Analyzing the current status of global 5G research from the perspective of bibliometrics

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Abstract. In order to fully understand the current research status in the field of 5G technology, using 5G documents included in the WOS, Derwent Innovations Index as the data source, this article conducts a bibliometric analysis of "5G technology" from multiple dimensions such as the number of publications, countries, institutions, and patents. Through the CiteSpace software, the scientific knowledge map in the 5G field is drawn, and the research overview in the 5G field is obtained, scholars in this field can make theoretical references in further research.

1. Introduction
After the development of human society has experienced the three industrial revolutions of steam, electricity, computer and communication technology, with the development of 5G technology, the fourth industrial revolution that integrates digitization, networking and intelligence is kicking off. The perfect combination of big data, artificial intelligence, cloud computing and other technologies with the characteristics of 5G's high speed, low energy consumption, low latency, and ubiquitous connection will deeply affect people's lives and the development of all walks of life in society. In 2013, the European Union announced the start of 5G research and development and plans to launch mature 5G technical standards in 2020. In 2016, the US government launched the "Advanced Wireless Communications Research Program" to accelerate the development of next-generation wireless networks. In 2020, 5G has become an important part of the new infrastructure in China. 5G has become a strategic high ground for global technology and industrial competition, leading technological innovation, reshaping the development model of traditional industries, and one of the key driving forces for the development of a new economy[1].

2. Data sources
This article uses the 5G technology research literature in the WOS core collection database, the Derwent Innovations Index database as the data source to construct the English search formulas and set the relevant search conditions. After screening and deduplication, the results are obtained 6884 related English documents, 20032 patent documents.

3. Global 5G technology research status

3.1. Analysis of the volume of English publications
The number of documents, the number of documents cited, and the number of articles cited can
scientifically reflect the changes in the amount and quality of knowledge. They are important indicators to measure the research progress of a certain discipline or field, and are of great significance for evaluating the stage of the field and predicting future trends[2]. According to the search results, the number of English documents published, the number of documents cited, and the number of articles cited in the 5G technology research field in the 11 years from 2010 to 2020 are counted, shown in Figure 1 and Figure 2.

![Figure 1. Statistics on the number of published articles in English for 5G technology research.](image)

By analyzing the development of the literature, scholars such as Liu Pei, Stefan Valentin, Klaus Doppler have begun to explore related technologies for next-generation wireless networks before 2010. Since 2011, papers with keywords such as The fifth generation of cellular wireless standards (5G) and 5G have been published successively.

It can be seen from Figure 1 that the general trend of publication of English literature on 5G technology-related research has shown an increasing trend year by year. 5G technology research can be roughly divided into two phases-the early research phase from 2010 to 2014 and the rapid growth phase from 2015 to 2020, and the rapid growth phase will continue for a longer period of time. The research theme from 2010 to 2014 is mainly the exploration of 5G theory and standards. It is the pre-concept, pre-research and prototype verification stage. After 2015, the research topic has gradually changed to the optimization of core technologies and the application practice in combination with specific scenarios, including Massive-MIMO, FBMC, UDN, MANET, SDN and other technologies.

The number of citations of English literature on 5G technology in Figure 2 generally shows an increasing trend each year, but the number of citations for each article shows a different state. At the beginning of the research, the number of citations of a single document was very high. The English document "What Will 5G Be" published in 2014 was cited 179 times, which comprehensively summarized the difference between 5G and the previous four generations of communication technology. At the same time, it determine the main challenges faced by future research and initial activities of 5G standardization[3].

From the perspective of the average number of citations, the average number of citations for English papers has turned from an inflection point in 2013 to an increasing state. The number of citations in English literature has increased year by year because of the global 5G technology research boom starting in 2013, and the number of English literature publications and citations has steadily increased.
3.2. Country and region analysis
This article uses Citespace software to count the number of papers published in the 5G research field of various countries in the WOS core collection database, draw a time zone view of the network area, and clearly show the research overview and mutual influence of various countries. As shown in Figure 3, the size of the "annual ring" in the figure can reflect the number of articles published in the country or region, that is, the larger the annual ring, the more articles published in the country[4].

The total citation frequency index can better show the influence of a country in this research field. Combined with the data in Figure 3 and Table 1, China and the United States rank in the top, and the number of countries with a total citation frequency of more than 20000 times is 5 countries.

Table 1. Number of published papers and total citation frequency of 5G technology research and development in the world's top 10 countries and regions over the years.

| Number | Country | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | Total number of articles | Total citations |
|--------|---------|------|------|------|------|------|------|------|------|------|------|--------------------------|---------------|
| 1      | China   | 1    | 0    | 1    | 28   | 118  | 190  | 400  | 557  | 683  | 513  | 2,491                    | 83,284        |
| 2      | USA     | 1    | 0    | 3    | 26   | 54   | 95   | 232  | 289  | 303  | 241  | 1,244                    | 49,282        |
3.3. Analysis of issuing agencies

Citespace software was used to count the number of papers published by various research institutions in the 5G research field in the WOS core collection database, and to draw a cooperation network of English 5G technology research institutions.

Figure 4. Knowledge Graph of English 5G Technology Research Institutions.

Figure 4 shows that Beijing University of Posts and Telecommunications, Southeast University, Xidian University, China University of Electronic Science and Technology, and Tsinghua University rank the top five in the number of publications. China has a large number of high-yield research institutions and has a clear advantage. In terms of the output of internationalization achievements, from the perspective of cooperation, Princeton University, Heriot-Watt University, etc. are highly centralized, and they are more active in 5G research cooperation and exchanges. In addition to global universities and scientific research institutions, 5G research institutions also include internationally renowned companies such as Huawei, Nokia, Samsung, and Intel.

3.4. Patent analysis

Patent documents contain technical, legal and economic information, and are important crystallization and carriers of technological innovation information[5]. Through the analysis of patent documents, we can grasp the distribution trend of the latest 5G technology research and development, monitor the development level and trend of 5G technology, and provide important scientific basis for policy formulation and competition analysis. It can be seen from Figure 5 that the change in the number of
5G patent applications has mainly gone through three stages. From 2010 to 2014, the number of 5G technology patent applications was relatively small but showed a steady upward trend. From 2015, the number of patent applications began to explode. After a small decline in 2017, 2018-2020 has ushered in more rapid growth. Looking at the long-term trend, the number of global 5G technology patent applications will also be on an upward path.

Figure 5. Statistics of 5G patent applications.

Global 5G competition is becoming increasingly fierce. Countries all want to have the initiative in 5G technology and services, and the essence of the competition for initiative is to see the number of 5G patents owned by each country. It can be seen from Table 2 that the top 10 companies with 5G patents in the world are mainly concentrated in 5 countries: China, South Korea, Finland, Sweden, and Japan. If you only look at the number of standard patents, South Korea’s Samsung is ranked first, Huawei is ranked second, and Qualcomm, the main 4G patent owner, is ranked fourth. From the perspective of the top 10 companies, companies are mainly divided into three categories, namely ICT infrastructure and smart terminal providers, mobile phone manufacturers and telecommunications group companies.

Table 2. Top 10 companies in the world for 5G related patent applications.

| Number | Patentee                          | Country | Total |
|--------|-----------------------------------|---------|-------|
| 1      | SAMSUNG ELECTRONICS CO LTD        | Korea   | 1182  |
| 2      | HUAWEI TECHNOLOGIES CO LTD        | China   | 719   |
| 3      | NOKIA TECHNOLOGIES OY             | Finland | 603   |
| 4      | QUALCOMM INC                      | USA     | 537   |
| 5      | NTT DOCOMO INC                    | Japan   | 493   |
| 6      | TELEFONAKTIEBOLAGET ERICSSON L M  | Sweden  | 410   |
| 7      | INTEL CORP                        | USA     | 339   |
| 8      | AT&T INTELLECTUAL PROPERTY I LP   | USA     | 288   |
| 9      | LG ELECTRONICS INC                | Korea   | 266   |
| 10     | ZTE CORP                          | China   | 185   |

4. Summary
By tracking and mining 5G technology-related literature information, conclusions can be drawn:
(1) Related 5G technology research literature began to appear around 2010 and the number of literatures was in the initial period of slow growth. In 2015, it entered a period of rapid growth. From the global focus, we can see that 5G technology is still a hot research field in the future.
(2) East Asia, North America, and the European Union are the core areas of global 5G technology research, and the number of related publications by China and the United States is much higher than that of other countries.
(3) China has a large number of 5G-related technology research institutions. In addition to global universities and scientific research institutions, 5G research institutions also include internationally renowned companies such as Huawei, Nokia, Samsung, and Intel.

(4) The top 10 companies with 5G patents in the world are mainly concentrated in 5 countries: China, South Korea, Finland, Sweden, and Japan. Looking at the long-term trend, the number of global 5G technology patent applications will also be on an upward path.

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