

A Bibliometric Study about Internet of Things

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Abstract—The objective of this study was to map the scientific production on the Internet of Things (IoT), through a bibliometric analysis. The methodological procedures were delineated by a quantitative approach, the research involved data taken from the scientific database of the Web of Science. The keyword "internet of things" was used for the searches in said database, within a period of 09 years, between the period from 2010 to 2018. In the searches 2,446 publications related to the topic were identified, an average of 271.7 articles published per year. The year with the highest number of publications was the year 2018, with 932 publications. The author with the largest number of publications was the Chinese researcher Zhang Y, of Jiangnan University, School of Internet of Thing Engineering, with 21 articles published. As for the article's publication areas, the ones that stood out the most were the following: Telecommunications, Computer Science Information Systems and Engineering Electrical Electronic, with 1,002; 940; and 811 published articles respectively. Among the journals, the ones that had the largest number of publications were: the IEEE Access and the IEEE Internet of Things Journal, both with 157 publications. Regarding the educational institutions, the highlights with regard to the number of articles published, were to the institutions: Chinese Academy of Sciences, Beijing University of Posts Telecommunications and King Saud University. The country with the largest number of publications in the area was China, with 783 publications. It should be noted that most of the publications were written in English, with a total of 2,402 publications in English.

Keywords—Bibliometrics, Scientific Production, Internet of Things.

I. INTRODUCTION

It is noticeable the significant increase in the use of technologies in the day to day of people: cell phones,

notebooks, tablets, among other electronic devices. In most cases these devices are connected to the internet, enabling interaction and communication between people in different parts of the world. The speed in communication is a characteristic of our daily life, information is available at the same time as it happens and all this computerization and interconnectivity have been changing the way we live in society.

The use of the Internet for communication between people is a consolidated reality, however, the trend points to a communication between objects and electronic equipment, capable of processing data and returning information to its users, called the Internet of Things (IoT).

Internet of Things (IoT) is when devices are connected to the Internet and can communicate with each other without human intervention. In this way, Mota and Batista [1] affirm that communications will be conceived not only between humans, but also between humans and things, and between things without interaction with humans.

The Internet of Things (IoT) aims to interconnect all the electronic equipment and objects (things) that are used in the everyday of the people to the internet, with the use of sensor networks, in order to process this information and return benefits to its users [2].

Teixeira et al. [6] states that in the Internet of Things (IoT) "things", objects or devices, become active participants in the informational and social business processes, being able to interact and communicate among themselves, exchanging information collected from the environment and reacting autonomously to the events of reality, as well as influencing in the social context without the intervention of the human.

In this sense, it is expected that there will be between 26 and 50 billion connected objects by the year 2020, reaching one trillion by 2025, 40% of which will be in emerging countries, such as Brazil and India [9],

generating approximately US\$ 14.4 trillion direct in IoT projects [11].

Therefore, the objective of this research was to analyze the academic scientific production related to the Internet of Things (IoT) in the last 9 years (from 2010 to 2018), providing researchers and academia with an overview of the studies and scientific technological developments in this area.

This article is divided into five sections. The first section presents an introduction on the topic covered in this research. The second section presents a brief review of the literature related to the subjects of bibliometric and Internet of Things (IoT). The third section shows the methodology used in the development of this research. The fourth section presents the analysis of the data obtained in the research. The fifth section brings the final considerations on the research.

II. REVIEW OF LITERATURE

Internet of Things (IoT)

Teixeira [6] states that the Internet of Things (IoT) is a dynamic, global network infrastructure with self-configuration capabilities based on standardized and interoperable communication protocols where physical and virtual "things" have identities, physical attributes and virtual personalities.

According to Maeda [8] the Internet of Things (IoT) is nothing more than the continuation of the digitalization and digital transformation movement, it is the Internet invading the physical world and connecting everything. According to Evans [20], the Internet of Things (IoT) represents a real evolution of the Internet, a major advance in the ability to collect, analyze and distribute data, representing a breakthrough that will lead to the use of revolutionary applications.

According to Lu and Singh [21], the Internet of Things (IoT) is a worldwide network of interconnected objects, with specific address based on standard communication protocols. Miorandi et al. [22], in turn, ensures that the Internet of Things (IoT) is based on three pillars, regarding intelligent: identifiable objects; communicable; and interaction between them, with several networks of objects interconnected with end users.

The application of the Internet of Things (IoT) can be understood by the interaction between objects, systems, services and people, represented by a basic infrastructure, which supports the development of complex platforms, allowing an environment and a more intelligent society [23].

The IoT consists of the network interconnection of the objects used in our daily life, equipped with intelligence, allowing to integrate all objects through embedded systems [24].

It is a revolution that is made possible by the combination of technologies, sensors, processors, cloud computing and wireless connectivity [25].

It is a new form of information and communication technology that differs from the traditional one, where people communicate with other people. Things can now also communicate with people and other connected objects [26].

Bibliometrics

According to Silva et al. [14] "*The term bibliometric is derived from the fusion of the suffix "metric" with bibliography, information, science and library respectively, are analogous or very close in nature, objectives and applications.*"

Table.1: shows some of the main bibliometric indicators, according to Splitter, Rosa and Borba [17]:

Table. 1: Adapted from Splitter, Rosa and Borba (2012).

INDICATORS	CONCEPTS
Lotka's Law	Investigates the frequency distributions of the author of articles of a certain theme/area.
Bradford's Law	It investigates the frequency distributions of the number of articles published by periodicals of a certain theme/area.
Zipf's Law	It investigates the frequency distributions of the vocabulary of texts of a certain theme/area.
Number of publications by author, journal, institution or subject	Investigates the volume of publications of authors, periodicals, institutions or subjects of a certain area.
Number of co-authors/collaborators	It investigates the dynamics of the volume of research carried out in a collaborative way, either between individual or group research, or national and international.
Co-publications: publication with authors of different countries, institutions	It investigates the cooperation between representatives of entities and countries, in joint research, with the purpose of creating a matrix that shows the main partners and provides the description of the scientific network.
Number of citations	It investigates the impact of articles, journals and researchers on the basis of the

	number of citations.
Affinity Index	It investigates the relative rate of scientific exchange (between countries, institutions) by means of quotations.
Scientific links	Investigates and measures the influence of networks between different scientific communities.
Co-citations	It investigates the number of times that two or more articles are quoted simultaneously in one article.

It is worth mentioning that for Vanti [18], the Bradford Law or Dispersion Law allows the measurement of journal productivity in order to establish the nucleus and dispersion areas on a given subject in the same set of journals.

The most popular indicators in bibliometric articles are based on counting the number of articles, journals, authors, authorships, institutions or quotes. Affinity indices, scientific links, and co-citations are rarely used, as are the frequency distributions used in the Lotka Laws of Bradford and Zipf [17].

Bibliometrics as a method has the advantage of softening the elements of judgment and generating quantitative results that tend to be the sum of many small judgments and judgments made by several people [13].

The bibliometric studies are used to evaluate the productivity and the quality of the research of the scientists, through the measurement based on the numbers of publications and quotations of the diverse researchers [18].

A bibliometric research allows the identification and description of a series of patterns in the production of scientific knowledge. In addition, it serves to estimate with quality and quantity, the production of published scientific articles on a particular theme, highlighting the main authors (researchers and institutions) involved in this process, who collaborate for the aggrandizement of science [4].

At the beginning of the 21st century, two phenomena occurred that modified the way researchers are using bibliometric indicators. One of them was the development of the open *Google Scholar* search engine, from 2004, by *Google* and the creation of *Microsoft Academic Search*, created in 2006 and relaunched as *Microsoft Academic*, in 2016. In addition to the two search engines mentioned, there is also the free software *Harzing's Publish or Perish*, created by the Australian researcher Anne-Will

Harzing, and developed based on the *Google Scholar* platform.

All these search mechanisms have been helping researchers in the development of bibliometric researches, allowing the use of several types of bibliometric indicators related to a particular theme.

The second phenomenon responsible for this change, in the form of the use of bibliometric indicators by researchers, was the indexing of journals in large international databases, which has been occurring over the years individually or collectively [15].

Unfortunately, in Brazil, the lack of indexation of Brazilian journals in various areas of knowledge in the large scientific databases has discouraged the creation of a culture of more sophisticated bibliometric indicators by the Brazilian research community until the beginning of the century XXI [15].

III. METHODOLOGY

The methodology used in this research had a quantitative and descriptive character, which initially undertook on a bibliographical research on the subjects bibliometrics and Internet of Things (IoT), carried out through research in scientific articles, dissertations, theses, seminars and periodicals of the area.

According to Cervo and Bervian [5], the method materializes as a set of several steps that must be followed to carry out a research and that configure the techniques. Then, bibliometric researches were carried out in the Web of Science's scientific production database, based on articles published in periodicals and annals of indexed congresses related to the Internet of Things (IoT) theme. The time cut used in this research comprised the period from 2010 to 2018.

Bibliometric research is widely used to quantify the processes of written communication related to a particular topic [12].

The quantitative technique seeks the theoretical basis in bibliometric laws and principles, detailing and outlining the paths that must be taken to map the scientific production [19]. Filho, Junior and Siqueira [7], affirm that the principle of bibliometrics is to analyze the scientific activity by the quantitative study of the publications.

Bibliometric studies also allow the measurement of the content of theses, articles published in annals and periodicals, among others, by means of analyzes referring to authors, citations and methodology [3].

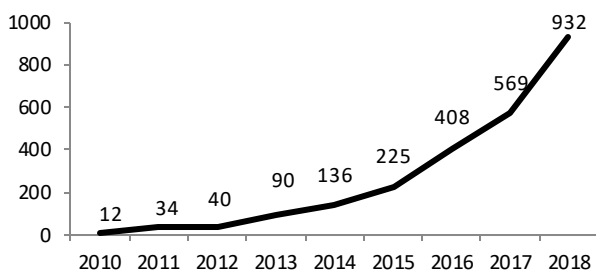
In this regard, the bibliometric research developed in this work had the following process steps: definition of the research theme; choice of the database; elaboration of the search criteria; data collection and analysis of the search results.

As for the search criteria used in the academic production databases, the keyword "internet of things" was inserted in the "title" field of the Web of Science database, obeying the time interval established by the research, between 2010 and 2018.

After the data collection, the data were transported to a spreadsheet, where they were processed, organized and tabulated, generating statistical graphs related to the bibliometric indicators related to the topic addressed in this research.

IV. DATA ANALYSIS

The findings about the volume of articles related to the theme "internet of things" published in the database of the Web of Science platform, from 2010 to 2018 are illustrated in the Graph 1.



Graphic. 1: Number of publications with the title internet of things in the Web of Science database. Prepared by the authors (2019).

According to the data collected, 2,446 publications were identified over the analyzed period (8 years). This is equivalent to an average of 271.7 articles published per year. On the other side, these figures show that studies in this area have grown over the years, arousing the interest of researchers and institutions for the subject.

Table 2 presents the authors with the highest indexes of publications related to the Internet of Things (IoT) theme in the Web of Science database within the analyzed period.

Table. 2: Authors with the highest indexes of publications on the topic "internet of things" in the Web of Science database. Prepared by the authors (2019).

AUTHORS WHO PUBLISH THE MOST	NUMBER OF PUBLICATIONS
ZHANG Y	21
QIU T	17
CHOO KKR	16
NING HS	16
XU LD	16
LI X	15
VASILAKOS AV	15
ZEADALLY S	15

ATZORI L	13
KIM J	13

The prominence with regard to the number of articles published is for the Chinese researcher Zhang Y, from the Jiangnan University, School of Internet of Thing Engineering, with 21 published articles.

Other authors worth mentioning, in relation to the number of articles published in the area of internet of things, based on the Web of Science, were: QIU T, with 17 articles; CHOO KKR, NING HS and XU LD, with 16 articles; and LI X, with 15 articles published in the area.

The areas of greatest coverage of the published articles on the subject of internet of things in the Web of Science database are shown in Table 3. The highlight in relation to the number of publications was for the Telecommunications areas; Computer Science Information Systems; Engineering Electrical Electronic; Computer Science Hardware Architecture and Computer Science Theory Methods.

Table. 3: Areas with the largest number of publications on the topic "internet of things" in the Web of Science database. Prepared by the authors (2019).

AREAS	AMOUNT	%
Telecommunications	1.002	40,96%
Computer Science Information Systems	940	38,43%
Engineering Electrical Electronic	811	33,15%
Computer Science Hardware Architecture	221	9,03%
Computer Science Theory Methods	210	8,58%
Computer Science Interdisciplinary Applications	193	7,89%
Computer Science Software Engineering	177	7,23%
Instruments Instrumentation	174	7,11%
Chemistry Analytical	120	4,90%
Electrochemistry	119	4,86%

Also, the journals that had the highest number of articles published on the subject of internet of things in the Web of Science database are shown in Table 4. The highlights with regard to the number of articles published were to the periodicals: IEEE Access and IEEE Internet of Things Journal, with 157 publications each; and Sensors, with 115 published articles.

Table. 4: Periodicals with the largest number of publications on the topic "internet of things" in the Web of Science database. Prepared by the authors (2019).

MAGAZINES AND NEWSPAPERS	NUMBER OF PUBLICATIONS
IEEE Access	157
IEEE Internet of Things Journal	157
Sensors	115
International Journal of Distributed Sensor Networks	83
Future Generation Computer Systems the International Journal of eScience	71
IEEE Communications Magazine	60
IEEE Transactions on Industrial Informatics	45
Wireless Personal Communications	41
International Journal of Online Engineering	32
Computers Electrical Engineering	28

IEEE Access is an open access online journal of the Institute for Electrical and Electronics Engineers (IEEE). Created in May 2013, IEEE Access is a multidisciplinary journal that publishes original articles in all IEEE fields of interest. All articles published in IEEE Access have a global reach, through the IEEE Xplore digital library for free. The editor-in-chief of the foundation was Michael Pecht and the current editor-in-chief is Derek Abbott. The magazine won the PROSE Award in 2015 for being the best new journal in the STM (International Association of Scientific, Technical, and Medical Publishers).

IEEE Internet of Things is one of the important, cross-disciplinary and cross-platform initiatives of the IEEE. The Internet of Things (IoT) is one of the most exciting technological developments in the world today and the global technical community is gathering around the leading thinking content, resources and collaboration opportunities provided by the IEEE IoT Initiative.

Information about the Internet of Things and its potential in transforming the way we communicate with machines is revealed daily. To bring clarity and dissemination of information globally, the IEEE Internet of Things serves as a home to the global community of engineering and technology professionals in the industry, academia, and to governments working on related technologies.

Sensors is a leading international open access journal on sensor science and technology, as well as biosensors, is published online every six months by the MDPI (Multidisciplinary Digital Publishing Institute). The magazine Sensors aims to encourage scientists to publish their experimental and theoretical results in as much detail as possible.

According to the research the most prominent educational institutions in relation to the volume of articles published in the area of internet of things. In the relationship of these institutions it is possible to identify the domain of Chinese institutions on this subject, as it can be seen in Table 5.

Table. 5: Educational institutions with the largest number of publications on the topic "internet of things" in the Web of Science database. Prepared by the authors (2019).

INSTITUTION / ORGANIZATION	NUMBER OF PUBLICATIONS
Chinese Academy of Sciences	73
Beijing University of Posts Telecommunications	64
King Saud University	39
Vellore Institute of Technology	33
Dalian University of Technology	31
University of Electronic Science Technology of China	30
Beihang University	27
Huazhong University of Science Technology	27
Shanghai Jiao Tong University	27
University of Science Technology Beijing	27

The highlight of the number of publications was the Chinese Academy of Sciences, an institution of the Beijing-based China Council of State. Followed by the Beijing University of Posts Telecommunications, which stands out for teaching and research in the field of cable communications, wireless communications, computing and electronic engineering.

In the third position in the ranking is King Saud University, a public institution of Arab higher education founded in 1957. This teaching institution was created by King Saud to meet the need for skilled labor in Saudi Arabia and is currently among the most prestigious universities in the Arab world. Currently has 37,874 students.

Table 6 shows the countries that had the largest number of publications on the topic internet of things in the Web of Science database. The ranking of the five countries with the highest number of publications is led by China, with

783 publications; followed by the United States, with 428 publications; South Korea, with 246 publications; England, with 196 publications; and India, with 161 publications in the area.

Table. 6: Countries with the largest number of publications on the topic "internet of things" in the Web of Science database. Prepared by the authors (2019).

COUNTRIES THAT PUBLISH THE MOST	NUMBER OF PUBLICATIONS
China	783
USA	428
South Korea	246
England	196
India	161
Italy	139
Spain	129
Australia	116
France	88
Taiwan	86

In relation to language of the publications, it is observed in Table 7 that the highlight is for the English language, in view of the universality of this language. In addition to publications in the English language, there are also publications in several languages, which shows that the topic internet of things (IoT) has a worldwide scope, attracting the interest of researchers worldwide.

The Portuguese and Spanish languages had 12 publications each, followed by German, with 6 publications and Turkish, with 4 publications in the area.

Table. 7: Languages with the largest number of publications on the topic "internet of things" in the Web of Science database. Prepared by the authors (2019).

LANGUAGE	NUMBER OF PUBLICATIONS
English	2.402
Portuguese	12
Spanish	12
German	6
Turkish	4

Figures 1 and 2 were produced using the CiteSpace software [27], which allows the visualization of patterns of relationship between topics, enabling the identification of moments of topic explosion and the evolution of research fronts.

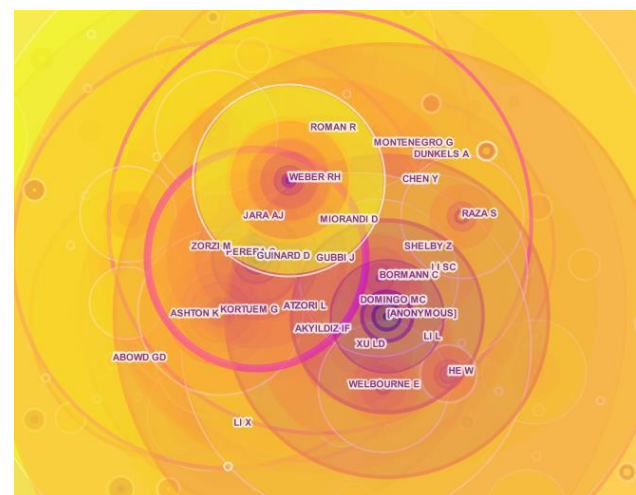
The keywords that appear most frequently in the title and in the abstracts of the scientific productions related to the theme of Internet of Things (IoT), among these keywords, the highlight are for the words: smart city; cloud; cloud

computing; security; RFID; energy, algorithm; big data; protocol among others (figure 1).

Fig.1: Keywords that most appear in the publications on the topic "internet of things" in the Web ofScience database. Prepared by the authors (2019).



In Figure 2, it is possible to observe the authors who were most cited in the scientific works related to the theme Internet of Things (IoT). The highlights are for the authors: ZHANG Y., LI X. and ATZORI L, which are listed in Table 2 of this paper.



*Fig.2: Most cited authors in the publications on the topic "internet of things" in the Web of Science database.
Prepared by the authors (2019).*

V. CONCLUSION

This research shows a study of the scientific productions related to the theme Internet of Things (IoT) in the scientific database of the Web of Science, in the temporal cut of 09 years (2010 to 2018).

The bibliometric study serves with an important mechanism of scientific research that shows the evolution of this technology in the world during the period investigated.

The measurement of scientific production through bibliometrics allows an evaluation of the performance of researchers, institutions, countries and periodicals, through a mapping of scientific articles and other

scientific productions, taking into account quantitative and qualitative metrics.

In this research, 2,446 publications related to the topic Internet of Things (IoT) were identified over the analyzed period, which is equivalent to an average of 271.7 articles published per year. The year with the highest volume of publications on the subject was 2018, with 932 publications.

All the articles identified in this research were analyzed according to the following criteria: authors, areas of knowledge, periodicals where they were published, institutions authoring articles, countries that published the articles and languages that were written.

With regard to the authors, the highlight is the Chinese researcher Zhang Y, from Jiangnan University, School of Internet of Thing Engineering, with 21 articles published in the area.

As for the areas of publication of the articles, it was observed that in the areas of Telecommunications, Computer Science Information Systems and Engineering Electrical Electronic, the most outstanding were, respectively, 1,002 (40.96%), 940 (38.43%), and 811 (33.15%) publications related to the research topic.

Among the journals identified in the research, it was verified that the ones that had the most prominence regarding the number of publications in the web of Science database were: IEEE Access and IEEE Internet of Things Journal, both with 157 publications. In addition to these two journals, it is also worth mentioning the journal Sensors, with 115 articles published in the IoT area.

In relation to the educational institutions identified in the research, the highlight in relation to the number of articles published in the area of internet of things (IoT) were for the following institutions: Chinese Academy of Sciences (China - 73 publications), Beijing University of Posts Telecommunications (China - with 64 publications) and King Saud University (Saudi Arabia - with 39 publications).

In the survey, five countries stood out for the number of publications in the IoT area: China (783 publications), United States (428 publications), South Korea (246 publications), England (196 publications) and India publications).

It is worth mentioning that most of the publications in the IoT area were written in English, with 2,402 publications made in that language.

This research shows a significant increase in the number of scientific publications related to the Internet Thing (IoT) theme, evidencing the importance of studies of this technology for the world technological development.

Through this study, it is hoped to have contributed to the evolution of the researched subject, and that the results of

this research can benefit researchers and scholars of the area, arousing interest in new studies in this technological area.

For future work, this study proposes the use of other databases of scientific research data and the use of new keywords related to the IoT theme.

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