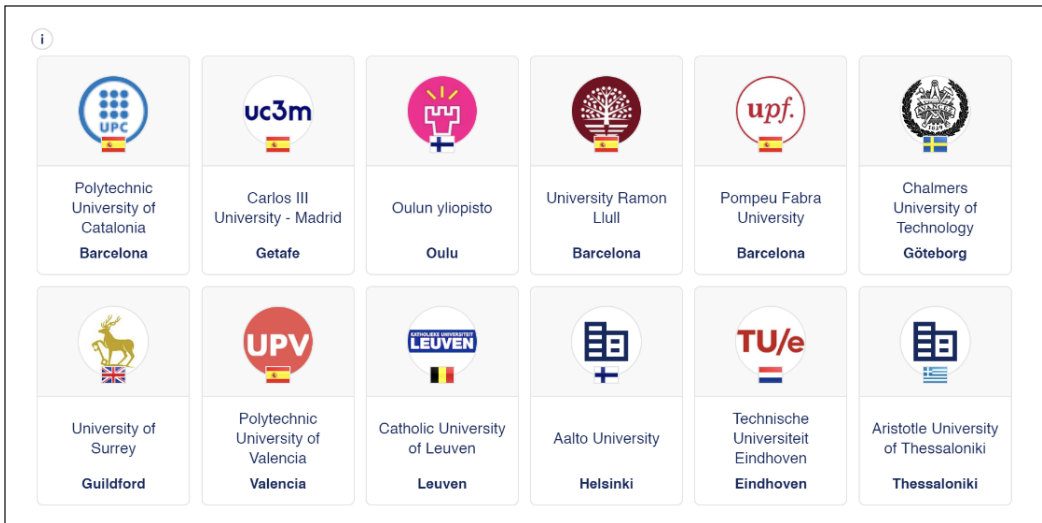


Figure 21. The academia participating in the 5G locale

Note. The figure is retrieved from Orbit Insight

Belgium, the Netherlands, and Greece formed these participants. By pooling resources, expertise, and perspectives, these institutions contribute to a more comprehensive and robust development of 5G technology, which is likely to have far-reaching implications for various sectors and industries worldwide.

As a result of this academic involvement, certain research themes have emerged as particularly significant. In this regard, the most prevalent ideas in scientific publications within a particular subject area can be identified by exploring the most commonly used keywords. This method allows a clearer understanding of the dominant themes and trends in research. When it comes to 5G research, examining scientific publications reveals that the core topics often revolve around cellular, mobile, and fifth-generation networks. By emphasizing these key areas, researchers can gain valuable insights into the current state of 5G technology and its future direction. Analyzing the frequency and context of specific keywords within these publications helps to highlight the mainstream ideas and research priorities. This approach uncovers the prevailing concepts and sheds light on emerging trends and potential areas for further investigation, as shown in Figure 22. This figure shows the most critical scientific activities related to 5G through a word cloud containing 10 principal topics. This representation highlights key scientific activities in 5G research by displaying prevalent expressions. It can reveal the relationships between different aspects of 5G technology, enabling researchers to identify gaps in current knowledge and potential avenues for innovation. It facilitates interdisciplinary understanding by providing a quick overview of the field to researchers from different disciplines. It serves as a powerful tool for synthesizing and presenting complex information on 5G technology research.

Although keywords provide a snapshot of research trends, understanding the fundamental scientific disciplines underpinning 5G offers a more overarching view. It is essential to delve into its core scientific disciplines to understand the scope and impact of 5G technology. By examining the primary areas of investigation within 5G, we can gain insights into the fundamental principles and innovations driving this technology forward. As graphically represented in Figure 23, the three main scientific fields that underpin 5G are networking and telecommunication, general computer science, and general astrophysics. By examining these primary scientific disciplines, researchers can comprehensively understand the multi-faceted nature of 5G technology and its applications. This holistic view helps identify the critical areas of research and development, thereby guiding future innovations and improvements in the field. As shown in Figure 23, all six of the prime 5G scientific domains indicate that 5G extends beyond traditional telecommunications and encompasses a diverse range of fields that contribute to its advanced capabilities. 5G technology relies on networking and telecommunications for robust infrastructure, efficient data

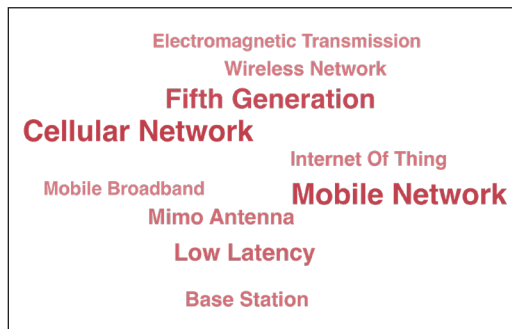


Figure 22. 5G scientific activity
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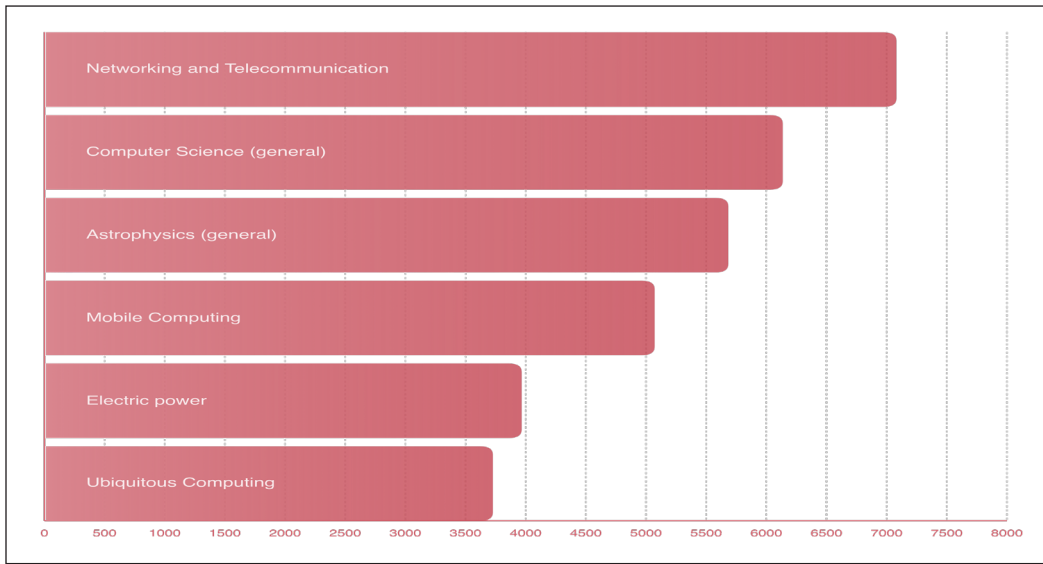


Figure 23. 5G scientific domains
 Note. The figure is retrieved from Orbit Insight

transmission protocols, and advanced network architecture. General computer science provides computational foundations for data processing, machine-learning algorithms, and software-defined networking. General astrophysics plays a significant role in satellite communications and space-based network components, understanding signal propagation, and designing global-coverage satellite constellations. Integrating these three scientific fields— networking and telecommunications, general computer science, and general astrophysics—creates a synergistic approach to 5G development. This interdisciplinary collaboration enables the creation of a highly advanced, efficient, and versatile communication ecosystem that supports a wide range of applications.

DISCUSSION

The 5G technology patent landscape is marked by fierce competition, the critical role of SEPs, and their potential for groundbreaking societal applications. As industries continue to innovate and merge 5G with other technologies, continuous patent analysis is vital for discerning trends, steering strategic decisions, and maintaining equitable competition in the 5G sphere.

The 5G patent landscape represents a complex and evolving sector that sheds light on telecommunication technology’s current state and future direction. Major players, such as Samsung, Huawei, Qualcomm, Nokia, and Ericsson, dominate this arena, holding a substantial share of the total 5G patents. This concentration underscores the competitive nature of the telecommunications industry and the considerable investments

these companies make in research and development. The geographic distribution of 5G patents indicates that innovation hubs are primarily situated in the United States, China, Europe, and South Korea. This can be attributed to strong governmental backing, favorable regulatory conditions, and significant funding for technological innovation. However, it also raises concerns about global equity in technological advancement and the potential for the digital divide.

Patents' quality and impact are vital for innovation. Many of the patents filed are high quality, broadly applicable, and represent significant technological contributions. SEPs play a crucial role in the 5G ecosystem by ensuring interoperability and compatibility across devices and networks. Leading companies possess a high number of SEPs, highlighting their strategic position to influence global 5G standards.

A high concentration of 5G patents raises issues related to Intellectual Property Rights (IPR) and market dynamics. Companies with extensive patent portfolios can leverage their patents to establish licensing agreements, generate revenue and engage in litigation. While this can incentivize innovation, it may also create barriers to entry for smaller firms and new market entrants. Policymakers and industry stakeholders must navigate these challenges to balance the protection of IPR with the promotion of healthy competition and innovation.

As 5G technology progresses, the patent landscape is likely to shift in response to emerging technological advancements and market needs. Policymakers must consider the implications of 5G patents for national security, economic competitiveness, and technological sovereignty. Collaborative efforts among governments, industry leaders, and international organizations are essential for establishing fair and transparent patent practices, promoting cross-border cooperation, and addressing potential geopolitical tensions arising from the strategic importance of 5G.

CONCLUSION AND REMARKS

This study aims to aid stakeholders worldwide in comprehending the 5G patent landscape to enhance strategic planning and gain a competitive edge. This underscores the strategic importance of 5G patents in shaping market dynamics and future industry competitiveness, aligning with Pohlmann et al. (2020), who noted that patents declared to the 5G standard significantly impact various sectors, including automotive and telecommunications. Additionally, this study suggests that 5G patents will continue to drive innovation and influence technological standards, consistent with Mendonça et al. (2022), who highlight the disruptive effects of 5G technologies on economies and societies. This research also recommends that policymakers financially support the patenting process and reduce related costs to encourage participation in 5G development. This recommendation aligns with other researchers advocating governmental support and standardization efforts to boost national and global competitiveness in 5G technology (Kochetkov & Almagambetov, 2021). Finally,

the study calls for future research to examine the impact of emerging technologies and legislative changes on 5G patent portfolios, echoing Trappey et al. (2023), who emphasize the need for continuous monitoring of patent trends to understand the evolving landscape of 5G technologies.

In contrast, Wang et al. (2022) analyzed the technical effects of 5G communication patents, such as security improvement, cost reduction, and reliability improvement; however, the conclusions and recommendations are specifically aimed at China and lack a global and panoramic view of the 5G patent landscape. Conversely, this study intends to assist companies and contingents in obtaining valuable insights into 5G technology, the market, and competitors by conducting a detailed and balanced review of 5G patents. A comprehensive study of 5G patents can help firms identify critical areas for innovation and development to sustain a competitive advantage in the 5G market. This information can be utilized to ensure that businesses are developing appropriate products and services to satisfy market demands and to concentrate research and development efforts in the right direction. In conclusion, analyzing 5G patents is an indispensable resource for organizations seeking to prosper in a dynamic and ever-changing 5G landscape.

By looking ahead, 5G patents will continue to drive innovation and have a significant impact on market dynamics, which will shape future industry competitiveness and technological standards. In general, examining 5G patents sheds light on the state of intellectual property and its strategic significance in the telecom sector. Businesses and legislators must carefully analyze their patent strategies to successfully traverse the rapidly changing 5G ecosystem. Policymakers should provide financial assistance, reduce the cost of patenting, and partially cover the expenses associated with international standardization to encourage participation in developing and commercializing telecommunications. Assertions that a single corporation or country is winning the 5G race are questionable (USPTO, 2022). Maintaining an advantage in the patent race is essential in the fast-developing 5G setting as technology develops. The paper concludes by highlighting the importance of 5G patents in influencing a multitude of sectors. Subsequent investigations into 5G patent analysis may also delve into the consequences of emerging technologies and legislative advancements on patent portfolios while also concentrating on the evolution of 5G patent trends and their impact on industry dynamics. This study recommends that policymakers prioritize facilitating collaborative patenting strategies between various 5G entities to stimulate constant innovation. Further research is required to examine the influence of emerging 6G technologies on the current 5G patent landscape.

ACKNOWLEDGEMENTS

This research did not receive any dedicated funding from public, private, or non-profit entities.

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