



Mapping of Internet of Things (IoT): A Scientometric Assessment on the Global Research Output

R Dhanya

Department of Library and Information Sciences
Tata Institute of Social Sciences
Mumbai

J. Shivarama

Assistant Professor, Department of LIS
Tata Institute of Social Sciences
Mumbai

Abstract

‘Internet of Things’ or ‘IoT’ is an interrelated system of machines, devices, objects, people or even animals with unique identifiers, which can exchange data or information via internet or networking, without human interference or any kind of interaction between humans and machines. The present study aims at conducting a scientometric assessment to observe the structure of the scientific literature on IoT more vividly, so as to improve the references on its information sources which further helps in knowledge recreation. The research is based on 7.961 document records on the topic ‘Internet of Things’. The study emphasizes areas such as citation analysis, authorship patterns, research collaboration, area or subject of research, publishers and publications, co-word analysis, etc. The results show that the most cited article till this day in the ‘IoT’ field is “The Internet of Things: A Survey”, by Luigi Atzori, et. al. with 5071 citations . The top author with the most publications is Zhang Y . The study proves that good collaborative works are happening in the field of ‘IoT’ and that the pattern of co-authorship is strong. The top publisher in the field of ‘IoT’ is IEEE Internet of Things Journal. There is a trend of gradual arithmetic increase in the number of publications with every passing year. China accounts for 31% of the total Global Research Output on ‘Internet of Things’, which is followed by the US contributing 19%. The study also gives much importance to the keywords that have the similar conceptual idea as that of ‘Internet of Things’. The study gives a better understanding for



information professionals and knowledge managers about the strength of literature revolving around the 'Internet of Things' domain.

Keywords: Scientometrics, Internet of Things, Global Publications, IoT

0 Introduction

The most common way to learn about a field of research is to evaluate and analyze the available literature of that particular domain. Scholarly publications form the background for all new theoretical discussions that take place within the research community. Analysing and reviewing the literature of a particular subject reveals various information patterns that further help in understanding the topic. Library and Information Science, being an interdisciplinary field, have managed to bring about various methods for evaluating the scholarly research output. And when it comes to quantitative analysis, more opportunities opened up to Metric studies, leading to further implementation of its analogies. These include concepts such as Bibliometrics, Librametrics, Scientometrics, Webometrics, Infometrics, Altmetrics, etc.

The term 'Scientometrics' was introduced in the year 1969 by Russian scientists Mulchenko and Namilov. "Scientometrics" is quantitative analysis of the literature available related to science topics. It involves mathematical and statistical methods to measure and analyse the research output on a scientific domain. Attributes such as title, subject, author, institution, country, etc. can be used for evaluating the scientific network validating the evolution happening in the scientific discipline. Scientometrics helps describe the relationship between science, scientific technologies and their research productivity. The goal of scientometric assessment is to observe the structure of the scientific literature more vividly, so as to improve the references on scientific information sources which further helps in knowledge recreation. Hence, the research here plans a scientometric analysis of the global research output on the topic 'Internet of Things'.

'Internet of Things' or 'IoT' is an interrelated system of machines, devices, objects, people or even animals with unique identifiers, which can exchange data or information via internet or networking, without human interference or any kind of interaction between humans and machines. Compared to other fields of information technology, research on 'Internet of Things' has revealed that there is so much potential hidden in this domain and furthermore investigation and integration of disciplines needed to be done. The application of Scientometrics on this particular domain can be deemed very useful for research scholars who intend to conduct an in-depth research on 'Internet of Things'. It reviews the relevance and validity of the available scholarly literature related to the field. These kinds of studies help to motivate young scholars to increase the creativity and productivity of research in their particular field of interests.



1. Literature Review

Kumaraswamy, Riyaz Ahamad and Chaman Sab (2019) published the article “Internet of Things (IoT) Research: A Scientometric study of Indian publications during 2015-2019”. It is a scientific analysis of Indian IoT research for 5 years. Their objective is to study the research output, citation rate, relative growth of research, international collaborations, co-authorship, research productivity, etc. in the IoT domain. According to their study, out of the 9,680 global research publications in the span of 5 years, 645 of them are Indian.

Jayasekara and Abu (2018) in their paper “Top Fifty Highly Cited Publications on the Internet of Things”, analyze the publication pattern of the most cited research papers on IoT. The top 50 most-cited publications of IoT were analysed according to the title publication details, citation, usage count, research collaboration, authorship pattern, and other related criteria. The study shows that most of the publications consisted of research articles. Co-authorship was more prominent than single author works. The USA and China promote more co-authorship or collaborative research than other countries.

Gupta et. al. (2015) did a “Scientometric assessment of the global output regarding Internet of Things from the year 2005-2014”. According to their study, the average annual growth rate of global publications in the field of IoT is 98.63% and the overall citation impact is about 1.97. The top 12 countries that contribute to the research on IoT account for about 89% of the total global publication on IoT. It also gives an idea about the top most authors, productive organizations, and journals in the field of IoT.

The article “Internet of Things: A Scientometric Review” Juan Ruiz-Rosero, et. al. (2017) worked on a scientometric study of 19,035 publications on the topic of “Internet of Things”, from 2002-2016. The study gives a vivid idea about the recent research trends in the field of IoT. The findings of the paper include the most published author, country affiliation of authors, top searched keywords, applications, hardware and software processing and communication protocols of IoT.

Yan et. al. (2015) worked on an article “Mapping the intellectual structure of the Internet of Things (IoT) field: a co-word analysis”. 758 research papers from 2000-2014 were selected. Their study was focused on co-word analysis so that more papers can be explored and identified in the Internet of Things domain. The paper helps researchers to easily understand the subject and direction of the IoT domain.

Shon and Young-Woo (2015) did a study and wrote an article ‘Dynamic Analysis via Keyword Mapping for Internet of Things’. Shon and Young, in their paper, proposes a searching method for the Internet of Things domain, using keyword mapping and dynamic analysis. Centering keywords for understanding the emerging technologies is one of the most successful ways for mapping technological advancements.

Lu Tan and Neng Wang, (2010) in their article “Future internet: The Internet of Things”, tries to show the basic structure of the Internet of Things. They also mention issues concerned with the interoperability and architecture of IoT. The authors have come up with an interesting

proposal of the architectural design of Internet of Things. With that idea, they design a specific application model of the Internet of Things. This model facilitates the management of automatic facilities in smart campuses.

2. Objectives of the Study

The specific objectives of the study is to;

- identify the top prolific authors, publishers and publications of the IoT domain.
- examine the citation pattern of the research output on ‘Internet of Things’.
- measure the co-authorship pattern and collaboration in the ‘Internet of Things’ research.
- analyse the significant keywords related to the domain of ‘Internet of Things’ based on co-word analysis.
- evaluate the top trending research topics related to ‘Internet of Things’.

3. Methodology

The present study focuses on conducting a scientometric study on the global scholarly research output available on the ‘Internet of Things’ domain. The aim is to understand and analyze the trend of the research done on ‘Internet of Things’ using scientometric methods. The study attempts to evaluate the overall growth pattern and development of the research productivity in the particular domain of ‘IoT’. The required data is downloaded from bibliographic databases and identifies the prominent research articles related to ‘Internet of Things’. Using various statistical methods, scientometric inferences are made based on the bibliographic data retrieved. Data retrieving required advanced searching techniques available in the databases. The retrieved data were organised into tables or converted into associated charts, graphs or diagrams using applications such as Google sheets, VOSviewer and Tableau.

4. Method of Sampling

The sample of study comprises the data or records downloaded from the Web of Science on February 1st, 2020. The attributes considered for the scientometric study of the scholarly publications on “IoT” are Title, Author, Author Full Name, Abstract, Publication Type, Source, etc. Since “Internet of Things” is considerably a new topic in the field of Information Sciences, scholarly publications only started gaining recognition from 2005 onwards. Hence, all the available publications from the year 2005 are considered for this research.

Moreover, there are many other keywords that bring about the same concept as that of the ‘Internet of Things’. The articles with keywords other than ‘Internet of Things’ or ‘IoT’ do not gain much recognition in the IoT domain. Hence, the sample also includes such articles with similar research potential.

5. Data Collection and Organizing

The data used for this research is secondary. It is collected from Web of Science (<https://apps.webofknowledge.com/>), which integrates bibliographic information from six online databases. Advanced searching techniques were used to dig up and filter data based on the Title, Topic, Author, Funding Agency, Publication Name, Year Published, Timespan, etc.

Two sets of data are collected for the study. The first set comprises the bibliographic data retrieved through boolean searching command **TI=(Internet of Things OR IoT)**. This gives the details of all the publications that mention “Internet of Things” or “IoT” in their Titles. 7,961 records were retrieved by this method of searching.

The second set of data was retrieved using **TS=(Internet of Things OR IoT) NOT TI=(Internet of Things OR IoT)** command. This gives the details of all the publications with “Internet of Things” or “IoT” as their topic, but is not mentioned in their Titles. 9,031 records were retrieved by this searching method.

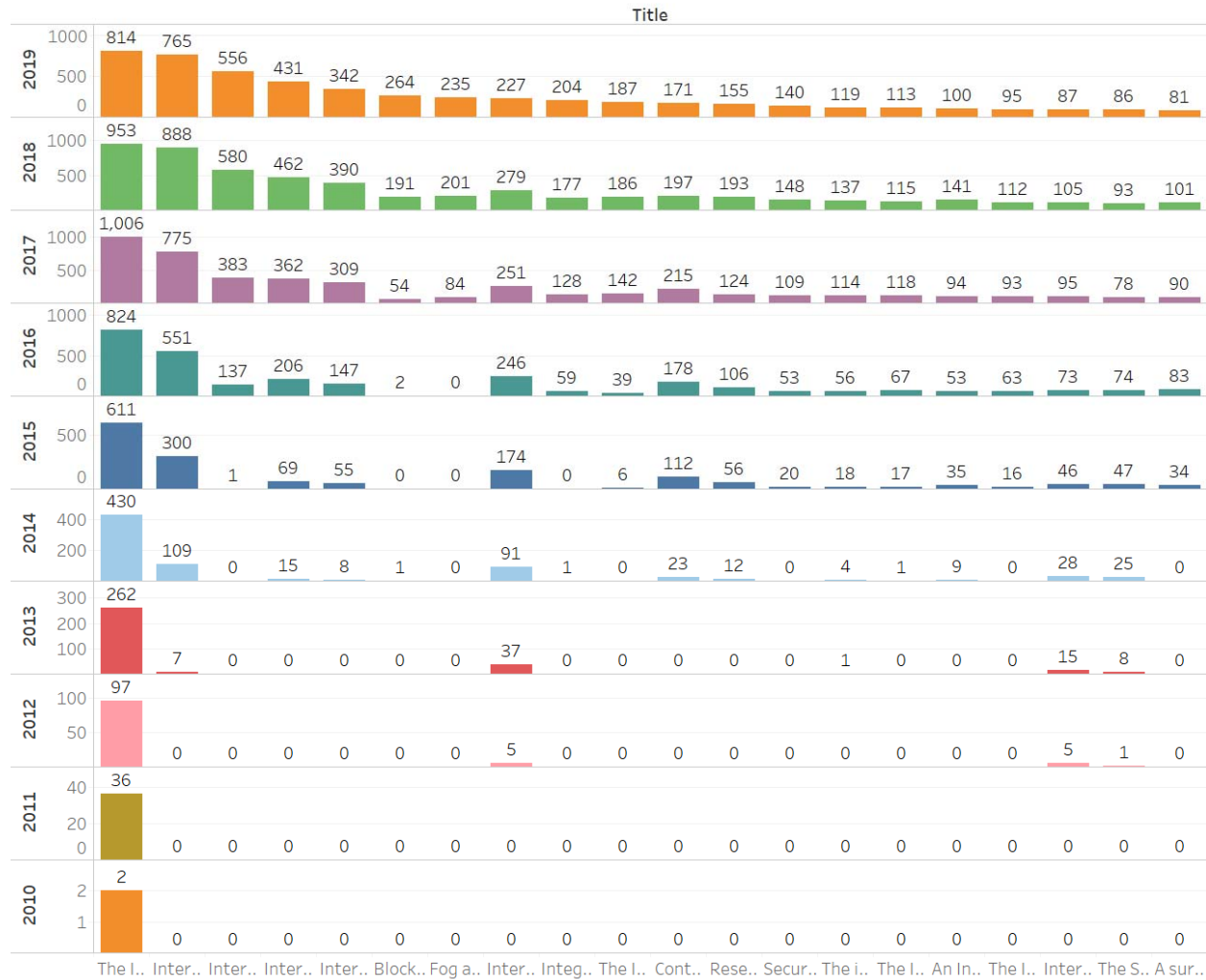
Both data sets are organised and arranged in descending order of the times cited. The retrieved records of data are stored in arrays of rows and columns with the help of Google Sheets (Cloud based Online Spreadsheet Program). The tabulated data is divided into columns such as Type of Publication, Title, Author, Author Full Name, Abstract, Publication Date, etc. Separate sheets are used to organise the different data sets - first data set comprising the records that have the term “Internet of Things” or “IoT” in their title, and the second dataset comprising every other bibliographic details of the publications within the topic range “Internet of Things”, without the term being mentioned in the title.

6. Data Analysis and Findings

The analysis was done mostly in Google Sheets. The data extracted from the Web of Science database was imported to the spreadsheets. Based on various categories and criterias, the data was filtered out. The output of the data filtering was arranged in various spreadsheets, where more analysis took place using various statistical formulas available in Google Sheets. The data organised in tables were converted into charts, graphs and diagrams using Google sheets, VOSviewer and Tableau.

6.1. Top Cited Articles in the “Internet of Things” domain

The data was analysed to find out the top 20 most cited documents in the “IoT” domain. The article name, their authors, their source of publishing and the total number of citations received are analysed. The citations are calculated from the year range of 2010 to 2019 and also the count through each year. Figure (1) is a bar graph showing the citation analysis of top 20 most-cited articles from the year 2010 to 2019.



The I.. Inter.. Inter.. Inter.. Inter.. Block.. Fog a.. Inter.. Integ.. The I.. Cont.. Rese.. Secur.. The i.. The I.. An In.. The I.. Inter.. The S.. A sur..

Figure 1: The year-wise citation count of the top 20 most-cited articles on the “IoT”

6.2. Top authors and authorship pattern

The analysis has resulted in interpreting the fact that the records available on ‘Internet of Things’ are the research outputs of various scholars from all around the world. Even Though there are no prominent authors in the domain as of now, each one of them have contributed much to this emerging topic. The details of the top authors and their number of contributions is analysed. Figure (2) is a Line graph depicting the authorship pattern as per the study.

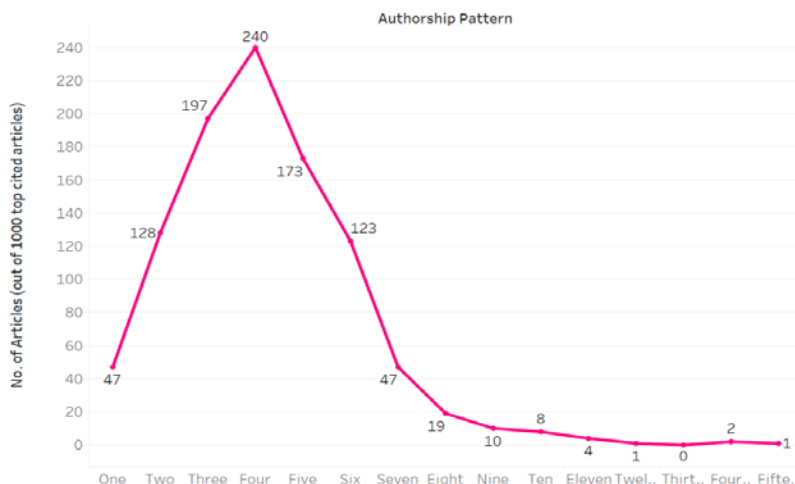


Figure 2: Authorship pattern as seen in the top-cited articles on IoT

6.3. Author collaborative works

Collaborative works improve the quality of the study as more than one intellectual mind is working simultaneously on a particular topic. Even Though ‘Internet of Things’ is a new domain, good signs of collaborative work can be seen from the analysed data. The top 30 authors who did collaborative works are mentioned in the connecting diagram of Figure (3). The authors are depicted by the coloured circles and their collaboration between other authors are depicted by the lines linking the circles. The size of the circle shows the strength in the number of documents produced by the respective authors.

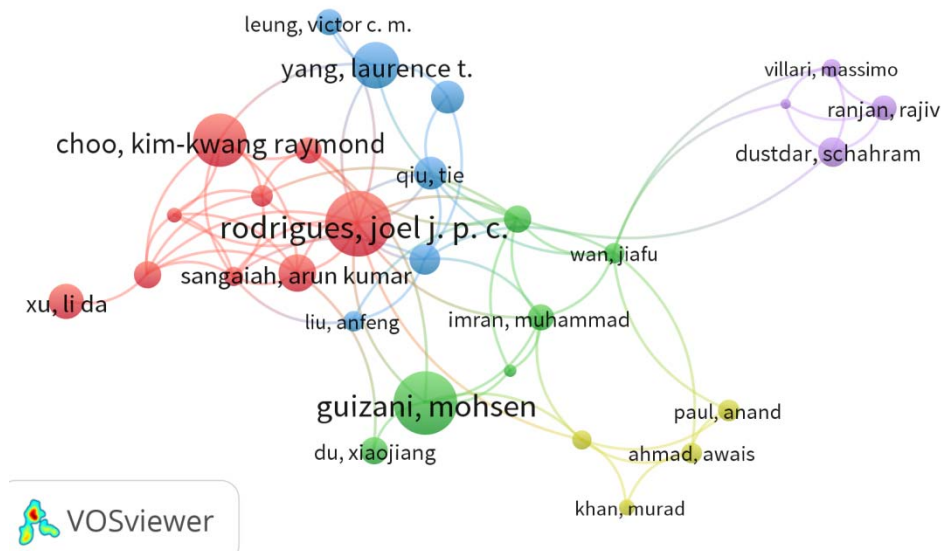


Figure 3: Connecting diagram showing author collaboration in the “Internet of Things” domain.

6.4 Publication of research documents

The study analyses the details of the number and type of documents comprising the literature. As per the data, articles make up the major portion. And the prominent contributors are the journals focused on communication and computer technology. Most of the publishing is done by IEEE Internet of Things Journal, a journal specifically for ‘IoT’. The analysis shows the trend where the number of documents getting published in the field is increasing in an arithmetic progression. Figure (4) is a Bubble map that depicts the year of publication and the corresponding number of records published.

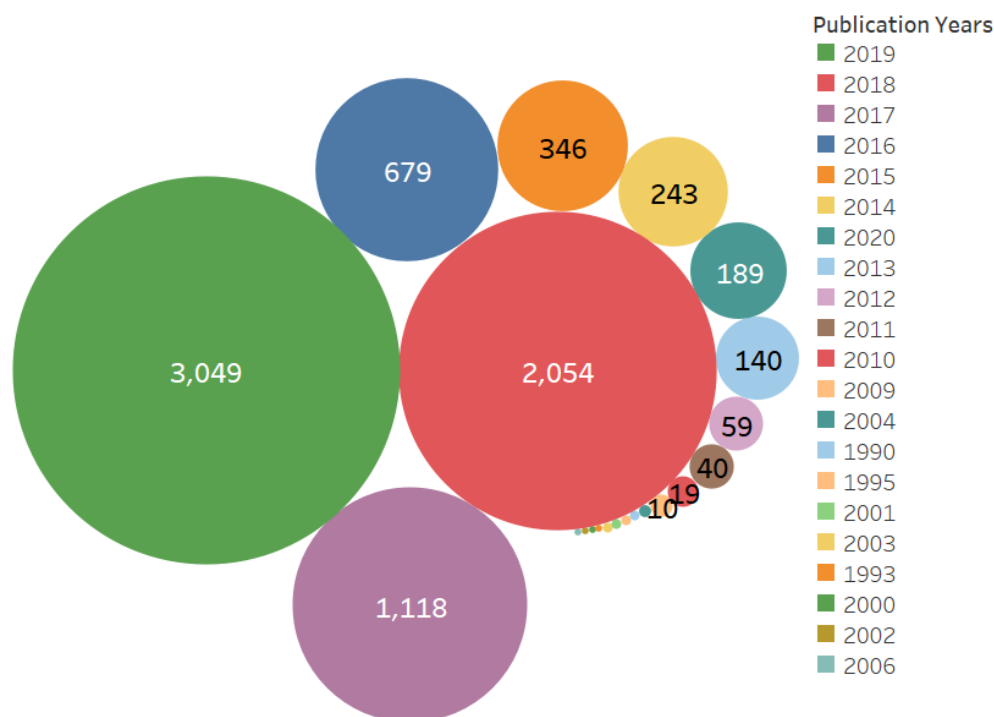


Figure 4: Year-wise publication count of “IoT” research documents

6.5. Research output on “IoT” based on Region and Language

An extensive analysis was done based on the countries/regions contributing to ‘IoT’ research, the number of records contributed and their percentage. Figure (5) is a Geo Chart showing the top regions that contributed to the “IoT” research. A language check was also done showing that 99% of records or documents were found to be in English.

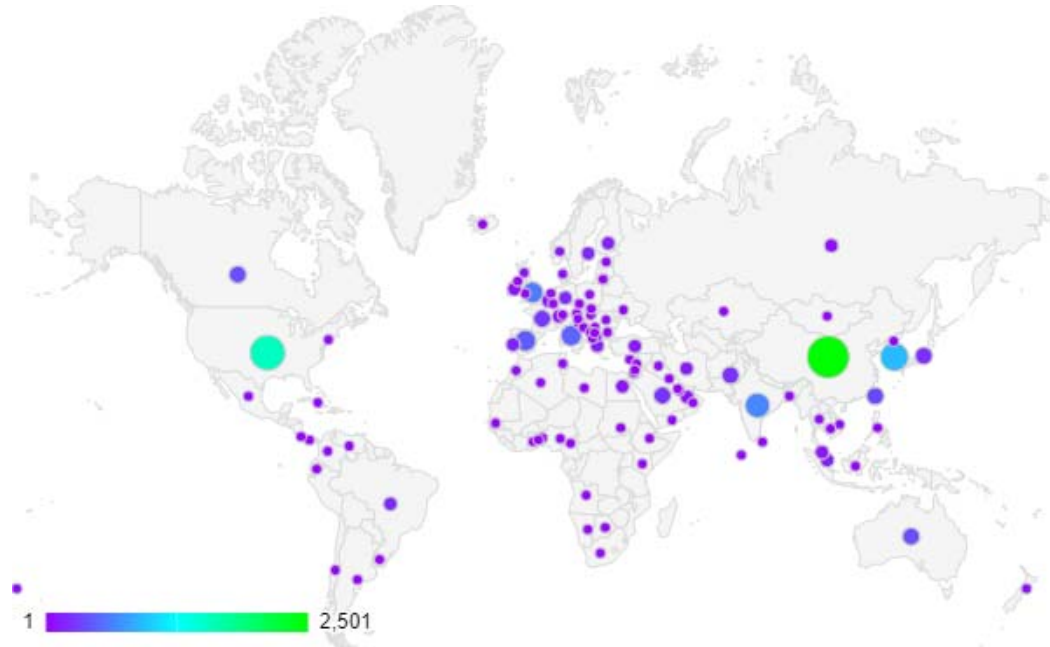


Figure 5: Top Regions contributing to “Internet of Things” research

6.6. Co-Word Analysis

When it comes to information retrieval about a particular topic, there might be confusion in the minds of the information seekers as to whether the particular search keywords are the only keywords that can provide them with the relevant pieces of information. A co-word analysis of a particular research domain helps in identifying keywords which may represent the same ideas, concepts, technology or subject domain as that of the particular research domain. Figure (6) is the connecting diagram showing the top Author keywords that are most-frequently commonly associated with IoT. The coloured boxes represent the keywords, the size of the box indicates their frequency of occurrence and the interlinking lines depict their relationships.

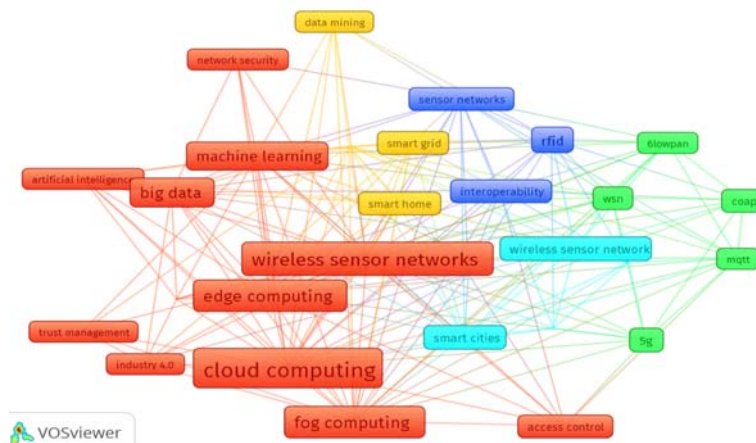


Figure 6: Frequency of Author keyword occurrences in the articles of “IoT” domain

Figure (7) shows the top 30 selected keywords related to ‘Internet of Things’ and their comparison based on the following criterias;

- Number of Articles showing the particular keyword as its topic out of the whole 7,961 documents that have ‘Internet of Things’ or ‘IoT’ in their title.
- Number of Articles coming under the topic ‘Internet of Things’ which has the particular keyword in their title.
- Number of Articles that have both ‘Internet of Things’ and the particular keyword in their title.

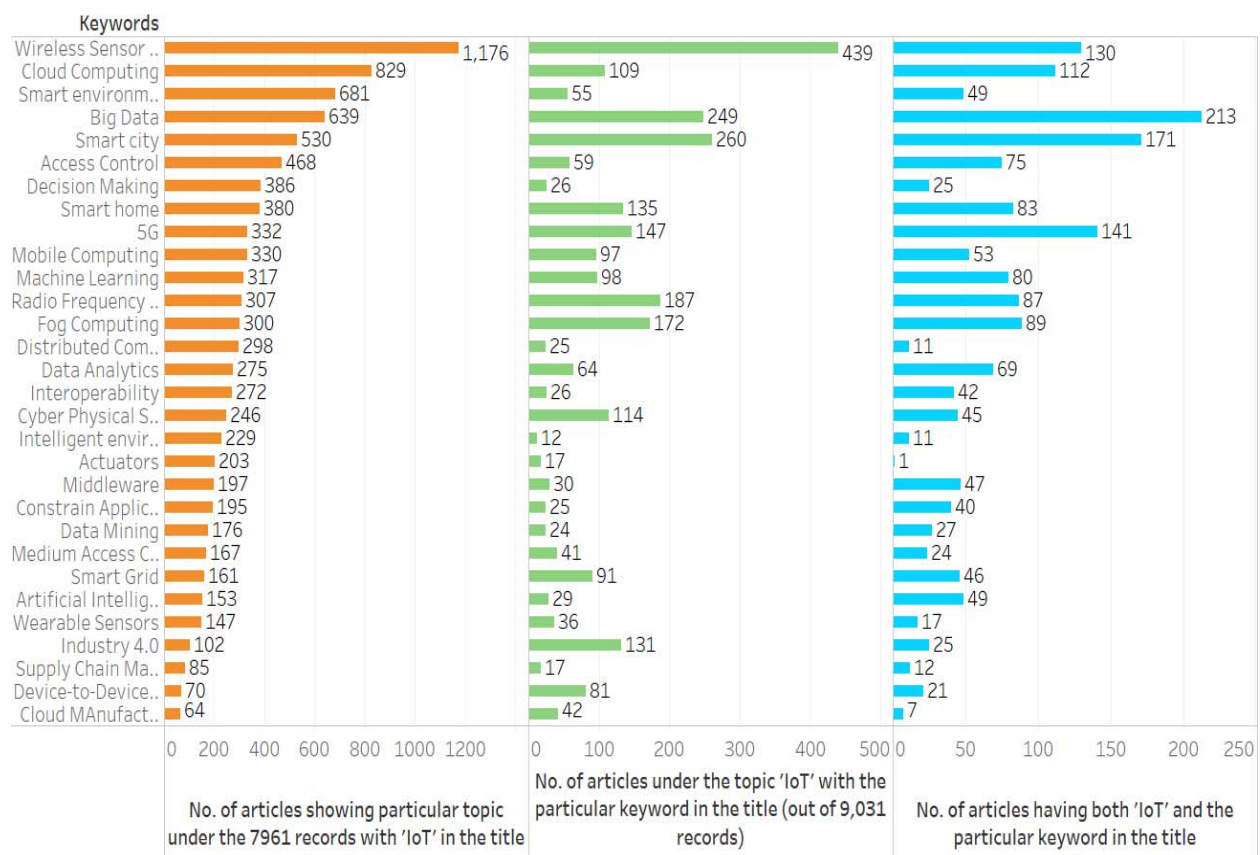


Figure 7: Top 30 Keywords that are most related to “Internet of Things”

7. Major Findings

The analysis shows that the article “The Internet of Things: A survey”, by Luigi Atzori, et. al. is the most cited article, which received 5,071 citations to this date. The article was published in “Computer Networks” journal. This is the only article that received citations every year from 2010 to 2019. For this particular article, the citation count is highest in 2017, which

gradually decreases to 2019. But for the other articles, there is a trend of gradual increase in citations with every passing year.

An analysis of the top 25 authors in the “Internet of Things” domain shows that Zhang Y is the author who published 64 articles on “IoT”, which is the highest. The highest record for co-authorship is 4 authors, which adds up to 240 articles out of the 1000, most-cited “IoT” articles. One and Two authored articles only make up to 4.7 % and 12.8 %. The study shows that Mohsen Guizani is the author with the highest number of collaborative works, which is 49 articles that received 2,326 citations.

Majority of the research documents available on the “Internet of Things” topic are Articles, which accounts to 6,934 documents that make up 87.1% of the total documents. “IEEE Internet of Things Journal” is the top journal that published 828 articles about “Internet of Things”, which accounts to 10.4% of the total publication. An analysis on the year-wise publication count of research documents on “IoT” shows a gradual increase in the number of publications with the passing year. The most number of records, that is 3,049, was published in 2019, which accounts to 38.3% of the total publication.

The field of Computer Science contributed about 4,841 documents to “IoT” research, accounting for 60.4% of the total documents, followed by Engineering, Telecommunication and Instruments instrumentation.

Considering the analysis on the top 25 countries contributing to the global research output on “Internet of Things”, it is evident that China tops all other countries with 2,501 research documents, accounting for almost 31% of the total “IoT” research output. The highest majority of documents are written in English. That is 7,931 out of 7,961 documents are in english (99.6%).

According to the study, Cloud Computing is the most used Author Keyword in the documents regarding “Internet of Things”. It occurred in 266 articles, followed by ‘Wireless Sensor Networks (WSN)’ and ‘Fog Computing’. According to three criteria defined for co-word analysis, in the first criteria, ‘Wireless Sensor Networks’ is the most used keyword. ‘Smart City’ is the most used keyword according to the second criteria. And ‘Big Data’ is the most frequently used keyword as per the third criteria.

8. Suggestions

- Scientometric study is one of the most genuine steps towards achieving the goal of increasing the number of research and development works in every field possible. Hence, it is advisable that more of these studies happen in every research domain.
- The records available on the topic ‘Internet of Things’ is comparatively low compared to other similar topics having a technological backbone. Hence, there is a big necessity for more research to be done in this domain.
- The citation receiving trend of articles in the ‘IoT’ domain is comparatively poor compared to that of other prominent research domains. More literature reviews and

Scientometric analysis on ‘IoT’ may help scholars to be more aware of the latest research works in the field.

- The research productivity is still improving for the ‘Internet of Things’ domain. The productivity is so low that even Lotka law cannot be applied. Hence, research have to be promoted in this field.
- Co-authorship is comparatively good in this domain. More collaborative works will help improve the research.
- Out of all the countries contributing to ‘Internet of Things’ research, China alone contributed 31% of the total Global Research Output. More countries have to understand the relevance of the ‘IoT’ domain and come up with more research projects.
- 99.6% of the 7,961 documents considered for this scientometric study are written in English language. This might be the reason why there is a drastic growth in the domain within a short period. More articles produced in English language might help in further growth of the ‘IoT’ domain.
- The co-word analysis conducted on this topic gave a basic idea about all the keywords that share a similar conceptual basis with that of the topic ‘Internet of Things’. Therefore, further publications could also mention the relevance of their relation with other similar topics.

9. Conclusion

In this research, most of the relevant criteria for evaluating an emerging field of research is mentioned and analysed. The study focused on the bibliographic data available about the topic and tried to conduct various analyses. The application of Scientometrics on this particular domain can be deemed very useful for research scholars who intend to conduct in depth research on ‘Internet of Things’. These kinds of studies help to motivate young scholars to increase the creativity and productivity of research in their particular field of interests.

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