Analysis of Research Situation of Wireless transmission of the Internet of Things Based on Bibliometrics

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Abstract: In order to objectively analyze the development of wireless transmission research of the Internet of things, and provide reliable data reference for researchers and decision-makers of wireless transmission of the Internet of Things, this paper adopts the bibliometric method and selects web of science database to analyze the number of papers and citations of countries, authors, publishing organizations, journals, and research contents of wireless transmission of the Internet of Things. A total of 15102 authors from 3843 organizations in 87 countries and regions, which include China, the United States, South Korea, and India, and 6105 articles published in 551 source publications were retrieved from Web of Science database. The research content involves the research focus, current development status, application scenarios, and future trends of the wireless transmission of the Internet of things. In terms of quantity, the most powerful country in the world is China, which has published 1912 papers, accounting for 31.319% of the total number of papers. At the same time, the research on wireless transmission of the Internet of Things is relatively active in China, with a wide distribution of research organizations, a large number of researchers, and the highest number of publications. Among the top 10 high-yield organizations, 7 are Chinese organizations, and some Chinese scholars have published the article has a high frequency of citations, but the number of results of different research directions is not balanced, and the research direction is more inclined to the direction of machinery, computer science and communication.

1.Introduction

The Internet of Things (IoT) is a novel paradigm that is rapidly gaining ground in the scenario of modern wireless telecommunications. The basic idea of this concept is the pervasive presence around us of a variety of things or objects – such as Radio-Frequency Identification tags, sensors, actuators, mobile phones and other objects or devices, which through unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals [1]. The Internet of Things collects any object or process that needs to be monitored, connected and interacted in real-time through various sensors, RFID technology and other technologies and various equipment. In today's era, the Internet has penetrated all aspects of our lives. People can conduct various interactive communication on the virtual ground level. On this basis, through the communication between actual objects and smart objects, the Internet of Things may add a new dimension to the process of Internet communication, and then it is possible to realize the beautiful vision of communication between any media and any object anytime, anywhere [2].
Our world consists of various ‘things’. As one of the enablers of the smart world, the Internet of Things (IoT) [2][3][4][5][6] targets to connect various objects (e.g., mobile phones, computers, cars, appliances) with unique addresses, to enable them to interact with each other and with the world. Further, green IoT targets at a sustainable smart world, by reducing the energy consumption of IoT [7].

Starting from the perspective of document informatics, this paper adopts the method of metrological analysis to analyze the current situation of wireless transmission of the Internet of Things at home and abroad, and reveal its development trend. Today, with the rapid development of science and technology, a systematic review of the global wireless transmission of the Internet of things with the bibliometric method is conducive to strengthening the accumulation of knowledge and theoretical innovation ability of wireless transmission of the Internet of things. This kind of research situation analysis can fully reveal the research direction and core technology of wireless transmission technology of Internet of things in different fields, further promote the technical exchanges among countries, organizations, and fields, so as to speed up the development of wireless transmission of the Internet of Things in the world. It aims to provide data reference for researchers and decision-makers in wireless transmission of the Internet of Things, and promote the continuous development of wireless transmission research of the Internet of Things.

2. Data and Methodology

2.1 Data Collection

The research literature is based on the SCIE database of Clarivate Analytics. This database is a network database that retrieves international research literature on wireless transmission of the Internet of Things. The types of literature involved include articles, conference papers, reviews or conference abstracts. The database was updated on December 12, 2020, with a total of 6105 articles from 2010 to 2020.

2.2 Methods of Data Analysis

Bibliometrics is a branch of library and information science that uses mathematical and statistical methods to describe, evaluate, and predict the current state and trends of science and technology by means of the number of various features of the literature [8]. In this paper, one of the best Science Citation Index Expanded (SCIE) databases in the world is selected as the data source, which has become the main retrieval tool of scientific statistics and scientific evaluation, so that researchers can understand the development status and trend of wireless transmission technology of the Internet of things. As the wind vane and the indicator of academic research, vital timeliness of journal papers can accurately reflect the evolution trend of a specific research topic [9]. The papers collected can reflect the development trend of scientific frontier in a timely manner to a certain extent and perform statistical analysis and content mining through bibliometrics.

Key words = ("Internet of things" or "the Internet of things" or IOT) and ("wireless communication" or wireless or "WiFi files" or "wireless transport") were used to search in Web of Science database. The literature types are articles, review, early access, and procedures paper, the statistics related to data and information are based on the first author and the first research organization, using VOS viewer and bibliometric online analysis platform for visual analysis. They all use the relationship construction and visual analysis of literature knowledge units to achieve the drawing of scientific knowledge graphs, display the structure of the knowledge field, cooperative relations, etc., and their outstanding feature is that they have strong graphics display capabilities and are suitable for large-scale data analysis.

3. Results

3.1 Distribution of Research Forces

3.1.1 Research on Publication Status and Output Trends of Papers

The published statistics show that the research field of wireless transmission of the Internet of Things
has received extensive attention at home and abroad. It can be seen from Figure 1 that the year when China began to study the wireless transmission of the Internet of Things is the same as the international one. In the figure, there is a black broken line and red dotted line as well as ten groups of histograms. The black broken line represents the change in the total number of international wireless transmissions of the Internet of Things in the past ten years, and the red dotted line represents the relationship between the total number of international postings and the year. The equation is \( y = 28.466x^2 - 160.69x + 208.03 \), and the regression equation determination coefficient \( R^2 \) is 0.9866, indicating that the regression equation can fully reflect the relationship between the total number of documents issued each year and the year. The histogram shows the number of articles published by the top ten countries in the wireless transmission of the Internet of Things. It can be seen clearly that before 2019, China, the United States, and South Korea are the top three countries in this field. However, in 2020, India will surpass South Korea in the total number of articles published and become the third country in this field. In the process of counting the total number of articles issued by various countries, there will be repeated statistics on articles jointly written by different countries. Therefore, the total amount of articles issued by countries in individual years is less than the total amount of articles issued by the top 10 countries, such as 2018. In the past decade, the research on wireless transmission of the Internet of Things has been on the rise, and the international growth is obvious around 2017-2018. The author believes that at the Mobile World Congress (MWC) held in 2017, NB-IoT was one of the biggest highlights of the conference, which also promoted the development of wireless transmission of Internet of Things. And on March 1 of the same year, China Mobile, as the three largest mobile communication operators in China, announced at the MWC conference that it would carry out relevant experiments in Hangzhou, Shanghai, and other four cities in 2017, which is also one of the important factors to promote the rapid development of wireless transmission of the Internet of Things.

![Figure 1. Number of documents issued by the top ten countries for wireless transmission of the Internet of Things (2010-2020).](image)

### 3.1.2. Research Country Analysis of Wireless Transmission of the Internet of Things

From Web of Science database, 87 countries, including China, the United States, South Korea, India, and the United Kingdom, have published research papers on wireless transmission of the Internet of Things. Table 1 lists the top 10 countries in terms of the number of papers on wireless transmission of the Internet of Things.
Table 1. The Top 10 Countries in the Total Number of Wireless Transmission of the Internet of Things

| Country                  | Total Articles | h-index | Total Citation Count | International Proportion | Number |
|-------------------------|----------------|---------|----------------------|--------------------------|--------|
| China                   | 1912           | 121     | 106758               | 31.319%                  | 1      |
| the United States       | 998            | 75      | 28315                | 16.347%                  | 2      |
| South Korea             | 663            | 43      | 8843                 | 10.860%                  | 3      |
| India                   | 564            | 39      | 6854                 | 9.238%                   | 4      |
| Britain                 | 430            | 47      | 11440                | 7.043%                   | 5      |
| Italy                   | 334            | 41      | 14775                | 5.471%                   | 6      |
| Spain                   | 332            | 34      | 6062                 | 5.438%                   | 7      |
| Canada                  | 317            | 38      | 5820                 | 5.192%                   | 8      |
| Australia               | 252            | 32      | 8083                 | 4.128%                   | 9      |
| Saudi Arabia            | 251            | 28      | 3437                 | 4.111%                   | 10     |

It can be seen from Table 1 that there are currently many countries researching wireless transmission of the Internet of Things, and the research level of wireless transmission of the Internet of Things in China, the United States, South Korea, and other countries are in a leading position in the world. In terms of quantity, the world's most powerful research country for wireless transmission of the Internet of Things is China, which has published 1912 papers, accounting for 31.319% of the total number of papers. The total number of papers published in the United States, South Korea, India, Britain, Italy, Spain, and Canada is 998, 663, 564, 430, 334, 332, and 317 respectively. The country with the most cumulative citations is China. At the same time, China is also the country with the highest h index, which shows that China has a great influence on the wireless transmission of the Internet of Things.

3.2. Distribution of Major Research Results

3.2.1. Top 20 Researchers

The largest number of articles is "IEEE ACCESS" with a total of 643 articles; the second is "IEEE INTERNET OF THINGS JOURNAL" with a total of 629 articles. Among them, "IEEE COMMUNICATIONS SURVEYS AND TUTORIALS" has the highest impact-factor at 23.7. It can be seen that "IEEE COMMUNICATIONS SURVEYS AND TUTORIALS" is the most influential journal in the wireless transmission of the Internet of Things.

In "IEEE ACCESS", which ranks first in the total amount of papers, the first article on wireless transmission of the Internet of Things was published in 2014, and only this article on wireless transmission of the Internet of Things was published in this journal in 2014. In 2019, there are 222 articles. As of December 12, 230 articles have been published in 2020. The increase in the number of publications also reflects that the popularity of wireless transmission of the Internet of Things has been increasing in recent years. In terms of h-index, the h-index of "IEEE INTERNET OF THINGS JOURNAL" and "IEEE ACCESS" are 49 and 41, respectively, ranking first and second, but the impact-factor of "IEEE COMMUNICATIONS SURVEYS AND TUTORIALS" and "IEEE COMMUNICATIONS MAGAZINE" ranks first and second, with 23.7 and 11.052 respectively, indicating that their research results have a high impact.

It can be seen from Figure. 2 that among the top 5 source titles, as early as 2011, "WIRELESS PERSONAL COMMUNICATIONS" first published an article on wireless transmission of the Internet of Things. And judging from the number of publications in recent years, "IEEE ACCESS" has become the most important journal for wireless transmission of the Internet of Things. In 2016, there were as many as 204 source titles related to wireless transmission of the Internet of Things. It can be seen that wireless transmission of the Internet of Things is receiving more and more attention.
3.2.2. Distribution of the Top 10 Research areas for the Number of Research Papers

The research area can display the field and scope of the research content of the research paper. The following research areas are selected from the research classification module in the field of result analysis of Web of Science.

Figure 3 analyzes the regional distribution of the research direction of wireless transmission of the Internet of Things. The top three research directions are engineering (65.56%), computer science (54.97%), and telecommunications (53.66%). Besides, there are also some comprehensive and related interdisciplinary subjects, such as instruments instrumentation, chemistry, material science, science technology other topics, etc. It can be seen that the main research directions of wireless transmission of the Internet of Things are now more inclined to the directions of machinery, computer science, and communication.

Figure 3. Distribution map of the top 10 research areas in wireless transmission based on Internet of things.
It can be seen from Figure 4 that before 2013, the number of research papers in each research direction did not exceed 50 per year. From 2011 to 2020, the number of papers in the three research directions of engineering, computer science, and telecommunications is higher than the total number of papers in the fields of instruments instrumentation and chemistry and engineer every year. As of 2017, the total number of articles in the direction of engineering has reached 913, followed by computer science with 817. Although the growth trend in 2019-2020 did not increase as sharply as in 2017-2019, judging from the overall number of published papers, machinery, computer science, and communications are still the focus of research on wireless transmission of the Internet of Things. It can also be seen from Figure 4 that there is no significant difference in the total number of published papers between telecommunications and computer science.

3.3. Research Focus and Hotspots in Wireless Transmission Based on Internet of Things

3.3.1. Visualization of Research Hotspots

Figure 5. Cluster density visualization of keyword from 2010 to 2020 based on VOS viewer.
Keywords provide important information about research status and development trends [9]. In the cluster density visualization of keywords, items are represented by their label. Each point in the item density visualization has a color that indicates the density of items at that point. The color of a point in the visualization is obtained by mixing the colors of different clusters. The weight given to the color of each cluster is determined by the number of items belonging to the cluster near the point [8].

By visualizing the cluster density of the keywords of wireless transmission of the Internet of things in Figure 5, we can conclude that the main research content of wireless transmission of the Internet of things is mainly divided into four clusters, which are respectively represented by red, green, blue, and purple. The content in the red cluster mainly includes network, communication system, optimization, and energy, the content in the green cluster mainly includes wireless sensor networks, algorithm protocols, and so on, the content in the blue cluster mainly includes architecture, cloud, cloud computing, model, smart city, etc., the content in the purple cluster mainly includes security, privacy, etc. Among them, internet of things, wireless sensor networks, internet, iot, and networks have the darkest colors, indicating that they are the main research hotspots.

In the network visualization, items are represented by their label and by default also by a circle. The size of the label and the circle of an item is determined by the weight of the item. The higher the weight of an item, the larger the label and the circle of the item. For some items the label may not be displayed. This is done to avoid overlapping labels.

Figure. 6 shows the Network visualization of keyword from in 2020 on VOS viewer.

Figure. 6 shows the Network visualization of keyword in 2020. By comparing the Network visualization of keyword in 2020 and the previous ten years, we can analyze the trend of recent research hotspots in wireless transmission of the Internet of Things. Whether in 2010-2020 or just in 2020, the terms security, optimization, protocol, communication, energy efficiency, etc. have always been the most searched keywords. It can be seen that the wireless transmission of the Internet of Things has maintained a high degree of research enthusiasm in terms of security, efficacy, and communication protocols. Different from before, in 2010-2020, machine learning has appeared 117 times, while in 2020 (as of December 12), it has appeared 72 times. Thus, the combination of wireless transmission of the Internet of things and machine learning has become a hot topic for researchers. From 2010 to 2020, the word cloud appeared 121 times in total, ranking 32nd in terms of frequency of occurrence. However, the frequency of occurrence of cloud in 2020 is not as high as before, indicating that his research interest has decreased slightly than before.
3.4 Research Cooperation

By analyzing the published papers of different countries and organizations, as well as the relationship between their cooperation and co-citation, the distribution of research power for wireless transmission of the Internet of Things can be determined. Besides, it can study the research dynamics of relevant countries and organizations, which has a guiding role in promoting academic exchanges and learning and conducting related research work.

Figure 7 shows the cooperative relationship between different countries. Among them, the larger the circle angle, the more the number of posts issued, the line indicates the cooperative relationship between different countries, and the width of the line indicates the number of cooperation. It can be seen from Figure 7 that China has the largest number of publications and has close cooperation with other countries. Cooperative countries include the United States, Canada, India, South Korea, etc.; in addition, the United States, the United Kingdom, South Korea, Australia, and other countries also publish a lot of articles.

In Figure 8, in the network visualization diagram of country cooperation relations, each dot represents a different country. The larger the dot, the more the country has cooperated with other countries, and the connection between the two dots indicates that they have cooperation, the closer the connection is to red, the more frequent the cooperation is. It can be seen from Figure 8 that China is the country that cooperates most closely with other countries, and has cooperation with the United States, Australia, the United Kingdom, South Korea, India, and other countries. The United States also has more frequent cooperation with other countries, second only to China.
As shown in Table 2, from the perspective of the co-authors of the paper, the international cooperation in the research of wireless transmission of the Internet of Things is also very extensive. There are 10 cooperative articles in 65 countries, accounting for 58.03% of the cooperative countries, and 20 articles or more than 30 collaborative articles also accounted for 45.54% and 38.39%.

Table 2. Cooperation posting case of wireless transmission based on internet of things studies countries and agencies

| Type     | Number of publications of cooperation countries or organizations | Number of cooperation countries or organizations | Proportion |
|----------|-----------------------------------------------------------------|-----------------------------------------------|------------|
| Countries| 10                                                              | 65                                            | 58.03      |
|          | 20                                                              | 51                                            | 45.54      |
|          | ≥30                                                             | 43                                            | 38.39      |
| Organizations| 5                                                               | 670                                           | 15.83      |
|          | 10                                                              | 312                                           | 7.37       |
|          | 15                                                              | 187                                           | 4.42       |

Figure 9. Network visualization of the cooperation of different organizations from 2010 to 2020 on VOS viewer

The same as Figure 6, in the network visualization, items are represented by their label and by default also by a circle. The size of the label and the circle of an item is determined by the weight of the item. The higher the weight of an item, the larger the label and the circle of the item.

In Figure 9, the visual graph of cooperation relationship between two organizations. The more connections an organization has, the closer cooperation it has with other organizations. For example, the circle of beijing univ posts&telecommu is very large and there are many connections, indicating that he is a popular cooperative organization and has a higher probability of appearing in the same paper with other organizations.

4. Conclusion and Discussion

This paper uses bibliometrics methods to conduct data mining and analysis on the wireless transmission of the Internet of Things, and finds that the international wireless transmission of the Internet of Things has the following characteristics and laws:

(1) Since the first article on wireless transmission of the Internet of Things appeared in 2010, the number of research papers on wireless transmission of the Internet of Things has increased steadily, and
so far the number of papers has not reached the peak. Although the growth rate of the number of published papers in 2018-2019 has declined, there are still more than 1,500 papers published in 2019. In the past 10 years, the number of authors studying wireless transmission of the Internet of Things has been steadily increasing each year. As of December 12, 2020, the total number of authors has reached more than 15,000. The total number of citations each year is also on the rise, with the citation frequency reaching 11457, 19739, 30793, and 33394 in 2017, 2018, 2019, and 2020 respectively.

(2) From the perspective of the research field of wireless transmission of the Internet of Things, the country that publishes the most papers is China, with 1912 papers published, accounting for 31.319% of the total number of papers, and China has the highest h-index (121) and the highest frequency of citations (106758), Which shows that China has a great influence on the wireless transmission of the Internet of Things. Among the top 20 research organizations, 12 are from China, three from South Korea, and one each from the United States, Australia, Spain, Singapore, and Saudi Arabia. The top 3 organizations are all universities in China, namely Beijing Univ Posts Telecommun, Chinese Acad Sci, Univ Elect Sci Technol China. Five of the top 10 researchers in this field are Chinese. "IEEE ACCESS", "IEEE INTERNET OF THINGS JOURNAL", and "SENSORS" have the largest number of published papers, 643, 629, and 626 respectively. Judging from the number of papers published in recent years, "IEEE ACCESS" has become the most important journal for research on wireless transmission of the Internet of Things.

(3) "The Internet of things: a survey", "Internet of things (IoT): a vision, architectural elements, and future directions", and "Internet of things in industries: a survey" are the three most frequently cited papers in the research of wireless transmission of the Internet of Things, with the highest citation rate of 5934. The VOS viewer's research on keyword hotspots shows that many researchers have done a lot of research on keywords such as "internet of things", "wireless sensor network(s)", and "protocol". Research focuses include sensor networks, communication protocols, security, efficiency, etc.

Although the international research on wireless transmission of the Internet of Things is at a high-speed discovery stage, there are still some issues that need to be further explored in data mining and visual analysis.

(1) At present, sensor networks, communication protocols, and efficiency are the hotspots of wireless transmission research on the Internet of Things. In addition, there are few researches on the specific methods of wireless transmission of the Internet of Things. Therefore, we should increase the research investment in the specific transmission methods, and at the same time, consider the application scenarios that are not used, and propose the corresponding best transmission method.

(2) Continue to increase innovation, strengthen the research and innovation of wireless transmission perception technology of the Internet of Things, especially the development of high-end chips, and further solve the problems of low power consumption, low cost, and miniaturization of sensor equipment, so as to break through communication networks, mobile terminals, application platform, and other key technologies, vigorously develop research on new sensor recognition technology, IoT support technology, and 5G communication technology.

(3) In the future, we should further broaden the breadth and depth of the research on wireless transmission of the Internet of Things, so as to promote the deep integration of Internet of Things wireless transmission technology with different disciplines, as well as the in-depth application of Internet of Things wireless transmission in smart grid, smart security, smart home, and other fields. Strengthen the research of mobile group perception technology, promote the wireless transmission of the Internet of Things to penetrate people's daily life, and provide intellectual support for fostering a harmonious and integrated Internet of Things ecological environment and promoting the industrialization of Internet of Things applications.

(4) The situation of cooperation between countries is relatively ideal, but the cooperation between organizations in different countries is less than that between different domestic organizations, which will not be conducive to the direction of research in this field and the globalization of scientific research forces. It is necessary to strengthen the connection between research institutions in different countries, coordinate innovation, establish a development model that uses industry to promote scientific research,
and scientific research to lead the industry, and promote the rapid transformation of scientific and technological achievements

5. Limitation
This study has some limitations. Our bibliometric analysis data comes from SCIE. Although this database is very authoritative and comprehensive, some research papers on wireless transmission of the Internet of Things will still be omitted. Our research has certain timeliness, because this database will be updated regularly, especially the collection of papers in 2020 is not particularly comprehensive, we searched for research papers as of December 12, 2020.

The phase division of keywords is not particularly detailed. It is not strictly in accordance with a uniform time span. Some documents with a small number of research papers may be omitted, but the research methods and materials are unique.

In the analysis of research power, the principle of screening and sorting is based on the number of research papers, so there may be a small number of papers published, but the research power with a high number of citations is missing. Subsequent research can be filtered and sorted according to the number of citations.

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